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(54) IDENTIFICATION OF STORAGE BACKENDS TO HIGHER-LEVEL PROCESSES TO PERFORM STORAGE VOLUME MANAGEMENT

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(52) **U.S. Cl.**
CPC ***G06F 3/0644*** (2013.01); ***G06F 3/0604*** (2013.01); ***G06F 3/0683*** (2013.01)

(58) **Field of Classification Search**
CPC G06F 3/0644; G06F 3/0604; G06F 3/0683
See application file for complete search history.

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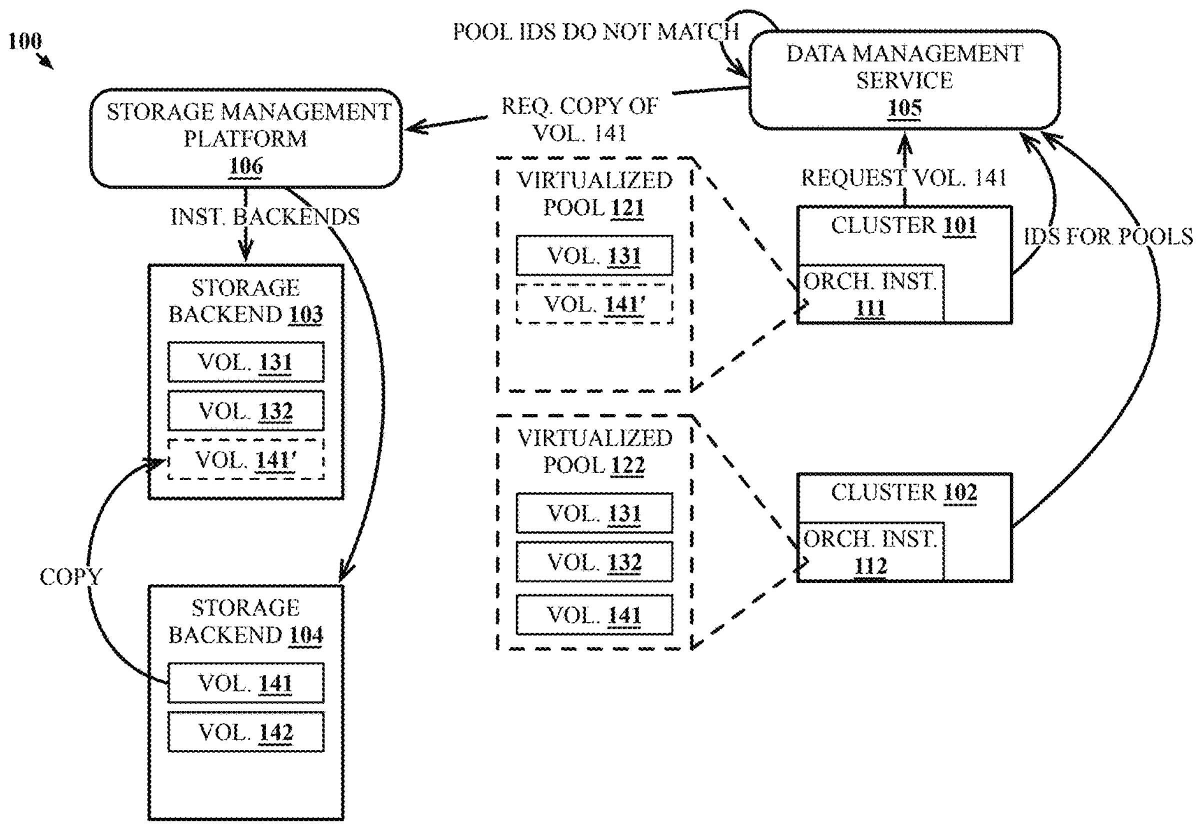
Primary Examiner — Ryan Bertram

(57) **ABSTRACT**

The technology disclosed herein enables a higher-level process to perform storage volume management with knowledge of a physical storage backend underlying a storage volume. In a particular example, a method includes mounting a storage volume to a computing node of the computing nodes. The storage volume is stored in a storage pool of a plurality of underlying storage pools. The method further includes determining an identifier for the storage pool, receiving a request to duplicate the storage volume, and determining a second identifier for a second storage pool of the plurality of underlying storage pools to which the storage volume will be duplicated. When the second identifier matches the identifier, creating a clone of the storage volume rather than copying the storage volume to the second storage pool.

20 Claims, 9 Drawing Sheets



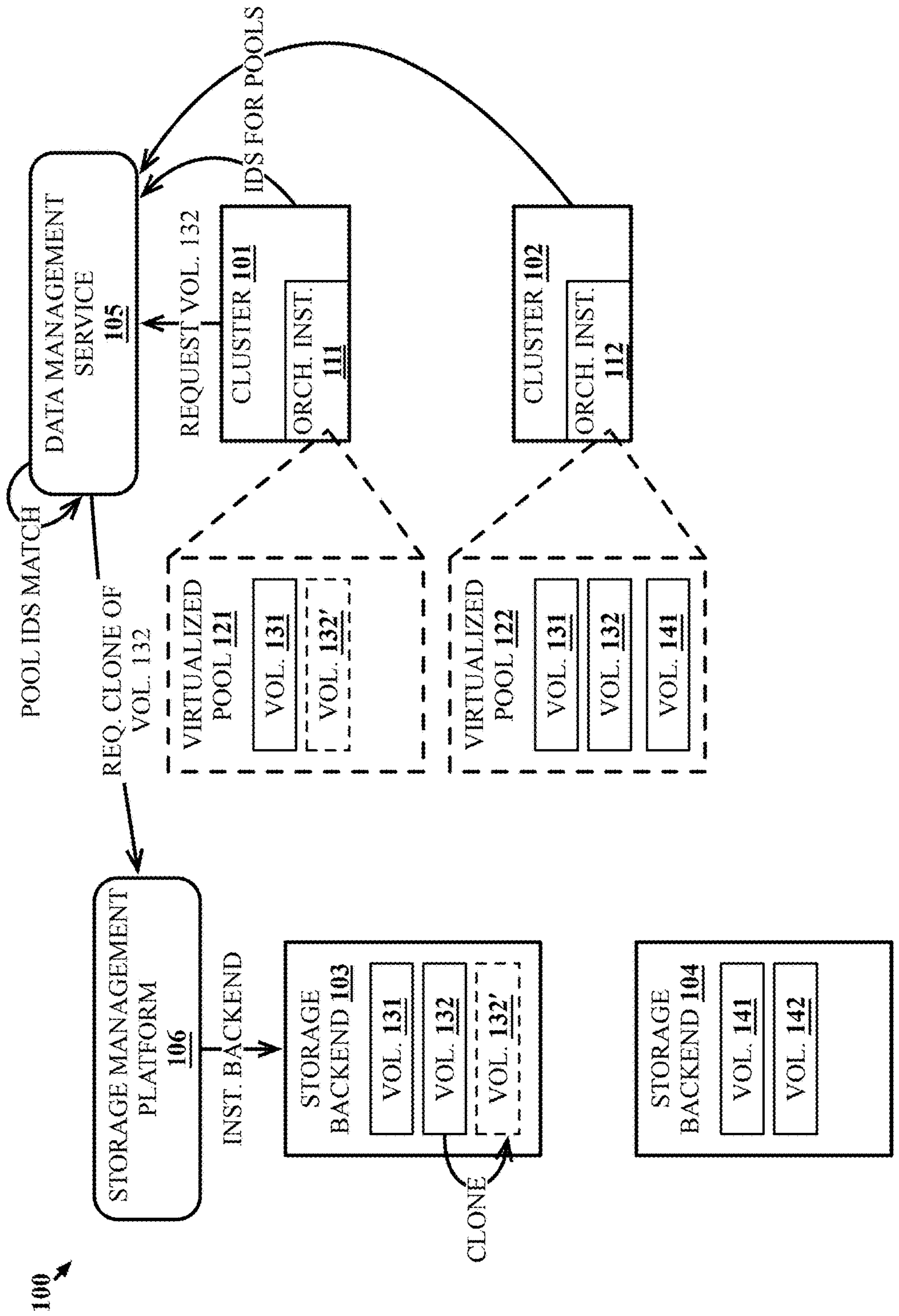

100
DATA MANAGEMENT SERVICE 105
POOL IDS MATCH
REQUEST VOL. 132
IDS FOR POOLS
CLUSTER 101
ORCH. INST. 111
CLUSTER 102
ORCH. INST. 112
REQ. CLONE OF VOL. 132
VIRTUALIZED POOL 121
VOL. 131
VOL. 132'
VIRTUALIZED POOL 122
VOL. 131
VOL. 132
VOL. 141
STORAGE MANAGEMENT PLATFORM 106
INST. BACKEND
STORAGE BACKEND 103
VOL. 131
VOL. 132
VOL. 132'
CLONE
STORAGE BACKEND 104
VOL. 141
VOL. 142

FIG. 1A

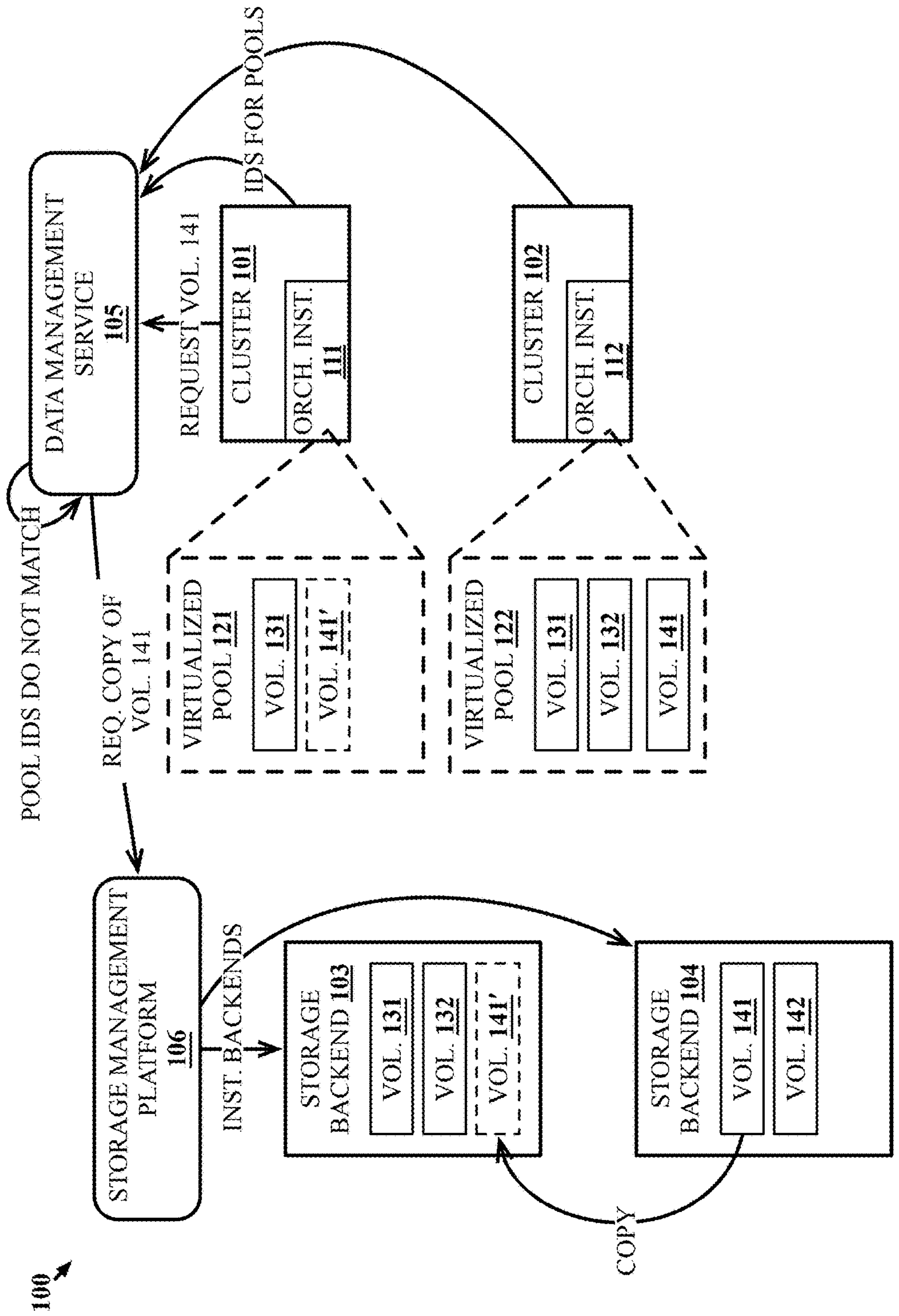

100
DATA MANAGEMENT SERVICE 105
POOL IDS DO NOT MATCH
REQUEST VOL. 141
IDS FOR POOLS
CLUSTER 101
ORCH. INST. 111
CLUSTER 102
ORCH. INST. 112
REQ. COPY OF VOL. 141
VIRTUALIZED POOL 121
VOL. 131
VOL. 141'
VIRTUALIZED POOL 122
VOL. 131
VOL. 132
VOL. 141
STORAGE MANAGEMENT PLATFORM 106
INST. BACKENDS
STORAGE BACKEND 103
VOL. 131
VOL. 132
VOL. 141'
STORAGE BACKEND 104
VOL. 141
VOL. 142
COPY

FIG. 1B

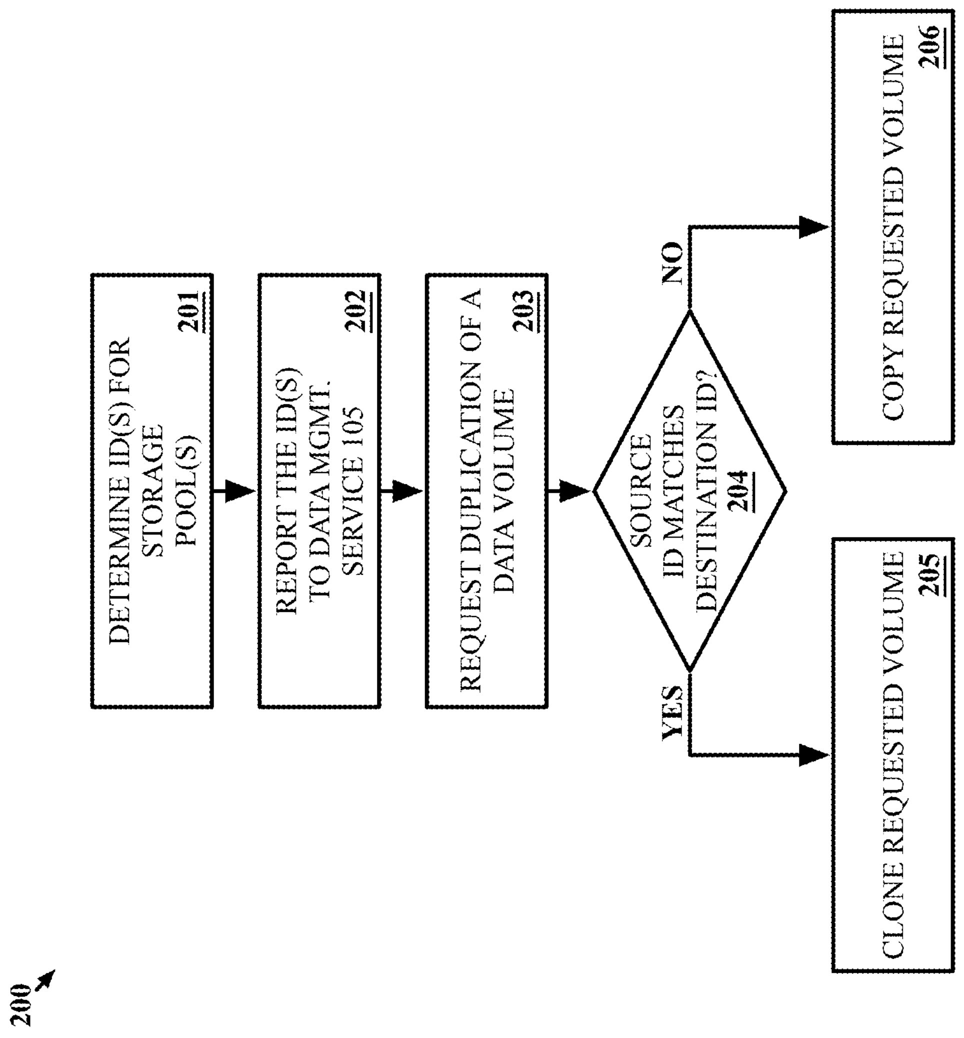

200
DETERMINE ID(S) FOR STORAGE POOL(S) 201
REPORT THE ID(S) TO DATA MGMT. SERVICE 105 202
REQUEST DUPLICATION OF A DATA VOLUME 203
SOURCE ID MATCHES DESTINATION ID? 204
YES
NO
CLONE REQUESTED VOLUME 205
COPY REQUESTED VOLUME 206

FIG. 2

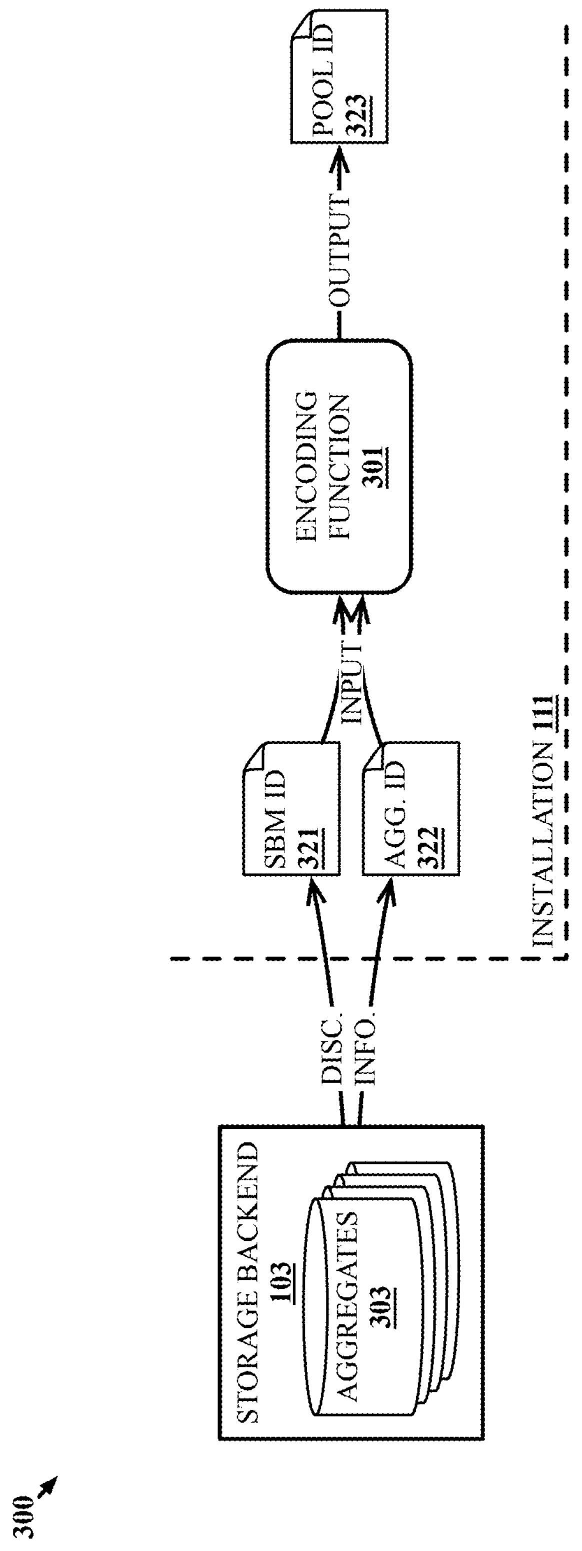

300
STORAGE BACKEND 103
AGGREGATES 303
DISC. INFO.
SBM ID 321
AGG. ID 322
INPUT
ENCODING FUNCTION 301
OUTPUT
POOL ID 323
INSTALLATION 111

FIG. 3

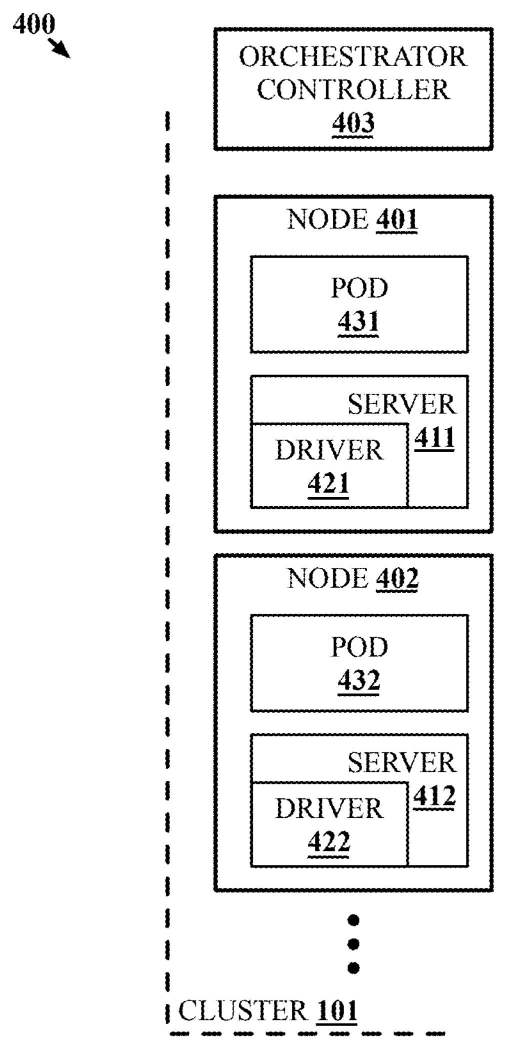

400
ORCHESTRATOR CONTROLLER 403
NODE 401
POD 431
SERVER 411
DRIVER 421
NODE 402
POD 432
SERVER 412
DRIVER 422
CLUSTER 101

FIG. 4

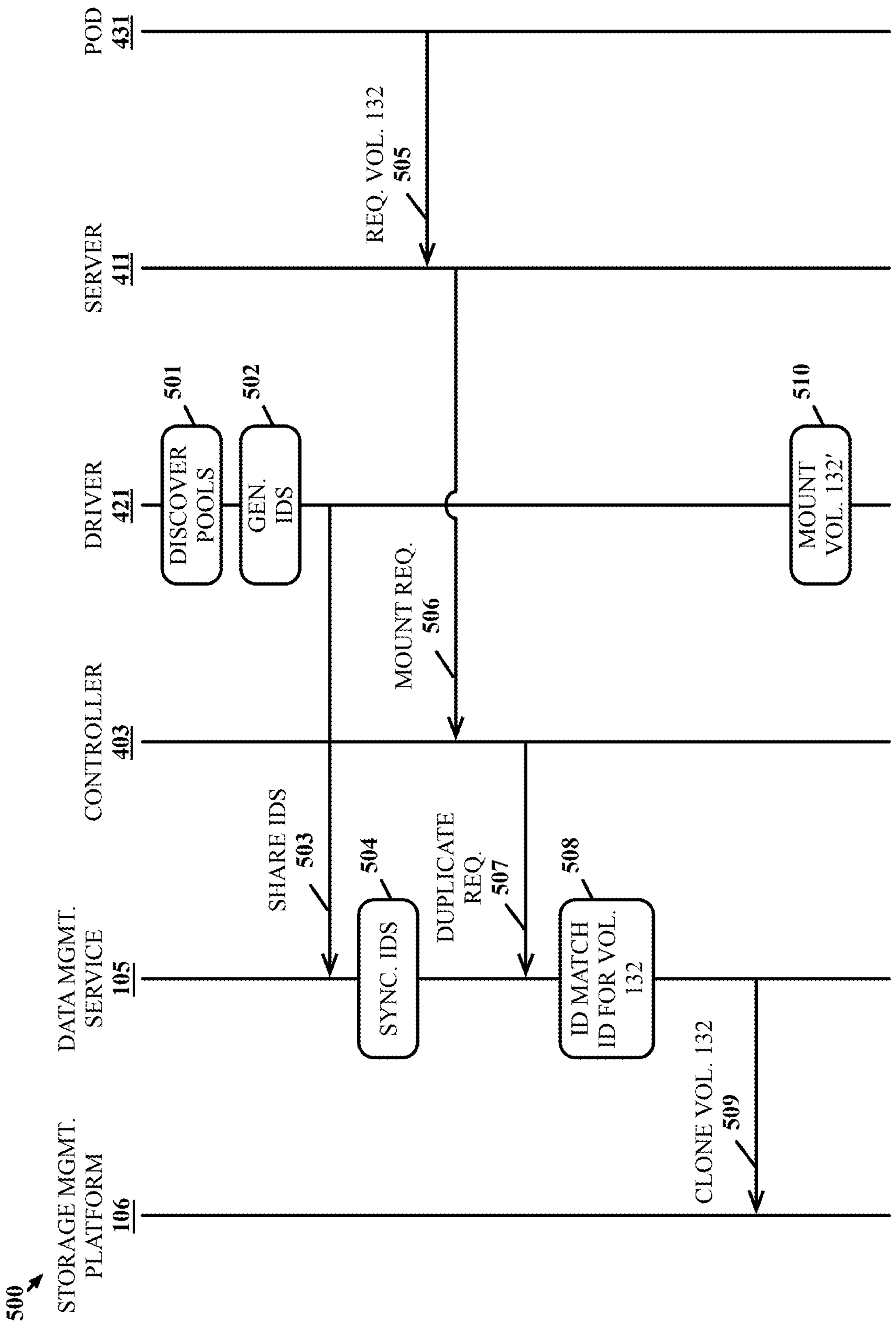

500
STORAGE MGMT. PLATFORM 106
DATA MGMT. SERVICE 105
CONTROLLER 403
DRIVER 421
SERVER 411
POD 431
DISCOVER POOLS
501
GEN. IDS
502
SHARE IDS
503
SYNC. IDS
504
REQ. VOL. 132
505
MOUNT REQ.
506
DUPLICATE REQ.
507
ID MATCH ID FOR VOL. 132
508
CLONE VOL. 132
509
MOUNT VOL. 132'
510

FIG. 5

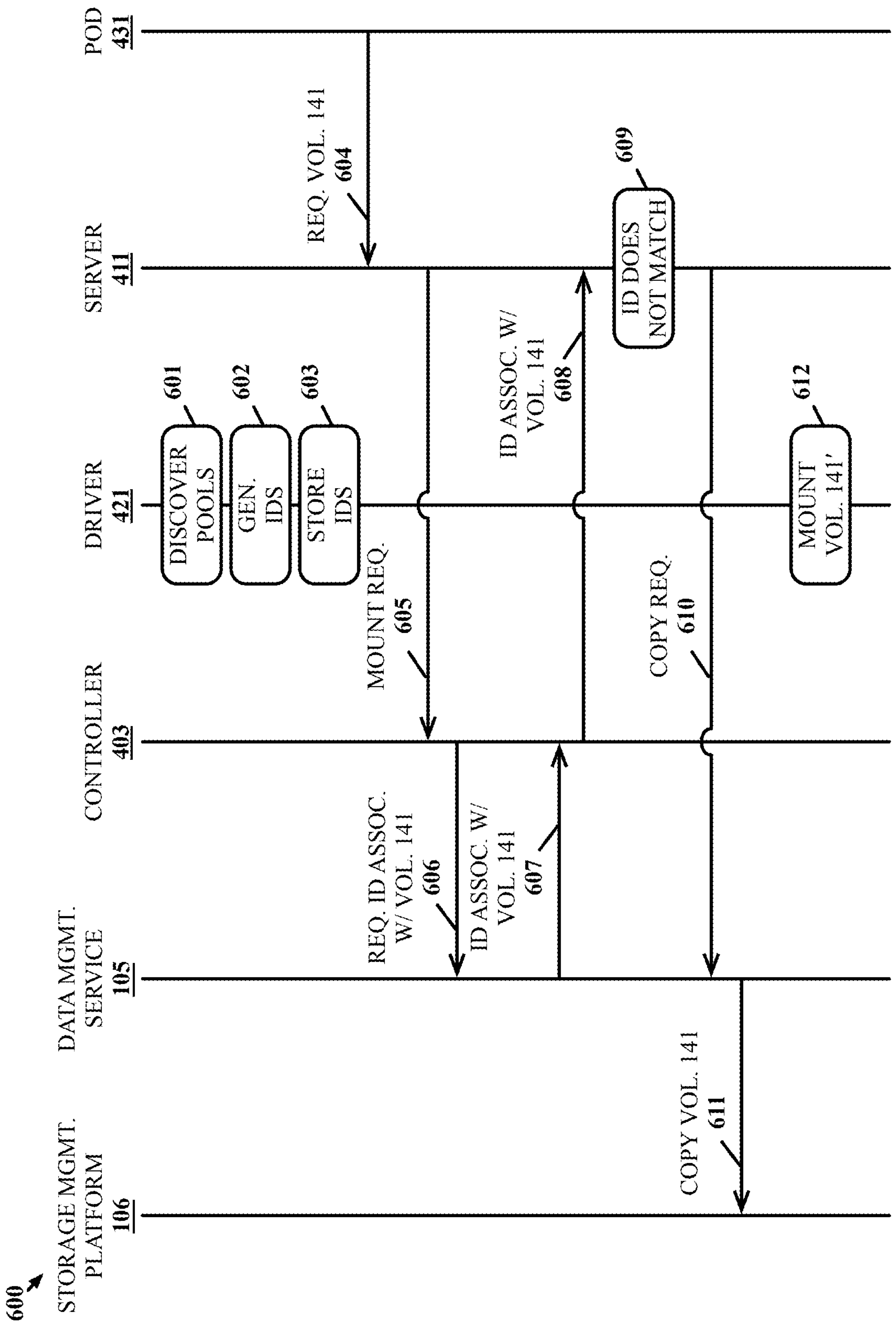

600
POD 431
SERVER 411
DRIVER 421
CONTROLLER 403
DATA MGMT. SERVICE 105
STORAGE MGMT. PLATFORM 106
DISCOVER POOLS
601
GEN. IDS
602
STORE IDS
603
REQ. VOL. 141
604
MOUNT REQ.
605
REQ. ID ASSOC. W/ VOL. 141
606
ID ASSOC. W/ VOL. 141
607
ID ASSOC. W/ VOL. 141
608
ID DOES NOT MATCH
609
COPY REQ.
610
COPY VOL. 141
611
MOUNT VOL. 141'
612

FIG. 6

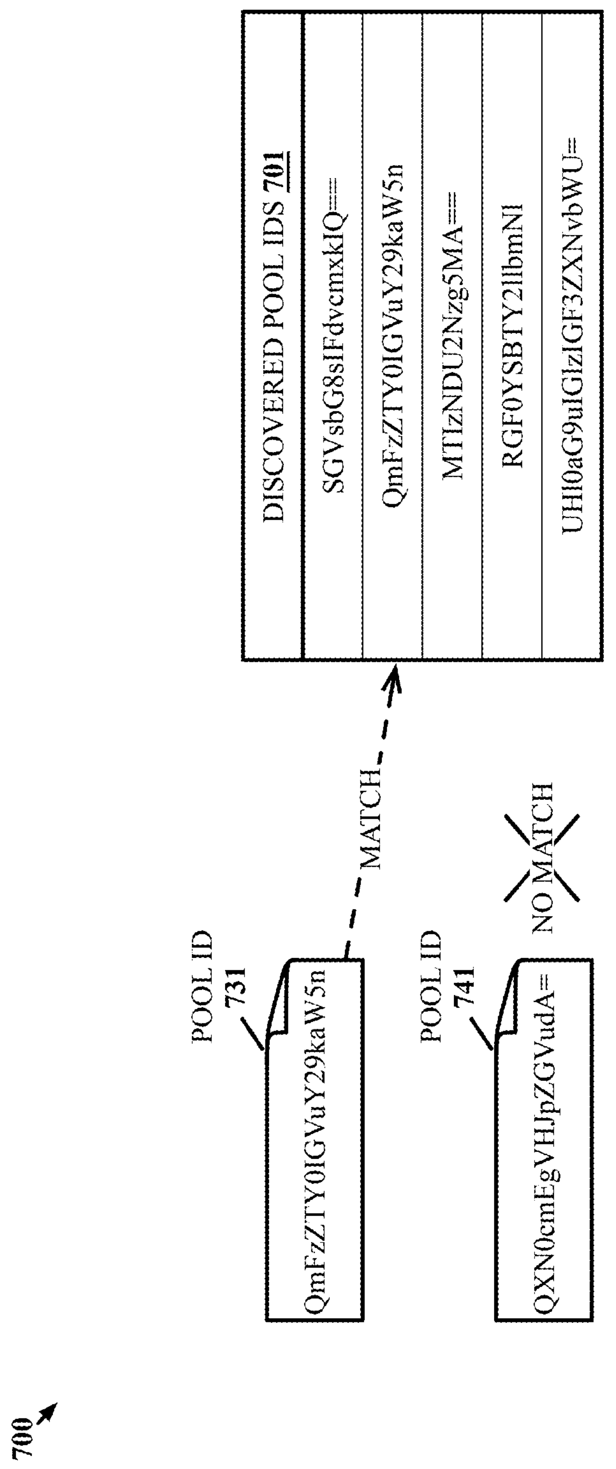

DISCOVERED POOL IDS 701
SGVsbG8sIFdvcmxkIQ==
QmFzZTY0IGVuY29kaW5n
MTIzNDU2Nzg5MA==
RGF0YSBTY2llbmNl
UHl0aG9uIGlzIGF3ZXNvbWU=
MATCH
NO MATCH
POOL ID 731
QmFzZTY0IGVuY29kaW5n
POOL ID 741
QXN0cmEgVHJpZGVudA=
700

FIG. 7

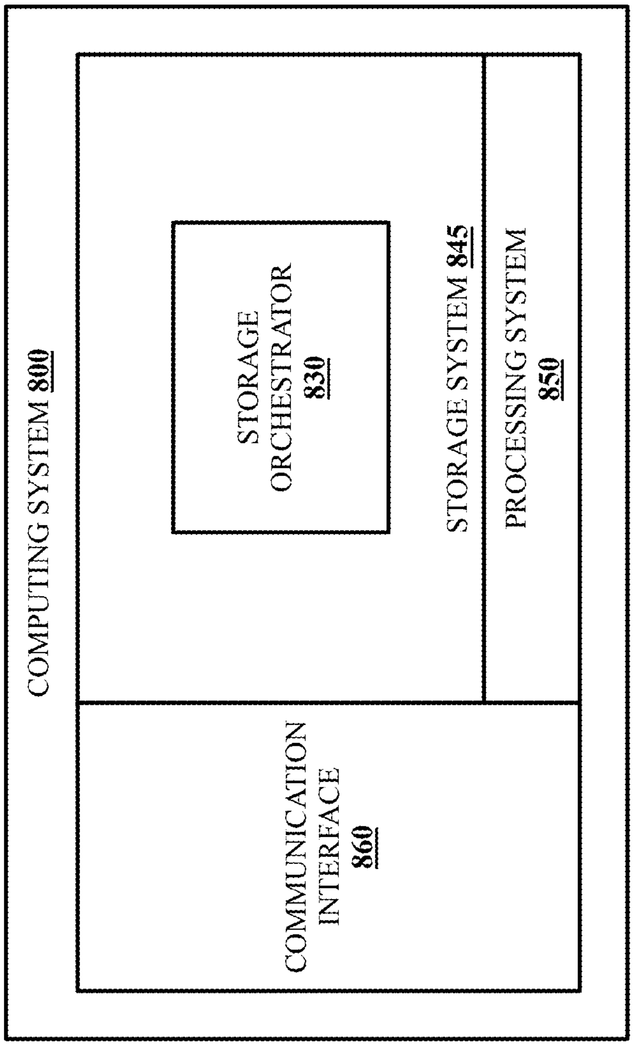

COMPUTING SYSTEM 800
STORAGE ORCHESTRATOR 830
STORAGE SYSTEM 845
PROCESSING SYSTEM 850
COMMUNICATION INTERFACE 860

FIG. 8

IDENTIFICATION OF STORAGE BACKENDS TO HIGHER-LEVEL PROCESSES TO PERFORM STORAGE VOLUME MANAGEMENT

TECHNICAL FIELD

Various embodiments of the present technology generally relate to storage volume duplication within storage pools accessible via computing cluster environments. More specifically, some embodiments relate to the identification of storage backends to higher-level process to perform storage volume management.

BACKGROUND

Storage orchestrators bridge between workloads (e.g., applications, virtual machines, containers, etc.) and storage solutions storing data for those workloads. In one example, Astra Trident is an open-source storage orchestrator designed for containerized applications running in Kubernetes pods. Trident acts as a bridge between containerized workloads and various storage solutions, such as ONTAP, Element, and cloud-based offerings like Azure NetApp Files. A storage orchestrator can simplify storage management for workloads by automating tasks like provisioning, attaching, and managing storage volumes.

A core functionality of a storage orchestrator may be storage pool virtualization. Traditionally, applications would need to interact with individual physical storage pools directly. However, the storage orchestrator may virtualize physical pools, presenting the pools as a unified storage resource (i.e., virtualized pool) to applications, such as those executing in a Kubernetes cluster. This simplifies storage management for administrators as the administrators only need to configure the storage orchestrator with the available storage pools. From there, the storage orchestrator handles dynamically allocating storage resources based on the needs of the containerized applications. The virtualized layer empowers users to define storage classes within a platform managing workloads (e.g., Kubernetes). The classes act as blueprints, specifying desired storage characteristics like performance tier or capacity requirements. When a container requests storage, the storage orchestrator leverages these classes to intelligently select and provision storage volumes to the virtualized storage pool. This ensures applications have the storage resources they need to function effectively.

SUMMARY

The technology disclosed herein enables a higher-level process to perform storage volume management with knowledge of a physical storage backend underlying a storage volume. In a particular example, a method includes mounting a storage volume to a computing node of the computing nodes. The storage volume is stored in a storage pool of a plurality of underlying storage pools. The method further includes determining an identifier for the storage pool, receiving a request to duplicate the storage volume, and determining a second identifier for a second storage pool of the plurality of underlying storage pools to which the storage volume will be duplicated. When the second identifier matches the identifier, creating a clone of the storage volume rather than copying the storage volume to the second storage pool.

In another example, a system includes a storage pool of a plurality of storage pools. A first installation of a storage orchestrator virtualizes the storage pool as a first virtualized pool and a second installation of a storage orchestrator virtualizes the storage pool as a second virtualized pool. The system also includes a first computing cluster executing the first installation. The computing cluster is configured to mount a data volume and the data volume is located in the second virtualized pool. The system further includes a data management service configured to determine the first computing cluster is requesting to mount the data volume from the first virtualized pool and clone the data volume to the first virtualized pool from the second virtualized pool in response to a determination that the storage pool underlies the second virtualized pool and the first virtualized pool.

In a further example, a method includes, in a server of a storage orchestrator installation for a cluster containing the computing node and executing on the computing node, receiving a request to mount a storage volume from a pod executing on the computing node and determining the storage volume does not exist in a virtualized storage pool accessible by the computing node. The method also includes determining the storage volume is stored on a storage backend underlying the virtualized storage pool and requesting the storage volume be cloned into the virtualized storage pool.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1A-1B illustrate an implementation for identifying storage backends to higher-level processes to perform storage volume management.

FIG. 2 illustrates an operation to identify storage backends to higher-level processes to perform storage volume management.

FIG. 3 illustrates an operational scenario for identifying storage backends to higher-level processes to perform storage volume management.

FIG. 4 illustrates an implementation for identifying storage backends to higher-level processes to perform storage volume management.

FIG. 5 illustrates an operational scenario for identifying storage backends to higher-level processes to perform storage volume management.

FIG. 6 illustrates an operational scenario for identifying storage backends to higher-level processes to perform storage volume management.

FIG. 7 illustrates an operational scenario for identifying storage backends to higher-level processes to perform storage volume management.

FIG. 8 illustrates a computing system for identifying storage backends to higher-level processes to perform storage volume management.

DETAILED DESCRIPTION

Some storage systems use Redirect-on-Write (ROW) cloning. ROW cloning is a data cloning technique for creating efficient and space-saving replicas of volumes or files. When using ROW cloning to generate a clone, the original data blocks of cloned volume are initially shared between the parent volume and the clone. As modifications are made to the clone, instead of altering the shared data blocks directly, ROW cloning redirects these changes to new blocks. This redirection ensures that the original data remains unchanged, preserving data integrity and consistency. By only storing the modified or new data separately, ROW cloning minimizes storage overhead and maximizes storage efficiency. This approach enables storage systems to optimize resource utilization and streamline data management tasks.

A storage orchestrator like Trident typically does not care which physical storage backends underlie a virtualized storage pool created by an orchestrator installation in a computing cluster. However, if a storage volume is to be duplicated, not knowing the physical storage location of the storage volume may prevent the storage orchestrator from leveraging the benefits of ROW cloning. In particular, a storage management platform, such as ONTAP, may be used to interface with backend storage systems and provide the storage orchestrator with access to the systems. Storage management platforms integrate on-premises, hybrid, and multi-cloud environments, offering features such as high availability, data protection, and scalability. The platforms also tend to support multiple storage protocols, such as NFS (Network File System), SMB (Storage Message Block), and iSCSI (Internet Small Computer Systems Interface), enabling the platforms to serve a wide range of workloads and applications. Even if a storage management platform supports ROW cloning, instructions must be provided to the storage management platform to request a clone be created. For tasks like data backup and versioning, it may be assumed that a clone can be produced in the same physical storage pool. In contrast, for other tasks where the duplicate may be needed on another storage pool, it cannot be assumed that cloning can be performed. As such, for those tasks, the opposite is assumed and the storage management system is directed to create a copy to a storage location rather than create a clone.

The examples below describe a mechanism whereby a storage orchestrator provides identification of the source and destination storage pools for a duplicate storage volume. If the source and destination are the same, then ROW cloning can be used in place of copying the storage volume. While copying the volume may still occur when the source and destination differ, the instances in which cloning can be used instead will still free up resources in the storage systems because ROW clones use less storage space and processing resources to create than copies.

Various embodiments of the present technology provide for a wide range of technical effects, advantages, and/or improvements to computing systems and components. For example, various embodiments may include one or more of the following technical effects, advantages, and/or improvements: 1) the data management service shares identifiers for physical storage pools across clusters that would otherwise be unaware of shared physical storage pools; 2) knowledge of the storage pools enables the data management service **105** to use cloning, instead of copying, when pool identifiers match; and/or 3) data management service **105** uses cloning to conserve additional storage system resources that are needed when copying a storage volume.

FIG. **1**A illustrates implementation **100** for identifying storage backends to higher-level processes to perform storage volume management. Implementation **100** includes clusters **101**-**102**, storage backends **103**-**104**, data management service **105**, and storage management platform **106**. While not shown, components of implementation **100** may communicate over various communication links, which may be direct links or may include intervening systems, networks, and devices. Clusters **101**-**102** are networks of interconnected computing systems (e.g., servers) that work together to perform processing tasks. Clusters enable efficient allocation of computing resources when distributing workloads across multiple nodes. Distribution of workloads across nodes in a cluster allows for enhanced scalability as demand for those workloads change. Each of storage backends **103**-**104** is accessed by clusters **101**-**102** through a defined protocol or interface (e.g., iSCSI, SMB, NFS, etc.), allowing the computing nodes in clusters **101**-**102** to read and write data stored within. This interaction typically involves the computing nodes sending requests to the storage backend in the storage backend's protocol, which then processes the requests and performs the necessary operations to retrieve or write the data.

Data management service **105** provides centralized management and coordination of orchestrator installations **111**-**112**. Data management service **105** may configure, deploy updates, and otherwise manage orchestrator installations **111**-**112** across clusters **101**-**102**, ensuring consistent storage provisioning and management operations throughout clusters of the environment. While two clusters are shown in implementation **100**, other examples may include more or fewer clusters with orchestrator installations managed by data management service **105**. In one example, data management service **105** may be an Astra installation while orchestrator installations **111**-**112** may be Trident installations. Data management service **105** is shown separately from clusters **101**-**102** but may be implemented as processes executing on one or more computing nodes in clusters **101**-**102**.

Each of orchestrator installations **111**-**112** handles establishment of connections to storage backends **103**-**104** to access underlying storage resources of storage backends **103**-**104**. Orchestrator installations **111**-**112** simplify the management of storage provisioning and operations within clusters **101**-**102**. Each of orchestrator installations **111**-**112** may be a Trident installation or may be an installation of some other storage orchestrator where multiple installations thereof are managed by a data management service like data management service **105**. Different clusters **101**-**102** may be used in this example due to different types of workloads being handled by the different clusters **101**-**102**. As such, clusters **101**-**102** may be located in the same physical data center location but are logically separated. Each of clusters **101**-**102** receives one of orchestrator installations **111**-**112** to handle access to storage backend **103** and/or storage backend **104**. Although, more or fewer storage backends may exist with which orchestrator installations **111**-**112** can communicate in other examples.

As part of orchestrator installations **111**-**112** simplification of storage provisioning and access to computing nodes in clusters **101**-**102**, orchestrator installations **111**-**112** virtualize the storage backends as virtualized storage pools **121**-**122**. Virtualized storage pool **121** is what orchestrator installation **111** makes available for nodes of cluster **101** to access and virtualized storage pool **122** is what orchestrator installation **112** makes available for nodes of cluster **102** to access. Virtualized storage pool **121** includes storage volume **131** and virtualized storage pool **122** includes storage volume **131**, storage volume **132**, and storage volume **141**. Storage volume **132** and storage volume **142** are present in respective storage backends **103**-**104** but may not currently be included in virtualized storage pool **121** and virtualized storage pool **122** (e.g., may be included in some other virtualized pool for some other cluster). One benefit of using virtualized storage pools **121**-**122** is that nodes can access storage backends **103**-**104** as though they are a single storage volume. The workloads on the nodes do not need to be configured with the protocols and other conventions of each specific storage backend. Rather, orchestrator installations **111**-**112** handle any translation necessary to communicate with storage backends **103-104**. For instance, if a workload in cluster **101** indicates storage volume **131** should be mounted to the computing node executing the workload, a component of orchestrator installation **111** will mount storage volume **131** in virtualized storage pool **121** from the perspective of the workload. The workload has no need to know storage volume **131** is actually being mounted from storage backend **103** since orchestrator installation **111** handles the translation between virtualized storage pool **121** and storage backend **103**. For instance, storage backend **103** may be an iSCSI physical storage pool while storage backend **104** may use NFS. Orchestrator installations **111-112** handles any translation needed from workload instructions to iSCSI or NFS depending on where a storage volume is located.

Storage management platform **106** is a unified storage platform that can integrate with on-premises, hybrid, and multi-cloud environments, offering features such as high availability, data protection, and scalability. Storage management platform **106** has the ability to create clones when instructed to do so and may be capable of other data management features like snapshotting, data protection, and disaster recovery. ONTAP is on example of storage management platform **106** but storage management platform **106** may also be an Isilon, HyperFlex, etc. platform.

Typically, when data management service **105** is to duplicate a storage volume, data management service **105** assumes the storage volume is being duplicated from one physical storage pool to another (e.g., from storage backend **103** to storage backend **104** or vice versa). This is because data management service **105** is unaware of the physical location (i.e., physical storage pool) of a storage volume and the physical location to which the storage volume is to be duplicated. Without such knowledge, if those two locations are not the same, cloning a storage volume will not result in a duplicate being accessible from the desired pool. Therefore, orchestrator installations **111-112** generate and share identifiers for the storage pools accessible thereby to data management service **105**. Data management service **105** uses the identifiers to determine whether the physical storage pool storing a storage volume is the same physical storage pool to which a duplicate of the storage volume is going to be stored. If the two identified physical storage pools are the same, data management service **105** can clone the storage volume rather than copy the storage volume, which consumes more storage space (i.e., because a full copy will be taking up space in the physical pool) and uses more processing resources to create.

For example, clusters **101-102** each generate identifiers for underlying physical storage pools that are being virtualized by respective virtualized storage pools **121-122**. The identifiers may be generated when the physical storage pools are discovered by orchestrator installations **111-112**, when particular identifiers are needed for comparison (e.g., in response to a duplication request), or at some other time prior to being used. Orchestrator installations **111-112** provide the generated pool identifiers to data management service **105**. When a workload executing on a computing node in cluster **101** requests a duplicate of storage volume **132**, orchestrator installation **111** responsively requests data management service **105** for a duplicate of storage volume **132**. In the request from orchestrator installation **111** to data management service **105**, data management service **105** at least identifies storage volume **132** to data management service **105** and may also provide a destination pool's identifier indicating the physical storage pool to which the duplicate should be stored. Had orchestrator installation **111** simply indicated virtualized storage pool **121**, then data management service **105** would still not know whether storage volume **132** can be copied or cloned from its current location. In some examples, orchestrator installation **111** may further provide an indicator of the physical storage pool where storage volume **132** is stored. Alternatively, data management service **105** may already track where storage volume **132** is stored such that data management service **105** can determine the physical storage pool for storage volume **132**.

In this example, storage backends **103-104** are two storage pools. As such, a storage pool identifier for storage backend **103** corresponds to storage backend **103** as a whole and a storage pool identifier for storage backend **104** corresponds to storage backend **104** as a whole. In other examples, storage backend **103** may include multiple physical storage pools. For instance, storage backend **103** may be a distributed storage system and each location of the distributed storage system may be considered its own storage pool. Each of those storage pools would include an identifier that distinguishes the storage pool from others. In this example, orchestrator installation **111** is requesting that storage backend **103** store the duplicate of storage volume **132**. Storage backend **103** may be the default destination for the duplicate because virtualized storage pool **121** does not include storage backend **104** or, as noted above, orchestrator installation **111** may explicitly indicate storage backend **103** as being the destination for the duplicate of storage volume **132**.

In response to receiving the request from orchestrator installation **111**, data management service **105** compares the pool identifiers for where storage volume **132** is stored and where the duplicate of storage volume **132** is going to be stored. In this case, storage volume **132** is located in the same physical storage pool, storage backend **103**, where the duplicate of storage volume **132** will also be stored. As such, the pool identifiers will match. Even though data management service **105** does not necessarily know any additional detail about storage backend **103**, data management service **105** knows storage volume **132** can be cloned due to the pool identifiers being the same. In response to determining the pool identifiers match, data management service **105** communicates with storage management platform **106** to request storage volume **132** be cloned. Then, in response to receiving the clone instruction from data management service **105**, storage management platform **106** instructs storage backend **103** to clone storage volume **132**, creating storage volume **132'**, using ROW cloning.

Storage volume **132'** is now included in virtualized storage pool **121** for access by the workload requesting the clone of storage volume **132**. Before storage volume **132'** is included in virtualized storage pool **121**, an identifier for storage volume **132'** may be created by storage backend **103** and sent directly, or through storage management platform **106**/data management service **105**, to orchestrator installation **111**. Once storage volume **132'** is included in virtualized storage pool **121**, the workload in cluster **101** can access storage volume **132'**. Since storage volume **132'** is a ROW clone, storage volume **132'** points to storage volume **132** when reading and creates new blocks when data is written to storage volume **132'**.

FIG. 1B illustrates another example of implementation **100** for identifying storage backends to higher-level processes to perform storage volume management. In this example, a workload in cluster **101** requests storage volume **141** be duplicated into virtualized storage pool **121**. Like storage volume **132'** above, the destination physical pool for the duplicate of storage volume **141** is storage backend **103**. The duplicate may be destined for storage backend **103** because virtualized storage pool **121** only virtualizes storage backend **103** or the duplicate may be directed to storage backend **103** for some other reason. In this example, virtualized storage pool **122** virtualizes both storage backend **103** and storage backend **104** because virtualized storage pool **122** includes storage volumes from storage backends **103-104** (i.e., storage volume **131**, storage volume **132**, and storage volume **142**). Unlike the example above, data management service **105** determines that the pool identifiers for the source and destination of storage volume **141** do not match, indicating to data management service **105** that storage volume **141** is stored in a different physical pool from where the duplicate will be stored. As such, data management service **105** requests that storage management platform **106** make a copy of storage volume **141** to storage backend **103**.

In response to the request from data management service **105**, storage management platform **106** communicates with storage backend **103** and storage backend **104** to create a copy, storage volume **141'**, of storage volume **141**. Storage volume **141'** may be created by storage backend **104** sending data of storage volume **141** to storage backend **103** directly, through an intermediate system, or through some other inter-system data copying mechanism. Once storage volume **141'** is stored in storage backend **103**, storage volume **141'** can be included in virtualized storage pool **121** by orchestrator installation **111**. As was the case with storage volume **132'**, an identifier for storage volume **141'** may be created by storage backend **103** and sent directly, or through storage management platform **106**/data management service **105**, to orchestrator installation **111**. Unlike the clone of storage volume **132**, storage volume **141'** is a regular storage volume that can be manipulated like any other non-clone storage volume.

FIG. **2** illustrates operation **200** to identify storage backends to higher-level processes to perform storage volume management. In operation **200**, orchestrator installations **111-112** determine identifiers for storage pools accessible by their respective clusters **101-102** (step **201**). The storage pools may include one or more storage pools in storage backend **103** and/or storage backend **104**. A storage pool may be a logical grouping of physical storage media, such as hard disks and solid-state drives, and sometimes referred to as an aggregate. Storage backends **103-104** may each include a single storage pool or may be divided into multiple storage pools. The identifiers may be received from storage backends **103-104**, calculated from information received from storage backends **103-104**, or determined in some other manner that ensure each identifier distinctly identifies a respective storage pool (e.g., is unique among all possible storage pools orchestrator installations **111-112** may access).

Orchestrator installations **111-112** report the determined identifiers to data management service **105** (step **202**). Typically, data management service **105** would have no use for identifiers corresponding to physical storage pools but, in those typical situations, data management service **105** would not have the option to clone a volume rather than copy the volume. After reporting the identifiers, orchestrator installation **111** (or orchestrator installation **112** in other examples) requests duplication of a data volume (e.g., storage volume **132** or storage volume **141** per the examples above) (step **203**). The request identifies the storage volume. The request may also include an identifier of the storage pool in which the storage volume is stored. Data management service **105** determines whether the identifier associated with the storage volume matches an identifier of a storage pool virtualized in virtualized storage pool **121** (step **204**). That is, data management service **105** received identifiers of storage pools virtualized by virtualized storage pool **121** in step **202** above. Data management service **105** may compare the identifier of the storage pool storing the storage volume with the set of identifiers received from orchestrator installation **111** to check whether there is a match within that set.

If the identifier matches an identifier received from orchestrator installation **111** at step **202**, then data management service **105** communicates with storage management platform **106** to clone the requested volume (step **205**). The matching identifier indicates to data management service **105** that the storage pool storing the requested volume is also a storage pool that is (or can be) virtualized as part of virtualized storage pool **121**. Thus, a ROW clone will conserve resources relative to producing a copy of the storage volume while still presenting to orchestrator installation **111** as a duplicate. If, however, no identifier received from orchestrator installation **111** matches the identifier of the storage pool containing the requested storage volume, then data management service **105** communicates with storage management platform **106** to copy the storage volume to a storage volume that is accessible by orchestrator installation **111** and virtualized as part of virtualized storage pool **121** (step **206**). In some examples, orchestrator installation **111** may identify a destination storage pool on which the copy should be stored or data management service **105** may select the storage pool from storage pool virtualized as virtualized storage pool **121**.

FIG. **3** illustrates operational scenario **300** for identifying storage backends to higher-level processes to perform storage volume management. Operational scenario **300** is an example of how a pool identifier may be determined. Specifically, orchestrator installation **111** includes encoding function **301** which encodes information received about respective storage pools into identifiers for the respective storage pools. The encoding function may be any algorithm that transforms information into an identifier that can be compared to other generated identifiers. The encoding function may be reversible to recreate the input data from the identifier produced but reversibility is not necessary. In one example, encoding function **301** may use Base64 encoding, which converts binary data into a string of characters selected from a set of 64 American Standard Code for Information Interchange (ASCII) characters. The resulting character string may be the identifier for a storage pool or further manipulation of the characters may be performed prior to settling on an identifier.

In this example, an identifier for storage backend **103**, specifically a Storage Backend Management (SBM) identifier **321**, and aggregate identifier **322** for a particular aggregate of aggregates **303** are used as input. SBM identifier **321** and aggregate identifier **322** may be discovered by orchestrator installation **111** from storage backend **103** through a discovery process defined by the storage access protocol used by storage backend **103** (e.g., iSCSI). SBM identifier **321** and aggregate identifier **322** are processed by encoding function **301** to generate storage pool identifier **323**. Thus, storage pool identifier **323** represents a particular physical storage pool that includes the aggregate having aggregate identifier **322** within storage backend **103**.

If orchestrator installation **111** is also able to access one or more aggregates in storage backend **104**, orchestrator installation **111** will similarly discover information from storage backend **104**. In those cases, SBM identifier **321** will be replaced with an SBM identifier of storage backend **104**. The

SBM identifier for storage backend **104** will be fed into encoding function **301** with respective aggregate identifiers of aggregates in storage backend **104** that are accessible to orchestrator installation **111**. Additionally, while operational scenario **300** is described from the perspective of orchestrator installation **111**, orchestrator installation **112** performs similar operations to generate pool identifiers for those of aggregates **303** and aggregates in storage backend **104** to which orchestrator installation **112** has access. Orchestrator installation **112** uses the same encoding function **301** to generate the pool identifiers because, if both orchestrator installations **111-112** has access to the same storage pool, the pool identifier generated for that storage pool must be the same from both orchestrator installations **111-112**. Since the input information received about the aggregate will be the same, using the same encoding function **301** results in the same pool identifier output.

FIG. **4** illustrates implementation **400** for identifying storage backends to higher-level processes to perform storage volume management. Implementation **400** is an example of components included in cluster **101**. Specifically, implementation **400** includes computing nodes **401-402** and orchestrator controller **403**. Only two computing nodes are shown for cluster **101** but any number of computing nodes may be supported by cluster **101**. Computing nodes **401-402** may each be a standalone unit equipped with processing power, memory, and storage, capable of executing tasks independently (e.g., a server computer). Computing nodes **401-402** collaborate within cluster **101** to distribute, perform, and otherwise manage workloads.

In this example, the workloads executed by computing nodes **401-402** are respective pods **431-432**. A pod is the smallest deployable unit in a Kubernetes cluster and includes one or more containers that share resources, such as networking and storage, on a computing node. Pods **431-432** are managed collectively by Kubernetes (not shown) and serve as the basic building blocks for scalable application. Kubernetes assigned pods **431-432** to their respective computing nodes **401-402** and may assign additional pods to additional computing nodes of cluster **101** should additional capacity be required. Workloads may be implemented as other types of processes (e.g., native applications, containers, virtual machines, etc.) in other examples.

Computing node **401** also executes orchestrator server **411** while computing node **402** executes orchestrator server **412**. Orchestrator servers **411-412** are components of orchestrator installation **111**. Orchestrator controller **403** is also a component of orchestrator installation **111**. Orchestrator controller **403** may execute as a process on one or more computing nodes in cluster **101** or may execute on a dedicated computing system. Orchestrator controller **403** functions as the orchestrator for data management tasks within the Kubernetes environment of cluster **101**, facilitating seamless interaction between pods **431-432** and orchestrator servers **411-412**. When pod **431** or pod **432** requires access to data stored on storage backends **103-104** managed by orchestrator installation **111**, the pod sends a request to orchestrator controller **403** specifying the required data and desired actions. Orchestrator controller **403** then coordinates with orchestrator servers **411-412**, which are responsible for executing the data operations on the underlying storage infrastructure of storage backends **103-104**. Through this orchestration process, orchestrator controller **403** ensures that pods **431-432** can efficiently access and manipulate data while adhering to defined access controls, storage policies, and performance requirements.

Orchestrator servers **411-412** include respective storage drivers **421-422**. Storage drivers **421-422** server as a bridge between pods **431-432** and storage backends **103-104**, enabling seamless interaction and data management. Essentially, a storage driver translates high-level commands and requests from pods into instructions that storage backend **103** and/or storage backend **104** can understand and execute. By leveraging specific APIs (Application Programming Interfaces) and protocols supported by different storage vendors, the storage driver ensures compatibility and interoperability across a wide range of storage platforms. Thus, even if storage backends **103-104** are from different vendors and use different protocols, storage drivers **421-422** ensure data stored thereon can be accessed by pods **431-432**.

FIG. **5** illustrates operational scenario **500** for identifying storage backends to higher-level processes to perform storage volume management. In operational scenario **500**, storage driver **421** discovers storage pools (step **501**). Storage driver **421** may employ a process of dynamic detection and configuration. Initially, storage driver **421** may leverage predefined or user-configured parameters to scan the network for storage backends **103-104** and available storage pools therein. This scanning process involves querying storage backends **103-104** to identify pools of storage capacity (e.g., aggregates) that can be allocated for use. Once identified, storage driver **421** collects relevant metadata and characteristics of each storage pool, including capacity, performance capabilities, redundancy levels, and access protocols. Storage driver **421** further collects information necessary to create identifiers for each discovered storage pool, which include SBM identifiers and aggregate identifiers in this example. Storage driver **421** may stop after performing an initial discovery (e.g., a first discovery upon being run) or storage driver **421** may continue to monitor (e.g., periodically) for additional storage pools (and backends) that come available or are removed during execution of storage driver **421** (i.e., rediscovers storage backends). These discovered pools are examples of pools virtualized as virtualized storage pool **121** by orchestrator installation **111**.

Storage driver **421** generates pool identifiers from the SBM identifiers and aggregate identifiers received during discovery (step **502**). The pool identifiers may be produced using encoding function **301** as described above. The pool identifiers are transmitted to data management service **105** after generation (step **503**). Transmitting the pool identifiers to data management service **105** informs data management service **105** of the storage pools accessible by storage driver **421**. In some examples, data management service **105** may synchronize the pool identifiers received from storage driver **421** with other drivers under control of data management service **105** (e.g., other drivers in cluster **101**, such as storage driver **422**, and/or drivers running on computing nodes in cluster **102** so that drivers in cluster **102** are aware of the storage pools available to cluster **101** without having to query data management service **105**) (step **504**).

After discovering storage backends, pod **431** requests that orchestrator server **411** mount a copy of storage volume **132** (step **505**). To make the request, pod **431** may issue a Kubernetes Persistent VolumeClaim (PVC), specifying a volume identifier for storage volume **132**. Pod **431** may be preprogrammed to request storage volume **132** or may be configured to determine storage volume **132** should be mounted during execution (e.g., based on information received from other pods in cluster **101**). In response to the request from pod **431**, orchestrator server **411** communicates with orchestrator controller **403** to request mounting of a copy of storage volume **132** (step **506**). Storage volume **132** is not currently included in the storage volumes accessible by orchestrator installation **111** so orchestrator controller **403** passes a request to duplicate storage volume **132** into a storage pool accessible by storage driver **421** (step **507**).

Upon receiving the duplication request, data management service **105** determines the pool identifier for the storage pool storing storage volume **132** matches a pool identifier accessible by storage driver **421** (step **508**). Data management service **105** may keep an index of storage volumes in association with pool identifiers associated therewith, data management service **105** may query orchestrator installation **112** for a pool identifier of a pool storing storage volume **132**, or data management service **105** may obtain the pool identifier associated with storage volume **132** in some other manner. Data management service **105** compares the pool identifier associated with storage volume **132** to the pool identifiers received from storage driver **421** to recognize the pool identifier matches with one of the pool identifiers received from storage driver **421**. In response to finding a match, data management service **105** directs storage management platform **106** to create a ROW clone, storage volume **132'**, of storage volume **132** (step **509**). To create the clone, storage management platform **106** may simply require the volume identifier for storage volume **132** and locates storage volume **132** in storage backend **103** based on the volume identifier. Storage volume **132'** is then mounted by storage driver **421** for access by pod **431** (step **510**). While storage volume **132'** is a clone of storage volume **132**, for all intents and purposes, pod **431** can interact with storage volume **132'** as though it is a full copy.

FIG. **6** illustrates operational scenario **600** for identifying storage backends to higher-level processes to perform storage volume management. Operational scenario **600** begins similarly to operational scenario **500** with storage driver **421** discovering storage pools (step **601**). Pool identifiers for the storage pools are generated from information obtained during the discovery process (step **602**). In this example, the pool identifiers are stored locally at computing node **401** by storage driver **421**, although, the pool identifiers may also be sent to data management service **105** like in operational scenario **500** (step **603**).

In this example, pod **431** requests a duplicate of storage volume **141** be mounted by orchestrator server **411** (step **604**). The request may identify storage volume **141** to orchestrator server **411** using a volume identifier for storage volume **141**. In response to the request from pod **431**, orchestrator server **411** communicates with orchestrator controller **403** to request mounting of a copy of storage volume **141** (step **605**). In this example, rather than passing the copy request to data management service **105** to determine whether to copy or clone storage volume **141**, orchestrator controller **403** requests the storage pool identifier corresponding to the storage pool on which storage volume **141** is stored (step **606**). In response to the request, data management service **105** may reference an index of storage volumes in association with pool identifiers associated therewith, data management service **105** may query orchestrator installation **112** for a pool identifier of a pool storing storage volume **141**, or data management service **105** may obtain the pool identifier associated with storage volume **141** in some other manner. Data management service **105** passes the pool identifier associated with storage volume **141** to orchestrator controller **403** in response to the request from orchestrator controller **403** (step **607**). Orchestrator controller **403** likewise passes the pool identifier to orchestrator server **411** in response to the mounting request (step **608**).

Once orchestrator server **411** has received the pool identifier for storage volume **141**, orchestrator server **411** compares the identifier to pool identifiers stored by storage driver **421** to determine the pool identifier for storage volume **141** does not match any identifier stored by storage driver **421** (step **609**). As such, a clone of storage volume **141** will not be accessible to storage driver **421** just like the original storage volume **141** is not accessible by storage driver **421**. Orchestrator server **411** requests data management service **105** have a copy created of storage volume **141** to a storage pool that is accessible by storage driver **421** (step **610**). In the copy request, orchestrator server **411** may identify one or more storage pools to which the copy of storage volume **141** should be stored. If multiple storage pools are identified by orchestrator server **411**, data management service **105** may select one of the storage pools. Data management service **105** then instructs storage management platform **106** to create a copy, storage volume **141'**, of storage volume **141** in the storage pool indicated in the instruction (step **611**). Once storage volume **141'** is in a storage pool accessible by storage driver **421**, storage driver **421** mounts storage volume **141'** for access by pod **431** (step **612**).

It should be understood that the above scenarios are merely examples of what may occur to achieve the desired results of cloning storage volumes when pool identifiers match. Data management service **105** being higher level than orchestrator installations **111-112** enables data management service **105** to be a broker of pool identifiers between clusters **101-102**. Whether data management service **105** compares the identifiers, as occurred in operational scenario **500**, orchestrator server **411** compares the identifiers, as occurred in operational scenario **600**, or some other component compares the identifiers, data management service **105** is still in the path through which the pool identifiers are exchanged between clusters **101-102** for comparison.

FIG. **7** illustrates an operational scenario **700** for identifying storage backends to higher-level processes to perform storage volume management. In operational scenario **700**, discovered pool identifiers **701** is an example of pool identifiers generated by storage driver **421** from storage pools discovered during the discovery process described in operational scenarios **500-600**. In this case, five pools were discovered, and five corresponding pool identifiers were generated. Also in operational scenario **700** are pool identifier **731**, which is an example pool identifier for a storage pool storing storage volume **131**, and pool identifier **741**, which is an example pool identifier for a storage pool storing storage volume **141**. Consistent with the examples above, pool identifier **731** matches one of discovered pool identifiers **701** indicating storage volume **131** can be cloned instead of copied. Conversely, pool identifier **741** does not match any of discovered pool identifiers **701** indicating storage volume **141** will need to be copied to one of the storage pools corresponding to discovered pool identifiers **701**.

FIG. **8** illustrates a computing system **800** for identifying storage backends to higher-level processes to perform storage volume management. Computing system **800** is representative of any computing system or systems with which the various operational architectures, processes, scenarios, and sequences disclosed herein can be implemented. Computing system **800** is an example architecture for computing nodes of clusters **101-102**, such as computing nodes **401-402**, and computing systems executing data management service **105** and storage management platform **106**, although other examples may exist. Computing system **800** includes storage system **845**, processing system **850**, and communication interface **860**. Processing system **850** is operatively linked to communication interface **860** and storage system **845**. Communication interface **860** may be communicatively linked to storage system **845** in some implementations. Computing system **800** may further include other components such as a battery and enclosure that are not shown for clarity.

Communication interface **860** comprises components that communicate over communication links, such as network cards, ports, radio frequency (RF), processing circuitry and software, or some other communication devices. Communication interface **860** may be configured to communicate over metallic, wireless, or optical links. Communication interface **860** may be configured to use Time Division Multiplex (TDM), Internet Protocol (IP), Ethernet, optical networking, wireless protocols, communication signaling, or some other communication format-including combinations thereof. Communication interface **860** may be configured to communicate with other computing systems via one or more networks.

Processing system **850** comprises microprocessor and other circuitry that retrieves and executes operating software from storage system **845**. Storage system **845** may include volatile and nonvolatile, removable, and non-removable media implemented in any method or technology for storage of information, such as computer readable instructions, data structures, program modules, or other data. Storage system **845** may be implemented as a single storage device but may also be implemented across multiple storage devices or sub-systems. Storage system **845** may comprise additional elements, such as a controller to read operating software from the storage systems. Examples of storage media include random access memory, read only memory, magnetic disks, optical disks, and flash memory, as well as any combination or variation thereof, or any other type of storage media. In some implementations, the storage media may be a non-transitory storage media. In some instances, at least a portion of the storage media may be transitory. In no interpretations would storage media of storage system **845**, or any other computer-readable storage medium herein, be considered a transitory form of signal transmission (often referred to as "signals per se"), such as a propagating electrical or electromagnetic signal or carrier wave.

Processing system **850** is typically mounted on a circuit board that may also hold the storage system. The operating software of storage system **845** comprises computer programs, firmware, or some other form of machine-readable program instructions. The operating software of storage system **845** comprises storage orchestrator **830**. The operating software on storage system **845** may further include an operating system, utilities, drivers, network interfaces, applications, or some other type of software. When read and executed by processing system **850** the operating software on storage system **845** directs computing system **800** to network routing advertisements as described herein. Storage orchestrator **830** may execute natively on processing system **850** or the operating software may include virtualization software, such as a hypervisor, to virtualize computing hardware on which storage orchestrator **830** executes.

In at least one example, storage orchestrator **830** executes on processing system **850** and directs processing system **850** to receive a request to mount a storage volume from a pod executing on computing system **800** and determine the storage volume does not exist in a virtualized storage pool accessible by the computing system **800**. Storage orchestrator **830** further directs processing system **850** to determine the storage volume is stored on a storage backend underlying the virtualized storage pool and request the storage volume be cloned into the virtualized storage pool.

The included descriptions and figures depict specific implementations to teach those skilled in the art how to make and use the best mode. For teaching inventive principles, some conventional aspects have been simplified or omitted. Those skilled in the art will appreciate variations from these implementations that fall within the scope of the invention. Those skilled in the art will also appreciate that the features described above can be combined in various ways to form multiple implementations. As a result, the invention is not limited to the specific implementations described above, but only by the claims and their equivalents.

What is claimed is:

1. A method for identifying underlying storage pools accessible by computing nodes, the method comprising:
- mounting a storage volume to a computing node of the computing nodes, wherein the storage volume is stored in a storage pool of a plurality of underlying storage pools;
- determining an identifier for the storage pool;
- receiving a request to duplicate the storage volume;
- determining a second identifier for a second storage pool of the plurality of underlying storage pools to which the storage volume will be duplicated; and
- when the second identifier matches the identifier, creating a clone of the storage volume rather than copying the storage volume to the second storage pool.

2. The method of claim **1**, wherein the second identifier matching the identifier indicates the second storage pool is the same as the storage pool and physical storage in the storage pool is the same.

3. The method of claim **1**, wherein determining the identifier comprises:
- identifying a Storage Backend Management (SBM) identifier of the storage pool and an aggregate identifier within the storage pool; and
- inputting the SBM identifier and the aggregate identifier into an encoding function, wherein the encoding function outputs the identifier.

4. The method of claim **1**, comprising:
- mounting the clone to a second computing node of the computing nodes, wherein the second node writes data to the clone, wherein the storage pool redirects the data to a new block corresponding to the clone.

5. The method of claim **1**, comprising:
- receiving a second request to duplicate the storage volume;
- determining third identifier for a third storage pool of the plurality of underlying storage pools to which the storage volume will be duplicated; and
- when the third identifier does not match the identifier, creating a copy of the storage volume to the third storage pool.

6. The method of claim **1**, wherein determining the identifier comprises:
- during initiation of a storage driver at the computing node, discovering the plurality of underlying storage pools;
- creating identifiers, including the identifier, for the plurality of underlying storage pools from information discovered about the plurality of underlying storage pools; and
- reporting the identifiers to a controller.

7. The method of claim **6**, wherein determining the identifier comprises:

after a period, rediscovering the plurality of underlying storage pools;

updating the identifiers; and

after updating the identifiers, reporting the identifier to the controller, wherein the controller updates the identifiers with a data management service.

8. The method of claim **6**, wherein the controller coordinates storage between installations of a storage orchestrator, the computing node is part of a first installation of the installations, and the request is received in response to a mounting request from a second computing node of the computing nodes that is part of a second installation of the installations.

9. The method of claim **8**, comprising:

synchronizing the identifiers across storage drivers of the computing nodes including to a second storage driver at the second computing node, wherein the second storage driver determines the second identifier matches the identifier based on the identifiers.

10. A system for accessing storage volumes, the system comprising:

a storage pool of a plurality of storage pools, wherein a first installation of a storage orchestrator virtualizes the storage pool as a first virtualized pool and a second installation of a storage orchestrator virtualizes the storage pool as a second virtualized pool;

a first computing cluster executing the first installation, wherein the computing cluster is configured to mount a data volume, wherein the data volume is located in the second virtualized pool; and

a data management service configured to determine the first computing cluster is requesting to mount the data volume from the first virtualized pool and clone the data volume to the first virtualized pool from the second virtualized pool in response to a determination that the storage pool underlies the second virtualized pool and the first virtualized pool.

11. The system of claim **10**, comprising:

the first computing cluster configured to mount the data volume to a computing node of the first computing cluster from the first virtualized pool after the data volume is cloned to the first virtualized pool; and

after the data volume is mounted, the computing node configured to access data in the data volume, wherein the storage pool handles modifications to the data volume such that data is not modified in the second virtualized pool.

12. The system of claim **11**, comprising:

a second computing cluster executing the second installation configured to mount the data volume to a second computing node of the second computing cluster from the second virtualized pool; and

after mounting the data volume, the second computing node configured to access data in the data volume, wherein the storage pool handles modifications to the data volume such that data is not modified in the first virtualized pool.

13. The system of claim **10**, comprising:

a second storage pool of the plurality of storage pools, wherein a third installation of the storage orchestrator virtualizes the second storage pool as a third virtualized pool;

a third computing cluster executing the third installation, wherein the third computing cluster is configured to mount a data volume; and

the data management service configured to determine the third computing cluster is requesting to mount the data volume from third virtualized pool and copy the data volume to the third virtualized pool in response to a determination that the second storage pool underlies the third virtualized pool.

14. The system of claim **10**, comprising:

the data management service configured to determine a first identifier associated with the first virtualized pool matches a second identifier associated with the second virtualized pool, wherein matching identifiers indicates a same storage pool underlies the first virtualized pool and the second virtualized pool.

15. The system of claim **14**, comprising:

the first computing cluster configured to compute the first identifier using an encoding function and share the first identifier with the data management service; and

a second computing cluster executing the second installation configured to compute the second identifier using the encoding function and share the second identifier with the data management service.

16. The system of claim **10**, comprising:

a computing node of the first computing cluster configured to execute a pod, wherein the computing node executes a server of the first installation, and wherein the pod requests the server mount the storage volume to the computing node.

17. A method for mounting storage volumes to a computing node, comprising:

in a server of a storage orchestrator installation for a cluster containing the computing node and executing on the computing node:

receiving a request to mount a storage volume from a pod executing on the computing node;

determining the storage volume does not exist in a virtualized storage pool accessible by the computing node;

determining the storage volume is stored on a storage pool underlying the virtualized storage pool; and

requesting the storage volume be cloned into the virtualized storage pool.

18. The method of claim **17**, wherein determining the storage volume is stored on the storage pool comprises:

in a storage driver for the server, calculating an identifier for the storage pool and storing the identifier in the storage driver and comparing the identifier to another identifier calculated for another virtualized storage pool storing the storage volume.

19. The method of claim **18**, wherein requesting the storage volume be cloned comprises:

in the storage driver, requesting a storage management platform clone the storage volume on the storage pool;

mounting a clone of the storage volume from the storage pool to the computing node; and

translating access requests from a workload on the computing node to access requests for the storage pool to access the clone.

20. The method of claim **17**, comprising:

determining a different storage volume is stored on a different storage pool; and

requesting the different storage volume be copied to the virtualized storage pool on the storage pool.

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