FUJITSU

Fujitsu Enterprise Postgres 18
for Kubernetes

User's Guide

Linux

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Preface

Purpose of this document

This document describes system configuration, design, installation, setup, and operational procedures of the Fujitsu Enterprise Postgres for Kubernetes.

Intended readers

This document is intended for people who are:

- Considering installing Fujitsu Enterprise Postgres for Kubernetes
- Using Fujitsu Enterprise Postgres for Kubernetes for the first time
- Wanting to learn about the concept of Fujitsu Enterprise Postgres for Kubernetes
- Wanting to see a functional overview of Fujitsu Enterprise Postgres for Kubernetes

Readers of this document are also assumed to have general knowledge of:

- Linux
- Kubernetes
- Containers
- Operators

Structure of this document

This document is structured as follows:

Appendix C Utilize Shared Storage

Describes how to build a FEPCluster when using shared storage.

Appendix D Key Management System Available for Transparent Data Encryption

Describes the key management system available for transparent data encryption.

Appendix E Fluent Bit Integration Using Custom Secret

Describes the Fluent Bit integration using custom secret.

Abbreviations

The following abbreviations are used in this manual:

Full Name	Abbreviations
Fujitsu Enterprise Postgres for Kubernetes Fujitsu Enterprise Postgres	FEP
Vertical Clustered Index	VCI
Transparent Data Encryption	TDE
Point in time recovery	PITR
Custom Resource	CR
Custom Resource Definition	CRD
Persistent Volume	PV
Persistent Volume Claim	PVC
Universal Base Image	UBI
SUSE Linux Enterprise Base Container Images	SLE BCI
OpenShift Container Platform	OCP
Mutual TLS	MTLS

Abbreviations of manual titles

The following abbreviations are used in this manual as manual titles:

Full Manual Title	Abbreviations
Fujitsu Enterprise Postgres for Kubernetes Release Notes	Release Notes
Fujitsu Enterprise Postgres for Kubernetes Overview	Overview
Fujitsu Enterprise Postgres for Kubernetes User's Guide	User's Guide
Fujitsu Enterprise Postgres for Kubernetes Reference	Reference

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Contents

Chapter 1 System Requirements

This chapter describes the system requirements.

1.1 Components Embedded

The FEP Server container embeds following components. However it is understood that these components are bound to be upgraded in the maintenance phase.

No	Component	Version	Description
1	Red Hat UBI minimal	9	Meant to provide base OS image for the container Either No. 1 or No. 2 will be incorporated.
2	SLE BCI	15	
3	Fujitsu Enterprise Postgres Server	18.4	To provide server capabilities
4	Patroni	4.1.0	To provide HA capabilities and other management to the Cluster

1.2 CPU

The following CPU architectures are supported.

- x86

To use a StreamingDiskANN index with pgvectorscale, you need a CPU that supports the AVX2 and FMA instruction sets.

Therefore, when using the StreamingDiskANN index, make sure that the instruction set of the Kubernetes Node where you deploy the container corresponds to that instruction set.

1.3 Supported Platform

It supports running on the following platforms.

No	Platform		Version
1	OpenShift Container Platform		4.14, 4.16, 4.18, 4.19, 4.20
2	Rancher Kubernetes Engine (on Linux hosts) (*1)		1.4.0+
3	Vmware Tanzu Kubernetes Grid (*1)		2.5+
4	Full Managed Kubernetes Service	- Azure Kubernetes Service - Amazon Elastic Kubernetes Service - Alibaba Cloud Container Service for Kubernetes - Google Kubernetes Engine - IBM Cloud Kubernetes Service	1.27, 1.29, 1.31, 1.32, 1.33

*1: Kubernetes 1.27, 1.29, 1.31 - 1.33

Supports storage supported by OpenShift or Kubernetes (AKS, EKS, RKE, ACK, GKE, IKS and TKG).

However, you need shared storage, like NFS, or object storage for backup and archive WAL volumes. Object storage supports Amazon Simple Storage Service, Azure Blob Storage, and Google Cloud Storage.

1.4 Collaboration Tool

Supports integration with the following tools.

No	Tool	Version	How to obtain
1	Prometheus	- OpenShift The version installed OpenShift - Kubernetes - Prometheus v3.2 and later - AlertManager v0.24.0 and later - Rancher The version provided by Rancher Monitoring Chart	- OpenShift Preinstalled with OpenShift - Kubernetes prometheus-operator (v0.61.1 and later) https://github.com/prometheus-operator/prometheus-operator/prometheus-operator - Rancher Using the Rancher Monitoring Chart
2	AlertManager		
3	Grafana	- OpenShift and Kubernetes Grafana v11.4 and later - Rancher The version provided by Rancher Monitoring Chart	- OpenShift Provided by OperatorHub - Kubernetes grafana-operator (v5 and later) https://github.com/grafana-operator/grafana-operator - Rancher Using the Rancher Monitoring Chart
4	Helm	3.10.0 and later	- Kubernetes only Helm Web Site https://helm.sh/docs/intro/install/
5	Rancher	v2.9 and later	Rancher Web Site https://rancher.com/
6	Prometheus Adapter	- OpenShift and Kubernetes Confirmed the operation with v0.9.1 and later - Rancher The version provided by Rancher Monitoring Chart	- OpenShift and Kubernetes Prometheus Adapter https://github.com/kubernetes-sigs/prometheus-adapter - Rancher Using the Rancher Monitoring Chart
7	Elastic Search	8.5.2 and later	- OpenShift Provided by OperatorHub - Kubernetes https://github.com/elastic/helm-charts/tree/main/elasticsearch
8	Velero	v1.15 and later	Refer to the documentation published below. https://velero.io/docs/main/basic-install/

Chapter 2 Overview of Operator Design

This chapter describes an overview of the operator design.

2.1 Design Task

Installation/operation using an operator and necessity of design are shown below.

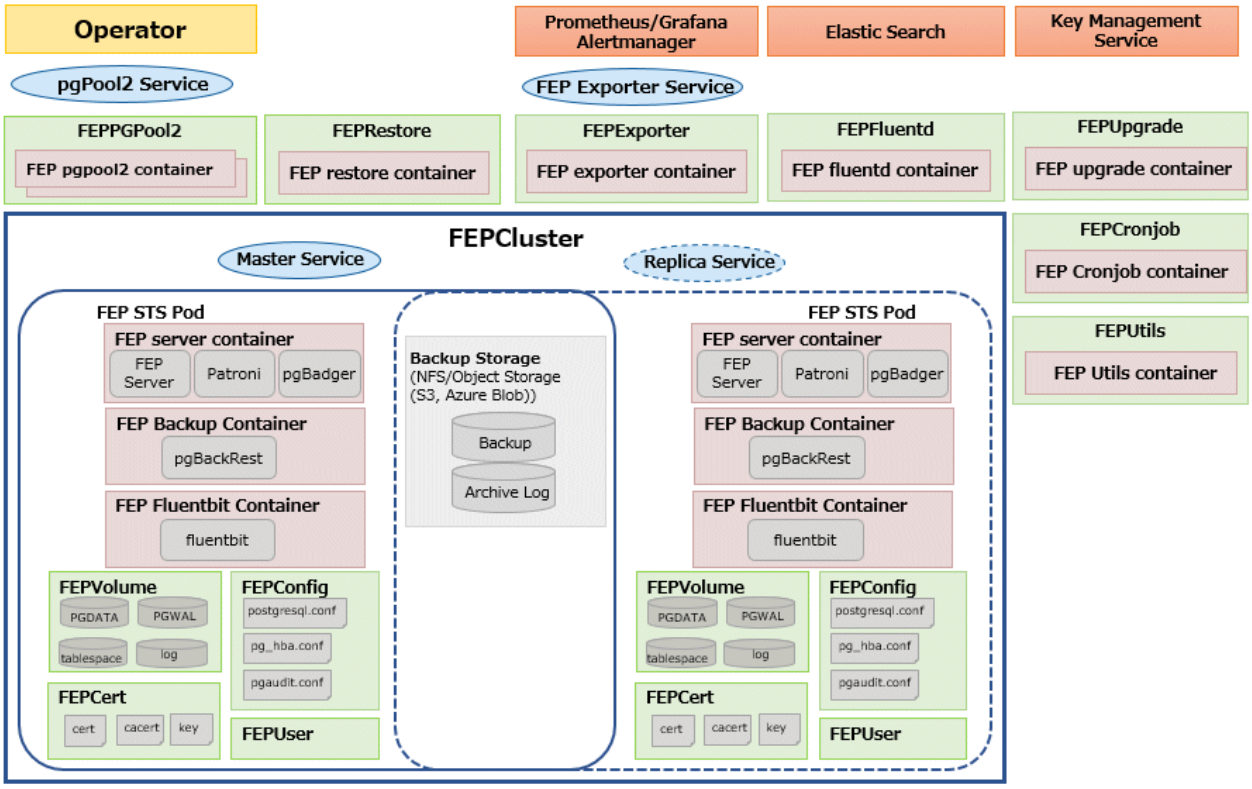
Task	Design required to operate FEP	Where to find
FEP setup	Required.	2.3.1 Deployment
High availability configuration	Recommended. (When checking or changing the behavior of high availability. However, even by default, constant high availability operation is possible.)	2.3.2 High Availability
Volume settings	Recommended. (When setting the volume. However, even by default, allocate a fixed volume.)	2.3.3 Configurable Volume per Cluster
Pgpool-II setup	Recommended. (When using Pgpool-II.)	2.3.4 Deploying Pgpool-II and Connect to FEPCluster from Operator
Backup/restore settings	Recommended. (When using a backup and restore.)	2.3.5 Scheduling Backup from Operator 2.3.6 Perform PITR and Latest Backup Restore from Operator
Monitoring & Alert(FEPExporter)	Recommended. (When using Monitoring and Alert)	2.3.8 Monitoring & Alert (FEPExporter)
Scaling Replicas	Recommended (When using scaling feature)	2.3.10 Scaling Replicas
Key management system	Recommended. (When the key management system manages the master encryption key for transparent data encryption)	2.3.12 Transparent Data Encryption Using a Key Management System

2.2 System Configuration Design

This section describes the system configuration.

2.2.1 Server Configuration

The following is an overview diagram of the server configuration:



System component

Describes various system resources.

Configuration server type	Description
FEP operator	A container that accepts user requests and is responsible for automating database construction and operational operations.
FEP server container	A container for the FEP server.
FEP backup container	A container that performs scheduled backup operations. Created on the same Pod as the FEP server container.
FEP Fluentbit container	A container that collect FEP database CSV log and forward to fluentd container for processing.
FEP pgpool2 container	A container that uses Pgpool-II to provide load balancing and connection pooling. If you do not use it, you do not need to create it.
FEP restore container	A container that performs the restore operation. Temporarily created during a restore operation.
FEP Exporter container	A container that exposes http/https endpoint for monitoring stats scraping.
FEP Fluentd container	A container that summarise FEP log severity as metrics for Prometheus to consume. Optionally, forward log entries to Elasticsearch for detailed log analysis.
FEP upgrade container	A container that executes the major version upgrade process of the server container. A container created temporarily during the upgrade process.
FEP Cronjob container	A container that is started when the regular processing of each feature of the operator is executed.
FEP Utils container	A container for cloud-based management.
Backup storage	Storage where backup data is stored. If you do not need to obtain a backup, you do not need to create one.

Configuration server type	Description
FEPCluster	Parent CR for FEP Cluster definition and configuration.
FEPBackup	Child CR for backup configuration.
FEPVolume	Child CR for volumes.
FEPConfig	Child CR for FEP configurations.
FEPCert	Child CR for system certificates.
FEPUser	Child CR for database users.
FEPAction	CR for performing actions.
FEPExporter	CR for monitoring configuration.
FEPUpgrade	CR for major upgrade.
Master service	A service to connect to the master FEP server.
Replica service	A service to connect to the replica FEP server.
Pgpool2 service	A service for connecting to Pgpool-II.
Fepexporter service	A service to scrape metrices from all FEPCluster nodes.

2.2.2 User Account

The user accounts used by this product are as follows.

It is possible to improve security by clearly separating and managing the accounts that operate the operators for each role by the infrastructure administrator. It is also possible to manage multiple tenants on a single container management platform.

User type	User name	Description
Infrastructure administrator	Mandatory	A system administrator (superuser) who manages the container management platform that installs operators.
Database administrator	Mandatory	An administrator who performs setup, regular operation, and maintenance operations.
Confidential administrator	Mandatory	An administrator who sets appropriate privileges for each database resource for database users.
Application developer	Mandatory	Develops and executes database applications.

2.2.3 Basic Information of the Container

This section describes the basic information of the container.

FEP server container

The naming convention for the FEP server container is as below.

fujitsu-enterprise-postgres-18-server:*OS*-*FEPBaseVersion*-*MajorVersion*.*MinorVersion*-*ARCH*

For each *Version*, specify the following:

Field	Values	Description
OS	ubi9	
FEPBaseVersion	18	
MajorVersion	1,2, ...	To be used when major change in image, including server patch application
MinorVersion	0,1,2 ...	To be used when minor changes in image, e.g bug fix in container script

The first publishing will expect following names / tagging (Manifest and Child images).

- fujitsu-enterprise-postgres-18-server:ubi9-18-1.0
    - fujitsu-enterprise-postgres-18-server:ubi9-18-1.0-amd64

FEP backup container

Use the same naming convention for FEP backup containers as for FEP server containers.

fujitsu-enterprise-postgres-18-backup:*OS-FEPBaseVersion-MajorVersion.MinorVersion-ARCH*

For each *Version*, specify the following:

Field	Values	Description
OS	ubi9	
FEPBaseVersion	18	
MajorVersion	1,2, ...	To be used when major change in image, including server patch application
MinorVersion	0,1,2 ...	To be used when minor changes in image, e.g bug fix in container script

The first publishing will expect following names / tagging (Manifest and Child images)

- fujitsu-enterprise-postgres-18-backup:ubi9-18-1.0
    - fujitsu-enterprise-postgres-18-backup:ubi9-18-1.0-amd64

FEP restore container

Use the same naming convention for FEP restore containers as for FEP server containers.

fujitsu-enterprise-postgres-18-restore:*OS-FEPBaseVersion-MajorVersion.MinorVersion-ARCH*

For each *Version*, specify the following:

Field	Values	Description
OS	ubi9	
FEPBaseVersion	18	
MajorVersion	1,2, ...	To be used when major change in image, including server patch application
MinorVersion	0,1,2 ...	To be used when minor changes in image, e.g bug fix in container script

The first publishing will expect following names / tagging (Manifest and Child images)

- fujitsu-enterprise-postgres-18-restore:ubi9-18-1.0
    - fujitsu-enterprise-postgres-18-restore:ubi9-18-1.0-amd64

FEP pgpool2 container

Use the same naming convention for FEP pgpool2 containers as for FEP server containers.

fujitsu-enterprise-postgres-18-pgpool2: *OS-FEPBaseVersion-MajorVersion.MinorVersion-ARCH*

For each *Version*, specify the following:

Field	Values	Description
OS	ubi9	
FEPBaseVersion	18	
MajorVersion	1,2, ...	To be used when major change in image, including server patch application
MinorVersion	0,1,2 ...	To be used when minor changes in image, e.g bug fix in container script

The first publishing will expect following names / tagging (Manifest and Child images)

- fujitsu-enterprise-postgres-18-pgpool2:ubi9-18-1.0
    - fujitsu-enterprise-postgres-18-pgpool2:ubi9-18-1.0-amd64

FEP Exporter container

FEP Exporter container as for FEP server containers.

fujitsu-enterprise-postgres-exporter: *OS-FEPBaseVersion-MajorVersion.MinorVersion-ARCH*

For each *Version*, specify the following:

Field	Values	Description
OS	ubi9	
FEPBaseVersion	18	
MajorVersion	1,2, ...	To be used when major change in image, including server patch application
MinorVersion	0,1,2 ...	To be used when minor changes in image, e.g bug fix in container script

The first publishing will expect following names / tagging (Manifest and Child images)

- fujitsu-enterprise-postgres-exporter:ubi9-18-1.0
    - fujitsu-enterprise-postgres-exporter:ubi9-18-1.0-amd64

FEP Fluentd container

FEP Fluentd container as for FEP server containers.

fujitsu-enterprise-postgres-fluentd: *OS-FEPBaseVersion-MajorVersion.MinorVersion-ARCH*

For each *Version*, specify the following:

Field	Values	Description
OS	ubi9	
FEPBaseVersion	18	
MajorVersion	1,2, ...	To be used when major change in image, including server patch application
MinorVersion	0,1,2 ...	To be used when minor changes in image, e.g bug fix in container script

The first publishing will expect following names / tagging (Manifest and Child images)

- fujitsu-enterprise-postgres-fluentd:ubi9-18-1.0
  - fujitsu-enterprise-postgres-fluentd:ubi9-18-1.0-amd64

FEP Fluentbit container

FEP Fluentbit container as for FEP server containers.

fujitsu-enterprise-postgres-fluentbit: *OS-FEPBaseVersion-MajorVersion.MinorVersion-ARCH*

For each *Version*, specify the following:

Field	Values	Description
OS	ubi9	
FEPBaseVersion	18	
MajorVersion	1,2, ...	To be used when major change in image, including server patch application
MinorVersion	0,1,2 ...	To be used when minor changes in image, e.g bug fix in container script

The first publishing will expect following names / tagging (Manifest and Child images)

- fujitsu-enterprise-postgres-fluentbit:ubi9-18-1.0
  - fujitsu-enterprise-postgres-fluentbit:ubi9-18-1.0-amd64

FEP Cronjob container

FEP Cronjob container as for FEP server containers.

fujitsu-enterprise-postgres-cronjob: *OS-FEPBaseVersion-MajorVersion.MinorVersion-ARCH*

For each *Version*, specify the following:

Field	Values	Description
OS	ubi9	
FEPBaseVersion	18	
MajorVersion	1,2, ...	To be used when major change in image, including server patch application
MinorVersion	0,1,2 ...	To be used when minor changes in image, e.g bug fix in container script

The first publishing will expect following names / tagging (Manifest and Child images)

- fujitsu-enterprise-postgres-cronjob:ubi9-18-1.0
  - fujitsu-enterprise-postgres-cronjob:ubi9-18-1.0-amd64

FEP upgrade container

FEP upgrade container as for FEP server containers.

fujitsu-enterprise-postgres-18-upgrade: *OS-FEPBaseVersion-MajorVersion.MinorVersion-ARCH*

For each *Version*, specify the following:

Field	Values	Description
OS	ubi9	
FEPBaseVersion	18	
MajorVersion	1,2, ...	To be used when major change in image, including server patch application
MinorVersion	0,1,2 ...	To be used when minor changes in image, e.g bug fix in container script

The first publishing will expect following names / tagging (Manifest and Child images)

- fujitsu-enterprise-postgres-18-upgrade:ubi9-18-1.0
    - fujitsu-enterprise-postgres-18-upgrade:ubi9-18-1.0-amd64

FEP Utils container

FEP Utils container as for FEP server containers.

fujitsu-enterprise-postgres-18-utils: *OS-FEPBaseVersion-MajorVersion.MinorVersion-ARCH*

For each *Version*, specify the following:

Field	Values	Description
OS	ubi9	
FEPBaseVersion	18	
MajorVersion	1,2, ...	To be used when major change in image, including server patch application
MinorVersion	0,1,2 ...	To be used when minor changes in image, e.g bug fix in container script

The first publishing will expect following names / tagging (Manifest and Child images)

- fujitsu-enterprise-postgres-18-utils:ubi9-18-1.0
    - fujitsu-enterprise-postgres-18-utils:ubi9-18-1.0-amd64

2.3 Design Perspective for Each Feature

This section describes the design of each feature.

postgresql-cfg format

A postgresql-cfg represent ConfigMap for containing postgresql parameters. The file is used to contain the parameters which need to be reflected in postgresql.conf of the instance. Since patroni ignores all parameters which are not known by OSS postgresql.conf, an approach is defined to treat FEP Parameters in a special way.

The content of the ConfigMap is defined by key=value format. The following table shows the detail:

Spec	Example	Comment
The content may have multiple key/value pairs	foo=bar foo1=bar1	-

Spec	Example	Comment
The value cannot have space unless quoted.	foo=bar bar2	Invalid
The quoted value cannot have another value after	foo='bar bar2' something	Invalid
The key value pair must have a '=' sign	-	-
White spaces are allowed before/ after/between the key value pair	foo = bar	-

Any content after '#' will be ignored	# this is a comment
	foo=bar #this is a comment
		-

The value may be quoted by single quotes	foo='bar bar2'	-
Single quote can be escaped by two single quotes	foo='It''s ok'	Note: single quotes are not supported by Patroni edit-config command
Backslash '\' will be replaced by '\\' when invoking patronictl edit-config command	-	To avoid command line escape
When a key value pair is invalid, it will be ignored. the update continue to process next pair	foobar foo2=bar2	The 'foobar' will be ignored
The container script does not validate the key and value as long as they are in correct format.	-	-

It is recommended to use the psql's show command to verify parameter is setting correctly.

2.3.1 Deployment

Information for the FEPCluster

Equivalent Kubernetes command: kubectl apply -f FEPClusterCR.yaml

This operation will create a FEPCluster with supplied information in FEPClusterCR.yaml.

Refer to "FEPCluster parameter" in the Reference for details.

2.3.2 High Availability

Describes the settings for using the highly available features.

Arbitration

Patroni is used to control and monitor FEP instance startup, shutdown, status and trigger failover should the master instance fails. It plays a significant role in the solution. If the Patroni process dies, especially on master POD, without notice, the Pod will not update the Patroni cluster lock. This may trigger an unwanted failover to one of the Replica, without corresponding corrective action on the running master. This can create a split brain issue. It is important to monitor Patroni's status to make sure it is running. This is done using liveliness probe. Important to note that this is not expected to be configured by end user.

```
livenessProbe:
  httpGet:
    scheme: HTTP
    path: /liveness
    port: 25001
```

```
initialDelaySeconds: 30
periodSeconds: 6
timeoutSeconds: 5
successThreshold: 1
failureThreshold: 3
```

2.3.3 Configurable Volume per Cluster

Cluster node (Pod) volumes are created according to the values set in the storage section of fepChildCrVal in the FEPCluster custom resource.

Note

- After you create the FEPCluster for the first time, you cannot add new volumes later or modify the storageClass or accessModes.
- You can resize the initially created volume only if the underlying storageClass supports dynamic resizing.

The following is the schema for the storage section of the FEPCluster customer resource:

Field	Mandatory	Sub-Field	Default	Description
archivewalVol	No	size	1Gi	Volume size of the archive log. Refer to "Estimating Database Disk Space Requirements" in the Fujitsu Enterprise Postgres Installation and Setup Guide for Server to help you design the size.
		storageClass	Defaults to platform default if omitted	SC is only set at start
		accessModes	Defaults to ReadWriteOnce if omitted	Access mode is only set at start
backupVol	No	size	2Gi	Volume size of the backup. Estimate based on the following formula: (full backup generations + incr backup generations + 1) * dataVol size
		storageClass	Defaults to platform default if omitted	SC is only set at start
		accessModes	Defaults to ReadWriteOnce if omitted	Access mode is only set at start
dataVol	Yes	size	2Gi	Volume size of the data. Refer to "Estimating Database Disk Space Requirements" in the Fujitsu Enterprise Postgres Installation and Setup Guide for Server and base the design on table/index size.
		storageClass	Defaults to platform default if omitted	SC is only set at start
		accessModes	Defaults to ReadWriteOnce if omitted	Access mode is only set at start
logVol	No	size	1Gi	Volume size of the log.

Field	Mandatory	Sub-Field	Default	Description
				If you change the log output level (default: WARNING) or enable the audit log feature, measure the actual amount of log output in a test environment.
		storageClass	Defaults to platform default if omitted	SC is only set at start
		accessModes	Defaults to ReadWriteOnce if omitted	Access mode is only set at start
tablespaceVol	No	size	512Mi	Volume size of the tablespace. When using tablespaces, as with dataVol, you should refer to "Estimating Database Disk Space Requirements" in the Fujitsu Enterprise Postgres Installation and Setup Guide for Server for information on sizing.
		storageClass	Defaults to platform default if omitted	SC is only set at start
		accessModes	Defaults to ReadWriteOnce if omitted	Access mode is only set at start
walVol	Yes	size	1200Mi	Volume size of the transaction log. Refer to "Estimating Database Disk Space Requirements" in the Fujitsu Enterprise Postgres Installation and Setup Guide for Server to help you design the size. Note that the default value for max_wal_size is 1 GB.
		storageClass	Defaults to platform default if omitted	SC is only set at start
		accessModes	Defaults to ReadWriteOnce if omitted	Access mode is only set at start

The 'accessMode' is been incorporated for the inclusion of pgBadger layer later. Giving it a shared volume capability will allow pgBadger Container to read logs from multiple server instance (master / replica) and expose it via a WebServer.

2.3.3.1 Disk Space Management

Due to a sudden increase in queries, etc., the amount of data and WAL will increase, and the disk capacity will be compressed, which may cause the database operation to stop. If the disk usage exceeds the threshold, or if database operation has stopped due to insufficient disk space, use the following methods to resolve the insufficient disk space.

- Increasing disk space
- Reducing disk usage

2.3.3.1.1 Increasing Disk Space

There are two ways to increase disk space:

- Expanding disk capacity

  If you are using a volume that can use the PVC extension function of Kubernetes, expand the disk capacity and solve the lack of space.

- Migrating to a database cluster with a large disk capacity

  If you are using a volume that cannot be used with the PVC extension function of Kubernetes, or if the volume cannot be expanded further due to the upper limit, etc., consider migrating the database cluster. Migrating data to a cluster that uses large-capacity disks solves the lack of capacity.

Expanding disk capacity

Expand your disk capacity with the Kubernetes PVC extension. Only disks that support the PVC expansion function can be expanded. Check the specifications of the CSI driver you are using to see if the disk supports PVC extensions.

Disk capacity expansion can be performed manually by the user at any time, or automatically by the operator when the usage exceeds the threshold in cooperation with the monitoring function.

Manual expansion can expand a PVC by changing the storage definition of the FEPCluster custom resource. Rewrite the custom resource and expand the PVC when AlertManager gives you a notification that the disk usage exceeds the threshold or the database stops due to lack of disk space.Refer to "5.3.2 Resizing PVCs" for more information on manual expansion. Also, refer to "Default Alert Rule" in the Reference for an example definition of AlertManager's alert rule.

Automatic expansion does not require database administrator monitoring or manual maintenance work (volume capacity expansion) until the expansion limit is reached.

For more information on auto expansion, refer to "2.3.3.2 Configuring PVC Auto Expansion".

If you are using a disk that does not support the PVC expansion function or if the disk capacity cannot be expanded, Refer to "Migrating to a database cluster with a large disk capacity" and "2.3.3.1.2 Reducing Disk Usage".

Migrating to a database cluster with a large disk capacity

Use the backup/restore function to construct a new database cluster on another disk and migrate the data. Use this method when:

- When the alert manager issues a notification that the disk usage exceeds the threshold
- When the database stops due to lack of disk space

Insufficient disk space can be resolved by changing to a disk with a larger capacity.

When migrating to a new database cluster, you can build a new FEPCluster and restore data by setting spec.changeParams of the FEPRestore custom resource and changing the definition from the restore source. For details, refer to "FEPRestore Custom Resource Parameters" in the Reference.

2.3.3.1.2 Reducing Disk Usage

Execute the REINDEX statement on the data storage destinations (dataVol, walVol, tablespaceVol) as preventive maintenance for insufficient disk space. For details, refer to "Reorganizing Indexes" in the Fujitsu Enterprise Postgres Operation Guide.

Consider reducing the amount of disk usage as preventive maintenance for insufficient capacity of the transaction log storage destination and backup data storage destination. If the capacity of the transaction log storage destination is insufficient, review the log file rotation settings and output level, and consider changing them. If the backup data or transaction log archive storage space is insufficient, consider reducing the number of backup generations saved.

You can reduce the number of backup generations by specifying "backup_expire" for spec.fepAction.type of the FEPAction custom resource. For details, refer to "FEPAction Custom Resource Parameters" in the Reference.

2.3.3.2 Configuring PVC Auto Expansion

By setting the FEPCluster custom resource spec.fepChildCrVal.storage.autoresize.enable to true, you can enable the PVC auto-grow feature that automatically expands disk space when disk usage exceeds a threshold.

The following two conditions must be met to enable the PVC auto-expansion function.

- Specify a volume that supports the PVC expansion function in StorageClass
- Specify true in the allowVolumeExpansion field in StorageClass

Check the specifications of the CSI driver you are using to see if the specified volume supports the PVC expansion function.

We also need Prometheus to monitor storage usage. Scrape the metrics captured by the kubelet below with Prometheus.

- kubelet_volume_stats_used_bytes (Volume used capacity (bytes))
- kubelet_volume_stats_capacity_bytes (Volume capacity (bytes))

Make sure that the scrape_config section of your Prometheus config file references /metrics, which the kubelet serves over https, for each node. Check the Prometheus documentation for more details.

The PVC auto-expansion feature can be enabled/disabled even after building the FEPCluster.

Enabling PVC auto-expansion builds a fep-tuning pod containing a pvc-auto-resize container. The pvc-auto-resize container periodically retrieves metrics from Prometheus for each defined PVC. If the PVC volume usage rate exceeds the defined threshold, the definition of the FEPCluster custom resource is automatically rewritten. The target PVC is automatically extended by rewriting the custom resource.

If the FEPCluster is configured with multiple units, the PVC will be expanded if the volume usage rate of even one unit exceeds the threshold.

The following parameters are used in the PVC auto expansion feature. For details of each parameter, refer to the Reference.

- spec.fep.autoTuning section: Prometheus connection information for retrieving metrics
- spec.fepChildCrVal.storage.autoresize section: Storage common extended settings
- spec.fepChildCrVal.storage.xxxVol section: definition and individual extension settings for each storage

In the expansion settings, it is possible to define the volume utilization threshold, amount of size expansion, upper limit of size that can be expanded, and so on.

Below is an example of defining a FEPCluster custom resource when enabling the PVC auto expansion feature.

```
spec:
  fep:
    autoTuning:
      prometheus:
        prometheusUrl: http://prometheus-prometheus-oper-prometheus.prometheus.svc:9090
  fepChildCrVal:
    storage:
      autoresize:
        enable: True
        threshold: 20
        increase: 20
      dataVol:         # Use the data volume as is defined under autoresize
        size: 10Gi
        storageClass: resizable-storage
      walVol:           # wal volume changes threshold and expansion limit
        size: 2Gi
        storageClass: resizable-storage
        threshold: 50
        storageLimit: 10
      backupVol:     # backup volume does not expand
        size: 20Gi
        storageClass: share-storage
        accessModes: ReadWriteMany
        storageLimit: 0
```

Concept of combination with monitoring feature

The PVC auto-expansion feature allows you to limit the amount of storage that can be expanded. However, there is a possibility that more data than expected may occur and the amount of data may exceed the set upper limit. To avoid this, we recommend using the monitoring function in conjunction with the PVC auto-expansion function.

In the alert rule created by default when using the FEPExporter function, an alert will be sent when the volume usage rate exceeds 90%. The default threshold for PVC autogrowth is 80%. As a result, even if the volume usage increases when the disk expansion limit is reached and automatic expansion is not performed, an alert will be sent from AlertManager, so you can be aware of the lack of disk space.

By setting the autogrowth threshold to a value lower than the alert rule threshold, you can keep more safe disk space.

2.3.4 Deploying Pgpool-II and Connect to FEPCluster from Operator

Equivalent Kubernetes command: kubectl create FEPpgpool2

This operation will create a FEP pgpool2 container with supplied information.

Refer to "FEPPgpool2 Custom Resource Parameters" in the "Reference" for more information.

2.3.5 Scheduling Backup from Operator

When creating a FEPCluster, users can obtain scheduled backups by setting up backup definitions. Users can also modify the backup schedule by modifying the Backup custom resource that was created.

A backup definition includes the following:

- Acquisition time (Specify in crontab format)
- Backup type (Full or incremental backups)

Backup is taken on master Pod only.

Backup processing is performed by pgBackRest.

Parameter can be set to pgbackrestParams in CR definition.

The maximum number of backup schedules is 5.

Refer to the pgBackRest User's Guide for details on the parameters.

However, some parameters are limited. Details are given below.

- Importantsetting items
- Parameters that cannot be set
- Restricted Parameters
- About sections in the config file

2.3.5.1 Important Setting Items

Here are the important parameters for setting pgBackRest. This parameter sets the retention period of backup information. If automatic backup is set and this parameter is not set, the risk of overflowing the backup area increases.

Parameter	Overview of parameters	Setting value
Full Retention Option (repo retention -full)	Specify number of full backups to keep No default (should be set according to user backup policy)	natural number
Full Retention Type Option (repo retention-full-type)	spec.retention -full Specifies whether the setting is a number of retention days (time) or a number of retention generations (count) No default (should be set according to user backup policy)	time/count

The following is a sample CR example of changing the backup retention period (How long the PITR is valid) to 30 days after the backup is taken.

```
apiVersion: fep.fujitsu.io/v1
kind: FEPBackup
metadata:
  name: fepcluster-backup
spec:
  pgBackrestParams: |
```

```
    # define custom pgbackrest.conf parameters below to override defaults.
    [global]
    repo-retention-full = 30
    repo-retention-full-type = time
...
```

2.3.5.2 Parameters that cannot be Set

The following parameters in the pgBackRest Configuration Reference are not configurable.

Parameter	Overview of parameters	Reason
Copy Archive Option (--archive -copy)	Copy the WAL segments needed for consistency to the backup	To use internal fixed values
Check Archive Mode Option (--archive-mode-check)	Check the PostgreSQL archive_mode setting.	Limited to backup from master
Backup from Standby Option (--backup-standby)	Back up from the standby cluster	Limited to backup from master
Stop Auto Option (--stop-auto)	Stops a previously failed backup on a new backup.	Because they are 9.6 not supported in
pgBackRest Command Option (--cmd)	pgBackRest command	To use internal fixed values
SSH client command Option (--cmd-ssh)	Path to ssh client executable	Not using ssh
Compress Option (--compress)	Use File Compression	For obsolete options (Use compresse-type option instead)
Config Option (--config)	pgBackRest configuration file.	To use internal fixed values
Config Include Path Option (--config-include-path)	Path to additional pgBackRest configuration files.	To use internal fixed values
Config Path Option (--config-path)	Base path of pgBackRest configuration files.	To use internal fixed values
Delta Option (--delta)	Restore or Backup with Checksum	For new restores only
Dry Run Option (--dry-run)	Execute a dry-run for the command.	command-line only option
Lock Path Option (--lock-path)	Path where the lock file is stored	To use internal fixed values
Keep Alive Option (--sck -keep-alive)	Enable keep-alive messages on socket connections	To use internal fixed values
Spool Path Option (--spool-path)	Path to store temporary data for asynchronous archive-push and archive-get commands	For automatic determination from FEPCluster CR values
Stanza Option (--stanza)	Defines the stanza.	To use internal fixed values
Console Log Level Option (--log-level-console)	Console Log Level	It is not expected to operate on Pod.
Std Error Log Level Option (--log-level-stderr)	Stderr log level	It is not expected to operate on Pod.
Log Path Option (--log-path)	Log File Destination	For automatic determination from FEPCluster CR values
Repository Host Option (--repo-host)	Repository host for remote operations via SSH	Repository Host is not used

Parameter	Overview of parameters	Reason
Repository Host Command Option (--repo-host-cmd)	Path of pgBackRest on Repository Host	
Repository Host Configuration Option (--repo-host-config)	Repository Host Configuration File Path	
Repository Host Configuration Include Path Option (--repo-host-config-include-path)	Repository hosts configuring include path	
Repository Host Configuration Path Option (--repo-host-config-path)	Repository Host Configuration Path	
Repository Host Port Option (--repo-host-port)	Repository host port when "repo-host" is configured	
Repository Host User Option (--repo-host-user)	Repository host user when "repo-host" is configured	
Repository Path Option (--repo-path)	Path where backups and archives are stored	For automatic determination from FEPCluster CR values
Archive Retention Option (--repo-retention-archive)	The number of consecutive WAL backups to keep.	This option is not recommended, and WAL retention is controlled by the Full Retention Option and Full Retention Type Option.
Archive Retention Type Option (--repo-retention-archive-type)	Backup Type for WAL Retention	It is recommended not to change from the default.
Differential Retention Option (--repo-retention-diff)	Number of incremental backups to keep	No incremental backups
Archive Mode Option (--archive-mode)	Retains or disables the archive for the restored cluster.	To use internal fixed values
Exclude Database Option (--db-exclude)	Restore excluding the specified databases.	To restore the entire FEP cluster, including all databases
Include Database Option (--db-include)	Restore only the specified database	To restore the entire FEP cluster, including all databases
Link All Option (--link-all)	Restore all symbolic links.	To use internal fixed values
Link Map Option (--link-map)	Changes the destination of a symbolic link.	To use internal fixed values
Recovery Option Option (--recovery-option)	Setting options in postgreSQL recovery.conf	To use internal fixed values
Tablespace Map Option (--tablespace-map)	Restoring tablespace to a specified directory	For automatic determination from FEPCluster CR values
Map All Tablespaces Option (--tablespace-map-all)	Restores all tablespaces to the specified directory	No tablespace required because there is only one tablespace per FEPCluster
TLS Server Address Option (--tls-server-address)	TLS server address.	TLS server not used
TLS Server Authorized Clients Option (--tls-server-auth)	TLS server authorized clients.	

Parameter	Overview of parameters	Reason
TLS Server Certificate Authorities Option (--tls-server-ca-file)	TLS server certificate authorities.	
TLS Server Certificate Option (--tls-server-cert-file)	TLS server certificate file.	
TLS Server Key Option (--tls-server-key-file)	TLS server key file.	
TLS Server Port Option (--tls-server-port)	TLS server port.	
PostgreSQL Database Option (--pg-database)	PostgreSQL database.	To use internal fixed values
PostgreSQL Host Option (--pg-host)	PostgreSQL host for remote operations via SSH	No SSH connection required
PostgreSQL Host Command Option (--pg-host-cmd)	Path of pgBackRest exe on the PostgreSQL host	To use internal fixed values
PostgreSQL Host Configuration Option (--pg-host-config)	Path of the pgBackRest configuration file	To use internal fixed values
PostgreSQL Host Configuration Include Path Option (--pg-host-config-include-path)	Setting pgBackRest on PostgreSQL host include path	To use internal fixed values
PostgreSQL Host Configuration Path Option (--pg-host-config-path)	Path to configure pgBackRest on the PostgreSQL host	To use internal fixed values
PostgreSQL Host Port Option (--pg-host-port)	SSH Port Specification	No SSH connection required
PostgreSQL Host User Option (--pg-host-user)	The logon user when hosting PostgreSQL, if pg-host is set.	No SSH connection required
PostgreSQL Path Option (--pg-path)	PostgreSQL data directory.	For automatic determination from FEPCluster CR values
PostgreSQL Port Option (--pg-port)	PostgreSQL Ports	For automatic determination from FEPCluster CR values
PostgreSQL Socket Path Option (--pg-socket-path)	PostgreSQL Unix socket path	For automatic determination from FEPCluster CR values
PostgreSQL Database User Option (--pg-user)	PostgreSQL database user	To use internal fixed values

2.3.5.3 Restricted Parameters

Of the parameters in the pgBackRest Configuration Reference, the following parameters limit the configurable values.

Parameter	Overview of parameters	Possible Values
repoX-gcs-key-type	The type of key file you specify when using Google Cloud Storage	service

2.3.5.4 About Sections in the Config File

In FEPBackup CR, you can write the contents of pgbackrest.conf, but the setting for stanza (Backup space for pgBackRest) is specified internally.

The following sections are not allowed;

[stanza: command] , [stanza]

2.3.6 Perform PITR and Latest Backup Restore from Operator

There are two types of restore: one is to restore backup data to an existing FEPCluster, and the other is to create a new FEPCluster and restore backup data.

The former retains the attributes of the FEPCluster, such as IP address and name, while the latter is created from scratch.

The restore process deploys a FEP restore container. The FEP restore container performs the pgBackRest restore operation from the backup data to be restored to the master server of the FEPCluster. After the data is restored to the master server, the FEPCluster is created by synchronizing the data to two replica servers.

If user create a new FEPCluster, the newly created FEPCluster will inherit the settings of the source cluster, unless otherwise specified

User can also create a cluster with different settings from the source cluster by including the settings in FEPRestore CR.

Switching connections to the new cluster

The restore creates a new FEPCluster. If necessary, you need to set up Pgpool-II and change the access point of the application to the new cluster or the new Pgpool-II.

About recovering a failed FEPCluster

Even if the existing FEPCluster fails and the FEP is not running, if the volume of the backup area is safe, it is possible to restore from the backup data.

2.3.7 FEP Unique Feature Enabled by Default

Enable the following FEP features:

- Data masking
- Transparent Data Encryption (TDE)
- Fixed statistics

Data masking

The Data masking is enabled by default in the example FEPClster CR (in OpenShift UI). The postgresql.conf in container contains the following parameters:

```
shared_preload_libraries = 'pgx_datamasking,pg_prewarm'
session_preload_libraries = 'pg_prewarm'
max_worker_processes= 20
```

The user can overwrite these values in config map.

TDE

TDE is enabled by default. Select one of the following as the keystore to store the master encryption key used for transparent data encryption.

- File-based keystore
- External key management service

If you use a key management service as your keystore, you can change the keystore to another key management service even after you deploy the FEP cluster. You cannot change from a file-based keystore to a key management service, or from a key management service to a file-based keystore.

Refer to "2.3.12 Transparent Data Encryption Using a Key Management System" for the design perspective when using a key management system.

Fixed statistics

Fixed statistics(pg_dbms_stats) is enabled by default.

A dbms_stats schema is created in each database.

The list of statistics backups and the list of currently fixed objects can be referenced with pguser defined in the FEPClsuter custom resource.

It also takes a backup of statistics by default.

During a major upgrade, the backup statistics maintained in the database are no longer available. The immobilization status will also be released. Ttake a backup and fix it again after executing the major upgrade.

2.3.8 Monitoring & Alert (FEPExporter)

As the operator is level 5 certified, the system expose various metrics about its operand i.e. FEP containers.

FEP generates lot of useful database statistics via various views. The default statistics can be further augmented by using extensions like pg_stat_statements.

FEPExporter container by default is configured to extract useful database statistics and make the metrcs available to Prometheus on the platform. External components and utilities can be used to visualise, analyse, trigger alerts and take operational decision based on exposed metrics.

FEPExporter also sets defalt alert rules based on Prometheus metrics which are useful for active monitoring of FEP cluster.

2.3.8.1 FEPExporter Custom Resource

Refer to "FEPExporter Custom Resource" in the Reference for FEPExporter Custom Resource parameters.

- Custom queries to scrape metrics can be added in CR in optional section.
- Custom Prometheus alert rules are created by user manually.

2.3.8.2 Change to FEPCluster CR - metrics user

User may define pgMetricsUser, pgMetricsPassword and pgMetricsUserTls in target FEPCluster. If it is defined, FEPExporter will use metrics user details to connect to FEP cluster machines. All metrics user fields are optional and can be omitted in FEPCluster.

Refer to "FEPCluster Parameter" in the Reference for FEPCluster parameters.

2.3.8.3 FEPExporter CR auto-create for FEPCluster

User may define enableMonitoring flag as part of FEPCluster CR to monitor FEPCluster. It will automatically create FEPCluster specific FEPExporter so matrics scraping for FEPCluster will work.

Refer to "FEPCluster Parameter" in the Reference for FEPCluster parameters.

- FEPExporter will be named as <cluster-name>-fepexporter.
- Once FEPExporter created automatically, user can modify it manually from FEPExporter CR.
- If FEPCluster will be deleted, it will delete dependent FEPExporter as well.
- MTLS for FEPExporter will only supported when tls configuration defined for both Prometheus & FEPExporter specs.

2.3.9 Collaboration with Amazon CloudWatch

You can use CloudWatch, a monitoring service for Amazon Web Services(AWS), to monitor FEP metrics and collect logs. Typically, CloudWatch requires you to forward metrics and logs to CloudWatch for database metrics monitoring and log collection, but you can use an operator to automatically forward FEP metrics and logs to CloudWatch. You can centrally monitor the FEP and services provided by AWS, such as EC2 and S3 object storage built into business systems, thereby reducing the workload of monitoring tasks.

For information on how to collaborate with CloudWatch, refer to "4.5 How to Collaborate with CloudWatch". For information on the metrics to be collected, refer to "5.7.2.5 Metrics Collected by CloudWatch".

2.3.10 Scaling Replicas

Auto scale out occurs when the average database CPU utilization or number of connections exceeds the threshold. Select whether the criteria for auto scale out is CPU usage or the number of connections, depending on the resource that is the bottleneck of the database.

The maximum number of replica containers, excluding the master container, is 15.

Scale out based on CPU utilization

Performs a scale out if the average CPU utilization of all pods (primary pods and all replica pods) in the FEPCluster exceeds the threshold for a period of time.

CPU utilization is calculated with the value specified in spec.fep.mcSpec.requests.cpu specified for the FEPCluster custom resource as the denominator.

Scale out based on the number of connections

Performs a scale out if the average number of connections for all pods (primary pods and all replica pods) in the FEPCluster exceeds the threshold for a period of time.

Specify the threshold for the number of connections to perform automatic scale-out with a value less than or equal to the max_connections parameter of the FEP server.

The prerequisites for using the scale out feature based on the number of connections are as follows.

- The monitoring feature (refer to "2.3.8 Monitoring & Alert (FEPExporter)") is enabled.
- Metrics for the number of FEP server connections are collected by the monitoring feature.
- A custom metrics server is installed in the OCP/Kubernetes cluster.
- The custom metrics server publishes the average number of connections collected by the monitoring feature.

When using the scale out feature based on the number of connections, the auto scale out feature requests the custom metrics server for metrics associated with the following Kubernetes resources.

- kind: FEPCluster
- apiVersion: fep.fujitsu.io/v2
- name: Name of FEP Cluster
- namespace: The name of the namespace in which FEP Cluster is deployed

The name of the requested metric is the name specified in the metricName parameter.

This metric should represent the average number of connections for each pod in the specified FEPCluster.

Limitations

- If you want to use the scale out feature based on the number of connections, deploy FEPExporter according to the procedure of "4.3 Deploying FEPExporter".
- If FEPCluster metrics are collected by FEPExporter in standalone mode (refer to "4.4 FEPExporter in Standalone Mode"), the scale out feature based on the number of connections is not available.

Note

When using the auto scale out feature, the FEPCluster sync mode should be "off".

Precautions when designing auto scale out

- The auto scale out feature adds replicas one at a time. In addition, additional replicas take time to service, depending on the environment and the amount of data stored. As a result, replica growth may not be able to keep up with the increased load.
- Even if the auto scale out feature increases the number of replicas, incoming requests are not given priority to those replicas. As a result, existing FEP instances may continue to be temporarily overloaded after the number of replicas increases.

- The auto scale out feature increases the number of replica requests that can be handled only by reference requests to the database. Requests with updates continue to be processed on the primary FEP instance. Therefore, the auto scale out feature may not reduce the load on the primary FEP instance.
- Currently, the auto scale out feature does not delete replicas (reduce the number of replicas). If the load decreases after the number of replicas increases due to a temporary increase in load, the number of replicas remains increased. If necessary, manually change the number of replicas.

2.3.10.1 Change to FEPCluster CR - auto scale out

If you want to use Auto Scale Out, set the parameter to FEPClusterCR.

Refer to "FEPCluster Parameter" in the Reference for FEPCluster parameters.

2.3.11 Disaster Recovery

By using object storage, data can be migrated to database clusters in different container environments. Even if it is difficult to operate in a container environment with a database cluster deployed due to a disaster, etc., it is possible to continue operation in a different container environment.

Available disaster recovery methods include the backup/restore method and the hot standby method.

Backup/restore method

Build a new container environment after a disaster (cold standby) and restore data from object storage. Compared to the method described later, this method does not require the construction of two container environments, so it is possible to keep costs down. It takes recovery time to execute.

Hot standby method

Before a disaster occurs, start the container environment of the production environment and the container environment of the disaster recovery environment. By implementing disaster recovery in a hot standby configuration, business systems can be restored more quickly in the event of a disaster.

You can also use Velero to back up a system in a Kubernetes environment to object storage for disaster recovery that restores the system to a different Kubernetes.

2.3.12 Transparent Data Encryption Using a Key Management System

Fujitsu Enterprise Postgres provides unique features that enhance the security of PostgreSQL. These security features help users keep their data safe from unauthorized access. One such security feature is Transparent Data Encryption (TDE), which encrypts data at rest, i.e. data stored on disk/persistent volume.

In contrast, TDE's default format stores the master encryption key in a password-protected file. A key management system allows you to store your master encryption key (MEK) in a cloud-based keystore, taking your security to the next level.

The key management system that can be used with transparent data encryption is one of the following:

- Key management server using KMIP protocol
- AWS key management service
- Azure key management service

Refer to "Appendix D Key Management System Available for Transparent Data Encryption" for detailed key management system requirements.

Transparent data encryption using a key management system can only be configured when the FEPCluster is first created. Users cannot configure an existing FEPCluster for transparent data encryption using a key management system.

If the master encryption key on the key management system is lost, the encrypted/backup data cannot be decrypted. As long as the data encrypted with the master encryption key remains valid, the master encryption key must also be available and maintained on a key management system.

If you have encrypted backups with old encryption key, you must keep the old encryption key available after the master encryption key is rotated. Otherwise, you will not be able to open the database restored from backup.

In addition, the key custodian must retain the referenced master encryption key for as long as the data encrypted under the old master encryption key remains valid.

2.3.13 Database Role Management

In order to manage data access control, you can easily implement database role privilege and expiration management.

Operators can easily create roles related to database operations, assign privileges, and manage the expiration dates of database roles with login privileges in order to manage data access control.

Databases contain important data such as personal information, and data protection is important.

Data protection is defined in security protocols and is an important aspect of operations.

In order to protect data from being viewed by a third party, it is necessary to properly set the access control of database roles.

In this feature, it is recommended to divide into the following database roles.

- Database administrator: Construction/operation of database system
- Confidential administrator: Set appropriate privileges for each database resource
- General users: End users of the database

By preparing multiple database operators/administrators and assigning privileges to each, it is possible to distribute privileges. This makes it possible to prevent data from being referenced or tampered with by users with strong privileges.

This section describes the roles of database roles created by this feature.

Database administrators can perform operations related to database operations, such as referencing system tables and canceling back-end queries.

Confidential administrators grant appropriate privileges to tables and roles to prevent third parties from viewing data. With this feature, it is possible to grant the confidential administrator the privilege to use the confidentiality management feature, and to grant the appropriate privilege to each database resource.

In addition, it is not recommended to use roles with SUPERUSER or BYPASSRLS privilege that can see all data for data protection. Therefore, in this feature, the SUPERUSER (postgres) password is isolated by hiding it, and the SUPERUSER and BYPASSRLS privileges are not granted to the created database role.

2.3.13.1 Creating Roles Related to Database Operation

2.3.13.1.1 Quarantine SUPERUSER

Create a database role "postgres" with SUPERUSER privileges for the operator when building the database.

By omitting "spec.fepChildCrVal.sysUsers.pgAdminPassword" in the FEPCluster custom resource, the postgres role password is created with a random value, making it impossible for general users to use SUPERUSER privileges. However, a separate method is provided to use the "postgres" role when the administrator needs SUPERUSER privileges for database operations. Therefore, monitor for unexpected usage using the audit feature of pgAudit.

2.3.13.1.2 Database Administrator Role

Database role for database management. Defining this role is mandatory.

The user name and password are defined in "pguser" and "pgpassword" under spec.fepChildCrVal.sysUsers in the FEPCluster custom resource. Has CREATE DATABASE privilege and can see system tables/cancel backend queries.

The database administrator role has the following privileges.

- NOSUPERUSER
- NOREPLICATION
- NOBYPASSRLS

- CREATEDB
- INHERIT
- LOGIN
- CREATEROLE

However, NOCREATEROLE privileges are granted when the confidential administrator role is created.

I also belong to the following roles:

- pg_monitor
- pg_signal_backend

2.3.13.1.3 Confidential Administrator Role

A database role that uses the confidentiality management feature to set appropriate privileges for each database resource for database users. Creating this role is optional.

User name and password are defined in "pgSsecurityUser" and "pgSsecurityPassword" under "spec.fepChildCrVal.sysUsers" of FEPCluster custom resource.

Confidential administrator roles can be defined after building FEPCluster. However, you cannot change the role name or delete the role after defining this role.

This role holds the following privileges.

- LOGIN
- CREATEROLE
- NOSUPERUSER
- NOREPLICATION
- NOBYPASSRLS
- NOCREATEDB
- NOINHERIT

The Confidential administrator role has ALL privileges for the database defined in the FEPCluster custom resource "spec.fepChildCrVal.sysUsers.pgdb", and can create database objects such as tables in the target database.

Confidential administrator roles are assigned the following privileges necessary to operate the confidentiality management feature of Fujitsu Enterprise Postgres, so the confidentiality management feature can be used immediately after the role is created.

- CREATEROLE privilege
- SELECT privilege, INSERT privilege, UPDATE privilege, and DELETE privilege to all tables included in the extension of confidentiality management feature

Grant ownership to the confidential administrator role for the database objects managed by the confidentiality management feature.

In addition, by granting the privileges required for the confidential administrator role to operate the confidentiality management feature to other database roles, the number of users who perform confidential management can be increased and the privileges can be distributed.

2.3.13.2 Expiration Management of Database Roles with Login Privileges

You can control who can connect to the database by managing role expiration.

This section describes two methods for managing role expiration:

- Policy-based password operation
- Password operation with the VALID UNTIL clause

In policy-based password operation, you define a policy as a profile and assign the profile to a role. It is possible to define policies other than expiration exactly as follows. By assigning the same profile to a role, you can apply the same policy at once.

- Set a password life time
- Restrict password reuse
- Lock accounts that have failed to log in continuously

For password operations with the VALID UNTIL clause, only an expiration date can be set. An operator can force a VALID UNTIL clause to be specified within a specified interval of time when a CREATE or ALTER ROLE command is executed.

2.3.13.2.1 Policy-based Password Operation

For information about how to create and apply profiles that define policies, refer to "Policy-based Login Security" in the Fujitsu Enterprise Postgres Operation Guide.

When FEPCluster is deployed, users for streaming replication (User specified in spec.fepChildCrVal.sysUsers.pgrepluser of the FEPCluster custom resource) are automatically assigned membership in the pgx_update_profile_status group role. This ensures that the user lock status and password status detected on the standby server are applied to the entire cluster immediately after the FEPCluster is built.

Operators can use the monitoring feature to monitor metrics such as expiration.

When you deploy FEPExporter, the following metrics collection and alert rules are enabled:

To deploy the FEPExporter, refer to "4.3 Deploying FEPExporter" or "4.4 FEPExporter in Standalone Mode".

For definitions of metric queries and alert rules, refer to "Default Metric Queries" and "Default Alert Rules" in the Reference.

Metrics Collected by Default

- Number of all roles
- Number of enabled roles
- Number of roles in grace period
- Number of roles that have expired
- Number of roles locked

You can also add metrics queries to monitor, for example, how many roles expire within a specified date.

Default Alert Rules

- When Expired Role is 1 or More
- When the Grace Period Expired Role is 1 or More
- When the locked role is 1 or more

When you are notified of an alert, you can verify the database role in question from the system catalog.

For more information about the system catalogs for managing profile information, refer to "System Catalogs" in the Fujitsu Enterprise Postgres Operation Guide.

2.3.13.2.2 Password Operation with the VALID UNTIL Clause

You can manage password expiration for database roles with login privileges.

When defining passwords for database roles with login privileges in the CREATE ROLE or ALTER ROLE statements, it is possible to force them to expire within a specified period.

Specify the following parameters in the FEPCluster custom resource to enable this feature.

- Specify "fsep_operator_security" in shared_preload_libraries of spec.fepChildCrVal.customPgParams
- "spec.fepChildCrVal.sysUsers.passwordValid.days" specifies the number of days that can be specified from the time the password is changed to the expiration date

FEPCluster custom resource definition example

```
fepChildCrVal:
  customPgParams: |
    shared_preload_libraries='pgx_datamasking,pg_prewarm,pg_stat_statements,fsep_operator_security'
    …
 sysUsers:
    passwordValid:
      days: 30
    pgdb: mydb
    pgpassword: mydbpassword
    pguser: mydbuser
```

When this feature is enabled, the password expiration for pgpassword and pgSecurityPassword, as defined in spec.fepChildCrVal.sysUsers in the FEPCluster custom resource, is defined after the length of time specified in spec.fepChildCrVal.sysUsers.passwordValid.days since the password was changed.

However, passwords defined in pgAdminPassword, pgreplpassword, pgRewindUserPassword, and pgMetricsUserPassword are database role passwords required for database operation management, so their expiration dates are not managed.

In addition, if the CREATE ROLE or ALTER ROLE statement defines/changes the password for a database role that has login privileges, and the password for the database role does not expire or is longer than the length of time specified by pec.fepChildCrVal.sysUsers.passwordValid.days, the executed SQL will fail.

spec.fepChildCrVal.sysUsers.passwordValid.days can be defined or changed after building the FEPCluster. Changing this parameter updates the password expiration period for all managing database roles that have not expired.

Removing spec.fepChildCrVal.sysUsers.passwordValid.days or setting it to 0 will stop password expiration management.

By using the FEPExporter custom resource feature, it is possible to monitor the password expiration date of database roles and send an alert using AlertManager when there is a database role that is about to expire or has passed.

2.3.14 User Synchronization Using ldap2pg

ldap2pg manages database roles in an LDAP-configured system by applying management information such as users on the LDAP server to the database server. ldap2pg allows automatic synchronization of LDAP directories with FEP user accounts. The synchronisation is done by ldap2pg on a regular basis. The frequency of synchronisation can be defined as a cronjob like entry. Connectivity from ldap2pg to LDAP directory and FEP to LDAP directory must support LDAP, LDAPS and LDAP over TLS.

Built-in Operator users such as postgres, repluser, rewind_user, mydbuser should not be created/deleted/modified by ldap2pg as it may interfere with normal operation of FEP Operator and FEP Cluster. The default ldap2pg.yml supplied by the FEP Operator excludes these users.

To use ldap2pg, you need the following:

LDAP connection info

Details about LDAP directory, include ldap uri, basedn, binddn must be defined and made available to ldap2pg. The ldap.conf is used to store such information. It will be available to any software that needs connectivity information to LDAP directory, including ldap2pg and FEP.

Details of ldap.conf will be stored in a secret and mounted to fep-patroni under /etc/openldap/ldap.conf. End user should pre-create this secret before enabling ldap2pg synchronisation. If this secret is not present when ldap2pg is enabled, Operator will create a sample ldap.conf with connectivity info commented out. End user can update the secret with corresponding LDAP connectivity info. This updated information will be reflected in fep-patroni when kubelet performs syncPod function.

The Secret can be named as user-preferred, e.g., <fep-cluster>-ldapconf. Its key must be "ldap.conf" and its value should contain LDAP configuration.

Trusted CA bundle for LDAP directory

If the LDAP directory is using certificates signed by private CA to secure connections, the chain of certificates up to the root CA must be provided for ldap2pg and FEP as trusted certificates for a secure connection, be it ldaps or ldap over TLS. This chain of certificates will be stored in a configmap and mounted to fep-patroni under /tls/ldap/ca.crt. The use of such trusted certificates is optional but is recommended to authenticate the authenticity of the LDAP servers.

The ConfigMap can be named as user-preferred, e.g., <fep-cluster>-cacrt. Its key must be "ca.crt" and its value should contain LDAP server certificates which are provided by end-user.

ldap2pg.yml

Configuration file for ldap2pg to interact with LDAP directory and FEP.

Details of ldap2pg.yml will be stored in a configmap and mounted to fep-patroni under /tmp/.config/ldap2pg.yml. End user should pre-create this confimap before enabling ldap2pg synchronisation. If this configmap is not present when ldap2pg is enabled, Operator will create a sample ldap2pg.yml. End user can update the confimap. The updated information will be reflected in fep-patroni when kubelet performs syncPod function.

The ConfigMap can be named as user-preferred, e.g., <fep-cluster>-ldap2pgyml. Its key must be "ldap2pg.yml" and its value should contain ldap2pg configuration.

2.3.14.1 How to Update FEPCluster CR for ldap2pg

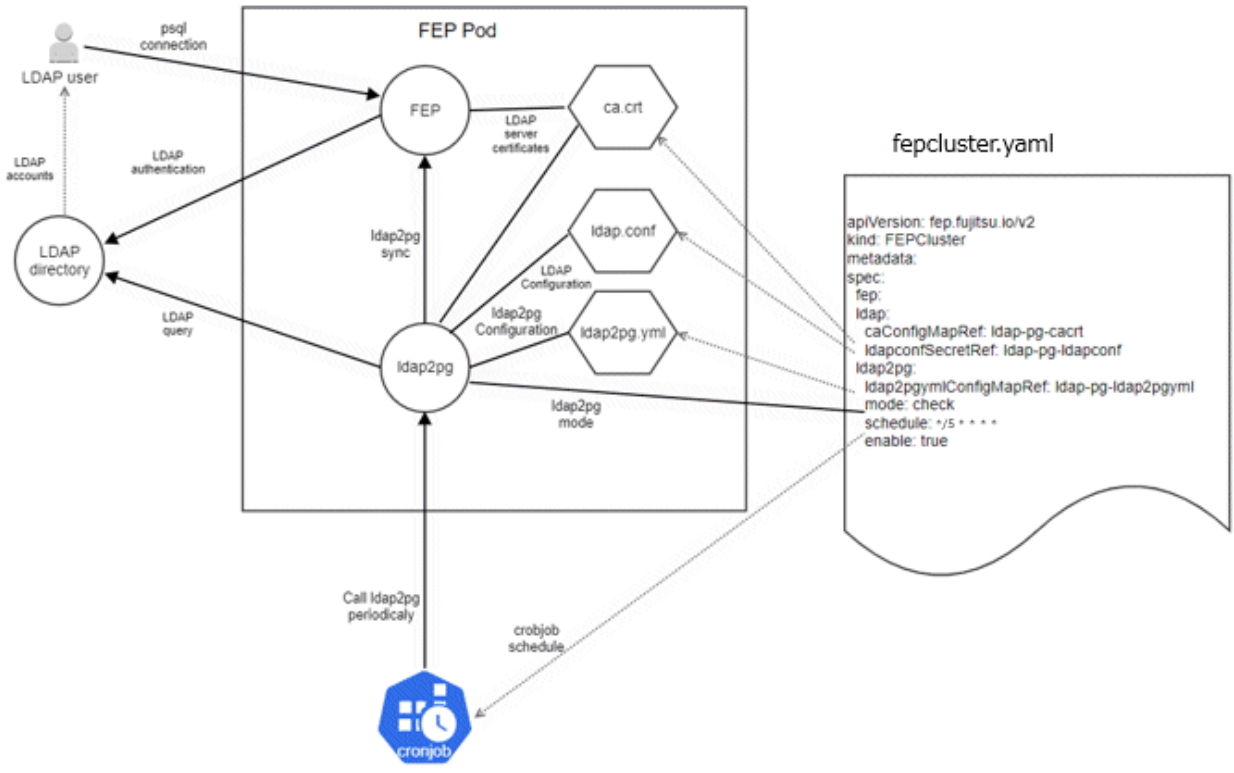
This section describes instructions for users to update FEPCluster CR to support ldap2pg.

First, it will need to create resources below for both LDAP configuration and ldap2pg configuration.

- Secret for LDAP Configuration (ldap.conf)
- ConfigMap for LDAP Server Certificates (ca.crt)
- ConfigMap for ldap2pg Configuration (ldap2pg.yml)

Second, it will need to add spec.ldap and spec.ldap2pg entries to a FEPCluster CR below to support ldap2pg (refer to figure below).

- FEPCluster with ldap2pg enabled (fepcluster.yaml)



Follow the steps below to update the FEPCluster CR for ldap2pg.

Each step includes the approach by using OpenShift console and command lines.

1. Create a Secret for LDAP configuration (ldap.conf)

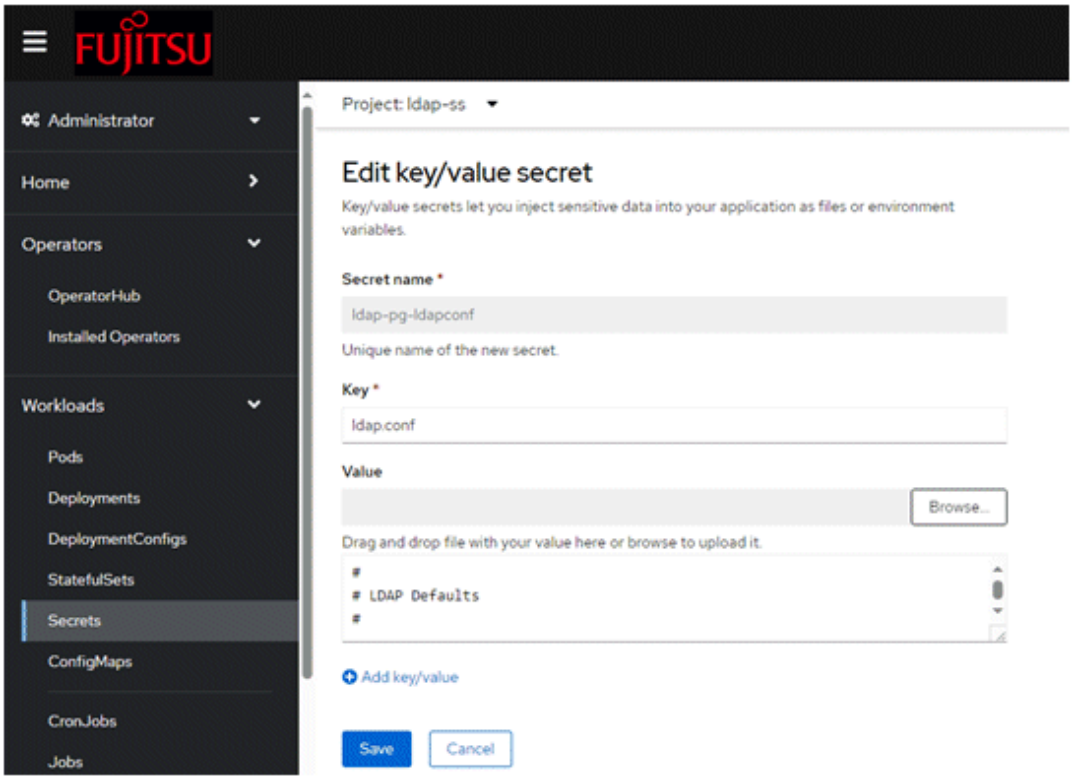
   LDAP configuration includes LDAP connection info.

   In this example, we assume that the LDAP server is running at ldap-server.testprj.svc, listening for LDAPS connection on port 636. The base DN is dc=example,dc=org. The LDAP user cn=admin,dc=example,dc=org is used to connect to LDAP server and the password is "mypassword".

   Sample LDAP configuration (ldap.conf)

```
$ cat ldap.conf

#
# LDAP Defaults
#

#Refer to https://www.openldap.org/software/man.cgi?query=ldap.conf for full configuration
details
# This file should be world readable but not world writable.

#BINDDN: This is the user to bind to LDAP server
BINDDN  cn=admin,dc=example,dc=org

#BASE: Set it to the base DN where search will begin
BASE   dc=example,dc=org

#PASSWORD: Password of user as defined in BINDDN
PASSWORD mypassword

#URI: Specify the URI of LDAP server
URI   ldaps://ldap-server.testprj.svc:636

#SIZELIMIT    12
#TIMELIMIT    15
#DEREF        never
TIMEOUT       15

# TLS certificates (needed for GnuTLS)
# TLS_CACERT      /tls/ldap/ca.crt

# Specifies what checks to perform on server certificates in a TLS session. We are
# being relax here even if server certificate cannot be verified.
TLS_REQCERT allow
```

- Create a Secret by OpenShift.



- Create a Secret by command-lines

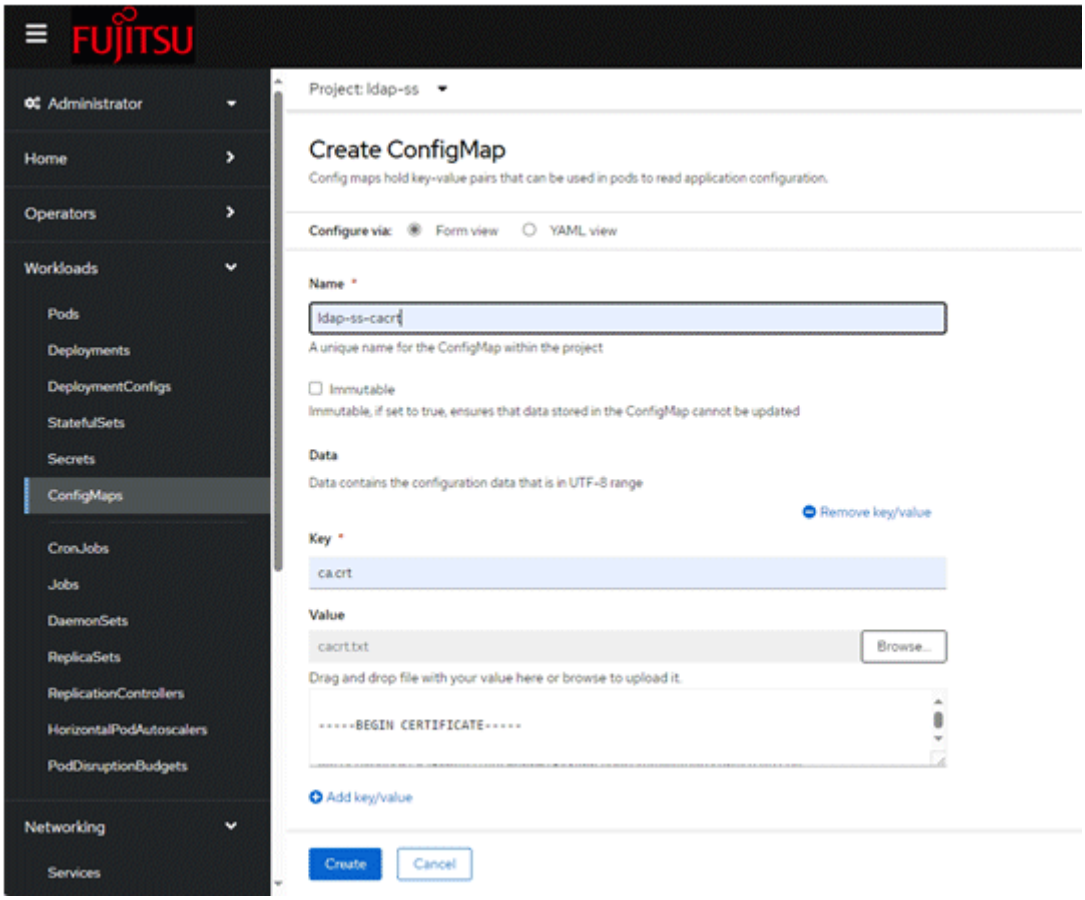
```
$ kubectl -n ldap-ss create secret generic ldap-ss-ldapconf --from-file=ldap.conf
secret/mysecret created
```

2. Create a ConfigMap with chain of certificates (ca.crt) that sign the LDAP server certificate

Sample LDAP server certificates (ca.crt)

```
$ cat ca.crt

-----BEGIN CERTIFICATE-----
xxx root cert xxx
-----END CERTIFICATE-----
-----BEGIN CERTIFICATE-----
yyy intermediate cert yyy
-----END CERTIFICATE-----
```

- Create a ConfigMap by OpenShift.



- Create a ConfigMap by command-lines

```
$ kubectl -n ldap-ss create configmap ldap-ss-cacrt --from-file=ca.crt
configmap/ldap-ss-cacrt created
```

3. Create a ConfigMap for ldap2pg.yml file

   The following users are managed by operators, so specify them in roles_blacklist_query in the postgres section to remove them from ldap2pg management.

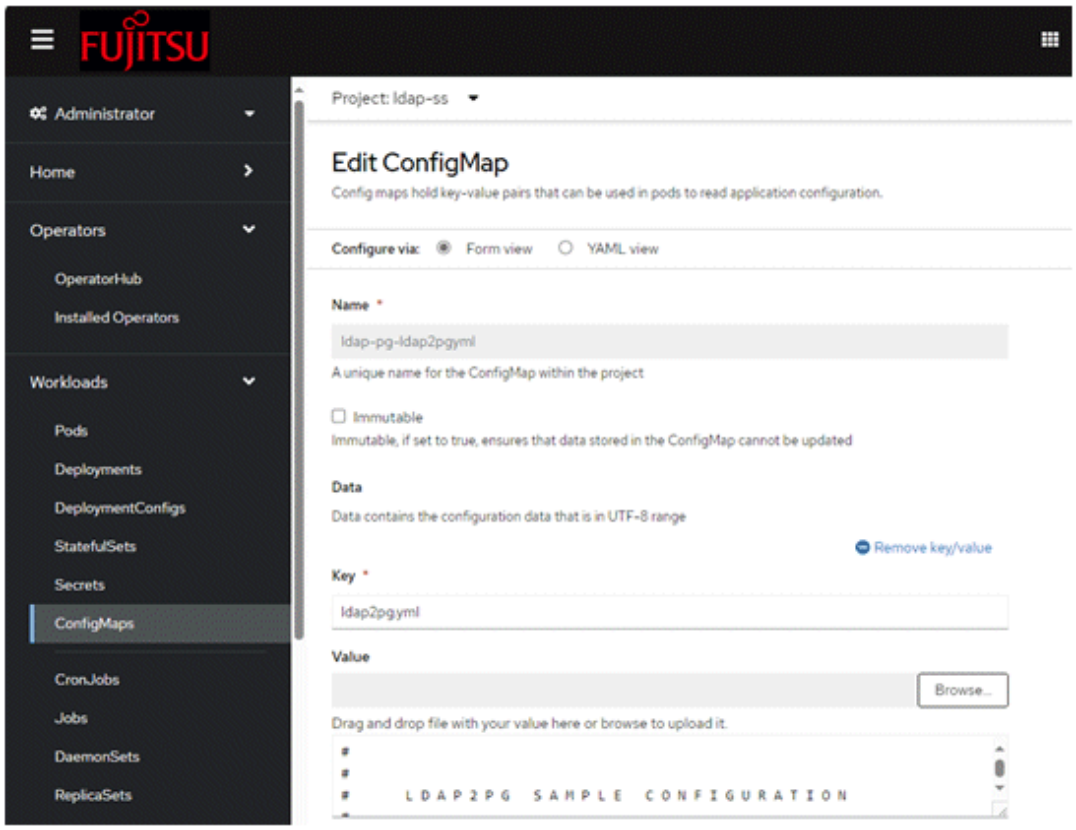
   - postgres user
   - Username specified in spec.fepChildCrVal.sysUsers of FEPCluster custom resource

   For other ldap2pg.yml settings, refer to "ldap2pg" in the Fujitsu Enterprise Postgres Installation and Setup Guide for Client.

   Sample ldap2pg configuration (postgres section of ldap2pg.yml)

```
postgres:
  roles_blacklist_query: [postgres, repluser, rewind_user, pwsyncuser, pg_*, pgx_*, ]
  databases_query: [postgres]
```

- Create a ConfigMap by OpenShift.



- Create a ConfigMap by command-lines

```
$ kubectl -n ldap-ss create configmap ldap-ss-ldap2pgyml --from-file=ldap2pg.yml
configmap/ldap-ss-ldap2pgyml created
```

4. Add spec.ldap and spec.ldap2pg entries to FEPCluster CR (fepcluster.yaml)

   It will need to add the entries below to FEPCluster CR during the creation and updating of FEPCluster.

Key	Value	Description
spec.ldap.caConfigMapRef	ldap-ss-cacrt	Refer to step 1
spec.ldap.ldapconfSecretRef	ldap-ss-ldapconf	Refer to step 2
spec.ldap2pg.ldap2pgymlConfigMapRef	ldap-ss-ldap2pgyml	Refer to step 3
spec.ldap2pg.mode		Default value is "check"
spec.ldap2pg.schedule		Default value is '*/5 * * * *'
spec.ldap2pg.enable		Default value is true

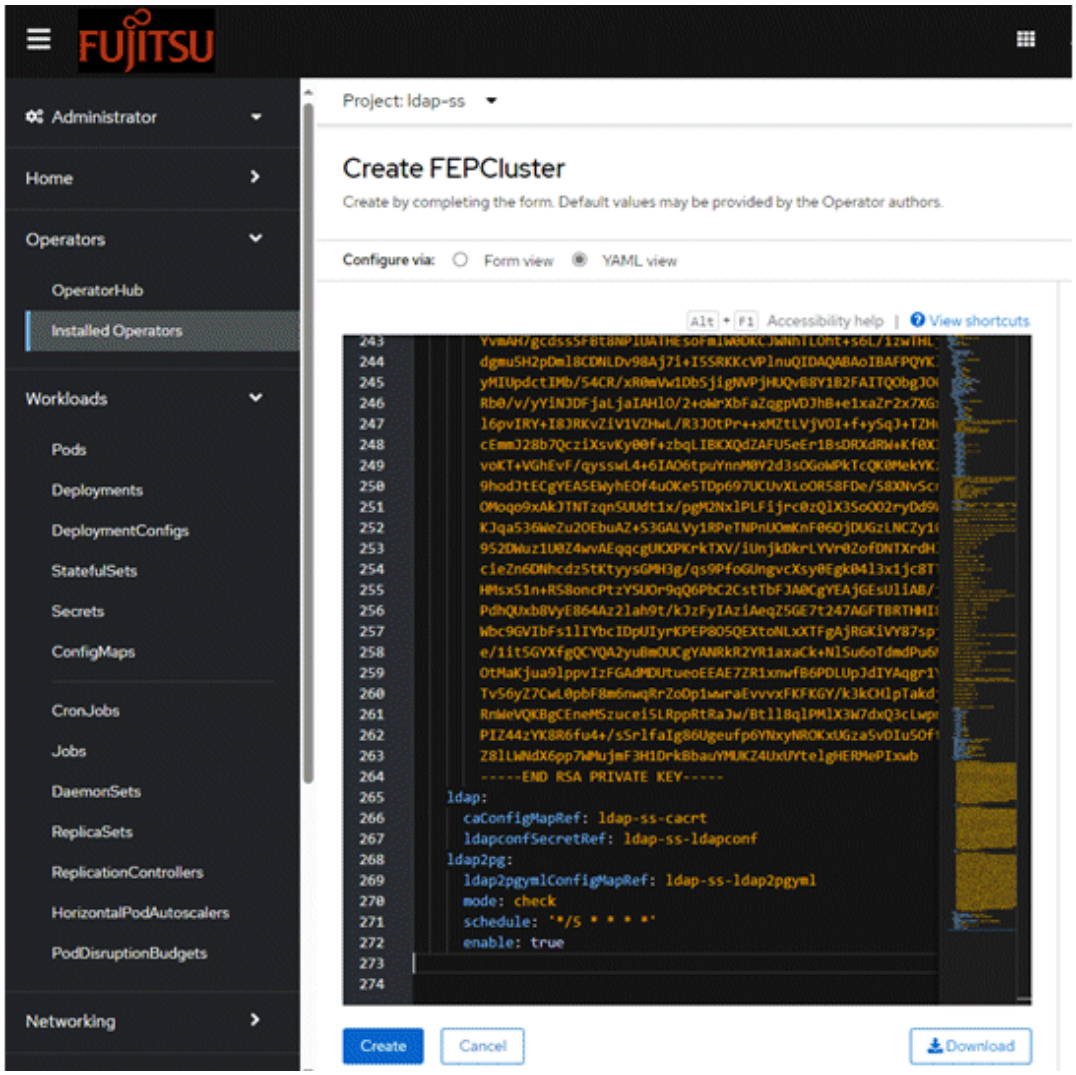
   You can disable ldap2pg feature by setting the spec.ldap2pg.enable to false.

Sample FEPCluster CR with ldap2pg changes (ldap2pg is enabled) (fepcluster.yaml)

```
$ cat fepcluster.yaml

apiVersion: fep.fujitsu.io/v2
kind: FEPCluster
metadata:
  name: ldap-ss
```

```
  namespace: ldap-ss
spec:
  ldap:
    caConfigMapRef: ldap-ss-cacrt
    ldapconfSecretRef: ldap-ss-ldapconf
  ldap2pg:
    ldap2pgymlConfigMapRef: ldap-ss-ldap2pgyml
    mode: check
    schedule: '*/5 * * * *'
    enable: true
```

- Update FEPCluster CR by OpenShift.



- Update FEPCluster CR by command-lines

```
$ kubectl apply -f fepcluster.yaml
```

2.3.15 Fixed Statistics

Fixed statistics means tuning the intended statistics so that they are always used to prevent performance degradation due to changes in query plans. This is achieved by the pg_dbms_stats extension. Operator can schedule statistics to be fixed. The user simply defines a schedule in the FEPCluster custom resource, and the operator automatically fixes the statistics that the user intended.

The following figure shows the procedure for executing the schedule. For more information, refer to "5.14 Operation of Fixed Statistics".

STEP1: Verify the performance of the statistics in the FEPCluster validation environment

STEP2: Store statistics from FEPCluster in validation environment to object storage

STEP3: Define a schedule for fixing statistics to FEPCluster custom resources in a production environment

STEP4: Deploy FEPCluster custom resources for production and schedule statistics consolidation
The binary file download of statistics from object storage occurs as needed.

You can also back up statistics on a regular basis. In the event of performance degradation due to changes in query plan, the backed up statistics can be used to achieve performance stabilization.

pg_dbms_stats allows you to do the following:

- Backup
- Restore
- Lock
- Unlock
- Purge
- Cleanup
- Import

Use FEPAction to perform various operations. For more information, refer to "FEPAction Specific Operation Details" in the Reference.

2.3.16 Environment Variable Definition for Container

You can add environment variables in FEPCluster and its containers. This makes it possible, for example, to define HTTP_PROXY and use cloud services on the Internet via a proxy server from a closed network.

Environment variables are defined in key/value format for any secret. Environment variables are applied in the constructed container by defining a Secret name with environment variables defined in the custom resource.

You can define global environment variables that are common to all containers in a Pod, and local environment variables that are unique to each container.

If you define a global environment variable and a local environment variable with the same name, the value of the local environment variable takes precedence.

2.3.16.1 Secret Example Defining Environment Variables

Here is an example of defining an environment variable with Secret:

Specify the name of the environment variable as key and the base64 encoded value as value.

The following is an example of a global environment variable definition that applies to all containers in the FEPCluster Pod. Secret "global-env-secret" defines two environment variables: HTTP_PROXY and MY_API_SERVER_KEY.

Value is defined as the base64 encoded value of the value written after #.

The name of the Secret is optional and is specified for the custom resource described in the "2.3.16.2 Custom Resource Definition Example" section.

The Secret Namespace specifies the Namespace to which the custom resource is applied.

```
kind: Secret
apiVersion: v1
metadata:
  name: global-env-secret
  namespace: my-namespace
```

```
data:
  HTTP_PROXY: aHR0cDovL215LnByb3h5LnNlcnZlci5pcDo4MDgwCg== # http://my.proxy.server.ip:8080
  MY_API_SERVER_KEY: NjBjZDgzMmMtNDNjZC00ZTI5LWE0N2QtZGI2MjU1MDNkYzJjCg==  # 60cd832c-43cd-4e29-a47d-
db625503dc2c
type: Opaque
```

The following is an example of an environment variable to be specified locally in a container on the FEP server. Secret "local-env-secret" has a different MY_API_SERVER_KEY than global-env-secret.

```
kind: Secret
apiVersion: v1
metadata:
  name: local-env-secret
  namespace: my-namespace
data:
  HTTP_PROXY: aHR0cDovL215LnByb3h5LnNlcnZlci5pcDo4MDgwCg== # http://my.proxy.server.ip:8080
  MY_API_SERVER_KEY: BjBjZDgzMmMtNDNjZC00ZTI5LWE0N2QtZGI2MjU1MDNkYzJjCg== # 0cd832c-43cd-4e29-a47d-
db625503dc2c
type: Opaque
```

2.3.16.2 Custom Resource Definition Example

Provide an example of specifying global and local environment variables when building an FEPCluster custom resource.

Specify the Secret "global-env-secret" in spec.globalEnvSec that defines the global environment variables that apply to all pods in common.

Specify Secret "local-env-secret" in spec.fep.fepEnvSec, which defines the environment variable to be applied to the FEP server container.

```
kind: FEPCluster
apiVersion: fep.fujitsu.io/v2
metadata:
  name: my-cluster
  namespace: my-namespace
spec:
  globalEnvSec: global-env-secret
  fep:
    fepEnvSec: local-env-secret
```

At this time, the environment variable MY_API_SERVER_KEY is defined in global-env-secret and local-env-secret with different values, but the value “0cd832c-43cd-4e29-a47d-db625503dc2c”defined in local-env-secret is applied in the FEP server container.

Refer to the Reference for parameters for applying environment variables to other containers.

Specifying a Secret with an environment variable defined can only be defined when creating a custom resource. Secrets cannot be added or modified after custom resource creation.

2.3.16.3 Environment Variables Update

After you update the contents of the Secret with environment variables defined, you can restart the Pod to reflect the latest environment variables in the container.

Pod reboots can be performed by specifying restart for spec.fepAction.type in the FEPAction custom resource.

Refer to the "FEPAction Custom Resource Parameters" in the Reference for more information.

2.3.17 Multi-master Replication

The Operator builds a multi-master replication configuration across three or more streaming replication clusters.

You can enable this functionality by defining the connection information/credentials for the logical replication destination and the databases to be replicated in each Kubernetes environment.

Multi-master replication is established between the master instances of the streaming replication clusters. When a master instance fails and a replica instance is promoted to master, logical replication is automatically enabled on the newly promoted master.

Additionally, it provides procedures for migrating the FEPCluster to a different Kubernetes environment if the Kubernetes itself hosting the FEPCluster experiences issues, and means to monitor metrics related to multi-master replication.

Chapter 3 Operator Installation

This chapter describes how to install FEP operator.

Refer to "6.6 Assigned Resources for Operator Containers" for more information about the resources assigned to installed operator containers and how to change them.

"<*x.y.z*>" in the screen example indicates the version level of the operator. Also, "<*X*>" indicates the product version of Fujitsu Enterprise Postgres.

Note

If you are using anti-virus software, exclude the directory for resource allocation from virus scanning.

Operator's Scope

Operators can switch whether the scope of operation management is a single Namespace or all Namespaces. An operator that manages a single Namespace is called a NamespaceScope, and an operator that manages all Namespaces is called a ClusterScope.

Note that you cannot install both NamespaceScope Operators and ClusterScope Operators on the same Kubernetes cluster. Additionally, you cannot directly upgrade a NamespaceScope Operator to a ClusterScope Operator. If a NamespaceScope Operator is already installed, uninstall all NamespaceScope Operators before installing the ClusterScope Operator.

Switching scopes varies depending on how the operator is installed, so refer to each installation method.

Automatic certificate generation feature

Operators can automatically generate certificates and improve security by making inter-container communication MTLS. For the automatic certificate generation feature, if cert-manager is installed in the Kubernetes environment, cert-manager is used, and if cert-manager is not installed, the openssl command in the container is used to generate certificates.

The settings for the automatic certificate generation feature (certificate generation method and CA certificate CN name) must be defined before the operator installation. Since the setting method for the automatic certificate generation feature differs depending on the installation method, refer to each installation method.

When certificates are automatically generated, the default connection method to PostgreSQL is mutual authentication TLS communication only. If you want to change the authentication method for each user, define the connection method for each user in spec.fepChildCrVal.customPgHba.

If you want to use a manually created certificate, refer to "4.8.2 When Using Your Own Certificate". If you want to use your own certificate, disable the automatic certificate generation feature.

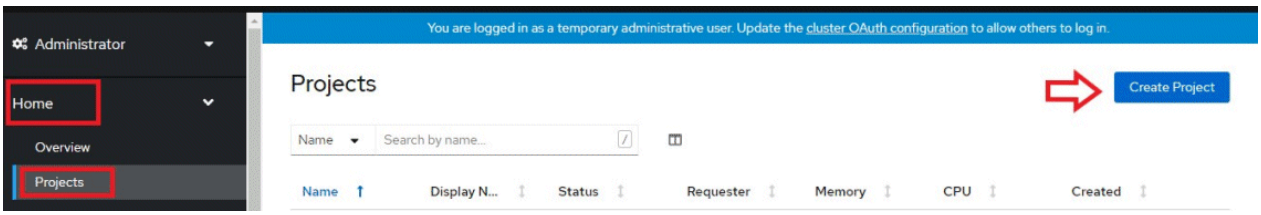
3.1 Using the OperatorHub

Describes how to use OperatorHub to install FEP operators into a new namespace on Openshift.

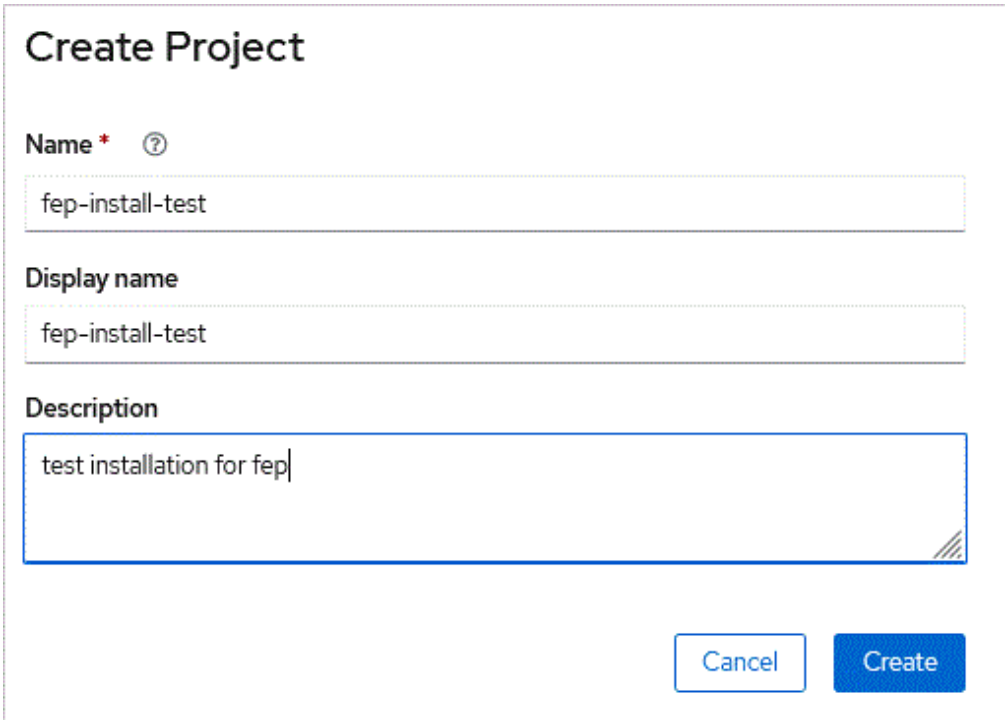
3.1.1 Pre-requisite

A project on openshift is essentially a namespace. It is a good practice to install FEP in a separate name space. On the RedHat OpenShift platform, click "Home" under "Projects" main menu and hence click on "Create Project".

(Screen Shot 1 and 2 - Create Project on OCP - ***for ref.***)



In the dialog box, specify a unique name for your namespace and an optional display name and description.



Note

Operator installation needs Prometheus to be pre-installed in the Openshift cluster.

3.1.2 Setting Up the Automatic Certificate Generation Feature

To automatically generate certificates using the automatic certificate generation feature, create the following ConfigMap "fepopr-cert-method" before installing the operator. In fepopr-cert-method, specify the certificate generation method and CN name.

Example of creating ConfigMap "fepopr-cert-method"

```
$ cat > /tmp/cert-method.yaml <<EOF
kind: ConfigMap
apiVersion: v1
metadata:
  name: fepopr-cert-method
data:
  fepopr-cert-method: disable
  fepopr-cert-common-name:  “Operator Common Name”
EOF
$ kubectl -n <namespace> apply -f /tmp/cert-method.yaml
```

Values that can be specified in the data of ConfigMap "fepopr-cert-method"

Parameter	Default	Description
fepopr-cert-method	If cert-manager is installed: cert-manager If cert-manager is not installed: openssl	Specify how to generate the certificate. You can specify cert-manager, openssl, or disable. If you want to disable the

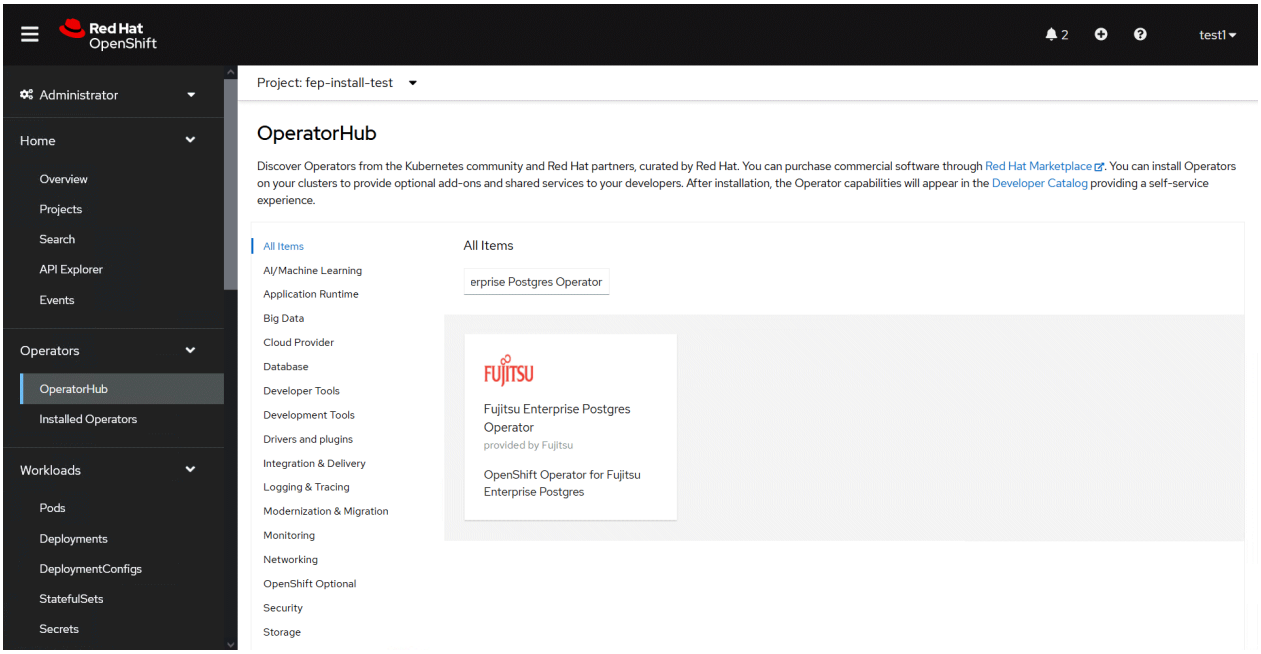
Parameter	Default	Description
		automatic certificate generation feature, specify disable.
fepopr-cert-common-name	-	If this value is specified, the CN name of the CA certificate created for the automatic certificate generation feature will be <Namespace name where the operator is installed>-<tlsCommonName value>. If not specified, the CN name will only be the Namespace name where the operator is installed.

When using the ClusterScope operator, if you create a ConfigMap "fepopr-cert-methood" in the Namespace where the operator is installed, the same definition will be applied to all Namespaces.

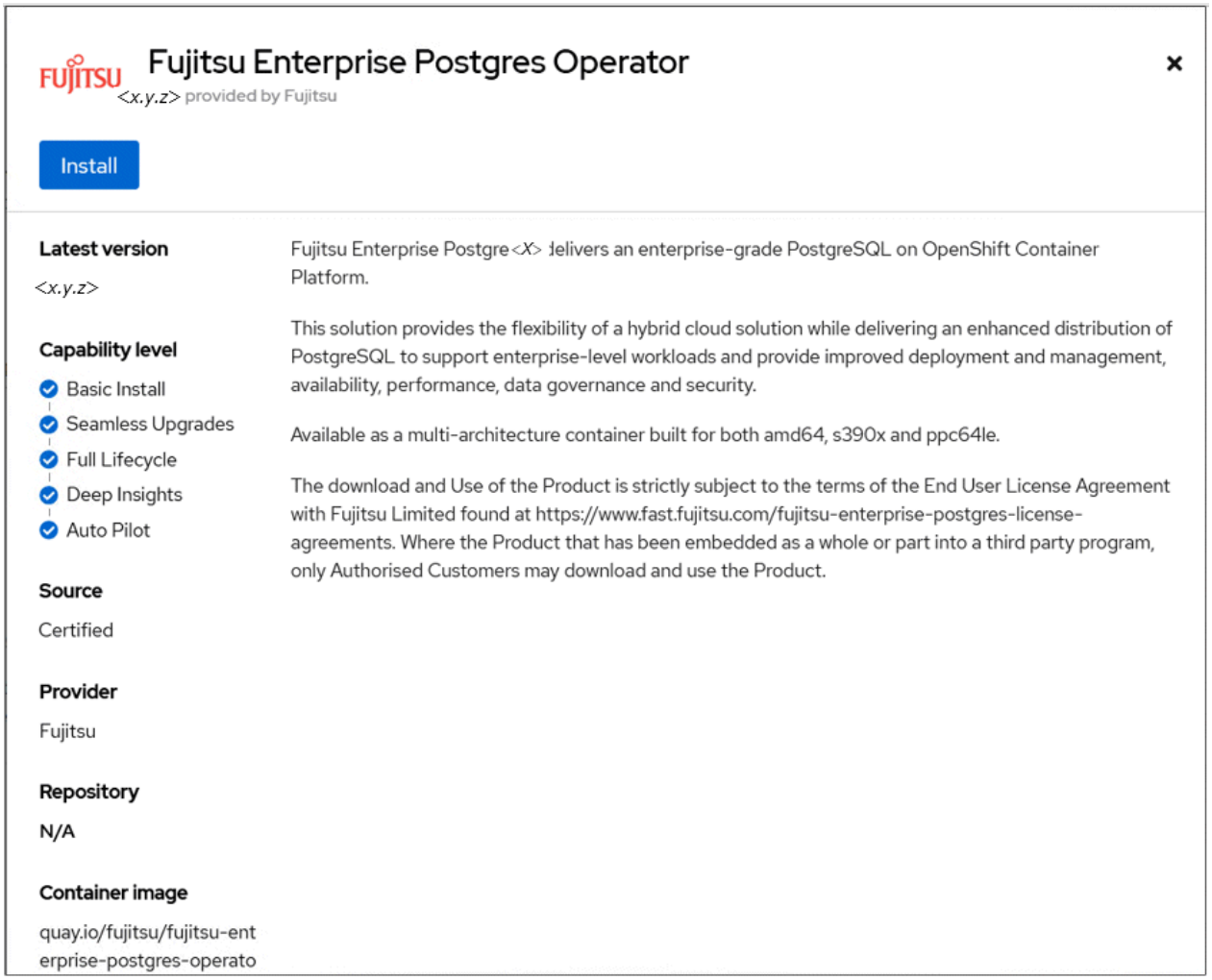
3.1.3 Deploying Operator

Once operator is certified by RedHat, it is made available on OperatorHub on all RedHat OpenShift container plaform.

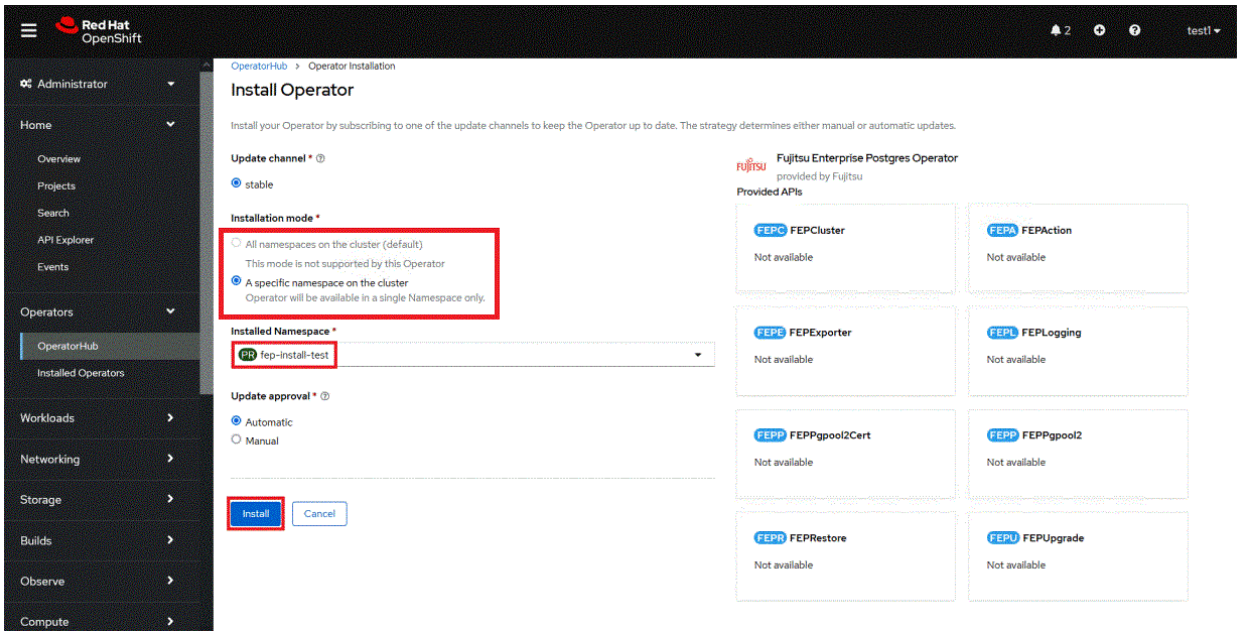
On OpenShift platform, logon with credentials that has privileges to install operator. Click on OperatorHub on menu item under Operators and type filter keyword "Fujitsu Enterprise Postgres Operator" to find Fujitsu Enterprise Postgres Operator.



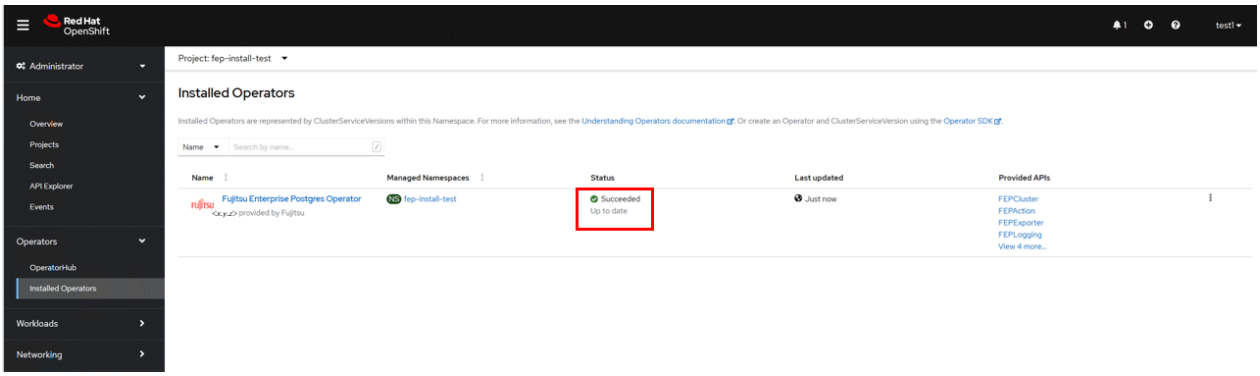
Click on Fujitsu Enterprise Postgres Operator to install operator. It will bring up details page with install button as below.



Click on "Install" button, to bring up following screen to choose namespace and approval strategy. For NamespaceScope Operators, select "A specific namespace on the cluster" and choose the desired namespace. For ClusterScope Operators, select "All namespaces on the cluster (default)". Leave everything else to default and click install.



Wait still installation is complete and status changes to "Succeeded".



3.1.4 Upgrading Operators

If you select Automatic for "Update approval" on the "Install Operator" screen under "3.1.3 Deploying Operator", the operator will be automatically upgraded when a new version is published.

If Manual is selected for "Update approval", perform the following steps to upgrade manually.

1. Select the installed "Fujitsu Enterprise Postgres Operator" from [Operators] - [Installed Operators].
2. Follow the on-screen instructions to upgrade your operator from [Subscription details] in the [Subscription] tab

3.2 Using the Helm Chart

Describes how to install FEP operators into a new namespace on Kubernetes using the Helm feature.

3.2.1 Preparation

This section describes the preparatory steps for installing an operator with HelmChart.

HemChart allows you to install operators according to the installation definition YAML file. The HelmChart installation definition allows you to specify the following:

- Scope of operator-managed operations
- Whether ClusterRole can be created
- Setting up automatic certificate generation feature

Refer to the table below for the default values of each setting. If you want to change the definition from the default, create a YAML file. The created YAML file will be used in "3.2.2 Deploying Operator".

Example of specifying installation definitions in values.yaml

```
$ cat > /tmp/value.yaml <<EOF
multiNamespace: true
tlsCertMethod: cert-manager
EOF
```

Values that can be specified in the HelmChart installation definition

Parameter	Default	Description
multiNamespace	false	If true, the operator will be installed in ClusterScope (a state where one operator manages all Namespaces).

Parameter	Default	Description
		If false, the operator will be installed in NamespaceScope (a state where the operator manages only the Namespace in which it is installed). However, if createClusterRole is false and this parameter is true, the operator cannot be installed.
createClusterRole	true	If true, ClusterRole will not be created. If ClusterRole is not created, the use of the following features will be restricted: - ClusterScope operator installation - PVC expansion feature
tlsCertMethod	If cert-manager is installed: cert-manager If cert-manager is not installed: openssl	Specify how to generate the certificate. You can specify cert-manager, openssl, or disable. If you want to disable the automatic certificate generation feature, specify disable. This parameter is equivalent to data.fepopr-cert-method in ConfigMap "fepopr-cert-method".
tlsCommonName	-	If this value is specified, the CN name of the CA certificate created for the automatic certificate generation feature will be <Namespace name where the operator is installed>-<tlsCommonName value>. If not specified, the CN name will only be the Namespace name where the operator is installed. This parameter is equivalent to data.fepopr-cert-common-name in ConfigMap "fepopr-cert-method".

3.2.2 Deploying Operator

1. Add a Helm Chart repository for the operator.

   Add the repository as follows, depending on the base image you are using.

   - Red Hat UBI

   ```
   helm repo add fep-repo https://fujitsu.github.io/fep-operator-helm/v1
   ```

   - SLE BCI

   ```
   helm repo add fep-repo https://fujitsu.github.io/fep-operator-helm-for-slebci/v1
   ```

2. Create a namespace to install the operator.

   ```
   kubectl create namespace fep-operator
   ```

> **Note**
>
> Operator installation needs Prometheus to be installed in the Kubernetes cluster in advance.

3. Run the helm command to install the operator.

```
helm install fep-operator-release fep-repo/fujitsu-enterprise-postgres-operator --namespace fep-operator
```

If you create a YAML file specifying the installation definition in "3.2.1 Preparation", install the Operator by specifying the created values.yaml file when executing the helm install command.

```
helm install fep-operator-release fep-repo/fujitsu-enterprise-postgres-operator --namespace fep-operator -f values.yaml
```

3.2.3 Upgrading Operators

1. Refresh Helm Chart repository information.

```
helm repo update
```

2. Check the Helm Chart version of the latest operator.

```
helm search repo fujitsu-enterprise-postgres-operator
```

3. Run the helm command to upgrade the operator.

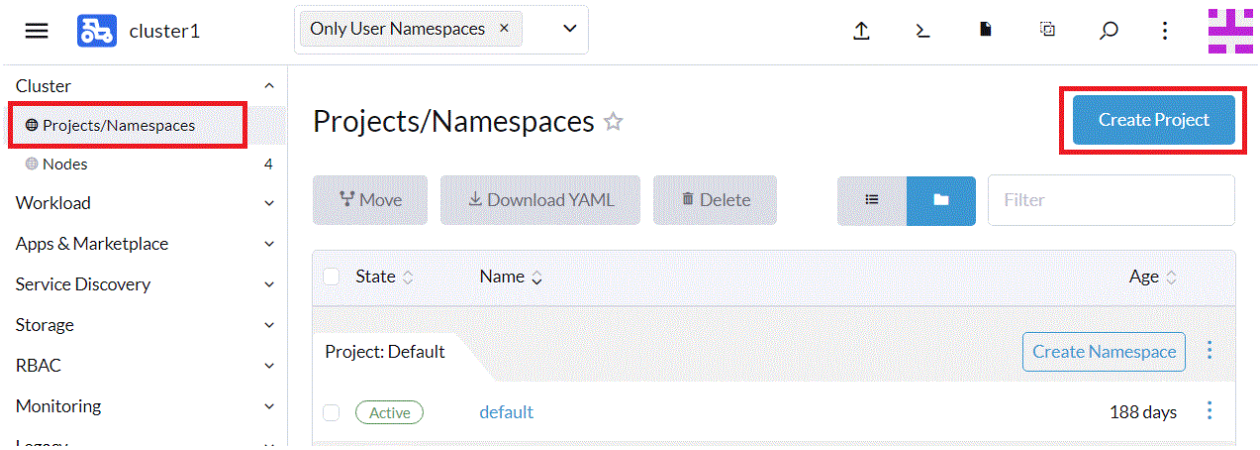
```
helm upgrade fep-operator-release fep-repo/fujitsu-enterprise-postgres-operator --namespace fep-operator
```

3.3 Using the Rancher UI

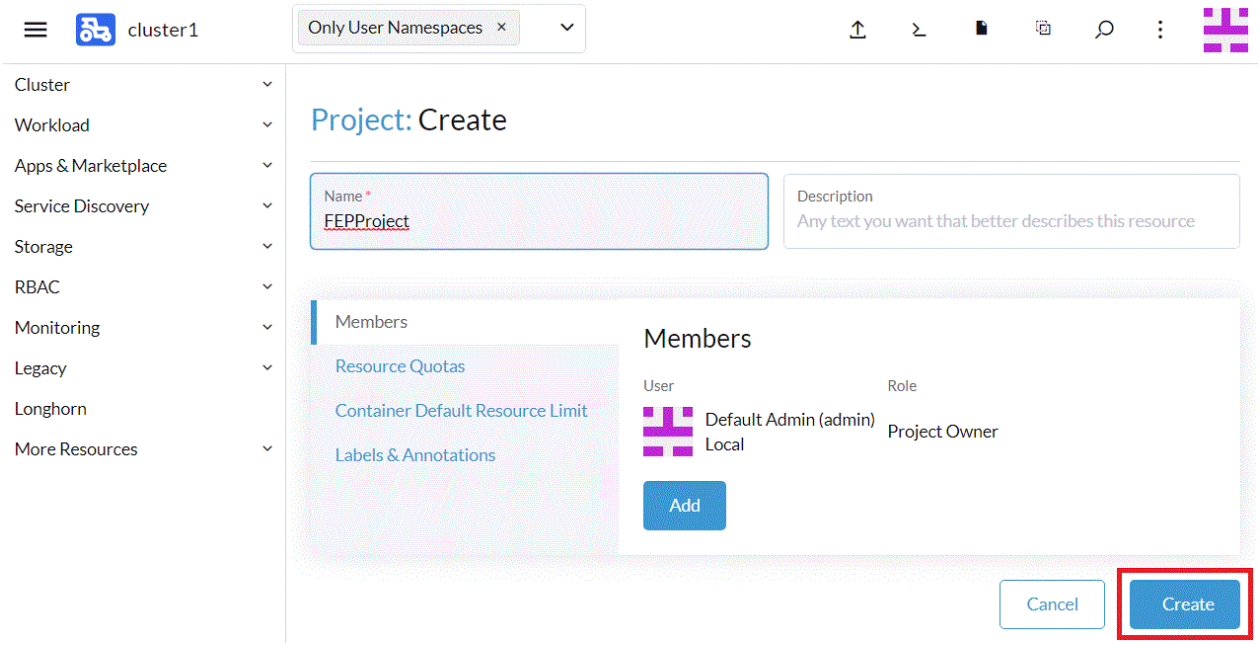
Describes how to install FEP operators into a new namespace on Rancher UI.

3.3.1 Pre-requisite

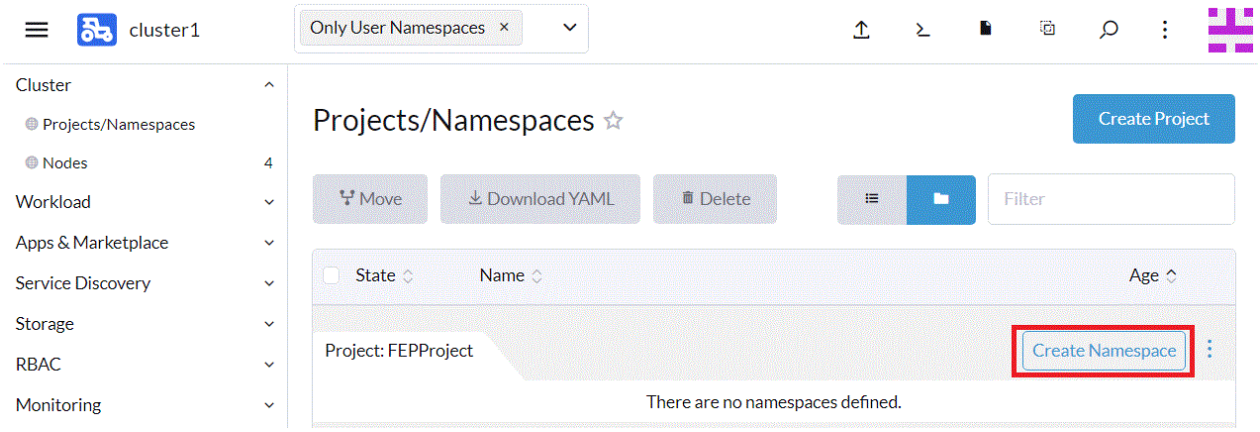
Create a project and its associated namespace on the Rancher UI. We recommend that you install FEP in a different namespace. In the Rancher UI, click [Projects/Namespaces], then click [Create Project] that appears.



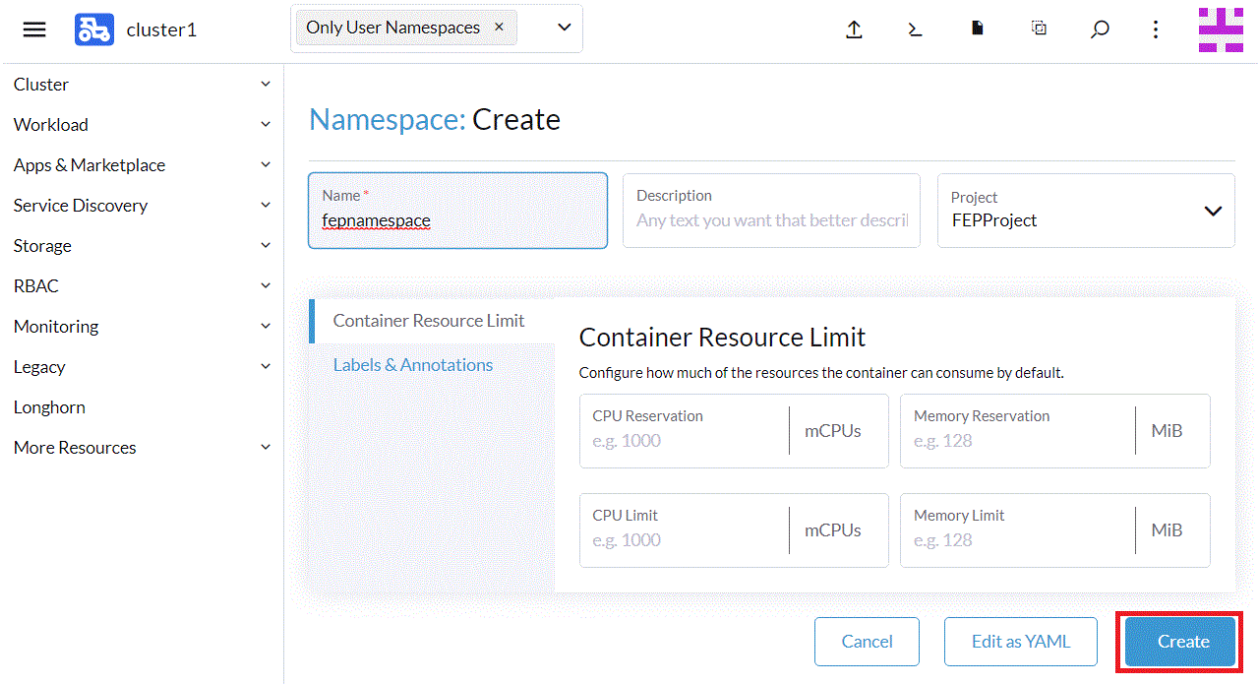
Specify a unique name for the project and click [Create].



Click [Create Namespace] displayed on the specified project.



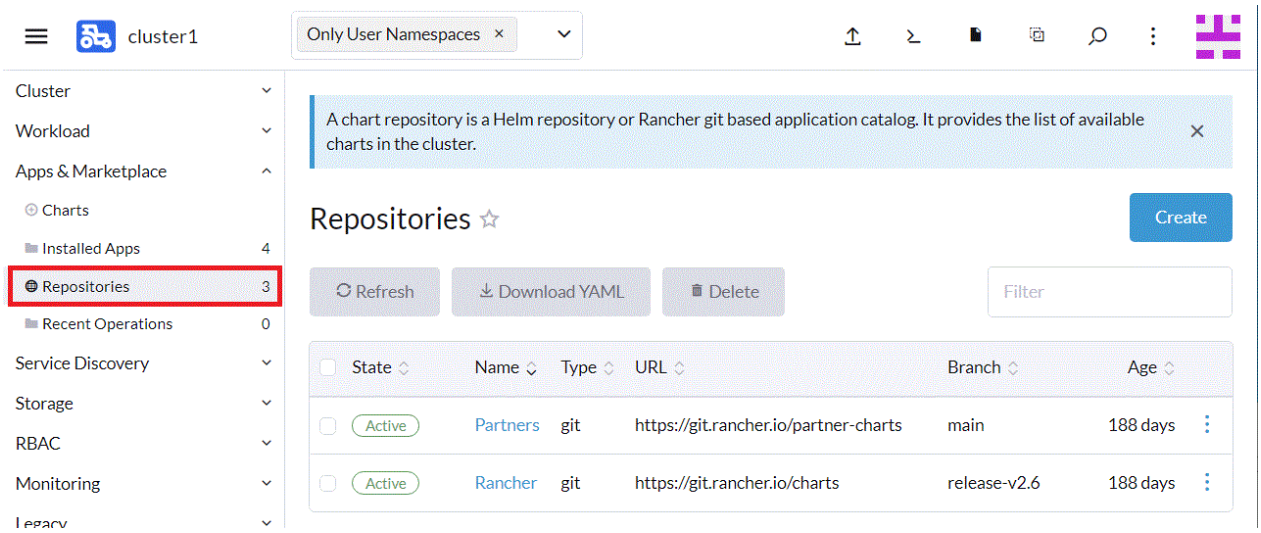
Specify a unique name in the namespace and click [Create].



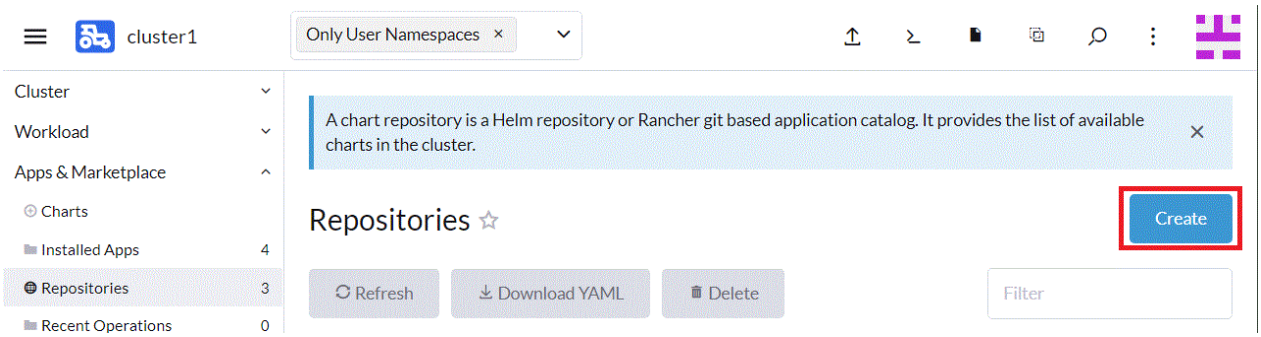
3.3.2 Register Helm Chart Repository

Register the Helm Chart repository of the operator feature on the Rancher UI.

In the Rancher UI, click [Apps & Marketplace], then click [Repositories] that appears.



Click [Create] to create the Helm Chart repository.



Enter the unique name of the catalog and the URL of the catalog below, and click [Create].

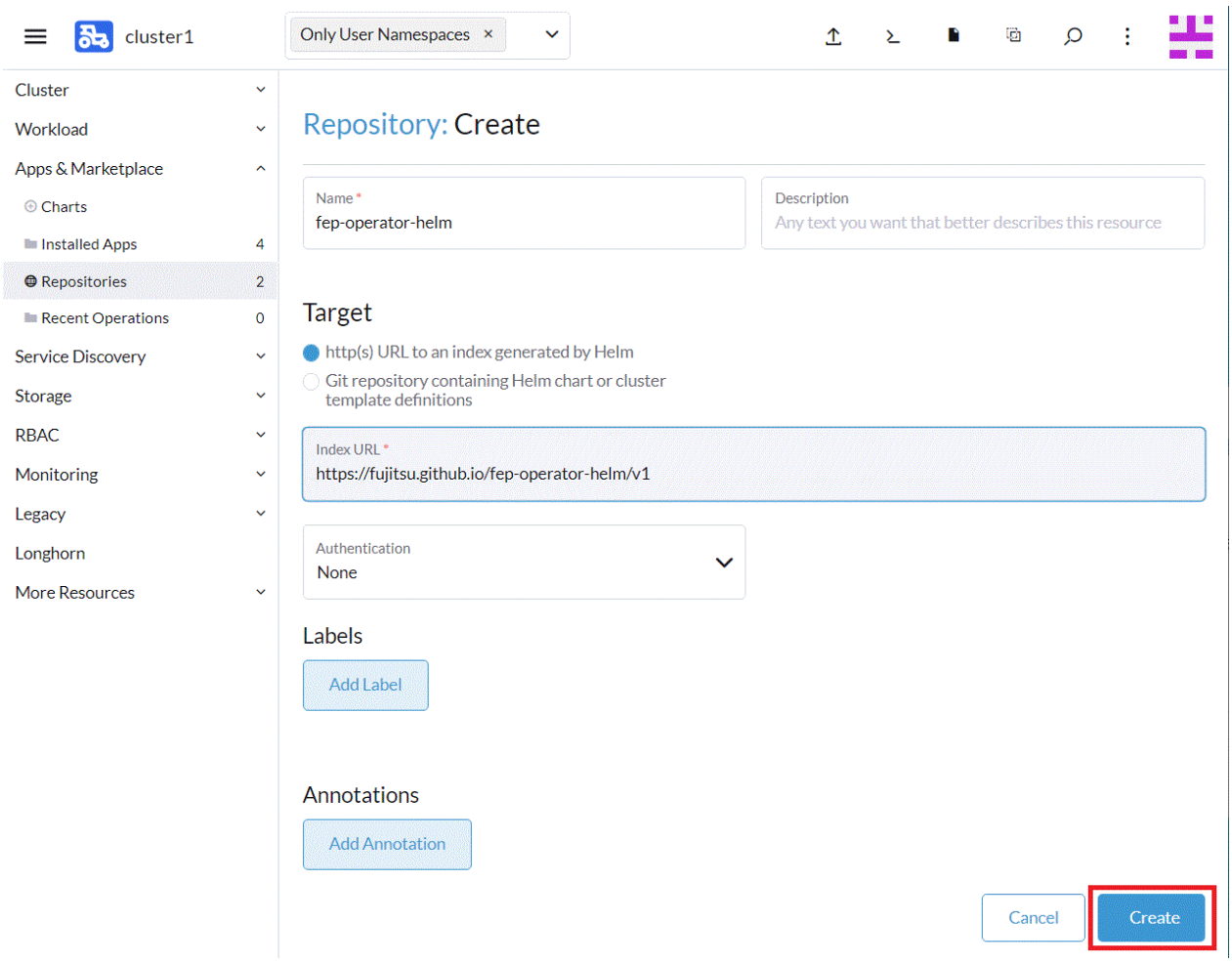
Add the repository as follows, depending on the base image you are using.

- Red Hat UBI

```
helm repo add fep-repo https://fujitsu.github.io/fep-operator-helm/v1
```

- SLE BCI

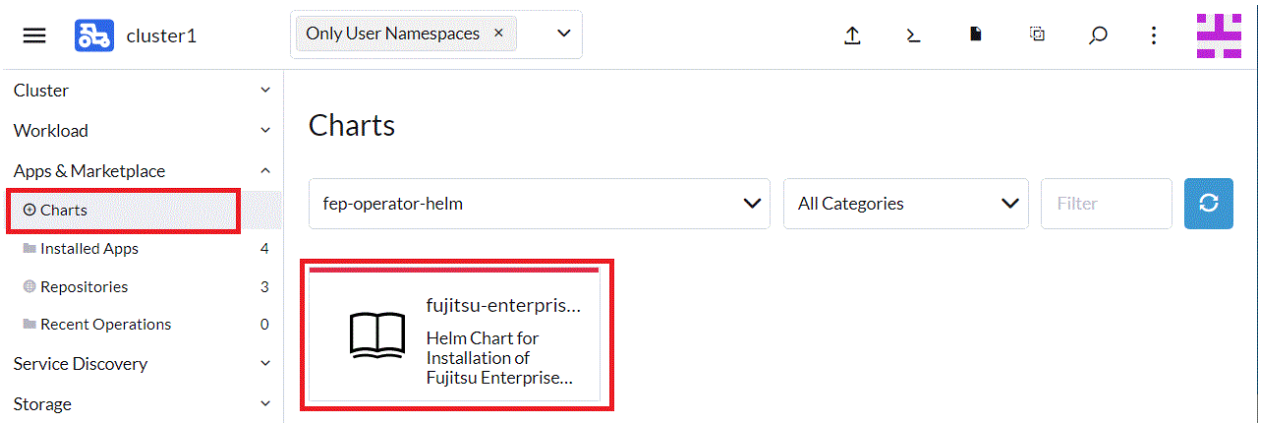
```
helm repo add fep-repo https://fujitsu.github.io/fep-operator-helm-for-slebci/v1
```



3.3.3 Deploying Operator

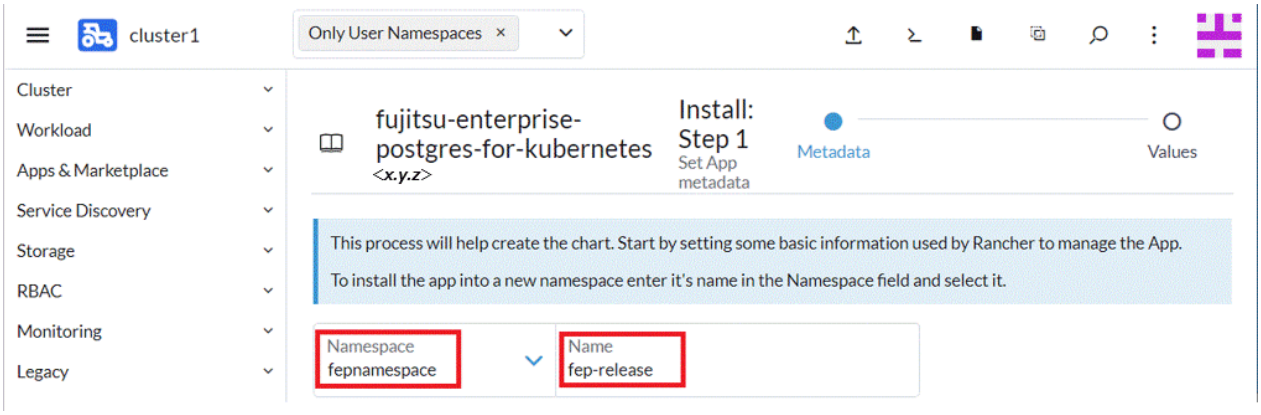
On the Rancher UI, apply the operator feature Helm Chart to the project / namespace created in "3.3.1 Pre-requisite" and install the operator.

From the leftmost tab, click [Charts], then click [fujitsu-enterprise-postgres-operator].

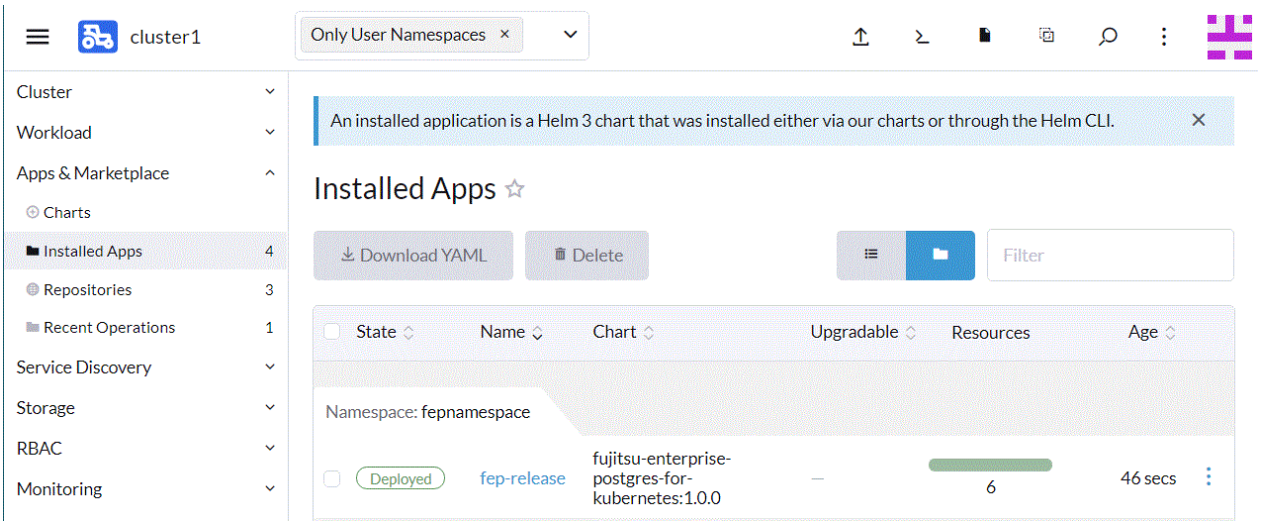


Click Install on the screen that appears.

Change the [Namespace] item to the name created in "3.3.1 Pre-requisite", enter the release name in the [Name] item, click [Next], and then click [Install] on the next screen.



The operator is deployed on the target namespace.



3.3.4 Upgrading Operators

1. Update the Helm Chart repository.

   In the Rancher UI, click [Apps & Marketplace] and then click [Repositories] that appears.

   Click Refresh to update the repository.

2. Upgrade the operator.

   In the Rancher UI, click Apps & Marketplace, then click Installed Apps.

   Select the operator you installed and follow the on-screen instructions to upgrade the operator.

3.4 Implement Collaborative Monitoring Tools

3.4.1 Implement GAP Stack

There is a pre-requisitie for running FEPExporter.

- GAP(Grafana, AlertManager, Prometheus) stack is installed on host OpenShift or Kubernetes cluster
- FEPCluster that needs to be scraped is deployed and running properly
- FEPCluster has following setting postgresql.conf:
  - pg_stats_statements library pre-loaded
  - track_activities and track_counts are turned on

For Prometheus and AlertManager, use the monitoring stack preinstalled on Openshift. Please refer to the following for deployment information.

(https://docs.openshift.com/container-platform/4.11/monitoring/monitoring-overview.html#understanding-the-monitoring-stack_monitoring-overview)

For Grafana, install and use the GrafanaOperator provided by OperatorHub.

Grafana comes pre-installed on OpenShift, but it is recommended to use Grafana published in OperatorHub to customize the dashboard and monitor FEP performance information.

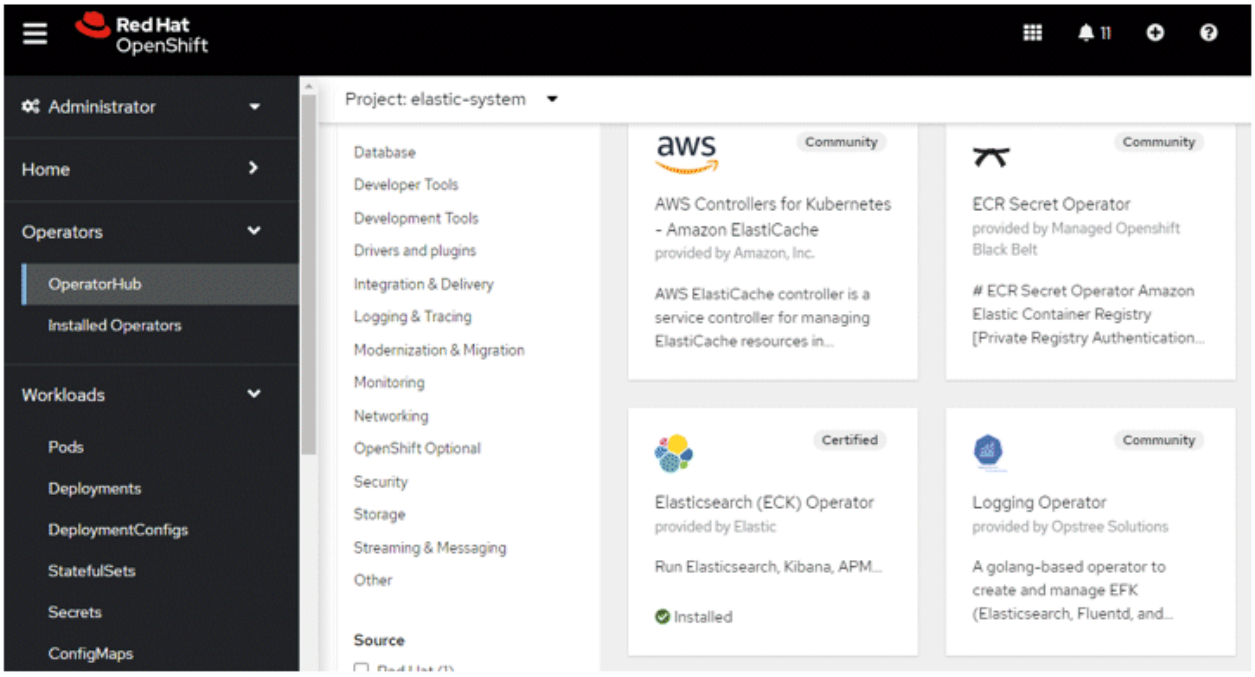
You can also use the sample dashboards published below.

https://github.com/fujitsu/fep-operator-examples/blob/v4/Monitoring/dashboard/fep-dashboard.json

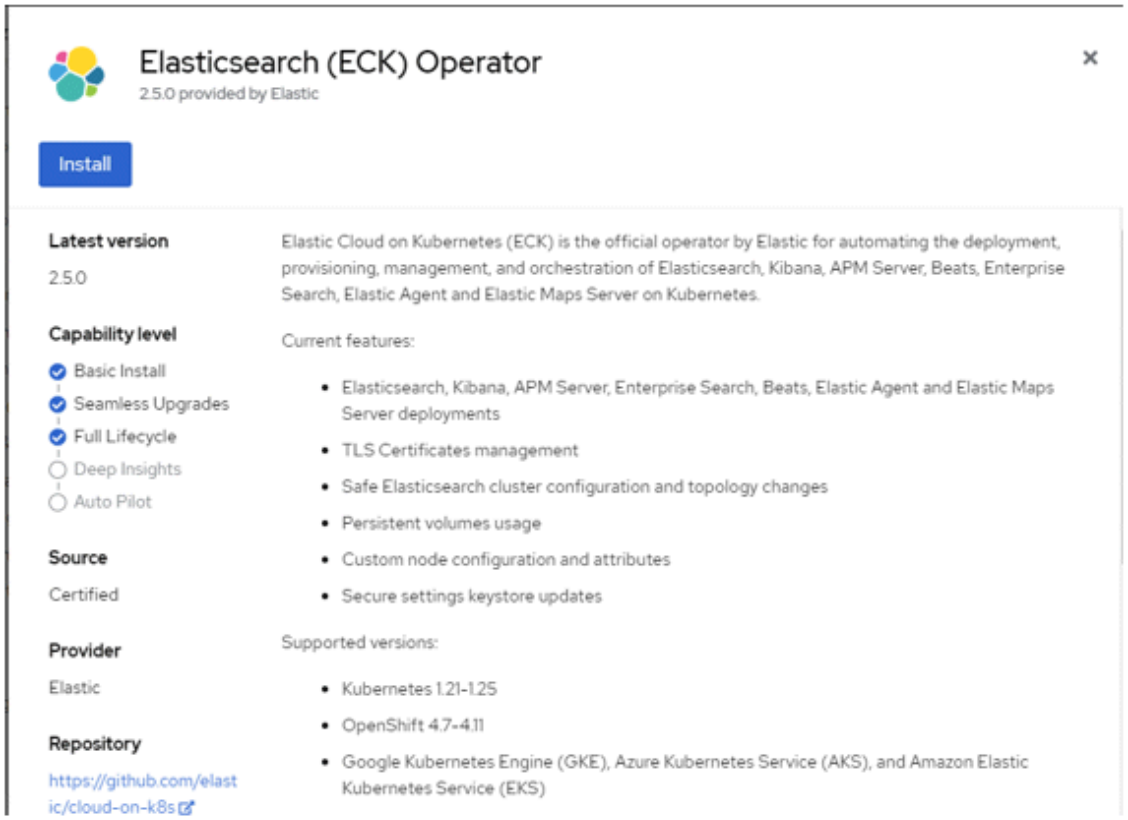
3.4.2 Implement Elastic Cloud on Kubernetes

3.4.2.1 Deploy ECK Operator

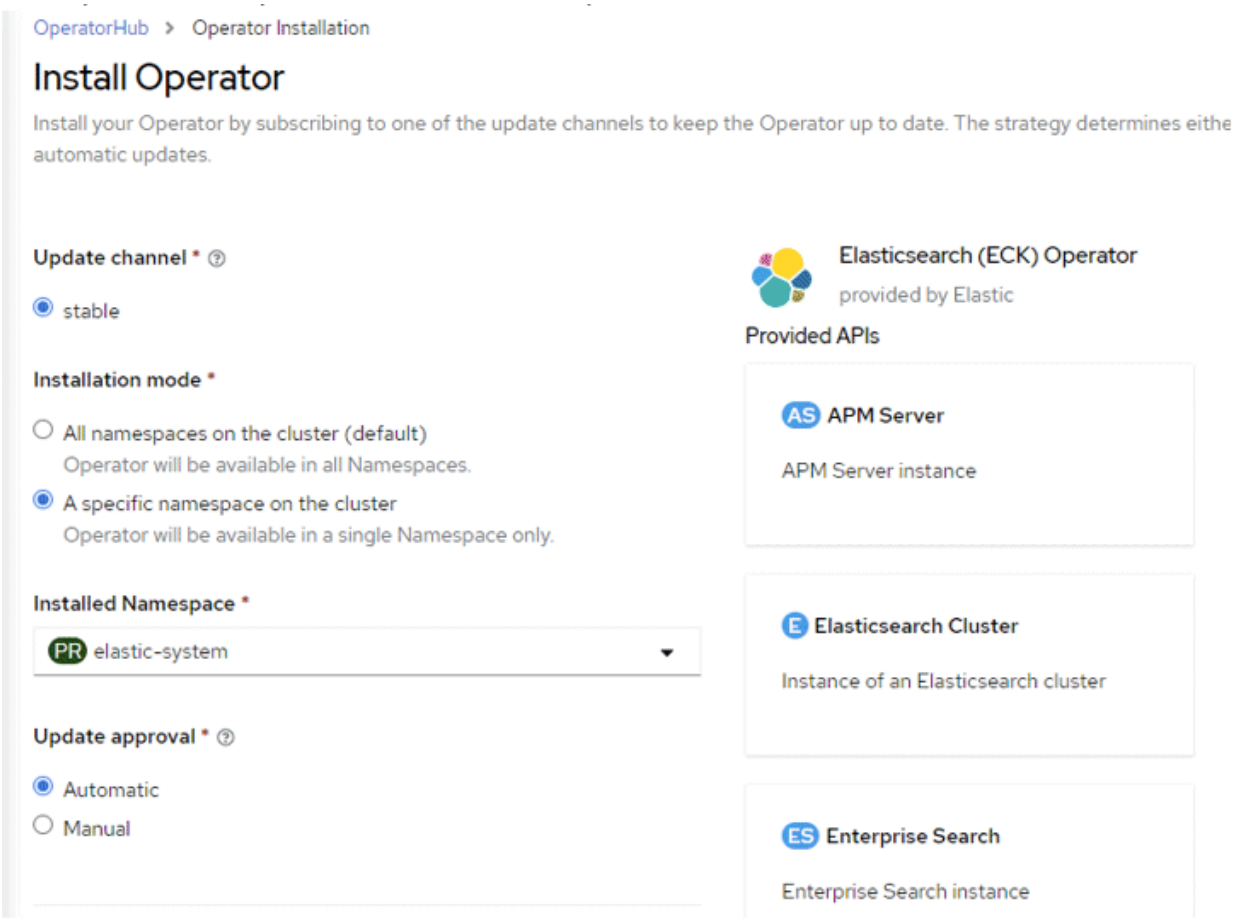
1. Create namespace(project) elastic-system.
2. In OperatorHub, install Elasticsearch (ECK) Operator provided by Elastic.



3. Click Install to start proceed.

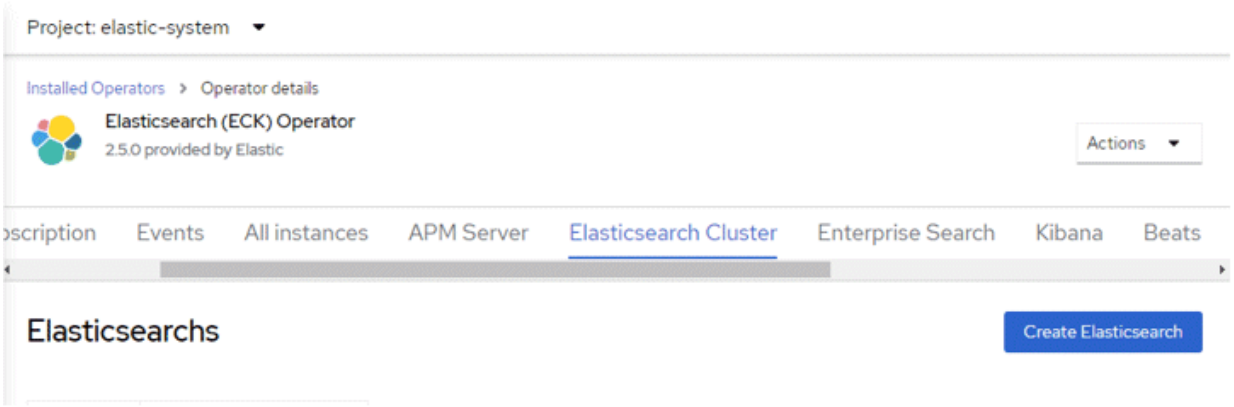


4. Change the Installation mode to "A specific namespace on the cluster" and select namespace "elastic-system". Click Install to complete the installation.



3.4.2.2 Deploy Elasticsearch Cluster

1. In Installed Operators, select "Elasticsearch (ECK) Operator".
2. Select "Elasticsearch Cluster" and "Create Elasticsearch".



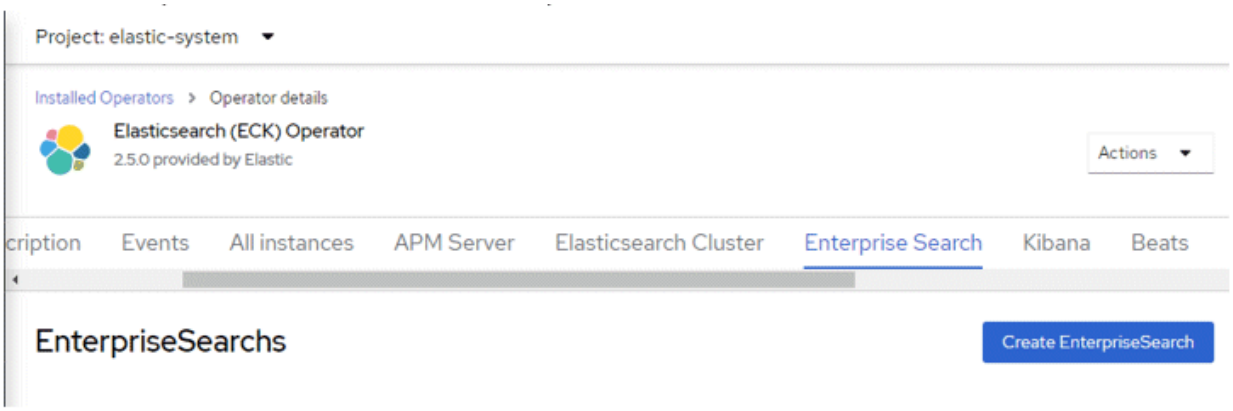
3. In YAML view, enter the following details and click "Create".

```
apiVersion: elasticsearch.k8s.elastic.co/v1
kind: Elasticsearch
metadata:
  name: quickstart
```

```
spec:
  version: 8.5.2
  nodeSets:
  - name: default
    count: 1
    config:
      node.store.allow_mmap: false
```

3.4.2.3 Deploy Enterprise Search

1. In Installed Operators, select "Elasticsearch (ECK) Operator".
2. Select "Enterprise Search" and "Create EnterpriseSearch".

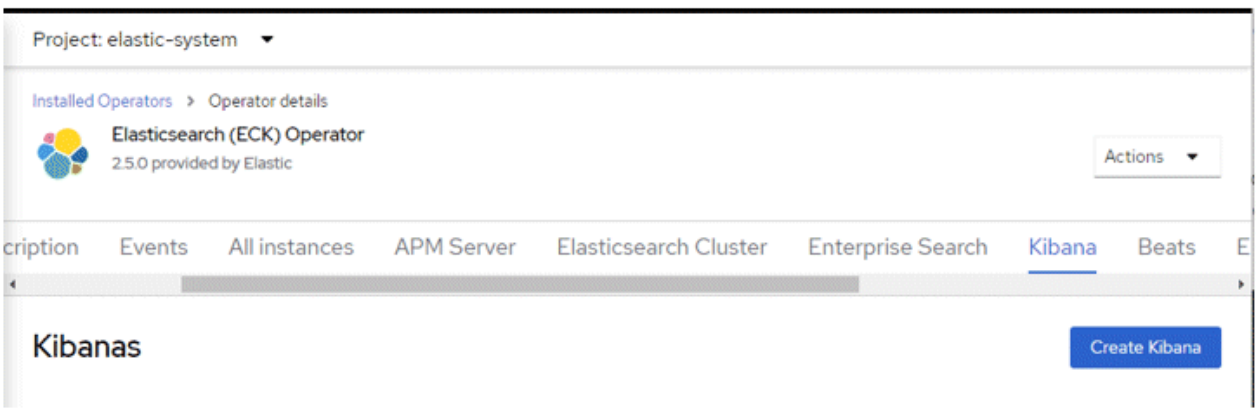


3. In YAML view, enter the following details and click "Create".

```
apiVersion: enterprisesearch.k8s.elastic.co/v1
kind: EnterpriseSearch
metadata:
  name: enterprise-search-quickstart
spec:
  version: 8.5.2
  count: 1
  elasticsearchRef:
    name: quickstart
```

3.4.2.4 Deploy Kibana

1. In Installed Operators, select "Elasticsearch (ECK) Operator".
2. Select "Kibana" and "Create Kibana".



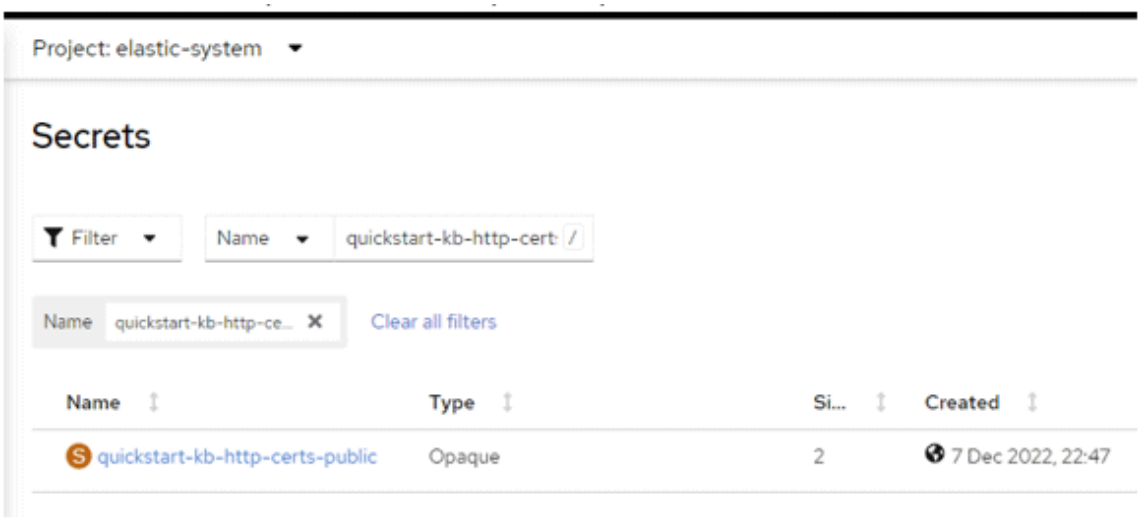
3. In YAML view, enter the following details and click "Create".

```
piVersion: kibana.k8s.elastic.co/v1
kind: Kibana
metadata:
  name: quickstart
spec:
  count: 1
  elasticsearchRef:
    name: quickstart
  enterpriseSearchRef:
    name: enterprise-search-quickstart
  version: 8.5.2
```

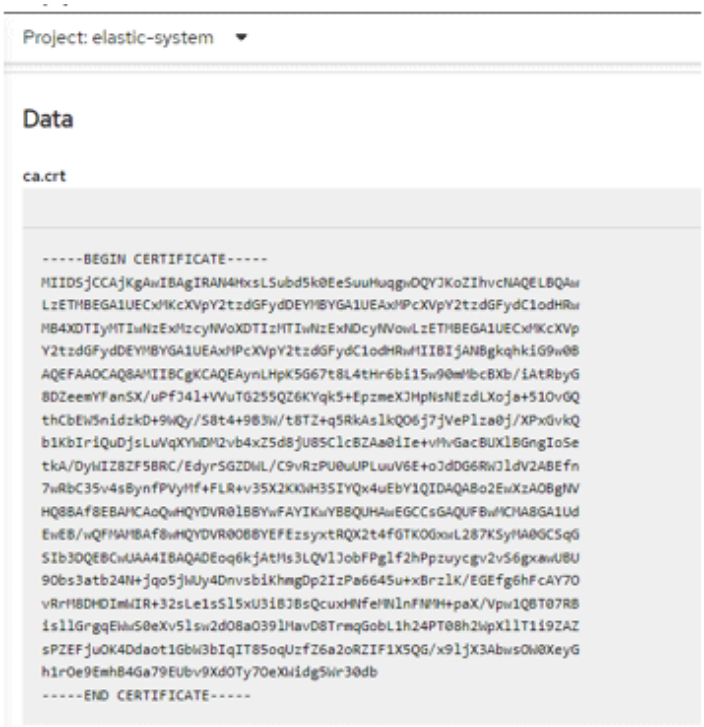
3.4.2.5 Expose Kibana using OpenShift Route

1. Obtain CA certificate that signs Kibana certificate.

   Locate the secret quickstart-kb-http-certs-public.



Copy the content of ca.crt.



2. Create route for Internet access.

   Navigate to Networking -> Route and select "Create Route".

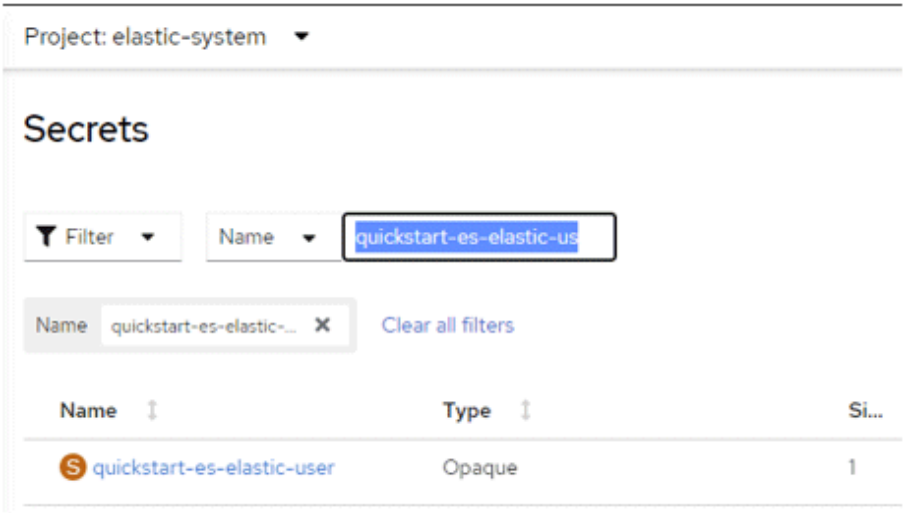
   Fill in the details

Key	Value
Name	kibana
Hostname	Leave empty
Path	/
Service	quickstart-kb-http
Target port	5601 -> 5601 (TCP)
Secure Route	selected
TLS termination	Re-encrypt
Insecure traffic	Redirect
Destination CA certificate	Content of ca.crt in previous step

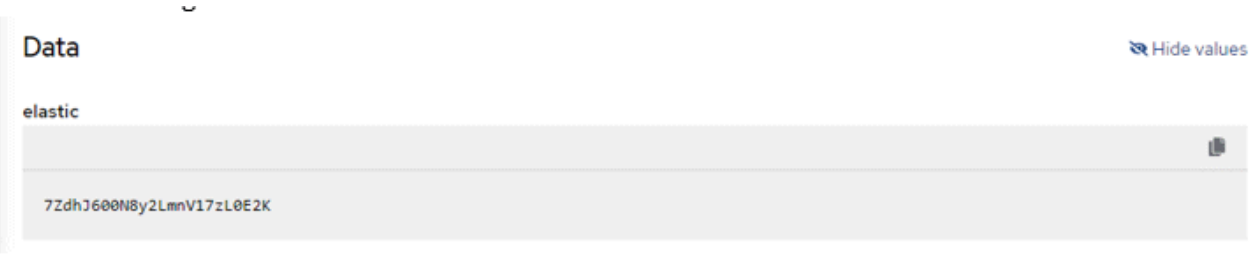
3.4.2.6 Login to Kibana

1. Obtain the Elasticsearch/Kibana login details

   Locate the secret quickstart-es-elastic-user

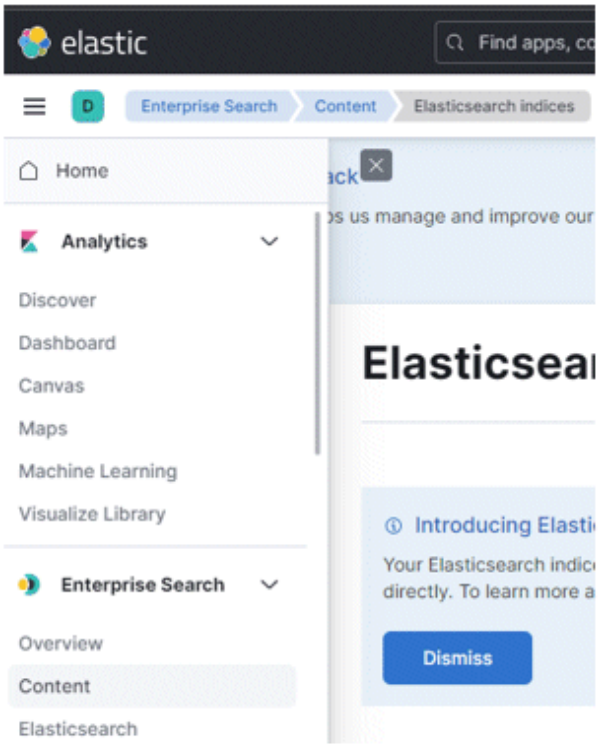


2. Observe the login details from the secret



3. Visit the URL as created in the Route above and use the above credential to login

4. Select the collapsed menu icon on top left corner and select Enterprise Search -> Content



5. If fluentd is forwarding logs to this elastic cluster, you will find the indexes here.

3.5 Implement Client

To use the FEP client, use the media or download the rpm module from the following site.

https://www.postgresql.fastware.com/fujitsu-enterprise-postgres-client-download

Chapter 4 Deployment Container

This chapter describes container deployment.

CR templates (sample files) for operating databases using Fujitsu Enterprise Postgres Operator are published in the following repository on GitHub. By using templates, you can easily deploy containers.

https://github.com/fujitsu/fep-operator-examples

Note

- Each volume of a Pod created by a FEPCluster deployment is sized by default for the following operations:
  - Data size: 1 GB
  - Daily update: about 50 MB

  Refer to "2.3.3 Configurable Volume per Cluster" to design each volume size according to actual operation.
- If you are using anti-virus software, exclude all volumes that make up the FEPCluster from virus scanning.

4.1 Deploying FEPCluster using Operator

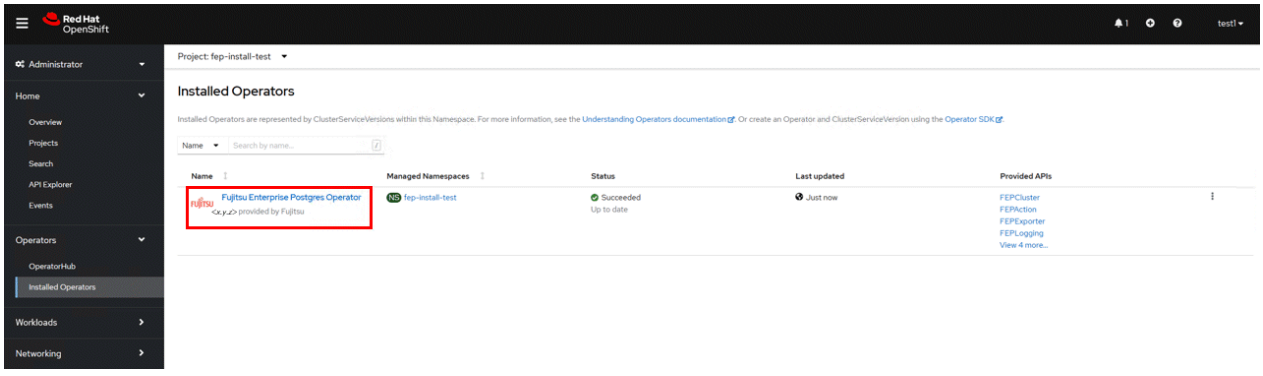
To deploy a FEPCluster in given namespace, follow these steps.

"<*x.y.z*>" in the screen example indicates the version level of the operator. Also, "<*X*>" indicates the product version of Fujitsu Enterprise Postgres.

Note

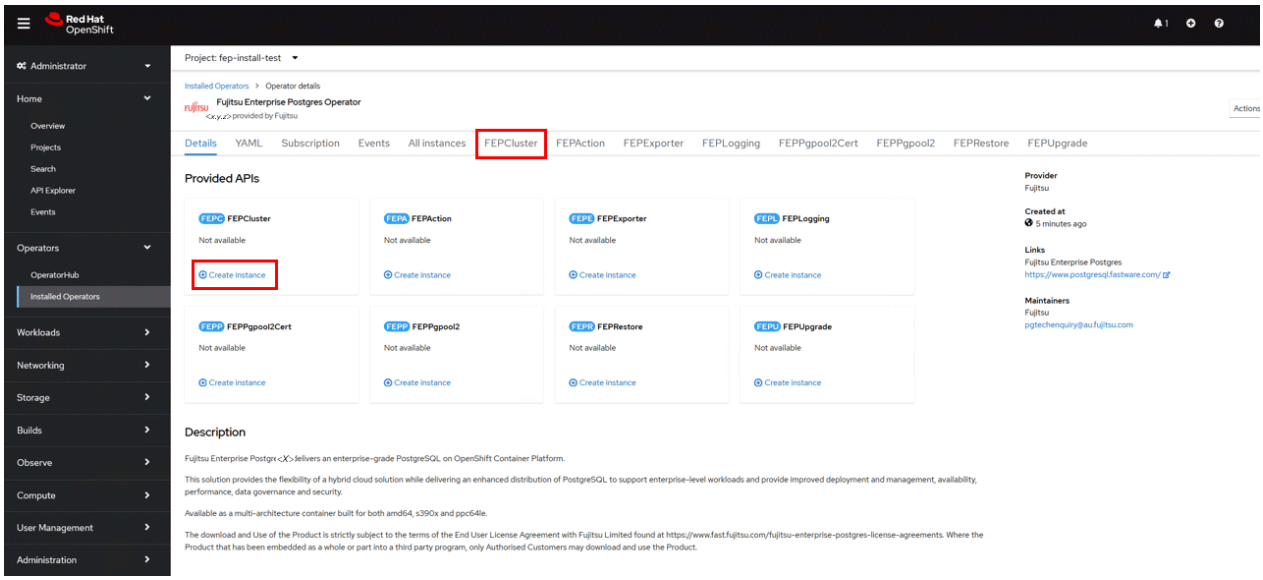
If you are deploying on a Kubernetes cluster, Refer to "Custom Resource Parameters" in the Reference to create and apply a yaml file.

1. Under "Operators" menu item, click on "**Installed Operators**". You would see the installed FEP operator deployed in "Chapter 3 Operator Installation". Click on the name of operator.

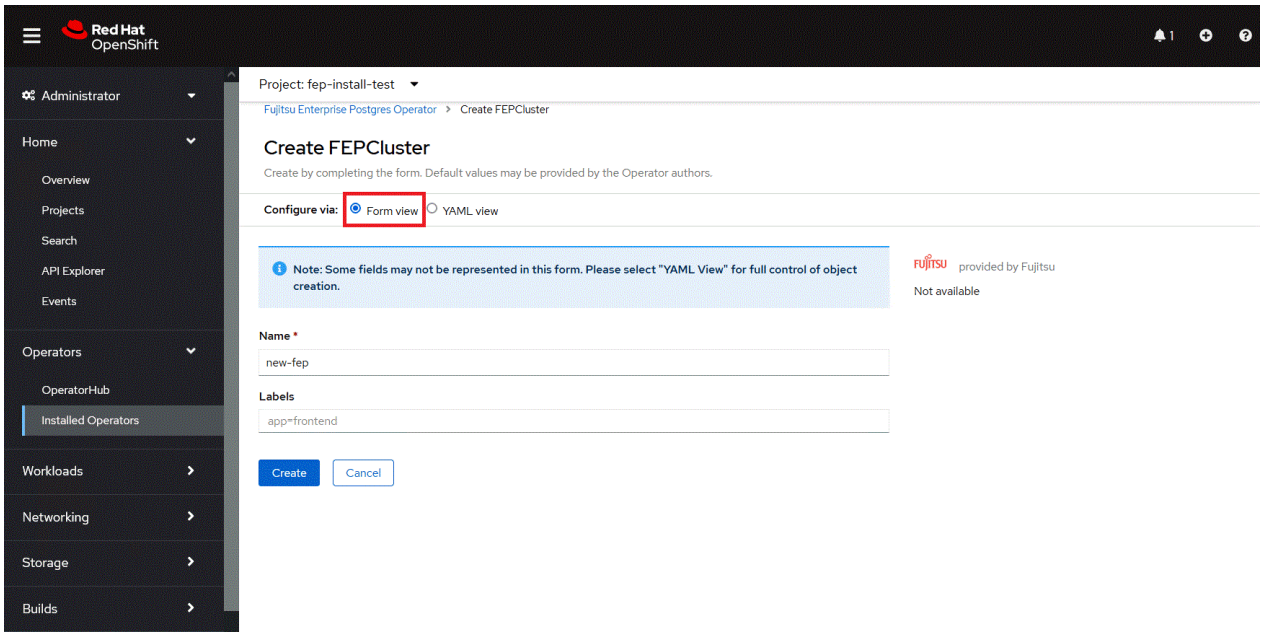


2. It will display a page with all CRs this operator supports. FEPCluster is the main CR and all others are child CR. We would create the main CR and all other CRs will be created automatically by Operator.
   To create Cluster CR, either
   (1) Click on "**Create Instance**" under FEPCluster.

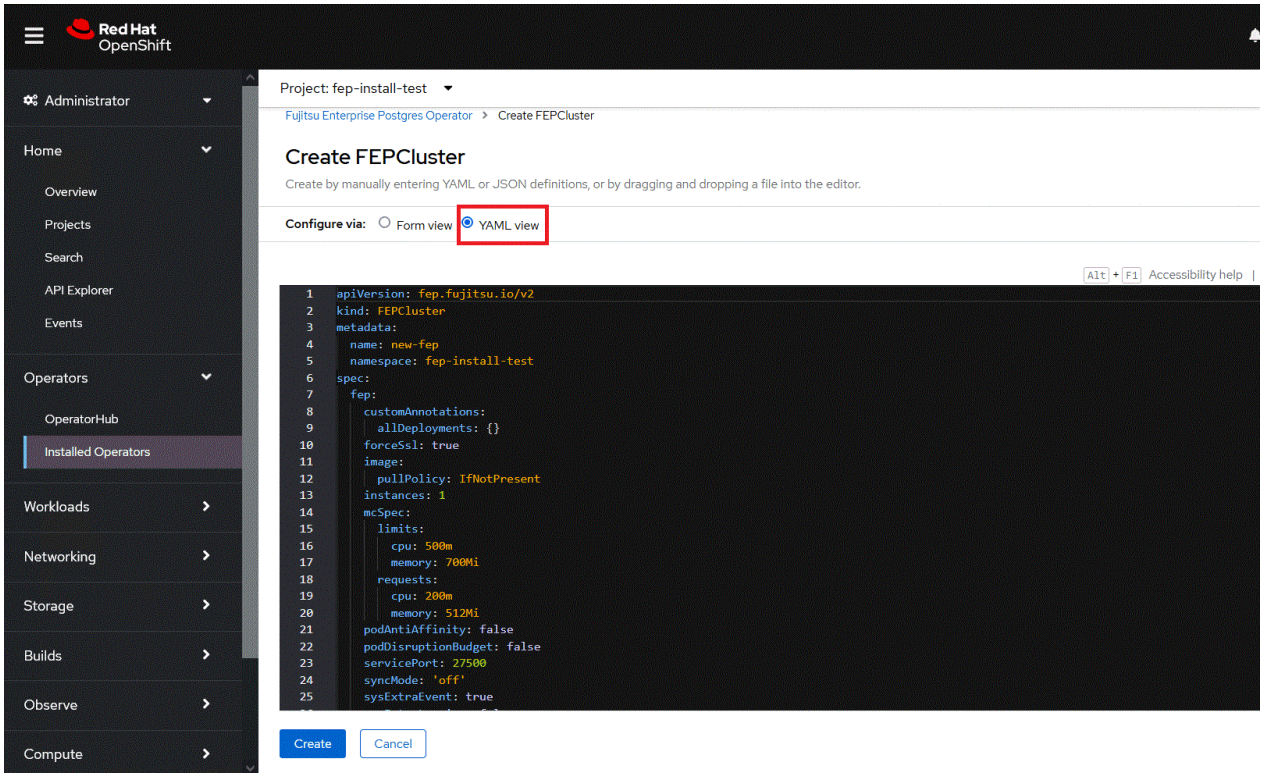
OR
(2) Click on "**FEPCluster**" on top and then click on "**Create FEPCluster**" on the next page.



3. This will bring to "Create FEPCluster" page. Here you have two options to configure. The first one is Form View. At the moment, in Form View , one can change only the name of cluster being deployed. The default name is "new-fep".
This name must be unique within a namespace.



4. In YAML View, starting value of CR is visible and one can choose to modify parameters before creating CR. Refer to the Reference for details of parameters.



The FEPCluster custom resource allows you to define the container's CPU, Memory, disk size, etc.

You can define each resource size individually, or you can use the following parameters to define the allocations for each resource in bulk.

Parameter	Description
spec.fep.databaseSize	Small, medium, and large define the following values for cpu/memory: small: 500m/700Mi medium: 2/4Gi large: 4/16Gi
spec.fepChildCrVal.storage.dataSize	Specifies the size of the data storage PV. Estimate and define the size of the backup storage area when the backup is enabled

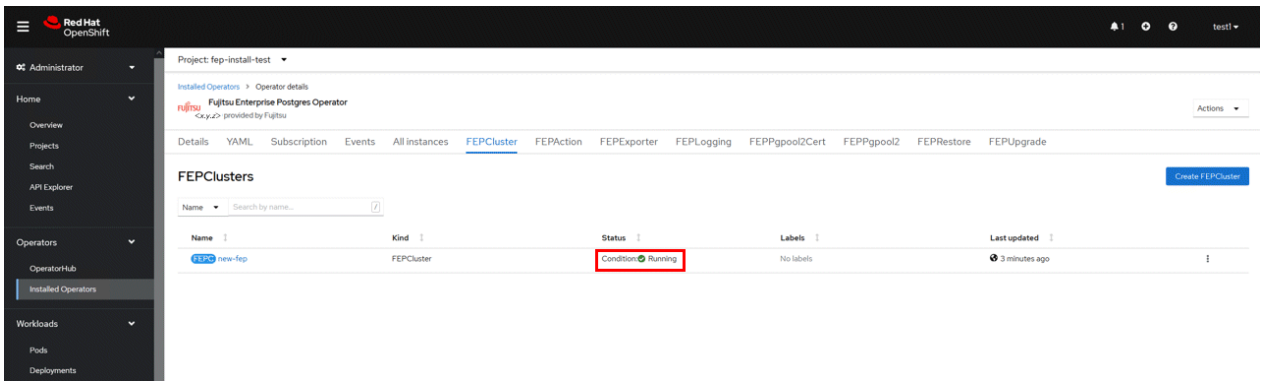
We recommend that you use transparent data encryption to store your data.
Tablespace PVs are mounted in/database/tablespaces/tbspace1.
After building the database cluster, create tablespaces and tables as follows:

```
# Creating an Encrypted Tablespace
CREATE TABLESPACE secure_tablespace LOCATION '/database/tablespaces/tbspace1' WITH
(tablespace_encryption_algorithm ='AES256');

# Create Table in Encrypted Tablespace
CREATE TABLE secure_table (id int, pref text, city text, data text) TABLESPACE secure_tablespace;
```

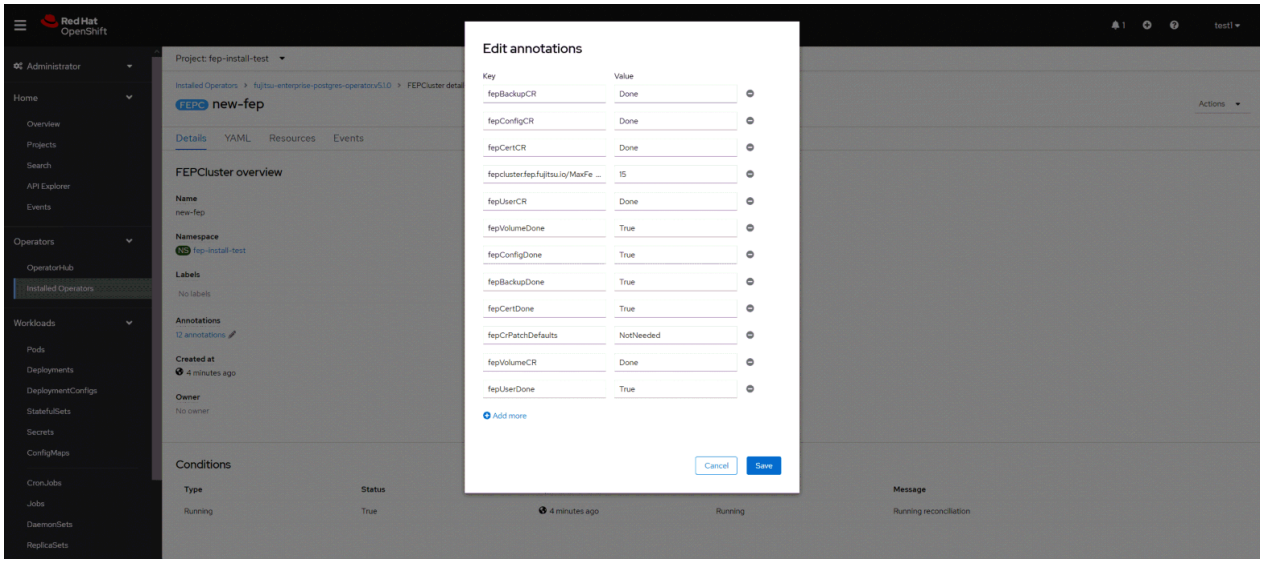
Operator provides features such as backup, audit logging, and monitoring.
These features can be enabled with the following parameters:

Parameter	Description
spec.fep.monitoring.enable	When true, monitoring feature is enabled.
spec.fep.pgAuditLog.enable	When true, audit log collection is enabled.
spec.fepChildCrVal.backup.type	local enables backup. The backup data is stored in the PV.
spec.fepChildCrVal.autoscale.scaleout.policy	cpu_utilization enables the ability to autoscale out replicas when CPU utilization exceeds a threshold.

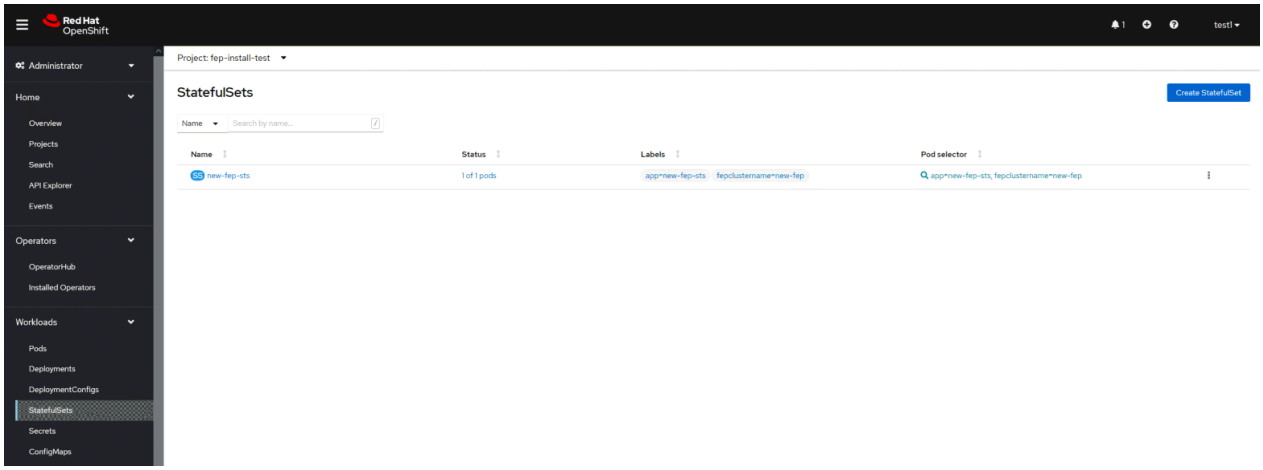
5. When "Create" is clicked on either of the two pages above, the operator creates FEPCluster CR, and there after one by one FEPBackup, FEPConfig, FEPVolume, FEPUser, and FEPCert child CRs are created automatically.
   The starting values for child CRs are taken from the "fepChildCrVal" section of the FEPCluster CR YAML file. Modifying value in FEPCluster "fepChildCrVal" section. Operator reflects changes from FEPCluster parent CR to respective child CRs. Only allowable changes are reflected in child CRs. Child CRs are marked internal objects and hence will not be visible on the OCP console. However, you can check child CRs using command-line tools.



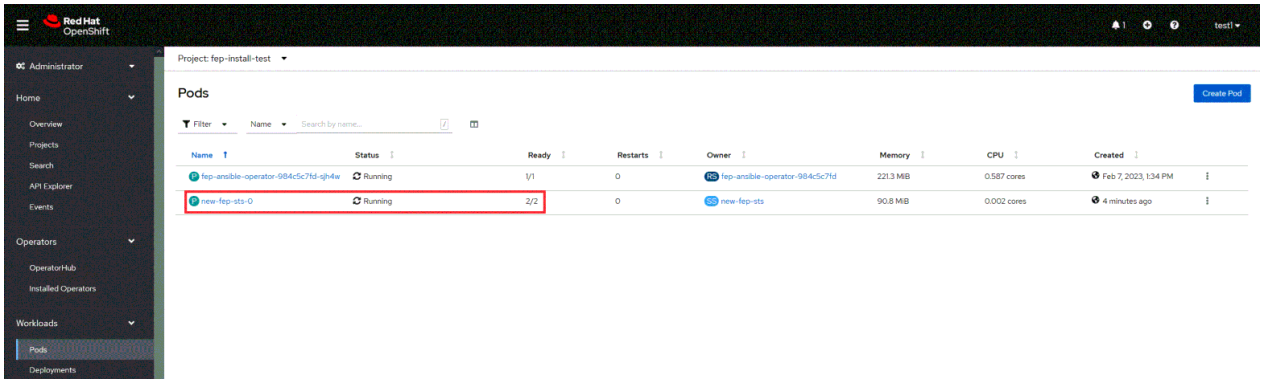
6. In FEPCluster CR, annotations are added to indicate that child CRs are created successfully and has initialised properly. It may take some time to complete.



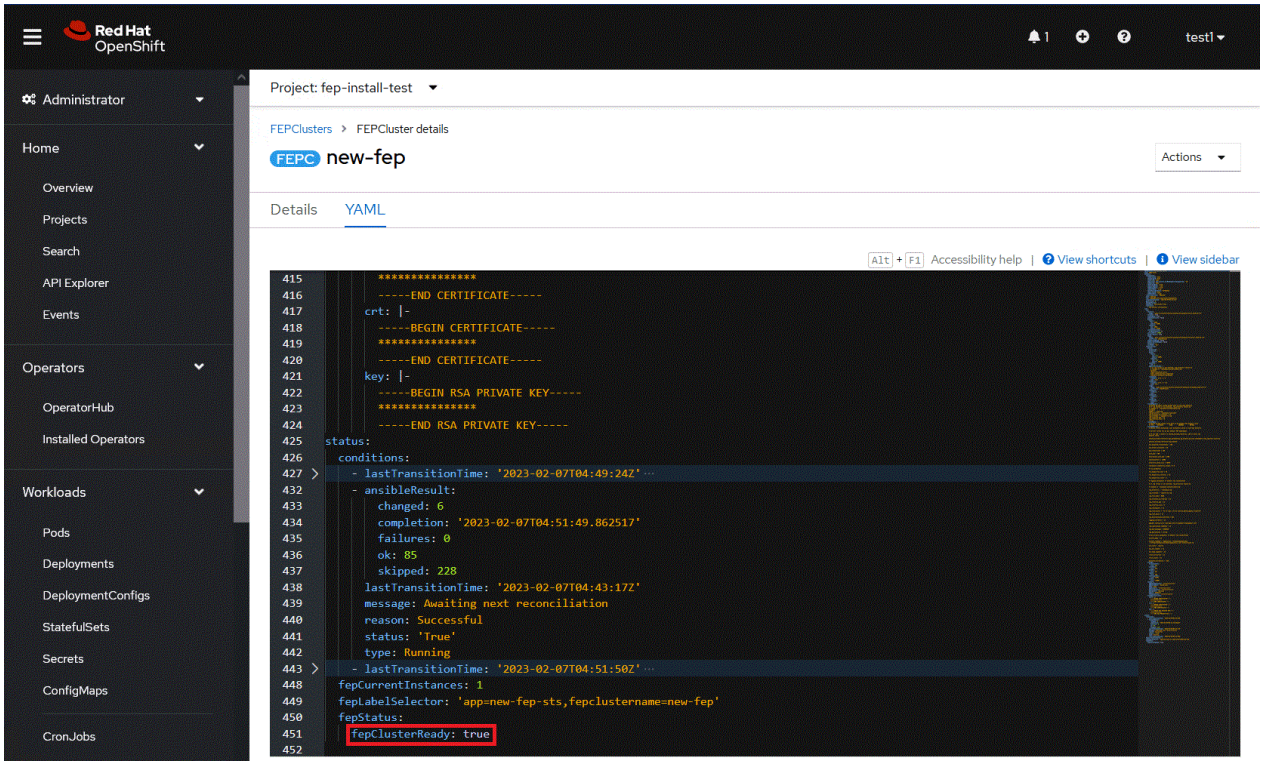
7. Once child CRs are marked done in annotations, operator creates StatefulSet for the cluster.



8. StatefulSet will start one FEP instance at one time and will wait it to be ready before starting next one.



9. Once all instances of FEP servers are started, the operator marks a flag "fepClusterReady" under "status.fepStatus" section of CR to be **true**, indicating that FEPCluster is ready for use. Looking at YAML of FEPCluster CR, it would look like as below:



10. Operator also masks the sensitive fields like passwords, passphrase, certificates and keys in FEPCluster fepChildCrVal and also in respective child CRs.

4.2 Deploy a Highly Available FEPCluster

In a highly available FEP cluster, load balancing is possible by distributing read queries to replica instances.

In addition, if the master instance fails, the user can switch to the replica instance immediately to localize the business interruption period.

In a highly available configuration, you can select the synchronization mode for the replica instance. Synchronous replication is recommended for systems that cannot tolerate data loss in the event of a master instance failure.

Because multiple instances are created in a highly available configuration, licenses are required for each.

To deploy a highly available FEPCluster in given namespace, follow these steps:

[Prerequisites]

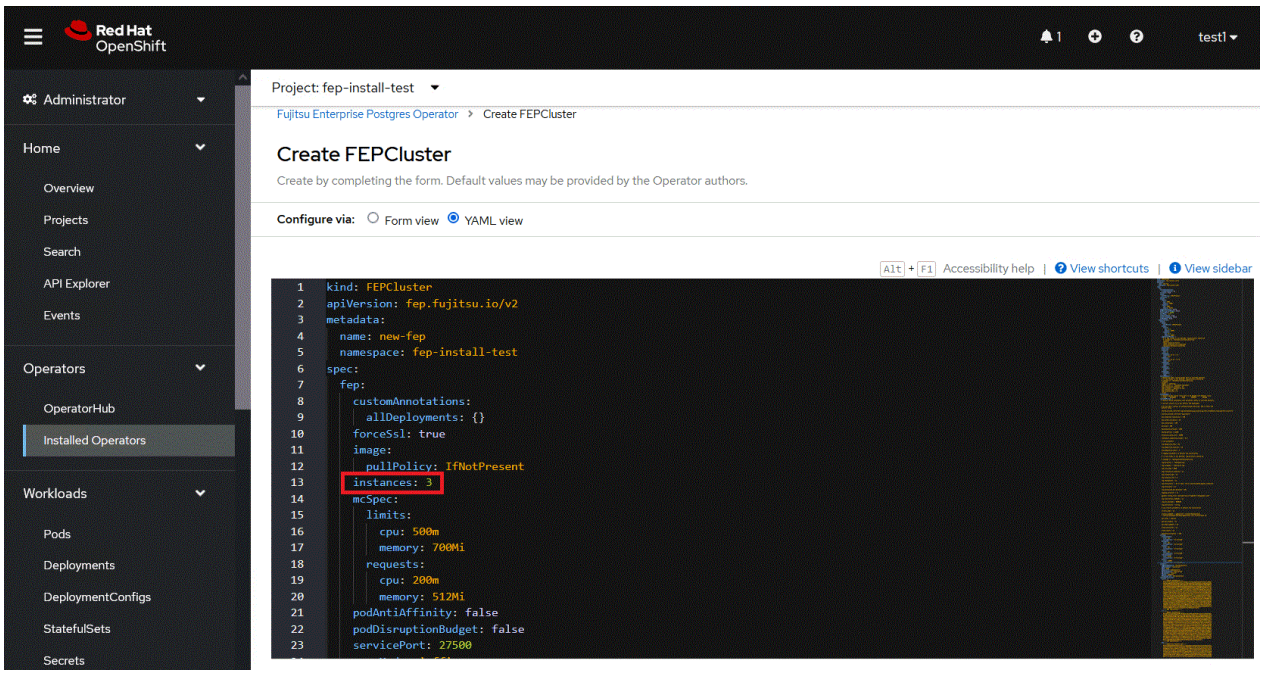
If the FEP cluster is running in HA mode, the backup and archive WAL volumes must be configured with shared storage (NFS, etc.) that supports ReadWriteMany. Refer to the Openshift documentation for instructions on setting up shared storage. Also, the reference procedure is described in "Appendix C Utilize Shared Storage", so please check if necessary.

If you do not have shared storage, you can remove the backup section and the backup and archive volume sections to disable the backup feature and deploy the FEP cluster.

Note

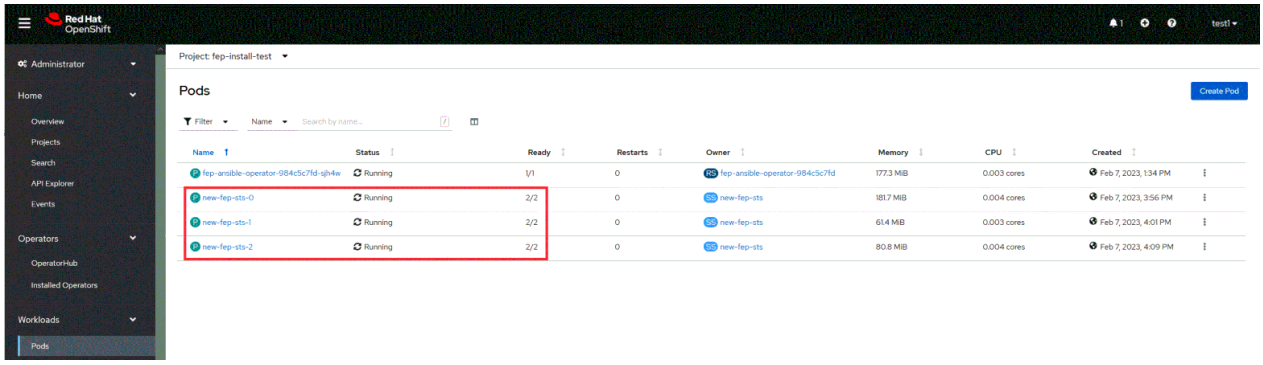
If you are deploying on a Kubernetes cluster, Refer to "Custom Resource Parameters" in the Reference to create and apply a yaml file.

1. It is the same as the procedure from step 1 to step 3 in "4.1 Deploying FEPCluster using Operator".
2. Instead of step 4 in "4.1 Deploying FEPCluster using Operator", change to the YAML view and specify '3' for the "instances" parameter of "fep" in "spec". Specify the storage class for the prepared shared storage for the backup and archive WAL volumes.



3. It is the same as the procedure from step 5 to step 10 in "4.1 Deploying FEPCluster using Operator".

4. Three pods deployed and ready for a highly available FEPCluster.



Information

You can determine whether the master or replica pod is the master or replica pod by issuing the following command:

```
$ oc get pod -L feprole
NAME                                    READY   STATUS    RESTARTS   AGE   FEPROLE
fep-ansible-operator-88f7fb4b-5jh85     1/1     Running   0          24m
new-fep-sts-0                           2/2     Running   0          17m   master
new-fep-sts-1                           2/2     Running   0          15m   replica
new-fep-sts-2                           2/2     Running   0          13m   replica
```

4.3 Deploying FEPExporter

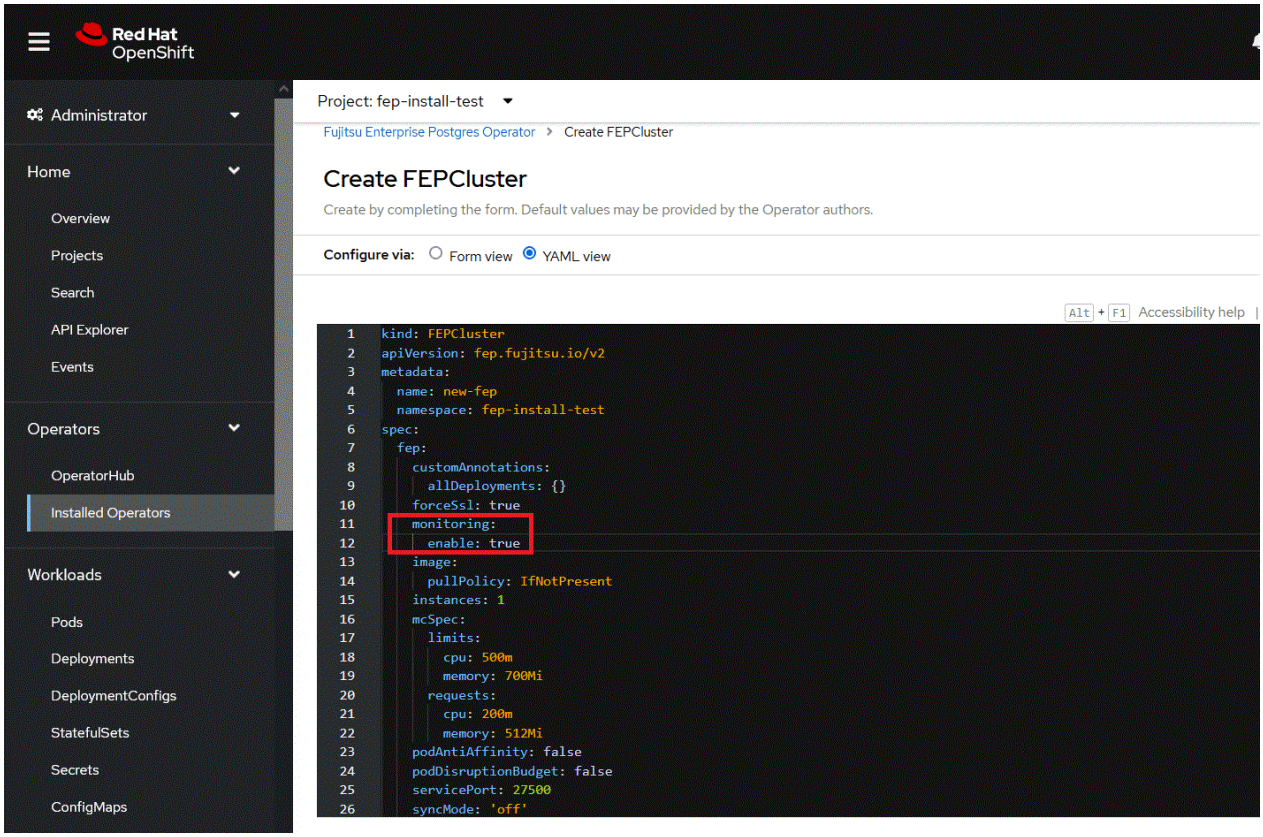
To deploy a FEPExporter, follow these steps.

"<*x.y.z*>" in the screen example indicates the version level of the operator.

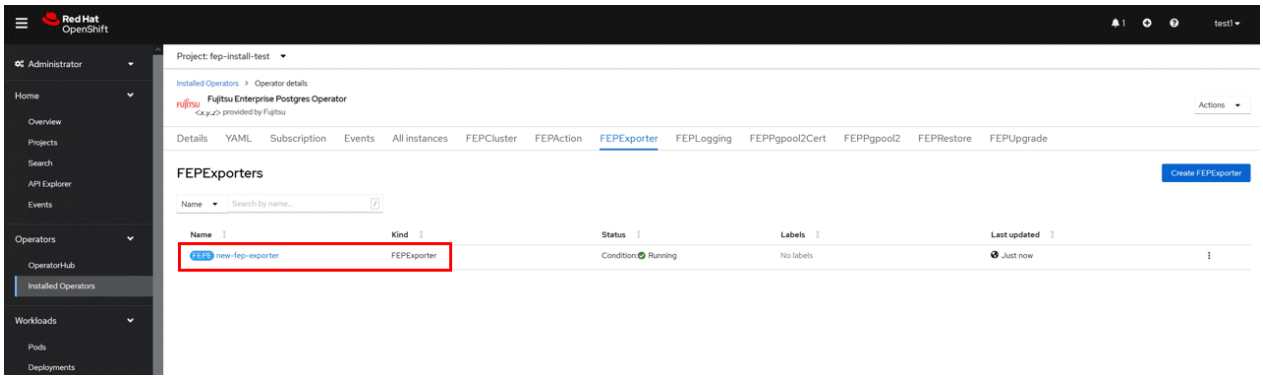
Note

If you are deploying on a Kubernetes cluster, Refer to "Custom Resource Parameters" in the Reference to create and apply a yaml file.

1. In order to deploy FEPExporter managed by Operator, it is as easy as setting fep.monitoring.enable to true in FEPCluster CR at the time of deployment.



2. FEPExporter will be created automatically under the name <cluster-name>-fepexporter. And it will list show all the database with statistics of specified FEPcluster.



3. FEPExporter spawned by FEP Operator in aforementioned way will scrape metrics by default from the Master and standby instances and make it available to Prometheus.

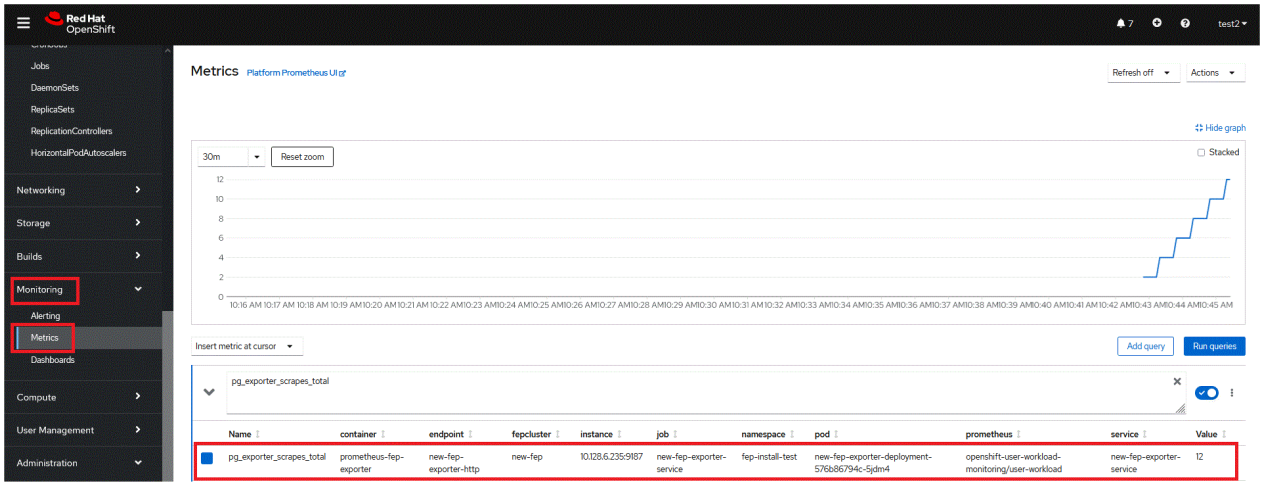
4. User can configure MTLS to be used for HTTP endpoint used by Prometheus for metrics scraping as well as connection from FEP Exporter to database.

    a. If pgMetricsUser, pgMetricsPassword and pgMetricsUserTls is defined in FEPcluster; FEPExporter will hence use these for securing connection to the postgres instances. In absence of these parameters, FEPExporter will use pgAdminUser (i.e. super user).

    b. User can configure Prometheus.tls and FEPExporter.tls to ensure that metrics end point (/metrics) by FEPExporter is also used with MTLS (Refer to "FEPExporter Custom Resource" in the Reference for details of fields)

5. User can also configure basic authentication by specifying a secret that contains username & password. (Refer to "FEPExporter Custom Resource" in the Reference for details of fields)

6. Now user can see scrape FEPExporter specific metrics on Openshift Platform in monitoring section area using PROMQL to specify a metrics of interest



Note

- User can set fep.monitoring.enable to true or false on an already instantiated cluster as well to achieve desired results
- pgMetricsUser can be defined later on a running FEPCluster with monitoring enabled and can force FEPExporter to use pgMetricsUser by mere restarting it (refer restartRequired). However, MTLS can not be configured in this case and user is expected to grant specific permission to pgMetricsUser for all the database objects which are expected to be use while scraping information.
- For MTLS to be forced, ensure usePodName and pg_hba.conf is been set appropriately.
- FEPExporter default metrics expects few following in postgresql.conf
  - pg_stats_statements library pre-loaded
  - **track_activities** and **track_counts** are turned on
  - Monitoring user needs permission on pg_stat_* views
- FEPExporter pod specification related to CPU memory can be changed. After changing resources specification, set **restartRequired** flag to true. FEPexporter will be restarted with new specifications
- FEP Monitoring is closely integrated with Prometheus available on platform. User should ensure that on openshift platform monitoring is enabled for user-defined projects (Refer: https://docs.openshift.com/container-platform/4.11/monitoring/enabling-monitoring-for-user-defined-projects.html). For platforms other than openshift, ensure Prometheus is installed before deployment of FEP operator

4.4 FEPExporter in Standalone Mode

FEPExporter is an independent CR; hence it does not necessarily depend on main FEPCluster CR. To deploy a FEPExporter in given namespace follow the below step.

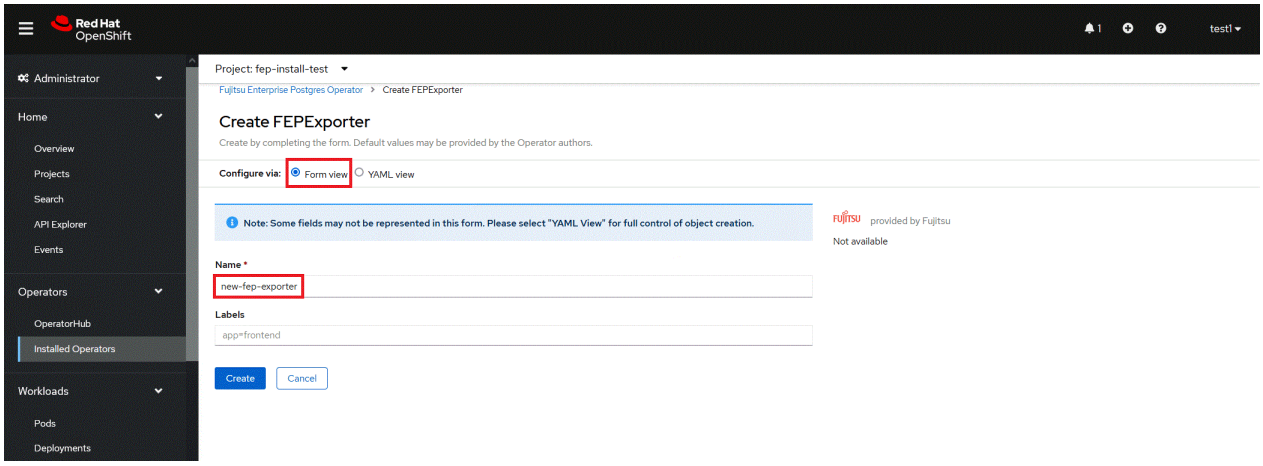
Note

If you are deploying on a Kubernetes cluster, Refer to "Custom Resource Parameters" in the Reference to create and apply a yaml file.

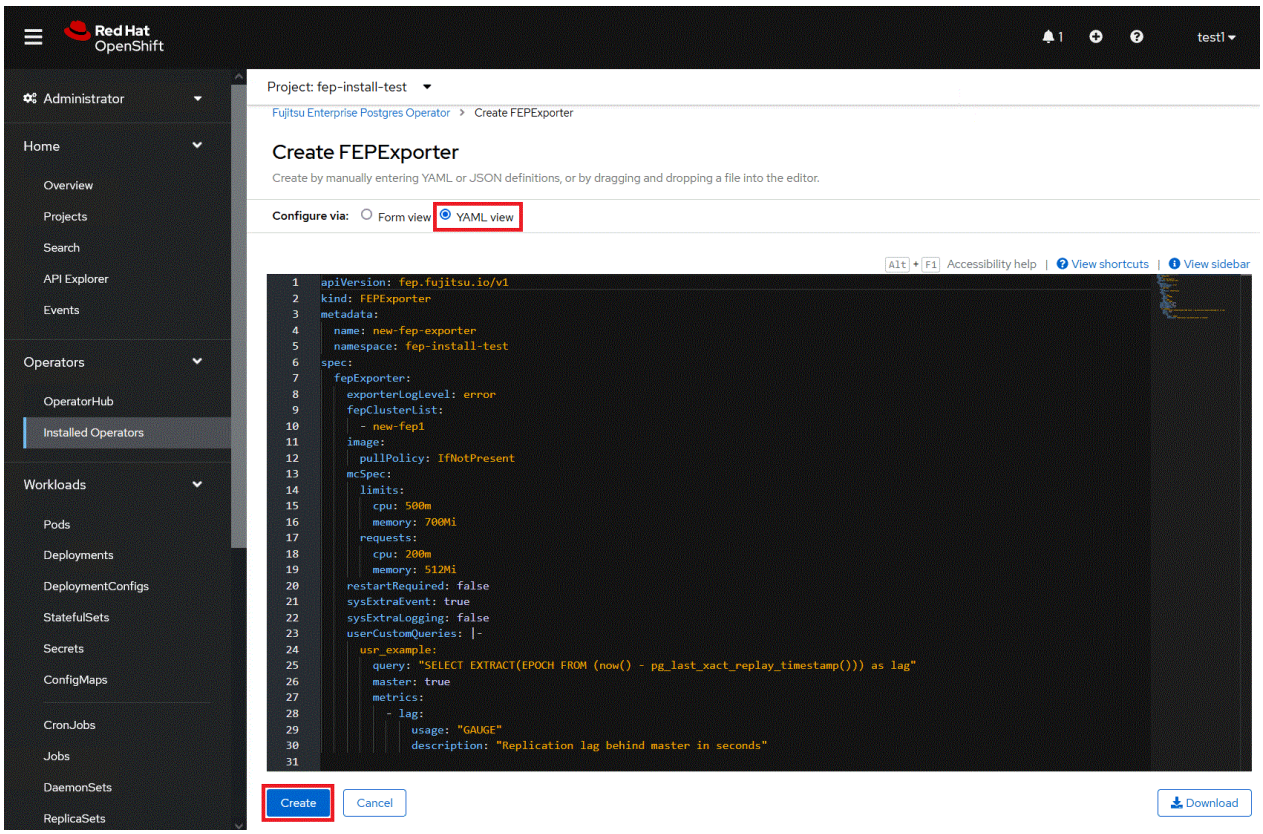
1. To create FEPExporter CR, either
   (1) Click on "**Create Instance**" under FEPExporter.
   OR
   (2) Click on "**FEPExporter**" on top and then click on "**Create FEPExporter**" on the next page.

2. In Form View, one can change only the name of cluster being deployed. The default name is "new-fep-exporter". This name must be unique within a namespace.

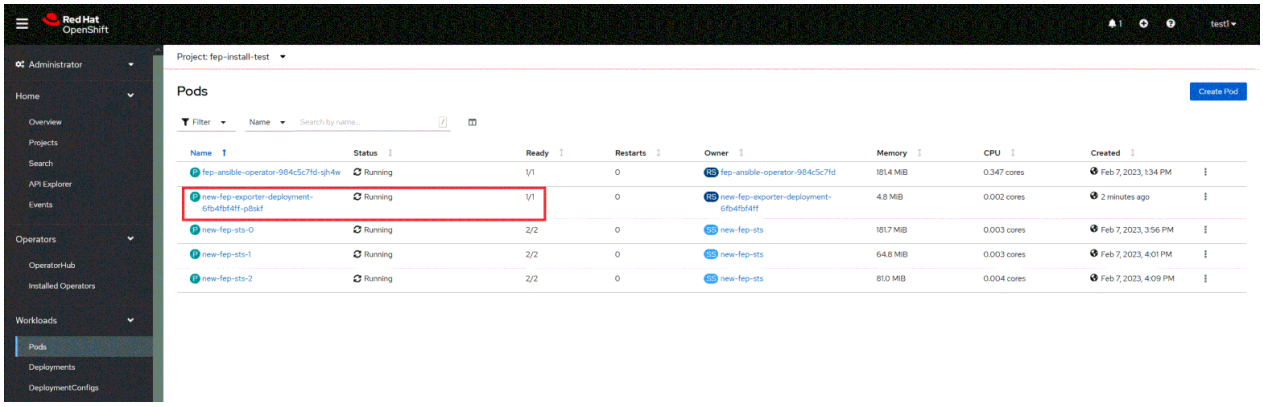
3. FEPExporter scrapes metrics for FEPCluster within same namespace.



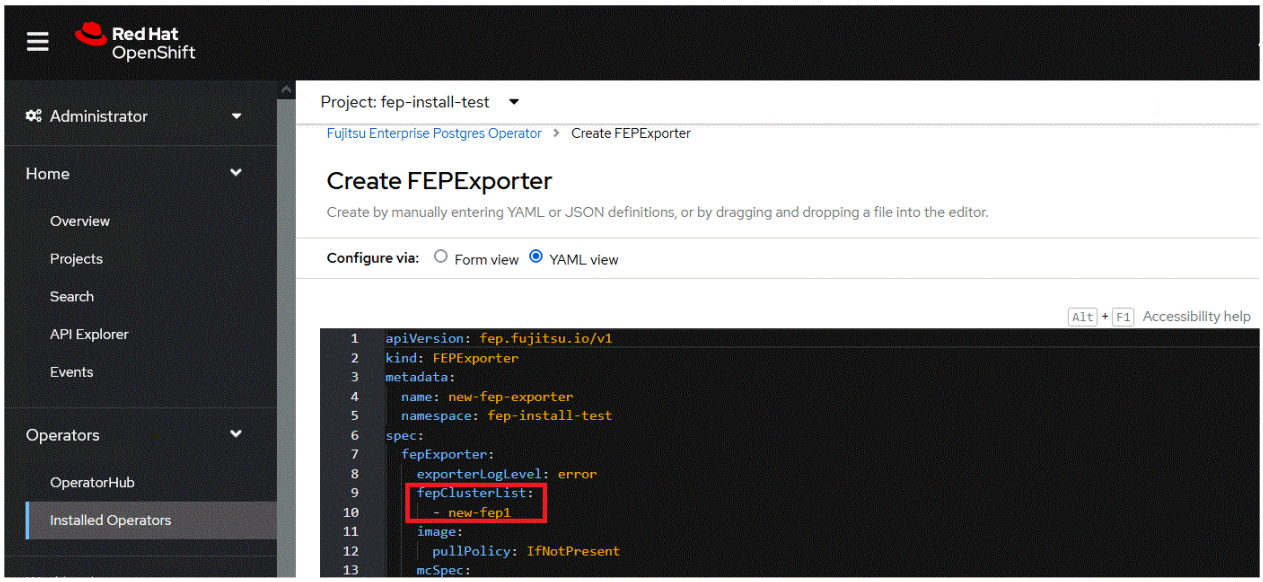
4. In YAML View, starting value of FEPExporter CR is visible and one can choose to modify parameters before creating CR. Refer to the Reference for details of parameters.



5. When clicked on the "Create" button. It will create FEPExporter pod with other resource like secret, service, configmap for data source queries.



6. Specify the name of the FEPCluster in spec.fepExporter.fepClusterList of FEPExporter. Before targeting cluster, Check the FEPCluster status and FEP StatefulSet are in running condition.



7. It will recreate FEPExporter pod with a new dataresource secret. It will list down all the database with statistics of specified FEPcluster in monitoring section.
8. If fepClusterList has more than one clusters listed, current exporter will collect metrics for all of those listed.
9. Multiple FEPExporters can be deployed within one namespace with their own cluster list to collect metrics from.

4.5 How to Collaborate with CloudWatch

Describe how to integrate with CloudWatch.

4.5.1 Preparation

Save credentials and other settings required for linking with CloudWatch in Secrets and ConfigMaps.

Prepare two files, credentials and config, which describe credentials and other settings according to the format specified by the AWS client interface. Specifying access_key_id and secret_access_key in the credentials file is mandatory.

An example of registering authentication information using the following configuration file is explained.

```
credentials   # credentials file
config        # config file
```

Create a ConfigMap to store config files. Specify config for the key name. The name of the ConfigMap is arbitrary (here my-aws-config).

```
$ oc create configmap my-aws-config --from-file=config=config -n my-namespace
```

Create a secret to save the credentials file. Specify credentials for the key name. The name of the Secret is arbitrary (here my-aws-credentials).

```
$ oc create secret generic my-aws-credentials --from-file=credentials=credentials -n my-namespace
```

See

Refer to below for AWS client interface configuration files.

https://docs.aws.amazon.com/cli/latest/userguide/cli-configure-files.html

4.5.2 FEPCluster Configuration

Add the following settings to the FEPClusterCR and deploy it.

- spec.fep.externalMonitoring.cloudWatch: Definition for forwarding metrics
- spec.fep.externalMonitoring.cloudWatch.authentication: Definition for authentication information to CloudWatch

Example of FEPClusterCR definition

```
spec:
  fep:
    externalMonitoring:
      cloudWatch:
        enable: true
        schedule: "0-59/10 * * * *"
        namespace:FEP_METRICS
        customMetrics:
          - config-map-query
        authentication:
          cloudWatchCredentials: my-aws-credentials
          cloudWatchConfig: my-aws-config
```

If spec.fep.externalMonitoring.cloudWatch.enable is true, FEP metrics are forwarded to CloudWatch as defined by spec.fep.externalMonitoring.cloudWatch.schedule.

This feature collects and transfers metrics from all FEPCluster Pods. When transferring metrics, the dimension name is specified as instance, and the value is specified as <kubernetesNamespace>-<FEP Pod name>. If you want to define additional dimensions, specify the dimensionName and dimensionValue under spec.fep.externalMonitoring.cloudWatch.

For information about the parameters under spec.fep.externalMonitoring, refer to "FEPCluster Parameter" in the Reference.

4.5.3 Forwarding Custom Metrics

If you want to forward metrics other than "5.7.2.5 Metrics Collected by CloudWatch" to CloudWatch, specify a file containing a query in spec.fep.externalMonitoring.cloudWatch.customMetrics. The query in the file can be read and executed, and the results can be forwarded to CloudWatch. Below is an example of a ConfigMap definition.

Example of ConfigMap "config-map-query**" definition**

```
kind: ConfigMap
apiVersion: v1
metadata:
  name: config-map-query
data:
  metricsName: <Any name>
  dimensionColumns: |
    - <Columns that can be obtained with metricsQuery>
```

```
    - <Columns that can be obtained with metricsQuery>
  metricsColumns: |
    - <Columns that can be obtained with metricsQuery>: <Metrics unit>
    - <Columns that can be obtained with metricsQuery>: <Metrics unit>
  metricsQuery.sql: |
    SELECT <Columns specified in dimension_columns and metrics_columns> FROM …
```

Create a ConfigMap that defines custom metrics for each query.

Details of each parameter specified in the ConfigMap are shown below.

Item	Description
metricsName	Optional Specify any metrics name. Metrics will be forwarded to CloudWatch with the metrics name <metricsName>_<metricsColumns>.
dimensionColumns	Optional Specify the column to be used for the Dimension from the column obtained by the query specified in metricsQuery. The column name is used as the key, and the value obtained by the query is used as the value, and the dimension is registered in CloudWatch.
metricsColumns	Specify the columns to be used as metrics from the columns retrieved by the query specified in metricsQuery in the following format. - *Column name*: *Metrics unit* If a column name or metricsName is specified, <metricsName>_<column name> will be transferred to CloudWatch as the metric name.
metricsQuery.sql	Define the query to get metrics from PostgreSQL. Create the query so that the columns of the retrieved data include the columns specified in dimensionColumns and metricsColumns.

4.6 Deploying FEPClusters with Cloud-based Secret Management

Note

The cloud-based secret management feature cannot be used together with the following parameters.

- spec.fepChildCrVal.sysUsers.pgSecurityUser
- spec.fepChildCrVal.sysTde.tdek
- spec.fepChildCrVal.sysUsers.passwordValid.days

4.6.1 Installing Secret Store CSI Driver Using Helm Charts

Install Secret Store CSI Driver from Helm chart.

Add helm chart repository.

```
helm repo add secrets-store-csi-driver https://kubernetes-sigs.github.io/secrets-store-csi-driver/
charts
```

Install with helm command.

```
helm install csi-secrets-store secrets-store-csi-driver/secrets-store-csi-driver --namespace kube-system --set enableSecretRotation=true --set rotationPollInterval=30s
```

Information

- Setting enableSecretRotation=true enables auto rotation of secret. i.e if value of secret gets changed in one of the external secret store (Azure/AWS/GCP/HashiCorp vault) then the updated value will be reflected in the FEPCluster as well.
- Setting rotationPollInterval=30s enables rotation poll interval which checks how frequently the mounted secrets for all pods need to be resynced to the latest.
- For OpenShift cluster to allow CSI type volumes to be mounted in container,system Security Context Constraints needs to be patched. Patch the volumes section to include CSI for providers(nonroot,anyuid,hostmount-anyuid,machine-api-termination-handler,hostaccess,node-exporter,privileged,privileged-genevalogging,restricted).
- In scearios where existing OpenShift is upgraded kindly verify that CSI is included in system Security Context Constraints for the above mentioned providers.

4.6.2 Installing and Configuring Azure Provider for Secret Store CSI Driver

4.6.2.1 Install Azure Provider drivers using helm chart

```
helm repo add csi-secrets-store-provider-azure https://azure.github.io/secrets-store-csi-driver-provider-azure/charts
```

Note: By default when installing Azure Provider ; secret-store-csi-driver installation is set to true by default. If secret-store-csi-driver is already installed as per steps in "4.6.1 Installing Secret Store CSI Driver Using Helm Charts" execute below command.

```
helm install csi csi-secrets-store-provider-azure/csi-secrets-store-provider-azure --namespace kube-system --set secrets-store-csi-driver.install=false
```

Note: If secret-store-csi-driver is not installed as per step "4.6.1 Installing Secret Store CSI Driver Using Helm Charts". Execute below command to install azure provider along with secret-store-csi-driver.

```
helm install csi csi-secrets-store-provider-azure/csi-secrets-store-provider-azure --namespace kube-system --set secrets-store-csi-driver.enableSecretRotation=true --set secrets-store-csi-driver.rotationPollInterval=30s
```

4.6.2.2 Create Secret to Access Azure Key vault

```
kind: Secret
apiVersion: v1
metadata:
 name: <Secret Name>
 namespace: <WHERE FEP CLUSTER TO BE INSTALLED>
 labels:
  secrets-store.csi.k8s.io/used: 'true'
data:
 clientid: XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXx
 clientsecret: XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX=
type: Opaque
```

Clientid: clientid is SERVICE_PRINCIPAL_CLIENT_ID

Clientsecret: clientsecret is SERVICE_PRINCIPAL_CLIENT_SECRET

4.6.2.3 Store Secret in Azure Key Vault

```
az keyvault secret set --vault-name <Vault Name> --name <Secret Name> --value <Secret value>
```

4.6.2.4 Store Certificate in Azure Key Vault

Certificate should be in below format before uploading cert to Azure Key Vault i.e it should be one .pem file (key, crt and CA in one file)

```
-----BEGIN RSA PRIVATE KEY-----
MIIEowIBAAKCAQEAx1rSsblocR8pROh5d2D3kuryTRRu6DA8axrSwrAaSDvdy1yU
KA7Q+Zg4IwaGwkt3cE2vK6oH4z3jwz+X0VjOxXo3hVh8tvfuXQ0uNpFEWCRRX1xt
3S8xc8OCzbnHRWQAKdxRGWhfmPSdWdlpPe7uNcVe865TVOWLMAjYzZbMOJnFHmK3
5EoxRkcLs3sGi74YhwDsGa1sNzBhZpdR+iIheEZKJUc65dl13jKx9oDhc1c8lcwR
ecrVgfRo6NfZ86bkR2ImL5xR0SWKnXP3KZqPOkL9DtCZK8iW2CgrfI8d2zcLbuUZ
UHEt4zzrwc9NV1yXe6nc8CrXbI6icwJYgVMZawIDAQABAoIBAF4kiN0/BpBtO8r7
0ejLVP7/jr9Rx/JEXTPjLeaczTyRcPNJW/nyzUMhXFlGCruUceoJ9ZA0Mpdgsb+R
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cPS7cajY9Tc0esvbvrhHZULpVLXhKl45SgDKgAWNaLJlm4u4gE56qpy+5kUKDzHg
yNOErpBSw2jlbtDE1Uta1hlR7BGWpK571UNvZ2AgLTbIgf1QFLq9IJdg9lll5pfm
DDn4AvcuFTHqJNj29DiMpsedvtPEnWceEkSScyzZnSvwJsADcdm2G8hyee0saQW+
/pVicfECgYEA7vADTIlWwOzcYH/CY+d0YAMaS0P08IPi5PXFj5FJ44q8BwZUDHGI
gUZylxJfipBvca2zYbrNSJ1ynF6mup30eeQDlVDSOdvcTg140CuSZuvl/mG+1sBK
G5QiXE15D6IJj3Ngu3wu+RFK3CCQuveERAaWD1kZizRlOFiacV7lJBkCgYEA1Zcz
1YNlLybKXJb0N3aFOhlz9RH1gNIx1PswJmDkM7qXlw5uxVpSPsvgngMsdAxMnSFQ
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sGIlG9IUY2i4rkgajNYtyeE6r6O3LljoD7qNuiMCgYA55G94MOKTNhCjVPE9kYvx
426Qg/Op/tqPzTjD81jqx+eM8CyXIz8Gy5HiJrJ9eUd3TLXk3QT2Lifh2VEecD0W
93ciy4VUPYAgbUUzcwsy4r9EJly93bNXAUpeAOtvLTyRxEvQwWMEN/tiYIWQt34V
mV7scxMsVlKcF2O8SljMqQKBgBUgGV5a2p0pRwaVX55EuLSgY9mvZwrQv2EDXyXM
m4WKRQgJw2b9ofjYDWVThwgLV2CLNQSOep0zVmqa7IPrwx0A4FVWZBkule6/uQKJ
DSVVKY29syvA1vfPdovsB0S8daePoxdA/c6cnqueZfXG5+laHblD75wDo1CQNpOn
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PJMbemXI7fyUltthzx6TkY/8uvQpjNw1gLkKNSUQw/Fez8acA59jtvBnFy3ERDQD
+hsETWiHZ43QRo5fV0LjrUxurM9k/NTWzVBRov3yqc3XnVsgxujL
-----END RSA PRIVATE KEY-----
-----BEGIN CERTIFICATE-----
MIIFfjCCA2agAwIBAgIUCVqIwocAj7N/1NNCyLjporXLbE8wDQYJKoZIhvcNAQEL
BQAwVzEYMBYGA1UECgwPTXkgT3JnYW5pemF0aW9uMQswCQYDVQQLDAJDQTEuMCwG
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MjEwMTMxMjE5MTBaFw0yMzEwMTMxMjE5MTBaMBMxETAPBgNVBAMMCHBvc3RncmVz
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eEZKJUc65dl13jKx9oDhc1c8lcwRecrVgfRo6NfZ86bkR2ImL5xR0SWKnXP3KZqP
OkL9DtCZK8iW2CgrfI8d2zcLbuUZUHEt4zzrwc9NV1yXe6nc8CrXbI6icwJYgVMZ
awIDAQABo4IBhDCCAYAwggF8BgNVHREEggFzMIIBb4IKKi5ucy1hLnBvZIIYKi5u
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cHJpbWFyeS1zdmMubnMtYS5zdmMuY2x1c3Rlci5sb2NhbIIQbmYzMy1yZXBsaWNh
LXN2Y4IVbmYzMy1yZXBsaWNhLXN2Yy5ucy1hghluZjMzLXJlcGxpY2Etc3ZjLm5z
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UjZpwVJjRuVY7N6ONgvZxOfC5HKb2Djb/u8RL8UrMmqqZlKNdh/060ZIZEX63esb
yHzQbiYSnop6LgpK5STtizJlaTpxkVcrJ2tzHuWp1PcCpShRTuKU+LFlOmOUMYk9
6Oi5h9GDTURDSO0O08RosiJd+locEBiKwZIA6dh98c+dd4eml9F+Pt3OlZA/wgcu
NwROKO5YLzFxBStiz2kiU0dZ
-----END CERTIFICATE-----
```

```
-----BEGIN CERTIFICATE-----
MIIFXzCCA0egAwIBAgIUR0l4D/Pjf9/VIxF+jYFV1MtKnpQwDQYJKoZIhvcNAQEL
BQAwVzEYMBYGA1UECgwPTXkgT3JnYW5pemF0aW9uMQswCQYDVQQLDAJDQTEuMCwG
A1UEAwwlTXkgT3JnYW5pemF0aW9uIENlcnRpZmljYXRlIEF1dGhvcml0eTAeFw0y
MjEwMTMxMjE5MTBaFw0zMjEwMTAxMjE5MTBaMFcxGDAWBgNVBAoMD015IE9yZ2Fu
aXphdGlvbjELMAkGA1UECwwCQ0ExLjAsBgNVBAMMJU15IE9yZ2FuaXphdGlvbiBD
ZXJ0aWZpY2F0ZSBBdXRob3JpdHkwggIiMA0GCSqGSIb3DQEBAQUAA4ICDwAwggIK
AoICAQDOh1UQb6QLw/e1J2gar/eRf6W4PhkNpOKGmdS5Rm0J58sDEwb/BNaBRYzu
e05mLQ7R3YF3I83AZf19E0ss36tfi9puRaCr5toC/XaBqK1zLPSZmZVtlxadZSFG
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sbT1h5gp3hHfh/WvZxFagirX66Uz5TY2FDzWVsQHvoIGMHD8hcr7Reia8IPFnneW
zRE1lNPQNXhqgc0pflg/6u8FCMdEeR/QV1lsjavVEMXoJU0PEx+srhUg+4gVlzc1
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BgNVHRMBAf8EBTADAQH/MA4GA1UdDwEB/wQEAwIBhjANBgkqhkiG9w0BAQsFAAOC
AgEAujV7RkipqwNopqW4kwbIbF4mn3JPBzbzKSjr8uraCFpk3ZTiRsiHm3D07/ox
N7KTqbk+DhSdbZ1NM+f1kZ7zDR6r4KGgBmKID51DOJ54jxNuCwRKndGUfePATuD0
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PJ7R+WBGvedt3TPEi3REubzUOMhgsDHuqeKKVBuRdh3zvcSI1q59DKYUir7wY60y
3fwJtEkrpyBD57Tp/Vsaf0Txv9KTtbyiCY0nwmiN3RqyFx4lIEipT1dhVc2oBUFq
YWvTkUPubFbG0aLxcbi5aySCOmjZHYZvUCNLSAekTL2wH649/RD8xSkQf+Qs2N6a
jJOE1nUrapYRrKlwFRXj+5aj+fhhoZ1uU43jPRakdwinEWmw7JPRk0gjRQwQE6a6
bhBvBfStOZKmuOULuoHrL75BCyQMK5JaOgljmcsAQMb0/ERpPxoNzkXAS825wOTx
E+lnRRuOKfmILIHMteOpn+ffozT2Djl3mFMJhbbbnYEL1NEYxwI2si2oL8GjE26i
A5ojkdJ06kmFgOp2boa49ja61lWVZToirWhbnR6G9AKHPy8aX0yH25xStxbdojjO
eTP+zKBUH3E15zT0YOnb7NnIplHNNhq1kwi/OCBXPs9FWow=
-----END CERTIFICATE-----
```

mycert.pem

```
az keyvault secret set --vault-name <Key Vault Name> --name <Secret Name> --file "mycert.pem"
```

Note

Only single key value for secret to be stored in key vault.

4.6.3 Installing and Configuring AWS Provider for Secret Store CSI Driver

4.6.3.1 Install AWS Provider drivers using helm chart

```
helm repo add aws-secrets-manager https://aws.github.io/secrets-store-csi-driver-provider-aws
```

```
helm install -n kube-system secrets-provider-aws aws-secrets-manager/secrets-store-csi-driver-
provider-aws -namespace kube-system
```

4.6.3.2 Setup EKS cluster along with service account with necessary IAM roles and permission to access Secret Manager

Follow below link to setup IAM roles and EKS for CSI.

https://github.com/aws/secrets-store-csi-driver-provider-aws

Create IAM role trust policy to access Secret Manager

```
Create IAM role trust policy to access Secret Manager
{
    "Version": "2012-10-17",
    "Statement": [
        {
            "Effect": "Allow",
            "Principal": {
                "Federated": "arn:aws:iam::123456789:oidc-provider/oidc.eks.ap-
southeast-3.amazonaws.com/id/ABCD1234567"
            },
            "Action": "sts:AssumeRoleWithWebIdentity",
            "Condition": {
                "StringEquals": {
                    " oidc.eks.ap-southeast-3.amazonaws.com /id/ ABCD1234567:sub":
"system:serviceaccount:myns:mysa",
                   " oidc.eks.ap-southeast-3.amazonaws.com /id/ ABCD1234567:aud": "sts.amazonaws.com"
                }
            }
        }
    ]
}
```

4.6.3.3 Store Secret in AWS Secrets Manager

```
aws secretsmanager create-secret --name <Secret Name> --secret-string <Secret Value>
```

4.6.3.4 Store Cert in AWS Secrets Manager

Certificate should be in below format before uploading cert to AWS Secrets Manager i.e it should be one .pem file (key, crt and CA in one file)

(Refer "mycert.pem" for sample certificate format)

```
aws secretsmanager create-secret --name <Secret Name> --secret-binary fileb://<File Name>
```

Note

Only single key value for secret to be stored in Secret Manager.

4.6.4 Installing GCP Provider for Secret Store CSI Driver

4.6.4.1 Install GCP Provider drivers using Kubernetes

```
wget https://raw.githubusercontent.com/GoogleCloudPlatform/secrets-store-csi-driver-provider-gcp/
main/deploy/provider-gcp-plugin.yaml
```

```
kubectl apply -f provider-gcp-plugin.yaml -namespace kube-system
```

4.6.4.2 Configure GCP secret manager and IAM

Create Service Account:

```
gcloud iam service-accounts create my-secret-acc;
```

Attach SecretManagerAdmin policy to the new service account

```
gcloud projects add-iam-policy-binding $PROJECT_ID \
--member="serviceAccount: my-secret-acc @$PROJECT_ID.iam.gserviceaccount.com" \
--role="roles/secretmanager.admin" \
--condition="None";
```

Generate a key for your new service account

```
gcloud iam service-accounts keys create iam-key.json \
--iam-account=" my-secret-acc @$PROJECT_ID.iam.gserviceaccount.com";
```

4.6.4.3 Create Secret to access GCP Secret manager

Use keys generated from "4.6.4.2 Configure GCP secret manager and IAM" (iam-key.json file)

```
kubectl create secret generic <secret-name> --from-file=<iam-key.json>
```

4.6.4.4 Store secret in GCP Secret manager

```
gcloud secrets create <secret name> --data-file="/path/to/file"
```

4.6.4.5 Store Cert in GCP Secret manager

Certificate should be in below format before uploading cert to GCP Secret Manager i.e it should be one .pem file (key, crt and CA in one file)

(Refer "mycert.pem" for sample certificate format)

```
gcloud secrets create <secret name> --data-file="/path/to/file"
```

Note

Only single key value for secret to be stored in Secret Manager.

4.6.5 Installing HashiCorp Vault Provider for Secret Store CSI Driver

4.6.5.1 Install HashiCorp Provider drivers using helm chart

```
helm repo add hashicorp https://helm.releases.hashicorp.com
```

```
helm install vault hashicorp/vault --set "server.enabled=false"  --set "injector.enabled=false" --set
"csi.enabled=true"
```

4.6.5.2 Configure Kubernetes Authentication for HashiCorp Vault

```
vault auth enable kubernetes
```

```
vault write auth/kubernetes/config \
token_reviewer_jwt="$(cat /var/run/secrets/kubernetes.io/serviceaccount/token)" \
kubernetes_host="https://$KUBERNETES_PORT_443_TCP_ADDR:443" \
kubernetes_ca_cert=@/var/run/secrets/kubernetes.io/serviceaccount/ca.crt
```

4.6.5.3 Store Secret in HashiCorp Vault

```
vault enable secret
```

```
vault kv put secret/<path> <secret name>=<secret value>
```

4.6.5.4 Store Cert in HashiCorp Vault

Certificate should be in below format before uploading cert to HashiCorp Vault i.e it should be one .pem file (key, crt and CA in one file)

(Refer "mycert.pem" for sample certificate format)

```
Vault kv put secret/<path> <secret name>=@<path to cert.pem>
```

4.6.5.5 Create policy and role to access the secrets from HashiCorp Vault

Policy:

```
vault policy write <policy name> - <<EOF
path "secret/database/credentials" {
capabilities = ["read", "write", "update","delete"]
}
EOF
```

Role:

```
vault write auth/kubernetes/role/<role name> \
bound_service_account_names=* \
bound_service_account_namespaces=*\
policies=<policy name> \
ttl=24h
```

Note: access can be restricted by assigning <fep-cluster>-sa service account to bound_service_account_names and also can be namespace restircted by assigning value to bound_service_account_namespaces

Only single key value for secret to be stored in HashiCorp vault.

4.6.6 Configuring FEPCluster to use Provider for Secret Store Driver

To enable use of Secret Store CSI driver, a new parameter "secretStore" under spec.fepChildCrVal section in the FEPClusterCR. Under secretStore.csi user should define the details to connect to external Seret store(Azure,AWS,GCP and HashiCorp Vault) and the list of secrets in that secret store. The definition of spec.fepChildCrVal.secretStore parameter will differ depending on the type of provider that is used.

4.6.6.1 Azure Provider for Secret Store CSI Driver

```
spec:
  ….
  fepChildCrVal:
    secretStore:
      method: csi
      csi:
        providerName: azure
        azureProvider:
          keyvaultname:
          tenantid:
          credentials:
          fepSecrets:
          - pgadminpassword: pgadminpassword
          - tdepassphrase: passphrase
          - systemCertificates: systemCerts
          - pguser: pgusername
          - pgpassword: pgpwd
```

```
          - pgdb: pgdbsecret
          - pgrepluser: pgrepluser
          - pgreplpassword: pgreplpassword
          - pgRewinduser: pgRewinduser
          - pgRewindpassword: pgRewindpassword
          - pgMetricsUser: metricsuser
          - pgMetricsPassword: metricspwd
          - patronitls: patronicrt
          - patronitlscacrt: patronica
          - postgrestls: postgrescrt
          - postgrestlscacrt: postgresca
          - pgAdminTls: admincrt
          - pgAdminTlscacrt: adminca
          - pgAdminTls_privateKeyPassword: adminpvtkey
          - pgRewindUserTls: rewindcrt
          - pgRewindUserTlscacrt: rewindca
          - pgRewindUserTls_privateKeyPassword: rwndpvtkey
          - pgrepluserTls: replcrt
          - pgrepluserTlscacrt: replca
          - pgrepluserTls_privateKeyPassword: replpvtkey
          - pgMetricsUserTls: metricscrt
          - pgMetricsUserTlscacrt: metricsca
          - pgMetricsUserTls_privateKeyPassword: adminpvtkey
          - modelOwner: modelOwner
          - modelOwnerPassword: modelOwnerPassword
          - modelUser: modelUser
          - modelUserPassword: modelUserPassword
          - loadUser: loadUser
          - loadUserPassword: loadUserPassword
          fepCustomCerts:
            - userName:user1
              userCrt: user1crt
              userCa: user1ca
            - userName: mydbuser
              userCrt: mydbusercrt
              userCa: mydbuserca
```

Note: The parameters which are in black in fepSecrets are mandatory.

4.6.6.2 AWS Provider for Secret Store CSI Driver

```
spec:
  ….
  fepChildCrVal:
    secretStore:
      method: csi
      csi:
        providerName: aws
        awsProvider:
          region:
          roleName:
          fepSecrets:
          - pgadminpassword: pgadminpassword
          - tdepassphrase: passphrase
          - systemCertificates: systemCerts
          - pguser: pgusername
          - pgpassword: pgpwd
          - pgdb: pgdbsecret
          - pgrepluser: pgrepluser
          - pgreplpassword: pgreplpassword
          - pgRewinduser: pgRewinduser
          - pgRewindpassword: pgRewindpassword
          - pgMetricsUser: metricsuser
```

```
          - pgMetricsPassword: metricspwd
          - patronitls: patronicrt
          - patronitlscacrt: patronica
          - postgrestls: postgrescrt
          - postgrestlscacrt: postgresca
          - pgAdminTls: admincrt
          - pgAdminTlscacrt: adminca
          - pgAdminTls_privateKeyPassword: adminpvtkey
          - pgRewindUserTls: rewindcrt
          - pgRewindUserTlscacrt: rewindca
          - pgRewindUserTls_privateKeyPassword: rwndpvtkey
          - pgrepluserTls: replcrt
          - pgrepluserTlscacrt: replca
          - pgrepluserTls_privateKeyPassword: replpvtkey
          - pgMetricsUserTls: metricscrt
          - pgMetricsUserTlscacrt: metricsca
          - pgMetricsUserTls_privateKeyPassword: adminpvtkey
          - modelOwner: modelOwner
          - modelOwnerPassword: modelOwnerPassword
          - modelUser: modelUser
          - modelUserPassword: modelUserPassword
          - loadUser: loadUser
          - loadUserPassword: loadUserPassword
          fepCustomCerts:
            - userName:user1
              userCrt: user1crt
              userCa: user1ca
            - userName: mydbuser
              userCrt: mydbusercrt
              userCa: mydbuserca
```

Note: The parameters which are in black in fepSecrets are mandatory.

4.6.6.3 GCP Provider for Secret Store CSI Driver

```
spec:
  ….
  fepChildCrVal:
    secretStore:
      method: csi
      csi:
        providerName: gcp
        gcpProvider:
          credentials:
          fepSecrets:
          - pgadminpassword: pgadminpassword
          - tdepassphrase: passphrase
          - systemCertificates: systemCerts
          - pguser: pgusername
          - pgpassword: pgpwd
          - pgdb: pgdbsecret
          - pgrepluser: pgrepluser
          - pgreplpassword: pgreplpassword
          - pgRewinduser: pgRewinduser
          - pgRewindpassword: pgRewindpassword
          - pgMetricsUser: metricsuser
          - pgMetricsPassword: metricspwd
          - patronitls: patronicrt
          - patronitlscacrt: patronica
          - postgrestls: postgrescrt
          - postgrestlscacrt: postgresca
          - pgAdminTls: admincrt
          - pgAdminTlscacrt: adminca
```

```
          - pgAdminTls_privateKeyPassword: adminpvtkey
          - pgRewindUserTls: rewindcrt
          - pgRewindUserTlscacrt: rewindca
          - pgRewindUserTls_privateKeyPassword: rwndpvtkey
          - pgrepluserTls: replcrt
          - pgrepluserTlscacrt: replca
          - pgrepluserTls_privateKeyPassword: replpvtkey
          - pgMetricsUserTls: metricscrt
          - pgMetricsUserTlscacrt: metricsca
          - pgMetricsUserTls_privateKeyPassword: adminpvtkey
          - modelOwner: modelOwner
          - modelOwnerPassword: modelOwnerPassword
          - modelUser: modelUser
          - modelUserPassword: modelUserPassword
          - loadUser: loadUser
          - loadUserPassword: loadUserPassword
          fepCustomCerts:
            - userName:user1
              userCrt: user1crt
              userCa: user1ca
            - userName: mydbuser
              userCrt: mydbusercrt
              userCa: mydbuserca
```

Note: The parameters which are in black in fepSecrets are mandatory.

4.6.6.4 HashiCorp Vault Provider for Secret Store CSI Driver

```
spec:
  …..
  fepChildCrVal:
    secretStore:
      method: csi
      csi:
        providerName: vault
        vaultProvider:
          roleName: "database"
          vaultAddress: "http://vault-url-addr:8765"
          fepSecrets:
          - pgadminpassword: pgadminpassword
          - tdepassphrase: passphrase
          - systemCertificates: systemCerts
          - pguser: pgusername
          - pgpassword: pgpwd
          - pgdb: pgdbsecret
          - pgrepluser: pgrepluser
          - pgreplpassword: pgreplpassword
          - pgRewinduser: pgRewinduser
          - pgRewindpassword: pgRewindpassword
          - pgMetricsUser: metricsuser
          - pgMetricsPassword: metricspwd
          - patronitls: patronicrt
          - patronitlscacrt: patronica
          - postgrestls: postgrescrt
          - postgrestlscacrt: postgresca
          - pgAdminTls: admincrt
          - pgAdminTlscacrt: adminca
          - pgAdminTls_privateKeyPassword: adminpvtkey
          - pgRewindUserTls: rewindcrt
          - pgRewindUserTlscacrt: rewindca
          - pgRewindUserTls_privateKeyPassword: rwndpvtkey
          - pgrepluserTls: replcrt
          - pgrepluserTlscacrt: replca
```

```
        - pgrepluserTls_privateKeyPassword: replpvtkey
        - pgMetricsUserTls: metricscrt
        - pgMetricsUserTlscacrt: metricsca
        - pgMetricsUserTls_privateKeyPassword: adminpvtkey
        - modelOwner: modelOwner
        - modelOwnerPassword: modelOwnerPassword
        - modelUser: modelUser
        - modelUserPassword: modelUserPassword
        - loadUser: loadUser
        - loadUserPassword: loadUserPassword
        fepCustomCerts:
          - userName:user1
            userCrt: user1crt
            userCa: user1ca
          - userName: mydbuser
            userCrt: mydbusercrt
            userCa: mydbuserca
```

Note: The parameters which are in black in fepSecrets are mandatory.

4.7 Deploying a customized FEP server container image

4.7.1 Requirements

The procedures documented below assume the use of docker command to build container image. Building container images using alternative tools such as podman is beyond the scope of this document.

4.7.2 Build custom FEP image with extension

Before building a new custom FEP Server container image, it is important to understand several build instructions specific to that image.

- FEP server container image is built on top of UBI8/UBI9 minimal image, ubi-minimal
- USER is default to 26

UBI8/UBI9 minimal image uses microdnf as package manager. Microdnf does not support installing RPM packages from remote URL or local file, only from a YUM repository. If you want to install RPM package that is not in YUM repository, first download the package and install it with rpm. However, rpm has the drawback that it does not resolve dependencies. The only way to resolve this problem is to install dnf first and use dnf to install packages from remote URL or local file.

As USER is default to 26, it does not have the permission to install RPM packages or write files to system directory such as /usr/bin, /usr/local/bin, etc. To workaround this issue, first set USER to root to continue the customization and set it back to 26.

```
FROM: quay.io/fujitsu/fujitsu-enterprise-postgres-18-server:ubi9-18-1.0

USER root

RUN …(customization)

USER 26
```

4.7.3 Adding SQLite Foreign Data Wrapper to FEP Server Container

We will demonstrate adding the SQLite Foreign Data Wrapper module to FEP Server container.

1. Create Dockerfile

```
#use FEP 18 image as a base to compile sqlite_fdw
FROM quay.io/fujitsu/fujitsu-enterprise-postgres-18-server:ubi9-18-1.0 as compile-sqlite_fdw

#change the user with root privilege
USER root
```

```
# install build tools
RUN microdnf -y install cmake gcc-c++ libtool clang which openssl-devel git llvm gettext

# Install sqlite_fdw build require
RUN microdnf install -y sqlite-devel

# Download sqlite_fdw source
RUN curl -sSL https://github.com/pgspider/sqlite_fdw/archive/refs/tags/v2.3.0.tar.gz | tar -zxf -

# Compile sqlite_fdw
RUN cd /sqlite_fdw-2.3.0 && \
    make install USE_PGXS=1

#Use base image is from FEPContainer to build the custom image
FROM quay.io/fujitsu/fujitsu-enterprise-postgres-18-server:ubi9-18-1.0

#change the user with root privilege
USER root

#copy the prepared OSS extension binaries to FEP server lib folder
COPY --from=compile-sqlite_fdw /opt/fsepv18server64/lib/sqlite_fdw.so /opt/fsepv18server64/lib/
COPY --from=compile-sqlite_fdw /opt/fsepv18server64/lib/bitcode/sqlite_fdw /opt/fsepv18server64/
lib/bitcode/
COPY --from=compile-sqlite_fdw /opt/fsepv18server64/share/extension/sqlite_fdw* /opt/
fsepv18server64/share/extension/

# Install sqlite_fdw run time dependencies
RUN microdnf install -y sqlite-libs

#change the user to postgresql
USER 26
```

2. Build custom image

```
docker build -f Dockerfile -t my.registry/my-repo/fep-18-server-sqlite_fdw:ubi9-18-1.0
```

3. Push image to custom container registry

```
docker push my.registry/my-repo/fep-18-server-sqlite_fdw:ubi9-18-1.0
```

4.7.4 Create FEP Cluster with custom image

If the custom container registry requires authentication, create a pull secret with the name quay-pull-secret. FEP Operator will this this pull secret to download container image.

```
kind:Secret
apiVersion:v1
metadata:
  name:quay-pull-secret
  namespace:fep-container-ct
data:
  .dockerconfigjson:~>-
    xxxxxxbCI6ICIiCiAgICB9CiAgfQp9
type:kubernetes.io/dockerconfigjson
```

Create FEP Cluster CR. Define the Pullsecret for pulling the customized image in spec.fep.imagePullSecret.

```
apiVersion: fep.fujitsu.io/v2
kind: FEPCluster
```

```
metadata:
  name: sqlite-fdw
  namespace: fep-container-ct
spec:
  fep:
    imagePullSecrets: cosutomPullSecret
    forceSsl: true
… …
   image:
      image: 'my.registry/my-repo/fep-18-server-sqlite_fdw:ubi9-18-1.0'
… …
   instances: 1
```

Deploy FEPCluster

```
oc apply -f sqlite_fdw.yaml
```

Create extension

```
postgres# CREATE EXTENSION sqlite_fdw;
CREATE EXTENSION
postgres=#
```

4.8 Configuration FEP to Perform MTLS

All three traffic can be secured by using TLS connection protected by certificates:

- Postgres traffic from Client Application to FEPCluster
- Patroni RESTAPI within FEPCluster
- Postgres traffic within FEPCluster (e.g. replication, rewind)

4.8.1 When Using an Automatically Generated Certificate

4.8.1.1 How to Create a Certificate

Operators can automatically generate certificates and use MTLS for communication between containers to improve safety. Automatic certificate generation settings must be defined before installing the operator. Refer to "Chapter 3 Operator Installation" for configuration methods.

If you want to use a manually created certificate, refer to "4.8.2 When Using Your Own Certificate". If you want to use your own certificate, disable the automatic certificate generation feature.

4.8.1.2 How to Create a Client Certificate

The automatic certificate generation feature automatically generates system user certificates for database management. If you want to create a certificate for a general user who connects to the database, refer to the following steps.

This section explains how to create a Secret resource containing a certificate to be mounted in the client container. The created Secret resource can mounte on the client's Pod and used to connect to FEPCluster using certificate authentication.

When using cert-manager to generate certificates

1. Verify that the Issuer resource "<namespace>-ca-issuer" exists.

2. Create a template for the Certificate resource.

```
$ cat mydbuser-cert.yaml
apiVersion:cert-manager.io/v1
kind:Certificate
metadata:
name: "<fepclustername>-<username>-cert"
namespace: "<namespace>"
spec:
commonName: "< username >"
issuerRef:
name: <namespace>-ca-issuer
secretName: "<fepclustername>-<username>-cert"
```

3. Apply the Certificate resource.

```
$ kubectl apply -f mydbuser-cert.yaml
```

When using openssl to generate certificates

1. Get the CA certificate stored in the Secret "fepopr-root-secret".

```
$ kubectl -n <namespace> get secret fepopr-root-secret -o jsonpath='{.data.tls\.key}' | base64
-d > <namespace>-ca.key

$ kubectl -n <namespace> get secret fepopr-root-secret -o jsonpath='{.data.tls\.crt}' | base64
-d > <namespace>-ca.crt
```

2. Create the certificate using the following command.

```
$ serial=$(openssl rand -hex 8)
$ openssl genrsa -out <fepclustername>-<username>.key 2048
$ openssl req -new -key <fepclustername>-<username>.key -out <fepclustername>-<username>.csr -
subj "/CN=<username>"
$ openssl x509 -req -in <fepclustername>-<username>.csr -CA <namespace>-ca.crt -CAkey
<namespace>-ca.key -set_serial "0x${serial}" -out <fepclustername>-<username>.crt -days 365
```

3. Create a secret to store the certificate.

```
$ kubectl -n <namespace> create secret tls <fepclustername>-<username>-cert --cert
<fepclustername>-<username>.crt -key=<fepclustername>-<username>.key
```

4.8.2 When Using Your Own Certificate

Here, we provide two methods to create certificates for securing the TLS connection and provide mutual authentication. The first method is to create and renew certificate manually. The second method is to use CertManager to create an automatically renew certificate.

Note

The following considerations apply to client connections to a database cluster in an MTLS configuration:

- Distribute the Root certificate for server (validation) that you specified when you created the MTLS database cluster to the client machines.
- Create and use a new client certificate.
- If the server root certificate and the client root certificate are different, a server-side configuration update is required.

4.8.2.1 Manual Certificate Management

Overview of Procedures

The procedures to enable MTLS communication are listed below:

1. Create a self signed certificate as CA
2. Create Configmap to store CA certificate
3. Create a password for protecting FEP Server private key (optional)
4. Create FEP Server private key
5. Create FEP Server certificate signing request
6. Create FEP Server certificate signed by CA
7. Create TLS Secret to store FEP Server certificate and key
8. Create private key for Patroni
9. Create certificate signing request for Patroni
10. Create certificate signed by CA for Patroni
11. Create TLS secret to store Patroni certificate and key
12. Create private key for "postgres" user client certificate
13. Create certificate signing request for "postgres" user client certificate
14. Create client certificate for "postgres" user
15. Create TLS secret to store "postgres" certificate and key
16. Repeat step 12-15 for "repluser" and "rewinduser"

- The information in the manual is only an example, and in operation, use a certificate signed by a certificate authority (CA) that the user can trust.
- When working on a Kubernetes cluster, replace the oc command with the kubectl command.

Creating a CA Certificate

1. Create a self signed certificate as CA

```
openssl genrsa -aes256 -out myca.key 4096
Generating RSA private key, 4096 bit long modulus (2 primes)
.......................++++
.....................................................++++
e is 65537 (0x010001)
Enter pass phrase for myca.key: 0okm9ijn8uhb7ygv
Verifying - Enter pass phrase for myca.key: 0okm9ijn8uhb7ygv

cat << EOF > ca.cnf
[req]
distinguished_name=req_distinguished_name
x509_extensions=v3_ca
[v3_ca]
basicConstraints = critical, CA:true
keyUsage=critical,keyCertSign,digitalSignature,cRLSign
[req_distinguished_name]
commonName=Common Name
EOF
```

```
openssl req -x509 -new -nodes -key myca.key -days 3650 -out myca.pem -subj "/O=My Organization/
OU=CA /CN=My Organization Certificate Authority" -config ca.cnf
Enter pass phrase for myca.key: 0okm9ijn8uhb7ygv
```

2. Create Configmap to store CA certificate

```
oc create configmap cacert --from-file=ca.crt=myca.pem -n my-namespace
```

3. Create a password for protecting FEP Server private key (optional)

```
oc create secret generic mydb-fep-private-key-password --from-literal=keypassword=abcdefghijk -n
my-namespace
```

Creating a Server Certificate

4. Create FEP Server private key

```
openssl genrsa -aes256 -out fep.key 2048
Generating RSA private key, 2048 bit long modulus
.............................................+++
.......+++
e is 65537 (0x10001)
Enter pass phrase for fep.key: abcdefghijk
Verifying - Enter pass phrase for fep.key: abcdefghijk
```

5. Create FEP Server certificate signing request

```
cat << EOF > san.cnf
[SAN]
subjectAltName = @alt_names
[alt_names]
DNS.1 = *.my-namespace.pod
DNS.2 =  *.my-namespace.pod.cluster.local
DNS.3 = mydb-primary-svc
DNS.4 = mydb-primary-svc.my-namespace
DNS.5 = mydb-primary-svc.my-namespace.svc
DNS.6 = mydb-primary-svc.my-namespace.svc.cluster.local
DNS.7 = mydb-replica-svc
DNS.8 = mydb-replica-svc.my-namespace
DNS.9 = mydb-replica-svc.my-namespace.svc
DNS.10 = mydb-replica-svc.my-namespace.svc.cluster.local
EOF

openssl req -new -key fep.key -out fep.csr -subj "/CN=mydb-headless-svc" -reqexts SAN -config
<(cat /etc/pki/tls/openssl.cnf <(cat san.cnf))
Enter pass phrase for fep.key: abcdefghijk
```

Note

- The cluster name and namespace must be changed appropriately.
- If you are connecting from outside the OCP cluster, you must also include the host name used for that connection.

6. Create FEP Server certificate signed by CA

```
openssl x509 -req -in fep.csr -CA myca.pem -CAkey myca.key -out fep.pem -days 365 -extfile
<(cat /etc/pki/tls/openssl.cnf <(cat san.cnf)) -extensions SAN -CAcreateserial  # all in one line
Signature ok
subject=/CN=mydb-headless-svc
Getting CA Private Key
Enter pass phrase for myca.key: 0okm9ijn8uhb7ygv
```

7. Create TLS Secret to store FEP Server certificate and key

```
oc create secret generic mydb-fep-cert --from-file=tls.crt=fep.pem --from-file=tls.key=fep.key -n
my-namespace
```

8. Create private key for Patroni

At the moment, FEP container does not support password protected private key for Patroni.

```
openssl genrsa -out patroni.key 2048
Generating RSA private key, 2048 bit long modulus
.............................................+++
.......+++
e is 65537 (0x10001)
```

9. Create certificate signing request for Patroni

```
cat << EOF > san.cnf
[SAN]
subjectAltName = @alt_names
[alt_names]
DNS.1 = *.my-namespace.pod
DNS.2 = *.my-namespace.pod.cluster.local
DNS.3 = mydb-primary-svc
DNS.4 = mydb-primary-svc.my-namespace
DNS.5 = mydb-replica-svc
DNS.6 = mydb-replica-svc.my-namespace
DNS.7 = mydb-headless-svc
DNS.8 = mydb-headless-svc.my-namespace
EOF

openssl req -new -key patroni.key -out patroni.csr -subj "/CN=mydb-headless-svc" -reqexts SAN -
config <(cat /etc/pki/tls/openssl.cnf <(cat san.cnf))  # all in one line
```

Note

- The cluster name and namespace must be changed appropriately.
- If you are connecting from outside the OCP cluster, you must also include the host name used for that connection.

10. Create certificate signed by CA for Patroni

```
openssl x509 -req -in patroni.csr -CA myca.pem -CAkey myca.key -out patroni.pem -days 365 -extfile
<(cat /etc/pki/tls/openssl.cnf <(cat san.cnf)) -extensions SAN -CAcreateserial  # all in one line
Signature ok
subject=/CN=mydb-headless-svc
```

```
Getting CA Private Key
Enter pass phrase for myca.key: 0okm9ijn8uhb7ygv
```

11. Create TLS secret to store Patroni certificate and key

```
oc create secret tls mydb-patroni-cert --cert=patroni.pem --key=patroni.key -n my-namespace
```

Creating a User Certificate

12. Create private key for "postgres" user client certificate

    At the moment, SQL client inside FEP server container does not support password protected certificate.

```
openssl genrsa -out postgres.key 2048
Generating RSA private key, 2048 bit long modulus
.............................................+++
.......+++
e is 65537 (0x10001)
```

13. Create certificate signing request for "postgres" user client certificate

```
openssl req -new -key postgres.key -out postgres.csr -subj "/CN=postgres"
```

14. Create client certificate for "postgres" user

```
openssl x509 -req -in postgres.csr -CA myca.pem -CAkey myca.key -out postgres.pem -days 365
Signature ok
subject=CN = postgres
Getting CA Private Key
Enter pass phrase for myca.key: 0okm9ijn8uhb7ygv
```

15. Create TLS secret to store "postgres" certificate and key

```
oc create secret tls mydb-postgres-cert --cert=postgres.pem --key=postgres.key -n my-namespace
```

16. Repeat step 12-15 for "repluser" and "rewinduser"

4.8.2.2 Automatic Certificate Management

There are many Certificate Management tools available in the public. In this example, we will use cert-manager for the purpose.

- Note that certificates created in this example are not password protected.
- When working on a Kubernetes cluster, replace the oc command with the kubectl command.

Install cert-manager

```
oc create namespace cert-manager

oc apply -f https://github.com/jetstack/cert-manager/releases/download/v1.3.0/cert-manager.yaml
```

Create a Self Signed Issuer (This can be namespace specific or cluster wise)

This example creates an Issuer, that can create self signed certificate, in namespace my-namespace.

```
cat << EOF | oc apply -f -
apiVersion: cert-manager.io/v1
kind: Issuer
metadata:
  name: selfsigned-issuer
  namespace: my-namespace
spec:
  selfSigned: {}
EOF
```

Create a Self Signed CA certificate using selfsigned-issuer

```
cat << EOF | oc apply -f -
apiVersion: cert-manager.io/v1
kind: Certificate
metadata:
  name: cacert
  namespace: my-namespace
spec:
  subject:
    organizations:
      - My Organization
    organizationalUnits:
      - CA
  commonName: "My Organization Certificate Authority"
  duration: 87600h
  isCA: true
  secretName: cacert
  issuerRef:
    name: selfsigned-issuer
EOF
```

The above command will create a self signed Root certificate and private key stored in the Kubernetes secret "cacert" in namespace my-namespace.

Create a CA Issuer with above certificate

```
cat << EOF | oc apply -f -
apiVersion: cert-manager.io/v1
kind: Issuer
metadata:
  name: ca-issuer
  namespace: my-namespace
spec:
  ca:
    secretName: cacert
EOF
```

Create FEP Server certificate using above CA Issuer

Assuming FEPCluster name is mydb in namespace my-namespace.

```
cat << EOF | oc apply -f -
apiVersion: cert-manager.io/v1
kind: Certificate
metadata:
  name: mydb-fep-cert
```

```
  namespace: my-namespace
spec:
  subject:
  commonName: "mydb-headless-svc"
  dnsNames:
  - "*.my-namespace.pod"
  - "*.my-namespace.pod.cluster.local"
  - "mydb-primary-svc"
  - "mydb-primary-svc.my-namespace"
  - "mydb-primary-svc.my-namespace.svc"
  - "mydb-primary-svc.my-namespace.svc.cluster.local"
  - "mydb-replica-svc"
  - "mydb-replica-svc.my-namespace"
  - "mydb-replica-svc.my-namespace.svc"
  - "mydb-replica-svc.my-namespace.svc.cluster.local"
  duration: 8760h
  usages:
  - server auth
  secretName: mydb-fep-cert
  issuerRef:
    name: ca-issuer
EOF
```

Create Patroni certificate using above CA Issuer

Assuming FEPCluster name is mydb in namespace my-namespace.

```
cat << EOF | oc apply -f -
apiVersion: cert-manager.io/v1
kind: Certificate
metadata:
  name: mydb-patroni-cert
  namespace: my-namespace
spec:
  subject:
  commonName: "mydb-headless-svc"
  dnsNames:
  - "*.my-namespace.pod"
  - "*.my-namespace.pod.cluster.local"
  - "*.mydb-primary-svc"
  - "*.mydb-primary-svc.my-namespace"
  - "*.mydb-replica-svc "
  - "*.mydb-replica-svc.my-namespace"
  duration: 8760h
  usages:
  - server auth
  secretName: mydb-patroni-cert
  issuerRef:
    name: ca-issuer
EOF
```

Create postgres user client certificate

```
cat << EOF | oc apply -f -
apiVersion: cert-manager.io/v1
kind: Certificate
metadata:
  name: mydb-postgres-cert
  namespace: my-namespace
spec:
  subject:
```

```
  commonName: "postgres"
  duration: 8760h
  usages:
  - client auth
  secretName: mydb-postgres-cert
  issuerRef:
    name: ca-issuer
EOF
```

Create repluser user client certificate

```
cat << EOF | oc apply -f -
apiVersion: cert-manager.io/v1
kind: Certificate
metadata:
  name: mydb-repluser-cert
  namespace: my-namespace
spec:
  subject:
  commonName: "repluser"
  duration: 8760h
  usages:
  - client auth
  secretName: mydb-repluser-cert
  issuerRef:
    name: ca-issuer
EOF
```

Create FEPLogging(Fluentd) server certificate using above CA Issuer

Assuming FEPLogging name is **nfl** in namespace **feplogging-dev.**

```
cat << EOF | oc apply -f -
apiVersion: cert-manager.io/v1
kind: Certificate
metadata:
  name: fluentd-cert
  namespace: feplogging-dev
spec:
  subject:
  commonName: "nfl-fluentd-headless-service"
  dnsNames:
  - 'nfl-fluentd-headless-service'
  - 'nfl-fluentd-headless-service.feplogging-dev'
  - 'nfl-fluentd-headless-service.feplogging-dev.svc'
  - 'nfl-fluentd-headless-service.feplogging-dev.svc.cluster.local'
  duration: 8760h
  usages:
  - server auth
  secretName: fluentd-cert
  issuerRef:
    name: ca-issuer
EOF
```

Create FEPLogging client(prometheus) certificate

```
cat << EOF | oc apply -f -
apiVersion: cert-manager.io/v1
kind: Certificate
metadata:
```

```
  name: prometheus-cert
  namespace: feplogging-dev
spec:
  subject:
  commonName: "prometheus"
  duration: 8760h
  usages:
  - client auth
  secretName: prometheus-cert
  issuerRef:
    name: ca-issuer
EOF
```

Create FEPLogging client(fluentbit) certificate

```
cat << EOF | oc apply -f -
apiVersion: cert-manager.io/v1
kind: Certificate
metadata:
  name: fluentbit-cert
  namespace: feplogging-dev
spec:
  subject:
  commonName: "fluentbit"
  duration: 8760h
  usages:
  - client auth
  secretName: fluentbit-cert
  issuerRef:
    name: ca-issuer
EOF
```

Create FEPExporter certificate using above CA Issuer

Assuming FEP Exporter name is **exp1** in namespace **my-namespace.**

```
cat << EOF | oc apply -f -
apiVersion: cert-manager.io/v1
kind: Certificate
metadata:
  name: fepexporter-cert
  namespace: my-namespace
spec:
  subject:
  commonName: "exp1-service"
  dnsNames:
  - 'exp1-service'
  - 'exp1-service.fepexporter-dev'
  - 'exp1-service.fepexporter-dev.svc'
  - 'exp1-service.fepexporter-dev.svc.cluster.local'
  duration: 8760h
  usages:
  - server auth
  secretName: fepexporter-cert
  issuerRef:
    name: ca-issuer
EOF
```

Create FEPExporter user client(prometheus) certificate

```
cat << EOF | oc apply -f -
apiVersion: cert-manager.io/v1
kind: Certificate
metadata:
  name: prometheus-cert
  namespace: my-namespace
spec:
  subject:
  commonName: "prometheus"
  duration: 8760h
  usages:
  - client auth
  secretName: prometheus-cert
  issuerRef:
    name: ca-issuer
EOF
```

4.8.2.3 Deploy FEPCluster with MTLS support

Deploy FEPCluster with manual certificate management

Use the following yaml as an example to deploy a FEPCluster with Manual Certificate Management. MTLS related parameters are highlighted in Red.

```
apiVersion: fep.fujitsu.io/v2
kind: FEPCluster
metadata:
  name: mydb
  namespace: my-namespace
spec:
  fep:
    usePodName: true
    patroni:
      tls:
        certificateName: mydb-patroni-cert
        caName: cacert
    postgres:
      tls:
        certificateName: mydb-fep-cert
        caName: cacert
        privateKeyPassword: mydb-fep-private-key-password
    forceSsl: true
    podAntiAffinity: false
    mcSpec:
      limits:
        cpu: 500m
        memory: 700Mi
      requests:
        cpu: 200m
        memory: 512Mi
    customAnnotations:
      allDeployments: {}
    servicePort: 27500
    image:
      image: 'quay.io/fujitsu/fujitsu-enterprise-postgres-18-server:ubi9-18-1.0'
      pullPolicy: IfNotPresent
    sysExtraLogging: false
    podDisruptionBudget: false
    instances: 3
    syncMode: 'on'
  fepChildCrVal:
```

```
  customPgAudit: |
    # define pg audit custom params here to override defaults.
    # if log volume is not defined, log_directory should be
    # changed to '/database/userdata/data/log'
    [output]
    logger = 'auditlog'
    log_directory = '/database/log/audit'
    [rule]
  customPgHba: |
    # define pg_hba custom rules here to be merged with default rules.
    # TYPE     DATABASE        USER        ADDRESS        METHOD
    hostssl    all             all         0.0.0.0/0      cert
    hostssl    replication     all         0.0.0.0/0      cert
  customPgParams: >+
    # define custom postgresql.conf parameters below to override defaults.
    # Current values are as per default FEP deployment
    shared_preload_libraries='pgx_datamasking,pgaudit,pg_prewarm'
    session_preload_libraries='pg_prewarm'
    max_prepared_transactions = 100
    max_worker_processes = 30
    max_connections = 100
    work_mem = 1MB
    maintenance_work_mem = 12MB
    shared_buffers = 128MB
    effective_cache_size = 384MB
    checkpoint_completion_target = 0.8

    # tcp parameters
    tcp_keepalives_idle = 30
    tcp_keepalives_interval = 10
    tcp_keepalives_count = 3

    # logging parameters in default fep installation
    # if log volume is not defined, log_directory should be
    # changed to '/database/userdata/data/log'
    log_directory = '/database/log'
    log_filename = 'logfile-%a.log'
    log_file_mode = 0600
    log_truncate_on_rotation = on
    log_rotation_age = 1d
    log_rotation_size = 0
    log_checkpoints = on
    log_line_prefix = '%e %t [%p]: [%l-1] user=%u,db=%d,app=%a,client=%h'
    log_lock_waits = on
    log_autovacuum_min_duration = 60s
    logging_collector = on
    pgaudit.config_file='/opt/app-root/src/pgaudit-cfg/pgaudit.conf'
    log_replication_commands = on
    log_min_messages = WARNING
    log_destination = stderr

    # wal_archive parameters in default fep installation
    archive_mode = on
    archive_command = '/bin/true'
    wal_level = replica
    max_wal_senders = 12
    wal_keep_segments = 64

  storage:
    dataVol:
      size: 2Gi
      storageClass: nfs-client
    walVol:
```

```
      size: 1200Mi
      storageClass: nfs-client
    logVol:
      size: 1Gi
      storageClass: nfs-client
  sysUsers:
    pgAdminPassword: admin-password
    pgdb: mydb
    pgpassword: mydbpassword
    pguser: mydbuser
    pgrepluser: repluser
    pgreplpassword: repluserpwd
    pgRewindUser: rewinduser
    pgRewindPassword: rewinduserpwd
    pgAdminTls:
      certificateName: mydb-postgres-cert
      caName: cacert
      sslMode: prefer

    pgrepluserTls:
      certificateName: mydb-repluser-cert
      caName: cacert
      sslMode: prefer

    pgRewindUserTls:
      certificateName: mydb-rewinduser-cert
      caName: cacert
      sslMode: prefer

    tdepassphrase: tde-passphrase
  systemCertificates:
    key: |-
      -----BEGIN RSA PRIVATE KEY-----
      MIIEowIBAAKCAQEA0DFkImha8CIJiVcwXbBPlL+/DmS9/ipRhQQHxfO5x7jSOnse
      IHdFd6+Qx2GX8KAiAhVykf6kfacwBYTATU1xDgwWTm82KVRPh+kZDIj2wPcJr14m
      mTP6I6a2mavUgDhezHc9F8/dchYj3cw81X0kU6xamqrKQYlxQH48NkI0qcwhO6sK
      AHF4eWfCr8Ot44xADIA1JcU2CS1RKSZEtURZ+30Py+j907Enjp1YR33ZKUHw30pU
      9dpIneyfXBN/pT6cX3MetYwtgmpV/pHqY8pbxqGfoyRhgQDsSRCl4dtlecaZeZ4j
      uTOotcPkZELHP6eu8gaLtycG9lpbAMQl5w0r8QIDAQABAoIBACq213qPuoimExrQ
      fqXaNJmqNYK4fJqXCB6oUwf0F1u4ubkx5V532hLSPHwLs+a0lAWlbNozSoBVOu8G
      64VwrA9bv3/cJVqZZ6/UzUTbHPU+Ogh24qhwF5QU8kXZEUI1To3YsPoftalgjX9G
      Ff0fLcLVC8nL3K9RiaDXxXbEYpWrYu39M3FCpAXAzV2PrNxsP9PKyNWHnBPc08z5
      tFj45/bHn+j31AVVvgWtqz0pLks57hc4Q7yW/2RoRYq2md1KI709OLNwtkWEOVqb
      qnraorh2TwGnNaOB5oX5/lJvKtlq778fw96jGqykBr0+DKozj9rlr1OGgYOKDwlD
      nsZJPAECgYEA+Oqf/fxtPdsNGiaL2Z/heewvtaxjw/WoEVBFECb6/y4Ro7aux9nB
      16FcVi79Cwfp0UTJ7cnZvYSmBk5GWEObEIAeo61lvm/QeltM5+usAPd5/TcHXLYe
      92OnXmq7h3F4UXEkMayak8Lpu/TdmR5uOaL+m4aEu+XMY5tlxqDCnyECgYEA1h4X
      jCPi7Ja5CHK7a2Ud4TL2DNpIBE6GSK9iQ+0xFL6TsiK2Sfu6n8mx2sh+Jm0KHTiE
      /gWHdHQZSSWiuULfHoYEq3Rq8S6Av3GsGtRSpO03j7BE8C20Vpt0FnNTjZmdzf2/
      YZxc5KuYLh9qeY7Y7ceOsWA8JckDgMHPYzyLAtECgYBALD0TPgDr8Y1vMIDdmlqH
      FF04eTk/TBYIYKltgJ81KqthibeFzp4q+W7UyUhzj5a4XQOySlfYhFpJReTc3JEd
      r+o2SH3ymuEkqmUpZZjyptrMbWN4g3t4TDjaHqo6QQbD+GdcZyNy9M1Np9N5pl7E
      fUEm14dg6d3H0Ehs7QVAAQKBgQDRUx3mLXc9oKRINBIyDerGLJILQqLBQxtYl81T
      ZuFizGWL8w+PCIAMkpxDrVpWqqcGpiiuRi2ElbPapOaOg2epaY/LJscd/j5z6uc8
      W3JoNljpKoRa4fO578Pv5tM6TYHOzlF5Veoiy/a8sI3hRNuiqkM/+TsUHY5FJDRh
      aeDk4QKBgCOHIevvR+MWuwakzD6lNCbb8H6fvZ3WRAT8BYYz3wW9YfnV4J4uh/Bl
      moWYgIK2UpkrhA8scMUC790FoybQeParQ35x7Jl91bmTKkCqsX63fyqqYhx3SXRl
      JSktmH4E2cGmosZisjB7COKHR32w0J5JCgaGInQxjldbGrwhZQpn
      -----END RSA PRIVATE KEY-----
    crt: |-
      -----BEGIN CERTIFICATE-----
      MIID2DCCAsCgAwIBAgIQDfFYteD4kZj4Sko2iy1IJTANBgkqhkiG9w0BAQsFADBX
      MRgwFgYDVQQKEw9NeSBPcmdhbml6YXRpb24xCzAJBgNVBAsTAkNBMS4wLAYDVQQD
```

```
      EyVNeSBPcmdhbml6YXRpb24gQ2VydGlmaWNhdGUgQXV0aG9yaXR5MB4XDTIxMDQy
      MDAwMDQ1OVoXDTIxMDQyMDAxMDQ1OVowGDEWMBQGA1UEAwwNKi5jaGctcHRjLnBv
      ZDCCASIwDQYJKoZIhvcNAQEBBQADggEPADCCAQoCggEBANAxZCJoWvAiCYlXMF2w
      T5S/vw5kvf4qUYUEB8Xzuce40jp7HiB3RXevkMdhl/CgIgIVcpH+pH2nMAWEwE1N
      cQ4MFk5vNilUT4fpGQyI9sD3Ca9eJpkz+iOmtpmr1IA4Xsx3PRfP3XIWI93MPNV9
      JFOsWpqqykGJcUB+PDZCNKnMITurCgBxeHlnwq/DreOMQAyANSXFNgktUSkmRLVE
      Wft9D8vo/dOxJ46dWEd92SlB8N9KVPXaSJ3sn1wTf6U+nF9zHrWMLYJqVf6R6mPK
      W8ahn6MkYYEA7EkQpeHbZXnGmXmeI7kzqLXD5GRCxz+nrvIGi7cnBvZaWwDEJecN
      K/ECAwEAAaOB3jCB2zATBgNVHSUEDDAKBggrBgEFBQcDATAMBgNVHRMBAf8EAjAA
      MIG1BgNVHREEga0wgaqCCWxvY2FsaG9zdIIbKi5jaGctcHRjLnBvZC5jbHVzdGVy
      LmxvY2FsghMqLm15ZGItaGVhZGxlc3Mtc3ZjghsqLm15ZGItaGVhZGxlc3Mtc3Zj
      LmNoZy1wdGOCHyoubXlkYi1oZWFkbGVzcy1zdmMuY2hnLXB0Yy5zdmOCLSoubXlk
      Yi1oZWFkbGVzcy1zdmMuY2hnLXB0Yy5zdmMuY2x1c3Rlci5sb2NhbDANBgkqhkiG
      9w0BAQsFAAOCAQEALnhliDflu+BHp5conq4dXBwD/Ti2YR5TWQixM/0a6OD4KecZ
      MmaLl0T+OJJvA/j2IufZpc7dzEx5mZDkR2CRmoq10qZXqCRTrBZSXm6ARQWoYpeg
      9c0l4f8roxrkMGUKVPTKUwAvbnNYhD2l6PlBPwMpkMUfqFaSEXMaPyQKhrtQxdpH
      WjuS54OP0lm0peYu/yiaD98LtrTXnb6jch84SKf6Vii4HAVQyMeJaW+dpkqcI2+V
      Q4fkwWYSJy8BNcmXCwvHDLDy+s4EXWvHafhusuUhcp4HyMb1A6hd5hJhgFSnEvLy
      kLA0L9LaScxee6V756Vt9TN1NGjwmwyQDOhnQQ==
      -----END CERTIFICATE-----
    cacrt: |-
      -----BEGIN CERTIFICATE-----
      MIIDXDCCAkSgAwIBAgIRAMPzF3BNFxT9HWE+NXlFQjQwDQYJKoZIhvcNAQELBQAw
      VzEYMBYGA1UEChMPTXkgT3JnYW5pemF0aW9uMQswCQYDVQQLEwJDQTEuMCwGA1UE
      AxMlTXkgT3JnYW5pemF0aW9uIENlcnRpZmljYXRlIEF1dGhvcml0eTAeFw0yMTA0
      MTkwNDQ0MjNaFw0zMTA0MTcwNDQ0MjNaMFcxGDAWBgNVBAoTD015IE9yZ2FuaXph
      dGlvbjELMAkGA1UECxMCQ0ExLjAsBgNVBAMTJU15IE9yZ2FuaXphdGlvbiBDZXJ0
      aWZpY2F0ZSBBdXRob3JpdHkwggEiMA0GCSqGSIb3DQEBAQUAA4IBDwAwggEKAoIB
      AQC5t6CS23Glk65YMw5e4i4xHldyxkCZS67w/6LWqeIlYKmFAaEl83WWy8MHUpOb
      4mahtUafEzDEOX6+URf72J8m0voldQ5FYr1AyUOyX8U90wGFqhbEgKRqt7vZEwIe
      2961fwqHh6917zI4xmt5W6ZJ5dBQVtkhzB+Pf7O6KBYjHoCnBBkfNVzsfZQ/1hnR
      0UzimfAc7Ze+UNwhXJhinFRJ3YuR+xiOTpPkl1GXPhLgFSQhekz4KepcbQEQKejb
      jg0dum1oBYIXZTSSbiO9rNmfUVLB5DcV0vZbSrGxLjWLBt5U8N2xf2d1bvkQW+bw
      Kklf9OG26bAi27tujurzN3r3AgMBAAGjIzAhMA4GA1UdDwEB/wQEAwICpDAPBgNV
      HRMBAf8EBTADAQH/MA0GCSqGSIb3DQEBCwUAA4IBAQAM0CN3n5C/KOT4uZ4ewwKK
      rHmANBPVM9u6MJBO8U62HcqLeoCuDFeU8zmUjLHjsQaPX64mJZlR7T5y52gEKO5A
      0qsBz3pg/vJ5DJTv0698+1Q1hB9k3smQdksAim19FZqysB7J4zK/+8aJ/q2kIFvs
      Jk3ekwQdQ3xfggklBQVuf76gr1v0uYlPtfPffPlfcGZ06Im6mqbajenXoR1PxPB0
      +zyCS8DkgPtDulplruwvXCFMYw9TPbzXKlt7tlsqRXogYLnxWJDzM1nOYCnD+rDm
      qxenV9Ir8RqZ0XSYuUyzRka5N4dhIhrzTAiNdeU5gzynXOz67u/Iefz1iK9ZcdE3
      -----END CERTIFICATE-----
```

Deploy FEPCluster with automatic certificate management

Use the following yaml as an example to deploy a FEPCluster with Automatic Certificate Management. MTLS related parameters are highlighted in Red.

```
apiVersion: fep.fujitsu.io/v2
kind: FEPCluster
metadata:
  name: mydb
  namespace: my-namespace
spec:
  fep:
    usePodName: true
    patroni:
      tls:
        certificateName: mydb-patroni-cert
    postgres:
      tls:
        certificateName: mydb-fep-cert
    forceSsl: true
    podAntiAffinity: false
```

```
  mcSpec:
    limits:
      cpu: 500m
      memory: 700Mi
    requests:
      cpu: 200m
      memory: 512Mi
  customAnnotations:
    allDeployments: {}
  servicePort: 27500
  image:
    image: 'quay.io/fujitsu/fujitsu-enterprise-postgres-18-server:ubi9-18-1.0'
    pullPolicy: IfNotPresent
  sysExtraLogging: false
  podDisruptionBudget: false
  instances: '3'
  syncMode: 'on'
fepChildCrVal:
  customPgAudit: |
    # define pg audit custom params here to override defaults.
    # if log volume is not defined, log_directory should be
    # changed to '/database/userdata/data/log'
    [output]
    logger = 'auditlog'
    log_directory = '/database/log/audit'
    [rule]
  customPgHba: |
    # define pg_hba custom rules here to be merged with default rules.
    # TYPE     DATABASE        USER        ADDRESS        METHOD
    hostssl    all             all         0.0.0.0/0      cert
    hostssl    replication     all         0.0.0.0/0      cert
  customPgParams: >+
    # define custom postgresql.conf parameters below to override defaults.
    # Current values are as per default FEP deployment
    shared_preload_libraries='pgx_datamasking,pgaudit,pg_prewarm'
    session_preload_libraries='pg_prewarm'
    max_prepared_transactions = 100
    max_worker_processes = 30
    max_connections = 100
    work_mem = 1MB
    maintenance_work_mem = 12MB
    shared_buffers = 128MB
    effective_cache_size = 384MB
    checkpoint_completion_target = 0.8

    # tcp parameters
    tcp_keepalives_idle = 30
    tcp_keepalives_interval = 10
    tcp_keepalives_count = 3

    # logging parameters in default fep installation
    # if log volume is not defined, log_directory should be
    # changed to '/database/userdata/data/log'

    log_directory = '/database/log'
    log_filename = 'logfile-%a.log'
    log_file_mode = 0600
    log_truncate_on_rotation = on
    log_rotation_age = 1d
    log_rotation_size = 0
    log_checkpoints = on
    log_line_prefix = '%e %t [%p]: [%l-1] user=%u,db=%d,app=%a,client=%h'
    log_lock_waits = on
```

```
    log_autovacuum_min_duration = 60s
    logging_collector = on
    pgaudit.config_file='/opt/app-root/src/pgaudit-cfg/pgaudit.conf'
    log_replication_commands = on
    log_min_messages = WARNING
    log_destination = stderr

    # wal_archive parameters in default fep installation
    archive_mode = on
    archive_command = '/bin/true'
    wal_level = replica
    max_wal_senders = 12
    wal_keep_segments = 64

  storage:
    dataVol:
      size: 2Gi
      storageClass: nfs-client
    walVol:
      size: 1200Mi
      storageClass: nfs-client
    logVol:
      size: 1Gi
      storageClass: nfs-client
  sysUsers:
    pgAdminPassword: admin-password
    pgdb: mydb
    pgpassword: mydbpassword
    pguser: mydbuser
    pgrepluser: repluser
    pgreplpassword: repluserpwd
    pgRewindUser: rewinduser
    pgRewindPassword: rewinduserpwd
    pgAdminTls:
      certificateName: mydb-postgres-cert
      sslMode: verify-full

    pgrepluserTls:
      certificateName: mydb-repluser-cert
      sslMode: verify-full

    pgRewindUserTls:
      certificateName: mydb-rewinduser-cert
      sslMode: verify-full

    tdepassphrase: tde-passphrase
  systemCertificates:
    key: |-
      -----BEGIN RSA PRIVATE KEY-----
      MIIEowIBAAKCAQEA0DFkImha8CIJiVcwXbBPlL+/DmS9/ipRhQQHxfO5x7jSOnse
      IHdFd6+Qx2GX8KAiAhVykf6kfacwBYTATU1xDgwWTm82KVRPh+kZDIj2wPcJr14m
      mTP6I6a2mavUgDhezHc9F8/dchYj3cw81X0kU6xamqrKQYlxQH48NkI0qcwhO6sK
      AHF4eWfCr8Ot44xADIA1JcU2CS1RKSZEtURZ+30Py+j907Enjp1YR33ZKUHw30pU
      9dpIneyfXBN/pT6cX3MetYwtgmpV/pHqY8pbxqGfoyRhgQDsSRCl4dtlecaZeZ4j
      uTOotcPkZELHP6eu8gaLtycG9lpbAMQl5w0r8QIDAQABAoIBACq213qPuoimExrQ
      fqXaNJmqNYK4fJqXCB6oUwf0F1u4ubkx5V532hLSPHwLs+a0lAWlbNozSoBVOu8G
      64VwrA9bv3/cJVqZZ6/UzUTbHPU+Ogh24qhwF5QU8kXZEUI1To3YsPoftalgjX9G
      Ff0fLcLVC8nL3K9RiaDXxXbEYpWrYu39M3FCpAXAzV2PrNxsP9PKyNWHnBPc08z5
      tFj45/bHn+j31AVVvgWtqz0pLks57hc4Q7yW/2RoRYq2md1KI709OLNwtkWEOVqb
      qnraorh2TwGnNaOB5oX5/lJvKtlq778fw96jGqykBr0+DKozj9rlr1OGgYOKDwlD
      nsZJPAECgYEA+Oqf/fxtPdsNGiaL2Z/heewvtaxjw/WoEVBFECb6/y4Ro7aux9nB
      16FcVi79Cwfp0UTJ7cnZvYSmBk5GWEObEIAeo61lvm/QeltM5+usAPd5/TcHXLYe
      92OnXmq7h3F4UXEkMayak8Lpu/TdmR5uOaL+m4aEu+XMY5tlxqDCnyECgYEA1h4X
```

```
    jCPi7Ja5CHK7a2Ud4TL2DNpIBE6GSK9iQ+0xFL6TsiK2Sfu6n8mx2sh+Jm0KHTiE
    /gWHdHQZSSWiuULfHoYEq3Rq8S6Av3GsGtRSpO03j7BE8C20Vpt0FnNTjZmdzf2/
    YZxc5KuYLh9qeY7Y7ceOsWA8JckDgMHPYzyLAtECgYBALD0TPgDr8Y1vMIDdmlqH
    FF04eTk/TBYIYKltgJ81KqthibeFzp4q+W7UyUhzj5a4XQOySlfYhFpJReTc3JEd
    r+o2SH3ymuEkqmUpZZjyptrMbWN4g3t4TDjaHqo6QQbD+GdcZyNy9M1Np9N5pl7E
    fUEm14dg6d3H0Ehs7QVAAQKBgQDRUx3mLXc9oKRINBIyDerGLJILQqLBQxtYl81T
    ZuFizGWL8w+PCIAMkpxDrVpWqqcGpiiuRi2ElbPapOaOg2epaY/LJscd/j5z6uc8
    W3JoNljpKoRa4fO578Pv5tM6TYHOzlF5Veoiy/a8sI3hRNuiqkM/+TsUHY5FJDRh
    aeDk4QKBgCOHIevvR+MWuwakzD6lNCbb8H6fvZ3WRAT8BYYz3wW9YfnV4J4uh/Bl
    moWYgIK2UpkrhA8scMUC790FoybQeParQ35x7Jl91bmTKkCqsX63fyqqYhx3SXRl
    JSktmH4E2cGmosZisjB7COKHR32w0J5JCgaGInQxjldbGrwhZQpn
    -----END RSA PRIVATE KEY-----
  crt: |-
    -----BEGIN CERTIFICATE-----
    MIID2DCCAsCgAwIBAgIQDfFYteD4kZj4Sko2iy1IJTANBgkqhkiG9w0BAQsFADBX
    MRgwFgYDVQQKEw9NeSBPcmdhbml6YXRpb24xCzAJBgNVBAsTAkNBMS4wLAYDVQQD
    EyVNeSBPcmdhbml6YXRpb24gQ2VydGlmaWNhdGUgQXV0aG9yaXR5MB4XDTIxMDQy
    MDAwMDQ1OVoXDTIxMDQyMDAxMDQ1OVowGDEWMBQGA1UEAwwNKi5jaGctcHRjLnBv
    ZDCCASIwDQYJKoZIhvcNAQEBBQADggEPADCCAQoCggEBANAxZCJoWvAiCYlXMF2w
    T5S/vw5kvf4qUYUEB8Xzuce40jp7HiB3RXevkMdhl/CgIgIVcpH+pH2nMAWEwE1N
    cQ4MFk5vNilUT4fpGQyI9sD3Ca9eJpkz+iOmtpmr1IA4Xsx3PRfP3XIWI93MPNV9
    JFOsWpqqykGJcUB+PDZCNKnMITurCgBxeHlnwq/DreOMQAyANSXFNgktUSkmRLVE
    Wft9D8vo/dOxJ46dWEd92SlB8N9KVPXaSJ3sn1wTf6U+nF9zHrWMLYJqVf6R6mPK
    W8ahn6MkYYEA7EkQpeHbZXnGmXmeI7kzqLXD5GRCxz+nrvIGi7cnBvZaWwDEJecN
    K/ECAwEAAaOB3jCB2zATBgNVHSUEDDAKBggrBgEFBQcDATAMBgNVHRMBAf8EAjAA
    MIG1BgNVHREEga0wgaqCCWxvY2FsaG9zdIIbKi5jaGctcHRjLnBvZC5jbHVzdGVy
    LmxvY2FsghMqLm15ZGItaGVhZGxlc3Mtc3Zjghsq Lm15ZGItaGVhZGxlc3Mtc3Zj
    LmNoZy1wdGOCHyoubXlkYi1oZWFkbGVzcy1zdmMuY2hnLXB0Yy5zdmOCLSoubXlk
    Yi1oZWFkbGVzcy1zdmMuY2hnLXB0Yy5zdmMuY2x1c3Rlci5sb2NhbDANBgkqhkiG
    9w0BAQsFAAOCAQEALnhliDflu+BHp5conq4dXBwD/Ti2YR5TWQixM/0a6OD4KecZ
    MmaLl0T+OJJvA/j2IufZpc7dzEx5mZDkR2CRmoq10qZXqCRTrBZSXm6ARQWoYpeg
    9c0l4f8roxrkMGUKVPTKUwAvbnNYhD2l6PlBPwMpkMUfqFaSEXMaPyQKhrtQxdpH
    WjuS54OP0lm0peYu/yiaD98LtrTXnb6jch84SKf6Vii4HAVQyMeJaW+dpkqcI2+V
    Q4fkwWYSJy8BNcmXCwvHDLDy+s4EXWvHafhusuUhcp4HyMb1A6hd5hJhgFSnEvLy
    kLA0L9LaScxee6V756Vt9TN1NGjwmwyQDOhnQQ==
    -----END CERTIFICATE-----
  cacrt: |-
    -----BEGIN CERTIFICATE-----
    MIIDXDCCAkSgAwIBAgIRAMPzF3BNFxT9HWE+NXlFQjQwDQYJKoZIhvcNAQELBQAw
    VzEYMBYGA1UEChMPTXkgT3JnYW5pemF0aW9uMQswCQYDVQQLEwJDQTEuMCwGA1UE
    AxMlTXkgT3JnYW5pemF0aW9uIENlcnRpZmljYXRlIEF1dGhvcml0eTAeFw0yMTA0
    MTkwNDQ0MjNaFw0zMTA0MTcwNDQ0MjNaMFcxGDAWBgNVBAoTD015IE9yZ2FuaXph
    dGlvbjELMAkGA1UECxMCQ0ExLjAsBgNVBAMTJU15IE9yZ2FuaXphdGlvbiBDZXJ0
    aWZpY2F0ZSBBdXRob3JpdHkwggEiMA0GCSqGSIb3DQEBAQUAA4IBDwAwggEKAoIB
    AQC5t6CS23Glk65YMw5e4i4xHldyxkCZS67w/6LWqeIlYKmFAaEl83WWy8MHUpOb
    4mahtUafEzDEOX6+URf72J8m0voldQ5FYr1AyUOyX8U90wGFqhbEgKRqt7vZEwIe
    2961fwqHh6917zI4xmt5W6ZJ5dBQVtkhzB+Pf7O6KBYjHoCnBBkfNVzsfZQ/1hnR
    0UzimfAc7Ze+UNwhXJhinFRJ3YuR+xiOTpPkl1GXPhLgFSQhekz4KepcbQEQKejb
    jg0dum1oBYIXZTSSbiO9rNmfUVLB5DcV0vZbSrGxLjWLBt5U8N2xf2d1bvkQW+bw
    Kklf9OG26bAi27tujurzN3r3AgMBAAGjIzAhMA4GA1UdDwEB/wQEAwICpDAPBgNV
    HRMBAf8EBTADAQH/MA0GCSqGSIb3DQEBCwUAA4IBAQAM0CN3n5C/KOT4uZ4ewwKK
    rHmANBPVM9u6MJBO8U62HcqLeoCuDFeU8zmUjLHjsQaPX64mJZlR7T5y52gEKO5A
    0qsBz3pg/vJ5DJTv0698+1Q1hB9k3smQdksAim19FZqysB7J4zK/+8aJ/q2kIFvs
    Jk3ekwQdQ3xfggklBQVuf76gr1v0uYlPtfPffPlfcGZ06Im6mqbajenXoR1PxPB0
    +zyCS8DkgPtDulplruwvXCFMYw9TPbzXKlt7tlsqRXogYLnxWJDzM1nOYCnD+rDm
    qxenV9Ir8RqZ0XSYuUyzRka5N4dhIhrzTAiNdeU5gzynXOz67u/Iefz1iK9ZcdE3
    -----END CERTIFICATE-----
```

4.8.2.4 Configurable Parameters

To enable MTLS, make changes to the following parameters.

Key	Value	Details
spec.fep.usePodName	True	For MTLS, this key must be defined and set to true. For TLS connection without MTLS, it can be omitted. However, it is recommended to set this to true as well.
spec.fep.patroni.tls.certificateName	<secret-name>	Name of Kubernetes secret that contains the certificate in tls.crt and private key in tls.key for Patroni REST API. For MTLS Patroni REST API communication, this key must be defined. The private key cannot be password protected. When using cert-manager, the secret also contains the CA bundle in ca.crt.
spec.fep.patroni.tls.caName	<configmap-name>	Name of Kubernetes configmap that contains the CA bundle. If using cert-manager, the ca.crt is already included in the secret above. In this situation, this key can be omitted.
spec.fep.postgres.tls.certificateName	<secret-name>	Name of Kubernetes secret that contains the certificate in tls.crt and private key in tls.key for Postgres server. For MTLS Postgres communication, this key must be defined. The private key can be password protected. When using cert-manager, the secret also contains the CA bundle in ca.crt.
spec.fep.postgres.tls.caName	<configmap-name>	Name of Kubernetes configmap that contains the CA bundle. If using cert-manager, the ca.crt is already included in the secret above. In this situation, this key can be omitted.
spec.fep.postgres.tls.privateKeyPassword	<secret-name>	Name of Kubernetes secret that contains the password for the private key for Postgres Server.
spec.fepChildCrVal.sysUsers.pgAdminTls.certificateName	<secret-name>	Name of Kubernetes secret that contains the certificate in tls.crt and private key in tls.key for "postgres" user. For MTLS Postgres communication, this key must be defined. The private key cannot be password protected. When using cert-manager, the secret also contains the CA bundle in ca.crt.
spec.fepChildCrVal.sysUsers.pgAdminTls.caName	<configmap-name>	Name of Kubernetes configmap that contains the CA bundle. If using cert-manager, the ca.crt is already included in the secret

Key	Value	Details
		above. In this situation, this key can be omitted.
spec.fepChildCrVal.sysUsers.pgAdminTls.sslMode	verify-full	For MTLS, this value must be set to verify-full. If only TLS is required, this can be set to verify-ca or prefer.
spec.fepChildCrVal.sysUsers.pgrepluserTls.certificateName	<secret-name>	Name of Kubernetes secret that contains the certificate in tls.crt and private key in tls.key for "repluser" user. For MTLS Postgres communication, this key must be defined. The private key cannot be password protected. When using cert-manager, the secret also contains the CA bundle in ca.crt.
spec.fepChildCrVal.sysUsers.pgrepluserTls.caName	<configmap-name>	Name of Kubernetes configmap that contains the CA bundle. If using cert-manager, the ca.crt is already included in the secret above. In this situation, this key can be omitted.
spec.fepChildCrVal.sysUsers.pgrepluserTls.sslMode	verify-full	For MTLS, this value must be set to verify-full. If only TLS is required, this can be set to verify-ca or prefer.
spec.fepChildCrVal.sysUsers.pgRewindUserTls.certificateName	<secret-name>	Name of Kubernetes secret that contains the certificate in tls.crt and private key in tls.key for "rewinduser" user. For MTLS Postgres communication, this key must be defined. The private key cannot be password protected. When using cert-manager, the secret also contains the CA bundle in ca.crt.
spec.fepChildCrVal.sysUsers.pgRewindUserTls.caName	<configmap-name>	Name of Kubernetes configmap that contains the CA bundle. If using cert-manager, the ca.crt is already included in the secret above. In this situation, this key can be omitted.
spec.fepChildCrVal.sysUsers.pgRewindUserTls.sslMode	verify-full	For MTLS, this value must be set to verify-full. If only TLS is required, this can be set to verify-ca or prefer.

It is also required to customize pg_hba.conf to perform MTLS. Below are two possible settings.

spec.fep.customPgHba	hostssl all all 0.0.0.0/0 cert hostssl replication all 0.0.0.0/0 cert

The above setting will force FEP server to perform certification authentication. At the same time verify the authenticity of client certificate.

spec.fep.customPgHba	hostssl all all 0.0.0.0/0 md5 clientcert=verify-full hostssl replication repluser 0.0.0.0/0 md5 clientcert=verify-full

The above setting will foce FEP server to perform md5 authentication as well as verifying the authenticity of client certificate.

4.9 Replication Slots

4.9.1 Setting Up Logical Replication using MTLS

This section describes setup of logical replication.

To setup logical replication using MTLS, follow these steps:

1. Create two FEPClusters - to act as Publisher and Subscriber) and ensure that they can communicate with each other. You can see the creation of FEPCluster in the "4.1 Deploying FEPCluster using Operator".
2. To setup Publisher, make following changes to the FEPCluster yaml of the cluster that you want to use as publisher:
   a. Add section replicationSlots under spec.fep to create replication slots.

      The "**database**" should be the name of the database for which we are setting up logical replication.

   b. Add section postgres under spec.fep as shown below.

      caName = enter the name of configmap created for the CA

      certificateName = secret created by the end user that contains server certificate

c. Change the value of wal_level parameter under spec.fepChildCrVal.customPgParams from replica to logical.

```
301
302     archive_mode = on
303
304     archive_command = 'pgbackrest --stanza=backupstanza
305     --config=/database/userdata/pgbackrest.conf archive-push %p'
306
307     wal_level = logical
308
309     max_wal_senders = 12
310
311     wal_keep_size = 401
```

d. Add entry under spec.fepChildCrVal.customPgHba as shown below.

This requires the client to present a certificate and only certificate authentication is allowed.

Replace "SubClusterName" and "SubNamespace" with the appropriate values as per the Subscriber FEPCluster.

```
  [rule]
customPgHba: |
  # define pg_hba custom rules here to be merged with default rules.
  # TYPE      DATABASE        USER        ADDRESS         METHOD
  hostssl all all .<SubClusterName>-primary-svc.<SubNamespace>.svc.cluster.local cert
customPgParams: >
```

3. To setup Subscriber, make following changes to the FEPCluster yaml of the cluster that you want to use as subscriber:

a. Add customCertificates under spec.fepChildCrVal as shown below.

caName = enter the name of configmap created for the CA (i.e. The CA certificate which is used to sign/authenticate the server/ client certificates is mounted as a configMap called 'cacert')

certificateName = secret created by end user that contains a client certificate which can be verified by the server

username = name of the role created on publisher cluster for logical replication

```
74    fepChildCrVal:
75      customCertificates:
76        - caName: cacert
77          certificateName: my-logicalrepl-cert
78          userName: logicalrepluser
79      customPgAudit: |
80        # define pg audit custom params here to override defaults.
81        # if log volume is not defined, log_directory should be
```

4. Connect to the pod terminal of the Publisher FEPCluster and then connect to the postgres database as shown below.

```
sh-4.4$ psql -h /tmp -p 27500 -U postgres
Password for user postgres:
psql (13.1)
Type "help" for help.

postgres=#
```

5. Next, on the publisher side, connect to the database that contains the tables you want to replicate and create a role e.g., logicalrepluser and give the required permissions to this role.

   Consider the below image as example only, the privileges to grant may differ as per the requirements.

```
db1=# CREATE ROLE logicalrepluser WITH REPLICATION LOGIN PASSWORD 'my_password';
CREATE ROLE
db1=# GRANT ALL PRIVILEGES ON DATABASE db1 TO logicalrepluser;
GRANT
db1=# GRANT ALL PRIVILEGES ON ALL TABLES IN SCHEMA public TO logicalrepluser;
GRANT
db1=#
```

6. At the Publisher side, create a publication and alter the publication to add the tables that need to be replicated.

```
db1=# create publication my_publication;
CREATE PUBLICATION
db1=# alter publication my_publication add table my_table;
ALTER PUBLICATION
db1=#
```

7. At the subscriber side, the custom certificates added in the above step 3.a will be mounted at the path /tmp/custom_certs/ as shown:

```
sh-4.4$ ls -rlt /tmp/custom_certs
total 0
drwxr-xr-t. 3 1001190000 root 103 Aug 10 10:08 logicalrepluser
sh-4.4$ ls -rlt /tmp/custom_certs/logicalrepluser
total 0
lrwxrwxrwx. 1 1001190000 root 14 Aug 10 10:08 tls.key -> ..data/tls.key
lrwxrwxrwx. 1 1001190000 root 14 Aug 10 10:08 tls.crt -> ..data/tls.crt
lrwxrwxrwx. 1 1001190000 root 13 Aug 10 10:08 ca.crt -> ..data/ca.crt
sh-4.4$
```

8. The structure of the table to be replicated should be present in the subscriber cluster since logical replication only replicates the data and not the table structure.

   Create a subscription as shown below:

```
db1=# CREATE SUBSCRIPTION my_subscription CONNECTION 'host=fepcluster-publisher-primary-svc.ns-a.svc.cluster.local port=27500 sslcert=/tmp/custom_certs/logicalrepluser/tls.crt sslkey=/tmp/custom_certs/logicalrepluser/tls.key sslrootcert=/tmp/custom_certs/logicalrepluser/ca.crt sslmode=verify-full dbname=db1 user=logicalrepluser' PUBLICATION my_publication WITH (slot_name=myslot1, create_slot=false);
CREATE SUBSCRIPTION
```

   The command in the above example is :

```
CREATE SUBSCRIPTION my_subscription CONNECTION 'host=fepcluster-publisher-primary-svc.ns-
a.svc.cluster.local port=27500 sslcert=/tmp/custom_certs/logicalrepluser/tls.crt sslkey=/tmp/
custom_certs/logicalrepluser/tls.key sslrootcert=/tmp/custom_certs/logicalrepluser/ca.crt
sslmode=verify-full password=my_password user=logicalrepluser dbname=db1' PUBLICATION
my_publication WITH (slot_name=myslot1, create_slot=false);

Host = primary service of the publisher FEP Cluster
sslcert, sslkey, sslrootcert = path to certificates mounted on the Subscriber FEP Cluster
user= Role created on the Publisher side
```

```
password= password for the role
dbname= database which contains the tables to be replicated
```

Where

Host = primary service of the publisher FEP Cluster
sslcert, sslkey, sslrootcert = path to certificates mounted on the Subscriber FEP Cluster
user= Role created on the Publisher side and used to establish logical replication connection fromSubscriber to Publisher
dbname= database which contains the tables to be replicated

4.10 FEP Logging

FEPCluster generates log files and auditlog files, if configured, over the lifetime of execuation. These log files can be useful for understanding cluster healthness and debugging purpose. By default, the log files are stored on persistent volume of the container. User can enable log monitoring feature by forwarding those log files and auditlog files to a analytics platform such as Elasticsearch.

There are two steps to enable monitoring and forwarding.

1. FEPLogging Configuration - Creating FEP Logging instance
2. FEPCluster configuration - Enabling logging in FEPCluster

The FEP Logging instance is a standalone container running fluentd. It accepts log forwarded from FEP Clusters and aggagrate data according to log entries severity and present that to Prometheus for monitoring and alerting purpose. It can optionally be configured to forward those logs to an Elasticsearch instance for detail analysis.

The Fujitsu Enterprise Postgres operator can forward PostgreSQL logs to supported destinations via Fluent-Bit. For more flexibility in choosing where to forward your logs, refer to "4.10.2 Configuring FEPCluster Remote Logging".

When logging is enabled on FEPCluster, a sidecar, containing fluentbit, will be deployed alongside the FEP server container. This fluentbit sidecar will monitor the FEP server log files and auditlog files on persistent volume and forward to the FEP Logging instance.

Multiple FEPClusters can forward logs to single FEPLogging instance.

User can have two types of connection between FEPCluster & FEPLogging

- Insecure connection: Without TLS/MTLS certificates
- Secure connection: With TLS/MTLS certificates

For the secure connections between the components, User have two options:

- User can use their own certificates
- User can generate self signed certificates (refre to "4.8.2.2 Automatic Certificate Management")

The FEP Logging instance can run standalone without additional component. For detail log analysis, the user can configure the FEP Logging instance to forward logs to Elastic Stack or Elastic Cloud.

See

For information on deploying the Elastic Stack or signing up for Elastic Cloud, refer to the Elastic Docs published at the following link.

https://www.elastic.co/guide/index.html

4.10.1 FEPLogging Configuration

This section describes how to deploy and configure FEP Logging instance via the FEPLogging custom resource. FEPLogging is a separate CR which will accept logs sent from FEPCluster and forwards them to Elasticsearch or Prometheus for raising alarm. User must create FEPLogging CR before enabling FEPCluster logging feature.

4.10.1.1 FEPLogging Custom Resources - spec

The fepLogging section needs to be added under spec to define required parameters for FEPLogging configuration.

Following is a sample template :

```
spec:
  fepLogging:
    elastic:
      authSecret:
        secretName: elastic-auth
        passwordKey: password
        userKey: username
      host: elastic-passthrough.apps.openshift.com
      logstashPrefix: postgres
      port: 443
      scheme: https
      sslVerify: true
      tls:
        certificateName: elastic-cert
        caName: elastic-cacert
    image:
      pullPolicy: IfNotPresent
    mcSpec:
      limits:
        cpu: 500m
        memory: 700Mi
      requests:
        cpu: 200m
        memory: 512Mi
    restartRequired: false
    sysExtraLogging: false
    scrapeInterval: 30s
    scrapeTimeout: 30s
    tls:
      certificateName: fluentd-cert
      caName: cacert
  prometheus:
    …
```

Below is the list of all parameters defined in the fepLogging section, along with their brief description

Custom Resource spec	Required/ Optional	Change Effect	Updating value allowed
spec.fepLogging.image.image	Optional	Fluentd Image of FEPLogging	Yes
spec.fepLogging.image.pullPolicy	Required	Fluentd Image pull policy of FEPLogging	Yes
spec.fepLogging.mcSpec.limits.cpu	Required	Max CPU allocated to fluentd container	Yes
spec.fepLogging.mcSpec.limits.memory	Required	Max memory allocated to fluentd container	Yes
spec.fepLogging.mcSpec.requests.cpu	Required	CPU allocation at start for fluentd container	Yes
spec.fepLogging.mcSpec.requests.memory	Required	Memory allocation at start for fluentd container	Yes
spec.fepLogging.sysExtraLogging	Required	To turn on extra debugging messages for operator, set value to true. It can be turned on/off at any time	Yes
spec.fepLogging.restartRequired	Required	To restart FEPLogging instance for applying any new configuration for example after certificate rotation	Yes
spec.fepLogging.scrapeInterval	Optional	Scrape interval for Prometheus to fetch metrics from FEPLogging instance	Yes

Custom Resource spec	Required/ Optional	Change Effect	Updating value allowed
spec.fepLogging.scrapeTimeout	Optional	Scrape Timeout for Prometheus to fetch metrics from FEPLogging instance	Yes
spec.fepLogging.elastic.host	Optional	Target Elasticsearch host name	Yes
spec.fepLogging.elastic.port	Optional	Target Elasticsearch port number	Yes
spec.fepLogging.elastic.authSecret.secretName	Optional	Secret name which contains Elasticsearch authentication username & password	Yes
spec.fepLogging.elastic.authSecret.userKey	Optional	Username key specified in Elasticsearch authentication secret	Yes
spec.fepLogging.elastic.authSecret.passwordKey	Optional	Password key specified in Elasticsearch authentication secret	Yes
spec.fepLogging.elastic.logstashPrefix	Optional	Logstash prefix to differentiate index pattern in elastic search. Default value is postgres	Yes
spec.fepLogging.elastic.auditLogstashPrefix	Optional	Logstash prefix to differentiate index pattern in elastic search for auditlog. If not specified, it will default to the same value as ‘logstashPrefix’.	Yes
spec.fepLogging.elastic.scheme	Optional	Connection scheme between FEPLogging & Elasticsearch. Possible options http & https	Yes
spec.fepLogging.elastic.sslVerify	Optional	Set to true if you want to verify ssl certificate. If set to false then will not consider TLS crtificate	Yes
spec.fepLogging.elastic.tls.certificateName	Optional	Kubernetes secret name which holds fluentd certificate	Yes
spec.fepLogging.elastic.tls.caName	Optional	Kubernetes configmap which holds cacert of Elasticsearch to verify Elasticsearch TLS connection	Yes
spec.fepLogging.tls.certificateName	Optional	Kubernetes secret name which holds Fluentd certificate	Yes
spec.fepLogging.tls.caName	Optional	Kubernetes configmap which holds cacert of Fluentd to configure MTLS between FEPLogging & Prometheus	Yes
spec.prometheus.tls.certificateName	Optional	Kubernetes secret name which holds Prometheus certificate	Yes
spec.prometheus.tls.caName	Optional	Kubernetes configmap which holds cacert of Fluentd to configure MTLS between FEPLogging & Prometheus	Yes

4.10.1.1.1 Define fepLogging image

The image property is used to specify other than default Fluentd image and it’s pullPolicy from FEPLogging CR.

If not specified it will use default image provided by Operator.

Example)

```
spec:
  fepLogging:
    image:
      image: 'quay.io/fujitsu/fujitsu-enterprise-postgres-fluentbit:ubi9-18-1.0'
      pullPolicy: IfNotPresent
```

4.10.1.1.2 Define fepLogging mcSpec

FEPLogging container Memory & CPU configuration can be provided by mcSpec properties.

Example)

```
spec:
  fepLogging:
    mcSpec:
      limits:
        cpu: 500m
        memory: 700Mi
      requests:
        cpu: 200m
        memory: 512Mi
```

4.10.1.1.3 Define fepLogging restartRequired

If FEPLogging required to be restarted to apply any new change, for example, after certificate rotation, FEPLogging container can be restarted by setting restartRequired flag as true. Default value of this flag is False. This flag will change back to false once the pod is restarted

Example)

```
spec:
  fepLogging:
    restartRequired: true
```

4.10.1.1.4 Define fepLogging scrapeInterval and scrapeTimeout

scrapeInterval and scrapeTimeout properties of FEPLogging are optional. These properties are used by Prometheus Servicemonitor to configure metrics fetching interval(scrapeInterval) and timeout of request.

Example)

```
spec:
  fepLogging:
    scrapeInterval: 30s
    scrapeTimeout: 30s
```

4.10.1.1.5 Define fepLogging elastic

To forward logs from FEPLogging(Fluentd) to Elasticsearch, need to configure elastic property. This is optional property. Elasticsearch server and certificates will be configured by user.

To configure log forwarding to Elasticsearch, the following properties are required.

- authSecret
- host
- port
- logstashPrefix
- auditLogstashPrefix
- scheme
- sslVerify
- tls(if sslVerify set to true)

Configure Elasticsearch server and use it's host name and port.

Here tls property is optional and works with sslVerify flag. To enable secure connection and tls verification set sslVerify true and provide valid certificateName & caName.

Elasticsearch caName is mandatory which holds CA cert of elastic search server.

Example)

```
  spec:
    fepLogging:
      elastic:
        authSecret:
          passwordKey: password
          secretName: elastic-auth
          userKey: username
        host: elastic-passthrough.apps.openshift.com
        logstashPrefix: postgres
        auditLogstashPrefix: postgres
        port: 443
        scheme: https
        sslVerify: false
        tls:
          certificateName: fluentd-cert
          caName: elastic-cacert
```

4.10.1.1.6 Define authSecret for elastic

authSecret is the secret which contains username & password in base64 format for elastic search authentication

Example)

```
kind: Secret
apiVersion: v1
metadata:
  name: elastic-auth
  namespace: my-namespace
data:
  password: OFBobzlyRUJWOGg1Mk0xcXdaMUQ5bzQ0
  username: ZWxhc3RpYw==
type: Opaque
```

4.10.1.1.7 Define fepLogging TLS

FEPLogging has optional TLS property. If user wants to forward logs from FEPCluster to FEPLogging instance over a secure connection, the TLS configuration for FEPCluster(remoteLogging section) and the TLS configuration for FEPLogging and Prometheus are mandatory. Configuring TLS configuration on just fepLogging or Prometheus will not work.

When a self signed certificate is used, caName can be skipped.

Example)

```
spec:
    fepLogging:
      tls:
        certificateName: fluentd-cert
        caName: cacert
```

4.10.1.1.8 Define Prometheus TLS

If secured connection between FEPLogging and FEPCluster is required, then TLS configuration for FEPLogging and Prometheus are mandatory. Configuring TLS on just fepLogging or Prometheus will not work.

When a self signed certificate is used, caName can be skipped.

Example)

```
spec:
  fepLogging:
   …
  prometheus:
     tls:
       certificateName: prometheus-cert
       caName: cacert
```

4.10.2 Configuring FEPCluster Remote Logging

This section describes how to enable logging in FEPCluster. FEP cluster provides a feature to forward logs to remote Fluentd(FEPLogging) and FEPLogging instance will forward the same logs to Elasticsearch(Optional) & Prometheus.

The following destinations can be used with remote logging:

- Fluentd
- Elasticsearch
- Azure BLOB
- Amazon CloudWatch

For more information about log forwarding with the remote logging feature, refer to "Appendix E Fluent Bit Integration Using Custom Secret".

4.10.2.1 FEP Custom Resources - spec.fep.remoteLogging

The remoteLogging section needs to be added under fep to define required parameters for remoteLogging configuration.

Following is a sample template:

```
spec:
  fep
    …
   remoteLogging:
      enable: true
      fluentdName: new-fep-logging
      tls:
        certificateName: fluentbit-cert
        caName: cacert
    …
```

Below is the list of all parameters defined in the remoteLogging section, along with their brief description:

Custom Resource spec	Required/ Optional	Change Effect	Updating value allowed
remoteLogging.enable	Required	The 'enable' is set to true for enabling Logging feature	No
remoteLogging.fluentdName	Optional	The 'fluentdName' is the name of the FEPLogging CR where logs will be forwarded Specify this when transferring logs using the FEP log feature	Yes
remoteLogging.tls.certificateName	Optional	Secret name which contains MTLS certs of fluentbit	No
remoteLogging.tls.caName	Optional	Cacert of Fluentd for ssl verification	No

Custom Resource spec	Required/ Optional	Change Effect	Updating value allowed
remoteLogging.image	Optional	Fluentbit image for remoteLogging	Yes
remoteLogging.pullPolicy	Optional	Fluentbit image pull policy	Yes
remoteLogging.mcSpec.limits.cpu	Optional	CPU allocation limit for fluentbit	Yes
remoteLogging.mcSpec.limits.memory	Optional	Memory allocation limit for fluentbit	Yes
remoteLogging.mcSpec.requests.cpu	Optional	CPU allocation request for fluentbit	Yes
remoteLogging.mcSpec.requests.memory	Optional	Memory allocation request for fluentbit	Yes
remoteLogging.fluentbitParams.memBufLimit	Optional	Defines the Mem_Buf_Limit in Fluentbit. This will affect all sections that use this parameter	Yes
remoteLogging.fluentbitConfigSecretRef	Optional	Specify the name of the Secret that contains fluent-bit.yaml when using the log forwarding feature with remote logging. If fluentbitConfigSecretRef is not defined or is defined but the referenced secret does not exist, the FEP operator creates a default Secret <fep-cluster>-fluent-bit-conf and updates this parameter with <fep-cluster>-fluent-bit-conf. If the referenced secret exists, the named secret is mounted to fep-logging-fluent-bit under /fluent-bit/etc.	Yes
remoteLogging.awsCredentialSecretRef	Optional	The 'awsCredentialSecretRef' is the name of a Secret that contains credentials to the AWS service. The credentials are stored in a configuration file and a credentials file. The configuration file must be named "config" and the credentials file must be named "credentials". If the referenced secret exists, the named secret will be mounted to fep-logging-fluent-bit under /fluent-bit/aws.	Yes

4.10.2.1.1 Define remoteLogging enable and fluentdName

Specify this if you want to forward logs to a Fluentd container created by the FEP logging feature.

The enable flag is used to describe that FEPCluster will enable logging feature if set as true.

If enable flag set as true then fluentdName is the mandatory field. It will describe the FEPLogging CR name to which FEPCluster will forwards the logs.

If the enable flag is set as false, the FEPCluster will not enable logging feature.

Example)

```
fep:
  remoteLogging:
    enable: true
    fluentdName: new-fep-logging
```

If user wants to update existing FEPCluster with logging feature then FEPCluster log_destination configuration must be set as **csvlogs.** For new cluster it will be already set.

Example)

```
  fep:
    …
   remoteLogging:
      enable: true
      fluentdName: new-fep-logging
    …

fepChildCrVal:
   customPgParams:
      …
     log_destination = csvlog
      …
```

4.10.2.1.2 Define remoteLogging tls

When FEPCluster uses secure connection for remoteLogging, then TLS section is mandatory.

In the TLS section, provide the secret name that contains certificate and private key that is used for ssl verification.

For MTLS connection caName is required to mutually validate certificate.

Example)

```
  fep:
    remoteLogging:
      enable: true
      fluentdName: new-fep-logging
      tls:
        certificateName: fluentbit-cert-secret
        caName: ca-cert
```

Note

The Elasticsearch server is configured by user and it is NOT part of FEPLogging deployment by operator.

4.10.2.1.3 Define remoteLogging image

The image property is used to specify other than default Fluentbit image and it's pullPolicy.

If not specified it will use default image provided by Operator.

Example)

```
spec:
  fep:
    remoteLogging:
      image: 'quay.io/fujitsu/fujitsu-enterprise-postgres-fluentbit:ubi9-18-1.0'
      pullPolicy: IfNotPresent
```

4.10.2.1.4 Define remoteLogging fluentbitConfigSecretRef

Specify this if you want to use the log forwarding function via the remote logging feature. 'fluentbitConfigSecretRef' is the name of the secret that contains fluentbit.yaml. Refer to "Appendix E Fluent Bit Integration Using Custom Secret".

If not specified, the default secret created by the operator, <fep-cluster>-fluent-bit-conf, is used.

Example)

```
spec:
  fep:
```

```
    remoteLogging:
      fluentbitConfigSecretRef: ' custom-secret'
```

4.10.2.1.5 Define remoteLogging awsCredentialSecretRef

'awsCredentialSecretRef' is the name of the secret that contains the credentials to the AWS service.

Example)

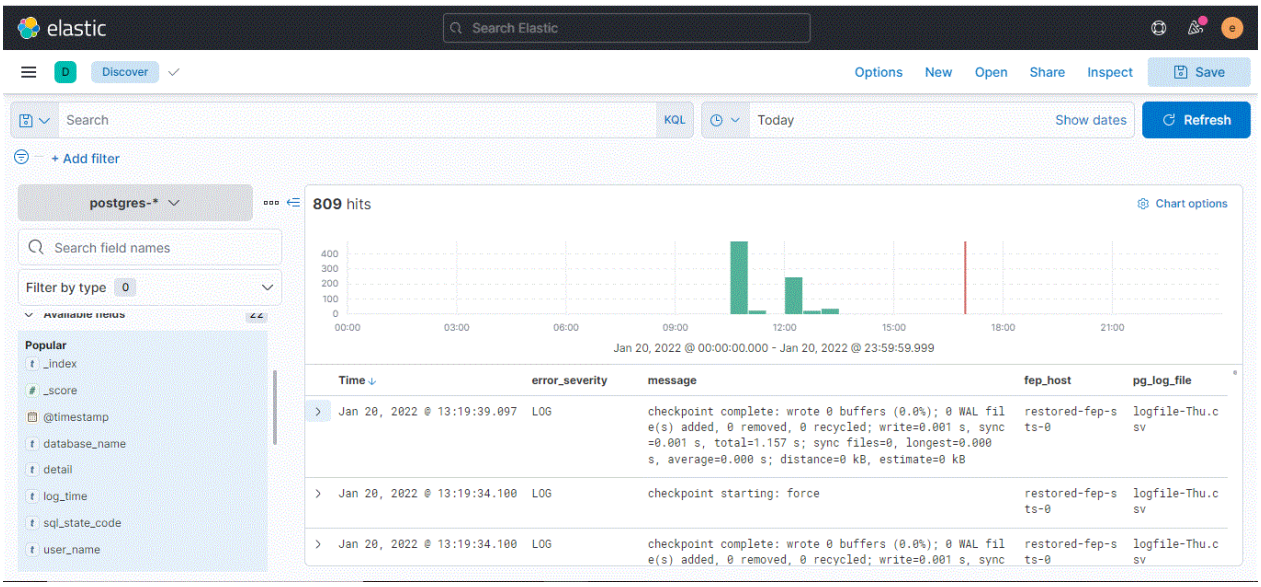
```
spec:
  fep:
    remoteLogging:
      awsCredentialSecretRef: 'aws-credential'
```

4.10.3 FEPLogging Operations

4.10.3.1 Log Forwarding to Elasticsearch

If the user has provided Elasticsearch configuration in the FEPLogging CR, and FEPCluster is configured to send server log files and auditlog files to that FEPLogging instance, those logs will be visible on Elasticsearch stack or Elastic Cloud. Assuming Elasticsearch has been configured with Kibana then logs will be visible in Kibana Dashborad. User can use fep log csv fields to create various Dashbord in Kiabana as well. LogstashPrefix and auditLogstashPrefix will be used to filter logs of specific FEPLogging instance.

User can verify if FEPLogging feature is configured properly or not by checking real time FEP logs are populating to the destination.

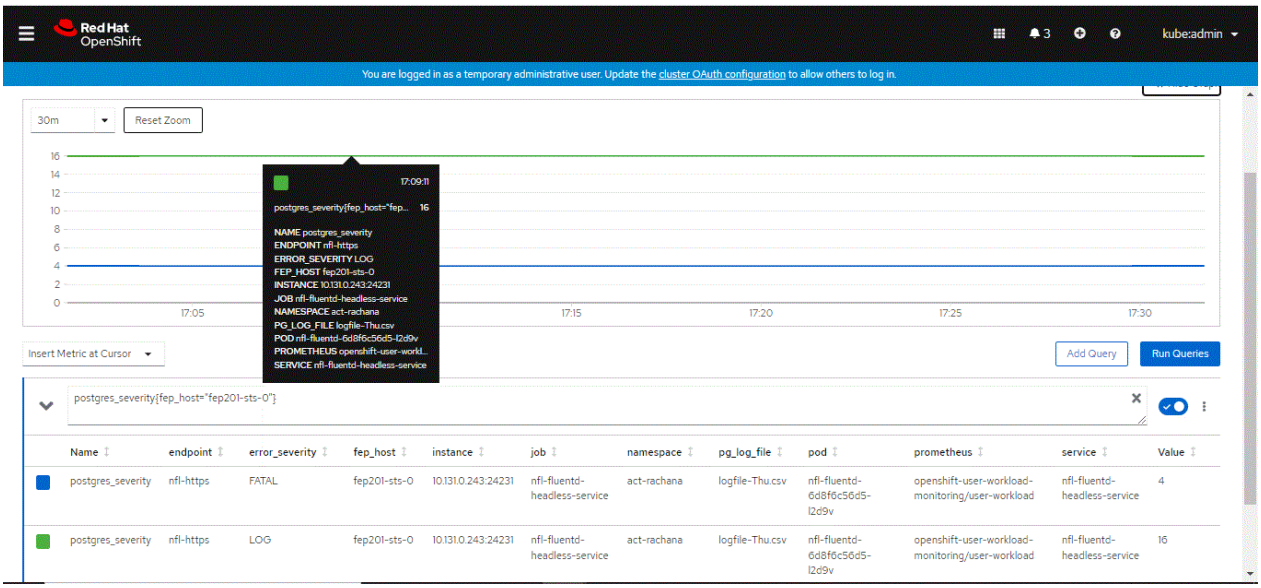


4.10.3.2 Log severity based Alarms/Metrics

FEPLogging feature is used for raising alarm/alert based on postgres severity counts as well. While user creates FEPLogging CR, Operator will forward real time counts of various postgres seviriry metrics to Openshift managed Prometheus. Openshift managed Alertmanager can access this metrics counters and user can use them to create alerts/alarms. There are 4 default alert rules already created as part of FEPLogging implementation as listed below:

- FEPLogErrorMessage
- FEPLogFatalMessage
- FEPLogPanicMessage
- FEPLogWarningMessage

Prometheus will scrape postgres_severity counter at every 30s as default scrape interval is 30s. User can modify this scrape interval from FEPLogging CR. After each scrape interval, if any change/increment found in postgres_severity counter then alert rule will be fired. User can check counts of postgres_severity metrics anytime from Prometheus dashboard as well.



4.10.3.3 Forwarding auditlog to Elasticsearch

In order to forward auditlog to Elasticsearch, update the FEPCluster to enable creating auditlog.

Example)

```
spec:
  fep:
    fepChildCrVal:
      customPgAudit: |
        [output]
        logger = 'auditlog'
        log_directory = '/database/log/audit'
      customPgParams: |
        shared_preload_libraries='...,pgaudit'
        session_preload_libraries='...,pgaudit'
```

Information

Refer to "4.12 Automating Audit Log Operations" for information on enabling audit logs. You can also enable audit logging by configuring the spec.fep.pgAuditLog.enable parameter.

4.10.4 Limitations

- Only postgres_severity including ERROR, PANIC, FATAL and WARNING are monitored.
- External fluentd can not be used for log monitoring and log forwarding.
- External Elasticsearch is required for log forwarding.
- User must decide at deployment time whether secured connection between FEPCluster and FEPLogging is required or not. After deployment, one can switch connection from insecure to secure but can not switch from secure to insecure connection.
- User must configure FEPLogging CR first then only FEPCluster can forward logs to particular FEPLogging otherwise Logging feature will not work.
- User must set log_destination in FEPCluster CR.

4.11 Configuring pgBadger

This section describes how to configure pgBadger. FEP cluster provides a feature to create pgbadger report on defined schedule and upload the report to a web server outside.

4.11.1 FEP Custom Resources - spec.fep.pgBadger

Custom Resource spec	Change Effect
pgBadger.schedules.create	The 'create' schedule to create report and upload it to endpoint
pgBadger.schedules.cleanup	The 'cleanup' schedule to delete the report left in container
pgBadger.options.incremental	Default: false; When set to True: create incremental report in pgbadger
pgBadger.endpoint.authentication	a secret to contain authentication info to access endpoint support basic auth only
pgBadger.endpoint.customCertificateName	Client certitificate reference in customCertificate CR
pgBadger.endpoint.fileUploadParameter	The file upload parameter defined by the web server Default: 'file'
pgBadger.endpoint.insecure	equivalent to curl -insecure option, default to false
pgBadger.endpoint.url	Web server url to upload the report file

4.11.2 Define pgBadger Schedules

The schedules are used to create and run a job periodically, written in Cron format.

If the schedule format is invalid, the cronjob will not be created, so no pgBadger report will be created and uploaded.

Example)

```
pgBadger:
  schedules:
    cleanup: '10 * * * *'
    create: '50 * * * *'
```

4.11.3 Define pgBadger Options

When the incremental option is set to false, pgBadger will create normal html report and upload the html file to the web server.

When the incremental option is set to true, pgBadger will create incremental report and upload a zip file to the web server.

Example)

```
pgBadger:
  options:
    incremental: true
```

4.11.4 Define Endpoint for Uploading Report

Web server url

Both http and https are supported.

Example)

```
pgBadger:
  endpoint:
    url: 'https://webserver-svc:4443/cgi-bin/upload.php'
```

Web Server authentication

Only basic auth is supported

To configure web server authentication:

Create a base64 encoded text from username:password

Example)

```
$ echo -ne "myuser:mypass" | base64

amFzb253Omphc29udw==
```

Wrap the output with base64 for creating a secret

Example)

```
$ echo -ne "amFzb253Omphc29udw==" | base64

YW1GemIyNTNPbXBoYzI5dWR3PT0=
```

Ceate a secret by using the wrapped text. The key must be 'basic_auth'.

Example)

```
kind: Secret
apiVersion: v1
metadata:
  name: pgbadger-endpoint-auth
  namespace: fep-container-ct
data:
  basic_auth: YW1GemIyNTNPbXBoYzI5dWR3PT0=
type: Opaque
```

Add the secret name in the endpoint definition.

Example)

```
    pgBadger:
      endpoint:
        authentication: pgbadger-endpoint-auth
```

Web Server certificates

When certificate files are required by the web server, FEP cluster provides customCertificate CR to mount the certificates files in container.

To use certificates for web server.

Create a secret based on the cert and key files.

Example)

```
oc create secret tls  webserver-cert --cert=webserver.pem --key=webserver.key
```

The webserver.pem and webserver.key are certificate files for accessing web server

Create a configmap based on the CA cert.

Example)

```
oc create configmap webserver-cacert --from-file=ca.crt=webca.pem
```

The webca.pem is the CA certificate file for accessing web server.

Define custom certificates in FEPCluster CR.

Example)

```
spec:
  fepChildCrVal:
    customCertificates:
      - userName: pgbadger-custom
       certificateName: webserver-cert
       caName: webserver-cacert
```

The userName is a reference in the pgBadger enpoint.

The certificateName is the secret created above.

The caName is the configmap created above.

Refer the custom certificate name in pgbadger endpoint.

Example)

```
    pgBadger:
      endpoint:
        customCertificateName: pgbadger-custom
```

Insecure access to web server

The pgbadger CR provides an option to the web server endpoint when secure connection is not required:

Example)

```
    pgBadger:
      endpoint:
        insecure: true
```

File upload parameter

This parameter specify the request parameter for uploading a file to a web server. The value of this parameter is depended on the web server implementation.

Example)

```
    pgBadger:
      endpoint:
        fileUploadParameter: uploadfile
```

curl command and parameters

FEP cluster uses curl command to upload the generated report to a web server endpoint. The CR in enpoint section will be converted to curl command parameters. The following table shows the mapping:

curl command parameter	User configuration
[URL]	Endpoint url
--cert	webserver.pem included in the secret referred in customCertificateName
--key	webserver.key included in the secret referred in customCertificateName

curl command parameter	User configuration
--cacert	webca.pem included in the configmap referred in customCertificateName
--form "uploadfile=@/path/to/report"	Endpoint fileUploadParameter
--header "Authorization: Basic passxxx"	Endpoint authentication configmap
--insecure	When endpoint.insecure is set to true

4.11.5 Uploaded File on Web Server

The FEP cluster uploads the pgbadger report according to the incremental mode:

incremental mode	Uploaded file name	Example
True	[fep cluster name]-sts-[pod index].zip	pgbadger-test3-sts-0.zip pgbadger-test3-sts-1.zip
False	[fep cluster name]-sts-[pod index].html	pgbadger-test3-sts-0.html pgbadger-test3-sts-1.html

The zip file contains a folder of pgbadger incremental report.

Example)

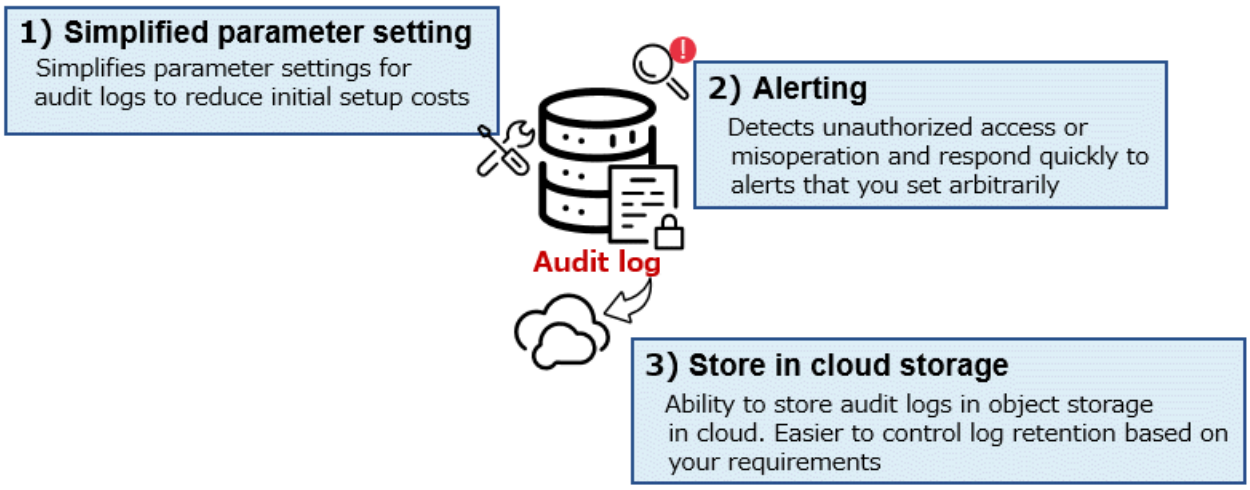
```
\database
  \log
    \pgbadger-report
      \[years]
        \[months]
        \[weeks]
```

Note

- The web server is NOT included in the FEP cluster solution.
- The web server is responsible to the uploaded files according to the customer's business logic.

4.12 Automating Audit Log Operations

Simplifies the operation of your audit logs to implement operations that meet security requirements such as audits.



4.12.1 Simplifies Parameter Setting

Simplify audit log parameter settings and reduce initial setup costs. The only setting required is enabling the enable parameter. The pgaduit module is loaded when the FEP server starts and audit logs are stored in the logs directory.

By customizing the audit log configuration file as necessary, it is also possible to make settings according to operational requirements.

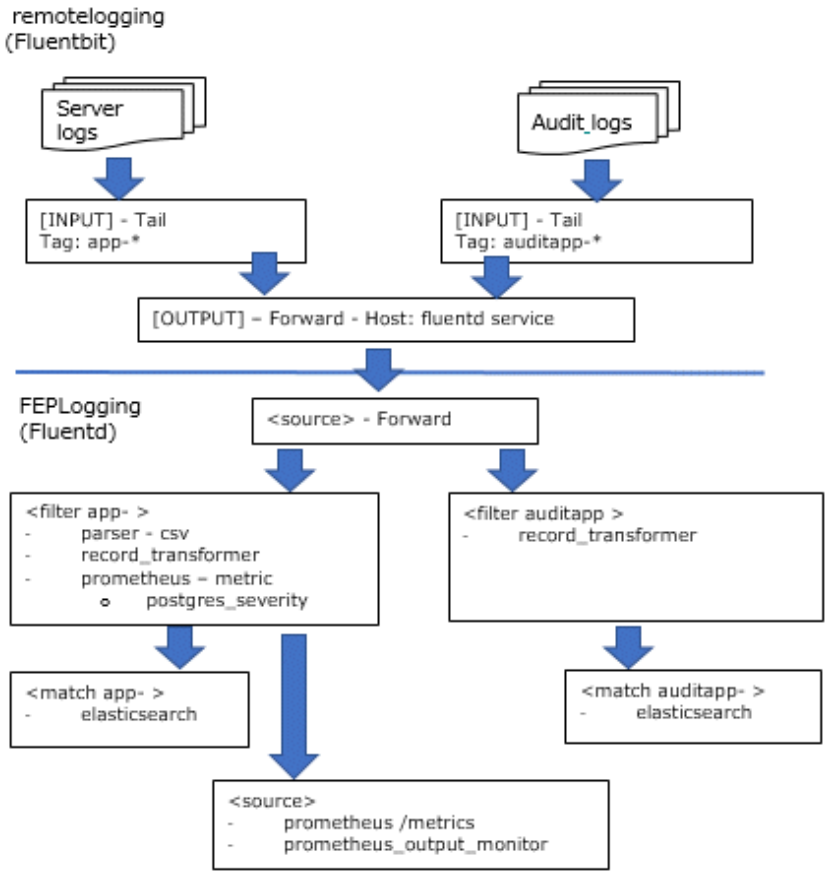
```
spec:
  fep:
    pgAuditLog:
      enable: true
```

4.12.2 Alerting

According to preset alert conditions, unauthorized access and erroneous operations can be detected at an early stage, enabling rapid response.

Audit logs are sent to Fluentd using the remotelogging function, and audit logs are monitored by setting alerts in Prometheus according to sqlstate conditions.

The alert is triggered when the 1 minute average of sqlstate(28P01) (invalid password) exceeds 50.



4.12.3 Store in Cloud Storage

Long-term retention of audit logs may be required in accordance with system or industry standard security policy requirements. However, long-term storage of logs requires the continuation of complicated operations such as disk management and rotation management.

Therefore, with this function, by saving audit logs to cloud object storage, you can easily control the saving of logs based on your requirements.

```
spec:
  fep:
    pgAuditLog:
      enable: true
      endpoint:
        protocol: s3
        url: s3://pgaudit/cluster1
        authentication: s3-secret
      schedules:
        upload: '30 * * * *'
```

4.13 Transparent Data Encryption Using a Key Management System

Describes how to configure transparent data encryption using a key management system.

Transparent data encryption using a key management system can only be configured when the FEPCluster is first created. Users cannot configure an existing FEPCluster for transparent data encryption using a key management system.

4.13.1 Registration of Authentication Information

4.13.1.1 When Using a KMIP Server

Save the certificate used for TLS communication between KMIP server in Secret or ConfigMap.

The Secret or ConfigMap you created gives the FEPCluster custom resource a resource name and mounts it in the FEP container.

Create a Secret to store the client certificate and private key for connecting to KMIP server.

Also, optionally create a ConfigMap to store the root certificate.

An example of registering credentials using the credentials file below is explained.

```
kmip.pem   # Client certificate for connecting to KMIP server
kmip.key   # Private key
myca.pem   # Root certificate
```

Create a Secret to store the client certificate and private key.

Specify tls.crt and tls.key as file names when mounting the client certificate and private key, respectively.

```
$ oc create secret generic kmip-cert --from-file=tls.crt=kmip.pem --from-file=tls.key=kmip.key -n
kmip-demo
```

Optionally create a ConfigMap to store your root certificates.

Specify ca.crt as the file name to be mounted.

```
$ oc create configmap kmip-cacert --from-file=ca.crt=myca.pem -n my-namespace
```

4.13.1.2 When Using AWS Key Management Service

Save credentials and other settings required to connect to AWS key management services in Secrets and ConfigMaps.

Prepare two files, credentials and config, which describe credentials and other settings according to the format specified by the AWS client interface. Specifying access_key_id and secret_access_key in the credentials file is mandatory.

An example of registering authentication information using the following configuration file is explained.

```
credentials   # credentials file
config         # config file
```

Create a ConfigMap to store config files. Specify config for the key name. The name of the ConfigMap is arbitrary (here aws-kms-config).

```
$ oc create configmap aws-kms-config --from-file=config=config -n my-namespace
```

Create a secret to save the credentials file. Specify credentials for the key name. The name of the Secret is arbitrary (here aws-kms-credentials).

```
$ oc create secret generic aws-kms-credentials --from-file=credentials=credentials -n my-namespace
```

 See

Refer to below for AWS client interface configuration files.

https://docs.aws.amazon.com/cli/latest/userguide/cli-configure-files.html

4.13.1.3 When using Azure Key Management Service

Save the credentials required to connect to Azure's key management service in Secret.

The available authentication methods are either authentication using passwords or authentication using client certificates.

For password-based authentication, create a YAML format file that defines a secret like the one below. The secret name is arbitrary (here azure-key-vault-passphrase). data.clientsecret contains a base64-encoded password.

```
kind: Secret
apiVersion: v1
metadata:
  name: azure-key-vault-passphrase
  namespace: my-namespace
data:
  clientsecret: XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX=
type: Opaque
```

Create a secret based on the created YAML file. Here we are using a YAML file named azure-client-secret.yaml.

```
$ kubectl apply -f azure-client-secret.yaml -n my-namespace
```

For authentication using a client certificate, store the client certificate file and private key in Secret.

Here is an example of creating a Secret using the certificate file below.

```
azuremycert.pem    # PEM file containing client certificate and private key
```

Create a secret to store the client certificate. Specify azure-key-vault.crt for the key name. The secret name is arbitrary (here azure-key-vault-secret).

```
$ oc create secret generic azure-key-vault-secret --from-file=azure-key-vault.crt=azuremycert.pem -n
my-namespace
```

4.13.2 Configuring FEPCluster Custom Resources

To enable TDE using a key management system, you need to set "spec.fepChildCrVal.customPgParams" and "spec.fepChildCrVal.sysTde".

4.13.2.1 Define spec.fepChildCrVal.customPgParams

The fepChildCrVal.customPgParams section must define the following parameters:

shared_preload_libraries

Add the 'tde_kms' library to the list of libraries in shared_preload_libraries.

Example)

```
spec:
  fep:
   …
   fepChildCrVal:
      …
     customPgParams:
       shared_preload_libraries='pgx_datamasking,pg_prewarm,pg_stat_statements,tde_kms'
```

Do not remove 'tde_kms' library from 'shared_preload_libraries' list after cluster creation.

4.13.2.2 Define spec.fepChildCrVal.sysTde

Add a sysTde section under spec.fepChildCrVal to define the parameters required to connect to your key management system. Under sysTde there are two parameters defined:

- tdeType
- tdek

Define spec.fepChildCrVal.sysTde.tdeType

sysTde itself is an optional parameter (if sysTde is not defined, use a file-based keystore). However, if sysTde is defined by the user, sysTde.tdeType must also be defined.

If configuring TDE with a key management system, set sysTde.tdeType to "tdek".

Example)

```
    sysTde:
      tdeType: tdek
```

Define spec.fepChildCrVal.sysTde.tdek.kmsDefinition

If you set sysTde.tdeType to "tdek", you must also define sysTde.tdek.

Define the connection information of the key management system in sysTde.tdek.kmsDefinition. Based on the information defined here, the operator creates the key management system connection information file used by Fujitsu Enterprise Postgres.

Information for multiple key management systems can be defined in kmsDefinition. For type, specify the type of key management system (either kmip, awskms, or azurekeyvault).

Example)

```
    sysTde:
      tdeType: tdek
      tdek:
        targetKmsName: kms_conninfo1
        kmsDefinition:
          - name: kms_conninfo1
            type: kmip
...
```

Refer to the Reference for details of each parameter.

Specify the name of the Secret or ConfigMap created in "4.13.1 Registration of Authentication Information" in the corresponding parameter under kmsDefinition. If type is awskms, profile specifies the name of the profile to use from the profile in the AWS client interface configuration file.

Example)

```
  spec:
    fep:
     ...
     fepChildCrVal:
        ...
       sysTde:
        tdeType: tdek
        tdek:
          targetKmsName: kms_conninfo1
          targetKeyId: xxxyyyzzz
          kmsDefinition:
            -  name: kms_conninfo1
               type: kmip
               address: xxx.xxx.xxx.xxx
               port: 100
               authMethod: cert
               sslpassphrase: ssl-password
               cert:
                 certificateName: kmip-cert
```

```
                caName: kmip-cacert
                sslcrlName: kmip-crl
```

Define spec.fepChildCrVal.sysTde.tdek.targetKeyId, spec.fepChildCrVal.sysTde.tdek.targetKmsName

Specify one of the key management system names defined in kmsDefinition in sysTde.tdek.targetKmsName as the name of the key management system to use as the keystore. sysTde.tdek.targetKeyId specifies the key ID of the encryption key within that key management system to use as the master encryption key.

4.14 Disaster Recovery in Hot Standby Configuration

By implementing disaster recovery in a hot standby configuration, business systems can be restored more quickly in the event of a disaster. This function has the following two methods.

Continuous recovery method

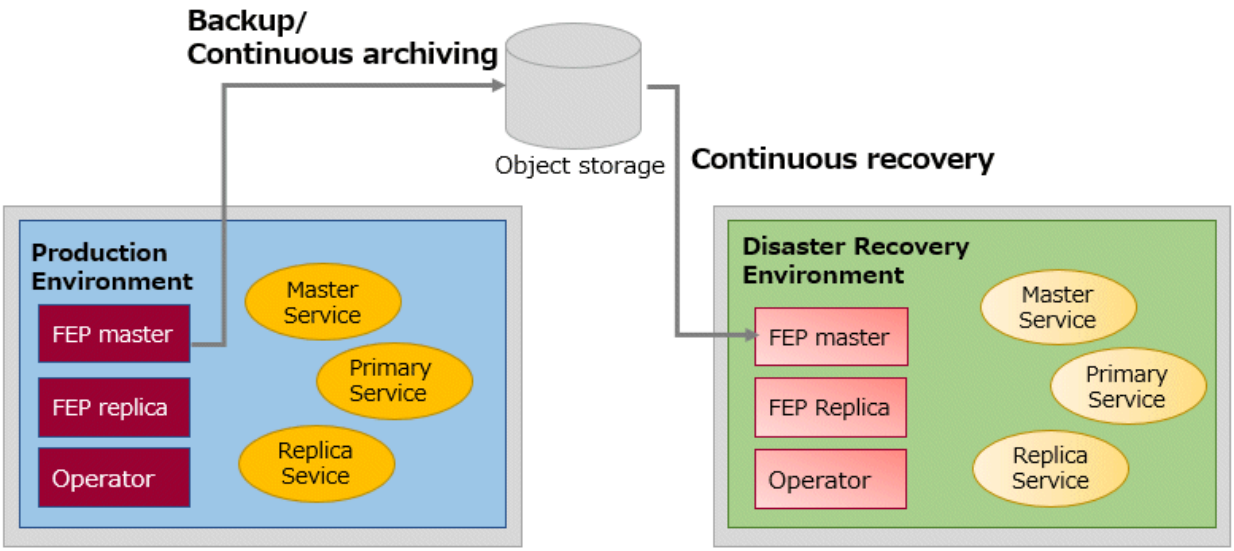
Create a container environment for production and another one for disaster recovery. Store the production environment data in object storage, and continuously restore to the disaster recovery environment. This method enables quick recovery compared to the backup/restore method, but RPO (Recovery Point Objective) increases depending on the timing of regular backups.

Streaming replication method

Similarly to the continuous recovery method, create a container environment for production and another one for disaster recovery. Use streaming replication methods to synchronize data to the disaster recovery environment. This method enables faster recovery compared to the backup/restore method, lower RPO compared to the continuous recovery method, and real-time data synchronization. However, because network settings for the streaming replication method are required, the management cost is high, and there is a slight impact on the performance of the database in the production environment.

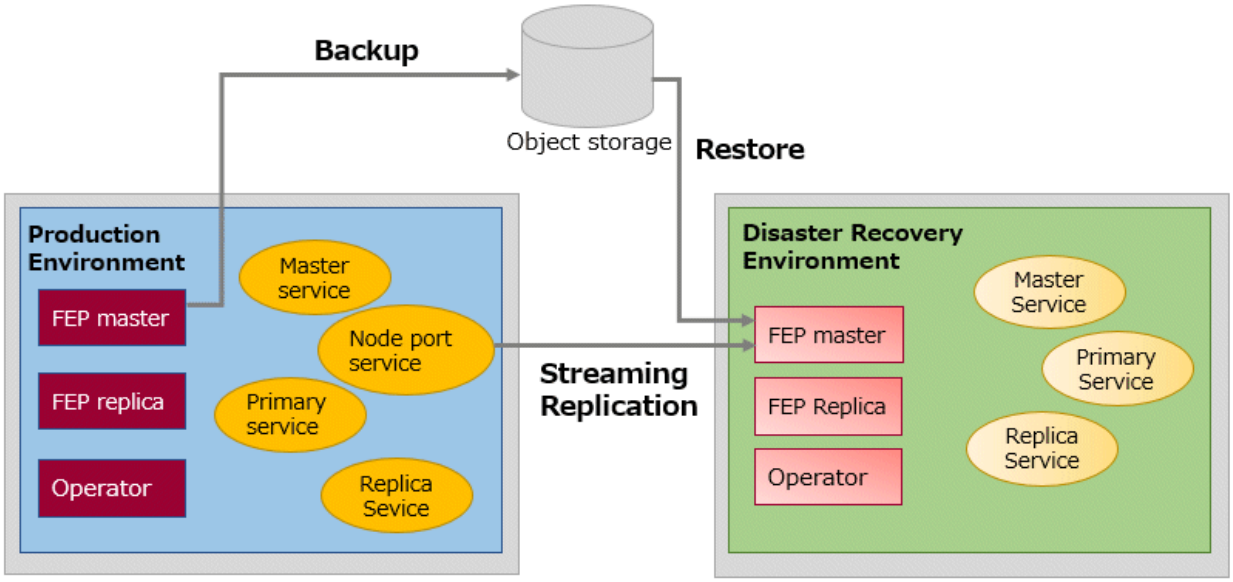
4.14.1 Continuous Recovery Method

The continuous recovery method uses object storage to synchronize production and disaster recovery environments. Specify object storage that is located in a region that you consider safe for the range of possible disasters.



4.14.2 Streaming Replication Method

The streaming replication method achieves direct data synchronization between the database in the production environment and the database in the disaster recovery environment.



4.14.3 Defining a Hot Standby Configuration

This section describes the deployment procedures for the continuous recovery method and the streaming replication method of the hot standby configuration.

4.14.3.1 Defining a Continuous Recovery Method

Custom resource definitions for FEPCluster in the production environment do not have parameters that are only used in hot standby configurations. When using the continuous recovery method, define the FEPCluster custom resource in the disaster recovery environment as follows.

```
apiVersion: fep.fujitsu.io/v2
kind: FEPCluster
metadata:
 …
spec:
  fep:
    standby:
      enable: true
      method: archive-recovery
      pgBackrestConf: |
        [global]
        log-path=/database/log/backup
        repo1-type=azure
        repo1-path=< Backup path of primary/ cluster from which data is to be restored>
        repo1-azure-account=<my storage account>
        repo1-azure-container=fepbackups
        repo1-azure-key=<my storage account key >
…
```

4.14.3.2 Defining a Streaming Replication Method

When using the streaming replication method, define as follows.

```
apiVersion: fep.fujitsu.io/v2
kind: FEPCluster
metadata:
...
spec:
  fep:
```

```
    standby:
      enable: true
      method: streaming
      streaming:
        host: <LoadBalancer IP>
        port: 27500
      pgBackrestConf: |
        [global]
        log-path=/database/log/backup
        repo1-type=azure
        repo1-path=< Backup path of primary/ cluster from which data is to be restored>
        repo1-azure-account=<my storage account>
        repo1-azure-container=fepbackups
        repo1-azure-key=<my storage account key >
...
```

For streaming replication, FEPClusterCR is defined as above, but a separate LoadBalancer must be deployed.

```
kind: Service
apiVersion: v1
metadata:
  name: my-fep-internal-svc
  namespace: sample-namespace
  annotations:
    service.beta.kubernetes.io/azure-load-balancer-internal: 'true'
spec:
  ports:
    - protocol: TCP
      port: 27500
  type: LoadBalancer
  selector:
    app: <my-fep-cluster>-sts
    feprole: master
```

4.14.3.3 Defining FEPCluster Custom Resources

The parameters of FEPClusterCR in the disaster recovery environment that are required to realize a hot standby configuration are shown below. For parameter details, refer to "FEPCluster Parameters" in the Reference.

- spec.fep.standby.enable
- spec.fep.standby.method
- spec.fep.standby.pgBackrestConf
- spec.fep.standby.streaming.host
- spec.fep.standby.streaming.port

4.15 Enabling Client Authentication with scram-sha-256 Authentication

This section describes step-by-step instructions on how to enable client authentication using scram-sha-256 authentication.

4.15.1 Enabling Client Authentication Using scram-sha-256 Authentication in the FEP Server Container

To enable scram-sha-256 authentication on a newly built FEP server container, deploy a FEPCluster custom resource with the following settings.

4.15.1.1 Define spec.fepChildCrVal.customPgParams

Specify scram-sha-256 for password_encryption.

```
password_encryption = 'scram-sha-256'
```

You must restart the database in the FEP server container for the configuration to take effect.

4.15.1.2 Define spec.fepChildCrVal.customPgHba

Add an entry to allow scram-sha-256 authentication.

To allow scram-sha-256 authentication, specify scram-sha-256 in the METHOD.

You must restart the database in the FEP server container for the configuration to take effect.

4.15.2 Enabling Client Authentication Using scram-sha-256 Authentication in the FEPpgpool2 Container

This section describes how to enable scram-sha-256 authentication on a newly built FEPpgpool2 container.

4.15.2.1 Creating the Resources Required to Enable scram-sha-256 Authentication

Create the resources required to enable scram-sha-256 authentication.

1. Create secret for encryption key

   Create an encryption key secret (pgpoolkeySecret) containing the password to use for scram-sha-256 authentication.
   The key is pgpoolkey and the value is a base64 encrypted version of the password to be used for encryption.

   ```
   apiVersion: v1
   kind: Secret
   metadata:
     name: scrampgpoolkey-secret
   type: Opaque
   data:
     pgpoolkey: cGdwb29sa2V5cGFzc3dvcmQ=
   ```

   After creating the secret, write the name of the secret you created in the FEPPgpool2 custom resource. This mounts the created secret in the FEPpgpool2 container as a file in the volume and passes the password used for encryption to the FEPpgpool2 container.

   If you use scram-sha-256 authentication and do not create a secret, the operator automatically creates the following secret based on the information in the FEPPgpool2 custom resource.

   ```
   apiVersion: v1
   kind: Secret
   metadata:
     name: "{{spec.name}}-feppgpool2-pgpoolkey"
   type: Opaque
   data:
     pgpoolkey:
   K1kxOVZxKzRrdWluT3A2UHNQMzcwcUJuOUZ2UUoxUklNMms2cktIY1NkekFOemZBYkhjZDFadG5VR3ZtTVR6Uw==
   ```

   Value is set to the value of a password randomly generated by the operator and encrypted with base64. The secret name is "{{spec.name}} -feppgpool2-pgpoolkey".

   Information

   scram-sha-256 encryption uses an encryption key. This encryption key is used by the FEPpgpool2 container to decrypt the AES-encrypted password if it was stored in the pool_passwd file. Therefore, the encryption and decryption keys must be the same.

2. Create a secret for database user information

   The user/password used for client authentication in the FEPpgpool2 container must be the same as the database user used in the database in the FEP server container.

   Create a database user information secret (userinfoSecret) in the FEPpgpool2 container to inform the database user username and password information in the FEP server container.
   The user name and password should describe the secret in the following format.

```
apiVersion: v1
kind: Secret
metadata:
  name: scramuserinfo-secret #Specify any name
type: Opaque
data:
  user1: dXNlcjFwYXNzd2Q=
  user2: dXNlcjJwYXNzd2Q=
```

   For database users that Operator creates automatically, you do not need to create a secret because Operator retrieves the database username and password information from the FEPCluster custom resource and the FEP server container.

   If you use scram-sha-256 authentication and do not create a secret, the operator automatically creates the following secret:

```
apiVersion: v1
kind: Secret
metadata:
  name: "{{spec.name}}-feppgpool2-userinfo"
type: Opaque
data:
```

   The secret name is "{{spec.name}}-feppgpool2-userinfo".

4.15.2.2 Editing FEPPgpool2 Custom Resources

To enable scram-sha-256 authentication, edit and deploy a FEPPgpool2 custom resource with the following settings:

1. Set secret information

   Specify scram for spec.clientAuthMethod in the FEPPgppol2 custom resource.

   In addition, in the secret for the encryption key (spec.scram.pgpoolkeySecret), specify the secret name that you created in step 1 of "4.15.2.1 Creating the Resources Required to Enable scram-sha-256 Authentication" Similarly, in the database user information secret (spec.scram.userinfoSecret), specify the secret name that you created in step 2 of "4.15.2.1 Creating the Resources Required to Enable scram-sha-256 Authentication".

```
spec:
  clientAuthMethod: scram
  scram:
    pgpoolkeySecret: scrampgpoolkey-secret
    userinfoSecret: scramuserinfo-secret
```

   This mounts the created secret in the FEPpgpool2 container as a file in the volume and notifies the FEPpgpool2 container of the username and password information.

2. Edit spec.customhba

   Edit the spec.customhba field in the FEPPgpool2 custom resource to add an entry for scram-sha-256 authentication.

3. Edit pgpool.conf

   You must edit the spec.customparams field in the FEPPgpool2 custom resource to edit the parameters related to the authentication settings.

```
enable_pool_hba=true
```

4.15.3 Enabling Client Authentication Using scram-sha-256 Authentication on Existing FEP Server and FEPpgpool2 Containers

This section describes how to enable client authentication using scram-sha-256 authentication on existing FEP server and FEPpgpool2 containers

For information about FEP server containers, refer to "4.15.1 Enabling Client Authentication Using scram-sha-256 Authentication in the FEP Server Container". At this time, if the database user created by the user already has a password encrypted with md5, change the password to one encrypted with scram-sha-256. Therefore, reset the password.

For information about the FEPpgpool2 container, refer to "4.15.2 Enabling Client Authentication Using scram-sha-256 Authentication in the FEPpgpool2 Container". If an existing FEPpgpool2 custom resource is deployed, delete the FEPpgpool2 custom resource. You do not need to delete the FEPpgpool2 custom resource if you want to change the contents of the secret specified in the FEPpgpool2 custom resource or the secret created automatically by the operator.

4.16 Backing Up Statistics

In case the query plan becomes unstable, you can periodically backup the statistics using pg_dbms_stats. Set spec.fep.backupStats.enable to true and set the backup to spec.fep.backupStats.scheduleN (N is an integer) in the FEPClsuter custom resource. Note that spec.fep.backupStats.enable defaults to true.

The following are the configurable items.

- Schedule
- Whether to execute the schedule
- What to back up
- Retention
- Comment

The example below is a setting to take a backup of mydb every day at 20:00, and at the same time delete the backup from 5 days ago.

Example) Definition example of FEPCluster custom resource

```
spec:
  fep:
    backupStats:
      enable: true
      schedule1:
        enable: true
        backupSchedule: "0 20 * * *"
        targetDb: mydb
        retention: 5
        comment: "mydbBackup"
```

Additionally, if there is no backup definition in spec.fep.backupStats.schedule1 when building FEPCluster for the first time, the backup definition will be defined in spec.fep.backupStats.schedule1 of the FEPCluster custom resource with the following settings by default.

Schedule: 23:30 every day

Target: All databases

Retention: Statistics backed up in that database older than 7 days will be deleted.

Comment: "FepDefaultBackup"

```
spec:
  fep:
    backupStats:
      enable: true
      schedule1:
        enable: true
        backupSchedule: "30 23 * * *"
```

```
        retention: 7
        comment: "FepDefaultBackup"
```

If you do not want to perform scheduled backups, set spec.fep.backupStats.scheduleN.enable to false. Also, if you do not want to perform all backups, set spec.fep.backupStats.enable to false.

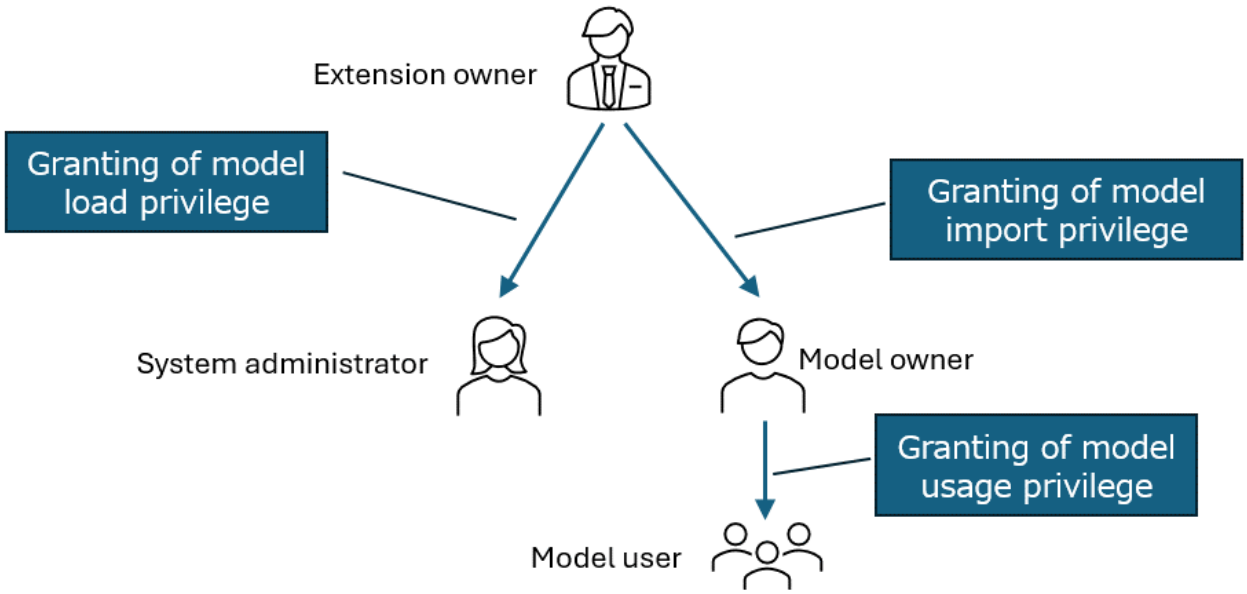
4.17 Model Management in the Database

By managing vector transformation models within the database, you can achieve model deployment (loading) integrated with database operations and granular access control. In such cases, ONNX format models can be utilized. Additionally, Triton Inference Server is used to perform vector transformations using these models.

4.17.1 New Setup

Configuring and applying the parameters for the in-database vectorization feature in the FEPCluster yaml enables this functionality. Enabling it creates users who can load, import, and execute models. The concept for each user is as follows. Additionally, an inference server pod is created and integrated with the database server.

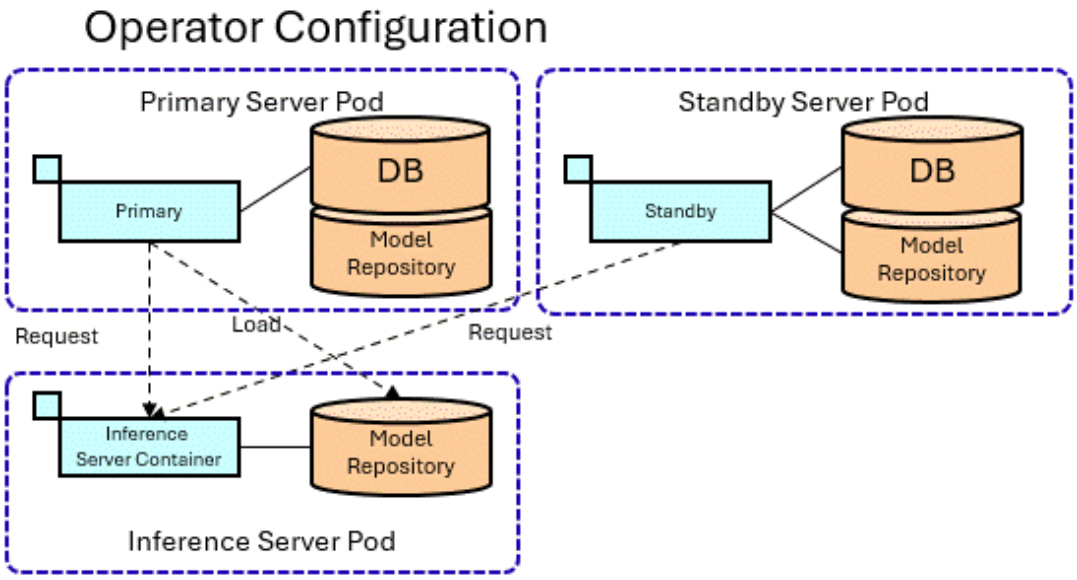
For details, refer to "Model Management in the Database" in the Fujitsu Enterprise Postgres Knowledge Data Management Feature User's Guide.



4.17.2 Creating an Inference Server Pod

4.17.2.1 Inference Server

Setting parameters in the FEPCluster yaml and applying them creates a Triton inference server. An inference server is the server that actually performs computations based on the model. Using Triton's inference server enables vector transformations utilizing the model. When creating the inference server, a service is also created to facilitate communication between the database server and the inference server. Communication with the inference server can also be encrypted using mutual TLS (mTLS).



4.17.2.2 Inference Server Pod Storage

In Operator, inference server Pods are created independently of database server Pods.

Since the inference server Pod also requires a workspace when loading model files, both the inference server Pod and the database server Pod require disk space for the model repository.

The disk to mount on the database server Pod must be defined in the spec.fepChildCrVal.storage.modelRepositoryVol parameter of the FEPCluster custom resource and prepared for each instance.

The disk to be mounted on the inference server Pod is defined in the spec.fepChildCrVal.storage.inferenceVol parameter of the FEPCluster custom resource, and one disk must be prepared.

Allocate the estimated capacity for each disk as specified in the Fujitsu Enterprise Postgres Knowledge Data Management Feature User's Guide.

4.18 Utilizing Business Data via the MCP Server

The MCP server functionality for business data utilization enables access to business data stored in Fujitsu Enterprise Postgres via the MCP (Model Context Protocol). MCP is a protocol and architecture that standardizes access to external resources and tools within Agentic AI applications.When both the application and the external tool support the MCP protocol, the external tool can be utilized without modifying the application.

This section explains how to integrate the Operator with the MCP Server.

Note: If you continue using instances created with FEP server container tags ubi9-17-2.0, ubi9-17-3.0, or ubi9-18-1.0, you must upgrade the extension version. Follow these steps:

Upgrade the Operator. Refer to "3.1.4 Upgrading Operators".

After upgrading the Operator, upgrade pgx_vectorizer, pgai, and pgvector. Refer to "6.7.2 ALTER EXTENSION" for the upgrade procedure.

For details, refer to the Fujitsu Enterprise Postgres Knowledge Data Management Feature User's Guide.

4.18.1 User Creation

To connect to the MCP server, you must create a dedicated database role for the MCP server.

4.18.2 Defining the Target Database and MCP Tool

Obtain a sample configuration file for MCP Toolbox for Databases using the following command. Two types of sample files are provided. Please use them according to your specific purpose. For details, refer to the Fujitsu Enterprise Postgres Knowledge Data Management Feature User's Guide.

Use the following command to check the name of the Operator's Pod.

```
kubectl get pods --selector=name=fep-ansible-operator -o name
pod/fep-ansible-operator-5985969857-ldj2x
kubectl cp fep-ansible-operator-5985969857-ldj2x:/opt/mcp/mcptoolbox_text2sql_tools_yaml.sample /
dir_for_mcp/mcptoolbox_text2sql_tools_yaml.sample
kubectl cp fep-ansible-operator-5985969857-ldj2x:/opt/mcp/mcptoolbox_semsearch_tools_yaml.sample /
dir_for_mcp/mcptoolbox_semsearch_tools_yaml.sample
```

4.19 Multi-master Replication

To set up multi-master replication between regions, create the following resources:

- A resource storing the postgres user credentials
- A Service resource for communication between Kubernetes clusters
- A definition file for multi-master replication
- The FEPCluster custom resource

4.19.1 Configuration

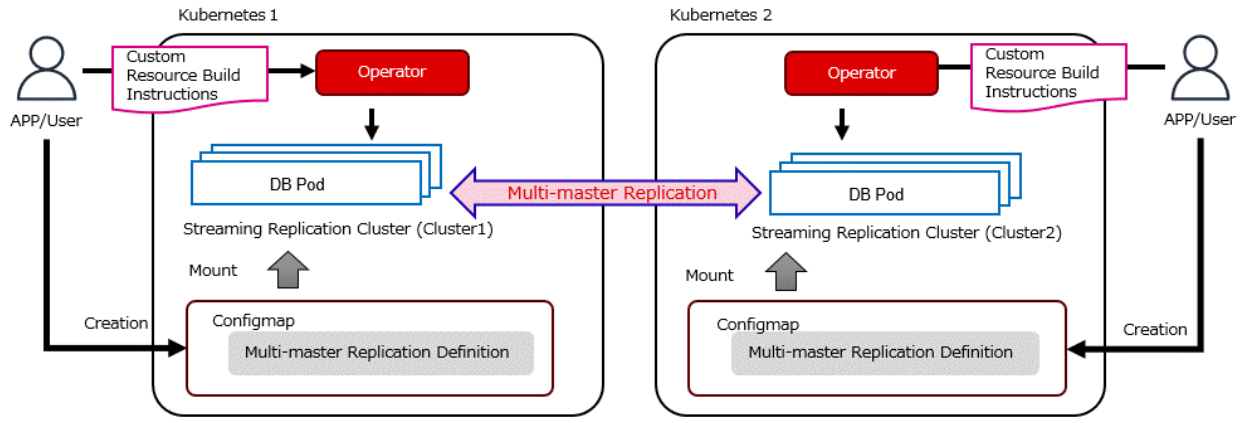
The configuration diagram for the multi-master replication setup is shown below.

It is divided into scenarios using Kubernetes resources and scenarios using CloudService, but you can choose which service to use for each specific function.

When using Kubernetes resources versus CloudService, you can choose which service to use for each specific function.

When using Kubernetes resources:

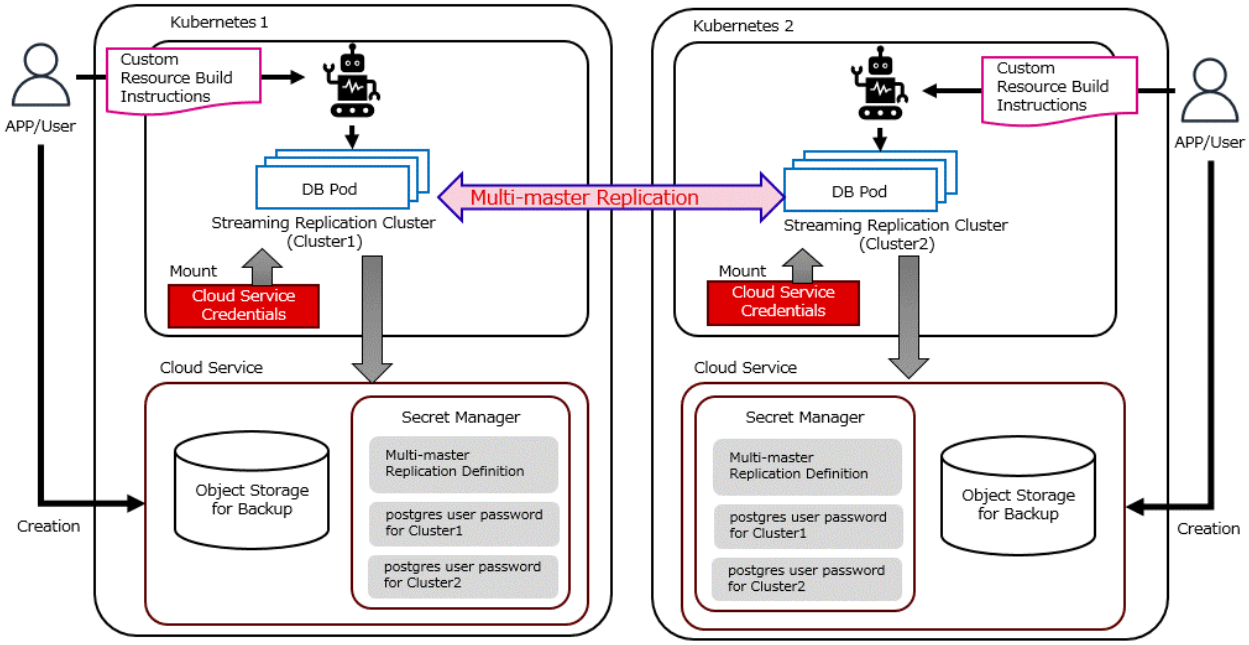
- Multi-master replication definition file: Stored in a ConfigMap resource
- Monitoring: Utilizes the GAP stack
- Backup data: Stored in a PersistentVolume resource



When using Cloud services:

- Multi-master replication definition file: Stored in Secret Manager
- postgres user password: Stored in Secret Manager

- Monitoring: Utilizes Amazon CloudWatch
- Backup data: Stored in object storage



4.19.2 Setup Procedure

4.19.2.1 Storing Credentials

In multi-master replication, superusers are used to connect to each other's databases.

Therefore, you must store the authentication credentials for the postgres user on the target FEPCluster.

Additionally, databases performing multi-master replication connect via password authentication. Protect the communication path between databases using features such as peering between cloud regions.

The postgres user password is either written directly to the FEPCluster custom resource or stored and managed in Cloud Secret Management.

Store the connection information for the postgres user of the target FEPCluster using the same method as defining the postgres user's credentials.

When storing in Kubernetes resources, the postgres user's password is defined by the FEPCluster custom resource. For the definition method, refer to "FEPCluster Parameter" in the Reference.

To share the postgres user credentials across three or more FEP Clusters, you must specify the postgres user password definition for both the replication source (fepChildCrVal.sysUsers.pgAdminPassword) and the replication destination (spec.fep.multiMasterReplication.replicationHosts[].pgAdminPassword). When using certificate authentication (mTLS), define spec.fep.multiMasterReplication.replicationHosts[] for each target cluster and specify a ConfigMap (ca.crt) containing the CA name:CA.

The CA defined here must be a root certificate that trusts the key and crt configured in sysUser.pgAdminTls for the target cluster.

When using the CSI driver, refer to the User's Guide section "4.6 Deploying FEPClusters with Cloud-based Secret Management".

Store the postgres user's password in the Secret management service.

Record the stored filename for definition in the FEPCluster custom resource.

Additionally, store the target postgres user information in the same location as the Secret management service defined in spec.fepChildCrVal.secretStore.csi. You cannot reference postgres user information from a location different from the Secret management service defined in spec.fepChildCrVal.secretStore.csi.

Therefore, store the postgres user information in the Secret management service within the region where Kubernetes is deployed. Alternatively, if the Secret management service provides cross-region replication services, use that functionality to ensure the postgres user information is accessible in each region.

4.19.2.2 Creating a Service

To establish multi-master replication between FEPClusters deployed on different Kubernetes clusters, create a Service resource to enable external connections to the database container.

Configure the Service resource to be externally accessible by selecting a type such as NodePort or LoadBalancer and assigning an ExternalIP.

Below is an example definition for a NodePort-type Service resource.

```
kind: Service
apiVersion: v1
metadata:
  name: my-fep-internal-svc
  namespace: sample-namespace # Apply the service to the namespace where the FEPCluster is deployed
spec:
  ports:
  - protocol: TCP
    port: 27500
type: NodePort
selector: # Specify the FEPCluster custom resource name for <FEPCR name>
  app: <FEPCR name>-sts
  feprole: master
```

After creating the Service resource, record the connection information for the Service (such as hostname and port) to define it as the destination for bidirectional replication in the FEPCluster custom resource.

4.19.2.3 Definition of Multi-master Replication Configuration File

Define the database to replicate using multi-master replication.

Mount this configuration file to the FEPCluster using one of the following methods:

- Apply as a ConfigMap and specify the ConfigMap name on the FEPCluster custom resource
- Store in a CSI and specify the mount point on the FEPCluster custom resource

An example of creating a ConfigMap is provided below. When storing in a CSI, place the YAML definitions under multi-master-replication-conf.yaml into the CSI.

```
kind: ConfigMap
data:
  multi-master-replication-conf.yaml: |
    - databaseName: app1
      replicationOwner: <Value matching FEPCluster's spec.fep.hostName>
      replicationName: app1
      state: create
    - databaseName: app2
      replicationOwner: <Value matching FEPCluster's spec.fep.hostName>
      replicationName: app2
      state: delete
```

Multi-master replication creates one replication per database. The following databases will never create a replication:

- postgres
- template0
- template1
- Databases defined in spec.fepChildCrVal.sysUsers.pgdb of the FEPCluster custom resource
- pgactive_supervisordb

Additionally, replication will not be created in the following cases:

- When a database name that does not exist is specified in databaseName
- When a database already replicated is specified with a different replicationName
- When the same database is specified multiple times, replication will not be created at any of the specified locations.

Furthermore, if there are elements with no databaseName specified (creating replication for all databases) and elements with a databaseName specified, the definition of the element with the databaseName specified takes precedence.

4.19.2.3.1 Multi-master Replication Definition

Specify the definition for the multi-master replication setup in data.multi-master-replication-conf.yaml using the following values.

Parameter	Default	Description
databaseName	-	Option Specify the database name to replicate. If the database to replicate does not exist, the replication group will not be created. If any of the databases specified as postgres, template1, template0, or spec.fepChildCrVal.sysUsers.pgdb are specified, no replication group will be created. If no database is specified, all databases other than those specified as postgres, template1, template0, or spec.fepChildCrVal.sysUsers.pgdb will be replicated when updating replication information. Replication is created per database.
excludeDatabase	-	Option When databaseName is not specified, you can specify databases to exclude from replication. Multiple databases can be specified in array format.
excludeTable	-	Options When databaseName is specified, this parameter designates tables to exclude from replication. Multiple tables can be specified in array format. The specified tables must already exist when executing "update_multi_master_replication" in the FEPAction custom resource, and no DML operations must have been performed on them. Tables once designated for exclusion cannot be removed from exclusion by deleting them from this parameter. To remove a table from exclusion after it has been specified, refer to the Fujitsu Enterprise Postgres Cluster Operation Guide (Multi-master Replication) for the pgx_pgactive_reset_table_replication_set() function.
replicationName	-	Option

Parameter	Default	Description
		You can specify the replication name. When omitted, the database name becomes the replication name.
state	-	Option create: Creates the specified replication. delete: Deletes the specified replication. When omitted, create a replication.
replicationOwner		Specify the hostname of the owner that creates the multi-master replication. The owner's FEP cluster creates a replication group based on the definition. FEP clusters other than the owner join the replication group.

4.19.2.4 FEPCluster Custom Resource Definition

Create or modify the FEPCluster custom resource.

When enabling multi-master replication on a pre-built FEPCluster where multi-master replication is disabled, the database Pod will restart to mount the multi-master replication definition file and the replication destination's authentication credentials.

Define the following values for the custom resource:

- Connection information for the replication destination
- Your hostname/IP address
- Location where the multi-master replication configuration file is stored

```
spec:
  fep:
    hostName: fep-cluster-1 #Enter connection information for the Service resource for external
    port: 27501
    multiMasterReplication:
      configMapName: multi-master-repl-info-cm
      replicationHosts:
        - hostName: fep-cluster-2
          port: 27502
          pgAdminPassword: multi-master-password
```

Apply the FEPCluster custom resource using the defined YAML file.

If multiMasterReplication is defined and pgactive is not defined in shared_preload_libraries under spec.fepChildCrVal.customPgParams, the Operator will automatically define it.

Chapter 5 Post-Deployment Operations

This chapter describes the operation after deploying the container.

5.1 How to Connect to a FEP Cluster

When connecting from within the same project of the OpenShift system

Service resources are used to connect to FEPCluster and FEPPgpool2 from within the same project.

A service resource provides a single endpoint for communicating with containers.

Service resources are created with the following naming conventions.

FEPCluster service

- <FEPCluster name>-primary-svc
- <FEPCluster name>-replica-svc
- <FEPCluster name>-headless-svc

FEPPGPool2 service

- <FEPPgpool2 name>-feppgpool2-svc

Example of checking service resources of FEPCluster container and FEPpgpool2 container

```
$ oc get all
```

Check where the resource type is Service (Begin with "svc/").

You can also check with the oc get svc command. The following is an example.

```
$ oc get svc
NAME                              TYPE         CLUSTER-IP      EXTERNAL-IP  PORT(S)             AGE
<FEPCluster name>-headless-svc    ClusterIP    None              <none>   27500/TCP,25001/TCP   24h
<FEPCluster name>-primary-svc     ClusterIP    xxx.xxx.xxx.xxx  <none>   27500/TCP,25001/TCP    24h
<FEPCluster name>-replica-svc     ClusterIP    yyy.yyy.yyy.yyy  <none>   27500/TCP,25001/TCP    24h
<FEPPgpool2 name>-feppgpool2-svc NodePort    zzz.zzz.zzz.zzz  <none>   9999:31707/TCP,9998:31906/TCP
24h
```

Example of accessing FEPpgpool2 container

```
$ psql -h <FEPPgpool2 name>-feppgpool2-svc  -p 9999 -c "select version();"
```

When connecting from outside the OpenShift system

Automatically creating a service with ClusterIP to connect to the deployed container. You can connect to FEP or FEP pgpool2 services from the OpenShift system's internal network. To access from outside the OpenShift system, you need to know the address of the OpenShift node.

For example, "Access the FEP pgpool2 container from an application server that is running outside the OpenShift system but is part of the Internal network".

Note

To perform this procedure, you need privileges to perform "get, list" operations on the nodes of an OpenShift or Kubernetes cluster.

An example of how to check the node IP in OpenShift.

```
$ oc get nodes
NAME                                    STATUS   ROLES    AGE    VERSION
openshiftcluster1-cmfv8-master-0        Ready    master   370d   v1.19.0+4c3480d
openshiftcluster1-cmfv8-master-1        Ready    master   370d   v1.19.0+4c3480d
openshiftcluster1-cmfv8-master-2        Ready    master   370d   v1.19.0+4c3480d
$ oc describe nodes openshiftcluster1-cmfv8-master-0 | grep IP
 InternalIP: 10.0.2.8
```

An example of verifying the service resource for the FEP pgpool2 container.

```
$ oc get all
```

Check where the resource type is Service (Begin with "svc/").

You can also see this with the oc get svc command. The following is an example.

```
$ oc get svc
NAME                       TYPE     CLUSTER-IP    EXTERNAL-IP PORT(S)                          AGE
svc-feppgpool2-feppgpool2 NodePort 172.30.248.12 <none>      9999: 30537/TCP, 9998: 30489/TCP 2m5s
```

This is an example of accessing the FEP pgpool2 container.

```
$psql -h 10.0.2.8 -p 30537 -c "show pool_nodes"
```

5.2 Configuration Change

This section describes changes to the FEPCluster configuration.

List FEPCluster

Equivalent Kubernetes command: kubectl get FEPClusters (-A)

This operation lists all FEPClusters in the namespace in the following format. Alternatively, if the -A option is specified, will list all FEPClusters in all namespace.

Field	Value	Details
NAME	.metadata.name	Name of Cluster
AGE	Elapsed time	Indicates the amount of time that has elapsed since the cluster was created

Example)

```
# kubectl get fepclusters -A

NAMESPACE       NAME            AGE
namespace1      ns1fep1         21h
namespace2      ns2fep2         22h
```

Update FEPCluster

Equivalent Kubernetes command: kubectl apply -f <new_spec>

Operations that can be performed here.

Custom Resource spec	Change effect
.spec.fep.instances: *n*	Increase the number of nodes in the cluster to *n*.
.spec.fep.image.image: 'quay.io/fujitsu/fujitsu-enterprise-postgres-18-server:ubi9-18-1.1'	Minor upgrade of FEP image to ubi9-18-1.1.
spec.fepChildCrVal.backup.image.image: 'quay.io/fujitsu/fujitsu-enterprise-postgres-18-backup:ubi9-18-1.1'	Minor upgrade of Backup image to ubi9-18-1.1.

This will impact behaviour for values in fep section only.
All parameters can be updated from the FEPCluster custom resource.

Delete FEPCluster

Equivalent Kubernetes command: kubectl delete FEPCluster <cluster_name>

This operation will remove the FEPCluster by the cluster_name and all Child CRs (FEPVolume, FEPConfig, FEPCert & FEPUser) & resources associated with it.

Note

Deleting a FEPCluster will delete all PV associated with the cluster, including backup and archived WAL volumes (except when using pre-made PV or AWS S3). This is an unrecoverable action.

5.3 FEPCluster Resource Change

5.3.1 Changing CPU and Memory Allocation Resources

Describes how to change the CPU and memory resources assigned to a pod created by a FEPCluster.

This allows you to scale the pod vertically through custom resources.

To modify CPU and memory resources, modify the spec.fep.mcSpec section(*1) of the FEPCluster custom resource and apply your changes.

When the changes are applied, restart the replica server with the new resource settings. If there are multiple replica servers, restart them one at a time. When all replica servers are restarted, one of them is promoted to the new master server due to a switchover. Then restart the container image on the original master server. This allows you to change resource settings for all servers with minimal disruption.

*1) Modifying this section scales up the FEP server container. For information about other container resource sections, refer to "FEPCluster Parameters" in the Reference.

5.3.2 Resizing PVCs

Describes how to resize a PVC assigned to a pod created by a FEPCluster.

This allows you to increase the size of the volume allocated to the pod through custom resources.

To change the PVC size, modify the size of each volume in the spec.fepChildCrVal.storage section of the FEPCluster custom resource and apply the change. These changes apply to all PVCs assigned to the pod created by the FEPCluster.

Note

- PVC resizing is extensible only.
- You can resize a PVC only if the StorageClass supports dynamic resizing.

- If the StorageClass does not support resizing PVCs, use the FEPRestore custom resource to create a new FEPCluster to resize the PVC. For more information, refer to "FEPRestore Custom Resource Parameters" in the Reference.

5.4 FEPPGPool2 Configuration Change

This section describes changes to the FEPPGPool2 configuration.

List FEPPGPool2

Equivalent Kubernetes command: kubectl get FEPPGPool2 (-A)

This operation lists all FEPPGPool2 in the namespace in the following format. Alternatively, if the -A option is specified, will list all FEPPGPool2 in all namespace.

Field	Value	Details
Name	.metadata.name	Name of pgpool2

Example)

```
# kubectl get feppgpool2 -A

NAMESPACE       NAME
namespace1      fep1-pgpool2
namespace2      fep2-pgpool2
```

Delete FEPPGPool2

Equivalent Kubernetes command: kubectl delete FEPPGPool2 <pgpool2_name>

This operation will remove the FEPPGPool2 by the pgpool2_name.

Update FEPPGPool2

Equivalent Kubernetes command: kubectl apply -f <new_spec>

Refer to "FEPPgpool2 Custom Resource Parameters" in the Reference and specify the parameters to be updated. Only the following parameters can be specified.

Custom Resource spec	Change Effect
.spec.count: n	Increase the number of nodes in the cluster to n.
.spec.serviceport	Change the TCP port for connecting to the Pgpool-II.
.spec.statusport	Change the TCP port for connecting to the PCP process.
.spec.limits.cpu	Change limits of cpus.
.spec.limits.memory	Change limits of memory.
.spec.requests.cpu	Change requests of cpus.
.spec.requests.memory	Change requests of memory.
.spec.fepclustername	Change fepcluster to connect.
.spec.customhba	Change pool_hba.conf file.
.spec.customparams	Change pgpool2 parameters
.spec.custompcp	Change pcp.conf file.
.spec.customsslkey	Change key content
.spec.customsslcert	Change the contents of the public x 509 certificate.

Custom Resource spec	Change Effect
.spec.customsslcacert	Change the contents of the CA root certificate in PEM format.

Some of the customparams parameters, customhba and custompcp, require a restart of pgpool2.

Equivalent Kubernetes command: Kubectl apply -f <new_spec>

"pgpool2_restart" action type expects users to specify the name of the pgpool2 that they want to restart from.

Specify the metadata.Name of the FEPPGPool2 CR in the targetPgpool2Name section of the FEPAction CR, as below:

```
spec:
    targetPgpool2Name: fep1-pgpool2
    fepAction:
        type: pgpool2_restart
```

When updating FEPPGPool2, the Pod of FEPPGPool2 is restarted. If configured with more than one FEPPGpool2, they are rebooted sequentially. The application should be designed to reconnect the connection because the connection being connected is broken.

Update each resource used for client authentication using scram-sha-256 authentication

Set password for new database user

When you add a new user to the database, you must notify the FEPpgpool2 container of the user and password.
In this case, in addition to the information of the existing user, add the information of the new user to the secret as follows.

```
apiVersion: v1
kind: Secret
metadata:
  name: test-secret
type: Opaque
data:
  user_name_1:cGFzc3dvcmRfMQ==
  user_name_2:cGFzc3dvcmRfMg==
  user_name_new:cGFzc3dvcmRfbmV3
```

After updating the secret, the FEPpgpool2 container automatically updates the contents of the password file pool_passwd.
If you want to edit the operator-created secret to add new user information, delete the postgres key entry. If there are still postgres key entries, the new user information will not be reflected.

Update passwords for existing database users

The FEPCluster container may update the passwords of database users for reasons such as password expiration.
In this case, keep the information of the existing user, and update the user information secret for the updated password as follows.

```
apiVersion: v1
kind: Secret
metadata:
  name: test-secret
type: Opaque
data:
  user_name_1:cGFzc3dvcmRfMQ==
  user_name_2:cGFzc3dvcmRfMl9uZXc=
```

After updating the secret, the FEPpgpool2 container automatically updates the contents of the password file pool_passwd.

Update encryption key file pgpoolkey

If you want to update the encryption key file pgpoolkey, update the contents of the secret defined in the encryption key secret pgpoolkeySecret.

```
apiVersion: v1
kind: Secret
metadata:
  name: pgpoolkey-secret
type: Opaque
data:
  pgpoolkey:bmV3LXBncG9vbGtleXBhc3N3b3Jk
```

If you want to update the encryption key file pgpoolkey, you must use the updated pgpoolkey and encrypt it again with scram-sha-256. You will also need to restart pgpool2 after updating the encryption key secret.

After updating the secret, the FEPpgpool2 container automatically updates the contents of the password file pool_passwd with the updated pgpoolkey.

5.5 Scheduling Backup from Operator

Operational status confirm

Information about the backup can be found by running the command in the FEP backup container, as shown in the example below.

```
$ oc exec pod/<fepcluster custom resource name>-sts-0 -c fepbackup -- fepbackup-info.sh
stanza: backupstanza
    status: ok
    cipher: none

    db (current)
        wal archive min/max (12-1): 000000010000000000000001/000000010000000000000005

        full backup: 20201125-025043F
            timestamp start/stop: 2020-11-25 02:50:43 / 2020-11-25 02:50:52
            wal start/stop: 000000010000000000000003 / 000000010000000000000003
            database size: 31.7MB, backup size: 31.7MB
            repository size: 3.9MB, repository backup size: 3.9MB

        incr backup: 20201125-025043F_20201125-025600I
            timestamp start/stop: 2020-11-25 02:56:00 / 2020-11-25 02:56:02
            wal start/stop: 000000010000000000000005 / 000000010000000000000005
            database size: 31.7MB, backup size: 24.3KB
            repository size: 3.9MB, repository backup size: 619B
            backup reference list: 20201125-025043F
```

Update FEPBackup

Equivalent Kubernetes command: kubectl apply -f <new_spec>

Refer to the parameters under spec.fepChildCrVal.backup within the FEPCluster parameter of the Reference and update the parameters.

Custom Resource spec	Change Effect
spec.fepChildCrVal.backup.schedule.num	Change the Number of Registered Backup Schedules
spec.fepChildCrVal.backup.scheduleN.schedule	Change the scheduled backup time
spec.fepChildCrVal.backup.scheduleN.type	Change the scheduled backup type
spec.fepChildCrVal.backup.pgBackrestParams	Change pgBackRest parameters
spec.fepChildCrVal.backup.scheduleN.repo	If you specified more than one repository for spec.pgBackrestParams, select the repository in which to store the backup data. The default is 1.

Note

- Changes made during the backup are reflected from the next backup.
- Changes to the backup schedule do not affect the application.
- If you perform any of the following update operations, be sure to obtain a backup after the update.
  - When the master encryption key is updated with pgx_set_master_key
  - When the encryption passphrase for transparent data encryption is updated (can be updated by the tdeppassphrase parameter of FEPCluster CR)

5.6 Configure MTLS Setting

5.6.1 Certification Rotation

All certificates are bounded by the time limit. At certain time, it needs to be renewed. We recommend to renew the certificate when it reaches 3/4 of its life cycle or as soon as possible if it is compromised. When a certificate is renewed, we need to rotate it inside the FEP server container. At the moment, FEP server container does not support automatic certificate rotation. Depending on which certificate has renewed, there are different procedures to handle that.

Patroni Certificate Rotation

When Patroni certificate is renewed, we have to re-deploy each and every Pod for FEP server container to pick up the new certificate. There is a down time on FEPCluster.

FEP Server Certificate Rotation

When FEP Server certificate is renewed, we can use FEPAction CR to trigger a reload of the database and FEP server will pick up the new certificate with no interruption to service.

Client certification Rotation

When any of the client certificate is renewed, FEP server container internally will use the new certificate next time it establishes a connection to FEP server. However, to avoid any unexpected interruption to service, it is recommended to re-deploy each and every Pod as soon as possible.

5.7 Monitoring

Monitoring is collecting historic data points that you then use to generate alerts (for any anomalies), to optimize databases and lastly to be proactive in case something goes wrong (for example, a failing database).

There are five key reasons to monitor FEP database.

1. Availability

   It is a very simple equation that if you do not have a database in running, your application will not work. If the application is critical, it directly effects on users and the organization.

2. System Optimization

   Monitoring helps to identify the system bottlenecks and according to the user can make changes to your system to see if it resolves the problem or not. To put this into perspective, there may be a situation where users see a very high load on the system. And figured out that there is a host parameter that can be set to a better value.

3. Identify Performance Problems

   Proactive monitoring can help you to identify future performance problems. From the database side, it could be related to bloating, slow running queries, table and index statistics, or the vacuum being unable to catch up.

4. Business Process Improvement

Every database user has a different need and priority. Knowing the system (load, user activity, etc.) helps you to prioritize customer tasks, reporting, or downtime. Monitoring helps to make business process improvement.

5. Capacity Planning

More user or application growth means more system resources. It leads to key questions: Do you need more disk space? Do you need a new read replica? Do you need to scale your database system vertically? Monitoring helps you to understand your current system utilization—and if you have data, points spread over a few weeks or months, it helps to forecast system scaling needs.

This article describes monitoring and alerting operations using OpenShift's standard Pod alive monitoring, resource monitoring and database statistics provided by the FEP Exporter.

5.7.1 Monitoring FEP Operator and Operands

The monitoring of FEP operators and operands are achieved by Prometheus' standard alive and resource monitoring.

Metrics name	Details
Alive monitoring	Can monitor Pod status
Resouce monitoring	You can monitor the following resource status - CPU Usage - CPU Quota - Memory Usage - Memory Quota - Current Network Usage - Receive Bandwidth - Transmit Bandwidth - Rate of Received Packets - Rate of Transmitted Packets - Rate of Received Packets Dropped - Rate of Transmitted Packets Dropped

By setting alert rules based on these monitoring items, operators and operands can be monitored. For the setting method, refer to the appendix in the Reference.

If an error is detected by monitoring the operator's alive, it can be dealt with by recreating the Pod.

If resource monitoring detects an error, consider allocating more resources to the Operator or Operands.

Check the Operator Hub or Red Hat Operator Catlog page to see which version you are currently using, which can be updated, and to check for security vulnerabilities.

5.7.2 Monitoring FEP Server

Monitoring and alerts system leverages standard GAP stack (Grafana, Alert manager, Prometheus) deployed on OCP and Kubernetes. GAP stack must be there before FEP operator & FEPCluster can be deployed.

Prometheus is a condensed way to store time-series metrics. Grafana provides a flexible and visually pleasing interface to view graphs of FEP metrics stored in Prometheus.

Together they let store large amounts of metrics that user can slice and break down to see how the FEP database is behaving. They also have a strong community around them to help deal with any usage and setup issues.

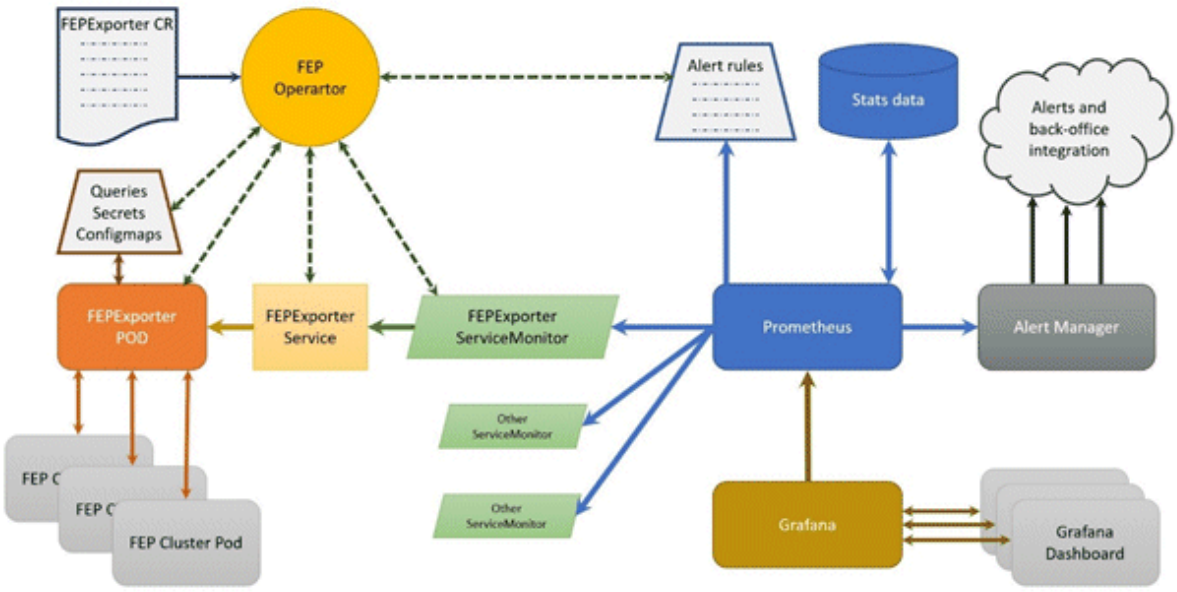
The Prometheus acts as storage and a polling consumer for the time-series data of FEP container. Grafana queries Prometheus to displaying informative and very pretty graphs.

If Prometheus rules are defined, it also evaluates rules periodically to fire alerts to Alert manager if conditions are met. Further Alert manager can be integrated with external systems like email, slack, SMS or back-office to take action on alerts raised.

Metrics from FEP Cluster(s) is collected by Prometheus through optional components deployed using FEP Exporter with default set of metrices and corresponding Prometheus rules to raise alerts. User may extend or overwrite metrics by defining their custom metrics queries and define their custom Prometheus rules for alerting.

5.7.2.1 Architecture

Block diagram of monitoring FEP server is as follows.



- FEPExporter CR is managed by FEP Operator
- When FEPExporter CR is created, FEP operator creates following kubernetes objects:
  - ConfigMap that contains default and custom queries to collect metrics from database cluster from each node
  - Secret containing JDBC URL for all FEPCluster nodes to connect and request metrics. This string contains authentication details as well to make JDBC connection.
  - Prometheus rules corresponding to default alert rules
  - ServiceMonitor for Prometheus to discover FEPExporter service
  - FEPExporter container using FEPExporter image to scrape metrices from all FEPCluster nodes

Note

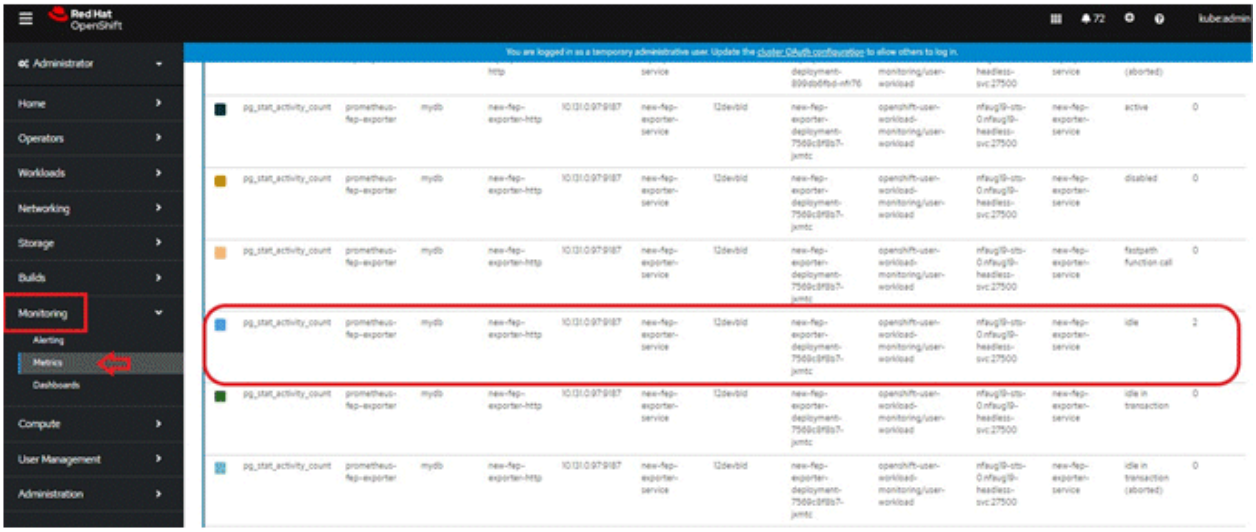
- Alert Manager integration to back-office to send mail / message / raising ticket is done by user based on their environment
- Grafana installation and integration is done by user. Use the Grafana Operator provided by OperatorHub.
- Grafana dashboard is created by user based on their requirements and design.

5.7.2.2 Default Server Metrics Monitoring

By default FEPExporter scrapes some useful metrics for server.

Once FEPExporter is running, user can check the collected metrics under Openshift->Monitoring->Metrics submenu.

Refer an example below.



There are 2 types of default server metrics defined by FEP Exporter.

Type	Details
Default mandatory	Are collected by FEP Exporter. These are kept enabled by default by FEP Exporter and can not be disabled by end user.
Default useful	Useful focused metrics for health and performance metrics. Can be disabled by end user.

Default mandatory metrics

These metrics are either from basic statistics view of the database or FEP Exporter own metrics;

Various metrics under this category are

Metrics name	Details
pg_stat_bgwriter_*	Maps to view in Statistic Collector
pg_stat_database_*	Maps to view in Statistic Collector
pg_stat_database_conflicts_*	Maps to view in Statistic Collector
pg_stat_archiver_*	Maps to view in Statistic Collector
pg_stat_activity_*	Maps to view in Statistic Collector
pg_stat_replication_*	Maps to view in Statistic Collector
pg_replication_slots_*	Maps to System Catalog pg_replication_slots
pg_settings_*	Maps to System Catalog pg_settings
pg_locks_*	Maps to System Catalog pg_locks
pg_exporter_*	Exposes exporter metrics: - last_scrape_duration_seconds (Duration of the last scrape of metrics from PostgresSQL) - scrapes_total (Total number of times PostgresSQL was scraped for metrics)

Metrics name	Details
	last_scrape_error (*Whether the last scrape of metrics from PostgreSQL resulted in an error; 1 for error & 0 for success*)
pg_*	Exposes exporter metrics - pg_up (set to 1 if the connection to service is success, 0 otherwise) - pg_static (can be used to fetch label short_version / version containing postgres server version information)

Default useful metrics

There are certain useful queries which are additionally added to evaluate the health of the Database system.

Metrics name	Details
pg_capacity_connection_*	Metrics on connections e.g. txns running for 1 hour
pg_capacity_schema_*	Metrics on disk space of schema
pg_capacity_tblspace_*	Metrics on disk space of tablespace
pg_capacity_tblvacuum_*	Metrics on tables without vacuum for days
pg_capacity_longtx_*	Number of transactions running longer than 5 minutes Review the information and consider SQL tuning and resource enhancements.
pg_performance_locking_detail_*	Details of processes in blocked state
pg_performance_locking_*	Number of processes in blocked state
pg_replication_*	Replication lag behind master in seconds Provides the ability to check for the most current data in a reference replica To solve the problem, it is necessary to consider measures such as increasing network resources and reducing the load
pg_postmaster_*	Time at which postmaster started
pg_stat_user_tables_*	Important statistics from pg_stat_user_tables
pg_statio_user_tables_*	Important statistics from pg_statio_user_tables
pg_database_*	Database size If the database runs out of space, database restore is required
pg_stat_statements_*	Statistics of SQL statements executed by server
pg_capacity_tblbloat_*	Fetched bloat in tables
pg_tde_encrypted_*	Presence or absence of transparent data encryption in the tablespace and the number of tables and indexes stored
pg_password_valid_*	Database Role Password Validity Period
pg_not_set_password_valid_*	Number of database roles with no password expiration
pg_user_profile_*	Number of database roles in each status for policy-based password operation
pg_txid_*	Transaction ID usage

Note

You can tune the intervals and thresholds at which information is gathered by changing the values specified in the information gathering query. For more information, refer to the queries in the appendix of the Reference Guide, and make your own settings.

5.7.2.3 Default Alerts

There are few basic alert rules which are setup by the FEP Operator as below

Alert rule	Alert Level	Condition persistence	Description
ContainerHighCPUUsage	Warning	5 mins	FEP server container/Pod CPU usage is exceeding 80% of the resource limits
ContainerHighRAMUsage	Warning	30 mins	FEP server container/Pod memory usage is exceeding 80% of the resource limits
PVCLowDiskSpace	Warning	5 mins	A FEP PVC (volume) has less that 10% disk available
ContainerDisappeared	Warning	60 seconds	FEP server container/Pod has disappeared since last 60 seconds
PostgresqlDown	Error	-	FEP server apparently went down or not accessible
PostgresqlTooManyConnections	Warning	-	FEP server container/Pod connection usage is beyond 90% of its available capacity
PostgresqlRolePasswordCloseExpierd	Warning	-	A Postgresql role exists with a password expiration of less than 7 days
PostgresqlRolePasswordExpired	Warning	-	A Postgresql role exists with an expired password
PasswordIsGraceTimeByUserProfile	Warning	-	There is a Postgresql role that is in the grace period due to policy-based password operation
PasswordExpiredByUserProfile	Warning	-	There is a Postgresql role whose password has expired due to policy-based password operation
PasswordLockedByUserProfile	Warning	-	There is a Postgresql role that is locked by policy-based password operation
PostgresqlTooManyTxidUsage	Warning	24 hours	The amount of transaction ID usage has exceeded the value of the autovacuum_freeze_max_age parameter in postgresql.conf for more than 24 consecutive hours.

You can configure any alert by adding alert rules to other monitoring items.

Alerts are based on statistics/metrics. Incorrect platform statistics can cause false alarms. For example, when using NFS storage, the system may raise false alarms for PVCLowDiskSpace when the storage driver is not showing the correct metrics for PV byte usage.

5.7.2.4 Graphical user interface

User can build their custom dashboard using default and custom metrics.

An example Grafana dashboard screenshot is shown below

5.7.2.5 Metrics Collected by CloudWatch

The metrics collected by CloudWatch are listed below.

Metrics name	Description
pg_stat_bgwriter_*	Maps displayed in statistics collection
pg_stat_database_*	Maps displayed in statistics collection
pg_stat_database_conflicts_*	Maps displayed in statistics collection
pg_stat_archiver_*	Maps displayed in statistics collection
pg_stat_activity_*	Maps displayed in statistics collection
pg_stat_replication_*	Maps displayed in statistics collection
pg_replication_slots_*	Mapping to the pg_replication_slots system catalog
pg_locks_*	Mapping to the pg_locks system catalog
pg_capacity_connection_*	Connection metrics (e.g. txns running for 1 hour)
pg_capacity_schema_*	Schema disk space metrics
pg_capacity_tblspace_*	Tablespace disk space metrics
pg_capacity_tblvacuum_*	Metrics for tables that haven't been vacuumed in days
pg_capacity_longtx_*	Number of transactions running for more than 5 minutes
pg_capacity_datfrozenxid_*	Transaction ID Usage Trend (Used for scheduling aggressive freeze for tuples (VACUUM FREEZE))
pg_performance_locking_detail_*	Blocked process details
pg_performance_locking_*	Number of blocked processes
pg_stat_user_tables_*	Vital statistics from pg_stat_user_tables
pg_statio_user_tables_*	Vital statistics from pg_statio_user_tables
pg_stat_statements_*	Statistics for SQL statements executed by the server
pg_capacity_tblbloat_*	Table fetch bloat

5.7.3 Monitoring FEP Backup

You can view information about the backed-up data and the status of the backup process in the FEP server tables and system views.

Backup information is updated when the automatic backup process completes or when backup data is deleted as specified by retention.

The following tables and views are added. The tables and views to be added are created under the fep_exporter schema in the postgres database on the FEP server.

Table/View name	Details
pgbackrest_info_backup	Backup Processing Status

5.7.3.1 pgbackrest_info_backup view

Contains one line per backup for information about the state of the backup.

Column	Type	Description
label	text	Information identifying the backup
type	text	full: full backup, incr: incremental backup
prior	text	Label of the backup that should be applied first (For incremental backups only)
database_size	bigint	Database size
database_size_comp	bigint	Database size (After Compression)
backup_size	bigint	Backup size
backup_size_comp	bigint	Backup size (After Compression)
archive_start	text	Range of WALs required for restore (Start)
archive_stop	text	Range of WALs required for restore (End)
backup_start	timestamp with timezon	Backup Start Time
backup_stop	timestamp with timezone	Backup End Time
backup_exec_time	interval	The duration of the backup

5.7.4 Monitoring FEP PGPool2

Information about pgpool2 activity and replication status can be found in the FEP server table and in the system view.

The pgpool2 statistics are updated according to the schedule specified in the parameter.

The tables and views that have been added are described below. The tables and views to be added are created under the fep _ exporter schema in the postgres database on the FEP server.

Table/View name	Details
pgpool2_stat_load_balance	Load Balance Information in pgpool2
pgcluster_stat_replication	Replication State
pgpool2_stat_conn_pool	Connection Pool State for pgpool2
pgpool2_stat_sql_command	SQL Command Statistics

5.7.4.1 pgpool2_stat_load_balance view

Contains one row for MasterService and one row for ReplicaService.

Column	Type	Description
node_id	integer	database node id (0 or 1)
status	text	status (up or down)
lb_weight	double precision	load-balancing weight
role	text	role (primary or standby)
last_status_change	timestamp with time zone	last status change time

5.7.4.2 pgpool2_stat_conn_pool view

Indicates the state of the connection pool. Contains connection pool information for each pcpool2 instance.

Column	Type	Description
pgpool2_node_id	integer	pgpool2 node id（0 - the number of pgpool2 instance -1）
pool_pid	integer	The PID of the displayed Pgpool-II process
start_time	timestamp with timezone	The timestamp of when this process was launched
pool_id	integer	The pool identifier (should be between 0 and max_pool - 1)
backend_id	integer	The backend identifier (should be between 0 and the number of configured backends minus one)
role	text	role (primary or standby)
database	text	The database name for this process's pool id connection
username	text	The user name for this process's pool id connection
create_time	timestamp with timezo	The creation time and date of the connection
majorversion	integer	The protocol version numbers used in this connection
minorversion	integer	The protocol version numbers used in this connection
pool_counter	integer	Counts the number of times this pool of connections (process) has been used by clients
pool_connected	boolean	True (1) if a frontend is currently using this backend

5.7.4.3 pgpool2_stat_sql_command view

Represents SQL command statistics.

Column	Type	Description
node_id	integer	The backend identifier (should be between 0 and the number of configured backends minus one)
role	text	role (primary or standby)
select_cnt	integer	The numbers of SQL command: SELECT
insert_cnt	integer	The numbers of SQL command: INSERT
update_cnt	integer	The numbers of SQL command: UPDATE
delete_cnt	integer	The numbers of SQL command: DELETE
ddl_cnt	integer	The numbers of SQL command: DDL
other_cnt	integer	The numbers of SQL command: others
panic_cnt	integer	The numbers of failed commands

Column	Type	Description
fatal_cnt	integer	The numbers of failed commands
error_cnt	integer	The numbers of failed commands

5.7.5 Monitoring Multi-master Replication

5.7.5.1 Metrics to Collect

The following metrics are collected in multi-master replication.

Metrics for created replication

Metrics name	Details
get_last_applied_xact_info	Retrieves the last applied transaction information for the applicable worker
pgactive_is_apply_paused_status	Checks whether replication application is paused
pgactive_is_apply_paused_replications	Retrieves the number of replication instances where replication application is paused
pgactive_pending_wal_decoding	Estimated size of WAL to be applied to the receiving node
pgactive_pending_wal_to_apply	Estimated size of WAL to be decoded on the sending node

5.7.5.2 Method of Collecting Metrics

5.7.5.2.1 Monitoring via FEPExporter

When bidirectional logical replication is enabled and the monitoring feature is activated by setting spec.fep.monitoring.enable to true in the FEPCluster custom resource, metric collection for bidirectional logical replication is enabled.

5.8 Event Notification

The eventing mechanism introduced, is to enable operator to raise customized Kubernetes events. The custom events will be raised during the creation of custom resources. Currently following events are raised.

5.8.1 Events raised

- fepcluster - During FEPCluster CR creation
  - Event is raised when FEPVolume CR creation is initiated and when FEPVolume CR creation initiation fails.
  - Event is raised when FEPConfig CR creation is initiated and when FEPConfig CR creation initiation fails.
  - Event is raised when FEPUser CR creation is initiated and when FEPUser CR creation initiation fails.
  - Event is raised when FEPCert CR creation is initiated.and when FEPCert CR creation initiation fails.
  - Event is raised when Statefulset creation is successful and Statefulset creation fails.
  - Event is raised when PDB creation is successful and when PDB creation fails.
  - Event is raised when FEPBackup CR creation is initiated and when FEPBackup CR creation initiation fails.
  - Event is raised when a FEPCluster custom resource with Velero enabled specifies the same object storage path for production and disaster recovery environments.

Please note the following child CR events are raised as part of Create FEP Cluster

- fepcert - During FEPCert CR creation
  - Event is raised when FEPCert CR creation is successful, when FEPCert CR fails annotating FEPCluster and when FEPCert CR creation fails.
- fepconfig - During FEPConfig CR creation
  - Event is raised when FEPConfig CR creation is successful, when FEPConfig CR fails annotating FEPCluster and when FEPConfig CR creation fails.
- fepvolume - During FEPVolume CR creation
  - Event is raised when FEPVolume CR creation is successful, when FEPVolume CR fails annotating FEPCluster and when FEPVolume CR creation fails.
- fepbackup - During FEPBackup CR creation
  - Event is raised when FEPBackup cronjob1 creation is successful and when FEPBackup cronjob1 creation fails.
  - Event is raised when FEPBackup cronjob2 creation is successful and when FEPBackup cronjob2 creation fails.
  - Event is raised when FEPBackup cronjob3 creation is successful and when FEPBackup cronjob3 creation fails.
  - Event is raised when FEPBackup cronjob4 creation is successful and when FEPBackup cronjob4 creation fails.
  - Event is raised when FEPBackup cronjob5 creation is successful and when FEPBackup cronjob5 creation fails.

- feppgpool2- During FEPPgPool2 CR creation
  - Event is raised when FEPPgPool2 CR creation is successful and when FEPPgPool2 CR creation fails.
  - Event is raised when FEPPgPool2Cert CR creation is initiated and when FEPPgPool2Cert CR creation initiation fails.

Please note the following child CR event are raised as part of Create FEP PgPool2

  - feppgpool2cert- During FEPPgPool2Cert CR creation
    - Event is raised when FEPPgPool2Cert CR creation is successful, when FEPPgPool2Cert CR fails annotating FEPPgPool2 and when FEPPgPool2Cert CR creation fails
- feprestore - During FEPRestore CR creation
  - Event is raised when FEPRestore CR creation is successful and when FEPRestore CR creation fails.

5.8.2 Events that Occur when Custom Resources are Updated

If the "sysExtraEvent" parameter is specified in the custom resource, an event will be generated when changes to FEPCluster, FEPLogging, FEPExporter are detected, or when the changes are applied successfully/failed.

Refer to "Operator operation event notification" in "Reference" for information about events that occur.

5.8.3 Viewing the Custom Events

The custom events can be viewed on CLI as well as the Openshift console

On cli

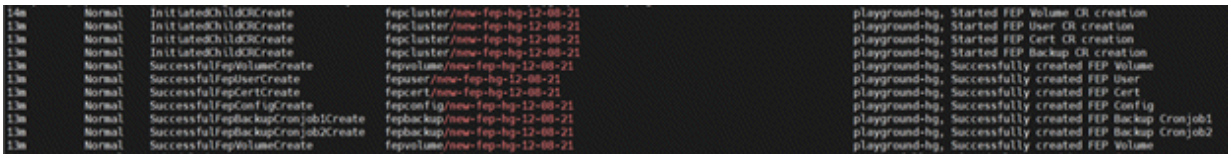
Executing the command

kubectl get events

OR

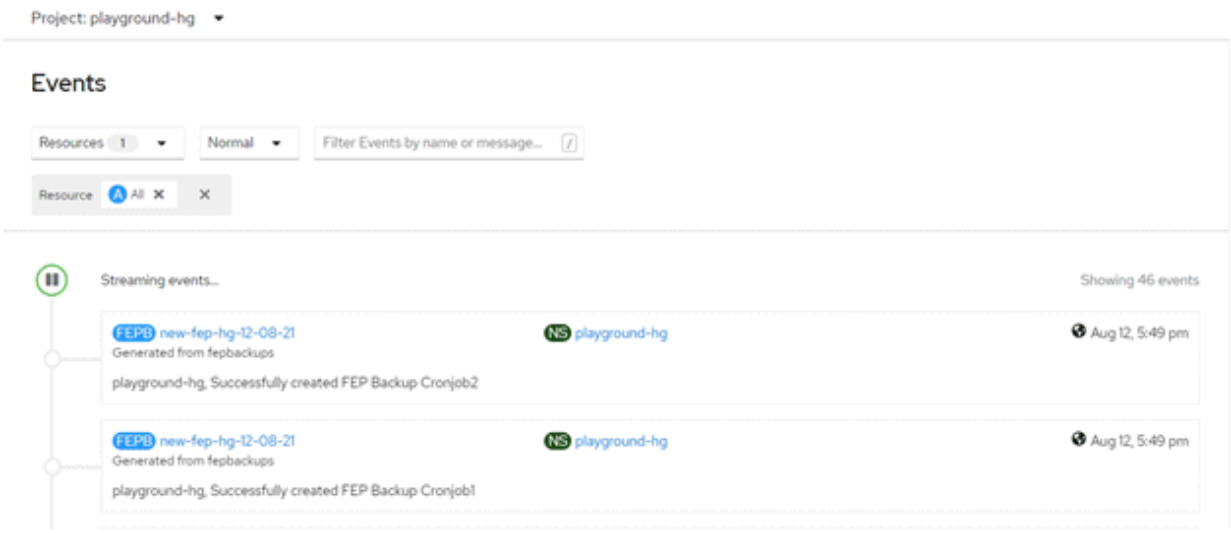
oc get events

Following is a snippet of the events output is ==shown when the above command is executed,



On openshift console

For the specific project/ namespace the custom events can be viewed along with Kubernetes events under the events as shown in the following screenshot.



5.9 Scaling Replicas

5.9.1 Automatic Scale Out

Automatic scale out occurs when the average CPU utilization or number of connections of the DB container exceeds the threshold.

The maximum number of replica containers, excluding the master container, is 15.

If the load decreases after the number of replicas increases due to a temporary increase in load, the number of replicas will remain increased. Perform manual scale in if necessary.

Specify spec.fepChildCrVal.autoscale.scaleout in FEPClusterCR when you want to perform Automatic scale out. Refer to "FEPCluster Parameters" in the Reference for information about the values to specify.

```
$ oc edit fepcluster <FEPClusterCR name>
```

5.9.2 Manual Scale In/Out

To manually scale in or out of a FEPCluster, edit the "spec.fep.instances" in FEPClusterCR.

The value must be between 1 and 16. (Number of instances with one master)

```
$ oc edit fepcluster <FEPClusterCR name>
```

Note

- Do not scale in from two to one replica instance when the syncMode is 'on'. Update SQL cannot be executed.
- Any database connections to the replica Pod that are deleted during a scale in will be forced to disconnect.

5.10 Backing Up to Object Storage

Describes how to store backup data in object storage.

5.10.1 Pre-creation of Resources

5.10.1.1 Storing CA Files (Root Certificates)

If you want to use a non-default root certificate for object storage connections, register it in ConfigMap.

```
$ oc create configmap storage-cacert --from-file=ca.crt=storage-ca.pem -n my-namespace
```

5.10.1.2 Storing Repository Key

When using the parameter (repo-gcs-key) of pgBackRest, register the GCS repository key in Secret.

```
$ oc create secret generic storage-key-secret --from-file=key.json=storage-key.json -n my-namespace
```

5.10.2 Defining a FEPCluster Custom Resource

List the backup settings under spec.fepChildCrVal.backup in the FEPCluster custom resource.

Specify the object storage for the backup data in pgbackrestParams. Refer to "2.3.5 Scheduling Backup from Operator" for possible values for pgbackrestParams.

Specify the ConfigMap name created in "5.10.1.1 Storing CA Files (Root Certificates)" for caName.

FEPCluster Custom Resource Example: Only Object Storage Used for Backup Repository

```
apiVersion: fep.fujitsu.io/v2
kind: FEPCluster
metadata:
  …
spec:
  fepChildeCrVal:
    backup:
      pgbackrestParams: |
        repo1-type=s3
        repo1-path=/backup/cluster1
        repo1-s3-bucket= sample-bucket
        repo1-s3-endpoint=s3.ap-northeast-1.amazonaws.com
        repo1-s3-region=ap-northeast-1
        repo1-storage-ca-file=/pgbackrest/storage-certs/ca.crt
      pgbackrestKeyParams: |
        repo1-s3-key=SAMPLEKEY
        repo1-s3-key-secret=SAMPLESECRET
      caName:
       - storage-cacert
…
```

If the persistent volume and object storage specified in spec.fepChildeCrVal.storage.backupVol are to be used together in the backup repository, specify the object storage setting after "repo2".

If "repo1" is not defined, a permanent volume is automatically designated as the storage destination for the backup volume.

FEPCluster Custom Resource Example: When using object storage and PV

```
  …
spec:
  fepChildeCrVal:
    backup:
```

```
      pgbackrestParams: |
        repo2-type=s3
        repo2-path=/backup/cluster1
        repo2-s3-bucket= sample-bucket
        repo2-s3-endpoint=s3.ap-northeast-1.amazonaws.com
        repo2-s3-region=ap-northeast-1
        repo2-storage-ca-file=/pgbackrest/storage-certs/ca.crt
      pgbackrestKeyParams: |
        repo2-s3-key=SAMPLEKEY
        repo2-s3-key-secret=SAMPLESECRET
      caName:
       - storage-cacert
...
```

When using object storage GCS as a backup repository, specify as follows.

For repoKeySecretName, specify the Secret created in "5.10.1.2 Storing Repository Key". Also, specify service for gcs-key-type.

FEPCluster Custom Resource Example: When using GCS as a backup repository

```
apiVersion: fep.fujitsu.io/v1
kind: FEPCluster
metadata:
  ...
spec:
  fepChildeCrVal:
    backup:
      pgbackrestParams: |
        repo1-type=gcs
        repo1-path=/backup-ct/test2
        repo1-gcs-bucket=dbaas-gcs
        repo1-gcs-endpoint=localhost
        repo1-storage-ca-file=/pgbackrest/storage-certs/ca.crt
        repo1-gcs-key=/pgbackrest/storage-keys/key.json
        repo1-gcs-key-type=service
      caName:
       - storage-cacert
      repoKeySecretName:
       - storage-key-secret
...
```

5.11 Disaster Recovery

Available disaster recovery methods include backup/restore method, continuous recovery method, and streaming replication method.

5.11.1 Disaster Recovery by Backup/Restore Method

5.11.1.1 Disaster Recovery Prerequisites

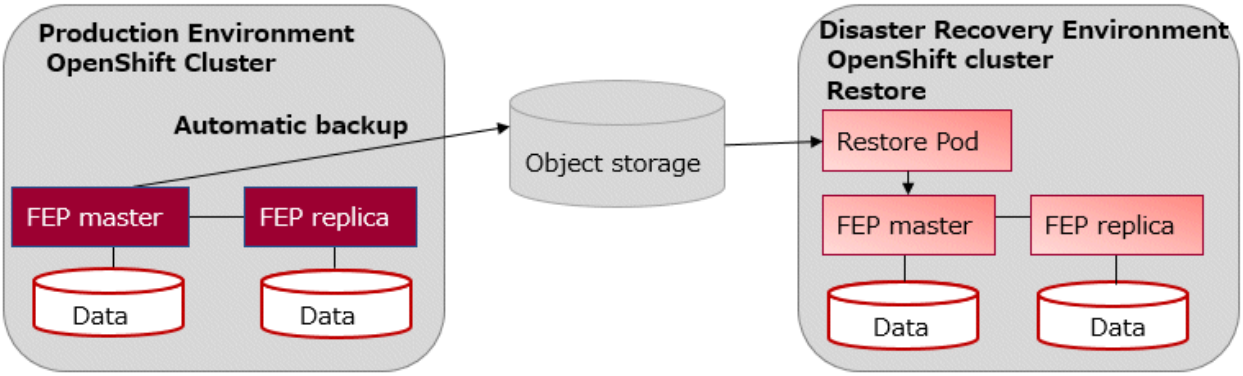
The configuration diagram of the Pod arrangement and backup repository, which are prerequisites for the backup function to perform disaster recovery using the backup/restore method, is shown below.

In FEPCluster to get a backup, specify the object storage as the backup data storage destination with spec.fepChildCrVal.backup.pgbackrestParams.

Specify object storage that is in an area that is considered safe for the scope of the expected disaster.

The definition of the FEPCluster custom resource is not inherited when performing disaster recovery.

We recommend that you save your production environment FEPCluster custom resource definitions in case of a disaster.



5.11.1.2 Performing Disaster Recovery

Describes the procedure for restoring to an OCP environment different from the restore source using the backup data stored in the object storage.

5.11.1.2.1 Pre-creation of Resources

Storing CA Files (Root Certificates)

If you want to use a non-default root certificate for object storage connections, register it in ConfigMap.

```
$ oc create configmap storage-cacert --from-file=ca.crt=storage-ca.pem -n my-namespace
```

Storing GCS Repository Key

When using the parameter (repo-gcs-key) of pgBackRest, register the GCS repository key in Secret.

```
$ oc create secret generic storage-key-secret --from-file=key.json=storage-key.json -n my-namespace
```

5.11.1.2.2 Defining a FEPCluster Custom Resource

In addition to the FEPCluster settings, specify the Restore settings below.

FEPCluster Custom Resource Example

```
apiVersion: fep.fujitsu.io/v1
kind: FEPCluster
metadata:
  …
spec:
  fepChildCrVal:
    restore:
      pgbackrestParams: |
        repo1-type=s3
        repo1-path=/backup/cluster1
        repo1-s3-bucket=sample-bucket
        repo1-s3-endpoint=s3.ap-northeast-1.amazonaws.com
        repo1-s3-region=ap-northeast-1
        repo1-storage-ca-file=/pgbackrest/storage-certs/ca.crt
      pgbackrestKeyParams: |
        repo1-s3-key=SAMPLEKEY
        repo1-s3-key-secret=SAMPLESECRET
      caName:
       - storage-cacert

…
```

When using object storage GCS as a backup repository, specify as follows.

For repoKeySecretName, specify the Secret created in "Storing GCS Repository Key". Also, specify service for gcs-key-type.

```
apiVersion: fep.fujitsu.io/v1
kind: FEPCluster
metadata:
  ...
spec:
  fepChildeCrVal:
    backup:
      pgbackrestParams: |
        repo1-type=gcs
        repo1-path=/backup-ct/test2
        repo1-gcs-bucket=dbaas-gcs
        repo1-gcs-endpoint=localhost
        repo1-storage-ca-file=/pgbackrest/storage-certs/ca.crt
        repo1-gcs-key=/pgbackrest/storage-key/key.json
        repo1-gcs-key-type=service
      caName:
       - storage-cacert
      repoKeySecretName:
       - storage-key-secret
...
```

Setting value

Field	Default	Details
spec.fepChildCrVal.restore		Define when restoring by specifying the backup data stored in the object storage.
spec.fepChildCrVal.restore.pgbackrestParams		Optional "|" is fixed, and the following lines specify the parameters to set in pgbackrest.conf. Specify the object storage where the backup data is stored. If you want to use a root certificate other than the default, specify the following: repo1-storage-ca-path=/pgbackrest/storage-certs/<*file name*> Register the CA file in ConfigMap and specify the ConfigMap name in spec.fepChildCrVal.restore.caName.
spec.fepChildCrVal.restore.pgbackrestKeyParams		Optional "|" is fixed, and the following lines specify the parameters to set in pgbackrest.conf. The value described by this parameter is masked with *****. Specify the parameter you want to mask, such as a password.
spec.fepChildCrVal.restore.caName		Optional Specify when you use a CA file other than the system default. Specify the name of the created ConfigMap in list format. The specified ConfigMap will be mounted in /pgbackrest/storage-certs.
spec.fepChildCrVal.restore.mcSpec.limits	cpu: 200m memory: 300Mi	Optional CPU and memory allocated to the container performing the restore.
spec.fepChildCrVal.restore.mcSpec.requests	cpu: 100m memory: 200Mi	Optional CPU and memory allocated to the container performing the restore.

Field	Default	Details
spec.fepChildCrVal.restore.restoretype	latest	Optional Restore Type (latest or PITR)
spec.fepChildCrVal.restore.restoredate		Optional Specify the date to restore when spec.fepChildCrVal.restore.restoretype is "PITR".
spec.fepChildCrVal.restore.restoretime		Optional Specify the time to restore when spec.fepChildCrVal.restore.restoretype is "PITR".
spec.fepChildCrVal.restore.image		Optional Image of the container to perform the restore. It is omitted by default. In this case, the URL for image is obtained from the operator container environment.
spec.fepChildCrVal.restore.imagePullPolicy	IfNotPresent	Optional

5.11.2 Disaster Recovery with Continuous Recovery Method

5.11.2.1 Disaster Recovery Prerequisites

When performing disaster recovery using the continuous recovery method, the database cluster must be configured based on the "4.14.3.1 Defining a Continuous Recovery Method". At this time, it is necessary to periodically back up the database to object storage.

5.11.2.2 Performing Disaster Recovery

In the event of a disaster, the FEPCluster in the disaster recovery environment should be promoted.

Describes the procedure for promoting a FEPCluster in a disaster recovery environment deployed in a hot standby configuration. If the production environment becomes unusable when a disaster occurs, you can promote the disaster recovery environment to the production environment by executing FEPAction(promote_standby).

An example FEPAction definition is shown below.

```
...
apiVersion: fep.fujitsu.io/v1
kind: FEPAction
metadata:
  name: new-fep-promote-standby-action
  namespace: my-namespace
spec:
  fepAction:
    type: promote_standby
  sysExtraEvent: true
  sysExtraLogging: true
  targetClusterName: my-fep
...
```

5.11.3 Disaster Recovery Using Velero

This section describes disaster recovery using Velero.

5.11.3.1 Disaster Recovery Prerequisites

Prepare for the following in production environment and disaster recovery environment. Before enabling this feature in a production environment, and before restoring using this feature in a disaster recovery environment, you must prepare the following:

- Installing VeleroCLI
- Installing Velero
- Installing FEPOperator
- StorageClass, namespace, CRD, and other resources needed to build the system

If you plan to use a static PV with FEPCluster, prepare the PV before restoring to a disaster recovery environment. If you use a storage class or certificate that is different from the production environment, provide a storage class or certificate with the same name as the production environment in your disaster recovery environment. However, if the object storage certificate or secret where the database backup data is stored differs between the production environment and the disaster response environment, set a different name. For more information, refer to "FEPCluster Parameters" in the Reference.

5.11.3.2 Performing Disaster Recovery

Provides step-by-step instructions on how to enable this feature to perform disaster recovery from a production environment to a disaster recovery environment. It also describes how to perform disaster recovery again from a disaster recovery environment to a production environment.

FEPCluster and FEPPool2 LOG volumes cannot be restored. Before using this feature, be sure to test and validate in both production and disaster recovery environments.

5.11.3.2.1 Configuring FEPCluster Custom Resources

To use this feature, in addition to the normal configuration of FEPCluster custom resources in your production environment, configure the following to deploy on Kubernetes. For more information, refer to "FEPCluster Parameters" in the Reference.

- fep.velero.enable
- fep.velero.labels
- fep.velero.backup
- fep.velero.restore
- fepChildCrVal.backup

Example) FEPCluster Custom Resource Definition Example

```
spec:
  fep:
    velero:
      enable: true
      labels:
        backup-dev: my-backup1
        backup-dep: my-backup2
      backup:
        pgbackrestParams: |
          [global]
           repo1-retention-full=5
           repo1-retention-full-type=count
           repo2-retention-full=5
           repo2-retention-full-type=count
           log-path=/database/log/backup
           log-level-file=debug
           repo2-path=/ velero-backup/ velero-backup-for-dr2
           repo2-s3-bucket=my-s3-backet
           repo2-s3-endpoint=s3.ap-northeast-1.amazonaws.com
           repo2-s3-region=ap-northeast-1
           repo2-type=s3
         pgbackrestKeyParams: |
           repo2-s3-key=XXXXXXXXXX
           repo2-s3-key-secret=YYYYYYYYYY
         caName: DR-objectstorage-cert
```

```
         repoKeySecretName: XXX

resotre:
         image:
           image: "XXX-amd64"
           pullPolicy: IfNotPresent
         mcSpec:
           limit:
             cpu: 200m
             memory: 300Mi
           request:
             cpu: 100m
             memory: 200Mi
         restoreTargetRepo: 2
  fepChildCrVal:
      backup:
        pgbackrestParams: |
        [global]
         repo1-retention-full=5
         repo1-retention-full-type=count
         repo2-retention-full=5
         repo2-retention-full-type=count
         log-path=/database/log/backup
         log-level-file=debug
         repo2-path=/ velero-backup/ velero-backup-for-dr1
         repo2-s3-bucket=my-s3-backet
         repo2-s3-endpoint=s3.ap-northeast-1.amazonaws.com
         repo2-s3-region=ap-northeast-1
         repo2-type=s3
       pgbackrestKeyParams: |
         repo2-s3-key=XXXXXXXXXX
         repo2-s3-key-secret=YYYYYYYYYY
       caName: objectstorage-cert
       repoKeySecretName: ZZZ

       schedule:
         num: 1
         schedule1:
           schedule: "0-59/3 * * * *" #schedule1.schedule
         type: "full" #schedule1.type
         repo: 2
```

5.11.3.2.2 Velero Backup

After building FEPCluster in this environment or modifying FEPCluster custom resources, use the following command to back up the resources on kubernetes, including FEPCluster custom resources, to object storage.

Example)

```
velero backup create ＜Bavkup name＞ --selector <Backup target label>
```

This feature supports only Velero backup commands that specify the labels described in fep.velero.labels for FEPCluster custom resources and back up only those resources to which the labels are attached. Other commands may back up and restore unnecessary resources, resulting in build and data recovery failures. When specifying labels, do not specify the following keys to avoid confusion with existing labels.

- app
- control-plane
- name
- pod-template-hash
- vendor

- app.kubernetes.io/component
- app.kubernetes.io/instance
- app.kubernetes.io/managed-by
- app.kubernetes.io/name
- app.kubernetes.io/part-of
- control-plane
- controller-revision-hash
- fepclustername
- feprole
- statefulset.kubernetes.io/pod-name
- controller-uid
- job-name
- pod-template-hash
- release

This feature labels the following resources:

- FEPCluster Custom Resources
- Secrets required to build FEPCluster

When backing up the following resources using Velero, assign the labels specified in spec.fep.velero.labels (If spec.fep.velero.labels is omitted, the default backup-group: fep-backup) to the ConfigMap and Secret specified for the various custom and custom resources.

- FEPPgpool2
- FEPExporter
- FEPLogging

You can also back up manually created resources (Application system, ConfigMap, Secret, etc.) by assigning them the labels specified in spec.fep.velero.labels (If spec.fep.velero.labels is omitted, the default backup-group: fep-backu) and making them eligible for Velero backups.

For more information about using the Velero command, refer to the official documentation.

Note

Each time you modify a custom resource, such as FEPCluster, a Velero backup is required. The database is brought up to date with object storage. If a custom resource is in a pre-change state, it may be inconsistent with the database, causing data loss, performance degradation, security, and other issues.

5.11.3.2.3 Database Backup

Perform regular database backups.

5.11.3.2.4 Velero Restore

If business cannot continue in a production environment due to a disaster, use the following command to restore the resources on kubernetes, including the FEPClueter custom resources stored in object storage. The database data is restored to the latest archived WAL state stored in object storage.

Example)

```
velero restore create <Reatore name> --from-backup <Backup name>
```

For more information about using the Velero command, refer to the official documentation.

5.11.3.2.5 Return from Disaster Recovery Environment to Production Environment

When restoring from a disaster recovery environment to a production environment again using Velero, the FEPCluster custom resources deployed in the disaster recovery environment must be modified. The FEPClsuter custom resource after disaster recovery, fep.velero.backup, fep.velero.restore, defines pre-disaster recovery information. Update the information to the object storage used in the production environment. Then back up with Velero in a disaster recovery environment and restore with Velero in a production environment.

5.11.4 Disaster Recovery with Streaming Replication Method

5.11.4.1 Disaster Recovery Prerequisites

When performing disaster recovery using the streaming replication method, the database cluster must be configured based on the "4.14.3.2 Defining a Streaming Replication Method". After deployment, database data is synchronized between the production environment and the disaster recovery environment using the streaming replication method, so no operation is required during operation.

5.11.4.2 Performing Disaster Recovery

When a disaster occurs, it is necessary to promote the FEPCluster in the disaster recovery environment. For promotion of FEPCluster in a disaster recovery environment, refer to "5.11.2.2 Performing Disaster Recovery".

5.11.5 Parameter Change in Disaster Recovery Environment

If parameters (such as FEPClusterCR) are changed in the production environment, manually reflect the changes in the disaster recovery environment. However, if the database password is changed, the post-change value is automatically reflected in the disaster recovery environment, so manual reflection is not required.

5.12 Operation of Transparent Data Encryption Using Key Management System

5.12.1 Updating Custom Resource Parameters

When using a newly generated master encryption key in your key management system, update the FEPCluster custom resource fepChildCrVal.sysTde.tdek.targetKeyId to the ID of the new master encryption key. The operator will automatically re-enable TDE when this value is updated.

Also, if the credentials for connecting with the key management system are updated, update the corresponding values in the FEPCluster custom resource. The operator automatically performs a keystore open when the credentials are updated.

When re-enabling TDE or opening the keystore is completed, the following event will be notified.

```
# When re-enabling TDE
$ kubectl get event
LAST SEEN   TYPE    REASON                      OBJECT                       MESSAGE
164m       Normal  SuccessfulTdeSetMasterKey  fepconfig/<FEPClusterCR name> <namespace>, Successfully
set TDE masterKey

# When re-enabling TDE fails
$ kubectl get event
LAST SEEN   TYPE    REASON                     OBJECT                       MESSAGE
164m        Warning  FailedTdeSetMasterKey      fepconfig/<FEPClusterCR name> <namespace>, Error/
Failure set TDE masterKey
```

If the process fails, review the parameters defined in the FEPCluster custom resource and re-enter the correct values.

If only the contents of the Secret or ConfigMap that stores the credentials are updated and the custom resource is not modified, open the keystore using the FEPAction custom resource described in "5.12.2 Update Credentials".

5.12.2 Update Credentials

If the credentials in the key management system are updated, update the contents of the corresponding Secret or ConfigMap. If there are no changes to the values specified in the FEP cluster custom resource, apply the FEPAction custom resource to update the credentials used by FEP.

Example) Definition example of FEPAction custom resource

```
apiVersion: fep.fujitsu.io/v1
kind: FEPAction
metadata:
  name: new-fep-action
spec:
  sysExtraLogging: false
  targetClusterName: nf-131851
  fepAction:
    type: open_tde_masterkey
```

5.12.3 Encrypting a Tablespace

If you create an encrypted tablespace, configure the encryption algorithm in runtime parameters. For example, to create a tablespace named secure_tablespace using AES with a 256-bit key length as the encryption algorithm, define:

```
-- Specify the encryption algorithm for the tablespace to be created below
SET tablespace_encryption_algorithm = 'AES256';
CREATE TABLESPACE secure_tablespace LOCATION /database/tablespaces/tbspace1;
-- Specify that the tablespace to be created below is not to be encrypted
SET tablespace_encryption_algorithm = 'none';
```

Or

```
CREATE TABLESPACE tbs_tst_new LOCATION '/database/tablespaces/tbspace1' WITH
(tablespace_encryption_algorithm = 'AES256' );
```

Checking for encrypted tablespaces

You can check which tablespaces are encrypted by executing the following SQL.

```
SELECT spcname, spcencalgo FROM pg_tablespace ts, pgx_tablespaces tsx WHERE ts.oid =
tsx.spctablespace;
```

5.12.4 Backup/Restore

In case the FEP cluster is damaged or lost, backups should be made at the following times:

- When the cluster is first created
- When the master encryption key is changed

When you use the FEPRestore custom resource to create a cluster restored from backup, the restored cluster is restored with the master encryption key at the time the backup was taken on the source cluster (where the backup was created from).

If a newer master encryption key is specified in sysTde.tdek.targetKeyId than when the source FEPCluster was backed up, the value will be carried over to the restore destination FEPCluster custom resource, and the operator automatically re-enables TDE with the new master encryption key after data recovery.

Also, update the authentication information to the key management system before executing the restore. If your credentials are not up-to-date, FEP will not be able to connect to the key management service and restore your data.

If you mistakenly update the information for connecting to the key management system under sysTde.tdek.kmsDefinition after building FEPCluster, FEP will not be able to refer to the key management system when restoring data. Before executing the restore process, confirm that the correct values are described in the FEPCluster custom resource.

5.12.5 Changing Key Management System Definitions

Modify the parameters under spec.fepChildCrVal.sysTde.tdek.kmsDefinition in the FEPCluster custom resource if you want to add or change the connection information to the key management system.

If you make any of the following changes, the replica server will be restarted with the new parameters. If there are multiple replica servers, they are restarted one at a time. When all replica servers are restarted, one of them is promoted to the new master server due to a switchover. The original master server's container image is then restarted. This allows you to change the definition of the key management system for all servers with minimal disruption.

- Add a new key management system definition
- Delete an existing key management system definition
- Change the order of key management system definitions
- Add, Delete, or rename ConfigMap or Secret resources that you specify as credentials

If you make changes that require a restart, temporarily disable the automatic scale out feature for the database before making the changes. The automatic scale out feature can be disabled with the spec.fepChildCrVal.autoscale.scaleout.policy parameter of the FEPCluster custom resource.

You cannot rename the ConfigMap/Secret resource that you currently specify as the credential for the key management system you are using as the keystore.

5.13 Confidentiality Management Feature

5.13.1 Enabling Confidentiality Management Feature

When building FEPCluster, the extension "pgx_confidential_management_support" of the confidentiality management feature was installed and set up in the following database.

- template1
- postgres
- Database specified in spec.fepChildCrVal.sysUsers.pgdb

In addition, when creating a confidential administrator role (spec.fepChildCeVal.sysUsers.pgSecurityUser), this role is assigned the following functions necessary for executing confidentiality management feature.

- CREATE ROLE
- SELECT, INSERT, UPDATE, and DELETE privileges on all tables included in the extension

Therefore, immediately after FEPCluster is built, database objects can be managed by the confidentiality management feature in a database in which the extension "pgx_confidential_management_support" is installed or in a database created from template1.

Refer to "Confidentiality Management" in the Fujitsu Enterprise Postgres Security Operation Guide for details on how to operate the security management support function.

Refer to "Tables Used by Confidentiality Management Feature" in the Fujitsu Enterprise Postgres Security Operation Guide for tables included in the extension.

In addition, if a database role other than the confidential administrator role needs to operate the confidentiality management feature, such as by preparing a database role for each schema that manages database objects using the confidentiality management feature, the confidentiality management feature assign the following privileges to the datdabase role.

- CREATE ROLE
- SELECT, INSERT, UPDATE, and DELETE privileges on all tables included in the extension

When using the confidentiality management feature to manage database objects created by other users, it is necessary to grant ownership of the database objects to the database role that operates the confidentiality management feature.

Example) When giving ownership of the table "security_table" to the confidential administrator user "security_user"

```
ALTER TABLE security_table OWNER TO security_user;
```

The owner of the database object can be confirmed using the PostgreSQL meta-command "\d".

5.13.2 Monitoring Confidentiality Management Feature

You can forward pgAudit's audit logs to Elasticseach using the FEP logging feature.

Analyze the transferred audit log and monitor for changes in privileges on database objects by unintended users.

For the FEP log feature, please refer to "4.10 FEP Logging".

5.14 Operation of Fixed Statistics

Describes how to periodically fix statistics in the production environment using statistics whose performance is guaranteed in the validation environment.

5.14.1 Preparing for Object Storage Connections

Deploy a secret that contains the credentials required to operate object storage.

5.14.1.1 Using S3

Secret - Name: my-aws-s3-secret

```
data:
aws_access_key: cG9zdGdyZXM=
aws_access_secret: ZnNlcaAZnNlcA3A==
```

5.14.1.2 Using AzureBlob

Secret - Name: my-azure-blob-secret

```
data:
azure_storage_account_name: cG9zdGdyZXM=
azure_storage_account_key: ZnNcG9zdGads3cGzdGdyZXMyZXMlcA==
```

5.14.1.3 Using Google Cloud Storage

Deploy the json file required for authentication with the following command:

```
kubectl create secret generic <sercret> --from-file=key.json=<json file>
```

5.14.2 Storing validation environment statistics in object storage

Run FEPAction to export the validation environment statistics and store them in object storage. Define the connection information to object storage in the FEPCluster custom resource before executing FEPAction.

The following is an example definition of FEPAction that stores a binary file that exports the database "mydatabase" in object storage AWS s3.

Example) Definition example of FEPCluster custom resource

```
spec:
  fep:
    fixedStats:
```

```
    endpoint: #Required
      protocol: s3
      authentication: aws-fixedstats-credentials
```

Example) Definition example of FEPAction custom resource

```
apiVersion: fep.fujitsu.io/v1
kind: FEPAction
metadata:
  name: fep-action-fixdStats
spec:
  fepAction:
    targetClusterName: new-fep #target cluster
    type: fixed_stats
    args:
      fixedStatsType: export
      targetDb: mydatabase
      url: 's3://export_stats/file'
      targetStats: effective
```

5.14.3 Schedule for Fixed Statistics

Define the object storage information and schedule where the statistics are stored in the FEPCluster custom resource in the production environment. You can also add, modify, or delete schedules after they are built.

The following is an example of the FEPCluster custom resource definition for each Friday from 20:00 to 23:00 when the database "mydatabase" is pinned with statistics stored in object storage AWS s3.

Example) Definition example of FEPCluster custom resource

```
spec:
  fep:
    fixedStats:
      schedule1:
        update: true
        fixSchedule: "0 20 * * 5"
        unfixSchedule: "0 23 * * 5"
        targetDb: mydatabase
        url: 's3://export_stats/file '
      endpoint:
        protocol: s3
        authentication: my-aws-s3-secret
```

Once the statistics are downloaded from object storage, they are backed up to the database. Also, spec.fep.fixedStats.schedleN.update will be from true to false.

If you want to update the statistics that you want to freeze, change spec.fep.fixedStats.schedleN.update to ture and run the statistics import from object storage again.

5.14.4 Using Local Storage

If object storage is not available, use local storage.

5.14.4.1 Exporting Statistics Files to FEPCluster in a Validation Environment

Execute FEPAction and export the statistics whose performance is guaranteed in the verification environment to the file system /database/userdata/action/local/ on the container.

Example) Definition example of FEPCluster custom resource

```
spec:
  fep:
```

```
    fixedStats:
      endpoint: #Required
        protocol: local
```

Example) Definition example of FEPAction custom resource

```
apiVersion: fep.fujitsu.io/v1
kind: FEPAction
metadata:
  name: fep-action-fixdStats
spec:
  fepAction:
    targetClusterName: new-fep
    type: fixed_stats
    args:
      fixedStatsType: export
      targetDb: mydatabase
      file: file_name.dump
      targetStats: effective
```

5.14.4.2 Deploying Statistics Files to FEPCluster in a Production Environment

Deploy the statistics binary file under /database/userdata/fixedstats/action/local/ in the primary database of FEPCluster in the production environment.

```
kubectl cp <file-to-copy> \
<namespace>/<primary-pod-name>:/database/userdata/fixedstats/action/local/ -c fep-patroni
```

5.14.4.3 Specify File Names for FEPCluster Custom Resources

Specify the name of the deployed statistics binary file for the FEPCluster custom resource.

Example) Definition example of FEPCluster custom resource

```
spec:
  fep:
    fixedStats:
      schedule1: #Required, N is the identification number
        update: true
        fixSchedule: "0 20 * * 5"  #Required
        unfixSchedule: "0 23 * * 5" #Optional,  If not specified, do not unfreeze
        targetDb: mydatabase #Required
        file: file_name.dump
      endpoint:
        protocol: local
```

5.15 Scheduling of an Aggressive Freeze for Tuples (VACUUM FREEZE)

As an architectural limitation, PostgreSQL has a transaction wraparound problem that can cause the system to stop, and in order to avoid this, it is necessary to collect transaction IDs by freezing tuples.

Tuple freezing works by autovacuum or aggressive freeze for tuples (VACUUM FREEZE). However, with autovacuum alone, in a system where transactions are consumed at a high speed, you may encounter transaction ID wraparound problems. This is because autovacuum is slow to prevent collisions with applications and increases in system load. In such a system, it is necessary to perform aggressive freeze for tuples at an appropriate time.

To avoid such problems, it provides the ability to monitor transaction ID usage and to periodically perform an aggressive freeze for tuples. When an FEPCluster is built with monitoring enabled, monitoring of transaction ID usage is enabled by default.

If AlertManager reports Warning "PostgresqlTooManyTxidUsage", it is possible that autovacuum alone is not sufficient to freeze transaction IDs in time. In such cases, consider enabling the periodic feature of aggressive freeze for tuples.

To enable the periodic execution of aggressive freeze for tuples, set spec.fep.freezingTuples.enable in the FEPClsuter custom resource to true. The default for spec.fep.freezingTuples.enable is false.

The following items can be set.

- Schedule
- Execution period

The following example defines an aggressive freeze for tuples for two schedules: Sunday at 1:00 AM for three hours and Wednesday at 2:00 AM for one hour.

```
spec:
  fep:
    freezingTuples:
      enable: true
      schedule1:
        start: 0 1 * * 0
        executionTime: 10800
      schedule2:
        start: 0 2 * * 3
        executionTime: 3600
```

When scheduling an aggressive freeze for tuples, specify a time period with low business load when tuple freezing will have minimal impact.

Even after aggressive freeze for tuples is scheduled, continue to monitor the trend in transaction ID usage. If you determine that the freezing process is not keeping up with the schedule, you will need to reconsider the schedule. To collect the statistical information required for the review, enable the extended functionality for aggressive freeze for tuples using the following procedure.

1. Set the shared_preload_libraries parameter in postgresql.conf

   ```
   shared_preload_libraries = 'pgx_stat_vacuum_freeze'
   ```

2. Execute the following SQL

   ```
   SELECT datname FROM pg_database WHERE datallowconn = true;
   ```

   Execute the following CREATE EXTENSION for all databases to be output and define the extension.

   ```
   CREATE EXTENSION pgx_stat_vacuum_freeze;
   ```

For information on tuning the allocation time for aggressive freeze for tuples, refer to the Fujitsu Enterprise Postgres Operation Guide.

5.16 Setup of Knowledge Data Management

Knowledge data management is the ability to search and manage data based on semantic relationships using vectors and graphs. It can be used to retrieve and manage knowledge data provided to the Large Language Model (LLM) in systems that use the method of Search Extension Generation (RAG).

In addition to the existing search methods for knowledge data stored in FEP, FEP can use the Knowledge Data Management feature to search for knowledge data in three ways:

- Vector data management feature
- Text semantic search and automatic vectorization
  Hybrid search is also available, combining semantic and full-text search
- Graph Management feature

This section describes how to set up each feature.

5.16.1 Setting up Vector Data Management

5.16.1.1 pgvector Setup

With pgvector, vector storage and similarity searching become standard.

Execute CREATE EXTENSION on the database to use this feature. Then use the psql command to connect to the database to be set up.

```
postgres=# CREATE EXTENSION vector;
CREATE EXTENSION
```

When using the automatic password generation function of SUPERUSER andsetting up this feature, refer to "6.7.1 CREATE EXTENSION" and execute CREATE EXTENSION.

Note that OSS is named "pgvector", but the binaries and the extensions themselves are named "vector".

5.16.1.2 pgvectorscale Setup

Using pgvectorscale can speed up processing of vector data.

Execute CREATE EXTENSION on the database to use this feature. Adding the CASCADE option will also CREATE EXTENSION any dependent pgvector. Then use the psql command to connect to the database to be set up.

```
postgres=# CREATE EXTENSION IF NOT EXISTS vectorscale CASCADE;
CREATE EXTENSION
```

When using the automatic password generation function of SUPERUSER and setting up this feature, refer to "6.7.1 CREATE EXTENSION" and execute CREATE EXTENSION.

Note that OSS is named "pgvectorscale", but the binaries and the extensions themselves are named "vectorscale".

5.16.1.3 Setting Up Vector Database Recall Measurement

Vector databases speed up responses with approximate searches. The comparison between approximate and full search can be represented by a metric called recall.

By measuring recall, you can measure the accuracy of vector database searches.

By regularly measuring the recall rate, you can ensure that the target recall rate is met. If the recall falls below the target, consider tuning the vector database parameters or rebuilding the index.

Operator allows you to periodically measure and monitor the recall of a vector database. This section describes how to enable periodic measurement and monitoring of vector database recall.

By setting spec.fep.measurement.recallForVector.enable to true for the FEPCluster custom resource, the vector database recall measurement is enabled.

When recall measurement is enabled for a vector database, a measurement Cronjob is built. The measurement Cronjob periodically performs approximate and full searches on random vectors for objects in a specified vector database to measure the recall rate.

The measured results are averaged and stored in the table vector_database_recall_summary. By looking at the table, you can see the average recall at the time of measurement.

When the vector database reproduction rate measurement is enabled, by setting spec.fep.monitoring.enable to true and enabling the monitoring feature of FEPExporter, you can collect the information of table vector_database_recall_summary as a metric and monitor the vector database recall rate.

In addition to enabling monitoring, you can define parameter spec.fep.measurement.recallForVector.alertThreshold for the FEPCluster custom resource so that the AlertManager can alert you when the vector database recall falls below the specified value.

5.16.1.3.1 Example of defining an FEPCluster Custom Resource

Provide an example of defining a custom FEPCluster resource that enables vector database recall measurement.

In this example definition, the measurement starts at 0:00 on the first day of each month and ends 40 hours after the measurement starts.

```
spec:
  fep:
    measurement:
      recallForVector:
        enable: true
        schedule: "0 0 1 * *"
        maxDuration: "40h"
        parallelJobs: 5
        topK: 50
        alertThreshold: 0.7 #Specify the alert threshold when monitoring is enabled

        #Specify the database object to measure
        targets:
        - database: "mydb"
          tableConfigs: #Specify multiple objects for the database
          - schemaObject: "schema.table1.column1"
          - schemaObject: "schema.table2.column2"
            distanceMetric: l2

    #Enabling vector database recall measurement and monitoring enables recall monitoring in
Prometheus
    monitoring:
      enable: true
```

Specify a schedule for vector database recall measurement at a time when the workload is low and there is little impact from the measurement.

5.16.1.3.2 vector_database_recall_summary Table

The table vector_database_recall_summar which stores the result of the recall measurement of the vector database, contains the following information. A row is inserted for each object being measured and the information is updated as it is measured.

Column name	Type	Description
db_name	text	Database name
schema_object_name	text	Schema object name
start_time	timestamp with timezone	Start time
end_time	timestamp with timezone	End time
avg_recall	numeric	Average recall
mean_num	numeric	Average number of vectors
expected_sample_size	integer	Expected number of attempts
actual_sample_size	integer	Actual number of attempts
failure_count	integer	Number of failures
created_at	timestamp with timezone	Record insertion time

5.16.1.3.3 Monitoring and notifying Vector Database Recall

If you enable the vector database recall measurement and set spec.fep.monitoring.enable to true for the FEPCluster custom resource, the FEPExporter monitoring feature enables recall monitoring.

Metrics that are valid when vector database recall measurement is enabled

Metrics name	Description
avg_vector_recall	Monitor the recall measure for approximate searches in vector databases.

You can also add the following alert rule by defining the FEPCluster custom resource parameter spec.fep.measurement.recallForVector.alertThreshold:

Alert Rule Added

Metrics name	Description	Metrics name	Description
VectorDbLowRecall	Warning	-	Vector database recall is below the threshold specified by spec.fep.measurement.recallForVector.alertThreshold in FEPCluster custom resource.

5.16.2 Semantic Text Search and Automatic Vectorization

5.16.2.1 Setting up Semantic Text Search and Automatic Vectorization

Semantic text search is a feature in which Fujitsu Enterprise Postgres searches for text data that is semantically similar to the input text without the application processing the vector data.

Automatic vectorization is the ability to automatically generate and manage semantic vectors used for semantic search of text, based on declarative definitions.

Add "pgx_vectorizer" to the parameter "shared _preload_ libraries" of spec.fepChildCrVal.customPgParams in the FEPCluster custom resource.

Execute CREATE EXTENSION for the database that uses this function. Adding the CASCADE option will also enable the dependencies pgai, pgvector, and plpython3u. After CREATE EXTENSION, execute the start_vectorize_scheduler() function to start the vectorize scheduler. Use the psql command to connect to the database you want to set up.

```
postgres=# CREATE EXTENSION IF NOT EXISTS pgx_vectorizer CASCADE;
CREATE EXTENSION
postgres=# SELECT pgx_vectorizer.start_vectorize_scheduler();
```

When using the automatic password generation function of SUPERUSER and setting up this feature, refer to "6.7.1 CREATE EXTENSION" and execute CREATE EXTENSION.

When creating a FEPCluster, the Operator creates a database role called "vectorizerrole" to be used by the automatic vector converter to perform vectorizations in the background.

Specify "vectorizerrole" when registering a user to perform vectorization.

```
postgres=# SELECT pgx_vectorize.set_worker_setting('user', 'VECTORIZE_USER', 'vectorizerrole');
```

If you are connecting to a embedded provider and need to define environment variables such as HTTP_PROXY, refer to "2.3.16 Environment Variable Definition for Container".

For details, refer to Fujitsu Enterprise Postgres Knowledge Data Management Feature User's Guide.

5.16.2.2 Setting up Hybrid Search Feature

Hybrid search is available by performing "5.16.2.1 Setting up Semantic Text Search and Automatic Vectorization".

To use GIN or GiST indexes as full-text indexes, enable the extension by adding "pg_trgm" or "pg_bigm" to the parameter "shared_preload_libraries" in spec.fepChildCrVal.customPgParams of the FEPCluster custom resource. Here is an example from pg_bigm:

Execute CREATE EXTENSION for the database that uses this function. Use the psql command to connect to the database you want to set up.

```
postgres=# CREATE EXTENSION IF NOT EXISTS pg_bigm;
CREATE EXTENSION
```

When using the automatic password generation function of SUPERUSER and setting up this feature, refer to "6.7.1 CREATE EXTENSION" and execute CREATE EXTENSION.

For more information, including how to perform hybrid searches and how to tune them, refer to Fujitsu Enterprise Postgres Knowledge Data Management Feature User's Guide.

Upgrading Extensions

To use this function in an environment where pgx_vectorizer of version ubi9-17-2.x or earlier has been set up in the FEP server container tag, you need to upgrade the extension. After upgrading the operator, perform the version upgrade following the procedure below. Connect to the database that you want to set up using the psql command:

```
postgres=# ALTER EXTENSION vector UPDATE;
postgres=# ALTER EXTENSION ai UPDATE;
postgres=# ALTER EXTENSION pgx_vectorizer UPDATE;
```

If you are using the automatic password generation feature of SUPERUSER and you want to set up this feature, refer to "6.7.2 ALTER EXTENSION" and execute the alter_extension command of ALTER EXTENSION.

5.16.3 Setting up Graph Management Feature

Apache AGE enables you to manage graph databases and search, manipulate, and update graph data.

Execute CREATE EXTENSION on the database to use this feature. Then use the psql command to connect to the database to be set up.

```
postgres=# CREATE EXTENSION age;
CREATE EXTENSION
```

When using the automatic password generation function of SUPERUSER and setting up this feature, refer to "6.7.1 CREATE EXTENSION" and execute CREATE EXTENSION.

Execute a LOAD statement for each session to use Apache AGE, or add 'age' to the session_preload_libraries parameter of spec.fepChildCrVal.customPgParams for the FEPCluster custom resource.

```
postgres=# LOAD 'age';
LOAD
```

5.16.4 Setting up Model Management in the Database

Add "pgx_inference" to the "shared_preload_libraries" parameter in the spec.fepChildCrVal.customPgParams section of the FEPCluster custom resource. This will launch the load launcher.

Additionally, add the number of databases for which this feature is enabled plus one to the "max_worker_processes" parameter. This determines the number of load launchers started by this feature.

Building the Inference Server

We provide a Dockerfile for building the inference server as a sample file. The Dockerfile is stored in the operator's Pod. Use the command below to retrieve the Dockerfile.

```
# Use the following command to check the OperatorPod name.
$ kubectl get pods --selector=name=fep-ansible-operator -o name pod/fep-ansible-operator-5985969857-
ldj2x
# For Linux clients, copy the plugin using the following command.
$ kubectl cp fep-ansible-operator-5985969857-ldj2x:/opt/fepopr-dockerfile/inference-triton.docker
<destination-path>/inference-triton.docker
```

Please build the inference server from the acquired Docker file. For build details, refer to the Fujitsu Enterprise Postgres Knowledge Data Management Feature User's Guide. After building, store the image in the container repository. Use the following command to push the inference server:

```
$ podman push my-triton-image:latest repository.io/triton-inference-server
```

5.16.5 Setting up MCP Server

5.16.5.1 Creating a Secret for MCP Tool Definitions

Refer to the official documentation for MCPToolbox for databases for setup procedures.

To load the MCP tool definitions obtained during the installation procedure into the MCP server, create a Secret using the following steps.

```
kubectl create secret generic mcp-secret \
    --from-file=/dir_for_mcp/tools.yaml \
    --namespace=your-namespace          # Namespace for creating toolbox servers
```

5.16.5.2 Creating an MCP Server

The following is an example of a deployment for creating an MCP server in a Kubernetes environment. The secret created above is mounted by specifying it in volumeMounts.

```
apiVersion: apps/v1
kind: Deployment
metadata:
  name: toolbox-kubernetes
  namespace: your-namespace # The namespace specified when creating the secret
spec:
  selector:
    matchLabels:
      app: toolbox
  template:
    metadata:
      labels:
        app: toolbox
    spec:
      containers:
        - name: toolbox
          # Recommend to use the latest version of toolbox
          image: us-central1-docker.pkg.dev/database-toolbox/toolbox/toolbox:latest
          args: ["--address", "0.0.0.0"]
          ports:
            - containerPort: 5000
          volumeMounts:
            - name: toolbox-config
              mountPath: "/app/tools.yaml"
              subPath: tools.yaml
              readOnly: true
      volumes:
        - name: toolbox-config
          secret:
            secretName: toolbox-config
            items:
            - key: tools.yaml
              path: tools.yaml
```

5.16.5.3 Creating Services for the MCP Gateway

Create a service for connecting to the MCP Gateway.

```
kubectl apply -f k8s_service.yaml --namespace $NAMESPACE
```

An example of the service is shown below.

```
apiVersion: v1
kind: Service
metadata:
```

```
  name: toolbox-service
  namespace: your-namespace # The namespace provided when creating the secret
spec:
  selector:
    app: toolbox
  ports:
    - port: 5000
      targetPort: 5000
  type: LoadBalancer
```

5.17 Setup of Job Scheduler

pg_cron allows SQL statements to run a job scheduler.

Add "pg_cron" to the parameter "shared _preload_ libraries" of spec.fepChildCrVal.customPgParams in the FEPCluster custom resource. Increase the parameter “max_worker_processes” as needed. In addition to one resident process of pg_cron, max_worker_processes must be increased depending on the number of concurrently running jobs.

```
postgres=# CREATE EXTENSION pg_cron;
CREATE EXTENSION
```

When using the automatic password generation function of SUPERUSER and setting up this feature, refer to "6.7.1 CREATE EXTENSION" and execute CREATE EXTENSION.

5.18 Operation of Multi-master Replication

5.18.1 Verifying the Creation Status of Multi-master Replication

The status of multi-master replication defined in the multi-master replication configuration file can be checked in the preparation_multi_master_replication table within the postgres database.

5.18.1.1 preparation_multi_master_replication table

Column name	Description
replicaction_name	Replication name to create
database_name	Database name for replication
operation	create delete
state	Status of replication creation or deletion Pending: Replication creation or deletion is pending Failed: Replication creation or deletion failed Created: Replication has been created
message	Error messages are stored when replication creation fails
processing_time	Last updated time

If the deletion process succeeds, the row in this table is deleted.

5.18.2 Adding and Removing Participating Nodes

After establishing bidirectional logical replication, nodes can still be added or removed.

This feature is primarily used in the following two scenarios:

1. Business scale expansion/contraction (increase/decrease in service locations)
    - Purpose: Deploying services to new regions (new locations) due to business growth, or scaling down systems due to cost optimization or location closures.
    - Decision: Implemented as a planned change based on business requirements.
2. Failure Response (Isolating Failed Nodes)
    - Purpose: To exclude nodes experiencing long-term failures from the group and maintain healthy operation of remaining nodes (e.g., preventing disk exhaustion).
    - Judgment: Implemented when isolation is prioritized over recovery in the following situations:
        - Prolonged Communication Loss: When recovery is not feasible due to network segmentation or hardware failure.
        - Avoiding Resource Constraints: When Write-Ahead Logs (WAL) for the failed node continue accumulating, beginning to consume disk space on the remaining nodes.

5.18.2.1 Adding Participating Nodes

Prepare a Service (NodePort/LoadBalancer, etc.) from existing participating nodes that can reach the new node's master database, and determine the hostName and port. If using mTLS, prepare certificates/CA and ensure TLS information can be defined in the new node's replicationHosts[].

Add the new node's element to the spec.fep.multiMasterReplication.replicationHosts[] of existing participating nodes (all FEPCluster nodes). Define pgAdminPassword and, if necessary, pgAdminTls, then apply. For subsequent steps, proceed with the "4.19.1 Configuration" process.

5.18.2.2 Removing Participating Nodes

For all remaining FEPClusters, remove the target node's element from spec.fep.multiMasterReplication.replicationHosts[]. After that, defining update_multi_master_replication in spec.fepAction.type and applying the FEPAction custom resource will trigger the deletion of the target node.

For databases where replication has already been created (preparation_multi_master_replication.state='Created'), the Operator behaves as follows:

- Detach the target node using pgactive.pgactive_detach_nodes().
- Only if detachment is confirmed, delete the FOREIGN SERVER/USER MAPPING for that node.
- If it fails during the process, stop the deletion and treat it as a failure.

5.18.3 Add/Remove Multi-master Replication

This document describes the procedures for adding or removing multi-master replication for a new database between database clusters that already have multi-master replication configured.

- Modify the multi-master replication definition file to add or remove replication definitions
- If the target database for the replication to be created does not exist, create the database
- Apply the FEPAction custom resource to reflect the definition file changes on the database nodes

Detailed explanations for each step follow.

5.18.3.1 Modifying Multi-master Replication Definition Files

Modify the multi-master replication definition file.

To add a new replication, add an array element and define the replication targets.

If the databaseName is not specified and you need to add replication target databases after cluster construction, execute the next turn without modifying the definition.

To delete an existing replication, specify "delete" in the "state" option of the corresponding replication definition. Deleting an array element does not delete the replication.

5.18.3.2 Creating a Database

When adding a database for multi-master replication, create the database to be replicated. For restrictions regarding the replicated database, refer to the chapter on multi-master replication in the Fujitsu Enterprise Postgres Cluster Operation Guide (Multi-master Replication).

FEPOperator adds several extensions to the template1 database. Since tables created by these extensions cannot be replicated, to make the database you create eligible for multi-master replication, use the template0 database as the template when creating your database.

5.18.3.3 Updating Multi-master Replication Using FEPAction Custom Resources

After defining the specification, set spec.fepAction.type to update_multi_master_replication and apply the FEPAction custom resource.

Below is an example definition.

```
apiVersion: fep.fujitsu.io/v1
kind: FEPAction
metadata:
  name: new-fep-update-replication
  namespace: myns
spec:
  fepAction:
    type: update_multi_master_replication
  args:
     targetRplication: m-replication-1
  targetClusterName: new-fep
```

If the databaseName is not defined in the multi-master replication definition file and a database is created after enabling multi-master replication, applying the FEPAction custom resource will include the added database in the replication scope.

If the "pgactive" extension has not been created with CREATE EXTENSION for the replicated database, the Operator will create the extension with CREATE EXTENSION before creating the replication.

When all defined replication updates succeed, the FEPAction custom resource's "fepActionStatus: fepActionCondition" is set to "Success".

If some updates fail, fepActionCondition is set to "Failed", and "fepActionResult" lists the names of the replication instances that failed to update.

If fepActionCondition is Failed, check the preparation_multi_master_replication table in the postgres database to determine the reason for failure.

To modify only a specific replication within the replication definition, specify `spec.args.targetReplicationName` to perform the modification only on the designated replication.

Chapter 6 Maintenance Operations

This chapter describes the maintenance operation after deploying the container.

6.1 Minor Version Upgrade

This section explains the steps for minor upgrade of a container image.

Before upgrading each container version, please refer to "Chapter 3 Operator Installation" to update your operators. Also, please refer to RedHat's ecosystem catalog for updated information on each container.

You can upgrade the container image by changing the parameters of the FEPCluster custom resource.

Parameter	Description
spec.fep.image.image	Update the FEP container image.
spec.fepChildCrVal.backup.image.image	Update the backup container image.
spec.fep.feputils.image	Update the container image responsible for cloud secret management feature.
spec.fep.remoteLogging.image	Update the container image that handles the Log Collection feature.

After changing the custom resource parameters, if you have multiple FEPPods, restart the Pods one by one from the replica server to upgrade the container image. Once all replica servers are upgraded, one of them will be promoted to master server. The old master server's Pods are then restarted and the container images are upgraded.

These rolling upgrades allow you to upgrade all container images with minimal disruption to your business.

Note

The upgrade process will cause an outage on the cluster for the duration to upgrade both Master and Sync Replica. If there is no Sync Replica in the cluster, the outage is limited to the length of time to upgrade the Master (or actually the failover time required to take another replica been promoted by patroni).

6.2 Cluster Master Switchover

You can switch a master instance to a replica instance in the event of a master instance performance failure or planned node maintenance.

Specify "switchover" for the action type of the FEPAction CR to update FEPAction CR.

Equivalent Kubernetes command: kubectl apply -f <new_spec>

The "switchover" action type requires the user to specify the name of the target cluster on which to perform the switchover. The args section is not needed for switchovers, as FEPAction internally identifies the pod to switch from and promotes a new master pod.

```
spec:
fepAction:
 type: switchover
 targetClusterName: new-fep
```

Refer to "FEPAction Custom Resource Parameters" in the Reference for more information on parameters.

6.3 Perform PITR and the Latest Backup Restore from Operator

It can be used to restore a database to a specific location due to an application failure or to prepare a duplicate database for production.

Restore process can restore data by creating a CR (FEPRestore CR) for the restore as follows:

oc create -f [Custom Resource Files]

Example)

```
$oc create -f config/samples/postgres_v1_restore.yaml
```

There are two methods of restoring: restoring data to an existing FEPCluster or restoring data to a new FEPCluster.

When restoring to an existing FEPCluster, information such as the FEPCluster name, IP address, and various settings remain the same.

If you restore to a new FEPCluster, the FEPCluster name is the one you specified in CR and the new IP address is also given. If the setting value is not specified, the new cluster will inherit the settings from the restore source cluster, but you can change the settings to create a new cluster by specifying them in CR.

6.3.1 Setting Item

Refer to "FEP Restore Custom Resource Parameters" in the Reference for the items to be set in a custom resource file.

6.3.2 After Restore

Switching connections to the new cluster

The restore creates a new FEPCluster. If necessary, you need to set up Pgpool-II and change the access point of the application to the new cluster or the new Pgpool-II.

Backup data of the destination cluster

PITR restores to the pre-restore time are not possible, because the backup of the destination cluster begins after the restore completes.

6.4 Restoring a Multi-Master Replication Database Cluster

As recovery use cases, there are instances where operations can continue within the region, and cases where the region itself experiences network outages or similar issues, necessitating a switch to a partner region. The recovery procedures for each use case are described below.

6.4.1 When Continuation is Possible Within the Region

If the primary container goes down, one of the replica containers can be promoted to primary and continue operations.

6.4.2 When switching between regions

When continuing operations in a different region, ensure the application can run in that region by migrating the application and modifying communication destinations.

Ensure the service is definitively stopped in the other region. Additionally, if the stoppage is due to a temporary network outage or other automatically recoverable cause, data duplication may occur because replication logs sent immediately before the stoppage are delivered. Before resuming operations in the target region, use the pgactive_apply_pause function to stop log reception.

When performing a rollback, follow the recovery steps below.

Handling data discrepancies during the failure is fundamentally the same as recovering the original region.

- When restoring the previous environment as-is

Once connectivity with the other region is reestablished after recovery, the stalled replication logs will resume. Resume operations in the original region.

- When building a new environment

After creating an empty database, add the new region to the operational region.

6.4.3 When the Database Stops in All Regions

If the database stops in all regions, you can restore from backup data by storing it in object storage.

Refer to "5.11.1 Disaster Recovery by Backup/Restore Method" to build an FEPCluster in one region. At this time, create the multi-master replication configuration file and Service resource to prepare for building the multi-master replication.

In the multi-master replication configuration file, specify the FEPCluster restored from backup data as the replicationOwner.

After building the FEPCluster, apply the update_multi_master_replication custom resource to enable multi-master replication.

In another region, build an empty database and replicate data by having it join the multi-master replication built by the previously constructed FEPCluster.

6.5 Major Version Upgrade

Describes the procedure for upgrading the major version of the operator and FEP container.

A major version upgrade of a FEP builds a new major version of the FEP in the same Namespace as the previous major version of the FEP. At this time, by defining the "spec.fepChildCrVal.upgrade" field in FEPClusterCR, the operator creates the upgrade execution container. The upgrade execution container uses the previous version of FEP Cluster specified in "spec.fepChildCrVal.upgrade.sourceCluster" as the data source FEPCluster and migrates the data to the newly created FEPCluster.

6.5.1 Pre-work on the Data Source FEP Cluster

Stop the running business application before executing the major version upgrade.

Next, edit "spec.fepChildCrVal.customPgHba" of the data source FEPCluster Custom Resource to allow the connection of the upgrade execution container.

The addresses that are allowed to connect are specified as follows:

```
<fep>-upgrade-pod.<fep>- upgrade-headless-svc.<namespace>.svc.cluster.local
```

<fep> specifies the name of the newly created FEPCluster Custom Resource.

The authentication method can be either trust/md5/cert.

Example of Editing a FEPCluster Custom Resource in a Data Source:

```
apiVersion: fep.fujitsu.io/v2
kind: FEPCluster
metadata:
  name: source-fep
  namespace: my-namespace
spec:
  fepChildCrVal:
    customPgHba: |
      host  all  all  destination-fep-upgrade-pod. destination-fep-upgrade-headless-svc. my-
namespace.svc.cluster.local  trust
...
```

6.5.2 Operator Upgrade

Describes the instructions for upgrading the operator.

Note

After an operator upgrade, any custom resource configuration changes you defined in the previous version are not reflected in the container.

6.5.2.1 Uninstalling the Old Operator

Uninstall the old operator.

Select "Uninstall Operator" from "Operators"> "Installed Operators"> "Fujitsu Enterprise Postgres <Old version> Operator"> Actions.

6.5.2.2 Installing a New Version of the Operator

Refer to "Chapter 3 Operator Installation" to install the new version of the operator.

6.5.3 Major Version Upgrade of FEP

6.5.3.1 Creating a New FEPCluster CR

Refer to the Reference to define a new major version of the FEPCluster custom resource. At this time, allow the running upgrade container to connect as you did in "6.5.1 Pre-work on the Data Source FEP Cluster".

In addition, a major version upgrade of FEP is performed by defining the "spec.fepChildCrVal.upgrade" field, as in the following example of defining a FEPCluster custom resource.

The upgrade execution container uses PV to store dump files retrieved from the FEPCluster of the data source.

If you have not enabled the automatic PV provisioning feature in your Kubernetes environment, create a PV for the upgrade in addition to the new PV for the FEPCluster before creating the FEPCluster custom resource.

Also, edit "spec.fepChildCrVal.customPgHba" to allow the connection of the upgrade execution container, as in "6.5.1 Pre-work on the Data Source FEP Cluster".

Example of Defining a FEPCluster Custom Resource to Perform an Upgrade:

```
apiVersion: fep.fujitsu.io/v2
kind: FEPCluster
metadata:
  name: destination-fep
  namespace: my-namespace
spec:
  fep:
    ...
  fepChildCrVal:
    upgrade
      sourceCluster: source-fep-cluster
      storage:
        size: 8Gi
    customPgHba: |
      host  all  all  destination-fep-upgrade-pod.destination-fep-upgrade-headless-svc.my-
namespace.svc.cluster.local  trust
    ...
```

FEPCluster Custom Resource Fields "spec.fepChildCrVal.upgrade"

Field	Default	Details
spec.fepChildCrVal.upgrade		Optional When this field is defined, a major version upgrade is performed. However, if spec.fepChildCrVal.restore is defined, the FEPCluster build stops.
spec.fepChildCrVal.upgrade.sourceCluster		Specify the FEPCluster CR name of the data migration source. Be sure to specify spec.fepChildCrVal.upgrade when defining it.
spec.fepChildCrVal.upgrade.mcSpec.limits	cpu: 200m	Optional

Field	Default	Details
	memory: 300Mi	Specify the maximum number of resources allocated to the upgrade execution container.
spec.fepChildCrVal.upgrade.mcSpec.requests	cpu: 100m memory: 200Mi	Optional Specify the lower limit of resources allocated to the upgrade execution container.
spec.fepChildCrVal.upgrade.image		Optional If omitted, the URL of the image is obtained from the operator container environment.
spec.fepChildCrVal.upgrade.imagePullPolicy	IfNotPresent	Optional Specify the pull policy for the container image. - Always - IfNotPresent - Never
spec.fepChildCrVal.upgrade.source.pgAdminTls.certificateName		Optional If the data source FEPCluster used "cert" as the authentication method for the Upgrade Execution Container, use the secret certificate that defines spec.fepChildCrVal.sysUsers.pgAdminTls.certificateName for the data source FEPCluster. If the above parameter is not defined, it points to the Kubernetes TLS secret containing the certificate of the Postgres user "postgres" in the data source. Refer to "4.8.2.1 Manual Certificate Management" for information about creating secrets.
spec.fepChildCrVal.upgrade.destination.pgAdminTls.certificateName		Optional If the newly created FEPCluster used the "cert" authentication method for the running upgrade container, use the secret certificate that defines the spec.fepChildCrVal.sysUsers.pgAdminTls.certificateName of the newly created FEPCluster. If the above parameter is not defined, it points to the Kubernetes TLS secret containing the certificate of the

Field	Default	Details
		newly created Postgres user "postgres". Refer to "4.8.2.1 Manual Certificate Management" for information about creating secrets.
spec.fepChildCrVal.upgrade.storage		Optional Defines storage for storing dump files.
spec.fepChildCrVal.upgrade.storage.storageClass		Optional If omitted, the default storage class of the operating environment will be used.
spec.fepChildCrVal.upgrade.storage.size	2Gi	Optional Specify the size of the storage to store the dump file.
spec.fepChildCrVal.upgrade.storage.accessModes	ReadWriteOnce	Optional Storage access mode for storing dump files As an array of access modes. e.g. [ReadWriteMany] If omitted, it is treated as [ReadWriteOnce].

Note

Connect to the database and run the following SQL to check the size of the database in advance:

```
$ SELECT pg_size_pretty(sum(pg_database_size(datname))) AS dbsize FROM pg_database;
```

Since the pg_dumpall command used in the upgrade execution container outputs the database data as an SQL command, the file actually created is as follows.

For example, the integer type 2147483647 is 4 bytes for database data.

However, this is 10 bytes because SQL commands output them as strings. Therefore, make sure that the storage (PV) for dump files has sufficient disk space.

6.5.3.2 Verifying FEP Major Upgrade Complete

If you migrate your data to the new FEPCluster and the FEP major version upgrade is successful, the following event will be output:

```
$ kubectl get event
LAST SEEN  TYPE    REASON               OBJECT                                          MESSAGE
164m       Normal  SuccessfulFepUpgrade fepupgrade/<Name of the new FEPClusterCR>  <namespace>,
Successfully FEP Upgrade
```

In addition, the following annotation will be added to YAML in FEPClusterCR:

```
apiVersion: fep.fujitsu.io/v2
kind: FEPCluster
```

```
metadata:
  annotations:
    FEPUpgradeDone: true
...
  name: destination-fep-cluster
  namespace: my-namespace
spec:
...
```

Note

When a major upgrade of FEP fails, an event similar to the following is output:

```
$ kubectl get event
LAST SEEN   TYPE     REASON            OBJECT                                          MESSAGE
164m        Warning  FailedFepUpgrade  fepupgrade/<Name of the new FEPClusterCR>  <namespace>, Error/
Failure in FEP Upgrade
```

Obtain the Kubernetes resource information listed in the OBJECT column, review the output messages, and then recreate the new FEPCluster custom resource.

```
$ kubectl describe fepupgrade/<Name of the new FEPClusterCR>
```

6.5.4 Updating Each Custom Resource

Describes the procedures for each custom resource used to operate the FEPCluster for the data source after the major FEP upgrade is complete.

After this process is complete, resume the suspended business applications.

6.5.4.1 Removing a FEPClusterCR for a Data Source

Delete the FEPCluster for the data source.

For the Openshift GUI console:

From "Operators" > "Installed Operators" > "Fujitsu Enterprise Postgres < New version > Operator" > "FEPCluster" > "FEPCluster name to delete" > Actions, select "Delete FEPCluster".

6.5.4.2 FEPPgpool2

Re-create FEPPgpool2 to match the version of the client with the version of the upgraded FEP.

6.5.4.3 FEPExporter Built in Standalone Mode

Edit the FEPExporter custom resource "spec.fepExporter.fepClusterList" to specify the new version of the FEPCluster custom resource.

Refer to "FEPExporter Custom Resource" in the Reference for more information about the parameters.

6.6 Assigned Resources for Operator Containers

The following resources are allocated by default to the operator containers provided by this product.

```
resources:
limits :
  cpu: 2
  memory: 1536Mi
requests :
  cpu: 500m
  memory: 768Mi
```

If there is only one FEPCluster custom resource managed by an operator, it can be operated with the resource assigned by default. However, when deploying and operating multiple FEPCluster custom resources, change the assigned resource of the operator container.

Note

If you have changed the resource, the resource value will revert to the default value after the operator version upgrade. Therefore, change the resource again after upgrading the operator.

6.6.1 How to Change Assigned Resources

Describes how to change the resources assigned to an operator container.

When updating resources assigned to an operator container, the operator container is recreated. At this time, the operation of already built containers such as FEPCluster will not stop.

How you change the allocated resources depends on how the operator was installed.

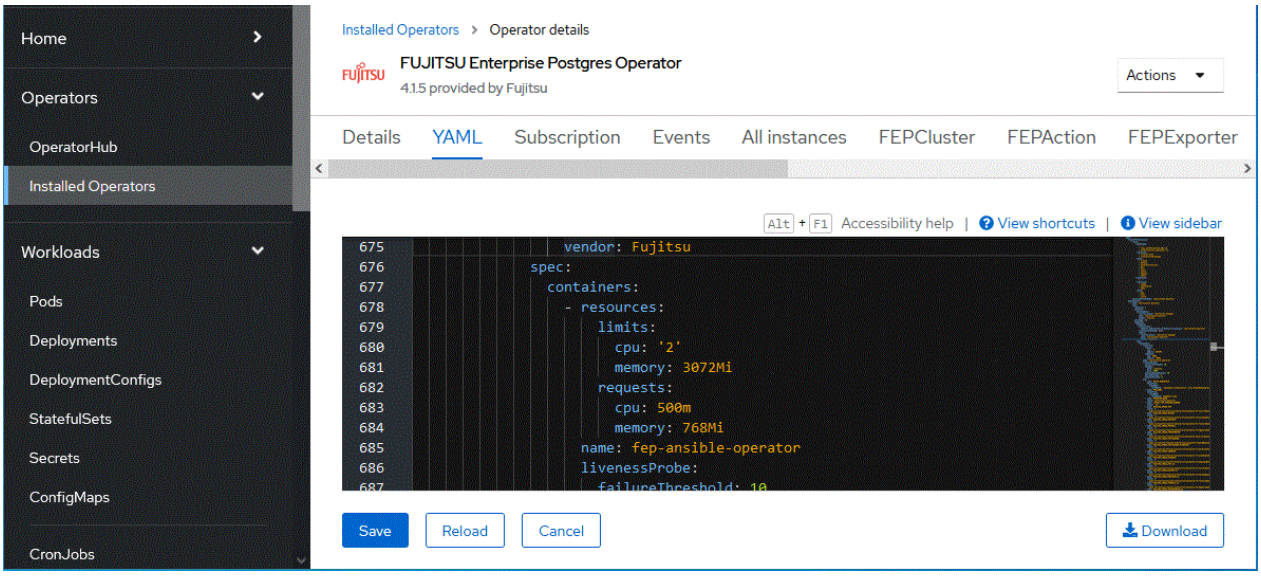
6.6.1.1 When installing using OperatorHub

If you are using an operator installed from OperatorHub To change the resources assigned to the operator container, edit the ClusterServiceVersion (CSV).

Editing the CSV "spec.install.spec.deployments[0].spec.template.spec.containers[0].resources" will recreate the operator container and apply the specified resources.

When editing CSV from the OCP GUI console

Click [Installed Operators] in the menu item under Operators and select the installed operator. On the [YAML] tab, edit the specified part of the allocation resource and click [Save].



When editing CSV from the CUI console using the OC client

Check the CSV name of the installed operator with the "oc get" command.

```
$ oc get csv
NAME                                      DISPLAY                                VERSION   REPLACES   PHASE
fujitsu-enterprise-postgres-operator.v4.1.5   Fujitsu Enterprise Postgres Operator
4.1.5                Succeeded
```

Edit the CSV with the "oc edit" command.

```
$ oc edit csv fujitsu-enterprise-postgres-operator.v4.1.5
```

6.6.1.2 When installing using Helm Chart or RancherUI

If the operator is installed using Helm Chart or RancherUI, edit the deployment of the operator container to change the resources assigned to the operator container.

Editing the Deployment's "spec.template.spec.containers[0].resources" will recreate the operator container and apply the specified resources.

Edit the Deployment "fep-ansible-operator" with the "kubectl edit" command.

```
$ kubectl get deployment fep-ansible-operator
NAME                   READY   UP-TO-DATE   AVAILABLE   AGE
fep-ansible-operator   1/1     1            1           2m10s

$ kubectl edit deployment fep-ansible-operator
```

6.7 Using SUPERUSER Privilege

6.7.1 CREATE EXTENSION

When executing the CREATE EXTENSION command to install external extensions for PostgreSQL, there are extensions that can only be installed by SUPERUSER. To install such extensions we make use of the FEPAction custom resource.

By specifying "create_extension" in spec.fepAction.type of FEPAction custom resource, CREATE EXTENSION can be executed for the specified FEPCluster container.

Please refer to the Reference for how to use.

6.7.2 ALTER EXTENSION

When you execute the UPDATE command of ALTER EXTENSION to upgrade an extension after installing an external PostgreSQL extension and performing CREATE EXTENSION, some extensions can be updated only by SUPERUSER. The FEPAction custom resource is used to update such extensions.

By specifying "alter_extension" in the spec.fepAction.type of the FEPAction custom resource, you can execute ALTER EXTENSION on the specified FEPCluster container.

Please refer to the Reference for how to use.

6.7.3 Change Password of SUPERUSER

To update the password of SUPERUSER "postgres", specify update_admin_password for fepActionType of the FEPAction custom resource.

Recreate the password with a random value and update it.

Please refer to the Reference for how to use.

6.7.4 Using SUPERUSER

If SUPERUSER privileges are required for database operation, you can obtain the password for SUPERUSER "postgres" by following the steps below.

1. Get the base64-encoded password from the Secret with the same name as the FEPCluster custom resource name.

   Example) When the FEPCluster custom resource name is new-fep

   ```
   $ kubectl get -o yaml secret new-fep | grep PG_ADMIN_PASSWORD
     PG_ADMIN_PASSWORD: YWRtaW4tcGFzc3dvcmQ=
   ```

2. Decode the obtained password.

```
$ echo YWRtaW4tcGFzc3dvcmQ= | base64 -d
admin-password
```

Note

In order to prevent SUPERUSER from being used by a third party, please set Kubernetes Role permissions to the Secret so that only the database administrator can refer it.

Chapter 7 Abnormality

This chapter describes the actions to take when an error occurs in the database or an application, while FEP is operating.

Depending on the type of error, recover from the backed-up material, reserve capacity, check the operator log, and check the FEP log.

7.1 Handling of Data Abnormalities

Recover the database cluster from the backup immediately prior to failure in any of the following cases:

- A hardware failure occurs on the data storage disk or the backup data storage disk.
- If the data on the disk is logically corrupted and the database does not work correctly
- Data corruption caused by user error

Refer to "6.3 Perform PITR and the Latest Backup Restore from Operator" for restore instructions.

7.2 Handling when the Capacity of the Data Storage Destination or Transaction Log Storage Destination is Insufficient

If you run out of space in the data storage location, first check if there are any unnecessary files on the disk, and then delete them so that you can continue working.

If deleting unnecessary files does not solve the problem, you may need to migrate the data to a larger disk.

Use a backup restore to migrate data.

You can use the FEPRestore custom resource to build a new FEPCluster and migrate data. Refer to "FEPRestore Custom Resource Parameters" in the Reference.

7.3 What to do when the Capacity of the Backup Data Storage Area is Insufficient

If you run out of space in the backup data destination, first check the disk for unnecessary files, and then delete the unnecessary files. Or reduce the backup retention generation.

By specifying backup_expire in spec.fepAction.type of the FEPAction custom resource, you can reduce the number of backup generations saved. Refer to "FEPAction Custom Resource Parameters" in the Reference for details.

7.4 Handling Access Abnormalities When Instance Shutdown Fails

If an instance fails to start or stop, refer to the Operator log and the FEP log to determine the cause.

For checking the operator log and the FEP log, refer to "7.5 Collection of Failure Investigation Information".

7.5 Collection of Failure Investigation Information

If the cause of the trouble that occurred during the construction or operation of the environment is not identified, information for the initial investigation is collected.

I will explain how to collect information for the initial investigation.

- Product log
- Operator log

Product log

FEP log

Get into the container and collect the log.

The log location is specified by log_directory in the custom resource FEP Clusterspec.startupValues.customPgParam parameter. The default is/database/log.

Pgpool-II log

Get into the container and collect the log.

The log location is/var/log/pgpool/pool.log.

Operator log

Check the operator log as follows.

Verification Example

```
$oc get po
NAME                                    READY   STATUS    RESTARTS   AGE
fep-ansible-operator-7dc5fd9bf7-4 smzk   1/1     Running   0          20m
```

How to check the log

```
$oc logs pod fep-ansible-operator-7dc5fd9bf7-4 smzk -c manager
```

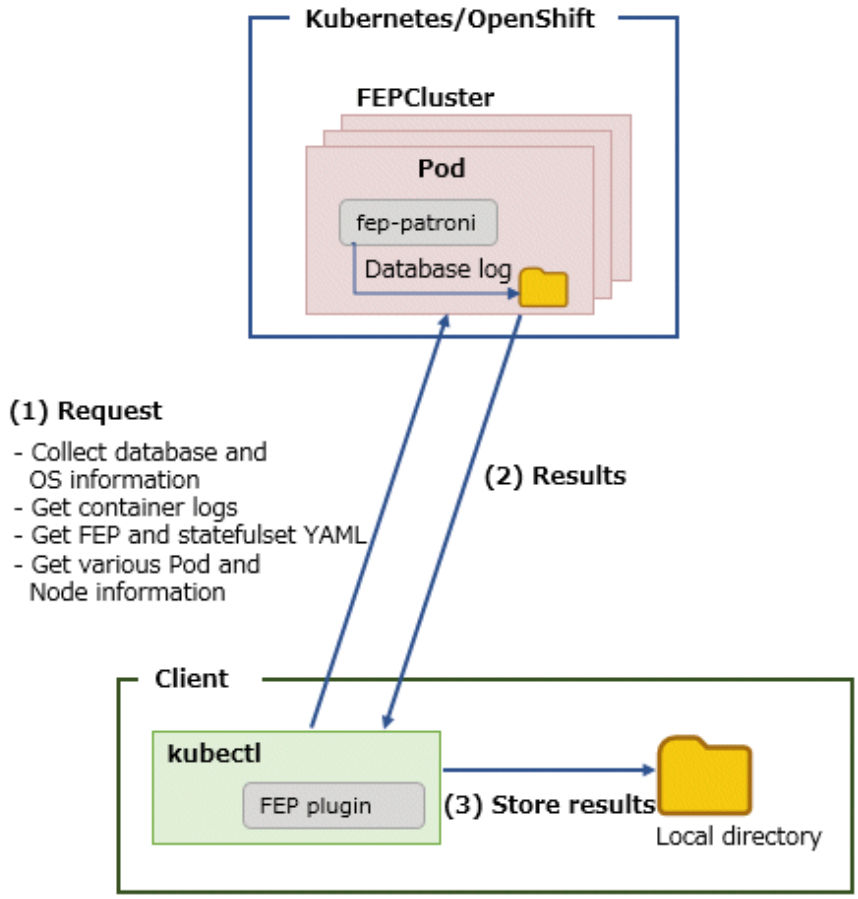
The log will be output to the console. Please check the file output by redirection.

7.6 Log Collection Tool

The Log Collection Tool is a client tool for the FEP container environment, that allows logs, and other useful environment and statistical information, to be retrieved from FEP containers running on a specified FEP cluster on Kubernetes/OpenShift. The collected information is stored locally in a filesystem directory on the client machine, for subsequent analysis.

The purpose of the tool is to obtain helpful diagnostic and troubleshooting information, in the case that an FEP containers is, for example, non-responsive, has terminated abnormally or exhibits abnormal performance.

The Log Collection Tool collects container-specific information as well as database and OS information.



7.6.1 Logs Collected

The following logs and information are collected by the Log Collection Tool:

- FEPCluster

Type of log(s)	Source
OS information and statistics, FEP catalog contents, database logs	fep-patroni (FEP server) container, in each pod
FEP yaml	FEP cluster
Statefulset yaml	FEP cluster
Container logs	Output of "kubectl log -p" for the FEP cluster
Container logs before restart	Output of "kubectl log -p" for the FEP cluster
Detailed pod information, for the namespace	"kubectl get pods -n <namespace> -o wide" output
Detailed node information, for the Kubernetes cluster	"kubectl get nodes -o wide" output
Pod CPU and memory utilization, for the namespace	"kubectl top pod -n <namespace>" output
Node CPU, memory, and resource utilization, for the Kubernetes cluster	"kubectl top node" output
fepautoscale	"get, describe, auth can-i" output
fepbackup	"get, describe, auth can-i" output
fepcerts	"get, describe, auth can-i" output
fepconfigs	"get, describe, auth can-i" output
fepupgrades	"get, describe, auth can-i" output

Type of log(s)	Source
fepusers	"get, describe, auth can-i" output
fepvolumes	"get, describe, auth can-i" output
configmap	"get, describe, auth can-i" output
stateful set	"get, describe, auth can-i" output
cronjob	"get, describe, auth can-i" output
service account	"get, describe, auth can-i" output
deployments	"get, describe, auth can-i" output
replicaset	"get, describe, auth can-i" output
Env	Folder where environmental information is stored
nodes	"get, describe, auth can-i" output
pvc	"get, describe, auth can-i" output
service	"get, describe, auth can-i" output
hpa	"get, describe, auth can-i" output
route	"get, describe, auth can-i" output
pv	"get,auth can-i" output
secret	"get,auth can-i" output

- Operator

For logs retrieved via the operator, when operating at the cluster scope, the output will be filtered by namespace name.

Type of log(s)	Source
Operator Container Logs	"kubectl logs" output
Operator Container Restart Logs	"kubectl logs -p" output
Operator Pod Information	"get,describe,top pod" output
Operator yaml	
deployment yaml	
Utils Container Logs	"kubectl logs -p" output
Utils Container Restart Logs	"get,describe,top pod" output
clusterrole	"get,describe,auth can-i" output Only files within the cluster scope are output.
role	"get,describe,auth can-i" output Only files within the namespace are output.
clusterrolebinding	"get,describe,auth can-i" output Only files within the cluster scope are output.
rolebinding	"get,describe,auth can-i" output Only files within the namespace are output.

- Feprestore

Type of log(s)	Source
Feprestore Container Logs	"kubectl logs" output
Feprestore Container Restart Logs	"kubectl logs -p" output

Type of log(s)	Source
Feprestore Pod Information	"get,describe,top pod" output
Feprestore yaml	

- Fepexporter

Type of log(s)	Source
Fepexporter Container Logs	"kubectl logs" output
Fepexporter Container Restart Logs	"kubectl logs -p" output
Fepexporter Pod Information	"get,describe,top pod" output
Fepexporter yaml	

- Feplogging

Type of log(s)	Source
Feplogging Container Logs	"kubectl logs" output
Feplogging Container Restart Logs	"kubectl logs -p" output
Feplogging Pod Information	"get,describe,top pod" output
Feplogging yaml	

- Fepaction

Type of log(s)	Source
Fepaction Container Logs	"kubectl logs" output
Fepaction Container Restart Logs	"kubectl logs -p" output
Fepaction Pod Information	"get,describe,top pod" output
Fepaction yaml	

- Feppgpool2

Type of log(s)	Source
Feppgpool2 Container Logs	"kubectl logs" output
Feppgpool2 Container Restart Logs	"kubectl logs -p" output
Feppgpool2 Pod Information	"get,describe,top pod" output
Feppgpool2 yaml	
feppgpool2certs	"get,describe,auth can-i" output

7.6.2 Location and Dependencies

The Log Collection Tool is the kubectl plugin "kubectl-fep". Add Log Collection Tool as subcommands to kubectl to extend the command line syntax.

To use the Log Collection Tool, the service account used when executing commands must be granted appropriate privileges. "get" and "list" privileges are required for the resources to be collected. The following are the privileges required for the Log Collection Tool to collect all resources.

```
verbs:
- get
- list
resources:
```

```
  - nodes
  - namespaces
  - pods
  - serviceaccounts
  - services
  - events
  - configmaps
  - roles
  - rolebindings
  - clusterrole
  - clusterrolebinding
  - persistentvolume
  - persistentvolumeclaims
  - deployments
  - replicasets
  - statefulsets
  - cronjob
  - horizontalpodautoscalers
```

Log Collection Tool are stored in the operator's Pod. Install it on the Kubernetes client machine using the command below. <destination-path> specifies the storage location of the plugin.

```
1.Check the OperatorPod name with the command below.
$ kubectl get pods --selector=name=fep-ansible-operator -o name
pod/fep-ansible-operator-5985969857-ldj2x

2. Copy the plugin.
# Linux Client
$ kubectl cp fep-ansible-operator-5985969857-ldj2x:/opt/fepopr-kubectl-plugin/kubectl-fep
<destination-path>/kubectl-fep

# Windows Client
$ kubectl cp fep-ansible-operator-5985969857-ldj2x:/opt/fepopr-kubectl-plugin/kubectl-fep.ps1
<destination-path>/kubectl-fep.ps1
```

The Log Collection Tool kubectl plugin is installed on client machines along with the kubectl/oc command for remote access to the target Kubernetes/Openshift environment. Specify the directory where both the kubectl plugin and the kubectl/oc command are stored in the PATH environment variable. Also, set appropriate execution privileges for the plugin.

```
# If the kubectl plugin "kubectl-fep" is stored under /home/client-user/.local/bin
$ export PATH=/home/client-user/.local/bin:${PATH}
$ chmod +x /home/client-user/.local/bin/kubectl-fep
```

On a client machine, the kubectl/oc command supports different methods of authentication/login to the Kubernetes Cluster (e.g., username + password, TLS client certificates, OAuth token) that allow different users to execute the command, provided they have suitable privileges to the Kubernetes Cluster.

The diagnostic logs collected by the Log Collection Tool are stored locally on the filesystem on the client.

7.6.3 User Interface

The Log Collection Tool is invoked through the kubectl plugin command-line interface.

7.6.3.1 Command-Line Syntax

The command-line syntax of the Log Collection Tool is shown below.

The Log Collection Tool corresponds to the "cluster logs" subcommand of the FEP kubectl plugin.

There is a companion "cluster list" subcommand which displays the list of FEP clusters in the specified namespace.

Usage:

```
kubectl fep cluster logs -n <NAMESPACE> [-o <OUTPUT-DIRECTORY>] [-d <DATABASE>] <FEP-CLUSTER>
kubectl fep operator logs -n <NAMESPACE> [-on <operatornamespace>] [-o <OUTPUT-DIRECTORY>]
kubectl fep restore logs -n <NAMESPACE> [-o <OUTPUT-DIRECTORY>] <FEP-RESTORE>
kubectl fep action logs -n <NAMESPACE> [-o <OUTPUT-DIRECTORY>] <FEP-ACTION>
kubectl fep logging logs -n <NAMESPACE> [-o <OUTPUT-DIRECTORY>] <FEP-LOGGING>
kubectl fep pgpool2 logs -n <NAMESPACE> [-o <OUTPUT-DIRECTORY>] <FEP-PGPOOL2>
kubectl fep exporter logs -n <NAMESPACE> [-o <OUTPUT-DIRECTORY>] <FEP-EXPORTER>
kubectl fep all logs -n <NAMESPACE> [-on <operatornamespace>] [-o <OUTPUT-DIRECTORY>]
kubectl fep cluster list -n <NAMESPACE>
kubectl fep operator list -on <operatornamespace>
kubectl fep restore list -n <NAMESPACE>
kubectl fep action list -n <NAMESPACE>
kubectl fep logging list -n <NAMESPACE>
kubectl fep pgpool2 list -n <NAMESPACE>
kubectl fep exporter list -n <NAMESPACE>
kubectl fep all list -n <NAMESPACE>

#For cluster-scope, specify the namespace where the target operator exists with -on
```

Note that for the Openshift Container Platform, the Openshift "oc" command can be used as an alternative to "kubectl", as it has the same features as the kubectl binary, but it has been further extended to natively support the OCP features.

Windows considerations

The command-line syntax for invoking the FEP kubectl plugin (but not supplying its command parameters) may differ between Operating Systems, due to the type of executable that the plugin is implemented as.

For example, under Windows, since the FEP kubectl plugin is implemented as a Powershell script the plugin needs to be invoked directly, rather than indirectly from kubectl/oc.

From a Command Prompt:

Powershell 5.1:

```
powershell kubectl-fep …
```

Powershell 7+:

```
pwsh -command kubectl-fep …
```

From a Powershell Window:

```
kubectl-fep …
```

An additional consideration is the current Powershell "ExecutionPolicy" in effect, which may block Powershell scripts from being run for security reasons, if they are not signed. In this case, since the FEP kubectl plugin is a trusted script, the ExecutionPolicy can be bypassed for the script execution, using the following syntax:

Powershell 5.1:

```
powershell -executionpolicy bypass kubectl-fep …
```

Powershell 7+:

```
pwsh -executionpolicy bypass -command kubectl-fep …
```

7.6.4 Log Collection Directory

7.6.4.1 Command-Line Specification

The Log Collection Tool output directory may optionally be specified using the -o flag, and if the directory exists, it must be empty. If the output directory is not specified, the following default output directory is used:

Linux:

```
/tmp/fep_cluster_logs_<namespace>_<cluster>_<date>_<time>
```

Windows:

```
%TEMP%\fep_cluster_logs_<namespace>_<cluster>_<date>_<time>
```

7.6.4.2 Directory Structure

The Log Collection Tool collects logs when a command is executed. The output directory is as follows. For items under the Env directory, it collects all information for each resource within the namespace specified by -n.

- FEPCluster

```
log/
├─── fepcluster/
│    ├─── get-fep
│    └─── <cluster-name>/
│         ├─── describe_fep
│         ├─── get_yaml_fep.yaml
│         ├─── pod/
│         │    ├─── <pod-name>/
│         │    │    ├─── fjqssinf/
│         │    │    ├─── get-yaml-pod.yaml
│         │    │    ├─── describe_kubeod
│         │    │    └─── containerlog/
│         │    │         ├─── patroni.log
│         │    │         ├─── patroni-restart.log
│         │    │         ├─── fepbackup.log
│         │    │         ├─── fepbackup-restart.log
│         │    │         ├─── feplogging-fluentbit.log
│         │    │         └─── feplogging-fluentbit-restart.log
│         │    └─── cronjob-pod/
│         │         ├─── get-yaml-pod.yaml
│         │         ├─── describe-pod.yaml
│         │         └─── containerlog/
│         ├─── service/
│         │    ├─── get_service
│         │    ├─── describe_service
│         │    ├─── authcan_i_service
│         │    └─── get-yaml-service.yaml
│         ├─── statefulset/
│         │    ├─── get_sts
│         │    ├─── describe_sts
│         │    ├─── authcan_i_sts
│         │    └─── sts-yaml
│         ├─── cronjob/
│         │    ├─── get_cronjob
│         │    ├─── describe_cronjob
│         │    ├─── authcan_i_cronjob
│         │    └─── get-yaml-cronjob.yaml
│         ├─── deployment/
│         │    ├─── get_deployment
│         │    ├─── describe_deployment
│         │    ├─── authcan_i_deployment
│         │    └─── get-yaml-deployment
│         ├─── replicaset/
│         │    ├─── get_replicaset
│         │    ├─── describe_replicaset
│         │    ├─── authcan_i_replicaset
```

```
│       │    └──── get-yaml-replicaset
│       └──── childcr/
│           ├──── backup/
│           │    ├──── get_backup
│           │    ├──── describe_backup
│           │    └──── auth_can_i
│           ├──── autoscale/
│           │    ├──── get_autoscale
│           │    ├──── describe_autoscale
│           │    └──── auth_can_i
│           ├──── certs/
│           │    ├──── get_certs
│           │    ├──── describe_certs
│           │    └──── auth_can_i
│           ├──── config/
│           │    ├──── get_config
│           │    ├──── describe_config
│           │    └──── auth_can_i
│           ├──── user/
│           │    ├──── get_user
│           │    ├──── describe_user
│           │    └──── auth_can_i
│           ├──── volumes/
│           │    ├──── get_volumes
│           │    ├──── describe_volumes
│           │    └──── auth_can_i
│           ├──── upgrade/
│           │    ├──── get_upgrade
│           │    ├──── describe_upgrade
│           │    └──── auth_can_i
│           └──── cronjob/
│               ├──── get_cronjob
│               ├──── describe_cronjob
│               └──── auth_can_i
```

- Operator

```
├──── fep-ansible-operator/
│    ├──── pod/
│    │    ├──── get-yaml-pod.yaml
│    │    └──── logs/
│    │        ├──── operator.log
│    │        ├──── operator-restart.log
│    │        ├──── utils.log
│    │        ├──── utils-restart.log
│    │        ├──── init-container.log
│    │        └──── init-container-restart.log
│    ├──── deployment/
│    │    ├──── get_deployment
│    │    ├──── describe_deployment
│    │    ├──── get-yaml-deployment.yaml
│    │    └──── authcan_i_deployment
│    ├──── service/
│    │   ├──── get_service
│    │   ├──── describe_service
│    │   ├──── get-yaml-service.yaml
│    │   └──── authcan_i_service
│    └──── replicaset/
│        ├──── get_replicaset
│        ├──── describe_replicaset
```

```
│        ├──── authcan_i_replicaset
│        └──── get-yaml-replicaset
```

- Feprestore

```
├──── feprestore/
│    ├──── get_restore
│    └──── <restore-cr-name>/
│        ├──── describe_restore
│        ├──── get_yaml_restore.yaml
│        └──── pod/
│            ├──── get_pod
│            ├──── describe_pod
│            ├──── get_yaml_pod.yaml
│            └──── logs/
│                ├──── restore.log
│                └──── restore-restart.log
```

- Fepexporter

```
├──── fepexporter/
│    ├──── get_exporter
│    └──── <exporter-cr-name>/
│        ├──── describe_exporter
│        ├──── get_yaml_exporter.yaml
│        ├──── pod/
│        │    ├──── get_yaml_pod.yaml
│        │    ├──── get_pod
│        │    ├──── describe_pod
│        │    └──── logs/
│        │        ├──── exporter.log
│        │        └──── exporter-restart.log
│        ├──── deployment/
│        │    ├──── get_deployment
│        │    ├──── describe_deployment
│        │    ├──── authcan_i_deployment
│        │    └──── get_yaml_deployment.yaml
│        ├──── replicaset/
│        │    ├──── get_replicaset
│        │    ├──── describe_replicaset
│        │    ├──── authcan_i_replicaset
│        │    └──── get_yaml_replicaset.yaml
│        └──── service/
│            ├──── get_service
│            ├──── describe_service
│            ├──── authcan_i_service
│            └──── get_yaml_service.yaml
```

- Feplogging

```
├──── feplogging/
│    ├──── get_feplogging
│    └──── <logging-cr-name>/
│        ├──── describe_feplogging
│        ├──── get_yaml_feplogging.yaml
│        ├──── pod/
│        │    ├──── get_yaml_pod.yaml
│        │    ├──── get_pod
│        │    ├──── describe_pod
│        │    └──── logs/
```

```
│        │        ├─── feplogging-fluentd.log
│        │        └─── feplogging-fluentd-restart.log
│        ├─── deployment/
│        │    ├─── get_deployment
│        │    ├─── describe_deployment
│        │    ├─── authcan_i_deployment
│        │    └─── get_yaml_deployment.yaml
│        ├─── replicaset/
│        │    ├─── get_replicaset
│        │    ├─── describe_replicaset
│        │    ├─── authcan_i_replicaset
│        │    └─── get_yaml_replicaset.yaml
│        └─── service/
│             ├─── get_service
│             ├─── describe_service
│             ├─── authcan_i_service
│             └─── get_yaml_service.yaml
```

- Fepaction

```
├─── fepaction/
│    ├─── fepaction.yaml
│    ├─── get_fepaction
│    └─── describe_fepaction
```

- Feppgpool2

```
├─── feppgpool2/
│    ├─── get_feppgpool2
│    ├─── describe_feppgpool2
│    ├─── get_yaml_feppgpool2.yaml
│    └─── <pgpool-cr-name>/
│         ├─── service/
│         │    ├─── get_service
│         │    ├─── describe_service
│         │    ├─── get-yaml-service.yaml
│         │    └─── authcan_i_service
│         ├─── childcr/
│         │    └─── feppgpool2certs/
│         │         ├─── get_feppgpool2certs
│         │         ├─── describe_feppgpool2certs
│         │         └─── auth_cani_feppgpool2certs
│         ├─── pod/
│         │    ├─── get_pod
│         │    ├─── describe_pod
│         │    ├─── get_yaml_pod.yaml
│         │    └─── logs/
│         │         ├─── feppgpool2.log
│         │         └─── feppgpool2-restart.log
│         ├─── deployment/
│         │    ├─── get_deployment
│         │    ├─── describe_deployment
│         │    ├─── authcan_i_deployment
│         │    └─── get_yaml_deployment.yaml
│         ├─── replicaset/
│         │    ├─── get_replicaset
│         │    ├─── describe_replicaset
│         │    ├─── authcan_i_replicaset
│         │    └─── get_yaml_replicaset.yaml
│         └─── service/
```

```
│            ├─── get_service
│            ├─── describe_service
│            ├─── authcan_i_service
│            └─── get_yaml_service.yaml
```

- resourcelist

```
├─── resourcelist/
│    ├─── get_pod
│    ├─── top_pod
│    ├─── get_node
│    ├─── top_node
│    ├─── get_event
│    ├─── get_all
│    ├─── get_secret
│    └─── get_storageclass
```

- Env

```
└─── env/
    ├─── hpa/
    │    ├─── get
    │    ├─── describe
    │    └─── authcan_i
    ├─── persistentvolumeclaim/
    │    ├─── get_persistentvolumeclaim
    │    ├─── describe_persistentvolumeclaim
    │    └─── authcan_i_persistentvolumeclaim
    ├─── serviceaccount/
    │    ├─── get_serviceaccount
    │    ├─── describe_serviceaccount
    │    └─── authcan_i_serviceaccount
    ├─── nodes/
    │    ├─── get
    │    ├─── describe
    │    └─── authcan_i
    ├─── clusterrole/
    │    ├─── get
    │    ├─── describe
    │    └─── auth_cani
    ├─── clusterrolebinding/
    │    ├─── get
    │    ├─── describe
    │    └─── authcan_i
    ├─── role/
    │    ├─── get
    │    ├─── describe
    │    └─── authcan_i
    ├─── rolebinding/
    │    ├─── get
    │    ├─── describe
    │    └─── authcan_i
    ├─── configmap/
    │    ├─── get
    │    ├─── describe
    │    └─── authcan_i
    └─── persistentvolume/
        ├─── get_persistentvolume
        ├─── describe_persistentvolume
        └─── authcan_i_persistentvolume
```

Appendix A Quantitative Values and Limitations

A.1 Quantitative Values

Refer to the Fujitsu Enterprise Postgres Installation and Setup Guide for Server.

A.2 Limitations

Note

If you log in to a container and edit the configuration file directly, restarting the container may undo your changes.

If you want to change the settings, modify the custom resource files as described in "5.2 Configuration Change" and reapply. Depending on the parameters to be changed, the container may be redeployed. Refer to "5.2 Configuration Change" for details of the parameters.

Unavailable FEP features

Since FEP server container is based on other components (like UBI and Patroni), there are certain limitations that doesn't allow it to be 100% functionally capable to VM based server instance. The known limitations are as below.

No	Limitation	Reason for Limitation	Description
1	Crypto Express cards are not supported	IBM LinuxOne doesn't support CryptoExpress cards in Openshift container platform at this stage.	FEP TDEz extension cannot be used on LinuxOne Openshift environment. However, User can still use TDE on both LinuxOne Openshift environment as well as Azure (x86) Openshift environment.

Fixed parameter

Some parameters cannot be changed. Refer to "2.3.5.2 Parameters that cannot be Set".

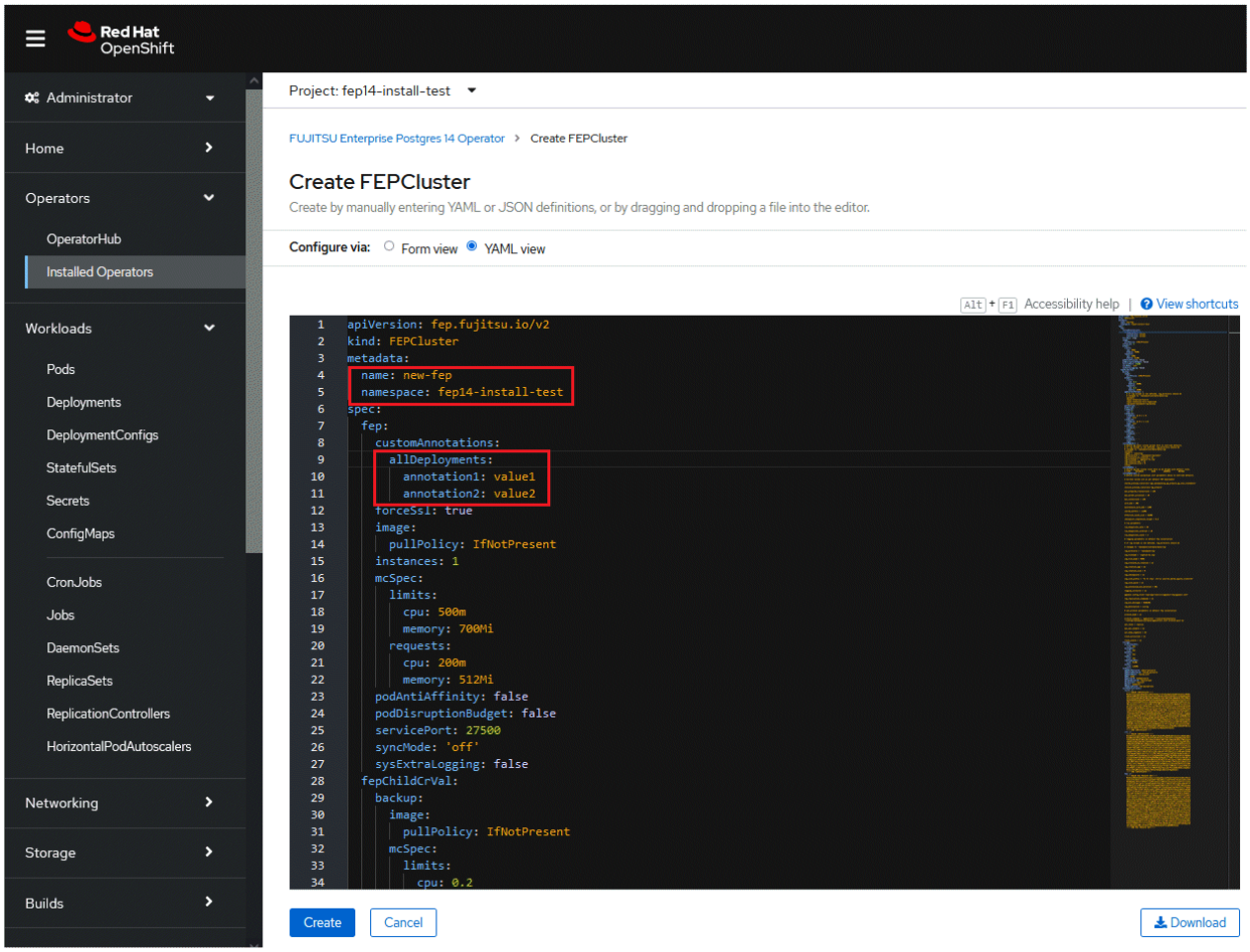
FEP features that needs to be set when using

Refer to "2.3.7 FEP Unique Feature Enabled by Default".

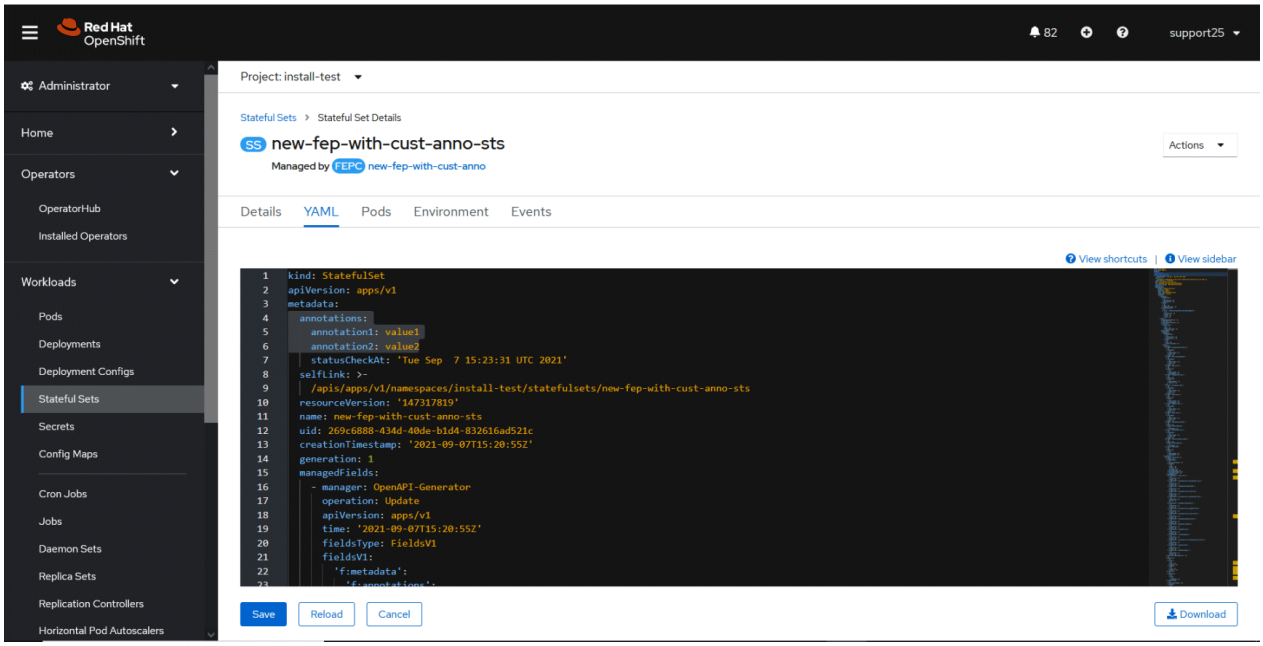
Appendix B Adding Custom Annotations to FEPCluster Pods using Operator

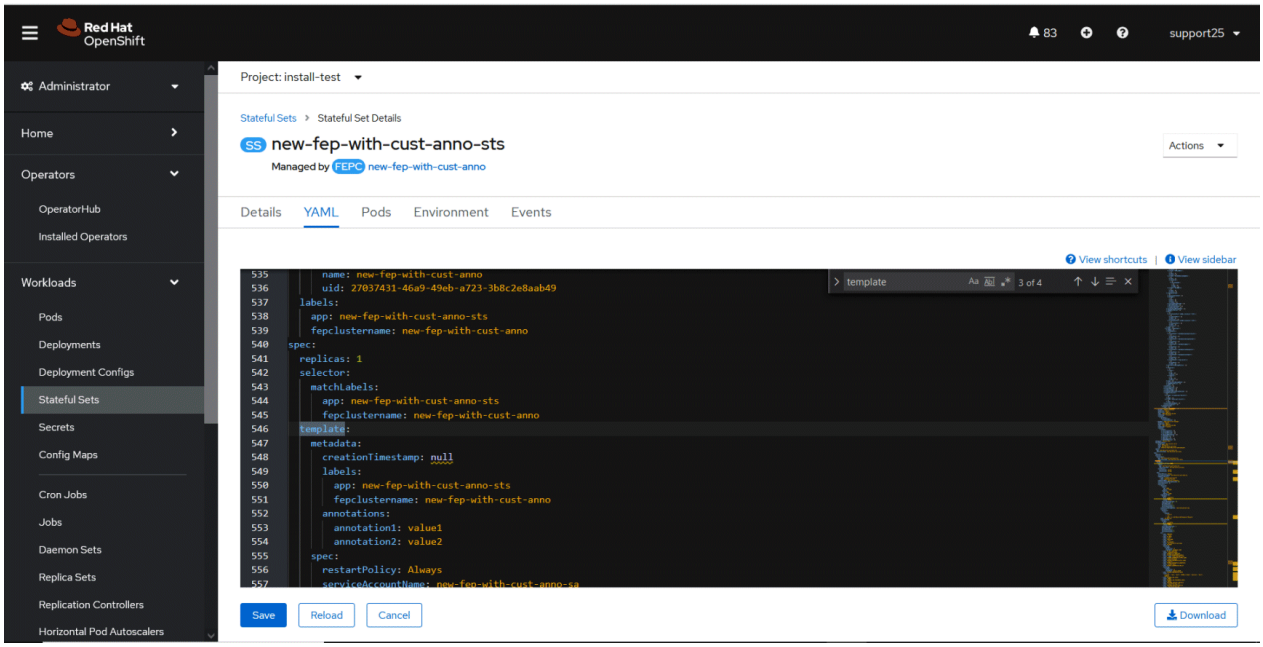
This section describes instructions for adding custom annotations to a FEPCluster pod.

1. In YAML view of the Create FEPCluster section, add custom annoatations as below and then click on Create.



2. Both the Statefulset and its resulting pods will be annotated with your prvided annotations: archivewalVol and backupVol must be ReadWriteMany.





Appendix C Utilize Shared Storage

Explains how to build a FEPCluster when using shared storage.

Use a disk where PV accessModes can specify ReadWriteMany.

This chapter shows an example of using NFS as PV in static provisioning.

C.1 Creating a StorageClass

Create a StorageClass.

In the OCP WebGUI screen, click "StorageClass" in the main menu "Storage", then press "Create Storage Class" > "Edit YAML" and edit YAML to create the StorageClass.

If you are using the CLI, create a yaml file and create a StorageClass with the following command:

```
$ oc create -f <file_name>.yaml
```

YAML definitions are created with reference to the following samples.

Example)

```
apiVersion: storage.k8s.io/v1
kind: StorageClass
metadata:
  name: < StorageClass Name >
provisioner: kubernetes.io/no-provisioner
reclaimPolicy: Delete
volumeBindingMode: WaitForFirstConsumer
```

C.2 Creating a PersistentVolume

Create as many PersistentVolumes (PV) as you need.

On the Web GUI screen, click "PersistentVolumes" in the main menu "Storage", click "Create PersistentVolume", and edit YAML to create PV.

If you are using the CLI, create a yaml file and create a PV using the following command:

```
$ oc create -f <file_name>.yaml
```

YAML definitions are created with reference to the following samples.

The StorageClass name specifies the StorageClass created in "C.1 Creating a StorageClass".

Assign a different NFS directory for each PV.

In addition, accessModes is ReadWriteMany.

Example)

```
apiVersion: v1
kind: PersistentVolume
metadata:
  name: < PV name >
spec:
  capacity:
    storage: < Capacity Required ex.8Gi >
  accessModes:
  - ReadWriteMany
  persistentVolumeReclaimPolicy: Retain
  mountOptions:
    - hard
  nfs:
```

```
    path: < NFS directory path (Assign a different directory for each PV) ex. /nfs/pv >
    server: < IP address of the NFS server ex. 192.168.1.10>
  storageClassName: < StorageClass name created in "C.1 Creating a StorageClass">
```

C.3 Creating FEPCluster

Specifies that ReadWriteMany PV is used in the YAML definition in step 4 of "4.1 Deploying FEPCluster using Operator".

In spec.fepChildCRVal.storage, specify the StorageClass and AccessModes of the PV created in "C.2 Creating a PersistentVolume".

The "spec.fepChildCRVal.storage.<Volume Type>.size" should be less than or equal to the PV allocated.

Example) Using PV created by archivewalVol and backupVol

```
apiVersion: fep.fujitsu.io/v2
kind: FEPCluster
metadata:
  name: t3-fep
spec:
  ~ Suppress ~
  fepChildCrVal:
    storage:
      archivewalVol:
        size: < Capacity Required ex. 8Gi >
        storageClass: <StorageClass name created in C.1 Creating a StorageClass" >
        accessModes:
        - "ReadWriteMany"
      backupVol:
        size: < Capacity Required ex. 8Gi >
        storageClass: <StorageClass name created in C.1 Creating a StorageClass" >
        accessModes:
        - "ReadWriteMany"
  ~ Suppress ~
```

Appendix D Key Management System Available for Transparent Data Encryption

Describes the key management system available for transparent data encryption.

D.1 KMIP Server

Refer to "To Connect to a key Management System Using the KMIP Protocol" in the Fujitsu Enterprise Postgres Installation and Setup Guide for Server for KMIP server requirements.

D.2 AWS Key Management Service

D.2.1 Available Services

By using the AWS KMS adapter, you can use encryption keys on the Key Management Service (hereafter referred to as AWS KMS) provided by AWS. There is no region restriction as long as it is a region supported by AWS KMS.

D.2.2 Available AWS KMS Keys

The KMS key's key spec must be "symmetric". "asymmetric" keys cannot be used. Also, the KMS key usage must be ENCRYPT_DECRYPT.

D.2.3 Required Privileges

For the KMS key to be used, the following operations must be permitted for the user accessing AWS KMS.

- Encrypt
- Decrypt
- DescribeKey

D.2.4 Key ID

The following can be specified as key IDs for the TDE key management system linkage feature.

- Key ARN

D.3 Azure Key Management Service

D.3.1 Available Services

Accessible via Azure's Key Vault API using the Azure KMS Adapter, and a key management service is available that allows you to use symmetric keys.

Refer to below for key management services for which symmetric keys are available.

https://learn.microsoft.com/en-us/azure/key-vault/keys/about-keys#key-types-and-protection-methods

Refer to below for Azure key management services.

https://learn.microsoft.com/en-us/azure/security/fundamentals/key-management#azure-key-management-services

D.3.2 Available Keys

A symmetric key is available.

D.3.3 Available Algorithms

The following algorithms are available during encryption/decryption operations.

- A256GCM

D.3.4 Key Operation

For the key to be used, the following operations must be permitted for the user who accesses Azure's key management service.

- encrypt
- decrypt
- get

D.3.5 Key ID

The following can be specified as key IDs for the TDE key management system linkage feature.

- Key object identifier

D.3.6 Sign In

Sign in to Azure using your service principal. You will need your application ID, tenant ID, and credentials to sign in.

 See

Refer to below for service principals.

https://learn.microsoft.com/en-us/cli/azure/create-an-azure-service-principal-azure-cli#4-sign-in-using-a-service-principal

Appendix E Fluent Bit Integration Using Custom Secret

Describes the Fluent Bit integration using custom secret.

E.1 Create Custom Secret

E.1.1 Sample fluent-bit.yaml template

fluent-bit.yaml

```
---
env:
  flush_interval: 5                  # Interval in seconds for flushing logs to outputs
  tail_path: /databaselogs/*.csv      # File path pattern for application logs (CSV format)
  audit_tail_path: /databaselogs/audit/*.log   # File path pattern for audit logs
  tail_db_path: /databaselogs/postgreslog.db   # Path to DB tracking log read positions for app logs
  audit_tail_db_path: /databaselogs/auditlog.db  # Path to DB tracking log read positions for audit
logs
  skip_long_lines: on                # Skip lines longer than the buffer limit
  refresh_interval: 60               # Interval in seconds to refresh and check log files
  read_from_head: true               # Start reading logs from the beginning of the file
  multiline: on                      # Enable processing of multiline log entries
  parser_firstline: firstline_app_parser    # Parser for the start of multiline entries in app logs
  parser_audit_firstline: firstline_audit_parser  # Parser for the start of multiline entries in audit
logs
  rotate_wait: 20                    # Time to wait before completing log file rotation
  storage_type: memory               # Type of storage used for logs, here using memory

service:
  flush: ${flush_interval}           # Sets the flush interval using the `flush_interval` variable
  daemon: off                        # Runs Fluent Bit in the foreground
  log_level: info                    # Sets log verbosity to 'info' level
  parsers_file: parsers.conf         # Specifies the file containing custom parsers
  http_server: On                    # Enables the built-in HTTP server for metrics and health checks
  http_listen: 0.0.0.0               # Configures the HTTP server to listen on all network interfaces
  http_port: 2020                    # Sets the port for the HTTP server
  hot_reload: On                     # Enables hot reload of the configuration without restarting

pipeline:
  inputs:
    - name: tail                     # Uses the `tail` plugin to monitor and read log files
      db: ${tail_db_path}            # Database file to track reading positions of log files
      tag: app-*                     # Tags logs with `app-*` for filtering/routing later
      path: ${tail_path}             # Path to the log files using `tail_path` variable
      Skip_Long_Lines: ${skip_long_lines}  # Skips lines longer than the buffer can handle
      Refresh_Interval: ${refresh_interval}  # Interval to refresh monitored files for new data
      Read_from_head: ${read_from_head}  # Reads logs from the start of the file
      Multiline: ${multiline}          # Enables support for multiline log entries
      Parser_Firstline: ${parser_firstline}  # Parser for identifying the start of multiline logs
      rotate_wait: ${rotate_wait}      # Time to wait before considering log file rotation complete

  filters:
    - name: parser                   # Applies a parser to the logs matching `app-*` tag
      match: app-*                   # Only processes logs tagged with `app-*`
      key_name: log                  # Specifies the key containing the log message to parse
      parser: app_parser             # Parser to use for the log messages
    - name: rewrite_tag              # Modifies log tags for re-emission
      match: app-*                   # Matches logs tagged with `app-*`
      rule: '$log_time "[^,]+"  appcsv-.$TAG[1].$TAG[2].$TAG[3].$TAG[4] false'  # Rule for renaming
tags
```

```
      emitter_name: re_emitted_appcsv # Name of the emitter for re-emitted logs
     emitter_storage.type: ${storage_type}  # Storage type for re-emitted logs, using `storage_type`
variable

  outputs:
    - name: azure_blob                # Azure Blob Storage Output plugin name
      match: "*"                      # Matches all logs for output to Azure Blob Storage
      account_name: <azure_storage_account>      # Azure Storage account name
      shared_key: <shared_key>     # Shared key for authentication with Azure
      path: < multiline_parser>         # Path within Blob Storage where logs are stored
      container_name: <fluentbit-aug28>  # Container name in Azure Blob Storage
      auto_create_container: on       # Automatically create the container if it doesn't exist
      tls: on                         # Enables TLS encryption for secure communication
      net.dns.resolver: legacy        # Uses legacy DNS resolver

    - name: es                         # Elasticsearch Output plugin name
     match: "*"                      # Matches all logs for this output plugin; the asterisk (*) means
all tags
     host: <Elasticsearch_Host>        # The hostname or IP address of the Elasticsearch server
     port: <Elasticsearch_Port>        # The port on which Elasticsearch is running (usually 9200)
     index: <fluentbit>              # The name of the index where logs will be stored in Elasticsearch
     type: _doc                   # The document type in Elasticsearch; _doc is the preferred type for
ES 7.x and  later
     http_user: <HTTP_User>           # Username for HTTP Basic Authentication to access Elasticsearch
     http_passwd: <HTTP_Password>      # Password for HTTP Basic Authentication
     tls: On                         # Enables TLS (Transport Layer Security) for secure communication
with Elasticsearch
     tls.verify: Off  # Disables verification of the Elasticsearch server's TLS certificate (not
recommended for production)
     Suppress_Type_Name: On  # Suppresses adding the '_type' field to documents (important for
Elasticsearch 7.x and later)

# Note:- for this integration please refer additional steps in section - "E.3 Fluent Bit configuration
for Prometheus exporter"
    - name : prometheus_exporter  #prometheus exporter Output plugin name
       match: "*"  # Applies to all logs
       host: 0.0.0.0  # Listens on all network interfaces
       port: 24231  # Port for receiving logs
       metrics_path: /metrics  # Endpoint for metrics exposure

    - name: stdout                    # Outputs logs to standard output (stdout)
      match: "*"                      # Matches all logs for output to stdout
```

See

Refer to below for Fluent Bit configuration..

https://docs.fluentbit.io/manual

E.1.2 Sample parsers.conf template

```
[PARSER]
    Name        firstline_app_parser
    Format      regex
    Regex       ^(?<log>[0-9]{4}-[0-9]{2}-[0-9]{2} [0-9]{2}:[0-9]{2}:[0-9]{2}\.[0-9]{3} [A-Z]+,(.*))
    # This regex captures both the timestamp and the rest of the line.
[PARSER]
    Name        firstline_audit_parser
    Format      regex
    Regex       ^(?<log>(?:AUDIT:\s(?:SESSION|OBJECT))(.*))
  # This regex captures both audit headers "AUDIT: (SESSION|OBJECT)" and the rest of the line.
```

E.1.3 Encode the fluent-bit.yaml content

```
cat fluent-bit.yaml | base64 -w 0
```

E.1.4 Encode the parsers.conf content

```
cat parsers.conf | base64 -w 0
```

E.1.5 Create the custom secret

The custom secret must contain the required key fluent-bit.yaml and optional included keys, e.g., parsers.conf as shown below.

Sample Secret YAML Definition:

```
apiVersion: v1
kind: Secret
metadata:
  name: fluent-bit-secret       # Name of the secret
  namespace: your-namespace     # Namespace where the secret will be created
type: Opaque
data:
  fluent-bit.yaml: <base64_encoded_content>
  parsers.conf: <base64_encoded_content>
```

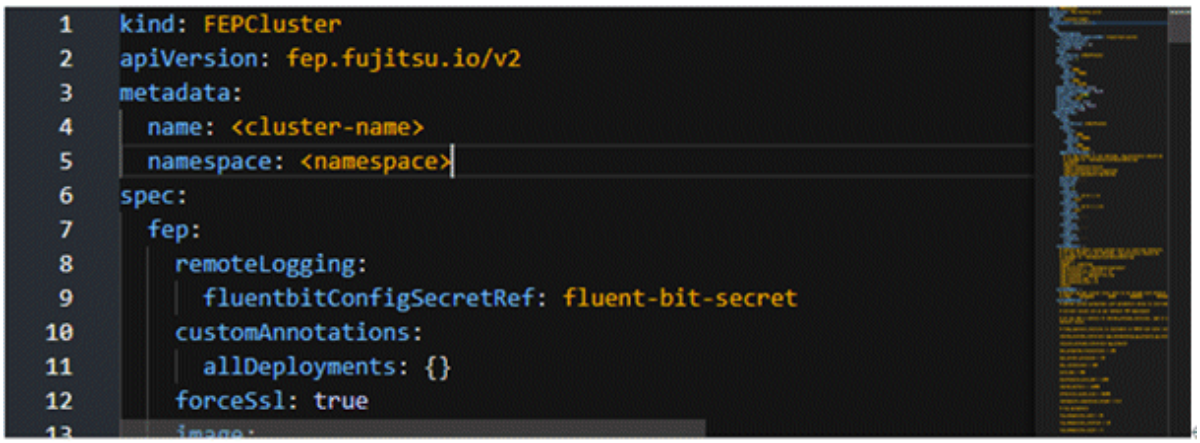
Example:

Assuming the base64 encoded content of the fluent-bit.yaml file is c29tZS1iYXNlNjQtZW5jb2RlZC1jb250ZW50, the secret would look like this:

```
apiVersion: v1
kind: Secret
metadata:
  name: fluent-bit-secret       # Name of the secret
  namespace: your-namespace     # Namespace where the secret will be created
type: Opaque
data:
  fluent-bit.yaml: c29tZS1iYXNlNjQtZW5jb2RlZC1jb250ZW50  # Replace with your actual base64 encoded
content
parsers.conf: a29tZS1iYXNlNjQtZW5jb2RlZC1jb250ZW51  # Replace with your actual base64 encoded
content
```

E.2 Reference to the secret in FEPClusterCR

spec.fep.remoteLogging.fluentbitConfigSecretRef as shown below:



E.2.1 Reload Fluent Bit Configuration

After saving the secret in FEPClusterCR, reload Fluent Bit container to apply the changes.

Apply the changes in one of the following ways:

- Create a FEPAction with type fluentbit_reload as shown below:

```yaml
kind: FEPAction
apiVersion: fep.fujitsu.io/v1
metadata:
  name: <fep-action-name>
  namespace: <namespace>
spec:
  fepAction:
    args:
    type: fluentbit_reload
  sysExtraEvent: true
  sysExtraLogging: false
  targetClusterName: <target-cluster-name>
```

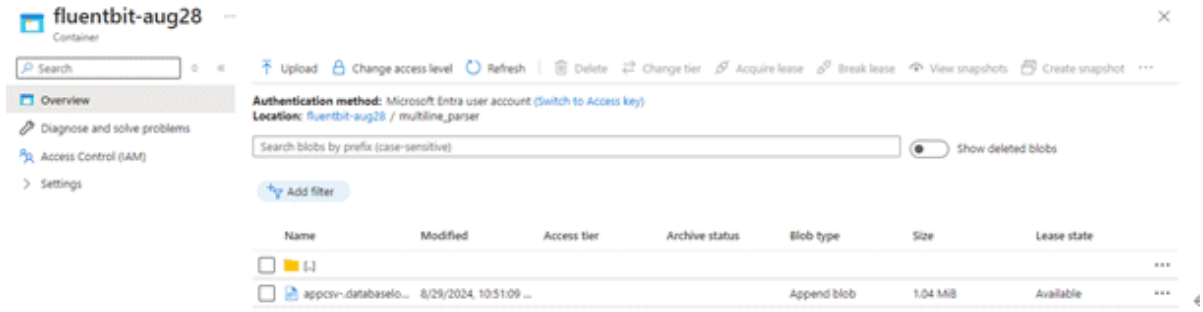
- Use the below command and execute in fluent-bit container if you wish to reload the Fluent Bit's configuration manually:

```
curl -s -X POST -d '{}' localhost:2020/api/v2/reload
```

E.2.2 Confirm Log Ingestion in Azure Blob

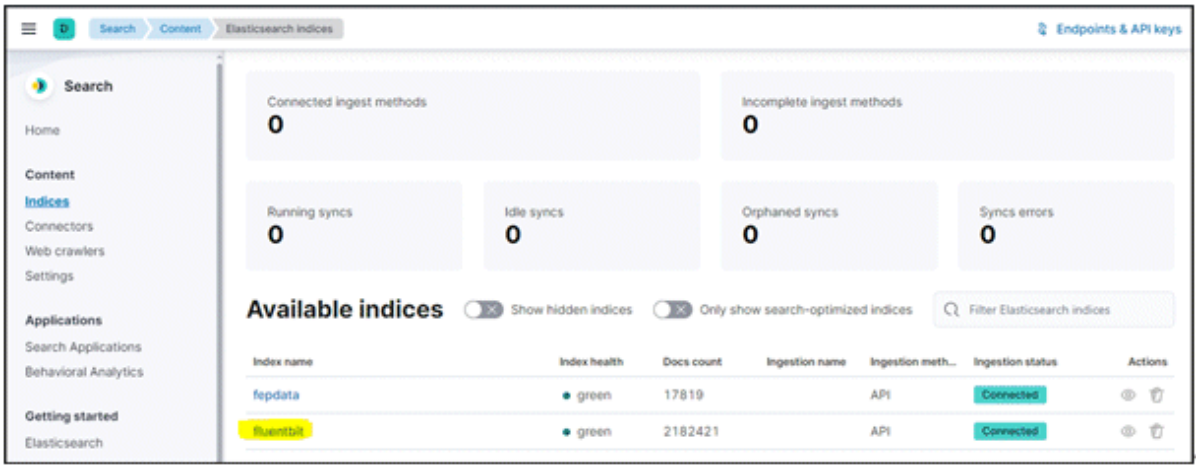
After reloading the configuration, check your Azure Blob container to confirm that logs are being ingested properly. You can use the Azure portal or Azure Storage Explorer for this purpose.

Based on the Output Plugin's specified path, the logs were stored in the respective directory.



E.2.3 Confirm Log Ingestion in Elasticsearch

Once Fluent Bit has been reloaded, verify that data is being correctly ingested into your Elasticsearch index.



E.3 Fluent Bit configuration for Prometheus exporter

To expose Fluent Bit metrics to Prometheus, you'll need to add the prometheus_exporter Output plugin and the appropriate Filters to the Fluent-bit.yaml configuration file and Create a custom secret. For more information, refer to the Fluent Bit Manual.

E.3.1 Create a Service

To allow Prometheus to scrape metrics from Fluent Bit, you need to create a Service in OpenShift.

Sample YAML file for create a Service:

```
apiVersion: v1
kind: Service
metadata:
  name: <service-name>
  namespace: <namespace>
  labels:
    app: <fluent-bit-pod-name>
    fepclustername: <fepcluster-name>
spec:
  ports:
    - name: prometheus-metrics
      port: 80
      targetPort: 24231
      protocol: TCP
  selector:
    app: <fluent-bit-pod-name>
```

- name: The name of the Service.
- namespace: The namespace in which this Service is deployed.
- ports: Maps the Service port (`80`) to the target port (`24231`) used by Fluent Bit's Prometheus Exporter.

E.3.2 Create a ServiceMonitor

To automatically configure Prometheus to scrape metrics from the Fluent Bit service, you'll need to create a `ServiceMonitor` resource. This is particularly useful in Kubernetes environments that use the Prometheus Operator.

Sample YAML file for Create a ServiceMonitor:

```
apiVersion: monitoring.coreos.com/v1
kind: ServiceMonitor
metadata:
  name: <serviceMonitor-name>
  namespace: <namespace>
```

```
    labels:
      release: prometheus
  spec:
    selector:
      matchLabels:
        app: <fluent-bit-pod-name>
        fepclustername: <fepcluster-name>
    endpoints:
      - port: prometheus-metrics
        path: /metrics
        interval: 15s
    namespaceSelector:
      matchNames: <namespace>
```

- name: The name of the ServiceMonitor.
- namespace: The namespace in which the ServiceMonitor is deployed.
- selector: The labels used to select the Service to be monitored, matching the labels used in the Fluent Bit service.
- endpoints: Specifies the port and path for the Prometheus metrics, along with the scrape interval.
- namespaceSelector: Specifies the namespace(s) in which the ServiceMonitor should look for Services to monitor.

E.3.3 Confirm Log Ingestion in Prometheus

Once Prometheus starts scraping Fluent Bit metrics, you can view them in OpenShift's Observe-Metrics tab.

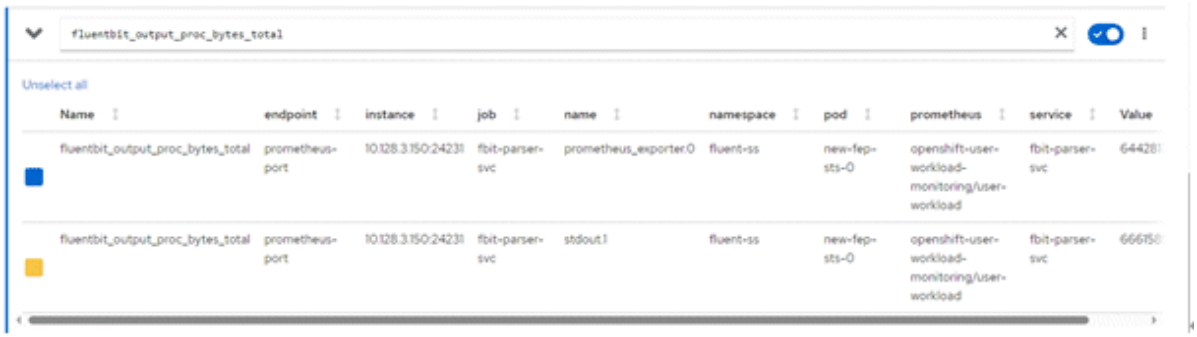
1. Access OpenShift Console

   Navigate to the OpenShift Console and go to the "Observe" section.

2. Explore Fluent Bit Metrics

   Use Prometheus queries to explore Fluent Bit metrics, for example:

   ```
   fluentbit_output_proc_bytes_total
   ```



E.4 Fluent Bit configuration for AWS CloudWatch

Integrating Fluent Bit with AWS CloudWatch allows you to efficiently collect, process, and forward logs from your FEP cluster to CloudWatch Logs. Please follow the detailed integration process below.

E.4.1 Create AWS credentials Secret

To allow Prometheus to scrape metrics from Fluent Bit, you need to create a Service in OpenShift.

Create a secret which include the config and credentials keys to export the environment variables as local variables for authentication to fep-logging-fluent-bit container, such as AWS_ACCESS_KEY_ID and AWS_SECRET_ACCESS_KEY.

Name of secret that contains the credential to AWS service. The credential is stored in Shared Configuration File and Credentials File.

The name of the Shared Configuration File must be "config" and the name of the Credentials File must be "credentials"

Sample template to create a config file

```
[default]  # Section for default AWS CLI settings that apply globally
region = <aws_region>  # The AWS region to be used for requests
output = json  # Format for the output of AWS CLI commands (e.g., json, text, table)
max_attempts = 1  # Maximum number of retry attempts for AWS CLI commands in case of failure

[profile svc-fep-tdedev0]  # Section for specific profile settings for svc-fep-tdedev0
region = ap-northeast-1  # The AWS region to be used for this specific profile
output = json  # Output format for commands executed under this profile (e.g., json)
```

Sample template to create a credentials file

```
[default]  # Section for the default profile
aws_access_key_id =  < aws_access_key_id > # Your AWS Access Key ID (to be filled in)
aws_secret_access_key = < aws_secret_access_key > # Your AWS Secret Access Key (to be filled in)

[svc-fep-tdedev0]  # Section for the svc-fep-tdedev0 profile
aws_access_key_id = < aws_access_key_id >  # Your AWS Access Key ID for this profile (to be filled
in)
```

E.4.2 Encode the config file content

```
cat config| base64 -w 0
```

E.4.3 Encode the credentials content

```
cat credentials | base64 -w 0
```

E.4.4 Create a secret using base64 encoded content

Sample aws-credentials secret YAML template

```
kind: Secret
apiVersion: v1
metadata:
  name: aws-credentials
  namespace: <namespace>
data:
  config: <base64_encoded_content>
  credentials: <base64_encoded_content>
type: Opaque
```

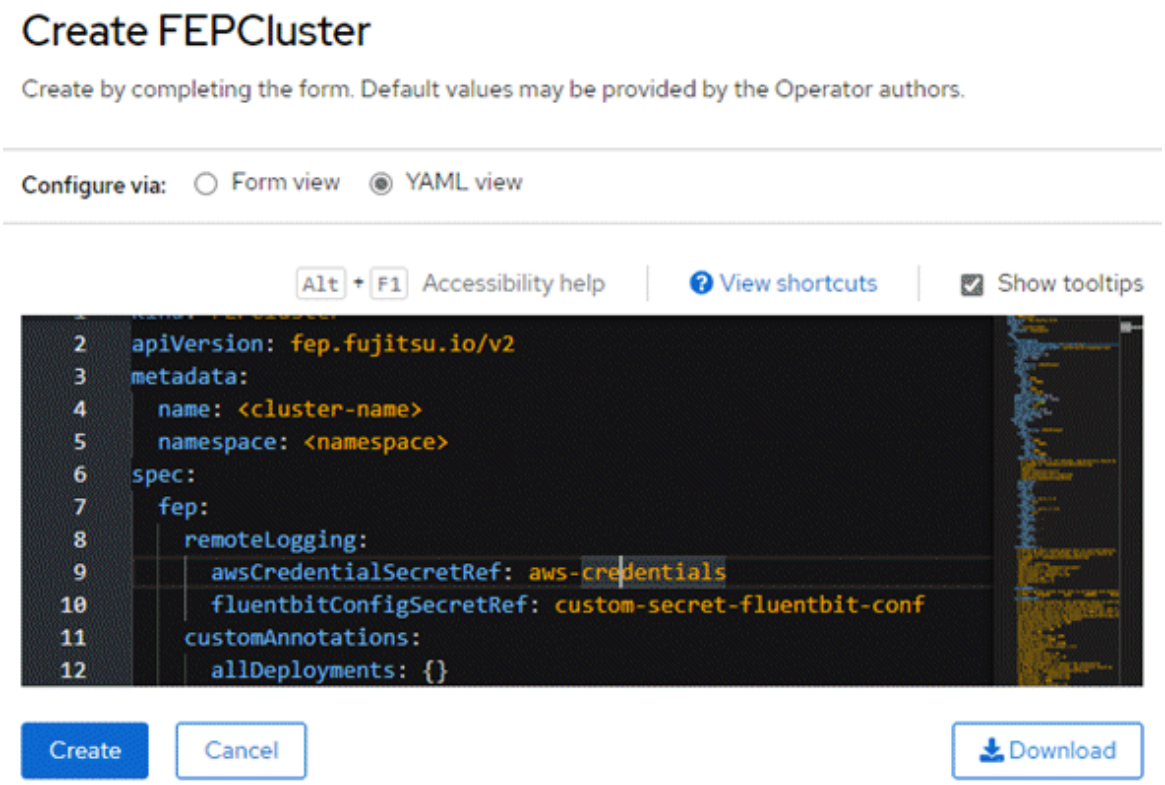
Create a Fluent Bit custom secret using the cloudwatch_logs Output plugin for Fluent Bit integration. For more information, refer to the Fluent Bit Manual.

In your main configuration file fluent-bit.yaml append the following Output section:

```
OUTPUT:
  Name: cloudwatch_logs  # Specifies the output plugin name
  Match: '*'             # Matches all log streams
  region: us-east-1      # The AWS region for CloudWatch Logs
  log_group_name: fluent-bit-cloudwatch  # Name of the CloudWatch log group
  log_stream_prefix: from-fluent-bit-     # Prefix for log stream names
  auto_create_group: On  # Automatically create the log group if it doesn't exist
  profile: <cloudwatch_logs_profile_default>  # The AWS profile to use for authentication
  auto_retry_requests: false  # Disables automatic retry for failed requests
  log_format: json    # Format of the logs to be sent
```

E.4.5 Reference the Secrets in FEPClusterCR

Reference the aws-credentials secret and the fluent-bit config secret in the FEPCluster CR using the appropriate parameters under remoteLogging, awsCredentialSecretRef and fluentbitConfigSecretRef as shown in the screenshot and create a cluster.



Once the FEPCluster is up and running, verify the fep-logging-fluent-bit container logs to ensure the integration is successful and Confirm Log Ingestion in Amazon CloudWatch Logs.