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# A Critical Review and Comparison of Cloud Storage Providers

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**Abstract**
Individuals these days want to store their personal data in a place where they can access the data anytime, from anywhere and from any electronic gadget like PC, tablet, phone etc. They also want a reliable storage which provides synchronization, backup facilities. Also, enterprises are in need of a storage service provider to relieve them from the establishment and maintenance problems of storage servers and networks. The major advantage of using cloud storage services is that at any instant of time, the storage requirements can be changed according to the user requirements hence saving cost. This paper is focused on introducing the basics of cloud computing, and the challenges that need to be encountered in providing cloud storage services. Some of the major commercial cloud storage providers like Amazon, Google, Dropbox, Microsoft and Apple have been discussed. A critical review has been performed and a comparison table has been framed comparing the major features of the selected commercial cloud storage providers.

**Keywords:** Cloud Storage, Amazon S3, Google Drive, Dropbox, Microsoft OneDrive, Apple iCloud.

## Introduction to Cloud Computing

Cloud computing can be termed as the infrastructure maintained by the third party that provides online services to the user in such a way as to reduce establishment and operational costs. For example, applications may be provided online to the users. Cloud computing allows application's proprietary to easily maintain their services, updates, licenses, contracts etc online through third party cloud providers. This allows user to exploit the services anywhere, anytime with ease once he/she is online. The society of cloud users is increasing, as large number of enterprises is raising their interest to avail applications, environment support, hardware resources etc available on cloud which provides practically maintenance-free services. The cloud has turned into a practically exclusive option for customary innovations, uprooting subsisting advancements, and foreseeing incipient abilities into business situations.

Fig. 1. depicts the general architecture of the cloud at its highest abstraction level [1]. It consists of the following components;

*Client-side platform* – This enables user to access cloud storage. It may be a thin client, PC, hand-held device etc.

*Back end platforms* – These are the ones which provide cloud computing services like servers, storage etc

*Network* – This may be Internet, Intranet etc.

The service provider is the third party who establishes the infrastructure necessary to maintain a cloud and is the one that hosts applications and services. The companies that want to provide online services to their users pay to the third party to host their services on the cloud. The users who are interested in using those services make up a contractual agreement with the service providers to use the services online. This relieves user from the hectics of purchasing, installing, maintaining, updating and troubleshooting the applications. Cloud computing has the capability of handling users with both massive and lenient usage of services.


**Fig.1. High-level Cloud Architecture**
***Courtesy: en.wikipedia.org***

In the field of cloud computing the term *service* is depicted as anything that is provided for use by the user like operating system, editors, compilers, storage, processing power etc. In this regard the services provided by the cloud can be categorized into three types [2].

*HAAS* (*H*ardware *a*s *a S*ervice) or *IAAS* (*I*nfrastructure *a*s *a S*ervice) – This is the model that provides hardware resources such as processing power, memory, storage space and other hardware equipment as service to the users.

*PAAS* (*P*latform *a*s *a S*ervice) – This is the model that provides the environment to support online development of applications as a service. From the initiation of application design to its testing and deployment, all the necessary tools are provided as services.

*SAAS* (*S*oftware *a*s *a S*ervice) – This is the model that allows a software application to be provided as a service to the user. Examples include editors, browsers, data converters, accounting tools, analytics tools etc.

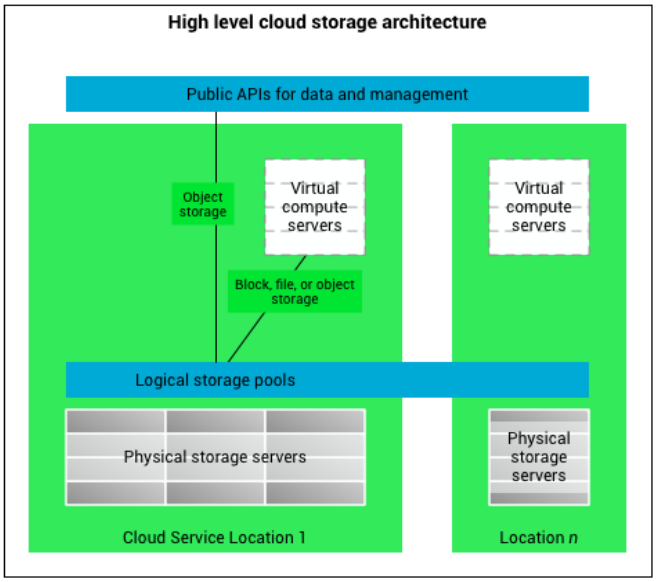


**Fig.2. High-level Cloud Storage Architecture**
***Courtesy: en.wikipedia.org***

## Cloud Storage

Ours has become an information-related society. Hardware and technology as being vastly and cheaply available, has paved way to the proposal of everyone documenting everything that happens in this world. Also, the development of efficient knowledge extraction techniques from the data has been inspirational for the government as well as private enterprises to store their data. Most of the companies generate huge amounts of data as their operations are computerized and data of all the years has to be stored safely thus generating the need for large storage space. Also, government and industry regulations are requiring much larger amounts of data to be stored than ever before for data integrity, compliance and to protect against costly outages.

Also, due to the vast availability of real-time applications and technologies, general users these days accumulate vast amounts of data like conversation history, documents, e-mails, movies, songs, photo albums etc. Now-a-days users taking storage for granted do not want to delete their data and as time goes on user's collection of data increases exponentially thus creating dramatic need for large storage space. Thus need for data storage continues to escalate as users try to manage an explosion of data. This is happening for many reasons, but namely an influx of new technologies and applications are creating a data-rich society.

When data is stored on local sites, users or enterprises have to handle varying problems like increasing their storage space from time-to-time, establishing and maintaining storage servers and networks, IRM tasks, taking measures against data loss, recovering data when necessary, updating to best practices and standards, providing security etc. Also, to access data from other sites or to share huge amounts of data with others, physical storage devices have to be carried between places.

Thus has popularized the disk space storage provided as a service by the cloud computing infrastructure. This service is more popularly termed as *cloud storage*. Any user who has access to web can easily upload, download, store and access even large data through the interface provided by the storage vendors. Cloud storage service along with facility for storing data on vendor's servers also provides other features like data protection, reduced data loss, data shareability, data synchronization etc. Cloud storage allows large data to be shared among geographically isolated individuals or team members easily and quickly. The major advantage of cloud storage is that is cost effective for small to medium business applications and individuals who cannot afford to establish and maintain their own storage servers.

This survey is intended to review the basic concepts of cloud storage and service providers dominant in commercial market. Providing disk space as a service is part of IAAS model in cloud computing. Cloud storage is different from DAAS (Database as a Service) as DAAS apart from storage also provides support to search or query the database. Fig. 2. shows the general architecture of the cloud storage.

## Challenges of Cloud Storage

Agility, integrity, flexibility, scalability, elasticity, security, billability, security and multi-tenancy have been declared to be the inherent characteristics of any cloud storage facility. For continued provision of the declared benefits the technology, applications, tools, processes, methods and practices involved in providing cloud storage must be kept in continuous progression. This leads to a new set of challenges to be handled by the cloud storage vendors [3]. Some of them are discussed below.

- ✓ **Performance** – The user data is maintained on cloud storage servers world-wide and user is allowed to access the same from any location in the world. The number of users thriving to avail the storage facilities is ever increasing. Thus the performance of the storage servers needs to be taken care of to keep users from migrating to other vendors.
- ✓ **Security and Sensitivity** – As users handover their data to the third-party vendor, it is the responsibility of the vendor to provide security from unauthorized

access and also has to promise to keep in mind the sensitivity of the data when it is needed to legally hand it over to other regulatory departments.

- ✓ **Data Integrity** – As data is replicated on cloud storage servers distributed world-wide, maintaining integrity of the user data is the responsibility of the vendors. Also, it is the responsibility of the cloud storage vendor to provide accessibility and availability of the data to the user at all times.
- ✓ **Capacity Management** – Updating the cloud storage infrastructure through time should not impact the performance of the system as per the contractual agreements with the user.
- ✓ **Unstructured Data** – With the increase in the advent of new technologies and applications is increasing the type and complexity of the unstructured data. The capabilities and implementations of the cloud storage infrastructure need to be checked constantly.
- ✓ **Storage Costs** – The increase in benefits provided to the users should not adversely affect the cost payable by the user.

**Cloud Storage Providers**

Many cloud storage providers have come up in the past decade and have been competing to keep up the pace with the worldly requirements [4], [5]. Some of the major cloud storage vendors who stood strong in the commercial market are discussed in the following sections.

***A. Amazon***

Amazon launched S3 (**S**imple **S**torage **S**ervice) to offer public cloud storage in March 2006 in US [6]. S3 provides hosting of static web sites, file storage and synchronization systems. CloudFront developed by Amazon, works in integration with S3 provides content delivery web service and is efficient in distributing audio, video, documents etc to users. S3 offers unlimited storage space and users can access the storage through simple web-based interfaces REST-style HTTP, SOAP, BitTorrent.

S3 supports object-based storage architecture. Data files are managed in the form of objects where objects of each user are maintained as a bucket. Each object in a bucket is identified using unique user-assigned key. The maximum size of each data object is limited to 5TB with each object supported with metadata of size 2KB.

S3 offers 3 types of storage options - Standard Storage, RRS, Glacier. In standard storage option, S3 will decide on which servers the replicated copies of the data will be stored. Instead user can choose AWS (Amazon Web Services) region where the data has to be stored to avail the benefits of optimized latency, minimized costs and to ensure regulations if any. Reduced Redundancy Storage (RRS) is another storage facility provided by Amazon for community of people who would like to compromise the reliability (by reducing the redundancy levels) of the data to reduce storage costs. This storage facility is suitable for storing routine and non-critical data. Amazon Glacier launched in August 2012, is online backup service which is much cheaper than S3, but user has to bear with data retrieval times of 3 to 5 hours. This storage option is suitable for backup of data rarely used. Amazon launched GovCloud in 2011 specifically to cater needs of government agencies in U.S. Security framework of GovCloud is designed keeping in view the confidentiality and authenticity requirements of the governmental data.

Object versioning facility is available enabling users to recover previous versions of the objects when necessary. Users can share their data with others by creating an authenticated URL valid for fixed amount of time using Amazon AWS Authentication tools. S3 has event notification system to notify upload events to the user using Amazon SQS or SNS or AWS Lambda.

S3's authentication mechanism uses 4 levels of access control mechanisms - query string authentication, bucket policies, AWS Identity and Access Management (IAM), Access Control Lists (ACLs).

While transiting data, S3 supports encryption and decryption of data via SSL-encrypted endpoints and https protocol. If needed server-side encryption can be chosen by user, in which case Amazon encrypts the data using its keys and stores the encrypted data on the server. Amazon provides three different ways to manage keys for encryption.

- SSE with Amazon S3 Key Management (SSE-S3)
- SSE with Customer-Provided Keys (SSE-C)
- SSE with AWS KMS (SSE-KMS**)**

This ensures that user's data is given maximal protection. For achieving higher levels of security, user can choose to go with client-side encryption so that the data can be encrypted on local system before transferring it to storage server. This allows storing encrypted data on the storage servers rather than storing open data to ensure that not even Amazon can see what is stored on their servers. Amazon's client encryption library is available for the purpose.

Amazon S3 follows SLA to ensure accessibility and availability of data to users at all times. Amazon S3 guarantees 99.99% and 99.999999999% of availability and durability of user data over a year. Not providing native bandwidth limiting may cause users to pay unwanted bills. This can become one of the major disadvantages of S3 in near future.

S3 offers 5 GB free storage on standard storage facility. Larger storage space can be acquired at the price varying from $0.01/GB-month to $0.03/GB-month depending upon the type of storage and storage space used. The prices of data request or retrieval vary from $0.004 to $0.05 based on the type and number of requests, geographical location. Price for transferring data from one location to another ranges from $0.05/GB to $0.09/GB depending upon size of data transferred out to Internet. All inward data transfers are free. Using storage on Amazon Glacier costs approximately $0.01/GB-month.

As of today, there are many enterprises that use Amazon S3 to host their services. Some of them are Dropbox, Tumblr, Stardust@Home project of NASA, Bitcasa, Minecraft etc.

***B. Google***

Google has launched Google Drive in May 2012 and as on October 2014 is serving approximately 240 million users and

is available in 68 languages [7]. Google claims the main features of its cloud storage system as interoperability, consistency, access control and resumable data uploads. Google Drive supports object-based architecture, thus considering each user file as an object.

The maximum object size is 5 TB where the images if any embedded in the object should not exceed 2MB each. User files of size up to 5 TB can be viewed and edited online. Each user's objects are maintained as a bucket, assigning each object in the bucket a unique key for identification. Such buckets are HTTP URL addressable, thus supporting owner to share links in the process of sharing data with others. Owner of the object has to apply Google account-based ACLs and then timed-URL has to be sent to the ones with whom he wants to share the data object. Google maintains different versions of the objects and buckets thus providing object versioning ability. User can access the data stored on Google Drive via RESTful API.

Google Drive uses partial object level replication and CRC-based technique for integrity checking. It has developed OAuth 2.0 for the purpose of authenticating the users. Browser-based authentication is supported to allow individual Google account holders to download their data.

Google Drive provides 15GB of free storage space for all the Google account holders. Google provides 3 types of storages to facilitate varying requirements of users - Standard Storage, Durable Reduced Availability (DRA) Storage, and Nearline Storage. These storages vary in their levels of data redundancy, data availability and service capabilities. The pricing list is as follows. Data storage charges for Standard Storage option is 0.026$/GB-month, for DRA is 0.02$/GB-month and for Nearline Storage is 0.01$/GB-month. Data retrieval prices vary from 0.01$ to 0.23$ depending upon size of data accessed, type of network (ingress or egress), geographical region, type of operation (class A, B and free) and destination.

### *C. Dropbox*

Dropbox has launched its personal file storage service in September 2008, Dropbox for Business and Mailbox in 2013 and Carousel in April 2014 [8]. It launched an application for windows mobiles on January 2015 in collaboration with Microsoft. With this application, users can communicate with Dropbox and manage their files directly from their smart phones. Dropbox badge feature brings collaboration tools to MS Office desktop applications. This allows users online viewing and editing of their documents.

Dropbox has proudly announced that its services are currently used in 97 % of Fortune 500 companies and over 300 thousand applications are built over Dropbox platform with integrations including Rackspace, Microsoft Azure, Facebook, HP, Yahoo, Adobe EchoSign, etc.

Currently Dropbox does not have its own establishment of cloud storage system and is relying on Amazon EC2 and S3 storage servers for the purpose. Dropbox as of now is supported in 16 different languages. As per its official announcement in February 2015, it is serving 400 million wireless users in partnership with Vodafone. It is handling the traffic generated by 200 million users trying to store 1 billion files per day [9].

Users can store data objects of maximum size 4MB. Users can also store larger files; Dropbox system will divide them into 4MB chunks before storing them for convenience of data management. Each object is accompanied with a SHA256 hash value stored as part of metadata which uniquely identifies the object. Users can access data through https by default. The shareable link management facility is provided since February 2014 over Android and iOS.

The following are the major features of the cloud storage system provided by Dropbox. It uses delta encoding to compress the data through the transit over network. It uses AES-256 bit encryption and two-step verification for providing security of data through transit and storage. It allows user to control data transfer speeds as per their requirements. It maintains synchronization of user files across multiple devices. Dropbox supports multi-user version control. Dropbox tracks versions of data files and history is maintained for 30 days for free of cost. Higher time periods of version maintenance can be availed by purchasing Pack-Rat.

Dropbox provides 3 types of storages; Dropbox Basic, Dropbox Pro and Dropbox for Business. Dropbox Basic offers 2GB free space. To cater users with need for higher storage space, Dropbox Pro offers 1TB space at 9.99$/month, Dropbox for Business offers unlimited space at 15$/user-month. Special features of Dropbox for Business includes the ability to prevent file sharing outside of the team, track logins, devices and locations, remote wipe, and SSO and active directory support.

### *D. Microsoft*

Microsoft launched its file hosting service named as Windows Live Folders or SkyDrive in August, 2007 which has been rebranded as OneDrive in February 2014 [10]. Windows 8, 8.1 and Microsoft Office 2010 come with integrated OneDrive. It is basically designed to allow users to backup, synchronize data among multiple devices and share data with others. Microsoft's PhotoDNA scanning tool automatically scans all the uploaded photos to avoid illegal activities.

OneDrive supports widespread number of platforms. It is the only one that has a native client for Windows PC and Mac, and has native applications for Android, iOS, Windows Phone. The OneDrive client application can also be used on Xbox. By installing OneDrive application on their mobiles, users can choose automatic upload of photos to their OneDrive account as and when they take photos. The technique of video transcoding, allows efficient media streaming.

User is given capability of choosing which files have to be maintained offline and which have to be maintained online. This is achieved through the technique of Smart Files to synchronize metadata and hierarchy of the files instead of synchronizing actual files. This leads to optimization of memory occupancy.

OneDrive limits data access to users by maintaining access control list specified by the owner of the data. Office 365 has developed its security frameworks compatible with ISO 27001 standards. This allows all the users using OneDrive via Office 365 to have high security for their data.

| Name | Amazon S3 | Google Drive | Dropbox | Microsoft OneDrive | Apple iCloud |
|---|---|---|---|---|---|
| Launched in | Mar 2006 | April 2012 (replacement of Google Docs) | Sep 2008 | Aug 2007 | Oct 2011 |
| Programmed in Language | ? | ? | Python, GO, Frontend in CoffeeScript | HTML5 Technologies | SproutCore Javascript framework |
| Available in Languages | English | 68 | 16 | 107 languages | Multi-lingual |
| Clients Supported | Mac, Winrdows, Linux, iPhone/iPad, Android and BlackBerry | Windows, Mac, Android, OS X and iOS | Windows, Mac, Linux, Android, iOS, Blackberry, Kindle Fire | Windows (Vista and later), Windows Phone, Mac, Android, OS X (Lion and later), iOS, Xbox, Blackberry | Windows (7 and later), Mac, iOS (5 and later), OS X (Lion 10.7.5 and later) |
| Free Storage | 5 GB | 15 GB | 2 GB<br>Extra space can be earned | 15 GB, (1 TB free for Office 365 subscribers, Extra space can be earned by referring) | 5 GB |
| Access Data via | REST-style HTTP, SOAP, BitTorrent | RESTful API | Web interface and client app | OneDrive REST interface and sync client | Web interface and client app |
| Maximum File Size | 5 TB | 5 TB | 10 GB if uploaded through web browser; None with usage of client application | Files up to 300 MB can be uploaded via drag and drop into the web browser and up to 10 GB via the OneDrive desktop application for Microsoft Windows and OS | 15 GB |

? – Information not clear/not known

Fig. 3. Comparison of Commercial Cloud Storage Providers

| Name | Amazon S3 | Google Drive | Dropbox | Microsoft OneDrive | Apple iCloud |
|---|---|---|---|---|---|
| **Media Streaming** | Yes, through CloudFront | Yes, through Google Drive Video Player | Yes, one item at a time (through HTTP Live Streaming (HLS) protocol) | Yes | Yes |
| **Online viewing, editing etc** | Supports viewing, not editing | Yes, files up to 5TB size and of 30 different kinds can be viewed and edited up in web browser, can only view MS Office documents | Can view common files, but need third-party apps for editing | Yes, in web browser Since Wave 4 update in Jun 2010 ( all office documents, JavaScript, CSS, HTML, C#, PHP, Ruby, Python , .sql, mp4, wmv etc) | Yes, in web browser through iWork client application since 2013 |
| **Sync while editing files** | As and when user saves the changes | Instant | As and when user saves the changes | Instant | Yes, Pages, Numbers, and Keynote upload files to iCloud instantaneously, other apps upload files as and when user saves the changes |
| **Sync entire file or only changes** | ? | Entire file | Only changed portions of the file using delta uploading | Entire file | ? |
| **Multiple Folder Sync** | ? | No | No | Yes | No |
| **Sync between Multiple Devices** | Yes | Yes | Yes | Yes | Yes |
| **Data Sharing** | Yes, through use ofAWS Authentication Tools | Yes, through use of ACLs and shareable links | Yes, since Feb 2015 on Android, iOS | Yes, through use of shareable links | Yes ( photos, music, and games can be instantly shared by linking accounts via AirDrop wireless, but no support for document sharing) |

Fig .3. Comparison of Commercial Cloud Storage Providers (continued…)

| Name | Amazon S3 | Google Drive | Dropbox | Microsoft OneDrive | Apple iCloud |
|---|---|---|---|---|---|
| **File Collaboration** | Yes, through CloudPointe Amazon S3 Connector | Yes | Yes | Yes | No |
| **Data security** | Through transit ( using SSL-encrypted endpoints using https protocol) and storage | Only through transit using AES-128 bit encryption, not encrypted on storage because that will restrict file view on web | Both in transit and storage using AES-256 bit encryption and 2-step verification | Only through transit using AES-256 bit encryption | Both in transit and storage using AES-128 bit encryption |
| **Password Protection for Files** | ? | No | No | No | No |
| **Data Replication** | Full | Partial | ? | ? | ? |
| **User control over data transfer speed** | No, Amazon S3 controls the speed and bandwidth | No, Limited by Google | Yes, depending on free/paid | No | Yes, depending on free/paid |
| **Resumable data transfers** | Yes | Yes | Yes | Yes | ? |
| **Client-side Encryption** | Yes, through Amazon client encryption library, using AWS KMS–Managed Customer Master Key (CMK) or Client-side Master Key | No native support, can use third-party apps | No native support, can use third-party apps | Yes, through Office 2007 file, and security settings | No native support, can use third-party apps |
| **Data Redundancy Control** | Yes, through RRS facility | Yes through DRA storage facility | Yes | ? | ? |

Fig. 3. Comparison of Commercial Cloud Storage Providers (continued ….)

Microsoft claims data availability of 99.9% with a financially backed Service Level Agreement. Microsoft offers 2 kinds of storage facilities – OneDrive and OneDrive for Business. The tariff plan details for OneDrive storage facilities are as follows. For personal storage, users get 15 GB of free storage. Higher storage space of 100 GB, 200 GB and 1 TB can be purchased at $1.99, $3.99 and $6.99 per month. OneDrive for Business option provides 1 TB of storage space for each user. Some of the beneficial features of OneDrive are efficient auditing and reporting, single sign on (SSO), ADFS, data loss prevention capabilities, regulation security compliance and advanced administration controls.

*E. Apple*

Apple Inc. has stepped into the list of cloud storage service providers by launching iCloud Drive on October, 2011 [11]. As on July, 2013 Apple has attracted 320 million users. iCloud stood as replacement for iTools, .Mac and MobileMe services launched by Apple for data synchronization support on Apple devices. Users can store files of varying formats like applications, media, documents, favorites, notifications, calendar, contacts etc.

All the users using iOS devices can avail the online backup and restore facility to maintain their device status through crashes. Features like Find My iPhone, Find My Friends allows to remotely access their other iOS devices and to keep in touch with friend's whereabouts respectively.iCloud Keychain application allows user to store all the confidential data on his local device securely using 256-bit AES encryption. iWork application allows user to create and edit documents online through a supporting web browser. Users can enable 2-step verification on their Apple devices to opt for high security. iCloud's file hosting service called as iCloud Drive supports operating systems iOS 8, OS X Yosemite (version 10.10), Windows 7 or later. Users can store their data in the form of Pages, Numbers, Keynote, or in any other file format. Multiple device synchronization is supported.

Free storage space of 5 GB is given to the user on creating an account on iCloud.com. Through paid plans iCloud allows user to choose storage space of 20 GB, 200 GB, 500 GB, or 1 TB according to his requirements. At any time it is possible to either upgrade/downgrade the plan with the varying requirements. Monthly pricing varies from $0.99 to $19.99 with respect to the storage space and geographical region.

**Comparison of Cloud Storage Providers**

Fig. 3. shows the critical comparison of the features of commercial cloud storage providers Amazon, Google, Dropbox, Microsoft and Apple. Clarification on some of the features is given below.

**Multiple folder sync:** Synchronization allowed to multiple folders instead of a single primary folder.

**Sync between Multiple Devices:** The file/folder which needs to be synchronized may exist on multiple devices.

**File Collaboration:** Multiple members can co-edit the same file at the same time.

**Password-protected files:** Links sent to others for sharing data can be password-protected or can't.

**Client-side Encryption:** The ability to store encrypted files on the cloud storage servers.

**Conclusion**

No particular cloud storage provider can be concluded as the best. User has to choose cloud storage provider based on the storage space required, type of content, features provided, access frequency and cost. As for now, the following conclusions can be made.

Google Drive is best for web applications. Dropbox provides seamless synchronization. Microsoft OneDrive is best for Windows/Office integration free space, Apple iCloud is best for heavy iTunes/Mac users and for instant camera uploads.

Google Drive and OneDrive offer more customization whereas Google Drive supports more file types. Dropbox offers easy file sharing and is suitable for HTC, Blackberry and Linux devices. Apple iCloud is weak for platforms other than idevices and Mac. Microsoft OneDrive is highly suitable for windows users.

Various companies like SugarSync, Copy, Mega, Yahoo, HP, Nirvanix, NetApp, Symantec, HDS etc are offering competing cloud storage services in the market. Cloud storage solutions are becoming more and more alluring alongside with their decreasing price and increasing performance thus becoming the principal means of storing data offsite. Over long haul, cloud storage will be more acceptable by network administrators, albeit most see the innovation as a supplement to classical storages.

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