Research on Cloud Storage Architecture and Key Technologies

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ABSTRACT
This paper proposes a general architecture of cloud storage system, analyzes the functions of the components, and discusses the key technologies, etc. Cloud storage is a novel storage service mode which the service providers supply storage capacities and data storage services through the Internet to the clients; meanwhile, the clients needn't know the details and lowered structures and mechanisms. The proposed architecture of cloud storage is layered and cooperative, and the discussed key technologies involve deployment, storage virtualization, data organization, migration, security, etc. The operation mechanism including ecology chain, game theory, ant colony optimization, data life cycle management, maintenance and update, convergence and evolution mechanisms are analyzed too. So an overall and new viewpoint to cloud storage system is illustrated.

Categories and Subject Descriptors
D.4.2 [**Operating System**]: Storage Management – allocation/deallocation strategies, *secondary storage, storage hierarchies, virtual memory.*

General Terms
Algorithms, Management, Measurement, Documentation, Performance, Design, Economics, Reliability, Experimentation, Security, Human Factors, Standardization, Languages, Theory, Legal Aspects, Verification.

Keywords
Cloud Storage Architecture, Key Technologies, Operation Mechanism, Ecology Chain, Game Theory, Ant Colony Optimization.

1. INTRODUCTION
Cloud computing is an emerging computing platform and service mode, which organize and schedule service based on the Internet. Cloud storage is one of the services which provide storage resource and service based on the remote storage servers based on cloud compting. Cloud storage will be able to provide storage service at a lower cost and more reliability and security.

Cloud storage system is a cooperation storage service system with multiple devices, many application domains, and many service forms. The development of cloud storage system is benefit from the broadband network, Web 2.0, storage virtualization, storage network, application storage integrated with servers and storage devices, cluster technology, grid computing, distributed file system, content delivery network, peer-to-peer, data compression, data encryption, etc.

The rest of the paper is arranged as follows. Section 2 introduces related work. Section 3 proposes a general architecture of cloud storage. Section 4 proposes policies of construction. Section 5 discusses the key technologies of cloud storage servers. Section 6 analyzes the operation mechanism of cloud storage system. Section 7 makes a conclusion.

2. RELATED WORK
There are many cloud computing and cloud storage providers, such as IBM, Google, Sun Microsystems, Microsoft, Amazon, EMC, NetApp, HP, Nirvanix, HDS, Symantec, etc.

There are also more and more cloud storage platforms, e.g., HDFS, GFS, Sun Network.com, SkyDrive, Amazon S3, EMC Atoms, Data ONTAP, HP Upline, CloudNAS, Hitachi Content Platform, FileStore, and KFS, etc.

The Storage Network Industry Association (SNIA) proposes Cloud Storage Initiative (CSI) to adopt Cloud Data Management Interface (CDMI) standard as cloud service standard.

Yunhong Gu et. al proposed Sector[1] which enables users to work with large datasets stored over multiple distributed nodes as if the files were on their local disk. Users do not need to locate data, manage data across multiple nodes, back up data, and manage the addition of new nodes or the deletion of existing nodes to the system.

The paper [2] introduced MetaCDN, a system that exploits 'Storage Cloud' resources, creating an integrated overlay network

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that provides a low cost, high performance CDN for content creators. MetaCDN removes the complexity of dealing with multiple storage providers, by intelligently matching and placing users' content onto one or many storage providers based on their quality of service, coverage and budget preferences. MetaCDN makes it trivial for content creators and consumers to harness the performance and coverage of numerous 'Storage Clouds' by providing a single united namespace that makes it easy to integrate into origin websites, and is transparent for end-users.

The paper [3] proposed a live storage migration mechanism over WAN, which can be referred in storage distributed migration.

The rapid development of cloud computing and cloud storage will produce cloud resource market and brought in the cloud services selection challenge, and the paper [4] proposed some related algorithms about this aspect. Cloud storage management technology such as Ying Zhan etc. [5] proposed is also an urgent problem which should pay more attention to.

Albert Greenberg et. al [9] discussed the cost of cloud service of data center including servers (45%), infrastructure (25%), power draw (15%) and networks (15%). All resources would be pooled to be dynamically drawn from the pools to meet demand and pay by use. To reduce the cost and improve agility, the policies are location-independent addressing, uniform bandwidth and latency, and security and performance isolation, etc. And the market mechanism for resource consumption shaping is adopted to increase efficiency, and geo-diversifying data center is adopted to improve end to end performance and improve reliability. These ideas can be referred by cloud storage.

In Storage summit 2009 [10], many people thought that the topic of Cloud, Cloud Computing, Cloud Services or Cloud Storage, just to name a few variations, has the attention of many IT professionals, developers, marketeers, presses and analysts.

Cloud storage enables new application types [11] through SOA, Web services APIs and unified service interface via virtualization over a network at low cost, and can provide anytime and anywhere access, massive data storing, sharing and collaboration via a single namespace, and policy management of storage, etc.

There is not yet a global standard specification and general architecture to cloud computing and cloud storage. The paper will analyze the requirements of cloud storage, propose the architecture, and analyze the key technologies.

The main idea is to integrated and improvement the current architecture, distribution mode, application area, etc. to construct a low cost, fault torrent, reliable, scalable, high performance and fair cloud storage alliance system.

The creativity in cloud storage is to impose the concept of ecology chain, service market, game theory, ant colony optimization and discusses some key technologies.

3. CLOUD STORAGE ARCHITECTURE

There exist many cloud storage architecture scheme from different cloud storage service platform. They are usually complexity and imcompatible. We propose a layered and generalized architecture of cloud storage. Cloud storage is a service type based on cloud computing.

3.1 Requirement Analysis

Cloud storage is catering for pervasive storage requirements and massive storage wishes. The operation and persistency is supported by the storage systems. Programs, data, texts, pictures, videos, etc. are all needed to store in the storage systems. Mobile terminals, PC, consume electronics such as cameras, smart phones; MP3/MP4, etc. are all need more and more storage resources. Usually, local storage is not sufficient, and lost easily, and consistency assurance when data stored across multiple storage devices, etc.

Therefore, the necessary and pervasiveness of storage requirements results to that the properties of cloud storage must be low cost, easy maintenance, reliable, security, recoverable, etc.

3.2 Architecture of Cloud Storage

Cloud storage is composed of thousands of storage devices clustered by network, distributed file systems and other storage middleware to provide cloud storage service for users. The typical structure of cloud storage includes storage resource pool, distributed file system, service level agreements (SLA), and service interfaces, etc. Globally, they can be divided by physical and logical functions boundaries and relationships to provide more compatibilities and interactions. Based on this idea, the architecture proposed here are as follows. It is a layered model. The architecture from bottom to upper is network and storage infrastructure, storage management, metadata management, storage overlay, service interface. The detailed functions will be discussed later.

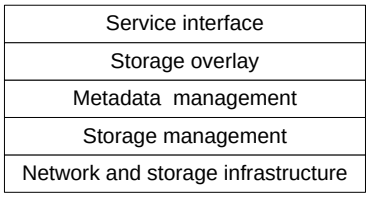

Figure 1. Cloud storage layered model

In network and storage infrastructure, there are distributed wired and wireless networks, storage devices networks.

In storage management, geographical distributed storage resources are organized by domains and logical entities, data can be stored by files or blocks in storage media.

The metadata management clusters the global domain data storage metadata information and collaborate different domains to load balance.

In storage overlay layer, the virtualization and service retrieving and redirection can be fulfilled. It may be thought as middleware which links storage devices distributed to a virtual storage networks and expose simplified and standard data structures to service interfaces.

In service interface layer, the cloud storage system provides clients uniform interface to access, and filter the illegal clients out of the system.

Service delivering mode is a key aspect in cloud storage. Storage resources can be thought as commerce products, and there are much commerce theories and experiences can be lead to cloud storage services.

3.3 Functions of the Components

According to the architecture of cloud storage, the infrastructure layer includes network, nodes hardware, and local operations and file systems. The storage management layer includes local storage organization and remote storage redirection. The metadata management means that they may be centralized and distributed to multiple nodes to promote the performance of query services. The storage overlay layer response for the abstraction of the cloud storage system, virtualization storage resources and scheduling optimized. The service interface layer provides clients access interface and applications interface or API calls.

4. POLICIES OF CONSTRUCION

Cloud storage is actually the implementation of storage as a service. The policies of construction of cloud storage include that requirement analysis, capacity prediction and performance planning, deployment, verification, distribution, maintenance, and updatability. The goal is to construct an available, reliable, cooperative, scalable, secure, concurrency storage system at economic and practical mode.

To construct cloud storage system, the distributed storage devices with releated management software should be comined with each other by virtualization, cluster and integration to expose a unified infinite virtual storage resource pool to users.

In the construction of cloud storage, the QoS (Quality of Service) is one of the important factors of storage performances. The QoS of cloud storage means storage rates, delay, bandwidth, responsibility, reliability, volumes size, life, recoverability, security, etc.

5. KEY TECHNOLOGIES OF CLOUD STORAGE SERVERS

The key technologies of cloud storage include many facets from servers, networks, clients, and related control measures, i.e. availability, reliability, virtualization, feedback, credits，security, etc. Cloud storage system should support automatic management, distributed collaboration, data integration, SLA matching, QoS, certification, access control, authority assignment, audit, etc.

The following discussions mainly focus on the cloud storage servers and some related control measures.

5.1 Deployment of Cloud Storage

The deployment phases of cloud storage include the following items: requirements analysis, storage resource redirection, optimization and evolution, etc.

5.1.1 Requirements and Foundations

The scale of cloud storage should be based on application requirements and technology foundation. The common storage networks are integrated by middleware and overlay layer, and distributed storage resources may be NAS, SAN, P2P storage, etc.

5.1.2 Storage Resource Redirection

The geographic locations should be selected by the data requirements of the applications. The base rules are nearing to the application and redundant autonomous replications management to adapt the access overloads.

5.1.3 Optimization and Evolution

The cost should be optimized based on the deployment mode. History experiences and feedbacks from the servers and clients should be collected to adjust the distribution policies and access controlling.

5.2 Virtualization and Availability of Cloud Storage

Virtualization is applied pervasively to many domains, such as operation system, servers, network, storage, etc. Storage virtualization is to map logical storage to physical storage in data access procedure. The cloud storage virtualization will help to hide storage geographic positions and storage modes and other technology details to storage users and clients.

The availability of cloud storage includes persistent runtime and recovery. High availability is needed to ensure application QoS.

Standard and common file systems such as NFS, CIFS, and GFS, etc. are adopted. Like Linux file system VFS, a new cloud file system may be propelled at near future.

5.3 Data Organization of Cloud Storage

The data organization of cloud storage can be database mode, file level, or block level. The database can be business database product, or opening source database. Information is organized as records to improve the retrieving speed. But the database can only manage some specified types data. The file level can be flexible and changeable according to the application processing. Block level is the lower storing data format, and the databases or files are all based on the block level. Pure block level data ignore semantic, and it must be combined with other storage organization mode over it. Object oriented storage is an emerging storage mode and it can be intelligent if addition to some autonomous operations.

5.4 Data Migration and Load Balance

Data migration of cloud storage means moving data in one storage system to other storage system in different places. It aims in cooperation and keepting load balance in cloud storage system. When the storage capacity is used over some threshold proportion values, the data should be migrated into other cloud storage units and keep pointers in the old stored positions, or modify and update the metadata at the same time.

Load balance is to keep available storage spaces for later application in different storage devices in cloud storage system. It can improve storage responsibility and availability globally. Data migration is one of the effective mechanisms for load balance, but it may bring overhead workload to network bandwidth and I/O process, and it doesn't relieve access bottleneck of concurrence clients.

Data replication is the specifial case of the data migration if the original data is kept. Data replication is a good resolution to the single point fault in distributed cloud storage system, which keeps multiple copies of the same content in different storage devices and places. The ideal cloud storage system should autonomously create necessary copy according to the client access frequency and storage server workload.

Data migration may take a relevant long time and suffer from data loss to massive data for the media and channel errors. The

problem is attracted much attention. So the centralized storage site for disaster recovery is necessary for Enterprise level storage [6].

5.5 Data Deduplication

Data deduplication [7] [8] is a new technology in storage backup, recovery and archiving to reduce the occupied storage spaces by compress the internal duplication data. Data deduplication is the best way to dramatically reduce data volumes, slash storage requirements, and minimize data protectioncosts and risks [7]. For the exponential growth enterprise and science data, there will need a massive storage space, data deduplication will bring relevant big storage space savings and the cost reductions. For the huge scale of cloud storage, data deduplication will be a good solution to save storage volumes and make storage data move secure and reliable. But there still a problem about where to do data deduplication, e.g., whether in cloud servers or in clients.

5.6 Storage Security

Storage security involves storage media physical security and data security. As general network storage, the security of cloud storage includes certification, authority, audit and encryption, etc. Through automatic redundant replications the data will be easy recovery once failover.

The cloud storage security can also expand to the whold procudure of storage service, including hardware, software, data, information, network security and clients' privacy security, etc.

Cloud storage is tending to combined with cloud security, which will provide more robust security.

6. OPERATION MECHANISM

The operation mechanism of cloud storage system means dynamic and long live storage organization, service delivery and evolution, and the cost is allocated by the time and storage space. In different periods and different places, the applications may have different storage requirements. The whole cloud storage system can be thought as an ecology system which storage resource is producing and consuming. We propose that the game theory and ant colony optimization may improve the performance and efficiency.

6.1 Ecology Chain of Cloud Storage

The cloud storage may be thought as an ecology system of storage producing and consuming, which includes cloud storage providers (hardware providers, software providers), storage integrators, storage brokers, data centers, content providers, and clients. The upper layer and the lower layer can interaction with each other through renting contract and added value services. The ecology chain can be divided into two sub-cycles, i.e. storage resource producing chain and storage resource consuming chain, as Figure 2. The storage resource producing chain will provide cloud storage service for the consuming chain.

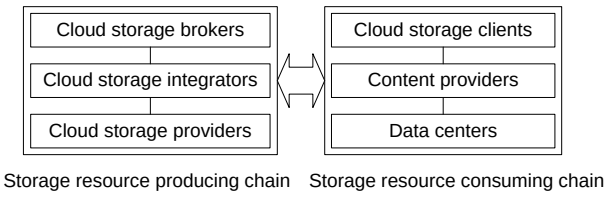

Figure 2. Cloud storage ecology chains

Storage resource as a service in cloud storage can be delivered through flexible modes, such as clients subsciption, enterpise storage cloud service for internal users, or the third storage cloud service for external users, and federated storage cloud service from multiple cloud storage service providers.

6.2 Game Theory in Cloud Storage

In fact, there are many cloud storage services providers, and they will make up of a storage service market. The storage service market needs cooperation and competition to balance and propel the cloud storage technology. Game theory in cloud storage is applied in the construction and cooperation phases. We are researching on this just now.

Assumed that there are multiple cloud storage service providers, they can get more benefits if they cooperate and make cloud storage federation in providing storage services to clients. In storage federation, who provide storage resources to clients can be seen as game theory problem. They will provide storage resources to the nearest geographic locations to reduce transports delay and communication cost.

6.3 Ant Colony Optimization

The ant colony optimization mechanism in cloud storage is applied in the consuming phase. The storage service selection of multiple cloud storage providers will be involved in the scope. When the storage clients request for the cloud storage services, which storage providers or storage servers will be selected will be based on ant colony optimization.

The clients may select a cloud storage resouces initially at random, and keep the experiences and satisfactory values in local and service paths (routers or storage servers). When next request is sent, the past experiences and satisfactory values will be refered in selection and update the related values by the current storage service, just as the pheromone in ant optimization algorithms. The pheromone can be adjusted by some rules and service overload situations to adapt the selection behavior of the clients and users of cloud storage.

6.4 Data Life Cycle Management

Cloud storage can provides storage resources for all kinds of clients, and the fee can be based on storage capacity or storage bandwidth periodically. The data life cycle management in cloud storage can be based on servers' configurations, or based on the contracts between servers and clients when storage services are initiated. Whether the access modes are desktop PCs, laptops, mobile terminals, application servers, or API [12], they can adopt leases to associate with the cloud storage servers about the periods of storage resources, and when the time is due, the storage spaces are released. To important data, the life cycle should be delayed by continuing the lease time.

6.5 Maintenance and Update Mechanism

Cloud storage integrates industry-leading technologies—including DAS, FTP/NAS, iSCSI/SAN, TAPE, distributed file systems (e.g. NFS, GFS, HDFS), cluster and grid computing, SOA, etc.—into a unified storage environment for the ultimate level of security and reliability [12]. The maintenance and update is centralized and controlled automatically by cloud storage management and monitor systems. So the clients needn't know complex storage management details and complex operation mechanisms and only

need to apply for storage resources by uniform interfaces to use on demand.

6.6 Storage Convergence and Evolution

Storage resources from different cloud storage providers are often hierarchical and incompatible. When the clients get storage service from one cloud storage providers, they often can't migrate the stored object or data to other ones, else if they ask for another storage service request again. It is not flexible and may be expensive if some application needs the same data based on different cloud computing platforms. So the cloud storage providers should make interactive interfaces to share with each other's data and contents seamlessly, and the fee of communication and convention mayn't be paid by the clients. This is the ideal situation of cloud storage convergence and evolution. For this goal, open source cloud storage platforms should be encouraged to deployment although security and risk of the data in cloud storage must be considered and ensured at first. There will be multiple convergence modes, i.e. centralized convergence, distributed convergence; pre-organized or ad hoc; local area or wide area or global area, etc.

According to the Sun Microsystems [13], cloud computing support every facet, including the server, storage, network, and virtualization technology that drives cloud computing environments to run virtual application to assemble in minimum time. Cloud storage as one kind service based on cloud computing, i.e. Storage as a Service (SaaS), can be used to store and hold application, business, and personal data, and integrate photos, maps, and GPS information, science data, etc. Cloud storage should be combined with other cloud services such as cloud database, cloud data, cloud security, etc. More and more valued services on cloud storage may be developed, e.g., mobile business, mobile learning, mobile game, etc.

Another evolution trend may be that there will be more wide range of cloud storage providers not just from information technology, but also from communication operators, enterpriser data centers, common community, personal storage sharing pools, etc.

7. CONCLUSION

The paper proposes the architecture of the cloud storage, and discusses the related key technologies. Although the applications of cloud storage have been developed practically and rapidly, the integration and operation mechanism in business and commerce should still need unified specifications and standards. The paper proposes layer architecture of cloud storage, discusses the deployment, virtualization and availability, data organization, data migration and load balance, redundant data deletion, storage security, etc. In the operation mechanism, ecology chain, game theory, ant colony optimization and storage resource convergence and evolution mechanisms are presented which deserve future deep research.

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