Opportunities, Concerns and Challenges in the Adoption of Cloud Storage

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Abstract— **The impact of Information and Communication Technologies on business models is posing new challenges. It has given birth to a new set of data and related applications. Changing business needs and the explosion of digital data have also created huge demand for massive and efficient storage. Increasing costs for electronic data storage and limited funds made people to think about cloud storage. Such infrastructures need reliable equipments and skilled manpower to handle it efficiently and effectively. Cloud Storage is an important part of cloud computing in which storage is provisioned, on-demand and pay-per usage basis from anywhere through Internet. The paper emphasizes on the adoption of Cloud storage. It reviews its evolution, design principles and different storage services. It presents a generalized architecture of Cloud storage along with opportunities, concerns and challenges in the adoption of Cloud Storage.**

Keywords—**Cloud Computing, Cloud Storage, Virtualization, Design principles, Cloud Storage Architecture.**

I. INTRODUCTION

Information and Communication Technology (ICT) is an integral part of all business processes as it affects delivery and performance of business operations. So companies spend major chunk of their budget on purchasing and then maintaining ICT infrastructure. Business needs never remain same, they tend to shrink and grow. But ICT infrastructure is usually acquired to meet the demand during the peak hours. So, huge investment in setting up ICT hardware and software goes underutilized most of the time. Frequent upgradation in the technology tends to make existing hardware and software obsolete. Companies have to spend huge amount on the maintenance of ICT infrastructure, which is not feasible especially for small businesses. ICT departments have to focus more on day-to-day ICT related activities rather than concentrating on core activities of the business. But now with Cloud Computing, Computing can be used as a utility service. Cloud Computing refers to the delivery of IT resources as services over the Internet, as opposed to hosting and operating those resources locally on subscription or pay-per-usage basis.

John McCarthy opined in 1961 that "computation may someday be organized as a public utility". His prediction has become true with the increase in network speed and reliability of the Internet. Cloud Computing allows people to use computing, storage and network on pay-per-usage basis similar to the way telephone and electricity services are used. Many other technologies like distributed computing, virtualization, grid computing and utility computing also led to the development of term Cloud Computing. According to the definition of National Institute of Standards and Technology (NIST), Cloud Computing is a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g. networks, servers, storage, applications and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction [1].

Cloud Computing provides an opportunity to store data in Cloud Storage instead of storing it to computer's local hard drive. Users do not need to maintain large storage infrastructures. They can store data in remote data centres, controlled and managed by big companies like Apple, Microsoft, Google, Amazon etc. Files saved in the cloud storage can be accessed from any device with an Internet connection. Cloud Storage is an important aspect of Cloud Computing. Cloud Storage refers to virtualized storage infrastructure that is provided as a service on demand, through network to save data and is maintained by a third party.

II. KEY ENABLERS FOR CLOUD STORAGE

Traditional approach of storing data locally in the user's hard drive is not able to fulfil the changing requirements of users, who daily deal with massive digital data. New breed of users want availability of data round the clock using any device from any location. Cloud storage becomes the natural choice for such users. The key enablers for Cloud storage are identified as follows:

A. Growing dependency of all business operations on ICT

Integration of business and ICT is a prerequisite to success these days. Business people depend on ICT to ensure that they can respond immediately to the changes in the competitive business markets as well as to gain flexibility. ICT also affects delivery and performance of business operations. It acts as a key business differentiator to have organizational excellence.

B. Explosion of digital data at an exponential rate

It has become easy to capture, alter and store data. Every company is generating piles of data every day and it is growing exponentially. Moreover, companies need large quantities of data to transform it into business intelligence for making smarter decisions.

C. New set of data and applications

Users are actively creating and sharing content in the form of text, video and photo postings along with comments, tags and ratings using Blogs, wikis etc., which has given rise to a novel set of data and applications.

D. The consumerization of IT

"Bring Your Own Device" (BYOD) movement is widely adopted in technical educational institutes and companies as a cost saving strategy [2]. Few organizations allow their employees to use their own devices and consumer-driven software on the enterprise network. Employees are also striving to become as productive as possible in this competitive world. They feel that they can work faster and easier using their own devices such as smartphones, notepads, laptops and iPads. All this has led to the consumerization of IT, which has created huge demand for massive and efficient storage accessible from anywhere with any device [3].

E. Lack of skilled storage professionals

Organizations are facing the requirement to store huge quantities of digital data. Storage professionals are required to design, manage and maintain the changing storage requirements. Companies are not getting skilled storage professionals due to lack of storage technology education.

F. Availability of Limited funds

Economic slow down, cut on grants and subsidies etc. have also made people to think about cost-effective alternatives of storing data.

G. Virtualization

The primary accelerator of Cloud Computing and cloud storage is virtualization [4], [5]. Virtualization makes it possible to run multiple applications on virtual machines within the same physical server instead of running only one application on a physical server. It is used for delivering greater availability, scalability along with optimization of resources such as storage, servers etc.

III. EVOLUTION OF CLOUD STORAGE

Slow and low-capacity punch cards are considered as the first data storage devices. Magnetic tapes for backup and hard disks for local storage of the computers are still used. Floppy Disk, Compact Disc, Digital Versatile Disc, Flash Drives and Pen drives has also changed the data backup scenario.

Earlier, each application server had its own storage known as Direct-Attached Storage (DAS). If an application needed more storage capacity, a disk array was added to the server via a high-speed interconnect, called Small Computer System Interface (SCSI). It provided performance at lesser cost. As the number of servers grew on a network, it became difficult to manage isolated storage resources. So, disks were separated from the servers in 1960s. Several protocols were developed to share disk storage among multiple servers. Redundant Array of Independent Disks (RAID) was a revolutionary step of 1980s. Its major purpose was to provide the fault tolerance subsystem which can provide efficiency and reliability to the overall performance of the system. Advances in storage management, ever-increasing need for storage and RAID led to the development of file-based Network-Attached Storage (NAS) and block-based Storage Area Networks (SAN) solutions. Both NAS and SAN provide remote access to storage devices via a network.

NAS devices utilize TCP/IP based networks. They are directly connected to the Local Area Network (LAN). They allow data sharing between different Operating Systems (OS) like Windows and Linux. NAS devices are cheaper, but it is difficult to scale their storage capacity. SAN devices are connected to the servers through Fibre Channel, switches or bridges. They are not directly connected to the LAN, so it significantly decreases the traffic load on the network. Only server class machines with SCSI or Fibre Channel can connect to a SAN. File sharing is OS dependent. Capacity of SAN devices is easily scalable, but they are expensive [6]-[8].

NAS and SAN were followed by Content-Addressable Storage (CAS) [9], [10]. CAS is a method of storing data and providing fast access to fixed content (i.e. data that is not expected to be updated). It uses hashing algorithm to assign a unique identifier called content address to each stored object. If a data element changes, it receives a new content address. Data is retrieved based on its content, instead of its storage location. CAS is useful in the long-term retention of content for regulatory purposes and in the archiving of massive amounts of medical records, government documents, images etc. CAS uses a Redundant Array of Independent Nodes (RAIN) architecture which allows data to be copied to one or more servers in the cluster, instead of storing it on different disks in the same server.

Traditional file systems are not able to support large unstructured data sets such as medical imaging, movies and entertainment. Object based Storage devices (OSDs) are better equipped to handle it. Objects are assigned an Object Identification number rather than an inode for file systems. They support scalability, data protection and data integrity, data sharing without performance degradation. Object storage, evolution of network and Internet technologies enabled use of remote computers storage all over the world for critical data backups. All these technologies led to the era of Cloud Storage.

Cloud storage is an online storage available on network hosted by third party vendors. Data is stored on virtualized pools of storage. It is delivered as a service on demand in a scalable and multi-tenant way [11]. Cloud storage includes storage hardware, network hardware, servers, applications, public access interfaces and the client programs. It also needs software to interconnect heterogeneous storage devices. Storage providers or third party vendors operate large data centres. Data centres house cloud storage systems which have data servers. Data Servers are used to store data/files by the clients through network. Users of cloud storage buy or lease storage capacity from them. A web-based user interface is used to access the data server. Data may be manipulated on the server itself or it is downloaded first and then manipulated on the client side. Same data is stored at multiple machines with different power supplies to make it easily available in case of data server failure or

maintenance. There are various examples of usage of Cloud storage. E-mail providers like Gmail, Hotmail and Yahoo store e-mail messages on their own servers. Sites like Flickr and Picasa host digital photographs. YouTube hosts user-uploaded video files. Google Docs allows users to upload documents, spreadsheets and presentations to Google's data servers [12]-[14].

IV. CLOUD STORAGE ARCHITECTURE

Cloud storage has led to the delivery of new application architecture. In these architectures, applications are fully contained on a variety of devices such as Smartphones, Tablets, PCs etc. and the backend is cloud storage accessible via web-oriented Application Programming Interfaces (APIs). The review of literature indicates that different Cloud storage providers use different storage architectures [15], [16]. After considering various architectures, a generalized architecture of Cloud Storage is presented in Fig. 1.
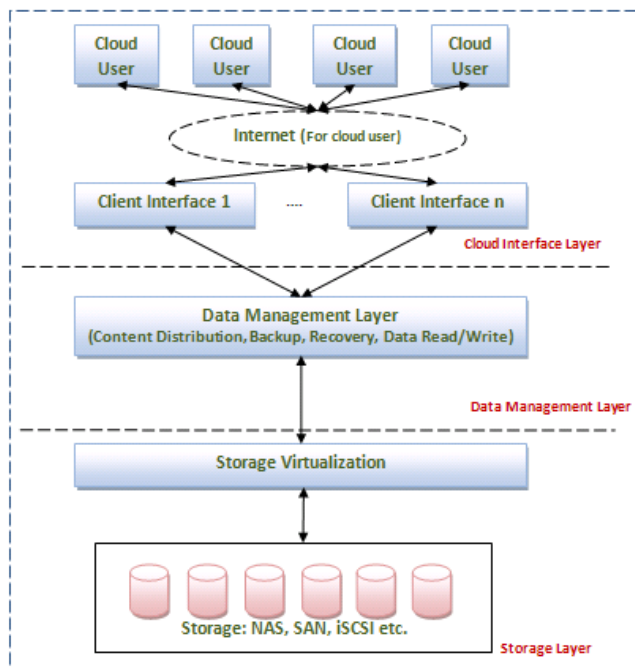

Fig. 1: Generalized Architecture of Cloud Storage

A. Cloud Interface Layer:

Cloud Interface layer is a software layer provided by Cloud storage provider to connect Cloud users to Cloud storage service through Internet. This layer applies authentication and authorization techniques to authenticate the users.

B. Data Management Layer

Data Management Layer is a software layer used to manage data of a particular cloud client. Data management is mainly concerned with activities like data storage, content distribution across storage location, data partitioning, synchronization, maintaining consistency, replication, controlling movement of data over network, backup, data recovery, handling millions of users, maintaining meta data and catalogue etc.

C. Storage Layer

Storage layer consists of two parts:

- *Virtualization:* Storage virtualization gives illusion of unified storage. It maps distributed heterogeneous storage devices to a single continuous storage space and creates a shared dynamic platform [17]. It is implemented by storage virtualization technology. Few virtualization technologies provide built-in availability, security and scalability to applications.
- *Basic storage:* It comprises of database servers and storage devices of heterogeneous nature such as DAS, SAN, NAS etc.

V. DESIGN PRINCIPLES OF CLOUD STORAGE

The main design requirements of cloud storage are scalability, availability, multi-tenancy, reliability, speed, cost and simplicity. Storage needs can scale up or down depending on business requirements. So, Cloud storage should be scalable to meet requests from unlimited and concurrent users without affecting performance and speed. The traditional method of allocating storage blocks is often called "fat" or "thick" provisioning. Thin provisioning is used in a shared storage environment. It uses virtualization to give the appearance of more physical resource than is actually available. It avoids over-provisioning and optimizes the efficiency. Initially, it limits the actual physical storage allocation to what is really required at the moment. Then it enables the automatic addition of storage blocks of data online as the application grows. It reduces the amount of storage required to service applications by minimizing the number of disk drives which in turn lessens energy consumption [18].

Cloud Storage services should be available round the clock. Decentralization techniques such as replication or erasure codes are used for fault–tolerance and better availability of cloud services [19]. Data is replicated on different servers residing at different locations to avoid a single point of failure. Multiple nodes provide same services. If primary node fails, backup nodes take over. Erasure codes are also used to provide redundancy by breaking up objects into smaller fragments and storing the fragments in different places. Data can be recovered from any combination of smaller number of those fragments. Snapshot and cloning services are also used for the duplication of data for better availability and reliability. A storage snapshot is a set of reference markers (pointers) to data stored on a disk drive, on a tape, or in a SAN. Snapshots streamline access to stored data and can speed up the process of data recovery [20].

Multi-tenancy means that storage is used by multiple users (tenants). Tenants should be able to gain access to their data without any disruption. So data should be stored in such a way that it is always available without any downtime. De-duplication and compression services [21] are used to reduce storage space requirement by eliminating redundant data. They also reduce the amount of data that must be sent across a network for remote backups, replication and disaster recovery. Only one unique instance of the data is actually retained on storage media. Redundant data is replaced with a pointer to the unique data copy.

It is necessary to provide inexpensive, simple, flexible and reliable storage so that users can use it for their different storage requirements. Cloud storage is rented using cost-per-gigabyte-stored or cost-per-gigabyte-transferred models by the storage service providers [22], [23]. Storage efficiency features such as thin provisioning and de-duplication increase storage utilization and make storage services cheaper and competitive. It also reduces the amount of storage that users may consume and hence lowers their bill.

VI. OPPORTUNITIES AND INDUSTRY PRACTICES IN THE CLOUD STORAGE

Cloud storage is a new way to deliver storage services effectively while saving time and costs. It serves concurrent users from multiple locations around the world. Cloud storage provides limitless scalability on pay as you store/transfer basis. Outsourcing storage infrastructure helps in cutting incremental storage expenditures and gaining unlimited capacity by reducing setup and maintenance costs.

By storing data in a cloud, one is free from risks like hard drives failure, human error, natural disaster. All the information is stored on more than one external server and is monitored 24/7.User does not feel the need to carry a physical storage device as data is available from any device and any location through Internet ready device like phone, laptop or tablet. Data can be moved between multiple gadgets.

Not only it improves responsiveness to the business, but enables IT staff to focus on innovation rather than focusing on day-to-day IT operations and data-related activities. If a project is of collaborative nature, other team members can also access related data.

Backup data is growing at fast pace. So, it is better to store it in cloud storage due to its lesser frequency of access. Data warehouse and data mining applications can use cloud storage. Hence, Cloud storage is a perfect choice for business people who are always on the move, for keeping backups of data as well as for better disaster recovery. On-line access of one's files from anywhere and from any device is the matter of convenience. Cloud storage provides this convenience at cheaper rate with ease of use. Some popular Cloud storage services are described in Table 1.

Dropbox is currently the leader of cloud storage provider. If user needs to sync, it should choose Dropbox [24]. If user requirement is free storage, then user should choose SkyDrive [25]. Apple's iCloud is a better solution for people with an iPhone and Mac since its features are exclusive to iOS and Mac customers [26]. If user wants to play music, then Cloud Drive is the best choice at reasonable price. But iOS, iPhone or iPad devices do not support Adobe Flash, so their users cannot access Cloud Drive [27]. Google lacks one unified cloud service. Users store photos using Picasa. Gmail is used for e-mail, Music Beta is for online music storage and Google Docs for documents. If user is having account with Google Apps then Google drive is a better option on the space front [28]. SugarSync [29] is an established cloud backup service. It is posing tough competition to Dropbox.

TABLE I
POPULAR CLOUD STORAGE SERVICES

Service Provider	Service Name	Free Storage	Availability	Devices	Platform	Supported fie type and size	Other Features
Dropbox	Dropbox	2 GB + extendable to 18GB through referrals	Everywhere	iPhone, iPad, Android, BlackBerry and any device with web browser	Windows, Mac, iOS, Linux	Any digital File (unlimited)	File versioning, auto sync, folder sharing, built-in audio player in web interface, off-line access through mobile apps, trash folder for deleted files
Apple	iCloud	5 GB	Everywhere	PC, iPhone, iPad, iPod	iOS, Mac	Any digital File (unlimited)	Exclusive to iOS
Amazon	Cloud Drive	5 GB	Everywhere except its Cloudplayer	All devices compatible with Adobe Flash	Windows, Linux, Mac	Any digital File (unlimited)	Cloud player music-streaming system is available only in US
Microsoft's Windows Live service	SkyDrive	7 GB	Everywhere	iPhone, iPad, tablet, Any device with Browser,	Windows PC, Windows Phone, iOS, Mac	Any digital file (2GB Max Size)	Suite of web apps for creating and editing Word documents, PowerPoint presentations and Excel spreadsheets.
Google	GoogleDrive	5 GB	Everywhere but Music Beta In US only	Any device with Browser, android device	iOS, Mac, Windows, Linux,	Any digital file (10 GB Max size)	1 GB free for Google Docs, 1 GB for Picasa, 7 GB for Gmail; Share and collaborate, 2-step verification, off-line access through mobile apps, trash folder for deleted files
Sugarsync	Sugarsync	5 GB + Unlimited bonus space for referrals.	Everywhere	iPhone, BlackBerry, Android device, Windows Mobile and Symbian mobile phones, Any device with web browser.	XP, Vista and 7, Mac, iOS, Linux.	Any Digital file (unlimited)	Sync files on multiple locations, streaming music, album sharing, backup, storage

VII. CONCERNS AND CHALLENGES

Adoption of Cloud storage is not easy. Users have some myths and fears in their minds which act as barriers to its adoption. Clients want full guarantee for their data which should be available all the time from anywhere. Reliability is the major concern as no one wants to save data to a system that can fail anytime. Replication techniques are used for better availability as companies can not progress unless they provide reliable storage.

Speed of network is very slow especially in developing countries. All replicas of data cannot be updated simultaneously due to distributed nature of the cloud. Such delay makes it unsuitable for some applications involving transactional data. So, Cloud storage is more suitable for data with a higher tolerance for delay.

Data ownership is another issue which works as deterrent for some organizations as it is not easy to give control of one's own data to a third party. Companies should sign Service Level Agreements (SLAs) with the cloud storage provider. SLAs should clearly state terms and conditions about the usage and ownership of data. Even ordinary users of cloud storage should carefully study vendor agreements and their terms of services before deciding which data should be stored in the cloud storage.

Security is another major concern for clients and companies. Disgruntled employees, back door entry by hackers through networks, corporate espionage, stealing of physical machines are the main security breaches. The consumerization of IT provides more productivity, greater flexibility and lesser turnaround time at the cost of security. Consumer devices are not adequately protected against malware and they can be stolen or lost easily. Hence, data becomes more vulnerable to theft or accidental loss. Data related to different customers also resides in the same server. So, there should be a secure and strong mechanism to isolate storage of various customers. Encryption, authentication and multiple-level authorization practices are used to secure the data on the cloud. Big companies are investing a lot of money in securing their data centres.

Storage professionals are not skilled in the latest technologies. It is not easy to have understanding of storage hardware or file system on which data will reside in the cloud storage. Users may get 'locked in' to one provider and it will be difficult for them to move from one cloud to the other as all cloud providers use different technologies and different standards. Failures of a cloud provider or vendor may affect its users adversely. Users may lose their important data. So, it is better to opt for established vendors. Some fears that it may give rise to "IT Dictatorship" regime.

Thin provisioning, snapshots, remote replication, standard SCSI/ POSIX semantics are the few basic capabilities required for cloud storage. So, legacy applications are not able to fully utilize the cloud storage. Cloud storage providers need to provide standardised access of data. Cloud Computing Interoperability Forum is trying to address vendor lock-in issue. Storage Networking Industry Association (SNIA) and the Open Grid Forum have created a working group to standardize an interface which is vendor neutral and provides standard API for cloud Storage. This will allow customers to move their data from one cloud vendor to another. Cloud storage is in its evolving stage. Its benefits will certainly outweigh the challenges in times to come [30].

VIII. CONCLUSIONS

Personal Computing brought a revolution in the IT industry. It replaced mainframe systems and minicomputers with home computers for personal computing needs. Cloud Computing is taking it back to big data centres where computing is treated as a utility service. Storage always plays an important role for all types of computing needs. Storage devices have already come a long way from punched cards to Cloud storage. Cloud storage has the capability to change the whole storage and data backup scenario. It is the future storage. It will redefine the way we think and use storage by overcoming all concerns and challenges.

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