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Design of File System Directory Services

Status of This Memo

This memo provides information to the Grid community about file system directory services. It does not define any standards or technical recommendations. Distribution is unlimited.

Abstract

This document discusses the design of file system directory services, which will be one of essential services for Grid file systems or virtual file systems in grid environment. It manages the namespace of federated and virtualized data from file system resources, access control mechanisms, and meta-data management. This document proposes a set of operations needed to be supported by file system directory services. For scalable, large-scale and distributed file system directory management, this document also proposes two types of federation of file system directory services.

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1. Introduction

Data in a grid can be of any format and stored in any type of storage systems. There can be many hundreds of petabytes of data in grids, among which a very large percentage is stored in files. A standard mechanism to describe and organize file-based data is essential for facilitating access to this large amount of data. The Grid File System Working Group (GFS-WG) was established in GGF data area to standardize the mechanism through providing a virtual file system in grid environment.

Two major deliverables of the WG are (1) architecture of Grid File System Services and (2) specification of File System Directory Services that is one of essential services for Grid file systems. File system directory services will manage the namespace of federated and virtualized data from file system resources, access control mechanisms, and meta-data management [1]. It will provide features such as (a) virtualized hierarchical namespaces for files or potentially other type of data (such as live data feeds), (b) efficient and transparent file sharing, and (c) flexible management of inter-organizational data access controls, and (d) ability to describe and manage file-system and application-specific metadata.

This document intends to describe the design of the file system directory services. It proposes a set of operations needed to be supported by file system directory services. For scalable, large-scale and distributed file system directory management, it also proposes two types of federation of the file system directory services.

The overall architecture of Grid file systems will be specified later in GFS-WG, which provides infrastructure of virtual file systems facilitating federation and sharing of virtualized data from file systems in the grid environment by using file system directory services.

2. File System Directory Services

File system directory services manage a hierarchical directory tree for a virtual file system, which consist of virtual directories and virtual files, having attributes such as access permission, and status such as opening and locking.

A virtual directory or a virtual file is specified by a *virtual file handle* (VFH). A virtual directory stores a list of a virtual name of a virtual directory or file and the corresponding VFH, which is called a *directory entry*. A virtual file includes a pointer to a physical location of a file data and access protocol to the file data. The pointer may be a pointer to a service to manage replica locations of the file data.

2.1 Operations of file system directory services

Basic operations of file system directory services are

1) Lookup operation to convert a hierarchical path name to the corresponding VFH under access permission control of a hierarchical directory tree,
2) Creation, removal, and rename operations for a virtual directory or file,
3) Operations for managing attributes or status of a virtual directory or file.

Table 1 shows an example set of operations of file system directory services. This list is not a complete set. Error codes or error status are not specified in this document. Detailed content of Attributes is not also covered in the document.

Table 1 Set of operations of file system directory services

Interface	Description
`VFH getrootVFH()`	Returns a virtual file handle of the root directory.
`VFH lookup(VFH fh, String path)`	Returns a virtual file handle of a virtual directory or file specified by a relative path from the virtual directory specified by `fh`. When `path` is an absolute path, `fh` is ignored.
`Direntry[] getdents(VFH fh)`	Returns an array of directory entries of the virtual directory specified by `fh`. `Direntry` is a structure consisting of a virtual name and the corresponding virtual file handle.
`Int mkdir(VFH fh, String name, Attr[] attrs)`	Creates a new virtual directory `name` under the virtual directory specified by `fh`, and sets attributes `attrs` to the virtual directory. This function returns `0` or an error code.
`Int rmdir(VFH fh, String name)`	Removes the virtual directory `name` in the virtual directory specified by `fh`.
`Int access(VFH fh, Int mode)`	Determines whether the virtual file or directory specified by `fh` can be accessed with the specified mode. `Mode` is one or more of `READ`, `LOOKUP`, `MODIFY`, `EXTEND`, `DELETE`, and `EXECUTE`.
`Attr[] getattrs(VFH fh, String[] attrkeys)`	Returns an array of attributes of the virtual file or directory specified by `fh`. Obtained attributes can be specified by `attrkeys`.
`Int setattrs(VFH fh, Attr[] attrs)`	Sets one or more attributes specified by `attrs` to the virtual directory or file specified by `fh`.
`Int addfile(VFH fh, String name, Attr[] attrs)`	Adds a new virtual file `name` in the virtual directory specified by `fh`, and sets attributes to the virtual file.
`Int removefile(VFH fh, String name)`	Removes the virtual file `name` in the virtual directory specified by `fh`.
`Int link(VFH destfh, VFH fh, String name)`	Creates the “hard” link `name` for the virtual file specified by `destfh`, in the virtual directory specified by `fh`.
`Int rename(VFH srcdir, String oldname, VFH destdir, String newname)`	Renames the virtual file `oldname` in the virtual directory specified by `srcdir` to the virtual file `newname` in the virtual directory specified by `destdir`.
`Int open(VFH fh, …)`	Creates server state for opening the virtual file specified by `fh`.
`Int close(VFH fh, …)`	Releases server state for opening the virtual file specified by `fh`.
`Int lock(…)`	Requests a record lock for the byte range.

`Int lookt(…)`	Tests the lock as specified in the arguments.
`Int lockf(…)`	Unlocks the record lock specified by the parameters.

Almost all operations need `lookup` operation to obtain a VFH at first. This means at least two round-trip interactions are required, while they could be critical overhead in wide area networks. One of solutions is introducing a COMPOUND procedure such as NFSv4 [2].

3. Federation of File System Directory Services

This section discusses federation of file system directory services for scalable, large-scale and distributed file system directory management. There are two major ways; one is an indirect federation such that a client library mounts several file system directory services, and the other is a direct federation such that file system directory services links each other.

3.1 Indirect federation introducing file system table services

File system table services manage a mount table or maps of mount points and mounting file systems. This approach assumes that a client library mounts several virtual file systems provided by file system directory services using a mount table or maps provided by file system table services.

File system table services provide similar functionality of a mount table of `/etc/fstab`, or maps of `automount` in Unix systems. A mount table is mostly used for small-scale federation of file system directory services, while maps using such as a domain name system (DNS) are used for large-scale federation.

There is no access control mechanism using a hierarchical directory tree when reading a mount table or maps of file system table services.

Using file system table services, a directory tree can be flexibly managed by changing a mount table or maps because there is no direct relationship among file system directory services. On the other hand, a client library has responsibility to control access permission between file system directory services, or when crossing a mount point. Moreover, renaming of a file or a directory, or making a hard link is only possible within the same file system directory services, and it is not possible across file system directory services because of the same reason.

3.2 Direct federation of file system directory services

When extending a virtual file handle to include a Grid service handle (GSH) of a factory service and an identifier (or a virtual file handle) within the services, it is possible to refer to a remote virtual directory provided by different file system directory services. This enables to link different file system directory services each other, and to provide single large-scale file system directory services using several distributed file system directory services.

On the other hand, to link different file system directory services each other, directory entries of both services need to be modified. To ensure the consistent modification, transaction across different services is required. These operations include creating and removing a remote virtual directory managed by different file system directory services, and moving a virtual directory between different file system directory services.

To create a remote virtual directory in different file system directory services, an additional argument of a GSH of a remote factory service is required by `mkdir`. In this case, `mkdir` will create a service instance using the remote factory service that is used to create a remote virtual directory, and create a link each other. To ensure the consistency of links, it is necessary to add two types of operations; `createdir` and `commitdir`, which are assumed to be called within `mkdir`. `Mkdir` creates a service instance using the remote factory service if necessary, calls `createdir` to obtain a new VFH, and adds the VFH to a directory entry temporally. After successful call of `commitdir` that checks whether the temporal entry exists in directory entries of the parent directory, `mkdir` makes the temporal entry formal.

`Int mkdir(VFH fh, String factoryGSH, String name, Attr[] attrs)`	Creates a remote virtual directory `name` in remote services created by `factoryGSH` under the virtual directory specified by `fh`, and sets attributes `attrs` to the virtual directory.
`VFH createdir(Attr[] attrs, long timeout)`	Creates a temporal virtual directory with attributes `attrs` having the lifetime `timeout`, and returns the virtual file handle.
`Int commitdir(VFH fh, VFH parentfh, String name)`	When the parent directory specified by `parentfh` has a directory entry of `name` and `fh`, makes the temporal directory formal.

When removing a remote virtual directory, it is necessary to keep consistency of links of both services. `Rmdir` requires an additional operation; `destroydir`, which removes a virtual directory after checking whether there is no entry for oneself in the parent directory. `Rmdir` first deletes a directory entry for `name` temporarily, and call `destroydir` to remove the remote virtual directory. When `destroydir` successfully removes the remote virtual directory, `rmdir` deletes the directory entry permanently.

`Int rmdir(VFH fh, String name)`	Removes the virtual directory `name` in the virtual directory specified by `fh`.
`Int destroydir(VFH fh, String childname)`	Removes the virtual directory specified by `fh` after checking whether there is no entry for oneself `childname` in the parent directory.

Renaming a virtual file or directory also requires a transaction across services, while the explanation is omitted in the document.

This approach provides complete access control mechanism using a hierarchical directory tree because of direct federation of file system directory services instead of relying on a client library. `getrootVFH` can return the VFH of the root directory even though it is managed by different file system directory services.

4. General problem

There are several problems not covered and also not settled in this document.

- Replication of file system directory services – To enhance fault tolerance and reliability, replication of file system directory services is indispensable. The consistency model required by file system directory services is need to be investigated.

- Backup – To prepare an unforeseen disaster, backup of data in file system directory services may be required. Moreover, even every file data itself may be required to be back up.
- Consistency problem between access permission of a virtual file and the corresponding file data
- Removal or modification of a file data without notification to file system directory services
- Consistency problem between file data replicas
- Interoperability issue with NFSv4 and CIFS

5. Summary and conclusion

This document intended to describe the design of the file system directory services, which will be one of essential services for Grid file systems or virtual file systems in grid environment. It manages the namespace of federated and virtualized data from file system resources, access control mechanisms, and meta-data management.

This document proposed a set of operations needed to be supported by file system directory services. For scalable, large-scale and distributed file system directory management, it also proposed two types of federation of the file system directory services.

Further detailed discussion for specification and evaluation by implementing file system directory services are needed with respect to performance, consistency, scalability, and reliability. The evaluation needs to consider functionality of a client library, especially, with and without client attribute cache.

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Intellectual Property Statement

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