The Business Model of Cloud Storage

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***Abstract*—The traditional service model of cloud storage is that the service providers supply both the storage capacities and data storage services through the Internet to the clients. The obvious disadvantage of this model is that the data of the same customer stored in multiple cloud storage providers can not interact with each other. This paper adds a new layer to this model. The new model consists of StaS (Storage as a Service) User, StaS Provider and Cloud Storage Provider, which can solve the above problem. It also possesses some other advantages, such as Cloud Storage Providers need not care about the market and how customers use their services, different customers can use the cloud storage services in different security levels as they need. This paper also discusses the functions of different modules at StaS Provider layer and analyzes two architectures of cloud storage at Cloud Storage Provider layer.**

Keywords-cloud storage; StaS; business model

I. INTRODUCTION

Nowadays the growth of data is just like flood overflowing. Enterprises, governments, the non-profit organizations and consumers are facing more and more stern challenges, such as data storage, data management, data protection, data excavation and so on (especially in the data storage). The traditional storage devices and storage methods have no ability to deal with such a huge data quantity. The birth of cloud storage can alleviate the pressure of the storage of mass data.

We can say that the birth of cloud computing have made cloud storage. Cloud storage develops very quickly on the basis of cloud computing. We all know that cloud computing is provided and researched by some well-known companies. So the technology of cloud storage mainly take some cloud storage products of some well-known companies as representative, such as Amazon's S3 (Simple Storage Service), Nirvanix's SDN, EMC's Atmos, IBM's Blue Cloud and Microsoft's Live Mesh [1-3].

These cloud storage products have their own advantages and disadvantages. Customers can choose different cloud storage products according to their needs. With the appearance of various cloud storage products, a serious problem occurred. Customers can not use multiple cloud storage services provided by different cloud storage providers because of different pricing standards, different access interfaces and different storage forms of data at the same time. SNIA has found this problem, so it began to do something on the relevant standard of cloud storage in 2009 [4]. SNIA presents a standard about Cloud Data Management Interface (CDMI) in September 2009 [4]. The version 1.0 of CDMI was released in 2010. The main content of this standard is the data access mode, data organization and management, classification and metadata management and data security in the cloud storage system. This standard has an undoubtedly huge promotion on the development of cloud storage and the compatibility of different cloud storage products.

As enterprises have an enthusiasm to cloud storage, more and more researchers do academic research on cloud storage. The main research content is as follows: the management of data in cloud [5-7], the architecture of cloud storage [8-10], the security of cloud storage [11], the migration of data in cloud system [12] and so on.

The rest of the paper is arranged as follows. Section 2 simply introduces the business model of cloud storage and its advantages. Section 3 introduces the details of StaS Providers Layer and the function of each module. Section 4 compares two architectures of Cloud Storage Providers, P2P architecture and Master-Slave architecture, in control way, fault tolerant and load balancing. Section 5 makes a conclusion.

II. BUSINESS MODEL OF CLOUD STORAGE

Patterson has provided the Business Model of Cloud Computing [13], which consists of SaaS User, SaaS Provider and Cloud Provider as follows:

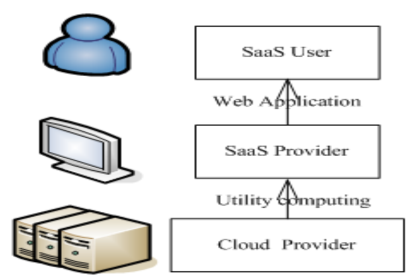

Figure 1. The Business Model of Cloud Computing [13]

So SaaS (Software as a Service) Provider can provide cloud computing service without any expensive hardware storage devices, and they only try their best to exploit the parallel software, whereas Cloud Provider only needs to manage their own cloud computing system and try their best to enable the cloud storage system to be more reliable, available, secure and effective. The advantages of this model are that Cloud Provider has no need to take care about market and customers. So cloud computing will develop more quickly and spread more widely.

In fact, the business model of cloud computing can be also applied to cloud storage, which consists of StaS User,

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StaS Provider and Cloud Storage Provider; nevertheless, the StaS here is Storage as a service (for distinguishing from Software as a Service, note that all StaS of this paper behind is referred to Storage as a Service.) and the Figure is as follows:

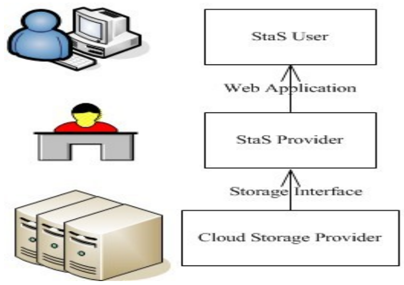

Figure 2. The Business Model of Cloud Storage

In this Business Model of Cloud Storage, Cloud Storage Provider only needs to manage the cloud storage system effectively, such as the deployment, the architecture, fault-tolerant and the interface which is provided to StaS Provider, etc. StaS Provider needs not to own enormous storage devices. However, it owns infinite storage capacity which can be assigned to StaS User. StaS Provider should have the functions as follows: managing the information of StaS User, purchasing storage space from different cloud storage providers, mapping this physical space to a logical space for StaS User through Virtual technology, providing different customers with different security levels.

The advantages of this business model of cloud storage include the following:

1. StaS User can interact with their data which is stored in multiple cloud storage systems provided by different cloud storage companies through promoting data interoperability to the StaS Provider layer. Because StaS Provider can call the corresponding interfaces functions of the cloud storage system, multiple physical spaces of different cloud storage providers can be added to a StaS User's logic space, which is just like mounting multiple disks.

2. StaS Provider can provide different StaS Users with different security levels. The higher security level is, the higher the price is. The reason why the previous cloud storage can not occupy the market is that cloud storage can only provide high security and the price is expensive. Many customers, such as general customers, do not need such a high security level. So they lose a lot of customers.

3. Owing to StaS Providers can concentrate storage space belonged to multiple Cloud Storage Providers, StaS Providers can own as much storage capacity as they want.

4. It is not necessary for Cloud Storage Providers to pay much attention to market and customers. Cloud Storage Provider in the traditional model maybe have to care about one million customers, whereas in this model maybe only care about one or several customers who are StaS Providers. They only need to pay all their attention to the design and management of cloud storage system (such as the arrangement, the architecture, the secure mechanism and so on).

III. STAS PROVIDER

The details of this business cloud storage model are as follows:

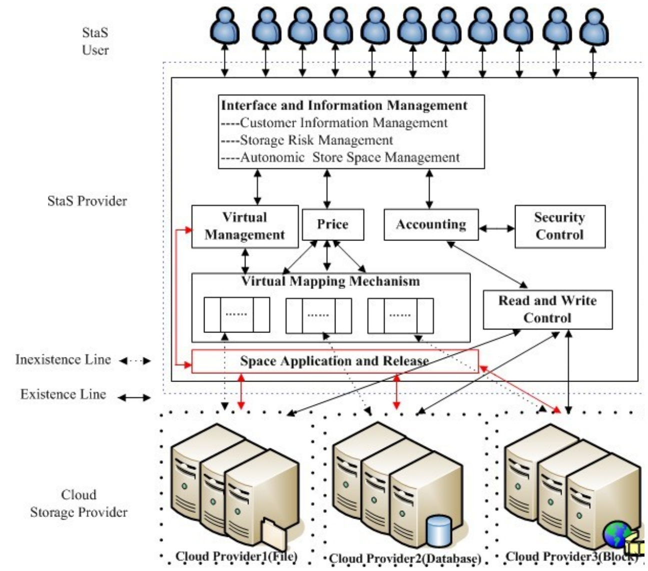

Figure 3. The Detail Business Cloud storage Model

From Figure 3 we can see that StaS Provider Layer own many modules. The functions of each module are as follows:

Interface and Information Management(IIM):This module provides interface for StaS User and manages the information of customers. Also it should monitor the risk of customers' application. Only in the none-risk case, the system will allow customers to apply for space. The last function of this module is the management of the logical store space.

*Accounting:*This module manage the status of customers` login. After a customer logs in, he/she should get the information data from the module of Interface and Information Management and then Accounting will make a map between customer's login and the information of his data (the information of data is equivalent to the customer's logical storage space).

*Virtual Management(VM):*This module manages and monitors the below logical storage space. When StaS Provider apply for storage space from Cloud Storage Provider through the module of Space Apply and Release, VM need to map the newly applied physical space to the logical space and manage it. When StaS User applies for some storage spaces, VM need to maintain available spaces for each customer. Of course, there is an assumption that Cloud Storage Provider can provide high availability (Even if there are server crashed in Cloud Storage Provider layer, there should be corresponding alternative server and the map with Virtual Mapping Mechanism can not change).

*Security Control(SC):*Different customers have different requirements for the security of their data. For example an enterprise demands a very high security level, whereas common customer does not need such a high security level. So StaS Provider can provide different security levels for

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different customers through SC. When a customer logs in StaS Provider, he/she should choose the security level through SC.

*Price:*This module is used to calculate the cost of customers. The traditional model of cloud storage do not own the layer of StaS Provider, so customers can not interact with their data stored in multiple cloud storage providers because of the different pricing standards and the different access interfaces. But customers can do this in this model. Because this module can calculate the cost of customers according to corresponding cloud storage manufacturer's charging standard. So customers can use storage space of different manufacturers, which is just like mounting disk.

*Read and Write Control(RWC):*This module can let customers use multiple storage services provided by different cloud storage manufacturers. We all know that there are different interfaces and storage forms (such as file, database, block and so on) among different cloud storage services. RWC can shield these differences. When customers access their data, they only need to send the access demand, the logical space of data, and the corresponding manufacturer's name to RWC. Then RWC will call corresponding access interface.

*Space Application and Release(SAR):*This module is used to apply for or release space from the layer of Cloud Storage Provider. When applying to the new space, it should finish the additional logical space mapping with the above VM. When releasing the space, it should cut the logical space with VM.

*Virtual Mapping Mechanism(VMM):*This module only map physical space to logical space and the above VM take charge of the management of this logical space. If we do not care about other modules, we can abstract the system as Figure 4. We can see that the space of all physical storage devices is mapped to a huge logical storage space and customers apply for logical space from StaS Provider.

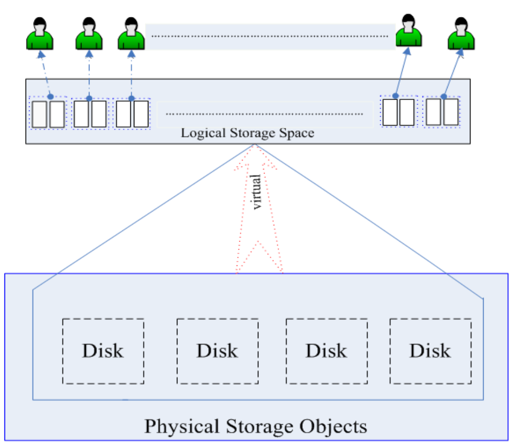

Figure 4. Abstract of Virtual Mapping

Now suppose that the total logical capacity is 1024TB and the average size of each customer purchase is 1 TB. So the number of customers StaS Provider can hold is 1024 at most. If there are any more new customers who want to purchase logical storage space, StaS Provider have to purchase more physical storage space from Cloud Storage Provider. Are there any methods which can tolerate that some customers continue to buy logical space from StaS Provider and by which StaS Provider have no need to purchase physical space from Cloud Storage Provider? Meanwhile we promise that each online customer's storage space is the same size as they have purchased.

In fact, there are two important statuses. Firstly, the possibility that all the customers are online is very small, or we can say that the number of online customers is just a certain amount of total customers. Secondly, the storage space that customers purchased will not be used up completely. For these two reasons, we can solve the above problems. We can recycle the unused storage space of the offline customers (Note: we just recycle it temporarily. If customers are online again, we will assign the space of the same size to them from other unused space) and allow online customers or new customers to purchase this space. If we do this, the system of the above example can hold more than 1024 customers.

For example, suppose that the average online rate is two-thirds and the average use rate of customers` space is two-thirds, then we can hold at least 110 customers to buy storage space of 1TB practically, according to

$$1024*(1-2/3)*(1-2/3)=113.78.$$

We just simply suppose the average online rate and the average use rate of space. If we want to do further research in this aspect, we can analyze the discipline of the customers (the average online rate or offline rate) and how much the average use rate of space is, we can hold the largest number of customers. Of course, we should pay attention to the number of spare capacity of the system and the present risks. We can create an optimization model with these parameters.

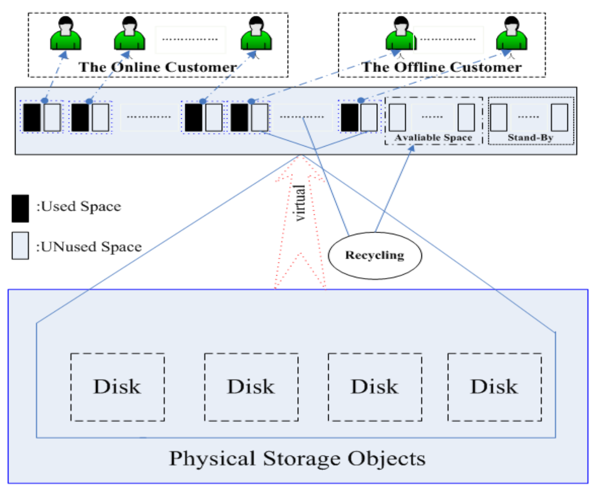

Figure 5. The Space Recycling Mechanism

If we take this mechanism, StaS Provider back up a certain space for emergency (the total space that online customers purchased is larger than the total space that StaS Provider can assign).The details are as shown above.

We can add the size of this emergency backup space to the above optimization model. But this mechanism has a high demand for the virtual technology and the management

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of space is a little complex. Of course, this is a very good mechanism.

IV. Cloud Storage Provider

As the real physical storage devices provider, Cloud Storage Provider should provide StaS Provider layer with high availability of services. It not only provides reading and writing interfaces, but also needs to ensure the security of data and the availability. As it should try to improve the efficiency, there would involve a lot of technologies. Now we will discuss Cloud Storage Provider as follows: model, architecture and instance.

A. *Model*

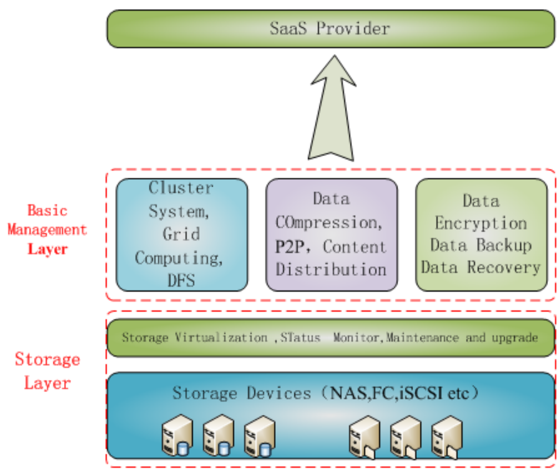

Figure 6. Cloud Storage Model

Compared with traditional storage systems, cloud storage is a complex system. It includes not only the hardware, but also the network equipment, the storage equipment, servers, applications, public access interfaces, access networks and so on. It provides data storage and business access services through the application software. Cloud Storage can be divided into two Layers: Basic Management Layer and Storage Layer.

1) *Storage Layer*

Storage Layer is the most basic part of the Cloud Storage Structure. Storage devices can be FC storage devices, also can be IP storage devices, such as NAS and iSCSI. Storage devices in the Cloud Storage Network are often located in different regions, and even different countries. The nodes can be linked together through the storage network and the storage network can be SAN, NAS, FC-SAN, etc.

Storage Device Management System is on the top of storage devices. It can mask the differences between various physical storage devices. So it can achieve storage devices logical, management virtualization, multi-link redundancy management, and hardware status monitoring and troubleshooting.

2) *Basic Management Layer*

This layer is the key part of the cloud storage system and is also difficult to realize. Basic Management Layer make multiple storage devices to work together, the external provision of service and provide better data access performance through the cluster, the distributed file system and the grid computing technologies.

Data encryption stored in the cloud will not allow unauthorized user access, while a variety of data backup and disaster recovery technology can guarantee that the data in the cloud storage will not be lost and the data will be safe and stable.

B. *Architecture*

Cloud storage network provides data backup, data migration and other operations through the internal network, and cloud storage services through the external network. Cloud storage system is a new storage system. In order to deal with immense data generated everyday. Generally speaking, when we build a cloud storage system, we should consider several aspects as follows:

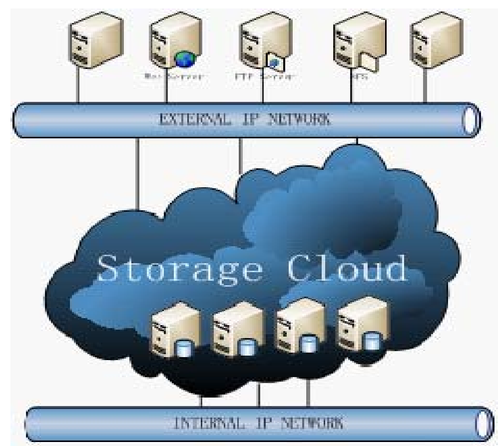

Figure 7. Cloud Storage Architecture

Expand the capacity: When increasing the capacity of the cloud storage system, we should be able to provide services continually, add the new storage nodes to the original storage pool automatically, and do not need too much duplication and complex configuration.

Reliability and Availability: Storage node failure is normal, not abnormal. When the storage node fails, ensure that we can provide cloud storage services continually, and the data in the cloud storage is not lost.

Management: Cloud storage networks include thousands of storage nodes, how to manage so many nodes effectively will become a key to how to build architecture successfully.

Costs: Because the cloud storage system has the same service interface with the tradition network storage system, it can be integrated into the existing storage system conveniently and do not require any structural change in the existing system. It can greatly reduce the cost of the deployment of the cloud storage system.

C. *Cloud storage architecture instance*

At present, there are two forms of typical cloud storage architecture, Master-Slave architecture and P2P architecture. Each company can select a model according to their characteristics. Each architecture has its own advantages and

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disadvantages, we will discuss control way, fault tolerance and load balancing as follows.

1) Master-Slave architecture

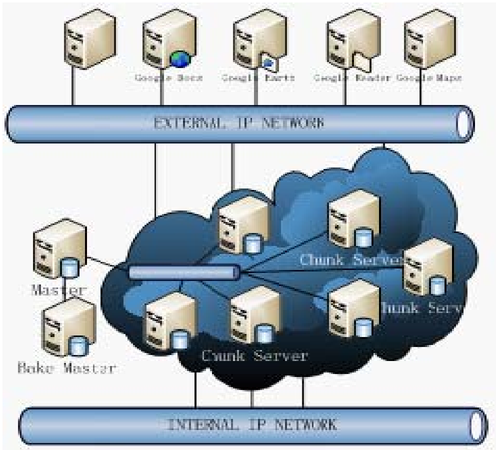

Figure 8. Master-Slave Architecture

a) Control way

This structure consists of a master server and many storage nodes; data storage format is a multi-dimensional map of the sparse structure. Data (including the index, log, and record data) is ultimately stored in the distributed file system. Data is assigned to each node by master server, which monitors the status of every storage node and storage load balancing between nodes. The client read the index file stored in the master server by the pre-reading and cache technology. This Master-Slave model has an obvious disadvantage. There is a single point of failure. In order to avoid the master became the bottleneck of system performance and reliability. We need remote backup for master. However, there is an obvious advantage of this architecture. The system can be easily controlled, easily maintained, easily added a host to it, and there are no data consistency problems.

b) Fault-tolerant

As the data is stored in many normal PC, the machine failure is normal, not abnormal. Usually, the data will have more than one copy. The copies are stored in different machines, different racks, and even different data centers. When one machine failed, the system can provide data service continually to ensure high availability.

If a data need N copies, of course, N can be configured by the user .Generally speaking, N=3. When the data is written to the storage node, according to relative algorithm, the system will write N-1 copies to other N-1 designated storage nodes. So it can ensure that every data has multiple copies stored in cloud storage system. The location information of the data and copies will be saved in the master server. When the clients accesse their data, at first, they need visit metadata stored in master server to get location information. Then according to the location information, the client can access the corresponding data storage nodes to read their data. So when the individual storage node fails, the system can still guarantee the integrity of the data, and client can still read their data. In addition, in order to recover data, when a machine fails, the master server gets the copy from other normal machine and transport the copy to the abnormal machine.

Since location information of all kind of data are stored in the master server. In order to ensure the high availability of data, there will be a metadata backup.

c) Load balancing

According to the load information migrate data, master server monitor the load information of every storage node.

2) P2P Architecture

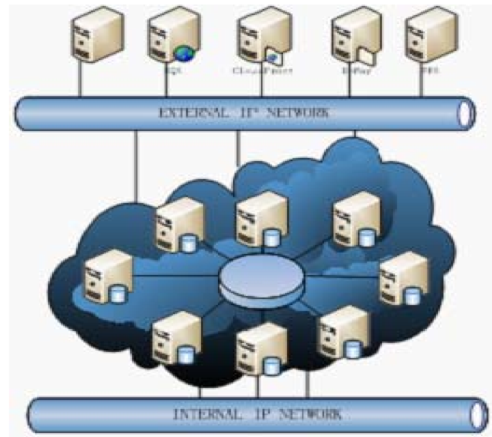

Figure 9. P2P Architecture

a) Control way

This architecture uses an improved DHT as its basic storage structure. The most important characteristic of this architecture is that the data are distributed on every storage node uniformly. Each storage node can communicate with each other .The data can be transported among the various nodes and detected if the data is in fault status. The advantage of this storage structure is that it has no single point of failure, and no master node control, but has self-management ability. The disadvantage is that there is data consistency problems, and inconvenient when adding the host to this system.

b) Fault-tolerant

The data stored in this structure uses redundant storage strategy as well as in the Master-Slave structure. We can use Dynamo's [14] strategy of redundant copies for reading and writing. It defines three parameters N, R, W. N represents the number of copies that each records. W represents the number of copies for each process of writing. R represents the number of copies for each reading. As long as R+W>N, we can read the latest copies. The number of R and W can be configured by us. We can update the lower version of data while we read the higher version of data. Thus we can handle the data consistency problem easily and adjust the demand of the high reading and high writing flexibly.

In addition, we can use Cassandra's [15] fault detection and recovery strategies, which determine the survival state of every storage node not by a BOOL value. Instead the failure detection module emits a value which represents a suspicion level for each of monitored nodes. This value is defined as Φ [16]. According to the size of this value, the system detects mal functions. The performances of Accrual failure detector in accuracy and speed are very good; they can be adjusted to different network environment and server load environment.

c) Load balancing

Because the structure of DHT uses a way that the data is distributed evenly across the different nodes, there are no hot issues. Access pressure of every storage node is balanced. We can also use virtual node like Dynamo. When the machine has high performances, it can be configured with more virtual nodes. While the machine has low performances, it can be configured with less virtual nodes. The number of virtual node configured in each machine is determined by the machine's performance. Heterogeneous machines can be easily managed, and the load of each machine is also more balanced. The number of virtual nodes should be far greater than the number of physical machine. Many virtual nodes correspond to a physical machine. When we add a new machine to the system, we need not re-HASH, but just need to move some virtual nodes to this new machine. So it significantly reduces the amount of data moved.

V. CONCLUSION AND FUTURE WORK

This paper adds the StaS Provider layer to the business model of cloud storage. This model can solve the problem that customers can not interact with their data stored in multiple cloud storage providers because of the different pricing standards and the different access interfaces. The key research contributions of this work include:

- We add the StaS Provider layer to the traditional model of cloud storage. So the new model of cloud storage is consisted of StaS User, StaS Provider and Cloud Storage Provider and Advantages of this model is discussed.
- The functions of the different modules at StaS Provider layer (such as virtual management. security control and so on) are discussed and a virtual mechanism which can hold more capacity for customers by recovering the unused space of the offline customers is provided.
- The model of the Cloud Storage Provider layer is provided and some relevant functions which should be provided by it are discussed. Two practical architectures are provided, one kind is the architecture of Master-Slave, and another kind is the architecture of P2P. We have compared them in the following three aspects: control mode, fault-tolerant and load balancing.

The prototype system of the business model of cloud storage mentioned above has been building. Our next work is to test and analyze the performance of the system**,** practically and theoretically

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