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# Across Kubernetes Namespace Boundaries:
## Your Volumes Can Be Shared Now!

2023/4/20 @ KubeCon + CloudNativeCon Europe 2023

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Masaki Kimura, Hitachi, Ltd.

# Who are we?

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Name: Takafumi Takahashi
Company: Hitachi Vantara
Github ID: ttakahashi21

- Has been contributing to Kubernetes community by implementing provision volumes from cross-namespace snapshots (KEP-3294).

Name: Masaki Kimura
Company: Hitachi, Ltd.
Github ID: mkimuram

- Has been contributing to Kubernetes community to make Raw Block Volume feature and CSI feature GA.
- Designed and proposed KEP-3294

This session is about details on KEP-3294: Provision volumes from cross-namespace snapshots .

# Disclaimer

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This session explains designs, specifications, and implementations which are under discussion and development.

Depending on the discussion, they are subject to change.

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# Contents

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# 1. Namespace and Volume in Kubernetes

## 1-1 Kubernetes Namespace
## 1-2 PersistentVolumeClaim and PersistentVolume
## 1-3 VolumeSnapshot and VolumeSnapshotContent
## 1-4 Creating PVC from VS/PVC

# 1-1 Kubernetes Namespace

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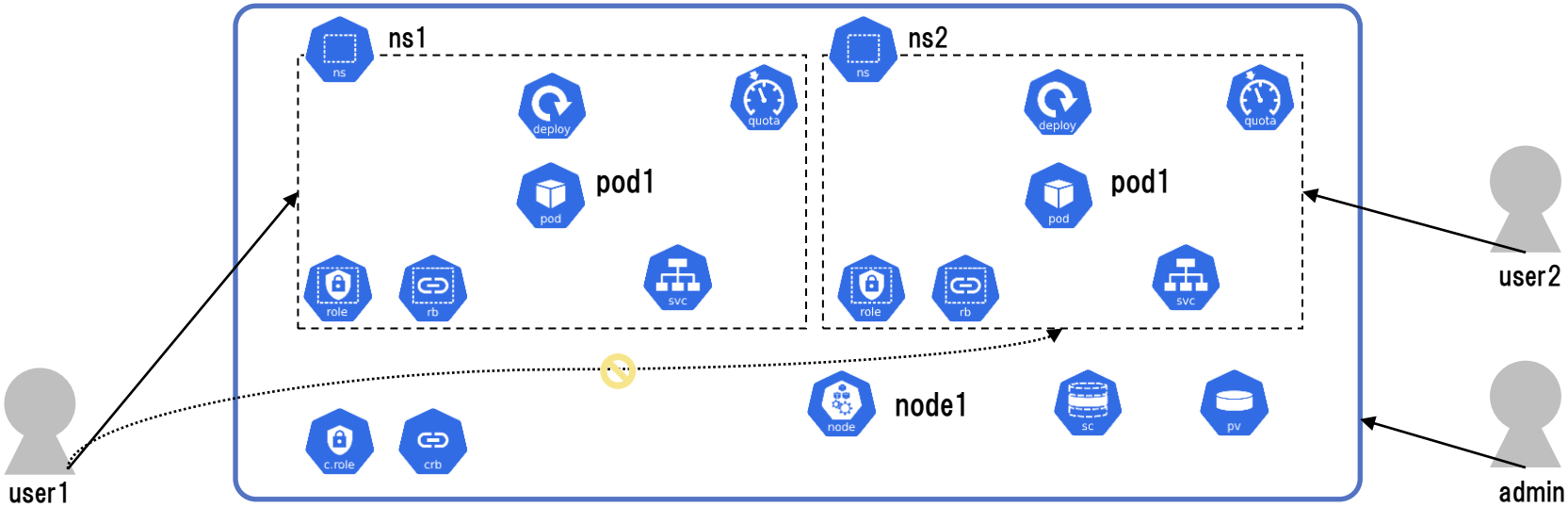
- “In Kubernetes, namespaces provide a mechanism for isolating groups of resources within a single cluster.”
  - Names of resources are unique within a namespace
  - RBAC can be set per namespace
  - Resource quota can be set per namespace
- Kubernetes resource consists of namespaced resource and cluster scoped resource:
  - Namespaced: Pod, Deployment, Service, ResourceQuota, Role, RoleBinding, etc …
  - Cluster-scoped: Node, StorageClass, PersistentVolume, ClusterRole, ClusterRoleBinding, etc …



# 1-2 PersistentVolumeClaim and PersistentVolume (1/2)

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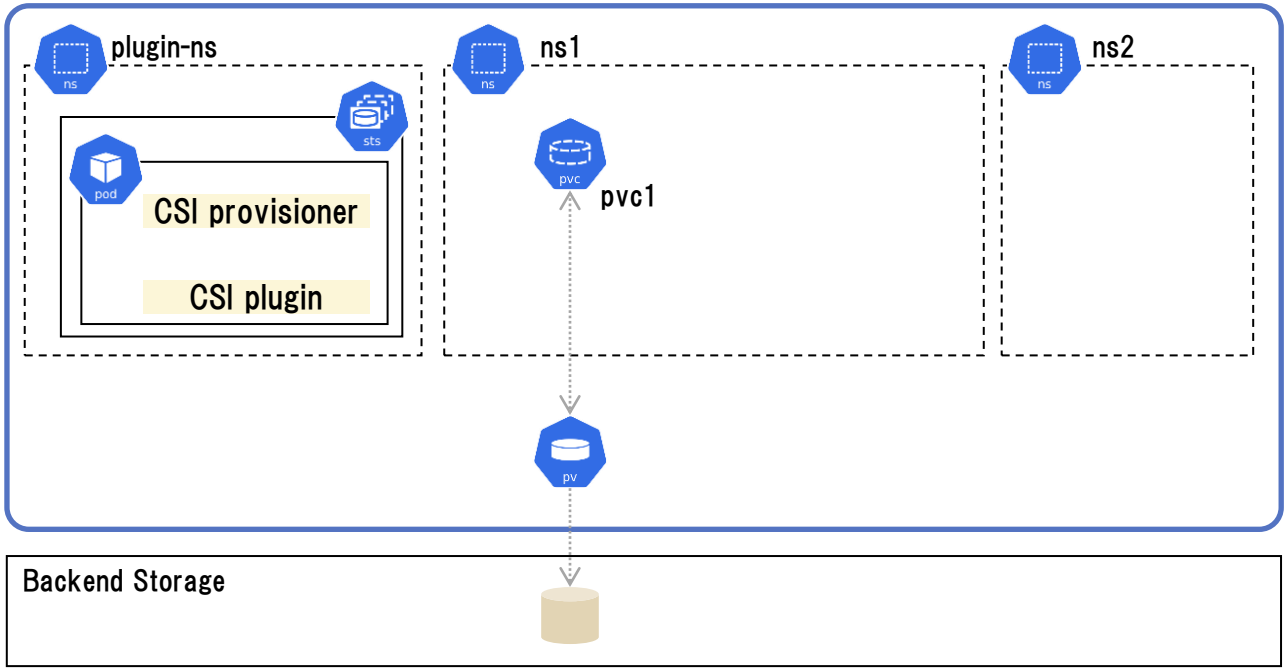
- Volumes are managed through PersistentVolumeClaim(PVC) and PersistentVolume(PV)
  - PVC is namespaced resource and PV is cluster-scoped resource
  - CSI plugin creates an actual volume specified in a PVC and provisioner creates a PV referenced from the PVC




▪Example of PVC:

```
apiVersion: v1
kind: PersistentVolumeClaim
metadata:
  name: pvc1
  namespace: ns1
spec:
  accessModes:
  - ReadWriteOnce
  resources:
    requests:
      storage: 1Gi
```

▪Example of PV:

```
apiVersion: v1
kind: PersistentVolume
metadata:
  name: pvc-xxxx
spec:
  accessModes:
  - ReadWriteOnce
  capacity:
    storage: 1Gi
  claimRef:
    apiVersion: v1
    kind: PersistentVolumeClaim
    name: pvc1
    namespace: ns1
  csi:
    driver: xxxx
    volumeHandle: xxxx
```

# 1-2 PersistentVolumeClaim and PersistentVolume (2/2)

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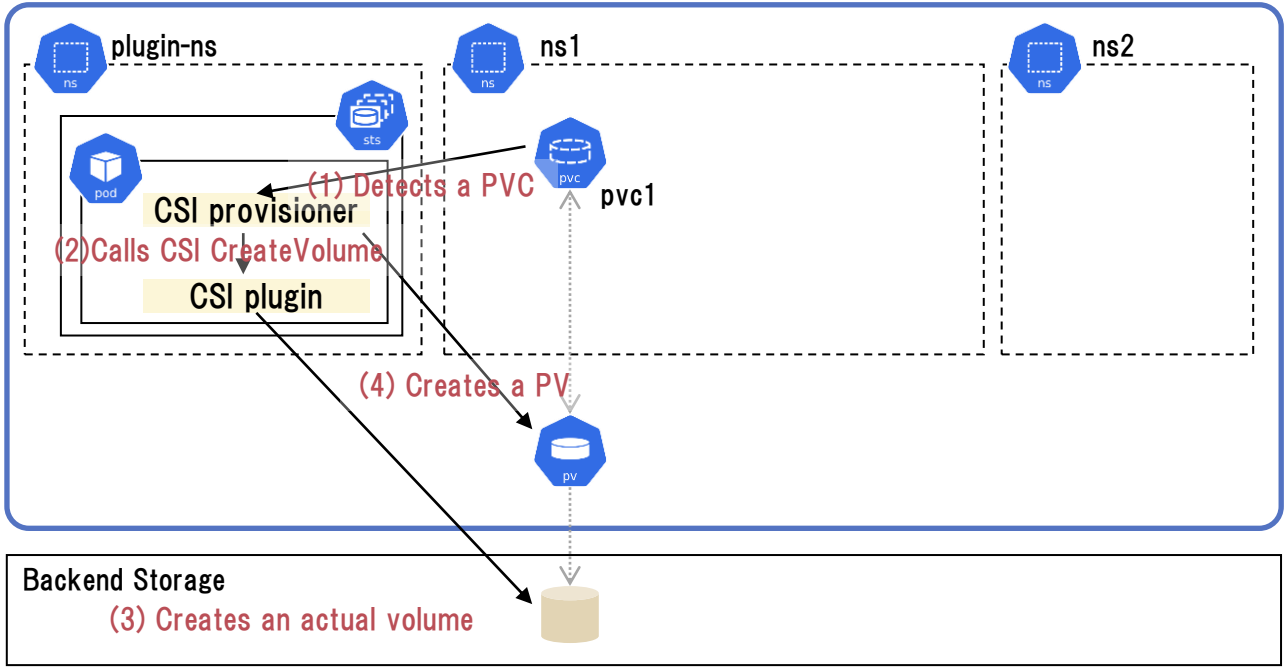
- Volumes are managed through PersistentVolumeClaim(PVC) and PersistentVolume(PV)
  - PVC is namespaced resource and PV is cluster-scoped resource
  - CSI plugin creates an actual volume specified in a PVC and provisioner creates a PV referenced from the PVC




▪Example of PVC:

```
apiVersion: v1
kind: PersistentVolumeClaim
metadata:
  name: pvc1
  namespace: ns1
spec:
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  - ReadWriteOnce
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```

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```
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kind: PersistentVolume
metadata:
  name: pvc-xxxx
spec:
  accessModes:
  - ReadWriteOnce
  capacity:
    storage: 1Gi
  claimRef:
    apiVersion: v1
    kind: PersistentVolumeClaim
    name: pvc1
    namespace: ns1
  csi:
    driver: xxxx
    volumeHandle: xxxx
```

# 1-3 VolumeSnapshot and VolumeSnapshotContent (1/2)

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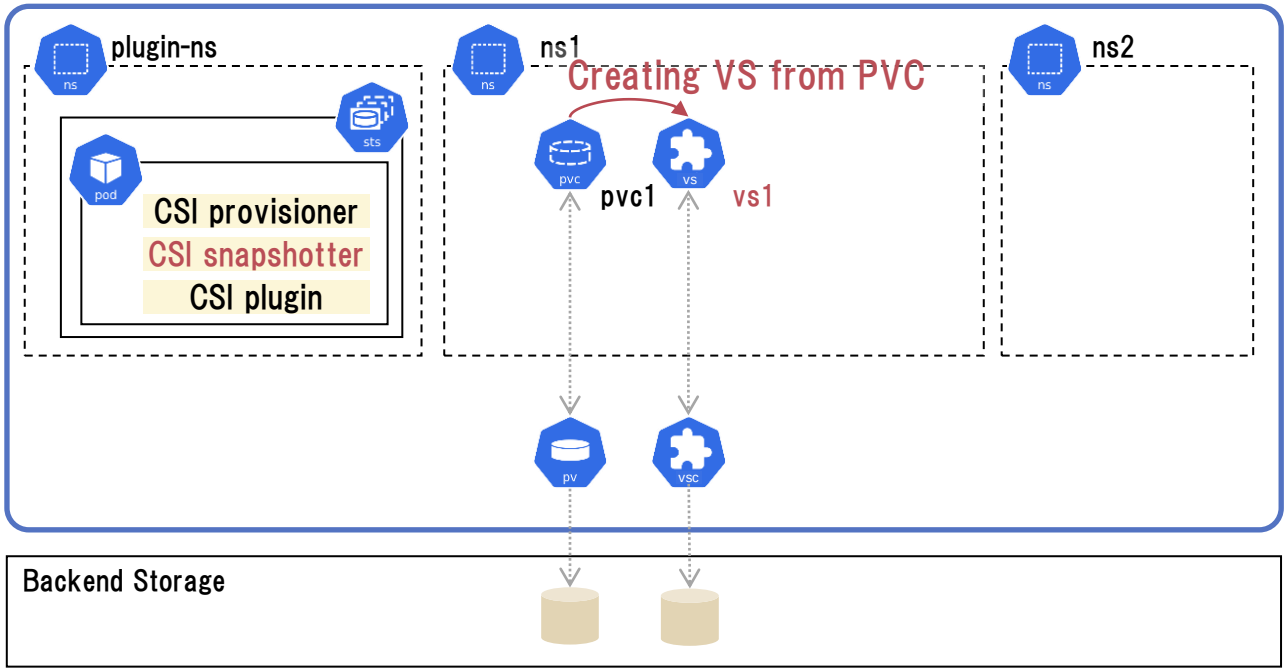
- Snapshots are managed through VolumeSnapshot(VS) and VolumeSnapshotContent(VSC)
  - VS is namespaced resource and VSC is cluster-scoped resource
  - CSI plugin creates an actual snapshot specified in a VS and snapshotter creates a VSC referenced from the VS




▪Example of VS:

```
apiVersion: snapshot.storage.k8s.io/v1
kind: VolumeSnapshot
metadata:
  name: vs1
  namespace: ns1
spec:
  source:
    persistentVolumeClaimName: pvc1
```

▪Example of VSC

```
apiVersion: snapshot.storage.k8s.io/v1
kind: VolumeSnapshotContent
metadata:
  name: snapcontent-xxxx
spec:
  deletionPolicy: Delete
  driver: xxxx
  source:
    volumeHandle: xxxxx
  volumeSnapshotClassName: xxx
  volumeSnapshotRef:
    apiVersion: snapshot.storage.k8s.io/v1
    kind: VolumeSnapshot
    name: vs1
    namespace: ns1
```

# 1-3 VolumeSnapshot and VolumeSnapshotContent (2/2)

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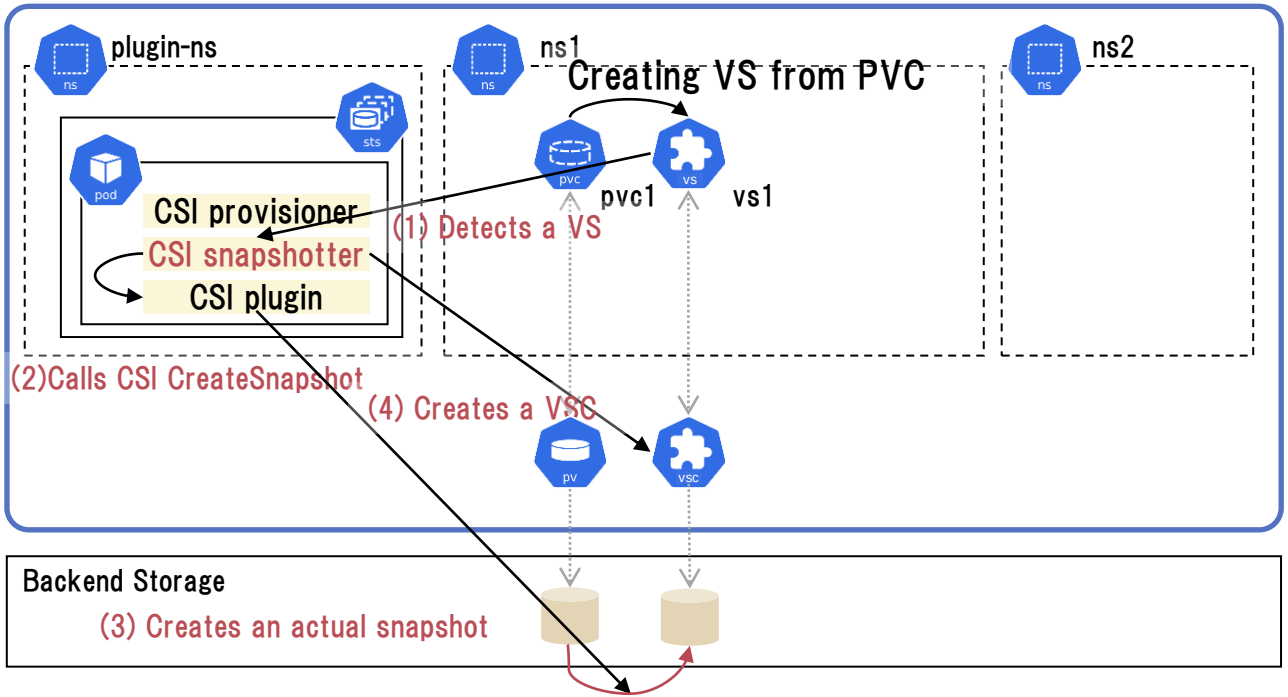
- Snapshots are managed through VolumeSnapshot(VS) and VolumeSnapshotContent(VSC)
  - VS is namespaced resource and VSC is cluster-scoped resource
  - CSI plugin creates an actual snapshot specified in a VS and snapshotter creates a VSC referenced from the VS




▪Example of VS:

```
apiVersion: snapshot.storage.k8s.io/v1
kind: VolumeSnapshot
metadata:
  name: vs1
  namespace: ns1
spec:
  source:
    persistentVolumeClaimName: pvc1
```

▪Example of VSC

```
apiVersion: snapshot.storage.k8s.io/v1
kind: VolumeSnapshotContent
metadata:
  name: snapcontent-xxxx
spec:
  deletionPolicy: Delete
  driver: xxxx
  source:
    volumeHandle: xxxxx
  volumeSnapshotClassName: xxx
  volumeSnapshotRef:
    apiVersion: snapshot.storage.k8s.io/v1
    kind: VolumeSnapshot
    name: vs1
    namespace: ns1
```

# 1-4 Creating PVC from VS/PVC (1/2)

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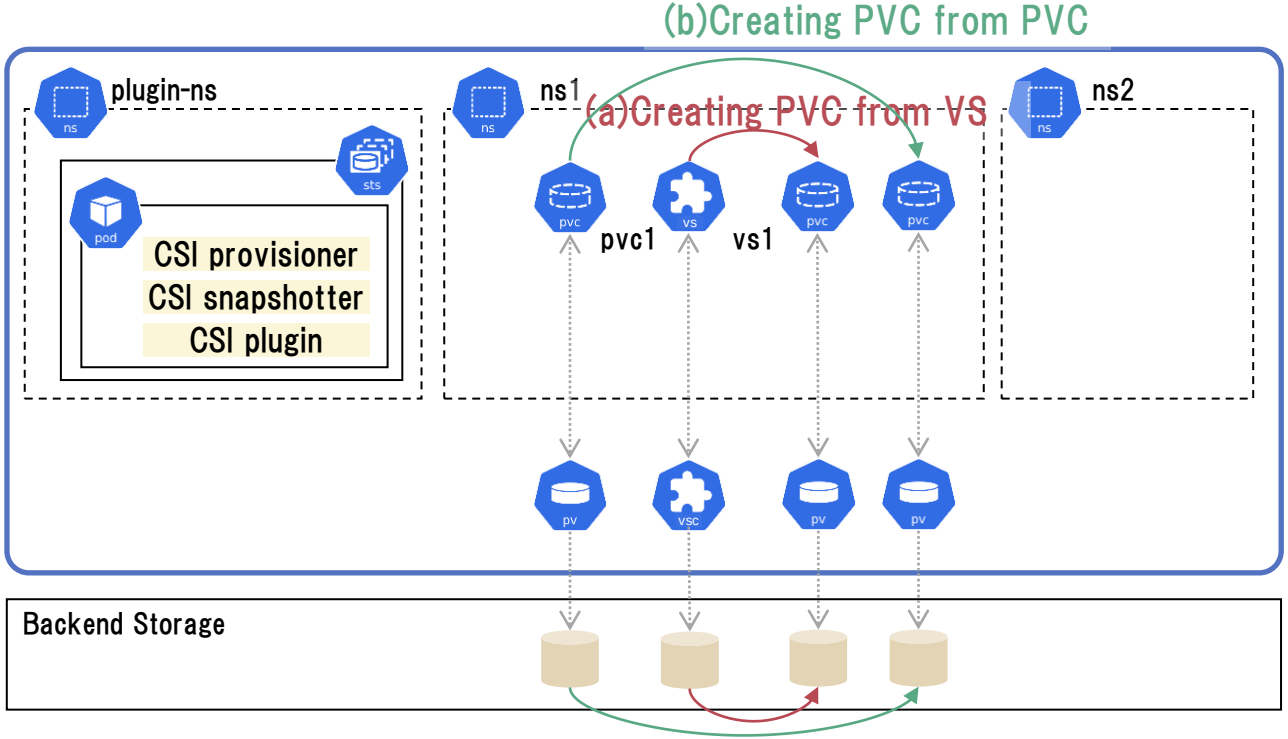
- PVC can be created from data sources like existing VS/PVC
  - Data source is specified through DataSource field of PVC
  - Only VS/PVC in the same namespace can be specified as a data source




(a)Creating PVC from VS

```
apiVersion: v1
kind: PersistentVolumeClaim
metadata:
  name: pvc1
  namespace: ns1
spec:
  accessModes:
  - ReadWriteOnce
  resources:
    requests:
      storage: 1Gi
  dataSource:
    apiGroup: snapshot.storage.k8s.io
    kind: VolumeSnapshot
    name: vs1
```

(b)Creating PVC from PVC

Namespace can't be specified

```
apiVersion: v1
kind: PersistentVolumeClaim
metadata:
  name: pvc1
  namespace: ns1
spec:
  accessModes:
  - ReadWriteOnce
  resources:
    requests:
      storage: 1Gi
  dataSource:
    kind: PersistentVolumeClaim
    name: pvc1
```

# 1-4 Creating PVC from VS/PVC (2/2)

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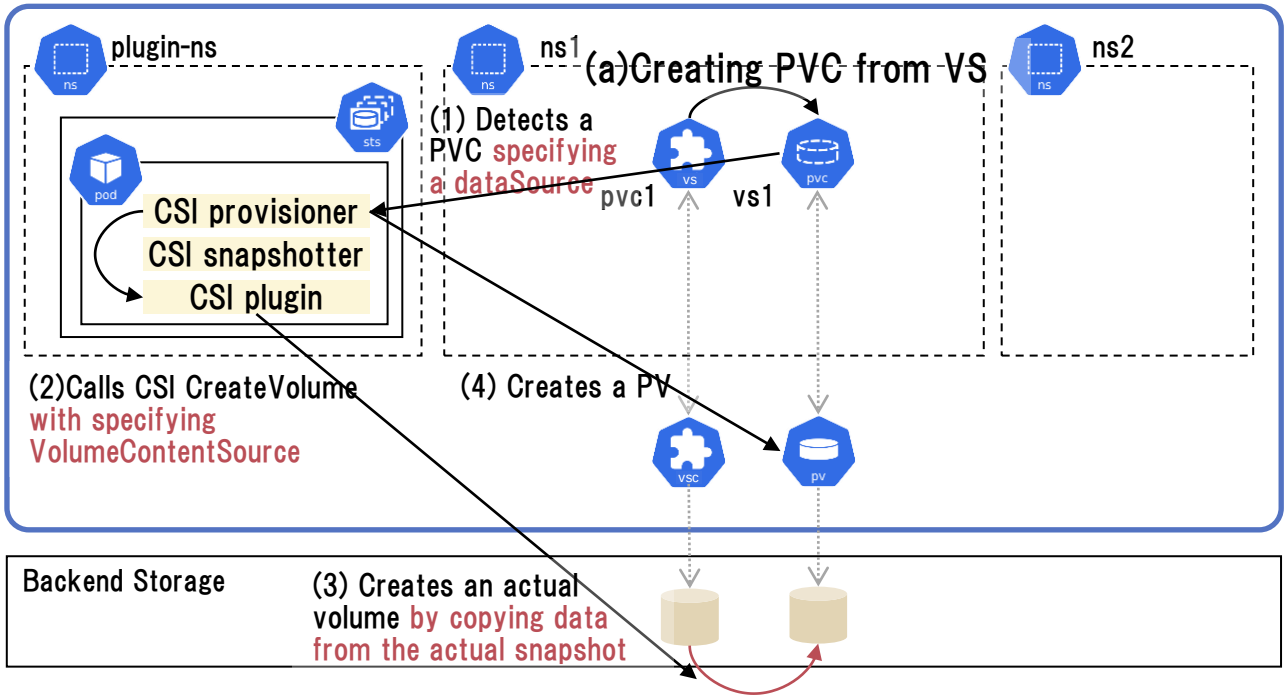
- PVC can be created from data sources like existing VS/PVC
  - Data source is specified through DataSource field of PVC
  - Only VS/PVC in the same namespace can be specified as a data source




## (a)Creating PVC from VS

```
apiVersion: v1
kind: PersistentVolumeClaim
metadata:
  name: pvc1
  namespace: ns1
spec:
  accessModes:
  - ReadWriteOnce
  resources:
    requests:
      storage: 1Gi
  dataSource:
    apiGroup: snapshot.storage.k8s.io
    kind: VolumeSnapshot
    name: vs1
```

Namespace can't be specified

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# 2. Issues and Use Cases Around Volumes in Different Namespaces

## 2-1 Issues Around Volumes in Different Namespaces
## 2-2 Use Case Around Volumes in Different Namespaces (1)
## 2-3 Use Case Around Volumes in Different Namespaces (2)

# 2-1 Issues Around Volumes in Different Namespaces

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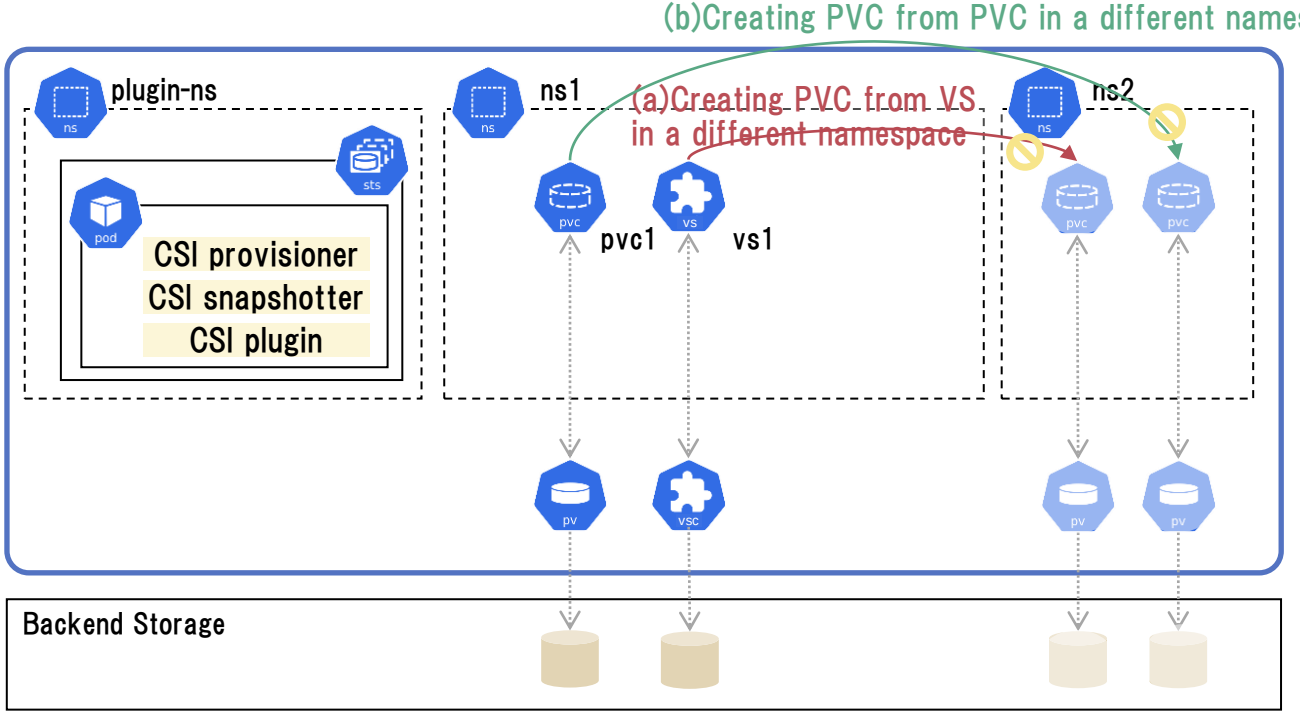
- PVC can't be created from an existing VS/PVC in a different namespace
  - Just allowing to copy any volumes in other namespaces causes a security issue
  - On the other hand, there are some use cases that require passing data beyond namespace boundaries




```
apiVersion: v1
kind: PersistentVolumeClaim
metadata:
  name: pvc1
  namespace: ns1
spec:
  accessModes:
  - ReadWriteOnce
  resources:
    requests:
      storage: 1Gi
  dataSource:
    apiGroup:
    kind:
    name:
```

Namespace can't be specified

# 2-2 Use Case Around Volumes in Different Namespaces (1)

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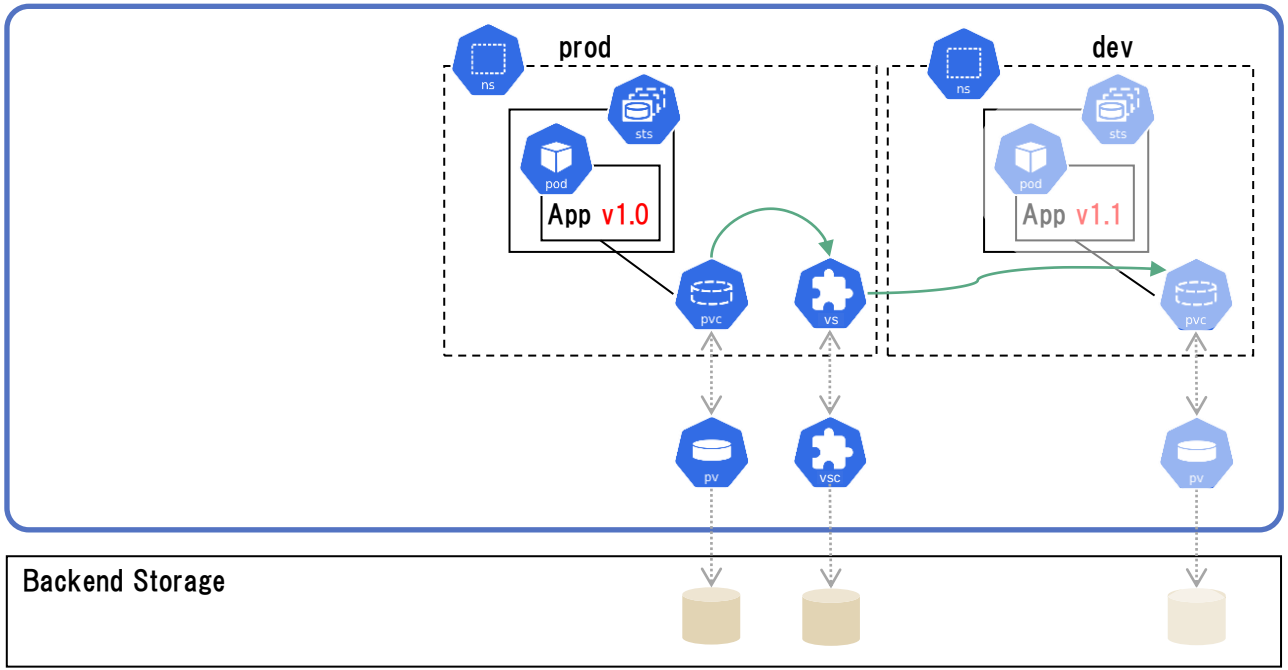
- Copying data from a production namespace to a development namespace
  - For test data in development environment
  - For datasets of machine learning



# 2-3 Use Case Around Volumes in Different Namespaces (2)

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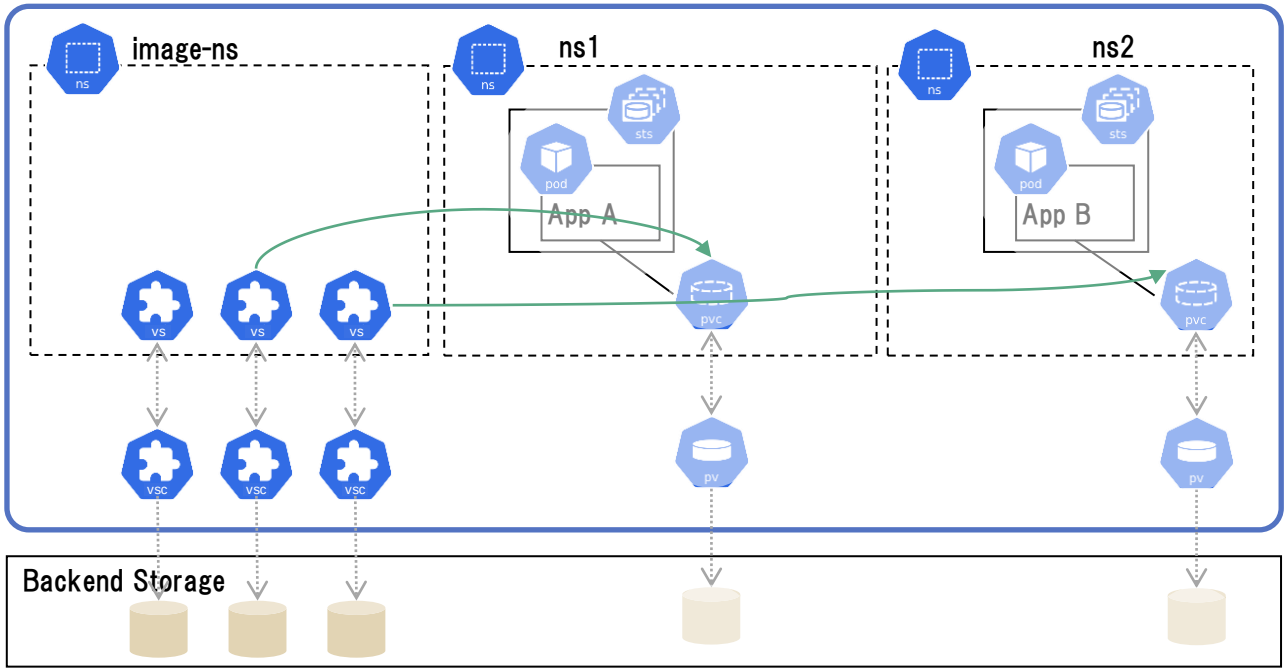
- Using golden images in one namespace from multiple other namespaces
  - VM image for KubeVirt
  - Common data like initial data and test data



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# 3. Long Discussion on the Issue

3-0 History of Discussion in k8s Community
3-1 Summary of the Initial Approach
3-2 Transfer + Clone Approach (API Design)
3-3 Transfer + Clone Approach (Challenges)

# 3-0 History of Discussion in k8s Community

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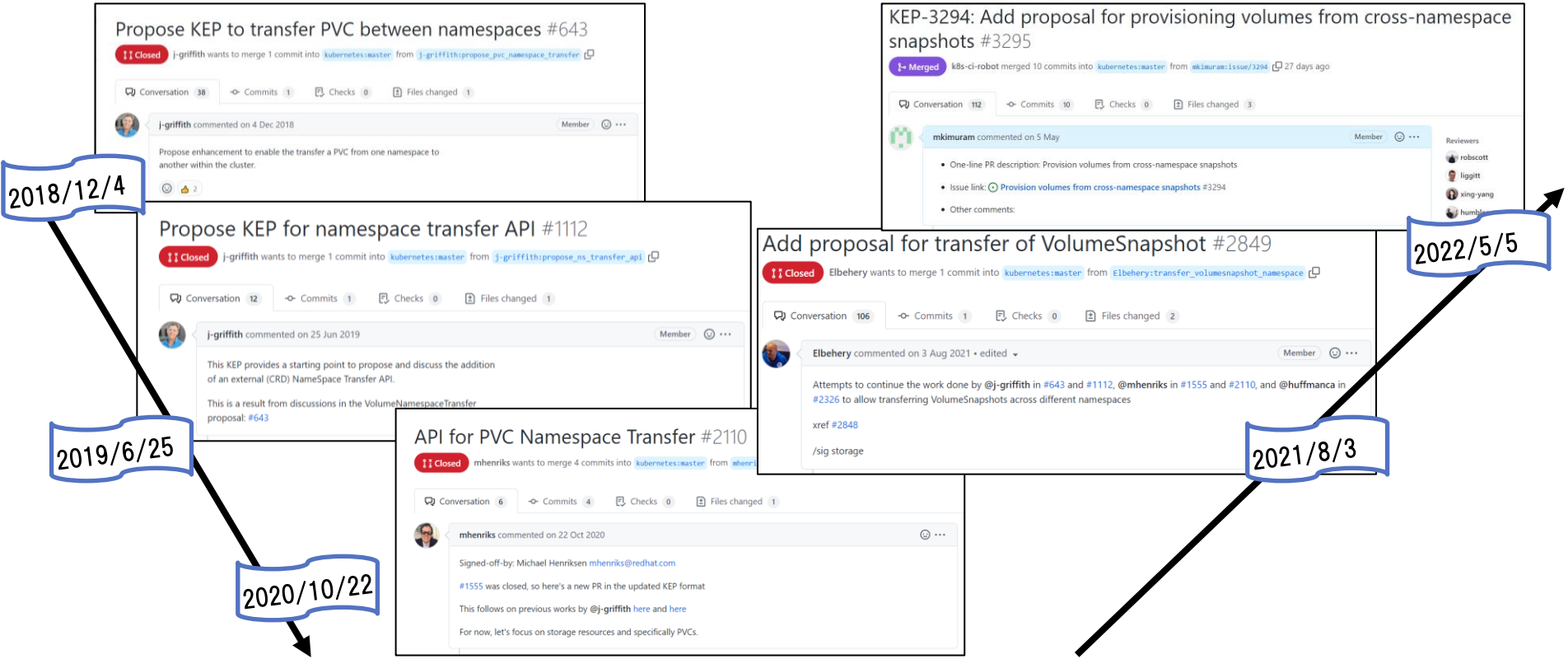
- Since 2018, 5 KEPs are opened by 4 authors to discuss for this issue.




https://github.com/kubernetes/enhancements/pull/643 , https://github.com/kubernetes/enhancements/pull/1112 , https://github.com/kubernetes/enhancements/pull/2110 , https://github.com/kubernetes/enhancements/pull/2849 , https://github.com/kubernetes/enhancements/pull/3295

# 3-1 Summary of the Initial Approach

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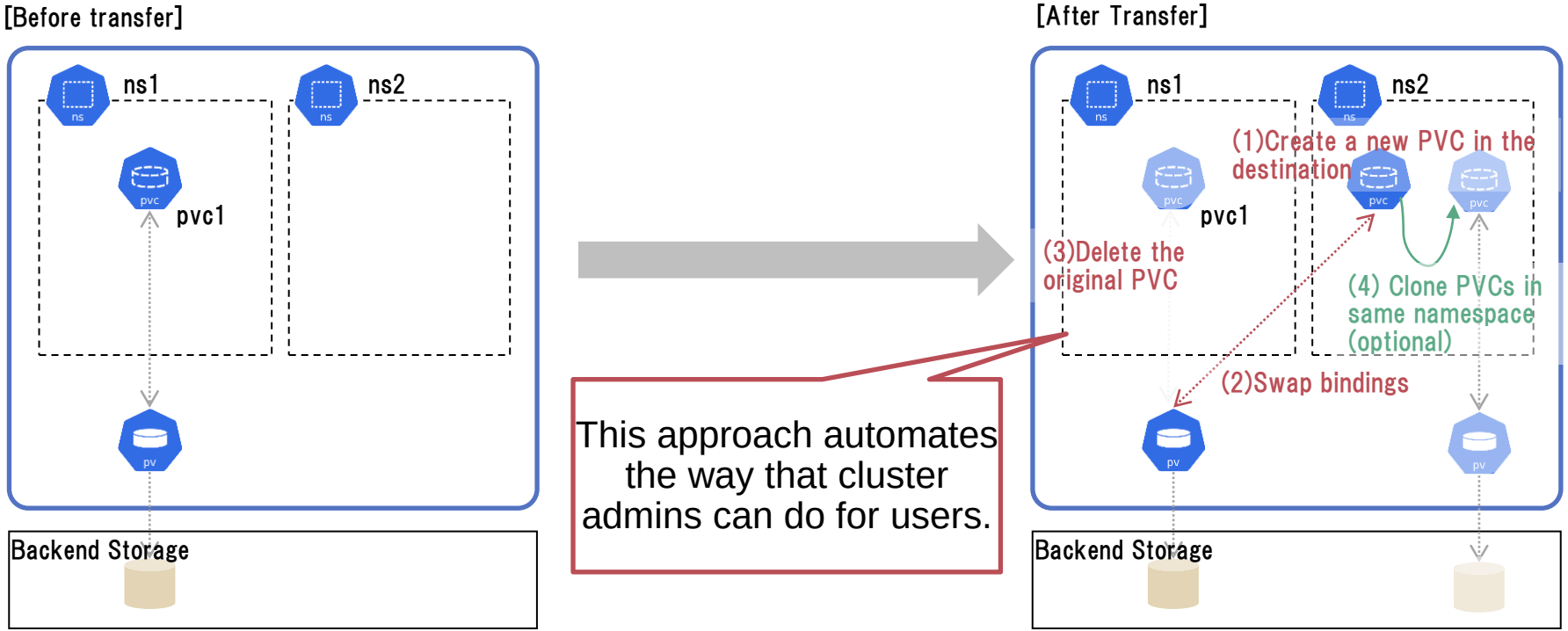
- Initial approach was the transfer of PVC/VS by rebinding the PVC-PV or VS-VSC.
- When copy of PVC/VS is required, clone of PVC/VS is done after transfer




https://github.com/kubernetes/enhancements/pull/643

# 3-2 Transfer + Clone Approach (API Design)

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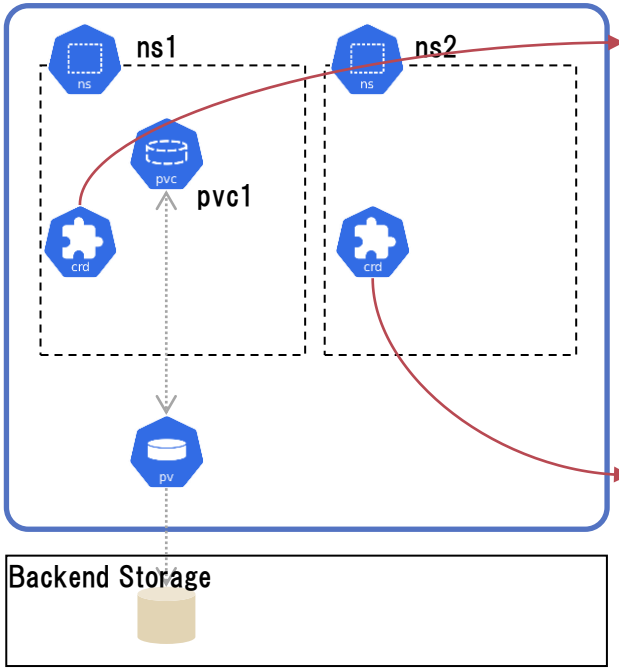
- StorageTransferRequest and StorageTransferApproval were planned to be defined.
  - To prevent malicious users from transferring PVCs to any other namespaces

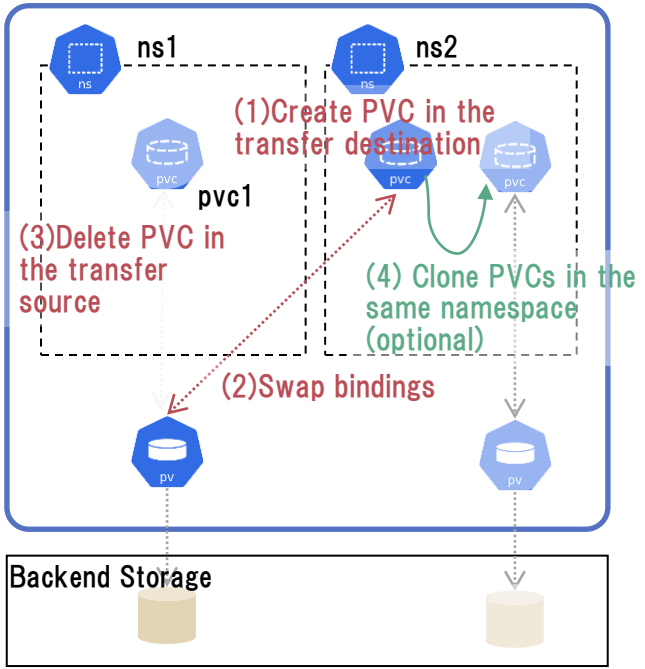
【Before Transfer】




```
apiVersion: v1alpha1
kind: StorageTransferApproval
metadata:
  name: approve-foo
  namespace: ns1
spec:
  source:
    name: pvc1
    kind: PersistentVolumeClaim
  targetNamespace: ns2
  requestName: transfer-foo
```

```
apiVersion: v1alpha1
kind: StorageTransferRequest
metadata:
  name: transfer-foo
  namespace: ns2
spec:
  source:
    name: pvc1
    namespace: ns1
    kind: PersistentVolumeClaim
  approvalName: approve-foo
  targetName: pvc1-moved
```

【After Transfer】




https://github.com/kubernetes/enhancements/pull/2849

# 3-3 Transfer + Clone Approach (Challenges)

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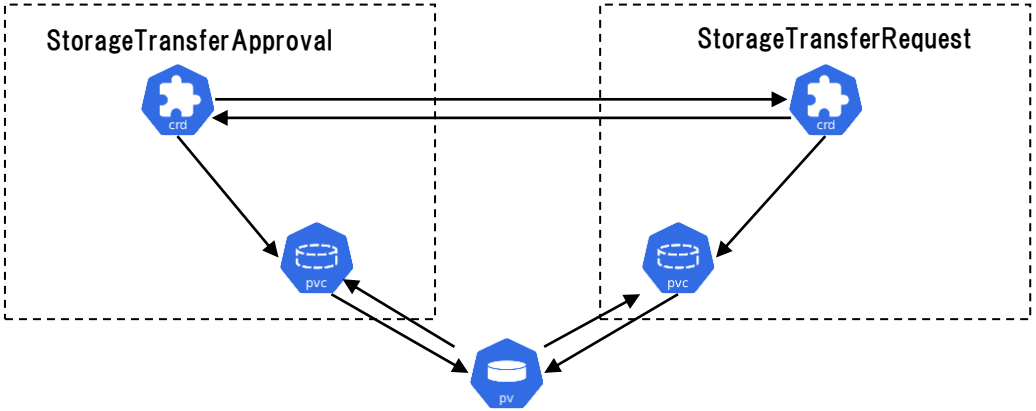
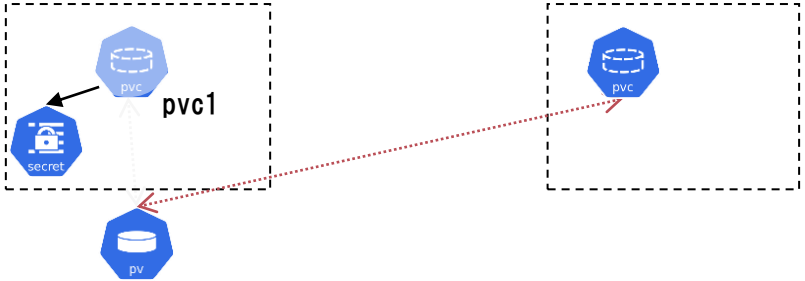
1. Difficult to rollback if errors occur or changes happen during the transfer process.




ex) While the same PV is bound to/from both source PVC and destination PVC:
- Deletion/Change/Resize is requested to the source PVC
- Approval/Request CRD is deleted

2. Difficult to handle secrets referenced by PVC/VS
   - Secret that is assumed to be in the same namespace as the PVC cannot be transferred



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# 4. Current Design and Implementation

4-1 Overview of Current Design
4-2-1 (1) AnyVolumeDataSource (Prerequisite Feature)
4-2-2 (1) Extension of DataSource
4-3-1 (2) ReferenceGrant (Prerequisite Feature)
4-3-2 (2) Grant cross-namespace access
4-4 Behavior
4-5 Development Status

# 4-1 Overview of Current Design

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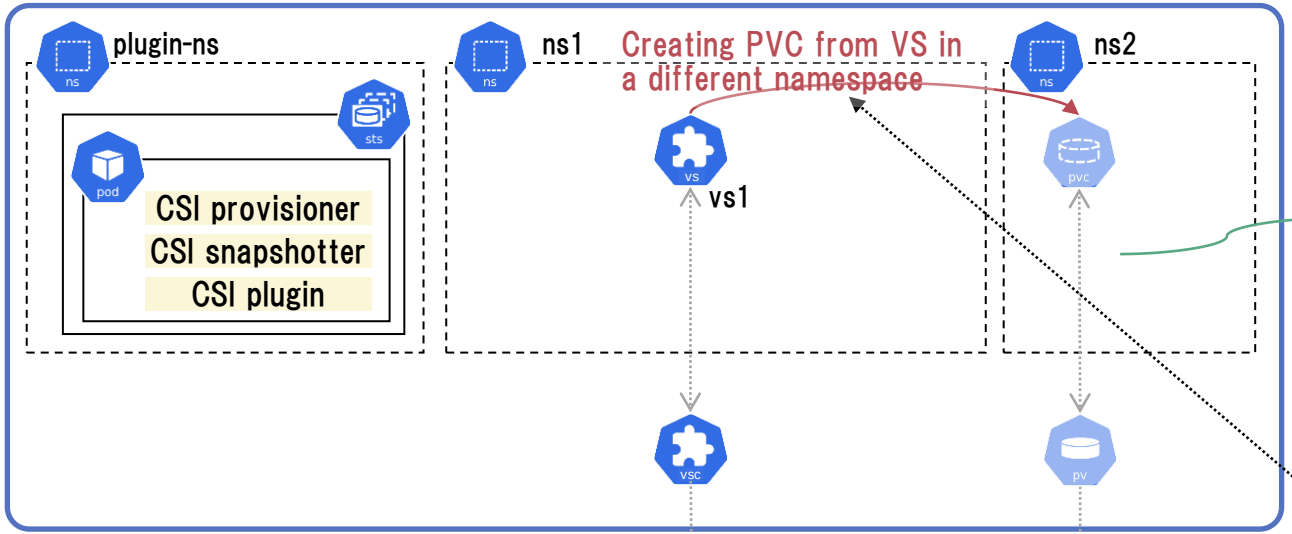
Current design utilizes two features that were recently added for another purposes:
(1) Extension of dataSource: by using AnyVolumeDataSource
(2) Grant cross-namespace access: by using ReferenceGrant




```
apiVersion: v1
kind: PersistentVolumeClaim
metadata:
  name: pvc1
  namespace: ns1
spec:
  accessModes:
  - ReadWriteOnce
  resources:
    requests:
      storage: 1Gi
  dataSource:
    apiGroup: snapshot.storage.k8s.io
    kind: VolumeSnapshot
    name: vs1
```

(1) Extension of dataSource

(2) Grant cross-namespace access

https://github.com/kubernetes/enhancements/pull/2849#issuecomment-949929595

# 4-2-1 AnyVolumeDataSource (Prerequisite Feature)

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- AnyVolumeDataSource feature extends data source (alpha in k8s v1.18, beta in k8s v1.24)
  - Existing DataSource field only allows specifying PersistentVolumeClaim and VolumeSnapshot
  - This feature allows any resources to be specified via a newly added DataSourceRef field
  - Copying the data is performed by volume populator for the corresponding resources
  - This feature itself allows only the same namespace to be specified as a data source

【When AnyVolumeDataSource feature is disabled】

```
apiVersion: v1
kind: PersistentVolumeClaim
metadata:
  name: pvc1
  namespace: ns1
spec:
  accessModes:
  - ReadWriteOnce
  resources:
    requests:
      storage: 1Gi
  dataSource:
    apiGroup: hello.example.com
    kind: Hello
    name: example-hello
```

Invalid data source

Other resource than PersistentVolumeClaim/ VolumeSnapshot

【When AnyVolumeDataSource feature is enabled】

```
apiVersion: v1
kind: PersistentVolumeClaim
metadata:
  name: pvc1
  namespace: ns1
spec:
  accessModes:
  - ReadWriteOnce
  resources:
    requests:
      storage: 1Gi
  dataSourceRef:
    apiGroup: hello.example.com
    kind: Hello
    name: example-hello
```

Valid data source

# 4-2-2 (1) Extension of DataSource

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- To allow specifying a namespace as a data source of a PersistentVolumeClaim, namespace alpha field is added to DataSourceRef

**Add namespace field to dataSourceRef**

```
apiVersion: v1
kind: PersistentVolumeClaim
metadata:
  name: pvc1
  namespace: ns2
spec:
  accessModes:
  - ReadWriteOnce
  resources:
    requests:
      storage: 1Gi
  dataSourceRef:
    apiGroup: snapshot.storage.k8s.io
    kind: VolumeSnapshot
    name: vs1
    namespace: ns1
```

- For compatibility purpose, existing DataSource field doesn't accept namespace. Therefore, users are required to pass namespace via DataSourceRef field.

# 4-3-1 (2) ReferenceGrant (Prerequisite Feature)

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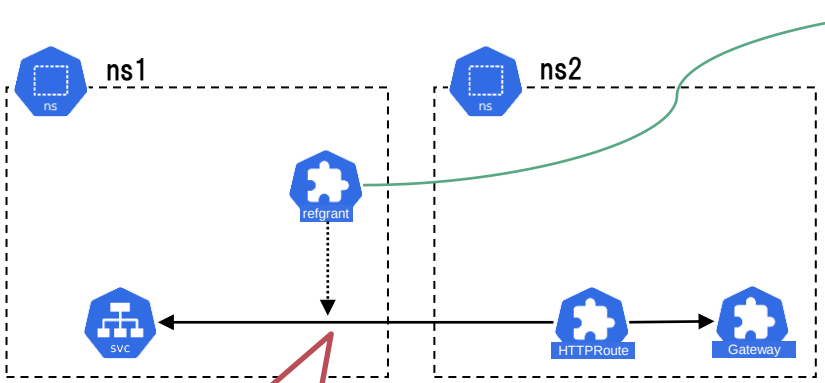
- ReferenceGrant is added in Gateway API (alpha in April 2021, beta in July 2022)
  - To allow Gateway API to access to the resource across namespaces
  - ex) To allow HTTPRoute in Gateway API to access to Service in a different namespace




```yaml
apiVersion: gateway.networking.k8s.io/v1beta1
kind: ReferenceGrant
metadata:
  name: allow-prod-traffic
  namespace: ns1
spec:
  from:
  - group: gateway.networking.k8s.io
    kind: HTTPRoute
    namespace: ns2
  to:
  - group: ""
    kind: Service
```

# 4-3-2 (2) Grant cross-namespace access

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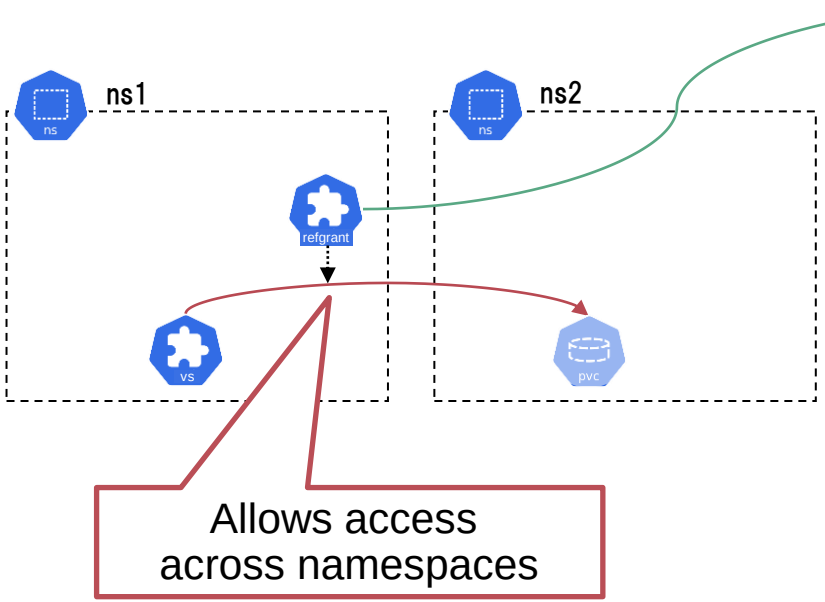
- ReferenceGrant is used to allow specifying VS/PVC across namespace as dataSource of PVC




```
apiVersion: gateway.networking.k8s.io/v1beta1
kind: ReferenceGrant
metadata:
  name: foo-grant
  namespace: ns1
spec:
  from:
  - group: ""
    kind: PersistentVolumeClaim
    namespace: ns2
  to:
  - group: snapshot.storage.k8s.io
    kind: VolumeSnapshot
    name: vs1
```

- ReferenceGrant is planned to be moved to new sig-auth API group in k8s 1.28

https://github.com/kubernetes/enhancements/issues/3766

# 4-4 Behavior (1/2)

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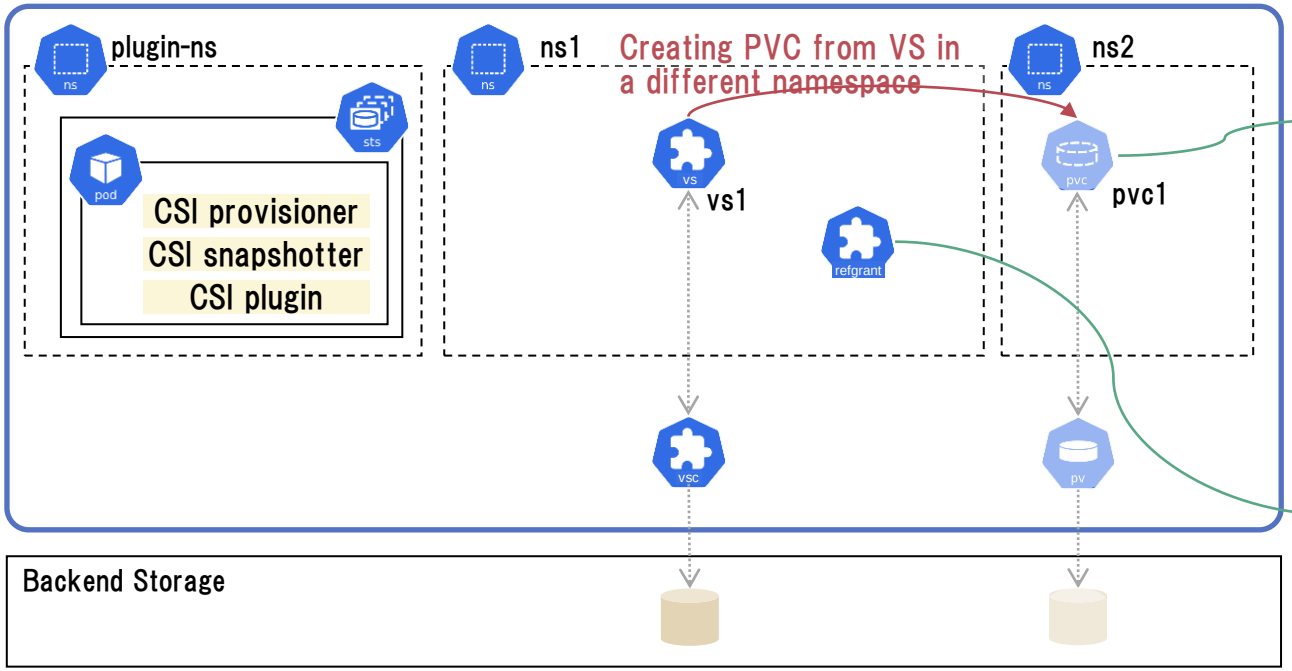
(1) Extension of dataSource: by specifying namespace via spec.dataSourceRef.namespace alpha field
(2) Grant cross-namespace access: by using ReferenceGrant




```
apiVersion: v1
kind: PersistentVolumeClaim
metadata:
  name: pvc1
  namespace: ns2
spec:
  accessModes:
  - ReadWriteOnce
  resources:
    requests:
      storage: 1Gi
  dataSourceRef:
    apiGroup: snapshot.storage.k8s.io
    kind: VolumeSnapshot
    name: vs1
    namespace: ns1
```

Namespace can be specified

```
apiVersion: gateway.networking.k8s.io/v1be
kind: ReferenceGrant
metadata:
  name: foo-grant
  namespace: ns1
spec:
  from:
  - group: ""
    kind: PersistentVolumeClaim
    namespace: ns2
  to:
  - group: snapshot.storage.k8s.io
    kind: VolumeSnapshot
    name: vs1
```

Allow access across namespace

# 4-4 Behavior (2/2)

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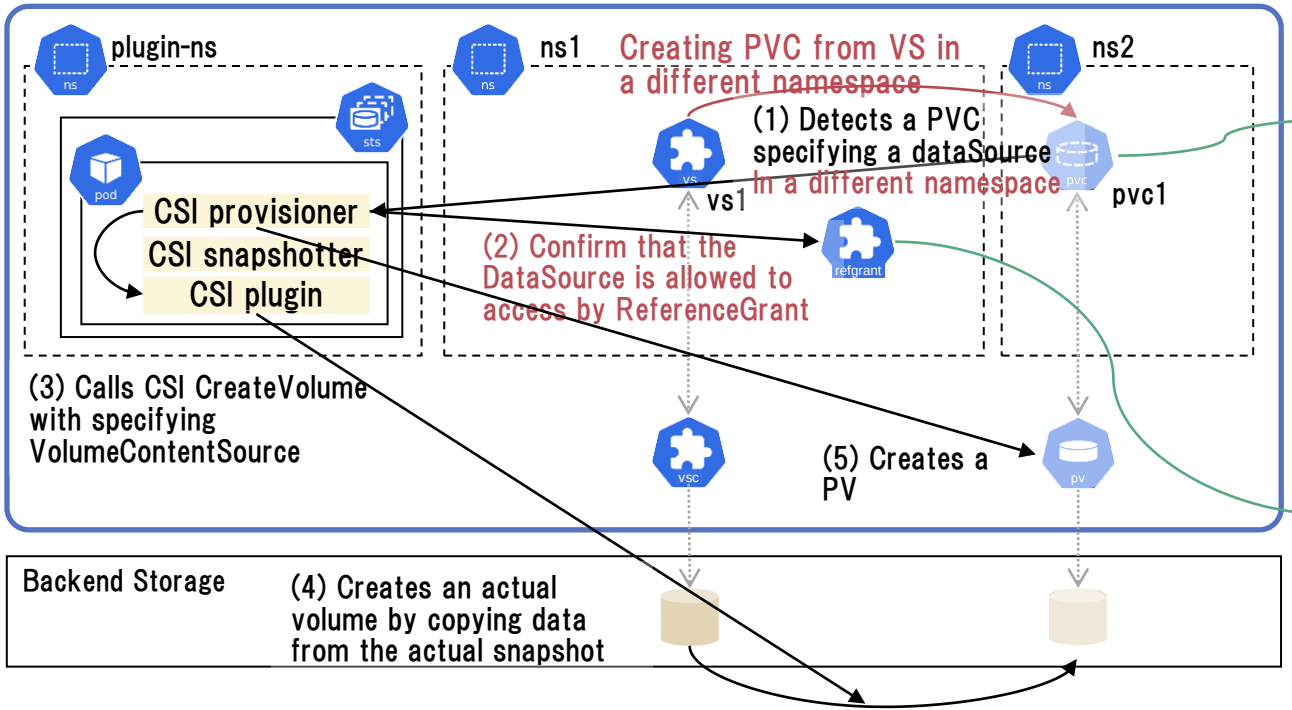
(1) Extension of dataSource: by specifying namespace via spec.dataSourceRef.namespace alpha field
(2) Grant cross-namespace access: by using ReferenceGrant




```yaml
apiVersion: v1
kind: PersistentVolumeClaim
metadata:
  name: pvc1
  namespace: ns2
spec:
  accessModes:
  - ReadWriteOnce
  resources:
    requests:
      storage: 1Gi
  dataSourceRef:
    apiGroup: snapshot.storage.k8s.io
    kind: VolumeSnapshot
    name: vs1
    namespace: ns1
```

Namespace can be specified

```yaml
apiVersion: gateway.networking.k8s.io/v1be
kind: ReferenceGrant
metadata:
  name: foo-grant
  namespace: ns1
spec:
  from:
  - group: ""
    kind: PersistentVolumeClaim
    namespace: ns2
  to:
  - group: snapshot.storage.k8s.io
    kind: VolumeSnapshot
    name: vs1
```

Allow access across namespace

# 4-5 Development Status

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- Alpha in k8s v1.26
- Release Plan:
  - Beta: v1.29
  - Stable: v1.31
- Scope:
  - Provision of PVC from cross namespace data source (No transfer of PVC/VolumeSnapshot)
  - Supported data source:
    - v1.26: VolumeSnapshot, PersistentVolumeClaim
    - planning: AnyVolumeDataSource
- Feature Gate:
  - Name: CrossNamespaceVolumeDataSource
  - Required components:
    - Kubernetes(controller)
    - CSI external-provisioner

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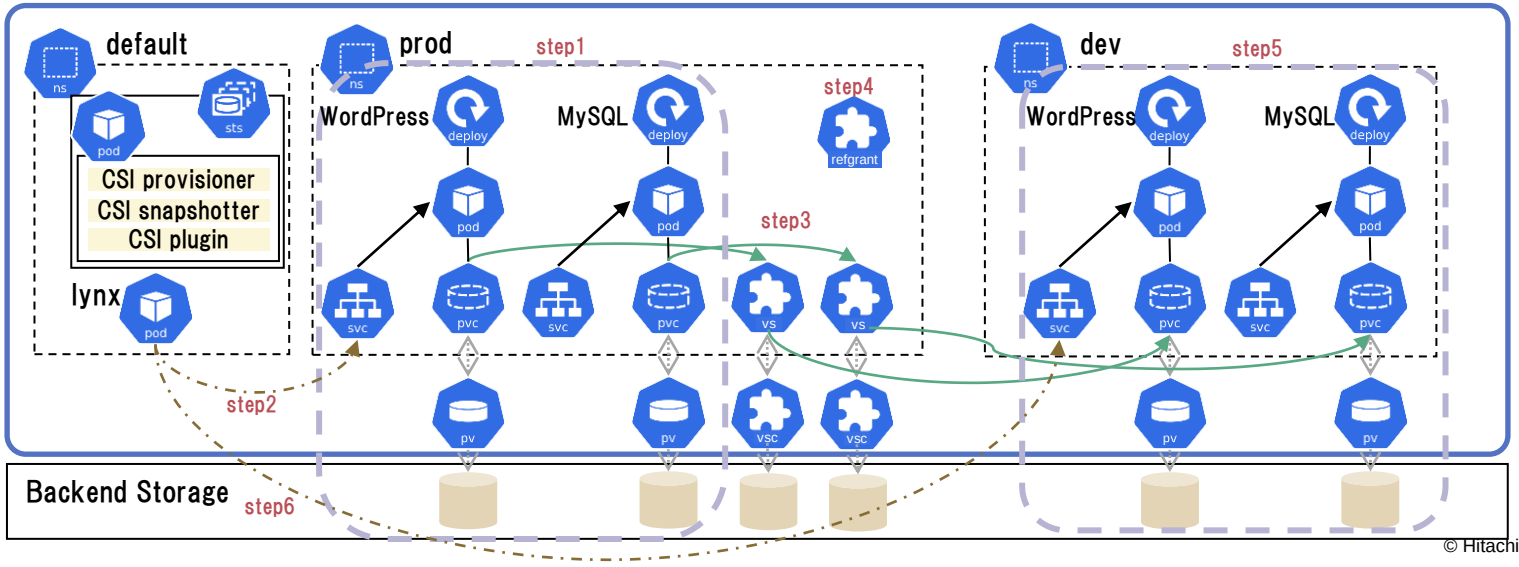
# 5. Demo

5-1 Overview
5-2-0 Check Demo Configuration
5-2-1 Deploying Prod WordPress
5-2-2 Accessing to Prod WordPress (Creating data)
5-2-3 Taking Snapshots
5-2-4 Creating ReferenceGrant
5-2-5 Creating Dev Volumes from Prod Snapshots and Using them
5-2-6 Accessing to Dev WordPress (Checking data)

# 5-1 Overview

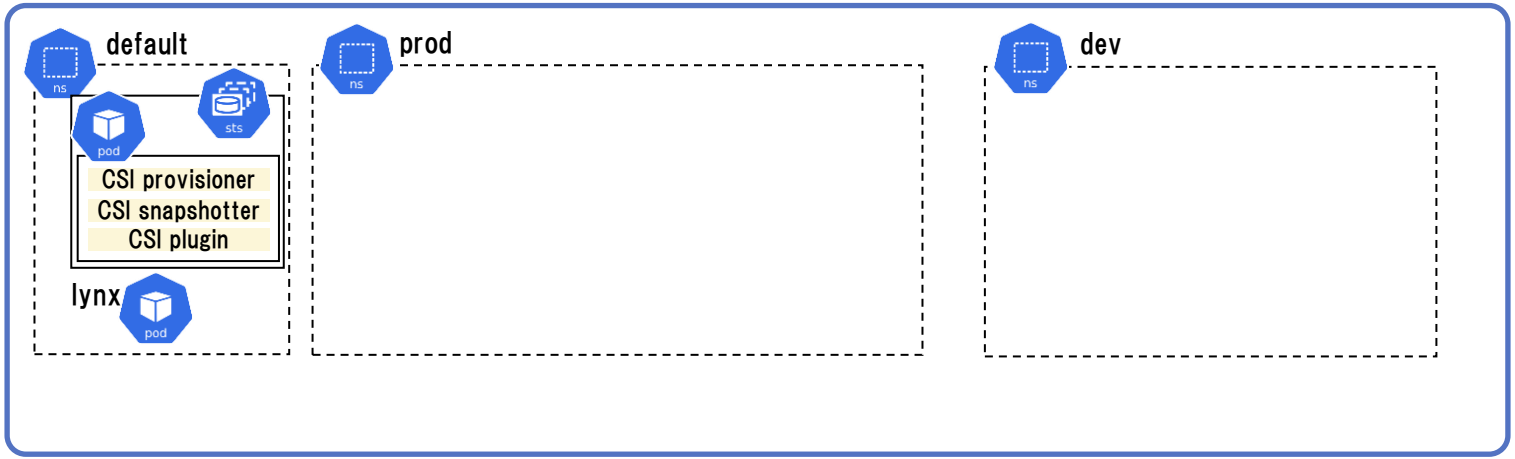
- Demo configuration
  - k8s v1.26.0 + external-provisioner (v3.4.0)
- Demo scenario
  - Creating snapshots from PVCs for WordPress in prod namespace
  - Creating PVCs from the snapshots and using them for WordPress in dev namespace

1. Deploying WordPress in prod
2. Accessing to the WordPress (Creating data)
3. Taking snapshots
4. Creating a ReferenceGrant
5. Creating volume from the snapshots in dev and using them from the WordPress in dev
6. Accessing to the WordPress (Checking data)



# 5-2-0 Check Demo Configuration (1/2)

- k8s v1.26.0 + external-provisioner (v3.4.0) are deployed
  - CrossNamespaceVolumeDataSource Feature Gate is enabled
- 2 namespaces, prod and dev, are created
- Lynx pod is deployed in default namespace for accessing to WordPress



# 5-2-0 Check Demo Configuration (2/2)

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```
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```
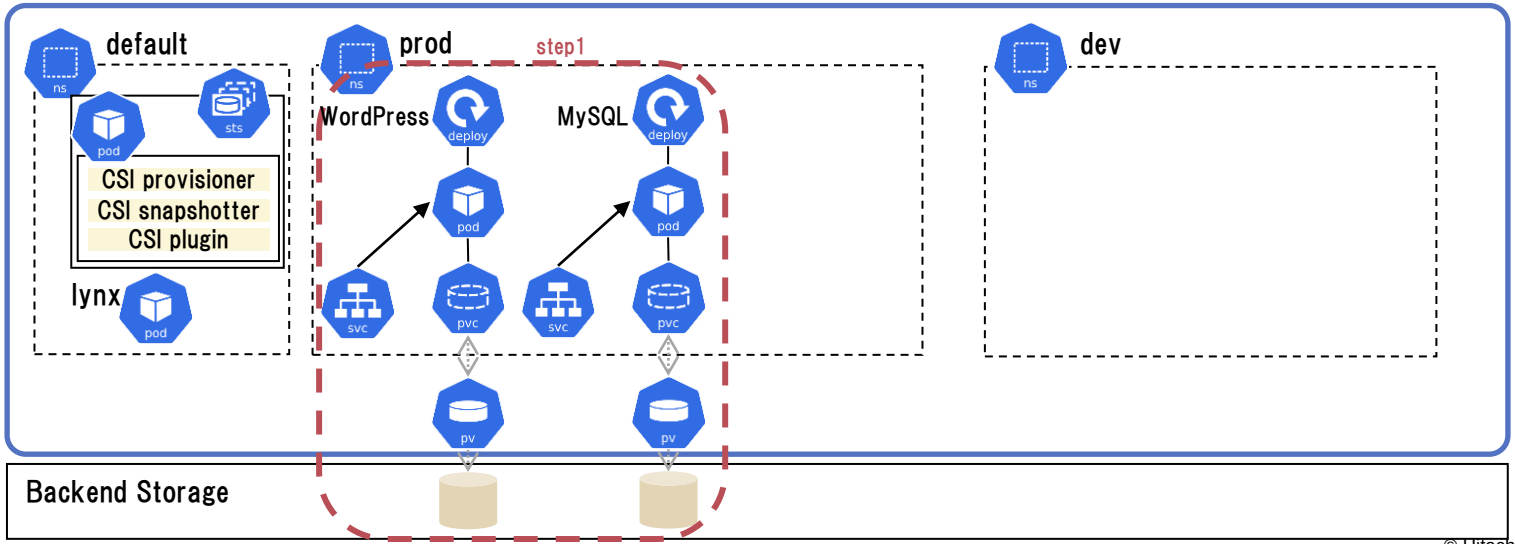

# 5-2-1 Deploying Prod WordPress (1/2)

- Deploy WordPress in prod namespace by using the steps described in Kubernetes official document
  Example: Deploying WordPress and MySQL with Persistent Volumes | Kubernetes
- Configuration:
  - WordPress: 1 pod with 1 PVC is managed by 1 Deployment.
  - MySQL : 1 pod with 1 PVC is managed by 1 Deployment.

  Note that the PVCs are empty when deployed.



# 5-2-1 Deploying Prod WordPress (2/2)

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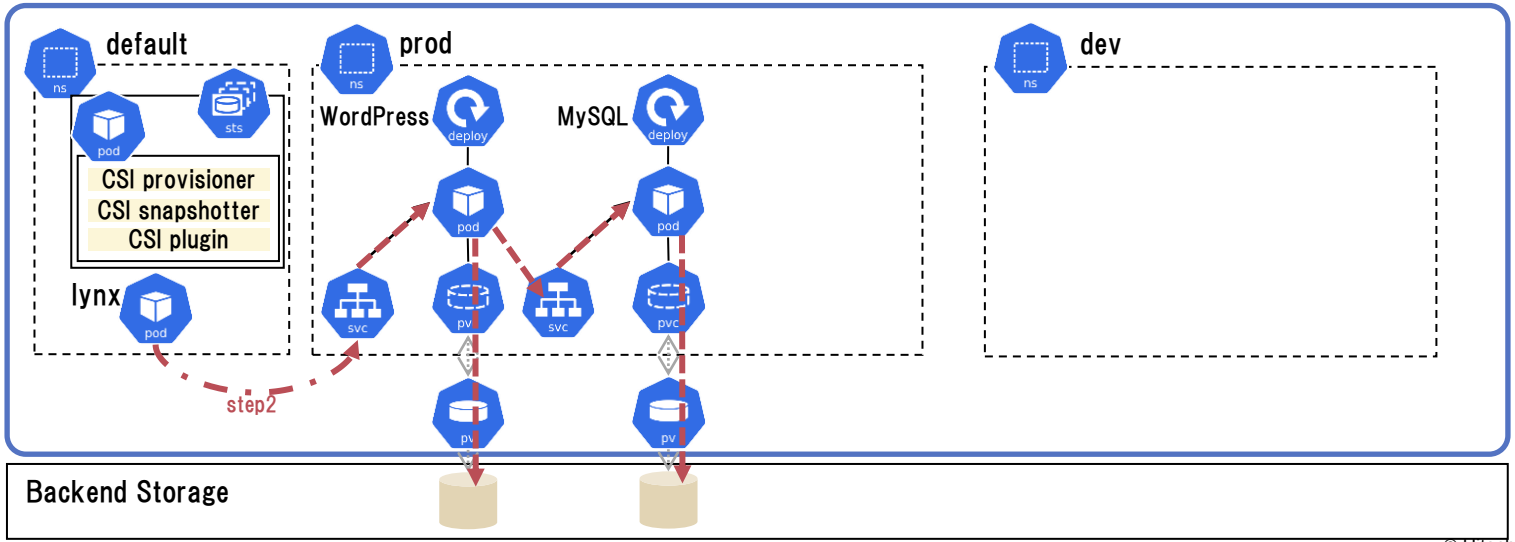
# 5-2-2 Accessing to Prod WordPress (Creating data) (1/3)

- Writing data to the PVCs by accessing to the WordPress



# 5-2-2 Accessing to Prod WordPress (Creating data) (2/3)

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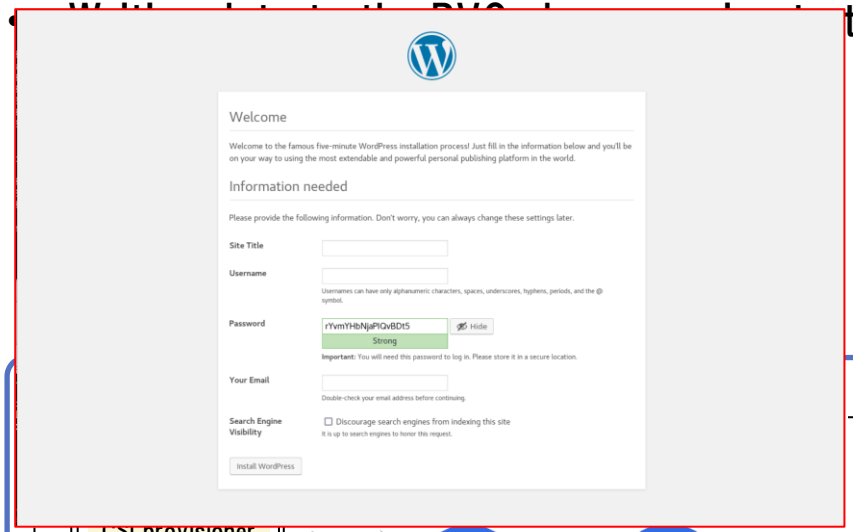
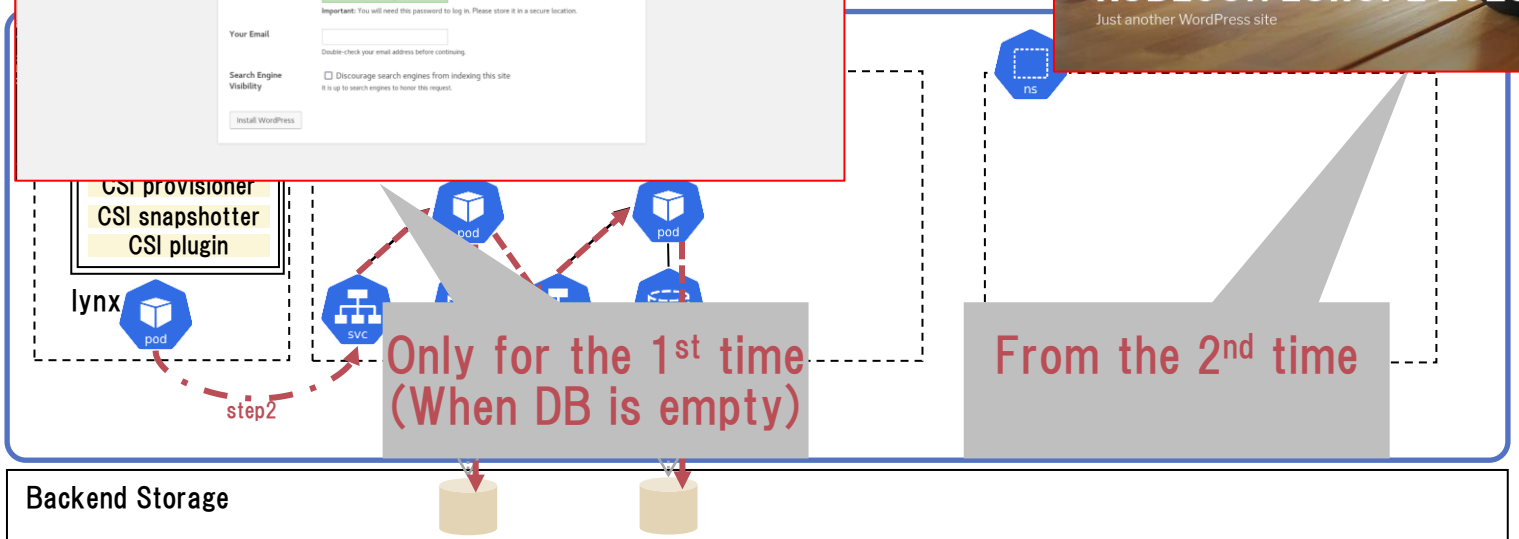
- With data to the PVC, access to the WordPress







# 5-2-2 Accessing to Prod WordPress (Creating data) (3/3)

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```
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```
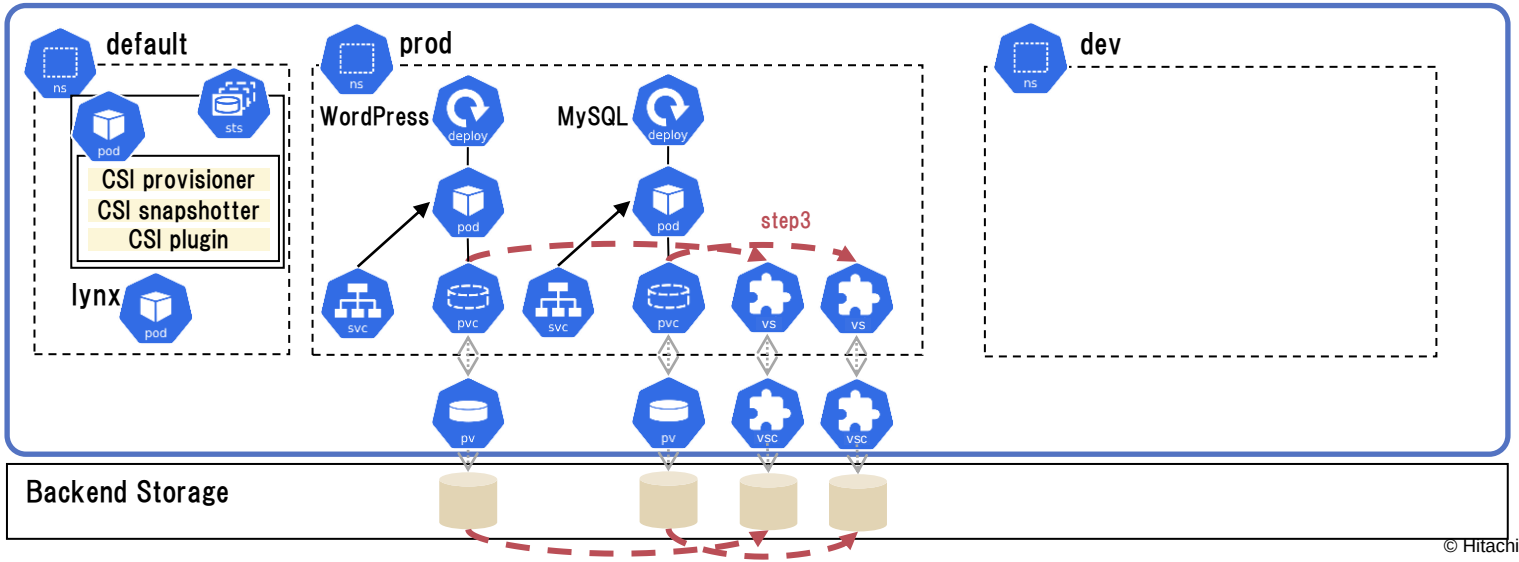

# 5-2-3 Taking Snapshots (1/2)

- Taking snapshots from PVCs for both WordPress and MySQL in prod namespace



# 5-2-3 Taking Snapshots (2/2)

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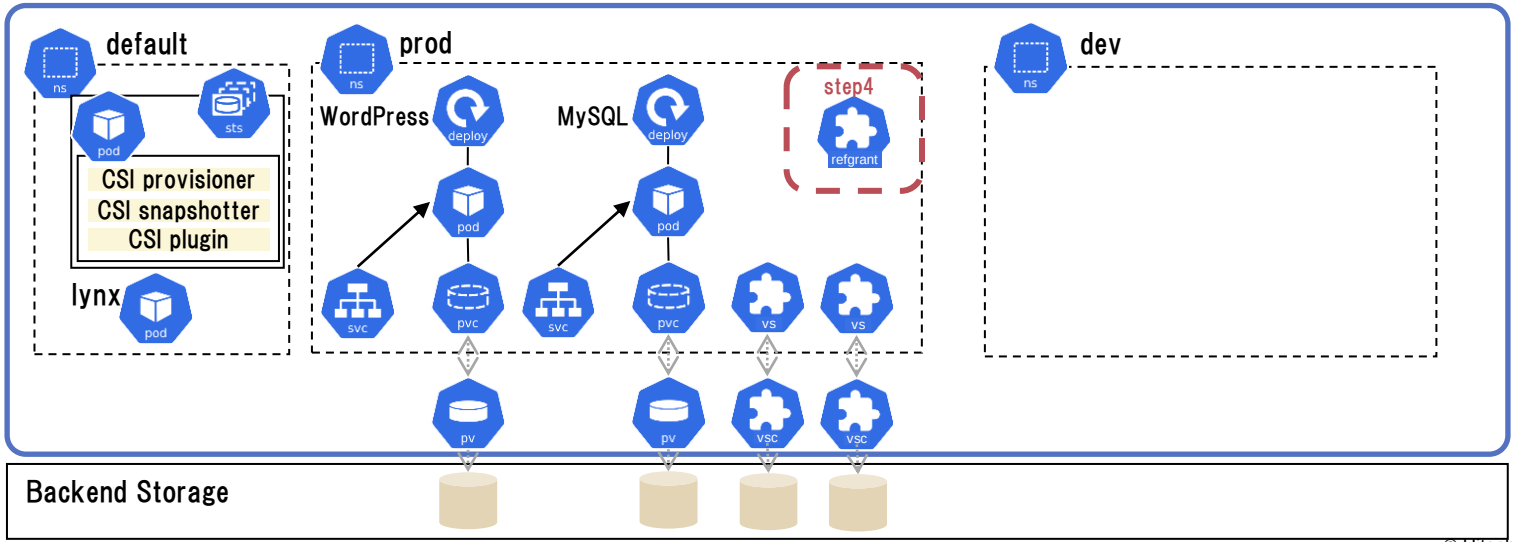
```
$
```

# 5-2-4 Creating ReferenceGrant (1/2)

- Creating a ReferenceGrant for allowing access to the snapshots in prod namespace from the PVCs in dev namespace



# 5-2-4 Creating ReferenceGrant (2/2)

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```

# 5-2-5 Creating Dev Volumes from Prod Snapshots and Using them

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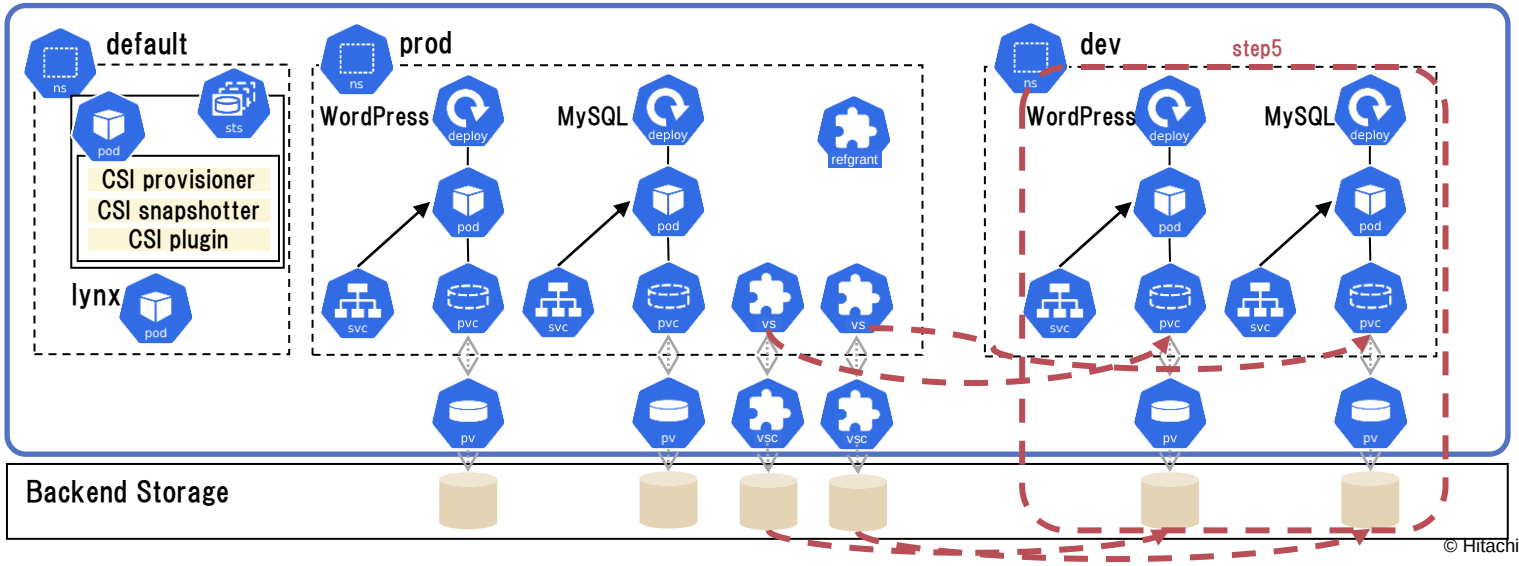
- Deploy WordPress in dev namespace
  - PVCs used from the WordPress are provisioned from the snapshot in prod namespace (PVCs are created with specifying the snapshots in the DataSourceRef field)



# 5-2-5 Creating Dev Volumes from Prod Snapshots and Using them

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```
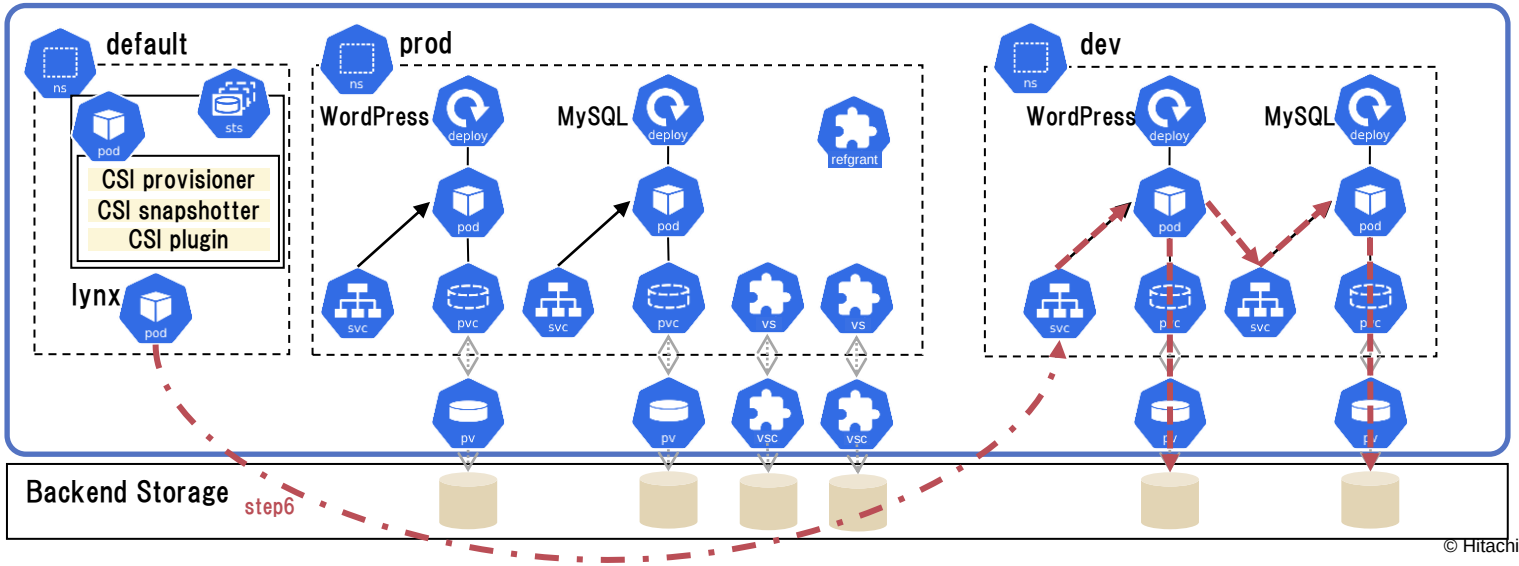

# 5-2-6 Accessing to Dev WordPress (Checking data) (1/2)

- Checking that data in dev PVCs are copied from prod snapshots by accessing dev WordPress (“KubeCon Europe 2023” should be displayed on the first access, instead of the initialization page).



# 5-2-6 Accessing to Dev WordPress (Checking data) (2/2)

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```
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```

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# 6. Conclusion

## 6-1 Conclusion
## 6-2 Reference

# 6-1 Conclusion

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- Issue: In k8s 1.25 or prior,
  - Data in production namespace can't be copied to development namespace for testing
  - Golden images in one namespace can't be shared from other namespaces

- Resolution: In k8s 1.26 or later, PVCs can be provisioned from PVCs or snapshots in a different namespace by using CrossNamespaceVolumeDataSource feature (Alpha in k8s 1.26)
  - To enable the feature (Only required during Alpha):
    - CrossNamespaceVolumeDataSource feature gate is required to be enabled for both CSI provisioner and k8s controllers
  - To utilize the feature:
    - Creating a ReferenceGrant to allow accessing to a data source from a PVC
    - Creating a PVC by specifying dataSourceRef with namespace

- Call to action: Please give your feedback on this feature to SIG Storage!

# 6-2 Reference

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- KEP:
  - KEP-3294: Provision volumes from cross-namespace snapshots
  - Old KEP discussions:
    - Propose KEP to transfer PVC between namespaces
    - Propose KEP for namespace transfer API
    - API for PVC Namespace Transfer
    - Add proposal for transfer of VolumeSnapshot
- Documents:
  - Concept: Persistent Volumes | Kubernetes
  - Blog: Kubernetes v1.26: Alpha support for cross-namespace storage data sources | Kubernetes

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