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(54) QOS-ENABLED LIFECYCLE MANAGEMENT FOR FILE SYSTEMS

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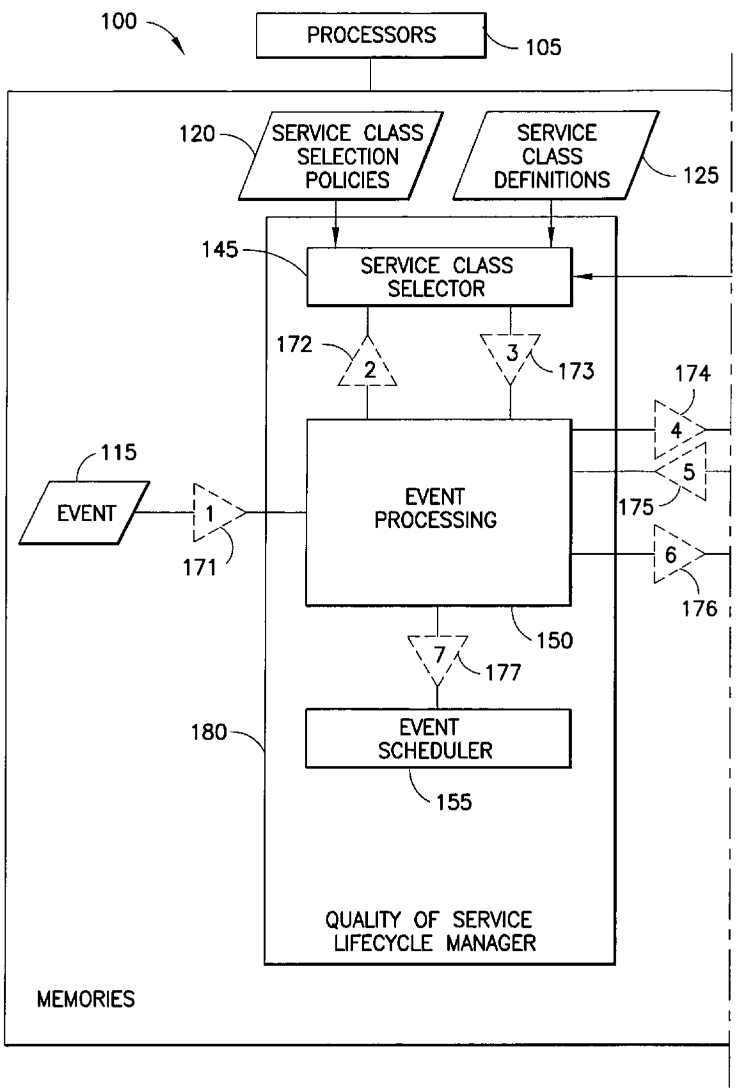
(57) **ABSTRACT**

In an exemplary aspect of the invention, a method is disclosed for lifecycle management for file systems. The method comprises the following steps. At least one storage container adapted to support a file system is allocated. The at least one storage container and the file system are associated with a service class. The file system is created in the storage container. The service class is used during lifecycle actions performed on the file system. Lifecycle actions may comprise, e.g., creating, extending, replicating, moving, or migrating a file system. The service class for the file system may also be maintained for a lifecycle of the file system.



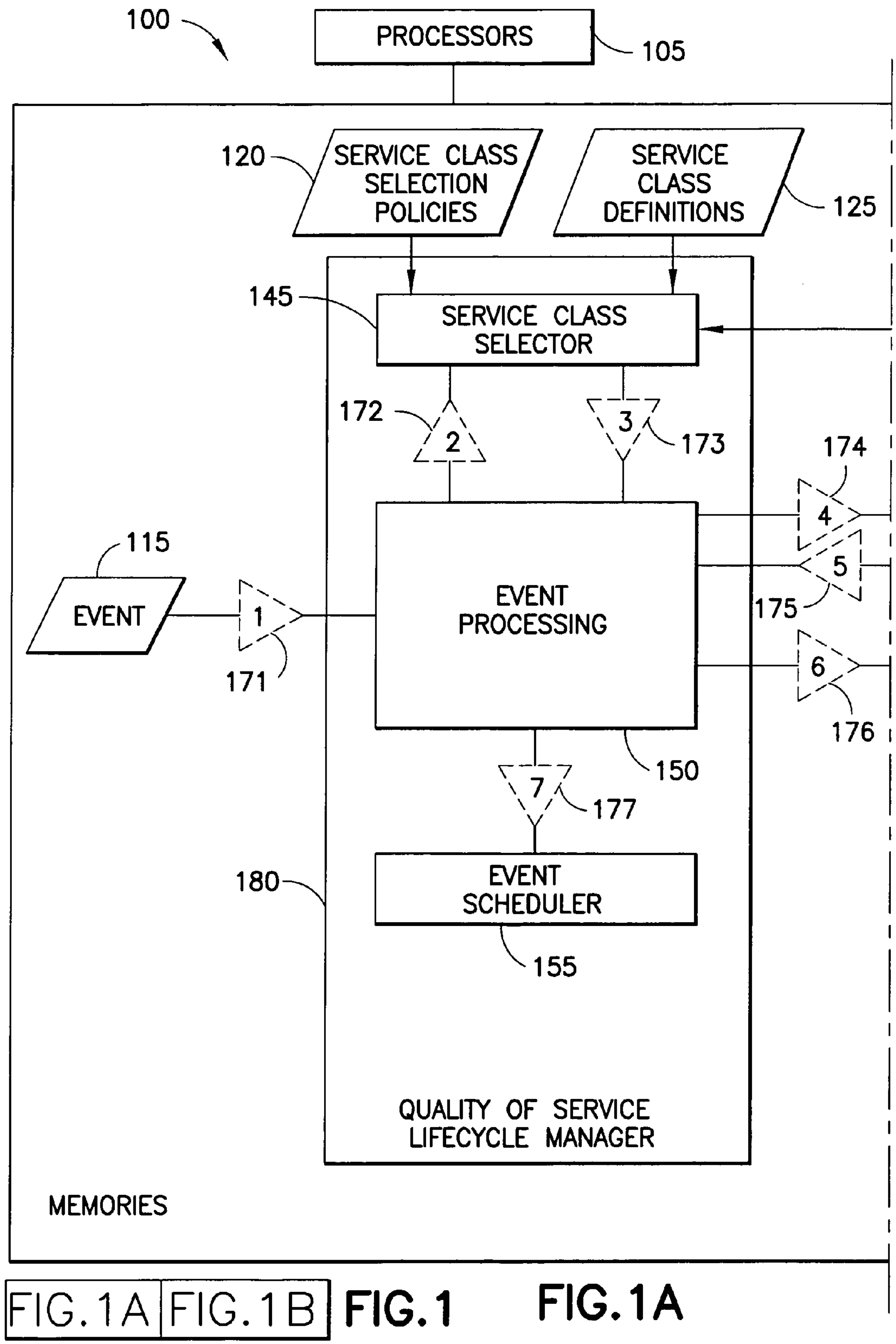

100
PROCESSORS
105
120
SERVICE CLASS SELECTION POLICIES
SERVICE CLASS DEFINITIONS
125
145
SERVICE CLASS SELECTOR
172
2
3
173
174
4
5
175
6
176
115
EVENT
1
171
EVENT PROCESSING
150
7
177
180
EVENT SCHEDULER
155
QUALITY OF SERVICE LIFECYCLE MANAGER
MEMORIES
FIG.1A
FIG.1B
FIG.1

FIG.1A

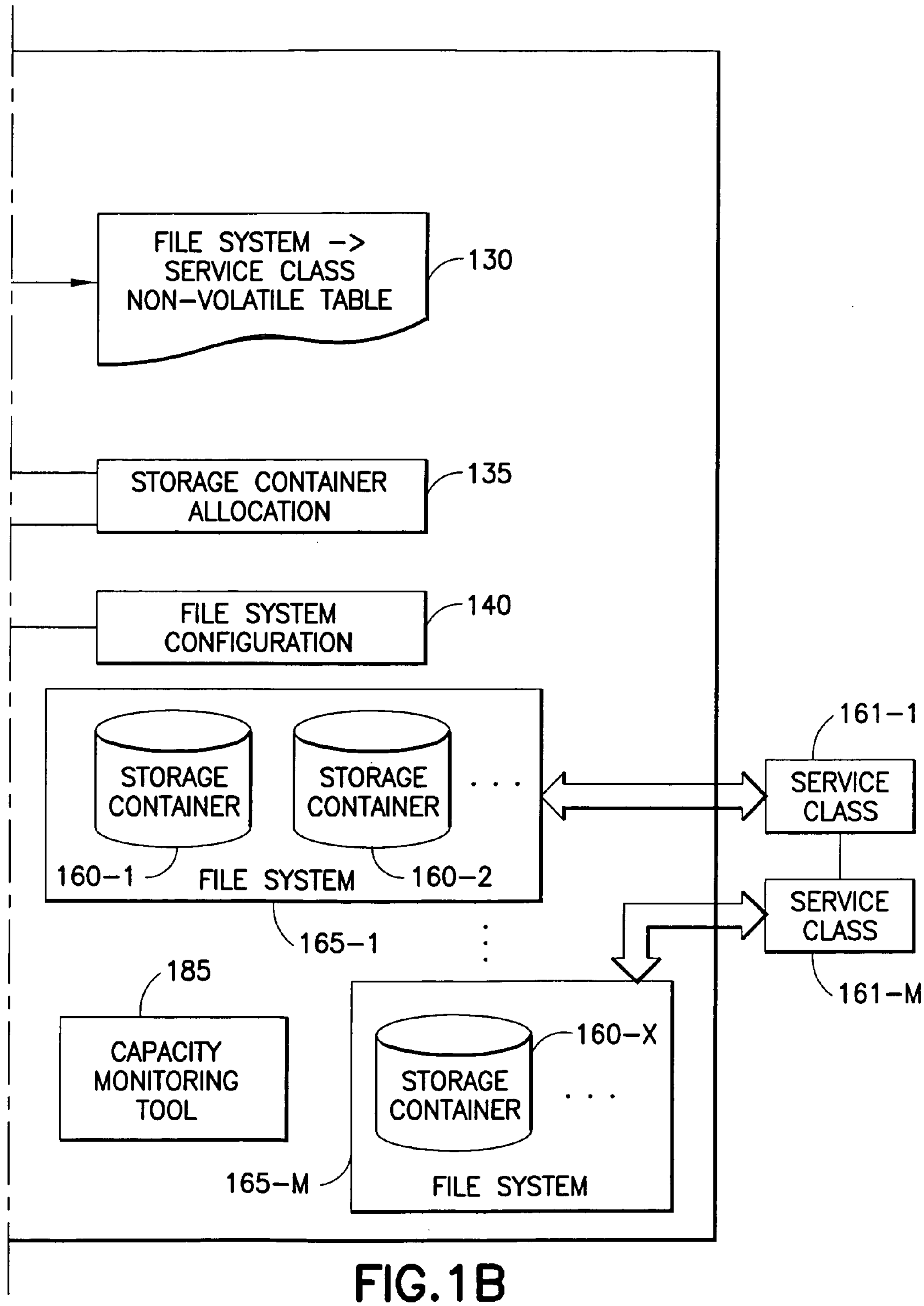

FILE SYSTEM -> SERVICE CLASS NON-VOLATILE TABLE
130
STORAGE CONTAINER ALLOCATION
135
FILE SYSTEM CONFIGURATION
140
STORAGE CONTAINER
STORAGE CONTAINER
160-1
FILE SYSTEM
160-2
165-1
161-1
SERVICE CLASS
SERVICE CLASS
161-M
185
CAPACITY MONITORING TOOL
160-X
STORAGE CONTAINER
165-M
FILE SYSTEM

FIG. 1B

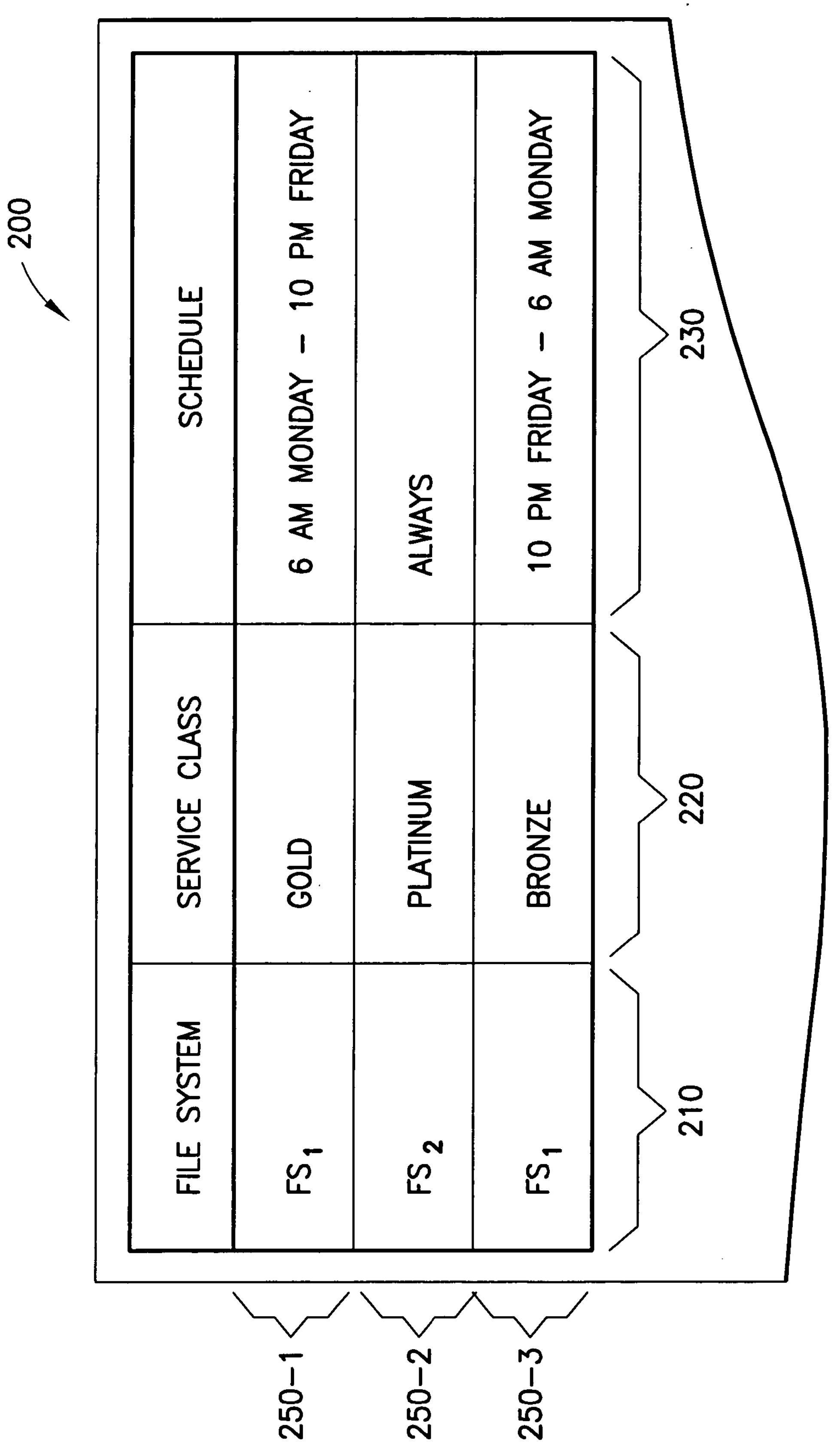

200
FILE SYSTEM
SERVICE CLASS
SCHEDULE
FS_1
GOLD
6 AM MONDAY – 10 PM FRIDAY
FS_2
PLATINUM
ALWAYS
FS_1
BRONZE
10 PM FRIDAY – 6 AM MONDAY
210
220
230
250–1
250–2
250–3

FIG.2

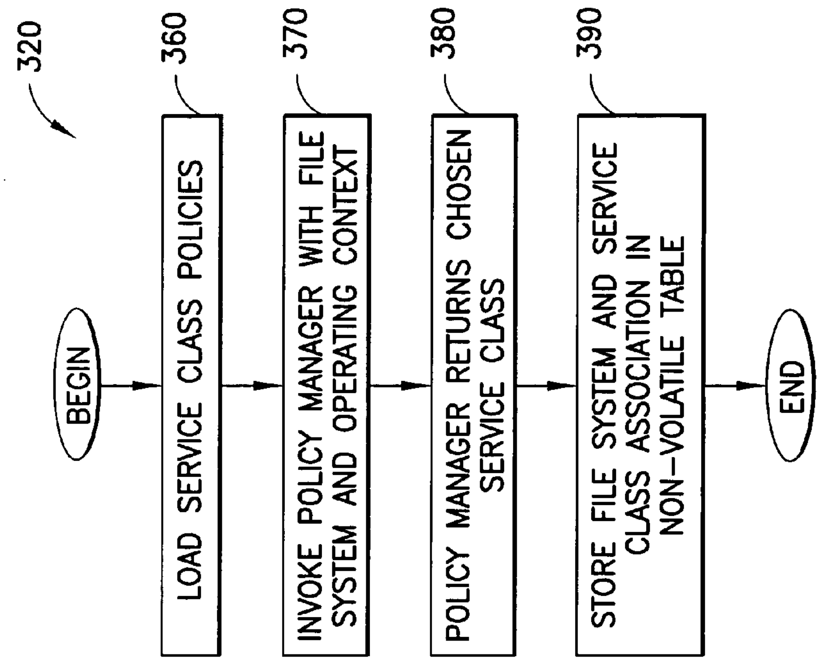

320
BEGIN
360
LOAD SERVICE CLASS POLICIES
370
INVOKE POLICY MANAGER WITH FILE SYSTEM AND OPERATING CONTEXT
380
POLICY MANAGER RETURNS CHOSEN SERVICE CLASS
390
STORE FILE SYSTEM AND SERVICE CLASS ASSOCIATION IN NON-VOLATILE TABLE
END

FIG.3B

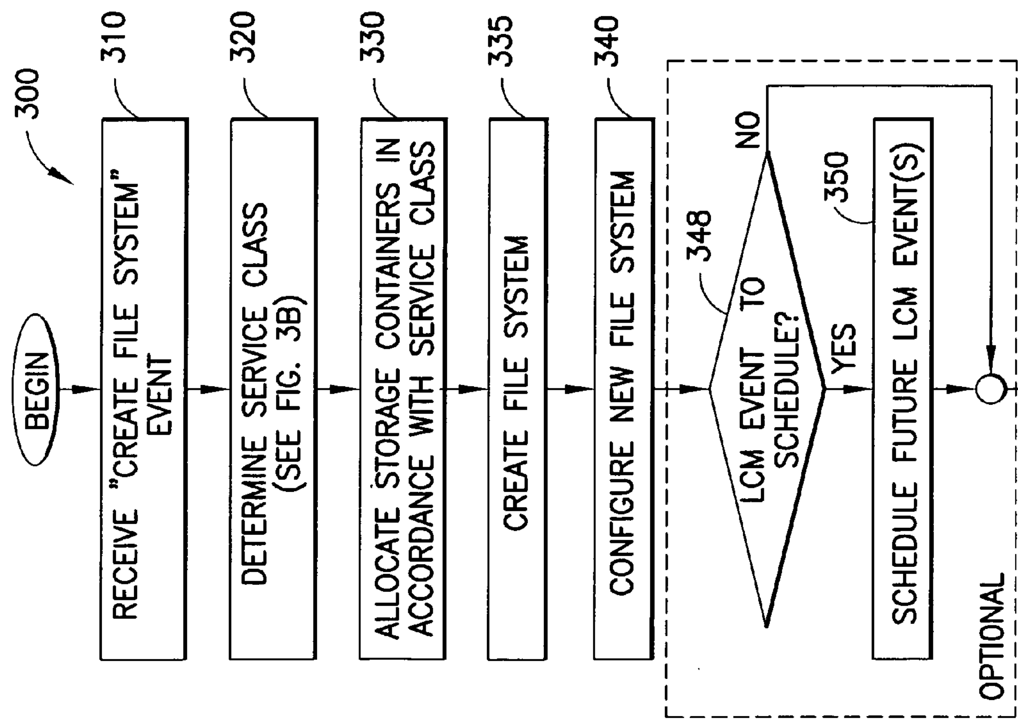

300
BEGIN
310
RECEIVE "CREATE FILE SYSTEM" EVENT
320
DETERMINE SERVICE CLASS (SEE FIG. 3B)
330
ALLOCATE STORAGE CONTAINERS IN ACCORDANCE WITH SERVICE CLASS
335
CREATE FILE SYSTEM
340
CONFIGURE NEW FILE SYSTEM
348
LCM EVENT TO SCHEDULE?
NO
YES
350
SCHEDULE FUTURE LCM EVENT(S)
OPTIONAL
END

FIG.3A

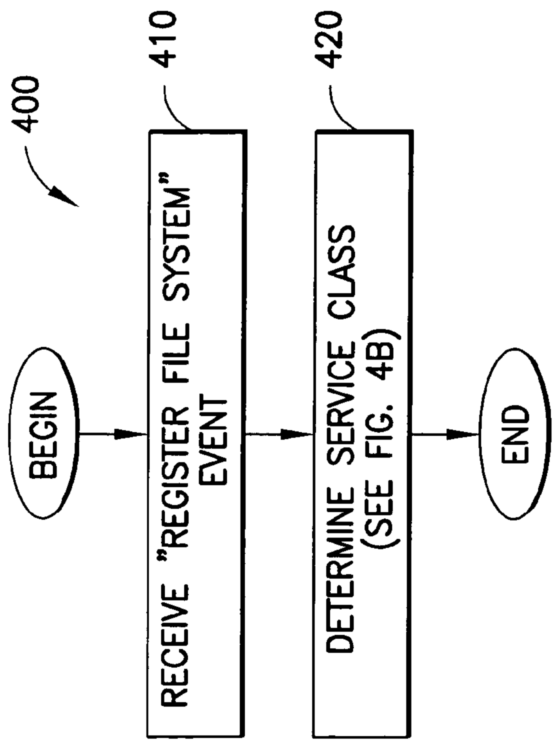

400
BEGIN
RECEIVE "REGISTER FILE SYSTEM" EVENT
410
DETERMINE SERVICE CLASS (SEE FIG. 4B)
420
END

FIG.4A

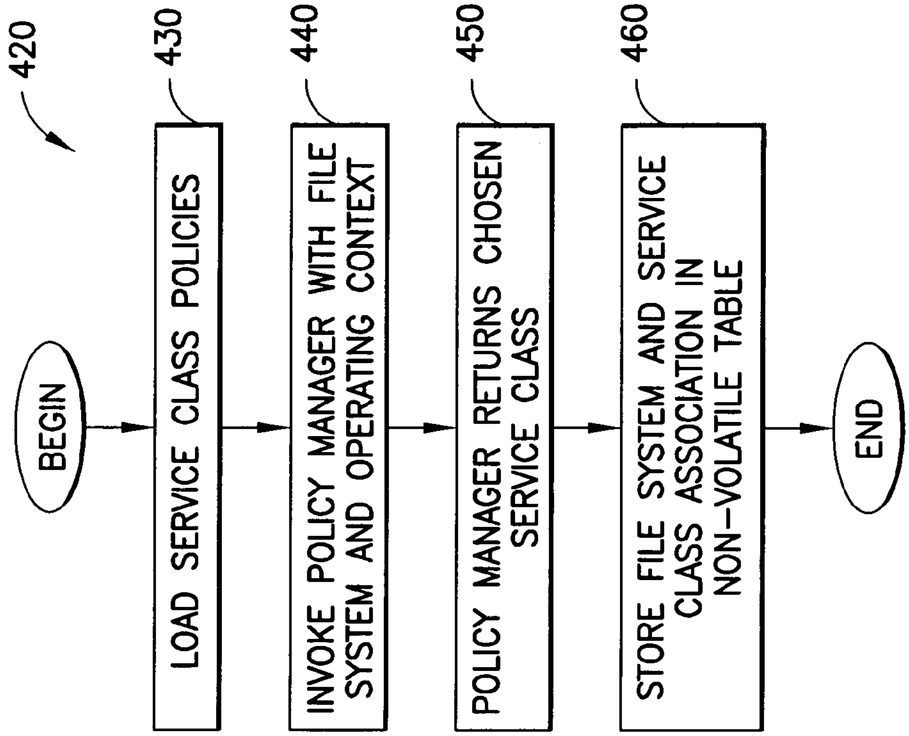

420
BEGIN
LOAD SERVICE CLASS POLICIES
430
INVOKE POLICY MANAGER WITH FILE SYSTEM AND OPERATING CONTEXT
440
POLICY MANAGER RETURNS CHOSEN SERVICE CLASS
450
STORE FILE SYSTEM AND SERVICE CLASS ASSOCIATION IN NON-VOLATILE TABLE
460
END

FIG.4B

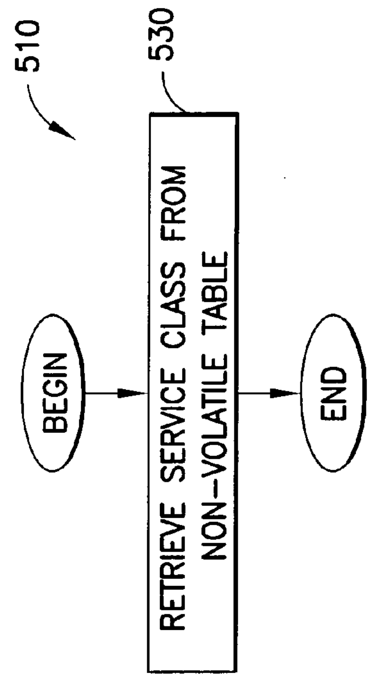

510
BEGIN
RETRIEVE SERVICE CLASS FROM NON-VOLATILE TABLE
530
END

FIG.5B

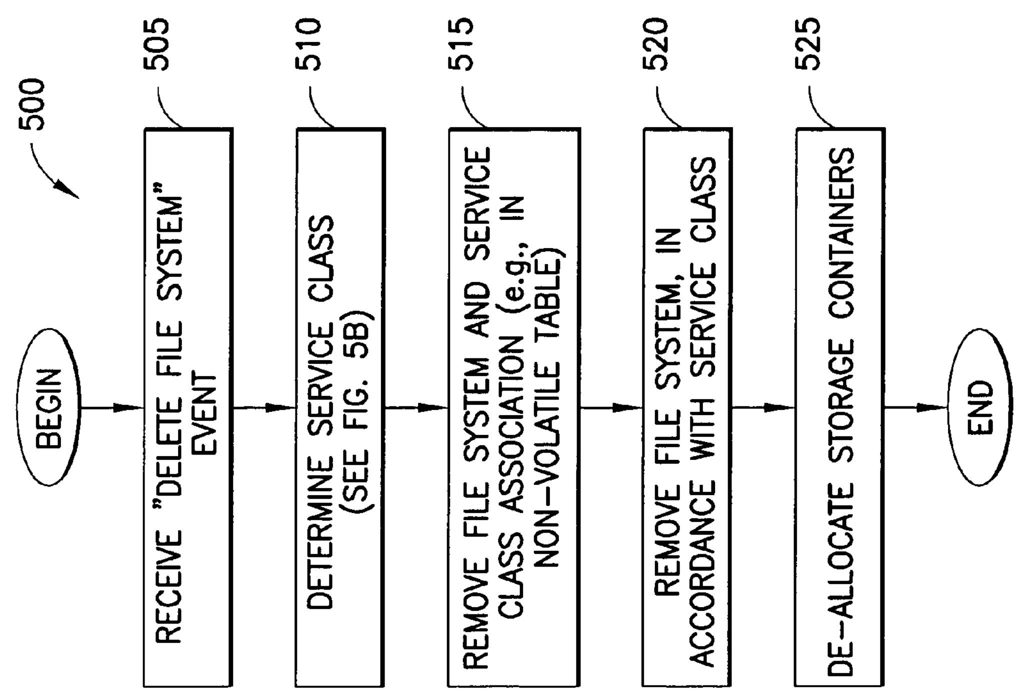

500
BEGIN
RECEIVE "DELETE FILE SYSTEM" EVENT
505
DETERMINE SERVICE CLASS (SEE FIG. 5B)
510
REMOVE FILE SYSTEM AND SERVICE CLASS ASSOCIATION (e.g., IN NON-VOLATILE TABLE)
515
REMOVE FILE SYSTEM, IN ACCORDANCE WITH SERVICE CLASS
520
DE-ALLOCATE STORAGE CONTAINERS
525
END

FIG.5A

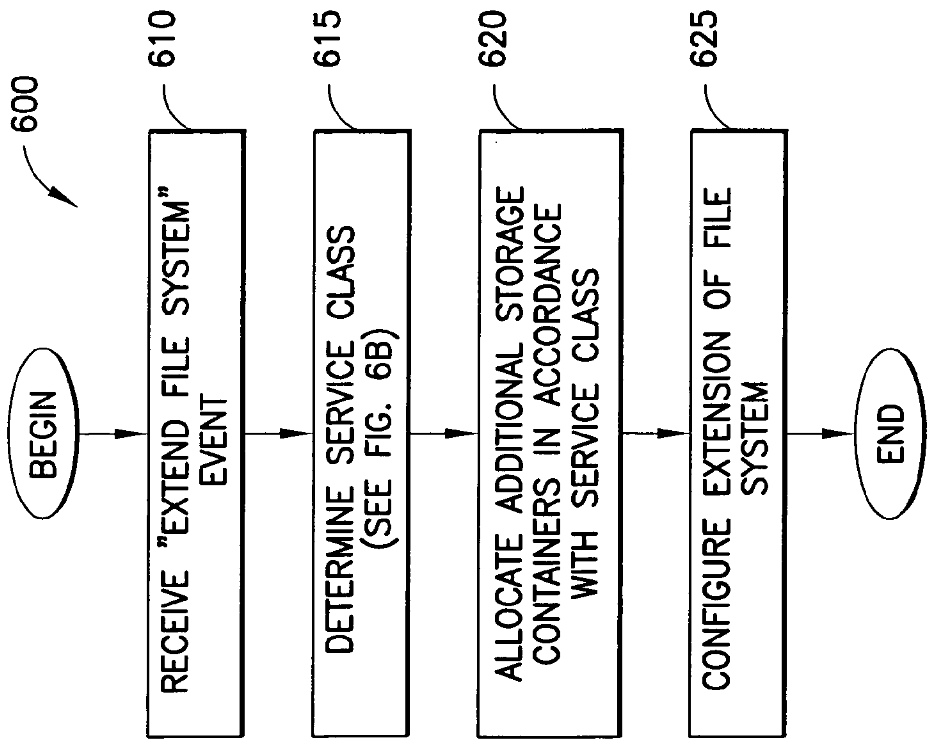

600
BEGIN
RECEIVE "EXTEND FILE SYSTEM" EVENT
610
DETERMINE SERVICE CLASS (SEE FIG. 6B)
615
ALLOCATE ADDITIONAL STORAGE CONTAINERS IN ACCORDANCE WITH SERVICE CLASS
620
CONFIGURE EXTENSION OF FILE SYSTEM
625
END

FIG.6A

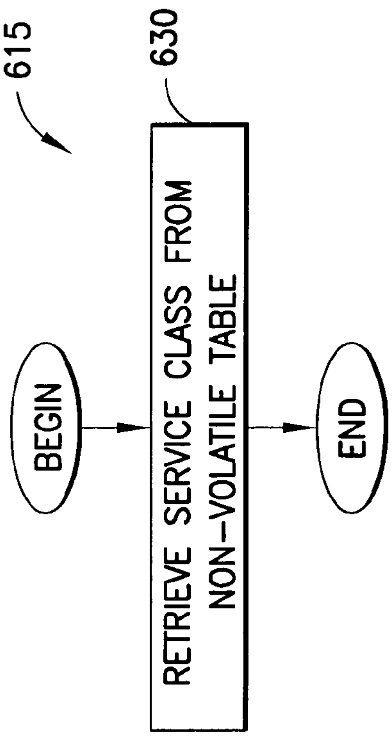

615
BEGIN
RETRIEVE SERVICE CLASS FROM NON-VOLATILE TABLE
630
END

FIG.6B

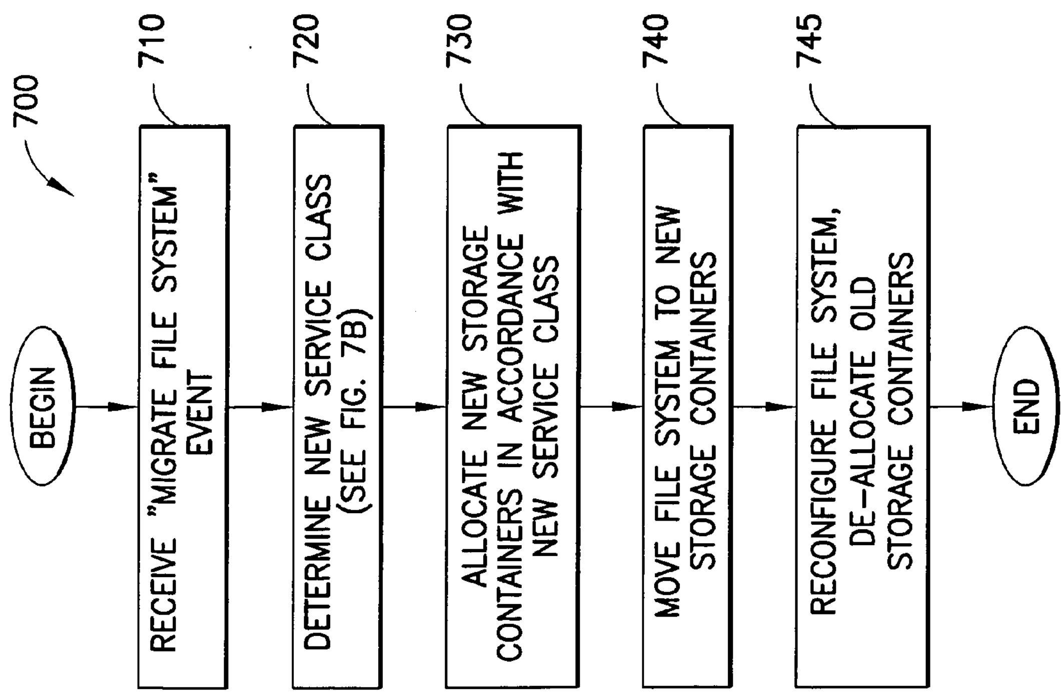

700
BEGIN
RECEIVE "MIGRATE FILE SYSTEM" EVENT
710
DETERMINE NEW SERVICE CLASS (SEE FIG. 7B)
720
ALLOCATE NEW STORAGE CONTAINERS IN ACCORDANCE WITH NEW SERVICE CLASS
730
MOVE FILE SYSTEM TO NEW STORAGE CONTAINERS
740
RECONFIGURE FILE SYSTEM, DE-ALLOCATE OLD STORAGE CONTAINERS
745
END

FIG.7A

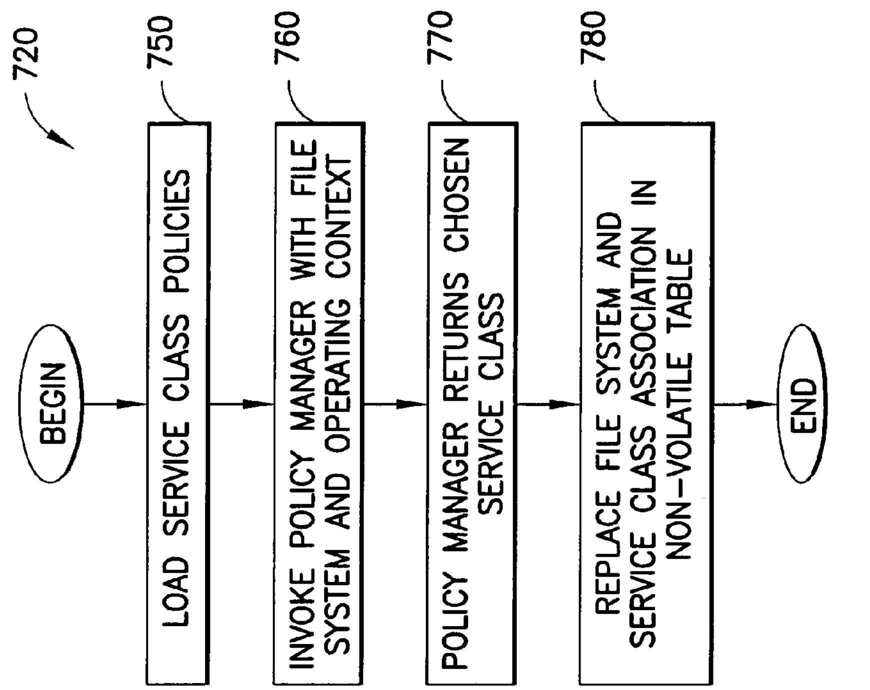

720
BEGIN
LOAD SERVICE CLASS POLICIES
750
INVOKE POLICY MANAGER WITH FILE SYSTEM AND OPERATING CONTEXT
760
POLICY MANAGER RETURNS CHOSEN SERVICE CLASS
770
REPLACE FILE SYSTEM AND SERVICE CLASS ASSOCIATION IN NON-VOLATILE TABLE
780
END

FIG.7B

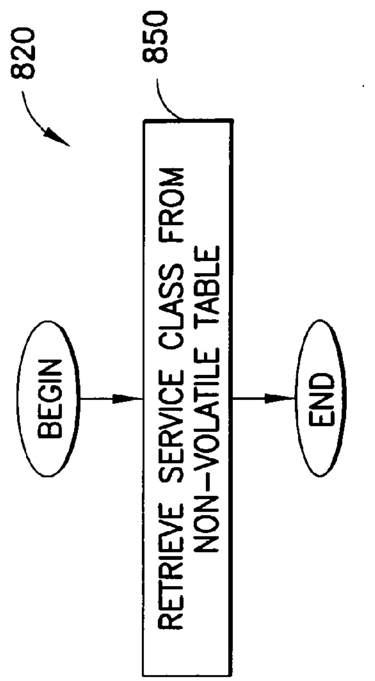

820
850
BEGIN
RETRIEVE SERVICE CLASS FROM NON-VOLATILE TABLE
END

FIG.8B

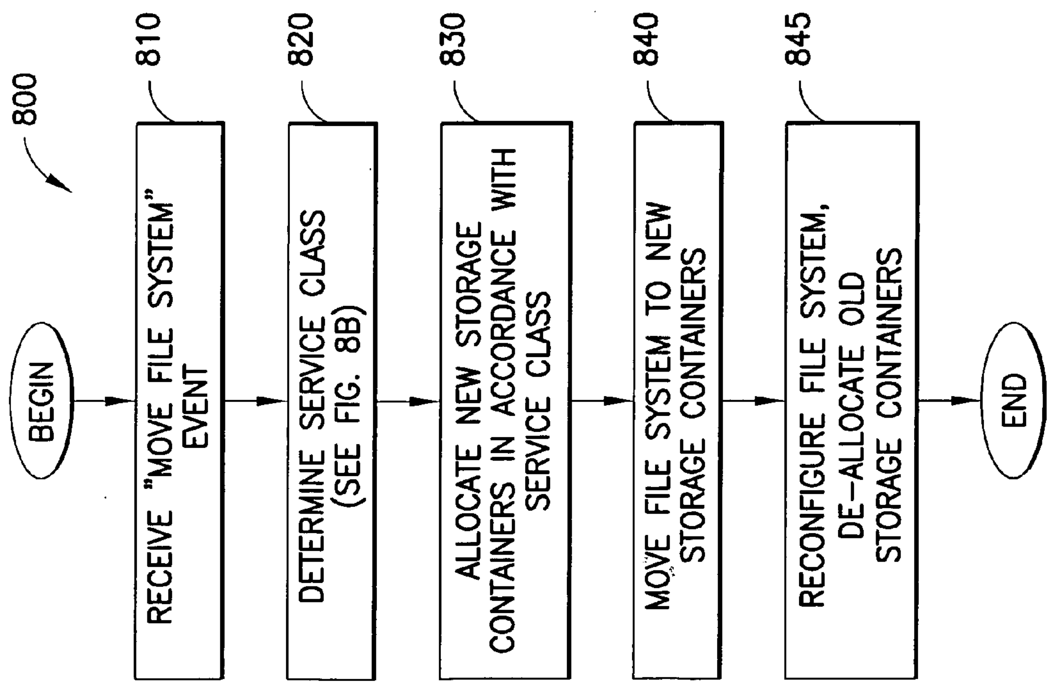

800
810
820
830
840
845
BEGIN
RECEIVE "MOVE FILE SYSTEM" EVENT
DETERMINE SERVICE CLASS (SEE FIG. 8B)
ALLOCATE NEW STORAGE CONTAINERS IN ACCORDANCE WITH SERVICE CLASS
MOVE FILE SYSTEM TO NEW STORAGE CONTAINERS
RECONFIGURE FILE SYSTEM, DE-ALLOCATE OLD STORAGE CONTAINERS
END

FIG.8A

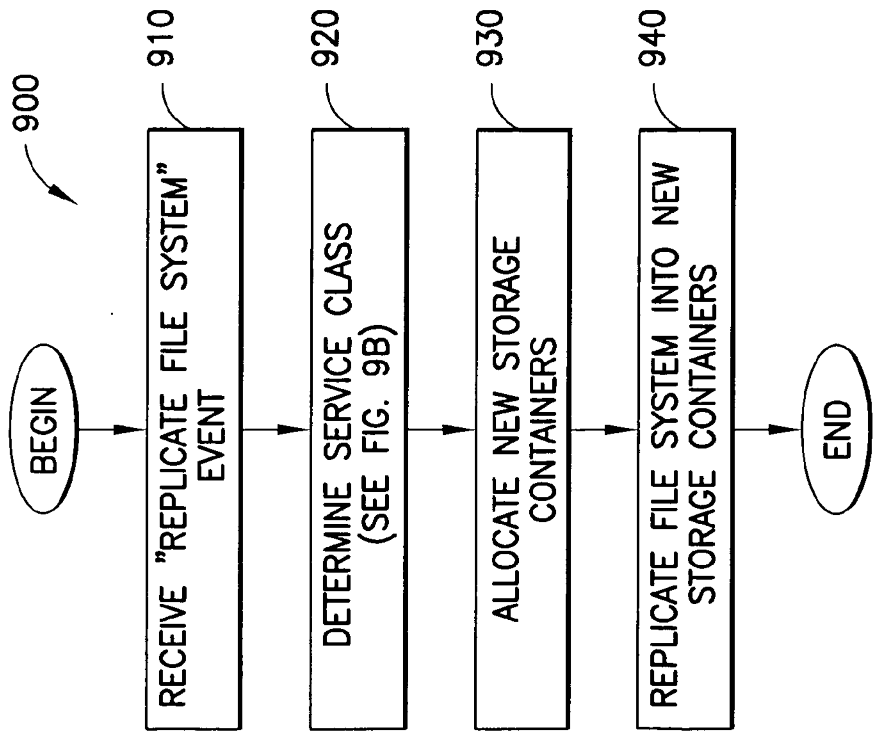

900
BEGIN
RECEIVE "REPLICATE FILE SYSTEM" EVENT
910
DETERMINE SERVICE CLASS (SEE FIG. 9B)
920
ALLOCATE NEW STORAGE CONTAINERS
930
REPLICATE FILE SYSTEM INTO NEW STORAGE CONTAINERS
940
END

FIG.9A

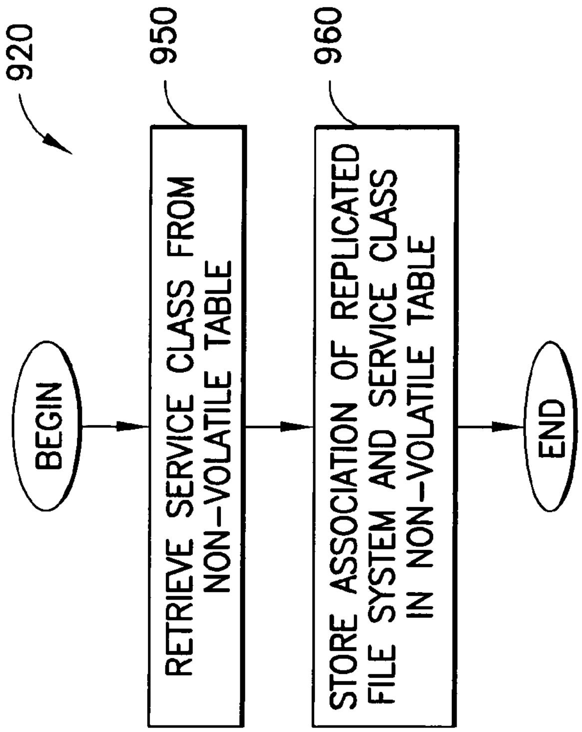

920
BEGIN
RETRIEVE SERVICE CLASS FROM NON-VOLATILE TABLE
950
STORE ASSOCIATION OF REPLICATED FILE SYSTEM AND SERVICE CLASS IN NON-VOLATILE TABLE
960
END

FIG.9B

QOS-ENABLED LIFECYCLE MANAGEMENT FOR FILE SYSTEMS

TECHNICAL FIELD

[0001] This invention relates generally to computer systems and, more specifically, relates to quality of service (QoS) for storage on computer systems.

BACKGROUND OF THE INVENTION

[0002] Storage in a computer system typically comprises file systems, although other storage such as databases may be used. File systems are generally implemented using operating systems that format storage containers such as hard disks in accordance with the file systems. File systems allow files to be named and located on a hard disk. The file systems also allow files to span non-contiguous sectors of the hard disk, yet be easily found, copied, modified, and deleted.

[0003] Existing widely-deployed file systems may be of different types, such as Window NT File System (NTFS) and UNIX file systems. Such file systems may also run on heterogeneous server platforms. However, today widely-deployed file systems usually do not support quality of service. Further, today's file systems do not support lifecycle management. But, quality of service is becoming more important for file systems, and as quality of service is becoming important, lifecycle management is also becoming important for file systems and other storage. Lifecycle management is already important in other fields and it would be beneficial to provide this management in storage for computer systems, but such management is not easily provided using conventional file systems.

[0004] What is needed then are techniques for creating file systems, while providing quality of service and maintaining quality of service during lifecycles of the file systems.

BRIEF SUMMARY OF THE INVENTION

[0005] The present invention provides for lifecycle management of file systems. In an exemplary aspect of the invention, a method is disclosed for lifecycle management for file systems. One or more storage containers are allocated. A file system is created on the one or more storage containers. The file system and the one or more storage containers are associated with a service class. The service class is used during lifecycle actions performed on the file system. Lifecycle actions may comprise, e.g., creating, extending, replicating, moving, or migrating a file system.

[0006] In another exemplary embodiment, an apparatus is disclosed for lifecycle management for file systems. The apparatus comprises at least one memory and at least one processor coupled to the at least one memory. The at least one processor is configured to allocate one or more storage containers associated with a service class in the at least one memory. A file system is created on the one or more storage containers, and the file system is associated with the service class. The at least one processor is additionally configured to use the service class during lifecycle actions performed on the storage.

[0007] In yet another exemplary embodiment, a signal bearing medium is disclosed that tangibly embodies a program of machine-readable instructions executable by a digital processing apparatus to perform operations for lifecycle management for storage. The operations comprise allocating one or more storage containers associated with a service class. The operations also comprise creating a file system in the storage container, where the file system is associated with the service class. The service class is used during lifecycle actions performed on the storage.

[0008] In another exemplary embodiment, an apparatus is disclosed that comprises means for allocating at least one storage container associated with a service class; means for creating a file system on the at least one storage container, wherein the file system is associated with the service class; and means for using the service class during lifecycle actions performed on the file system.

[0009] In yet another exemplary embodiment, a method for lifecycle management for file systems is disclosed. The method comprises allocating at least one storage container associated with a service class. A file system is created on the at least one storage container, wherein the file system is associated with the service class. The service class of the file system is maintained throughout a lifecycle of the file system.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The foregoing and other aspects of embodiments of this invention are made more evident in the following Detailed Description of Exemplary Embodiments, when read in conjunction with the attached Drawing Figures, wherein:

[0011] **FIG. 1** is a block diagram of an exemplary storage system providing QoS-enabled lifecycle management for file systems;

[0012] **FIG. 2** is an illustration of an exemplary table for storing associations between file systems and service classes;

[0013] **FIG. 3**, including **FIGS. 3A and 3B**, is a flowchart of an exemplary method for creating a file system;

[0014] **FIG. 4**, including **FIGS. 4A and 4B**, is a flowchart of an exemplary method for registering a file system;

[0015] **FIG. 5**, including **FIGS. 5A and 5B**, is a flowchart of an exemplary method for deleting a file system;

[0016] **FIG. 6**, including **FIGS. 6A and 6B**, is a flowchart of an exemplary method for extending a file system;

[0017] **FIG. 7**, including **FIGS. 7A and 7B**, is a flowchart of an exemplary method for migrating a file system;

[0018] **FIG. 8**, including **FIGS. 8A and 8B**, is a flowchart of an exemplary method for moving a file system; and

[0019] **FIG. 9**, including **FIGS. 9A and 9B**, is a flowchart of an exemplary method for replicating a file system.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

[0020] Meeting quality of service (QoS) goals is becoming an important requirement for file systems in an on-demand environment, where quality of service goals may include goals corresponding to capacity, performance, and availability requirements. Besides the need to support a level of quality of service at the time of allocation of a file system, it is also beneficial to maintain the quality of service requirements throughout lifecycle of the file system, for example, whenever the file system has to be extended, replicated, moved, migrated, and/or deleted. Providing quality of service for existing types of file systems from different vendors at the time of creation of the file systems, as well as during lifecycles of the file systems, is a significant challenge.

[0021] Present attempts to solve to this challenge include the following: (1) Do nothing; (2) Use human-based and/or tool-based monitoring of file systems and perform manual provisioning and lifecycle management as needed; (3) Create a new file system type that is capable of quality of service support on heterogeneous systems and migrate existing data to this file system; and (4) Use scripts to add storage in response to out of space alerts.

[0022] The first proposed solution is generally not acceptable in an on demand environment. The second proposed solution can be expensive and is error prone. The third proposed solution has a disadvantage that this solution requires extensive development costs of a new file system type and risks that customers may not want to switch to a new file system. Finally, the fourth proposed solution has limited functionality and does not assure quality of service through the entire lifecycle.

[0023] Thus, there is a need for techniques that provide lifecycle management and quality of service for file systems. Before proceeding with a description of the present invention, which provides both lifecycle management and quality of service for file systems and other storage, it is helpful to describe information about file systems and techniques used for quality of service for file systems.

[0024] In an exemplary embodiment, a file system is a conventional file system, which is a structured organization of data, where the data is organized into named entities called files, each can have zero to a system-defined limit of bytes. There are special files called directories that contain names of other files or directories. Files and directories have attributes such as owner and group ids, creation, modification, and access time, size, and so on. When files are organized hierarchically, there is a unique file called the root of the file system. Data that describes files and directories is called meta-data.

[0025] In certain commercial operating systems, such as AIX by IBM, a file system is created using one or more logical volumes, where the logical volumes are abstractions. See Vanel et al., "AIX Logical Volume Manager, from A to Z: Introduction and Concepts," IBM, First Edition, January 2000.

[0026] Other operating systems employ similar concepts. A logical volume is created using one or more physical volumes. A physical volume may be a disk or a partition of a disk that is directly attached to a server, or a physical volume may be a virtual disk in a Storage Area Network (SAN), which is commonly referred to as LUN (Logical Unit Number). Presently, administrators create files systems using any available storage containers such as physical and logical volumes, as there is no requirement or support for quality of service enabled file system creation.

[0027] In the present invention, a storage container comprises a collection of storage objects (e.g., any persistent memory structure that can be used for storage, such as hard disks, segments, regions, and feature objects). A storage container consumes one set of storage objects and produces a new set of storage objects. One common subset of storage containers is a logical volume. In general, the present invention will typically be used for storage containers that expose a "disk-like" interface, such as one would see in the logical volumes.

[0028] U.S. patent application Ser. No. 10/449,269, entitled "Policy-Based, Autonomically Allocated Storage," filed on May 29, 2003 by inventors Murthy V Devarakonda, Bill Arnold, Alla Segal, David M Chess, and Ian N Whalley teaches allocation, monitoring, and re-allocation of storage and creation of storage, under policy constraints. U.S. patent application Ser. No. 10/449,269 is called the "ALOMS-Tango patent application" herein. Specifically, the ALOMS-Tango patent application describes a method for allocating storage in a computer storage system, the method comprising specifying constraints on resource allocation in said computer storage system, analyzing capabilities of the computer storage system and forming analysis results, associating an allocation request with a given quality of service, allocating a portion of available storage in the computer storage system based on at least one policy in said constraints, the analysis results and the quality of service, monitoring the computer storage system in forming a determination that there is a failure to meeting the quality-of-service, reallocating resources in response to the determination that there is a failure to meet the quality-of-service. Policy constraints include selection of a service class, e.g., based on the requesting user and application.

[0029] The ALOMS-Tango patent application also teaches that a service class is defined as an abstraction that comprises at least one of performance, availability, space requirements, and security requirements of a storage-using application. Performance requirements comprise at least one of: throughput, response time, and transfer rate. Availability requirements comprise at least one of: storage system up time and error rate. Space requirements comprise at least one of: maximum size, initial size, size increments, and guaranteed size. Security requirements include: a physical location of the storage; who is authorized to access data, and who is authorized is to request new storage or change an existing storage allocation. While the ALOMS-Tango patent application is a tremendous improvement over conventional techniques, that patent application does not describe how to manage lifecycle functions of a file system.

[0030] In Brooks et al., "IBM Tivoli Storage Resource Manager: A Practical Introduction," International Technical Support Organization, IBM, August 2003, features are described of a product that monitors file systems for extending sizes of file systems in a plurality of networked computer systems of an enterprise. The product includes agents running on the computer systems for collecting information about individual file systems, and a central server where the information is collected from the distributed agents and analyzed for the purposes of reporting and for extending the size of file systems if the underlying logical volumes have free space. The product can also add additional physical volumes to a logical volume and hence to a file system using a command template and a specific type of SAN storage. The Brooks et al. document does not describe how to add physical volumes with quality of service and also does not describe how to manage lifecycle functions of a file system.

[0031] By contrast, in an exemplary embodiment of the present invention, a file system of an existing type may be created in one or more quality of service enabled storage containers (e.g., logical volumes as in the AIX operating system), which are allocated, monitored, or re-allocated. Such allocation, monitoring, and re-allocation may be performed, for instance, as described in the ALOMS-Tango patent application. In an exemplary embodiment, an association between the file system and a corresponding quality of service for the file system is stored in non-volatile memory. Associating appropriate storage containers with a file system and maintaining quality of service requirements throughout the lifecycle of a file system are aspects of this invention.

[0032] An exemplary embodiment of the present invention provides an interface by which an administrator can request that a file system with a certain predefined quality of service class be created. For instance, a request to create a file system with a predefined quality of service might be created through the following steps:

[0033] (1) Configuring one or more storage containers (e.g., logical volumes) that meet the specified quality of service;

[0034] (2) Creating a file system using the one or more storage containers; and

[0035] (3) Recording an association between the one or more storage containers, a file system, and the quality of service that the file system is required to support.

[0036] Creation of a file system is a lifecycle action. Additionally, an exemplary embodiment of the present invention provides an interface by which an administrator can request that an existing file system have other lifecycle actions be performed, such as extending, replicating, moving, or migrating a file system. In these cases, this exemplary embodiment can create (e.g., using techniques disclosed in the ALOMS-Tango patent application) additional storage containers of the required quality of service and then perform necessary extension, replication, movement or migration of the file system onto the newly created storage containers. An exemplary embodiment also provides an interface by which an administrator can request that an existing file system be deleted, optionally after a set retention period. In an exemplary embodiment, to delete a file system, the file system is unmounted (e.g., using "umount") and techniques are performed to remove and erase the logical volumes on which this file system was created. Such techniques may be performed using techniques disclosed in the ALOMS-Tango patent application.

[0037] An exemplary advantage of the present invention is that quality of service management and resource arbitration can occur in a distributed environment of existing file system types. It is an added exemplary advantage of this invention that an embodiment of the present invention leverages existing monitoring software and operating systems and does not require data migration to a new file system.

[0038] Turning now to **FIG. 1**, an exemplary storage system **100** is shown that provides QoS-enabled lifecycle management for file systems. Storage system **100** is typically implemented, as shown in **FIG. 1**, on a distributed computer system comprising a number of processors **105** and a number of memories **110**, where the processors **105** and memories **110** are from computer systems interconnected through one or more networks (not shown). However, the storage system **100** could be implemented in a single computer system. Additionally, the storage system **100** could be "embedded" as part of a network-addressable storage device, for instance.

[0039] The memories **110** comprise event **115**, service class selection policies **120**, service class definitions **125**, file system to service class non-volatile table **130**, storage container allocation module **135**, file system configuration module **140**, quality of service lifecycle manager **180**, storage containers **160**, of which storage containers **160-1** through **160**-X are shown, and a capacity monitoring tool **185**. The quality of service lifecycle manager **180** comprises a service class selector **145**, an event processing module **150**, and an event scheduler **155**. Each file system **165** resides on one or more storage containers **160** and each file system **165** is associated with a service class **161**. The association between the service class **161** and the file system **165** is in an exemplary embodiment stored in a table, shown in **FIG. 2**.

[0040] The service classes **161** are in an exemplary embodiment an abstraction that comprises at least one of performance, availability, space, and security requirements. The service classes **161** in an exemplary embodiment of the present invention describe requirements for file systems **165**. The service classes **161** may be named, e.g., Gold, Silver, Bronze, as shown in **FIG. 2**. While names for service classes **161** are not necessary, names are beneficial and any name may be used that allows administrators to conveniently remember the associated requirements of a file system **165**.

[0041] Users, typically administrators or other authorized users, specify service class definitions **125** and service class selection policies **120**, which act as interfaces between a user and the quality of service lifecycle manager **180**. The service class definitions **125** provide definitions of requirements for service classes and also generally provide names (e.g., as described above) for the service classes. For instance, a service class of "Gold" might mean that storage is placed only on highly-available equipment and a high performance rate is to be maintained. A service class of Platinum might mean that very high availability (e.g. with mirrored, redundant highly-available equipment), high security, and very high performance requirements are to be maintained.

[0042] The service class selection policies **120** allow service classes **161** to be selected for file systems **165**. A policy is, e.g., a rule that defines a choice in the behavior of a system. In many cases, a policy has a conditional part and an action part. In an exemplary embodiment, when the conditional part is evaluated to a Boolean value true, the action part is executed. Furthermore, a policy states constraints under which the storage system should operate. A policy can include a set of constraints. Example policies include: (1) For customerA, applicationDB, and logTableSpaces, use service class Gold; (2) For storage having Gold service classes, notify if throughput falls below 25 percent of the value specified in a service class definitions **125**.

[0043] A user invokes lifecycle actions at the quality of service lifecycle manager **180**, typically through an event

115, which acts as an interface between the user and the quality of service lifecycle manager **180**. A lifecycle of a file system **165** is the series of events that occur between creation of the file system **165** (e.g., when the file system **165** can physically be accessed) to deletion of the file system **165** (e.g., when the file system **165** can no longer be accessed).

[0044] Note that a user is not the only generator of events **115**. A capacity monitoring tool **185** (e.g., to request to extend a file system when space is getting low) and the event scheduler **155** (e.g., to request to migrate a file system at a certain time) may also generate events **115**. An exemplary schedule (e.g., a calendar) used by the event scheduler **185** is described in **FIG. 2**.

[0045] Events **115** have event types in an exemplary embodiment, which include the following: Create File System; Delete File System; Extend File System; Migrate File System; Move File System; and Replicate File System. Each of these event types cause a corresponding lifecycle action, methods for which are described in **FIGS. 3-9**, respectively. An event **115** will generally comprise arguments that identify the file system upon which a lifecycle action is to be taken and the event type, as well as additional information that is unique for a lifecycle action. For example, when a file system of a certain quality of service is needed, an administrator invokes an event **115** having a Create File System event type with the specification of the mount point, server, service class name (e.g., corresponding to a quality of service), and initial size for the file system. It should be noted that the latter event **115** having the Create File system event type is merely exemplary. As another example, a service class **161** could include an initial size for a file system, which means that the event **115** need not contain an initial size. A user and/or application may also be provided for the Create File System event type. A lifecycle action (e.g., method **300** of **FIG. 3**) to create a file system **165** is performed in response to the event **115**.

[0046] An administrator can also specify a capacity monitoring policy (e.g., as part of the service class selection policies **120**) which the quality of service lifecycle manager **180** uses to instruct a capacity monitoring tool **185** when the capacity monitoring tool **185** should raise an alert (e.g., as an event **115**) as a file system **165** begins to fill up from usage (e.g., the remaining capacity of the file system **165** reaches a predetermined remaining capacity).

[0047] The file system to service class non-volatile table **130** is one exemplary result of analyzing the service class selection policies **120** and producing associations between file systems **160** and the service classes **161** associated therewith. An exemplary file system to service class non-volatile table is shown in **FIG. 2**. Note that the file system to service class non-volatile table **130** is optional but beneficial. Without the file system to service class non-volatile table **130**, the service class selection policies **120** would typically be analyzed each time an event **115** is received, and such an analysis could be slow. The file system to service class non-volatile table **130** provides much quicker indexing than provided by analyzing the service class selection policies **120**. Note that the file system to service class non-volatile table **130** would typically be updated or re-determined when changes are made to the service class selection policies **120**.

[0048] Also shown in **FIG. 1** is a series of exemplary steps **171-177**, which illustrate how data flow might occur in the storage system **100**. In step **171**, an event **115** is passed to the quality of service lifecycle manager **180**. The event **115** includes, in an exemplary embodiment as described above, event type, file system, and context (user, application, and the like). In step **172**, the event processing module **150** processes the event **115** and communicates a processed version of the event **115** to the service class selector **145**. The service class selector **145** determines the service class **161** for the file system **165** in the event **115**. Beneficially, this is done by lookup in the file system to service class non-volatile table **130** for known file systems (e.g., file systems **165** already created and appearing in the file system to service class non-volatile table **130**). Typically, any events **115**, other than events **115** having a Create File System event type, that relate to file systems **165** not yet created will cause an error.

[0049] In step **173**, the service class selector **145** communicates the service class to the event processing module **150**. The event processing module **150** communicates, in step **174**, to the storage container allocation module **135** the service class and other information (e.g., space requirements) so that the storage container allocation module **135** can set up a suitable storage container **160**. The storage container allocation module **135** sets up an appropriate storage container **160**. Storage containers **160** are allocated with a target service class. It is assumed that each storage container **160** (e.g., or an entity in communication with a storage container **160**) supports and enforces quality of service. The present invention enables and maintains quality of service for file systems **165** by, e.g., making sure that a file system **165** is stored in appropriate storage container(s) **160** at all times, throughout the lifecycle of the file system **165**.

[0050] In step **175**, the storage container allocation module **135** informs the event processing module **150** that the storage container has been set up. The event processing module **150** in step **176** then communicates to the file system configuration module **140** information (e.g., a reference to the storage container **160**) used to set up a file system **165**. Exemplary references to the storage container **160** include logical volume identifiers, physical volume identifiers, volume groups, disk drive letters, Small Computer System Interface (SCSI) Logical Unit Numbers (LUNs), SCSI targets, device serial numbers, Common Information Model (CIM) object paths, and Universal Naming Convention (UNC) paths. The file system configuration module **140** then configures or reconfigures the file system **165** to use associated storage container(s) **160**.

[0051] In step **177**, which is optional, the event scheduler **155** schedules known events **115** (e.g., data retention period expiration). Scheduling may be performed in another part of the quality of service lifecycle manager **180** if desired.

[0052] It should be noted that steps **171-177** may be performed through, for instance, messages, methods performed by objects, and any other suitable technique. Furthermore, steps **171-177** are merely exemplary and some or all of them need not be performed. Additionally, the present invention may be performed by a signal bearing medium tangibly embodying a program of machine-readable instructions. The machine-readable instructions are executable by a digital processing apparatus (such as a storage system **100**) to perform operations for lifecycle management for file systems. Furthermore, typically the quality of service lifecycle manager **180** and other entities in memory(ies) **110** would be implemented as software and brought into the processor(s) **105** in order to configure the processor(s) **105** to perform operations for lifecycle management of file systems. It should also be noted that the entities in memory(ies) **110** could also be implemented as hardware (e.g., as a semiconductor circuit and/or part of a programmable gate array), or implemented as some combination of hardware and software.

[**0053**] An exemplary table **200** is shown in **FIG. 2** for storing associations between file systems and service classes. In the example of **FIG. 2**, there are a number of entries **250-1**, **250-2**, and **250-3**. Each entry **250** has a file system name **210**, a service class name **220**, and a schedule **230**. The file system section has a name (e.g., FS_1, FS_2, and FS_1). Each entry **250** provides an association between the file system name **210** and the service class name **220**. A file system name **210** in an exemplary embodiment is simply a unique, opaque, identifier corresponding to a file system **165**. The file system name **210** could be a character string, a pointer, or some type of data structure with multiple fields (e.g. field-1: server address, field-2: server-specific pointer and additional fields are possible). A part of meta-data for the file system name **210** may contain a special, unique identifier that identifies the file system, and this could be the "name" for the file system **165**.

[**0054**] The service class names **220** are Gold, Platinum, and Bronze, and each of these has a corresponding defined set of requirements (e.g., in service class definitions **125**) for a service class **161**. As with the file system name **210**, each of the service class names **230** is typically a unique, opaque, identifier corresponding to a service class **161**. The schedule **230**, which is optional, indicates when the service class **220** is valid.

[**0055**] In this example, a file system has a service class name **220** of Bronze for weekends and Gold for weekdays. On Friday at 10 p.m., the file system named FS_1 is migrated (see, e.g., **FIGS. 7A and 7B**) from the service class **161** associated with the service class name **220**"Gold" to the service class **161** associated with the service class name **220**"Bronze." Similarly, on Monday at 6 a.m., the file system named FS_1 is migrated (see, e.g., **FIGS. 7A and 7B**) from the service class **161** associated with the service class name **220**"Bronze" to the service class **161** associated with the service class name **220**"Gold." The file system named FS_2 has a service class name **230** of Platinum and has a schedule **230** of "Always," which means that the Platinum service class is valid until modified by a user.

[**0056**] The schedule **230** could be used, for instance, by the event scheduler **155** of **FIG. 1**, which would generate events **115** as per the schedule **240**. For instance, an event **115** could be generated at 10 p.m. on Friday to migrate the file system FS_1 from Gold service class, to the Bronze service class.

[**0057**] Turning now to **FIG. 3**, including **FIGS. 3A and 3B**, an exemplary method **400** is shown for creating a file system **165**. As described in **FIG. 3A**, when a "Create File System" event is received (step **310**) the quality of service lifecycle manager **180** determines the service class **161** (step **320**) and allocates a storage container **160** with the appropriate service class **161** (step **330**). In an exemplary embodiment, step **330** is performed by having the quality of service lifecycle manager **180** invoke storage container allocation by calling the storage container allocation module **135**. The storage container allocation module **135** creates a storage container **160** of the specified service class **161**.

[**0058**] It should be noted that in certain systems, storage allocation (e.g., performed by a storage container allocation module **135**) may expect as input a storage container service class instead of a file system service class **161**. A description associated with a storage container service class can be derived from a description associated with a service class **161** for file systems **165**. For instance, a description for a service class for a storage container **160** may contain a block-level Input/Output Per Second (IOPS) throughput metric and a description for a file system service class **161** may contain a file-level MBps (Megabyte per second) bandwidth metric. Rough approximations of block-level metrics may be obtained by simple computations based on the file-level metrics. More accurate block-level metrics may be obtained with detailed knowledge of the storage container internals (e.g., cache size, block size, intermediate components, and more). Typically, those skilled in the art can create appropriate storage system service class transformations which will provide sufficient performance that meets or exceeds the performance requirements in the file system service classes **161**.

[**0059**] In step **335**, the quality of service lifecycle manager **180** creates a file system **165** using the storage container **160**. Typically, step **335** entails formatting and otherwise manipulating the storage container(s) **160** so that the structure of the file system **165** can be stored on the storage container(s) **160**. For example, in UNIX, step **335** could be performed with the "mkfs" command. In Disk Operating System (DOS), step **335** could be performed with the Format command, and Windows provides a Graphical User Interface (GUI) which allows one to interact with the Windows Disk Management Service to create the file system **161** on the storage container(s) **160**. Note that step **335** can be automated.

[**0060**] In step **340**, the quality of service lifecycle manager **180** configures the new file system **165** (e.g., by invoking the file system configuration module **140**). Generally, step **340** involves one or more steps to allow a computer system to access the file system **165**. For example, in the UNIX, step **340** may be performed using the "mount" command. In Windows/DOS, one could configure (e.g., including reconfiguring) file systems **165** using the "NET USE" command for instance, through the Disk Management GUI and the "Rescan Disks" command, and/or the "Change Drive Letter" command. Step **340** may also be automated.

[**0061**] Once a file system **165** is created, monitoring of the file system **165** may commence, if desired, using steps **345** and **350**. For instance, a capacity monitoring tool **185** could recognize the new file system **165** and start monitoring the capacity of the new file system **165**. The quality of service lifecycle manager **180** sends any capacity monitoring policies for the file system **165** to the (e.g., distributed) capacity monitoring tool **185** to guide the monitoring and alerting process. If there is a quality of service lifecycle manager (LCM) **180** event **115** to schedule, the capacity monitoring tool **185** can schedule such an event in step **450**. Additionally, the event scheduler **155** can use steps **345** and **350** to schedule events such as those shown in schedule **240** of **FIG. 2**.

[0062] In an exemplary embodiment, **FIG. 3B**, the quality of service lifecycle manager **180** determines the service class **161** using, e.g., a service class selector **145**, which acts as a policy manager. The quality of service lifecycle manager **180** invokes (step **365**) the service class selector **145** with a set of service class selection policies **120** (step **360**) and information from the event **151**. This information may contain, as described above, the event type, the name of the file system **165**, and contextual information such as the identity of the user and/or application making the request. The service class selector **145** (e.g., acting as a policy manager) examines this information and returns a service class **161**. This occurs in step **380**. An association between the file system **165** and the service class definition is then, in an exemplary embodiment, stored in non-volatile memory (e.g., as file system to service class non-volatile table **130/200**) for quick reference (step **390**).

[0063] In alternate embodiments, the quality of service lifecycle manager **180** determines the service class **161** by table lookup (e.g., using file system to service class non-volatile table **130/200**), prompting the user via a user interface, and/or by referencing a service class name which may optionally included in the lifecycle event.

[0064] Turning now to **FIG. 4**, including **FIGS. 4A and 4B**, an exemplary method **400** is shown for registering a file system. Registration may be performed, for instance, to ensure that the file system **161** is entered into the file system to service class non-volatile table **130**. In step **410** of **FIG. 4A**, a "Register File System" event **115** is received. In step **420**, the service class **161** is determined for the file system **161**, which registers the files system **165** in the file system to service class non-volatile table **130**.

[0065] In **FIG. 4B**, step **420** is shown in greater detail. In step **430**, the service class selection policies **120** are loaded. The service class selector **145**, acting as a policy manager, is invoked (e.g., by the event processing module **150**) with the file system **165** (e.g., a reference to the file system **165**, such as file system name **210**) and with operating context. The service class selector **145** determines the chosen service class **161** (step **450**) and stores the association between the file system **165** and the service class **161** in the file system to service class non-volatile table **130** (step **460**). Registration, while not required, has a benefit of faster determination of the association between a file system **165** and a corresponding service class **161** and allows the quality of service lifecycle manager **180** to determine more easily whether a lifecycle action is requested on a registered file system **165**.

[0066] Referring now to **FIG. 5**, including **FIGS. 5A and 5B**, an exemplary method **500** is shown for deleting a file system. When a "Delete File System" event **115** is received (step **505**), the service class **161** is determined in step **510** through techniques already described above. In step **515**, the quality of service lifecycle manager **180** removes the file system **165** and, if necessary, the association in the file system to service class non-volatile table **130/200** between the file system **165** and the storage container **160**. Note that it is assumed that a confirmation process, if any, has already been gone through and such as process is not included in **FIG. 3** but may be included if desired. Such confirmation process would typically have steps modified at least partially by the service class **161**. For instance, a Platinum service class might require multiple confirmations and/or passwords, while a Generic service class might only require a simple confirmation.

[0067] In step **520**, the file system is deleted (e.g., removed) in accordance with the service class **161**. The service class **161** is checked to see if there are special disposal instructions, such as data being required to be securely scrubbed from a disk. Any disposal instructions are followed in step **520**. In step **525**, the storage containers are de-allocated.

[0068] Note that any capacity monitoring tool **185** will recognize the deletion of the file system **165** and will make appropriate changes to the internal functionality of the capacity monitoring tool **185**.

[0069] As indicated in **FIG. 5B**, one way to determine a service class **161** is by retrieving a service class **161** from a file system to service class non-volatile table **130/200** (step **530**).

[0070] Turning now to **FIG. 6**, including **FIGS. 6A and 6B**, an exemplary method **600** is shown for extending a file system. When a file system **165** is reaching a size limit, a capacity monitoring tool **185** can recognize the event and based on the policies (e.g., determined through service class selection policies **120**) in effect, the capacity monitoring tool **185** will generate an alert to the quality of service lifecycle manager **180**. In the example of **FIG. 6**, the alert is an "Extend File System" event **115**. The quality of service lifecycle manager **180** determines the service class **161** (step **615**) for the file system **165** in the event **115**, e.g. by retrieving the service class **161** from the file system to service class non-volatile table **130/200** (step **630**). The quality of service lifecycle manager **180** requests (step **620**) the storage container allocation module **135** to extend the previously allocated storage for the file system **165** while maintaining the quality of service as defined by the service class **161**. The storage container allocation module **135** might extend the physical volumes on which the storage container **160** (e.g., as a logical volume) is created, or the storage container allocation module **135** might create a new physical volume and extend the storage container **160** (e.g., as a logical volume) over the added physical volume, and all of this is done while maintaining the service class requirements. If the request is successful, then the quality of service lifecycle manager **180** configures the extended file system **165** (step **625**). If the request is denied, then the quality of service lifecycle manager **180** reports a failure to extend the file system to the user.

[0071] Turning now to **FIG. 7**, including **FIGS. 7A and 7B**, an exemplary method **700** is shown for migrating a file system. Migrating is a process where the old file system has a particular service class **161** and the new file system is to have a different service class **161**. **FIG. 7** illustrates one way of performing migration, which is to create a new file system and to fill the new file system with data from the old file system.

[0072] As described in **FIG. 7A**, when a "Migrate File System" event **115** is received (step **710**) the quality of service lifecycle manager **180** determines the service class **161** (step **720**) and allocates a storage container **160** (e.g., or storage containers **16**) with the appropriate service class **161** (step **730**). In an exemplary embodiment, step **730** is performed by having the quality of service lifecycle manager **180** invoke storage container allocation by calling the storage container allocation module **135**. The storage container allocation module **135** creates a storage container **160** (e.g., or storage containers **160**) of the specified new service class **161**.

[**0073**] In step **740**, the quality of service lifecycle manager **180** moves the file system **165** to the new storage container(s) **160**. When the file system **165** is moved, the structure of the file system **165** is copied or otherwise recreated on the new storage container(s) **160**. The move could be done through the Unix "dd" (disk dump) command. On Windows, one might use a program such as Partition Magic. Additionally, one storage container **160** may be copied to another storage container **160**, while preserving internal data structures, using, e.g., FlashCopy techniques or PPRC (Peer-to-Peer Remote Copy).

[**0074**] In step **745**, the quality of service lifecycle manager **180** reconfigures file system **165** and de-allocates the old storage container(s) **160** (e.g., by invoking the storage container allocation module **135**, which performs the de-allocation). Reconfiguration of the file system **165** is performed to so that computer systems accessing the file system **165** function correctly with the new storage containers **160**. The reconfiguration of the file system **165** may be performed, in part, by using commands (e.g. "mount", "NET USE") as described in step **340**, above.

[**0075**] In an exemplary embodiment, **FIG. 7B**, the quality of service lifecycle manager **180** determines the service class **161** using a service class selector **145**, which acts as a policy manager. The quality of service lifecycle manager **180** invokes (step **760**) the service class selector **145** with a set of service class selection policies **120** (step **750**) and information from the event **151**. This information may contain, as described above, the event type, the name of the file system **165**, and contextual information such as the identity of the user and/or application making the request. The service class selector **145** (e.g., acting as a policy manager) examines this information and returns a service class **161**. This occurs in step **770**. In step **780**, an association between the new file system **165** and the service class definition is, in an exemplary embodiment, stored in non-volatile memory (e.g., as file system to service class non-volatile table **130/200**). The new association replaces the old association between the old service class **161** and the old file system **165**.

[**0076**] Referring now to **FIG. 8**, including **FIGS. 8A and 8B**, an exemplary method **800** is shown for moving a file system **165**. As described in **FIG. 8A**, when a "Move File System" event **115** is received (step **810**) the quality of service lifecycle manager **180** determines the service class **161** (step **820**) and allocates new storage container(s) **160** with the appropriate service class **161** (step **830**). Note that a file system **165** would also be created in step **830**. In an exemplary embodiment, in step **850** of **FIG. 8B**, the appropriate service class **161** is retrieved from file system to service class non-volatile table **130/200**.

[**0077**] The quality of service lifecycle manager **180** moves (step **840**) the old file system **165**, removes the old file system (step **845**), and de-allocates (step **845**) the old storage containers (e.g., by invoking the storage container allocation module **135**, which performs the de-allocation). It should be noted that associations between the file system **165** and the storage containers **160** should also be updated.

[**0078**] **FIG. 9**, including **FIGS. 9A and 9B**, an exemplary method **900** is shown for replicating a file system. As described in **FIG. 9A**, when a "Replicate File System" event **115** is received (step **910**) the quality of service lifecycle manager **180** determines the service class **161** (step **920**) and allocates new storage container(s) **160** with the appropriate service class **161** (step **930**). Note that a file system **165** would also be created in step **930**. In an exemplary embodiment, in step **950** of **FIG. 9B**, the appropriate service class **161** is retrieved from file system to service class non-volatile table **130/200**. Additionally, in step **960** of **FIG. 9B**, the association between the replicated file system and the service class is stored in the file system to service class non-volatile table **130/200**. The quality of service lifecycle manager **180** replicates (step **940**) the file system **165** to the new storage containers **160**.

[**0079**] While a typical use of the present invention is for conventional file systems **165**, the techniques presented herein could be adapted to provide quality of service lifecycle management of other types of persistent data organization (such as databases) and virtualized storage. For example, IBM makes a product, called IBM SAN Volume Controller Software for the Cisco MDS 9000 (SANVC4MDS), which performs "Volume Virtualization." This SANVC4MDS acts as a storage container by creating virtualized disk volumes out of collections of storage subsystem volumes (e.g., storage containers **165**). Just as the present invention provides quality of service lifecycle management for file systems, the invention could also provide quality of service lifecycle management for file systems for the virtual volumes created by the SANVC4MDS.

[**0080**] The embodiments of this invention may be implemented by computer software executable by one or more processors (e.g., processors **105**) or by other hardware circuitry, or by a combination of software and hardware circuitry. Further in this regard it should be noted that the various blocks of the flow diagrams of **FIGS. 3A-9B** may represent program steps (e.g., defined by software), or interconnected logic circuits, blocks and functions, or a combination of program steps and logic circuits, blocks and functions for performing the specified tasks. Circuitry includes semiconductor circuits, processors such as digital signal processors or general purpose processors, and programmable logic devices.

[**0081**] The foregoing description has provided by way of exemplary and non-limiting examples a full and informative description of the best method and apparatus presently contemplated by the inventors for carrying out the invention. However, various modifications and adaptations may become apparent to those skilled in the relevant arts in view of the foregoing description, when read in conjunction with the accompanying drawings and the appended claims. Nonetheless, all such and similar modifications of the teachings of this invention will still fall within the scope of this invention.

[**0082**] Furthermore, some of the features of the preferred embodiments of this invention could be used to advantage without the corresponding use of other features. As such, the foregoing description should be considered as merely illustrative of the principles of the present invention, and not in limitation thereof.

What is claimed is:

1. A method for lifecycle management for file systems, comprising:

allocating at least one storage container associated with a service class;

creating a file system on the at least one storage container, wherein the file system is associated with the service class; and

using the service class during lifecycle actions performed on the file system.

2. The method of claim 1, further comprising determining the association between the file system and the service class.

3. The method of claim 2, wherein determining the association between the file system and the service class further comprises analyzing a set of policies and determining the association based on the analysis.

4. The method of claim 2, wherein determining the association between the file system and the service class further comprises accessing a table comprising the association.

5. The method of claim 4, wherein accessing a table further comprises:

accessing the table to compare a given name corresponding to the file system and first names stored in the table corresponding to created file systems;

in response to a match between the given name and one of the first names stored in the table, determining a second name corresponding to a given service class and to the first name; and

determining the association so that the file system is associated with the given service class.

6. The method of claim 1, wherein using further comprises:

in response to an event requesting registration of the file system, determining the service class based on at least service class policies; and

storing the association between the file system and the service class in memory.

7. The method of claim 6, wherein storing further comprises storing the association between the file system and the service class in a table.

8. The method of claim 1, wherein the method further comprises:

removing the file system; and

de-allocating the at least one storage container.

9. The method of claim 8, wherein using further comprises performing a confirmation process that is at least partially determined by the service class.

10. The method of claim 8, wherein using further comprises performing at least one disposal instruction on the file system, the at least one disposal instruction corresponding to the service class.

11. The method of claim 1, wherein using further comprises allocating at least one additional storage container, the at least one storage container associated with the service class, wherein the at least one additional storage container comprises an extension of the file system.

12. The method of claim 1, wherein using further comprises:

the file system is a first file system;

allocating at least one additional storage container, the at least one additional storage container associated with a second service class;

moving the file system from the at least one storage container to the at least one additional storage container; and

associating the file system with the second service class.

13. The method of claim 12, further comprising de-allocating the at least one storage container.

14. The method of claim 1, wherein using further comprises:

allocating at least one additional storage container, the at least one additional storage container associated with the service class;

moving the file system from the at least one storage container to the at least one additional storage container; and

de-allocating the at least one storage container.

15. The method of claim 1, wherein using further comprises:

allocating at least one additional storage container, the at least one additional storage container associated with the service class;

replicating the file system on the at least one additional storage container.

16. The method of claim 1, wherein:

the method further comprises the step of specifying the service class associated with the file system; and

allocation further comprises allocating the at least one storage container so that the at least one storage container is associated with the specified service class.

17. The method of claim 1, wherein:

the service class comprises a file system service class;

the method further comprises determining a storage system service class by using the file system service class; and

allocation further comprises allocating the at least one storage container so that the at least one storage container has the determined storage system service class.

18. The method of claim 1, further comprising configuring the file system for access.

19. The method of claim 1, further comprising:

receiving an event; and

determining from the event a lifecycle action to be performed on the storage.

20. The method of claim 19, further comprising generating a given event when a remaining capacity of the file system is below a predetermined remaining capacity.

21. The method of claim 19, further comprising generating a given event when a schedule indicates the given event should be generated.

22. An apparatus for lifecycle management for file systems, the apparatus comprising:

at least one memory; and

at least one processor coupled to the at least one memory, the at least one processor configured to perform:

allocating at least one storage container associated with the service class in the at least one memory;

creating a file system on the at least one storage container, wherein the file system is associated with the service class; and

using the service class during lifecycle actions performed on the file system.

23. The apparatus of claim 22, wherein the at least one storage container comprises at least one of a logical volume, a database, and a file.

24. A signal bearing medium tangibly embodying a program of machine-readable instructions executable by a digital processing apparatus to perform operations for lifecycle management for file systems, the operations comprising:

allocating at least one storage container associated with a service class;

creating a file system on the at least one storage container, wherein the file system is associated with the service class; and

using the service class during lifecycle actions performed on the file system.

25. An apparatus for lifecycle management for file systems, comprising:

means for allocating at least one storage container associated with a service class;

means for creating a file system on the at least one storage container, wherein the file system is associated with the service class; and

means for using the service class during lifecycle actions performed on the file system.

26. The apparatus of claim 25, further comprising means for determining the association between the file system and the service class.

27. A method for lifecycle management for file systems, comprising:

allocating at least one storage container associated with a service class;

creating a file system on the at least one storage container, wherein the file system is associated with the service class; and

maintaining the service class of the file system throughout a lifecycle of the file system.

28. The method of claim 27, wherein maintaining comprises ensuring that the file system is stored at all times in storage containers associated with the storage class.

29. The method of claim 27, further comprising, in response to a modification of the storage class to a new storage class, allocating at least one new storage container associated with the new storage class, moving the file system to the at least one new storage container and deallocating the at least one storage container associated with the storage class.

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