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Cloud Computing: Its History of Development, Modern State, and Future Considerations

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Abstract—In this article, the author describes the history of the development, modern state, and future considerations of cloud (diffused) computing as one of the modern innovative technologies. The models of cloud computing and its advantages and disadvantages are analyzed. A number of cloud operating systems, cloud computing vendors, and the capabilities of their platforms are considered.

Keywords: public cloud, innovative technology, cloud computing, information technology, community cloud, cloud data processing, operating system, private cloud

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Over the last decade, the rapid penetration of the Internet and modern information technologies into all spheres of society and individuals' lives has led to a sharp increase in Internet users: in 2011, their number exceeded 2 billion in the world and in Russia this figure is 50 million. In this case, a number of studies have noted [1] that in 2005 in Russia the epoch of the so-called Internet-2 began, where many companies and users could not imagine their daily activities without the Internet. These facts also tell us that to increase the efficiency of Russian business it is good to prepare specialists who are well oriented in modern innovative technologies, including connection to the Internet.

Today it is necessary to form and teach the special course "Modern innovative technologies" in Russian higher-educational institutions. In the framework of the course it is desirable to introduce students to cloud computing, semantic technologies, massively parallel computing platforms, modern mobile computing platforms, and the National software platform, as well as to innovative technologies for the public examination of the state's significant decisions [2].

In this article, the author describes the history of development, modern state and future considerations of the first of these modern innovative technologies, viz., cloud computing [3–7].

An increase in the capacities of media and, consequently, a decrease of the cost of 1 MB of stored information have led to a significant decrease of the cost of storage media services along with a significant increase in the volume of stored data. The development of programming technologies led to the efficient use of computing resources of multiprocessor systems and the flexible distribution of cloud-computing capacities. An increase in the data throughput of the Internet contributed to an increase in the data-exchange speed, reduction of the cost of Internet traffic and the greater availability of cloud technologies. All these factors have led to an increase in the competitiveness of cloud computing in various spheres of information technologies [8–13].

Cloud (diffused) computing (or cloud (diffused) data processing) is a technology of data processing where computer resources and capacity are provided to the user as an Internet services. The user has access to their own data, but should not care about the infrastructure, operating system, and software he works with. According to a 2008?IEEE?paper, "cloud computing is a paradigm in which information is permanently stored in servers on the Internet and cached temporarily on clients that include desktop computers, entertainment centers, table computers, notebooks, wall computers, hand-held devices, sensors, and monitors."

The founder of the cloud-computing concept was John McCarthy, who suggested in the 1960s that in the future calculations would be carried out through public utilities.

The ideology of cloud computing gained popularity in 2007, thanks to the rapid development of communication channels and an increase in the geometric progression of the needs of both business and private users to expand their information systems.

The emergence of the term began to be discussed in 2008 at one of the thematic Internet conferences. As a result of these discussions, different versions of cloud computing were proposed. Due to one of these, the term *cloud* was used for the first time by the head of

Google, *Eric Schmidt* and was further disseminated by the mass media.

Today, many companies, for example, Google, actively use the concept of cloud computing. The most typical example is Google Docs, which allows work with office documents.

In July 2008 HP, Intel, and Yahoo! announced the creation of a global open computing laboratory, Cloud Computing Test Bed, which encompassed a variety of platforms for the development of research and technology in the field of cloud computing. This laboratory is a globally distributed Internet environment, which supports research aimed at the development of software, improvement of the management of data centers and the solution of hardware problems that are connected with Internet calculations on a much larger scale than ever before.

The main models of *cloud computing* that are used at the present time are:

- infrastructure as a Service,
- platform as a Service,
- software as a Service,
- data as a Service,
- workplace as a Service.

Infrastructure-as-a-Service (IaaS) is the ability of the consumer to control processing and storage. For example, the consumer is able to deploy and run arbitrary software, which can include operating systems, platforms and applications. The consumer can control operating systems, virtual storage and deployed applications, and have limited control over a set of networking components. The control and management of the main physical and virtual infrastructure of clouds, including the network, servers, types of operating systems, and storage systems are implemented by the cloud provider.

Platform-as-a-Service (PaaS) is a model, where consumers are able to use the cloud infrastructure for the installation of base software in order to use new or previously existing applications (consumer-created, developed on order, or acquired packaged applications). Such platforms include tools for the creation, testing, and implementation of application software, database management systems, middleware, and the programming environment that is given by the cloud provider. The cloud provider performs the control and management of the main physical and virtual infrastructure clouds, including networks, servers, operating systems, and storage, except for developed or installed applications, as well as the configurations of the application hosting environment.

Software-as-a-Service (SaaS) is provided to the consumer in order to use the provider's applications that run on a cloud infrastructure, which are accessible from various client devices through a thin client interface, such as a Web browser (e.g., web-based e-mail). The control and management of the main physical and virtual infrastructure of clouds, including networks, servers, operating systems, storage, or even individual application capabilities (with the exception of limited user-specific application configuration settings) is implemented by the cloud provider.

Workplace-as-a-Service (WaaS) occurs when companies organize work places for employees by installing and configuring the necessary software.

Data-as-a-Service (DaaS) means that users are provided with disk space on which to data store.

The main distinguishing feature of any cloud system is that its resources are not tied to particular dedicated servers.

The National Institute of Standards and Technology (NIST, USA) fixed the following essential characteristics of cloud computing:

- *on-demand self-service*: a consumer independently defines and modifies computing capabilities, such as server time, the speed of data access and processing, and the amount of stored data without requiring human interaction with each service's provider;
- *broad network access*: services are available to customers via a data transmission network independently of the terminal device;
- *resource pooling* means that providers pool computing resources to serve multiple consumers with different physical and virtual resources being dynamically assigned and reassigned according to consumer demand. Consumers only control the basic parameters of services (for example, the volume of data or the access speed), while the actual allocation of resources provided to the consumer is carried out by the provider (in some cases, consumers can still control some of the physical parameters of the redistribution, for example, they can specify a desired data-processing center for reasons of geographic proximity);
- *rapid elasticity*: services can be provided, widened, or narrowed at any time without additional costs to the interaction with the provider and, as a rule, in the automatic mode;
- *measured service*: providers automatically control resource use at some level of abstraction (e.g., the amount of stored data, bandwidth, number of users and the number of transactions) and estimate the volume of provided service users on the basis of these data.

Cloud services can also be categorized by a series of deployment models:

- *private cloud*: the cloud infrastructure is operated solely for an organization, including some consumers (e.g., departments in an organization), possibly, clients and contractors. It may be managed by the organization or a third party and may exist both within and outside the jurisdiction of the owner;
- *public cloud*: the cloud infrastructure is designed for the free use of a wide range of users (the public). A public cloud may be in the ownership, management

and operation of commercial, academic, and government organizations (or any combination of them). It exists within the jurisdiction of the owner, an organization that sells cloud services.

• *community cloud*: the cloud infrastructure is available for use by a user community of organizations that perform general tasks. A community cloud may be in cooperative ownership, management, and operation by one or more of the organizations of the community or by a third party (or any combination of them) and it can also physically exist both within and outside the jurisdiction of the owner;

• *hybrid cloud*: the cloud infrastructure is a composite of two or more clouds (private, community, or public) that remain as unique entities but are bound together by standardized or proprietary technology that enables data and application portability (e.g., cloud bursting for load balancing between clouds).

Advantages that are common to both public and private clouds include:

• *high efficiency* – because both public and private clouds are based on grid computing and virtualization, both offer high efficiency and high utilization due to the sharing of pooled resources, thus enabling better workload balancing across multiple applications;

• *high availability* – another benefit of being based on grid computing is that applications can take advantage of a high availability architecture that minimizes or eliminates planned and unplanned downtime, thus improving user-service levels and business continuity;

• *elastic scalability* – grid computing also provides public and private clouds with elastic scalability, i.e., the ability to add and remove computing capacity on demand. This is a significant benefit for applications with highly variable workload or unpredictable growth, or for temporary applications;

• *fast deployment* – public and private clouds can provide self-service access to a shared pool of computing resources. The software and hardware components are standard and re-usable. Thus, application deployment is greatly accelerated.

Some benefits are unique to public cloud computing:

• *low upfront costs* – public clouds are faster to start; thus, they provide users with a low entry barrier because there is no need to buy, install, and configure hardware;

• *economies of scale* – large public clouds enjoy economies of scale in terms of equipment purchasing power and management efficiencies. In some cases, customers also may have a portion of the savings;

• *simpler to manage* – public clouds do not require IT to manage and administer, update, patch, etc. Users rely on the public cloud service provider instead of an IT department.

• *operating expense* – public clouds are paid out of the operating expense budget, often by the users, not the IT department. Capital expense is avoided, which can be an advantage in some organizations.

Other benefits are unique to private cloud computing:

• *greater control of security, compliance and quality of service* – private clouds enable one to maintain control of security (privacy and data loss), compliance (data handling policies, data retention, regulations governing data location, audit), and quality of service (private clouds can optimize networks in ways that public clouds do not allow);

• *easier integration* – applications that run in private clouds are easier to integrate with other in-house applications;

• *lower total costs* – private clouds may be cheaper over the long term than public clouds, since this is essentially owning versus renting. According to several analyses, the breakeven period is between 2 and 3 years.

The work of clouds is provided by a special operating system (OS), which supports the work with the client based on a network of major data processing and storage centers. All the leading companies of the world that sell to business on computer technologies and the Internet are actively developing its cloud operating systems [14, 15]. For example, in 2011 Google launched the sale of an entire model range of laptops and netbooks under the control of the Google Chrome OS operating system. Apple launched the new iOS 5, which is completely "aimed" at "clouds."

The virtual operating system EyeOS is one of the first cloud OSs. Applications that are integrated in EyeOS allow one to edit documents, watch videos, listen to music, etc. (unfortunately, there is no support for the Russian language).

At the present time the virtual operating system CloudMe (with support of the Russian language) deserves more attention. It allows one to use 3 GB of cloud storage free of charge (volume can be increased up to 100 GB for a fee of about $40 a year). As well, all of the necessary set of applications needed for full use of a virtual machine are available: a graphics editor (for writing and editing of documents), a browser (for Internet access via the virtual OS), a player (for watching movies and listening to music) and many more applications.

The benefits of cloud computing are:

1. *Cheap computers for users*. Users do not need to buy expensive computers with more memory and disk space. Users can switch from conventional PCs and laptops to more compact and convenient notebooks.

2. *It reduces costs and increases the efficiency of the IT infrastructure*. The conventional server of an average company is loaded at a 10–15% level. In some periods there is the need for additional computing resources, in others, these expensive resources are idle. By using the required amount of computing resources

in the cloud, at any time, companies can reduce the cost of equipment and maintenance by up to 50%.

3. *Fewer problems with the service*. Since physical servers are becoming smaller with the introduction of Cloud Computing, they are becoming faster and easier to maintain. On the software side, software is installed, configured, and updated in the cloud.

4. *It is less expensive than the cost of buying software*. Instead of purchasing software packages for each local user, a company buys programs in the cloud. These programs will be used only by the users who need these programs. Moreover, the cost of programs that are designed to access the Internet is much lower than their counterparts for personal computers. If the programs are not often used, they can simply be rented by the hour.

5. *Constant updating of programs*. At any time when a user runs a remote program, one can be sure that this program is the latest version, without the need to reinstall something or an upgrade fee.

6. *The increase in available computing power*. Compared with the PC computing power that is available to a user, a cloud of computers is virtually limited only by the size of the cloud, i.e., the total number of remote servers. Users can run more complex tasks with a large memory and storage space, if necessary.

7. *Unlimited volume of stored data*. Compared with the accessible place for the storage of information on a personal computer, storage in a cloud can flexibly and automatically adjust to a user's needs. When information is stored in a cloud users can forget about the limitations that are imposed by conventional discs; cloud dimensions of billions of gigabytes of free space are available.

8. *It is compatible with most operating systems*. In Cloud Computing operating systems do not play a role. Unix users can share documents with users of Microsoft Windows and vice versa, without any problems. Access to programs and virtual machines use a web browser or other means of access that are installed on any PC with any operating system.

9. *Improved compatibility of document formats*. If users use a single cloud software for creating and editing documents, their are no incompatible versions and formats, as opposed to those who, for example, receive a Word 2007 document and are unable to read it on their computer with Word 2003 or OpenOffice. A good example of interoperability is the office suite Google Docs, which allows collaboration on documents, presentations, and spreadsheets using any computer with a Web browser.

10. *Its easier to work together with a groups of users*. When one works with documents in the cloud is not necessary to send each person their version or sequentially edit them. Users can be confident that they have the latest version of the document and any changes made by one user immediately affect the others.

11. *Economical consumption of resources*. Cloud computing makes it possible to save on electricity, computing resources, and the physical space that is occupied by servers. In this case, if the documents are stored in a cloud they can be available to users anytime and anywhere.

12. *Stability to data loss or theft of equipment*. If data is stored in a cloud copies are automatically distributed across multiple servers, which may be located on different continents. When theft or damage to a personal computer occurs, users do not lose valuable information, as one can obtain it from any other computer.

Cloud computing also has limitations:

1. *Permanent Internet Connection*. Cloud Computing always requires an Internet connection. If there is no Internet access there are no jobs, programs, or documents. This is probably the strongest argument against cloud computing. But to be honest, can a modern person do without the services that are available on the Internet, mobile phones, payment cards, etc.? Many cannot live without e-mail for even 1 day. Therefore, considering the development of the modern world, the Internet will be available at all times and wherever one is, like electricity and water.

2. *Work is difficult under conditions of slow Internet access*. Many of the cloud programs require a good Internet connection with high bandwidth.

3. *Programs may run more slowly than on a local computer*. Some of the programs on which one wants to transfer a significant amount of information will run on a computer faster, not only because of the speed limit of access to the Internet, but also because of congestion on remote servers and problems on the path between the user and the cloud.

4. *Not all programs or their properties are available remotely*. If one compares programs for local use, and their cloud counterparts, the latter still lose in functionality. For example, Google Docs spreadsheet has far fewer features and functions than Microsoft Excel.

5. *The high cost of the equipment*. The creation of a cloud requires significant financial resources.

6. *Software*. The user has access only to cloud software and cannot customize an application to fit his needs.

7. *Privacy and security*. As of now there is no technology for ensuring the absolute confidentiality of data; although a cloud is a fairly reliable system, in the case of a hacker attack an enormous amount of data will be available to those committing unlawful acts.

Although speed and cost are the two main advantages of cloud computing, there are several issues that hold some companies back from transition to clouds. The most important of these is security. Many companies are not rushing to trust confidential information to public clouds, where they will not be able to fully control it. Thus, some particularly confidential appli-

cations will continue to function within a company and others will go to public clouds.

In the classification of cloud providers, two major groups exist: the suppliers of cloud-computing platforms and the suppliers of cloud services that use software from other companies to create various services. The first group of suppliers can be divided into three subgroups: Google, Microsoft, and other large companies (IBM, Apple, Yahoo!, EMC, HP/EDS, Amazon, Facebook, Adobe, etc.). The second group of providers of cloud computing can be divided into the independent service providers that provide services to external customers and the private service providers that service branches, divisions, and affiliated companies.

Let us consider the best-known suppliers that provide access to clouds.

The developers of Microsoft Corporation have proposed the **Azure Services Platform**, which provides four main services: *Windows Azure*, *.NET Services*, *SQL Services (SQL Server in the cloud)*, and *Live frameworks*.

In particular, *Windows Azure* is a platform for scalable hosting of Web applications, whose usage scenarios can be different, e.g., from an Internet-shop to video hosting or the service of scientific and technical tasks. The *.NET Services* solve the problem of linking various services and also perform access control to methods of service and the support business processes. This class of solutions is called the Internet Service Bus (by analogy with the term Enterprise Services Bus).

The **Google App Engine** is a service for the hosting of websites and web applications on Google's servers. The use of the Google accounts service allows one to quickly begin to work with an application without separate account registration on each site. It also allows developers to avoid the implementation of another system for user registration specifically for their application. The *App Engine* platform is closely integrated with applications and imposes some limitations on developers. The *App Engine* requires the mandatory use of the programming languages Python or Java from a developer as well as data storage in their own repository (Datastore).

The **Amazon Web Services**(AWS) has many services, such as data storage (file hosting and a distributed data warehouse), rental of virtual servers, computing power, etc., as well as several services such as *Amazon Elastic Compute Cloud (Amazon EC2)*, *Amazon Simple Storage Service (Amazon S3)*, *Amazon CloudFront*, *Amazon Simple Queue Service (Amazon SQS)*, etc.

The *Amazon Elastic Compute Cloud* (Amazon EC2) is a web service that provides computing power in a cloud. A simple web services interface allows one to obtain access to computing power. It gives users full control over computing resources, as well as an accessible environment in which to work. The service reduces the time that is required to obtain and boot a new server.

The *Amazon Simple Storage Service* (Amazon S3) is an online web service that is offered by Amazon Web Services, which provides the capacity to store and retrieve any amount of data at any time from any point of the network (so-called file hosting). Using Amazon S3 one can achieve high scalability, reliability, high speed, and an inexpensive data-storage infrastructure.

The *Amazon Simple Queue Service* (Amazon SQS) is a message queue service. Using Amazon SQS, developers can simply move the data that is distributed between the different components of their application and perform various tasks without losing their message.

Cloud computing is gradually penetrating into the Russian market. The first commercial SaaS cloud services was the Softcloud project by the Softline Company, which is a Russian software distributor. The technology partner of Softcloud is the Parallels Company, a global developer of software solutions for virtualization and service automation that has Russian roots. The accessibility and security of services are provided by hosting with a distributed network of data centers that are located in Russia, Belarus, European countries, and the USA.

In order to automate the processes of providing of cloud services, Parallels has developed Parallels Automation, a special software package. It automates deployment, updating, and billing applications, enabling service providers to manage SaaS applications and settings and to optimize the installation of patches and updates to proposed products. Parallels have developed a proposal for granting rent on the "1C-Bitrix" virtual machine, which was created on the basis of the technology of Parallels' Virtuozzo Containers. The machine enables companies to simplify the support of their own web sites and Internet shops, as well as social networks.

Today, cloud computing is a large dynamic system that uses various technologies. In 2010, the First International Cloud Computing Congress was held [16].

In Russia, cloud computing is only at the beginning of its development. Therefore, it is important to note the prospects of the development.

1. *Further technological development*. Cloud computing is a new direction of development, a "trend," with incomplete models and technologies. According to most experts, cloud computing is in its initial stages now. Conceptually, these technologies define a new direction for the development of ICT in the coming years.

2. *Standardization*. A technology is in the mature stage when it becomes standardized. At the present time, this is not so. Standardization is desperately necessary for both customers and suppliers and no doubt will be achieved in the coming years. Some experts estimate this period will be 2–3 years, others, up to a decade.

3. *The transformation of a resource to a service*. The emergence of cloud computing is a reflection of global trends on the transition to outsourcing and external services. Thus far, the IT industry has focused on the use of its products by means of the purchase of equipment or the rights to use software. Cloud computing involves the use of the service model of the relationship between the supplier and the consumer. Given that, the transition to a service model is not a feature of the IT market but a global trend; the understanding that not all the resources should owned by the company is coming gradually to the IT industry.

4. *A new model of the relationship between a customer and supplier*. Cloud computing, as a form of outsourcing, actively influences the maturity of the service relationship between the customer and the provider of IT services. Cloud computing has revived the question of how and on what models is it more effective to build relationships between the customer and the provider of IT services. Today, we see an active search for new forms and models of business by suppliers. In the opinion of the experts at Forrester Research, the suppliers of cloud services are in dire need of new business models and ideas. One such idea is Cloud Broker, which is a new layer of suppliers' cloud services. It must provide storage of public cloud services and manage dynamic resource allocation, perform the monitoring and billing of consumed services, and plan and predict the needs of services and their costs, as well as integrating cloud services among themselves and with the traditional enterprise applications of a company.

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