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A Review of Cloud Computing

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Abstract—Cloud computing is one of the methods for distributed data processing and storage. With the use of cloud technology data is processed and stored on the Internet all the time. Data appears on client devices (PCs, notebooks, netbooks, smartphones, etc.) temporarily as needed. The concept of cloud computing is supported by many users, but has received criticism from people who see in this technology the loss of user control over computing processes.

Keywords: cloud computing, grid systems, distributed-data system, information security, cloud services, cloud office suites, economic aspects of cloud services, Internet, reviews

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PRINCIPLES OF CLOUD COMPUTING AND ITS PLACE IN INFORMATION TECHNOLOGY

The term "cloud computing" means computing with the use of the Internet for searching for computational resources and databases. The term "cloud" means a set of Internet resources. There are ten basic principles that define the specific characteristics of cloud computing: a user-centric system, friendliness to users, openness, transparency, interoperability, construction of task representations, division of tasks in accordance with their specifics, evolution, balance, and security [1].

The architecture of cloud computing is based on some important factors, the most significant of which is that users are always able to get the resources they need.

Cloud computing, as well as grid computing, allows solving computing tasks on remote computers. The main differences from common grid systems are in their aims and organizations of work. Grid computing should be used for solving computing tasks requiring large computational resources in parallel on multiple computers. Therefore, the main research area of grid systems is scientific investigation and technical development. In cloud computing, the stress is laid on the independence from a platform and the ability to work with dynamic and scalable databases. The concept of cloud computing makes it possible to choose the best combination of computational capabilities and required cost.

The difference between cloud computing and relational databases is that in the first case, the data is distributed geographically, which leads to transit delays. Therefore, at present it is appropriate to use cloud computing where there are no complex queries.

Cloud computing is efficient from an economic point of view because it allows one not to pay for hardware, software, and its maintenance, and to avoid data storage costs and management. As well, it significantly reduces the time required to build and deploy applications. Cloud computing is particularly suitable for use in small and midsized business.

Cloud computing has gained support from environmentalists, because it increases energy efficiency. According to research by the WSP Company, performed by an order from Salesforce.com, in 2010, the savings via Salesforce.com through the use of a joint information infrastructure was 17900 tons of carbon; this is equivalent to the retirement from service of 37 000 automobiles.

To ensure security (which is particularly important in cloud computing due to its distributed data storage), one can use standard means of protection, which are available to the public.

Another advantage of cloud computing is scalability, which is achieved through the use of virtual servers. Virtualization helps to optimize the use of servers that serve many users simultaneously.

One specific use of cloud computing is the task of organizing data storage. One of the main directions of research and developments in this area is providing the ability of different user data storage in one place so that data changes of one user do not affect the data of all other users.

The management of cloud computing is performed centrally. The central server defines the balance between system capabilities and user needs, controls traffic, and avoids congestion in the network. The protocols of the intermediate level are used to implement these features.

The main models of cloud computing that are used at the present time are [2]:

– IaaS (Infrastructure as a Service).

– PaaS (Platform as a Service).

– DaaS (Data as a Service).
– SaaS (Software as a Service).
– WaaS (Workplace as a Service).
– AaaS (All as a Service).

In all models, customers pay a monthly fee and can stop or suspend payment and renew it at any time.

The best-known online cloud computing applications are Google Apps., Salesforce.com, and Zoho Office. All of these are based on the SaaS model. Access to an application is realized via web browsers; applications are able to support many users simultaneously. It is considered that this model best takes the interests of users and providers into account.

Amazon.com, Sun, and IBM provide memory and computing resources on order.

Web service and APIs allow one to use a cloud completely and create very large applications.

The number of cloud computing providers is increasing rapidly. Thus, new models of services have emerged.

For potential users, one important problem, naturally, is the problem of choosing the best provider. The first criterion of the problem is the reliability of a provider. Very useful information of this question is found in the database of CCID (Cloud Computing Incidents Database, http://wiki.cloudcommunity.org/wiki/CCID). A list of the best providers for various applications can be found on the site: http://www.crn.ru/numbers/spec-numbers/detail.php?ID=39947.

The main factors that prevent widespread cloud computing in business are lack of knowledge and skills of staff and managers fear of losing control over their information and communication technologies, or the problem of information security.

The design of complex, multi-field, and hybrid services for cloud computing is still practically in its conceptual stage. This is under study by leading companies, viz., Microsoft, IBM, Google, and others, but today there are no common directions of the development of this field yet.

As cloud computing allows one to implement complex projects without significant investment, its role in information and computing technologies will grow.

One example of the practically realized usage of cloud computing is the cloud office suite, which has been available on the information services market since 2005. User interests in these products are satisfied by major participants in the information technology market, such as Adobe, Google, Microsoft, Zoho, and many other companies. In [3] an analysis and comparison of their solutions was provided: "In the market of services for storing and editing documents the most comfortable and best in the "price/quality" ratio for the task of placing documents on the Web in order to provide selective access to it for one or more persons are the services from Adobe and Google. The benefits of the first are convenient user interface and reasonable price policy; one issue is the lack of Cyrillic support in the editor. Google provides free cloud service and supports many languages, including Russian, but has problems with format compatibility."

SOURCES OF CLOUD COMPUTING

Cloud computing was the result of merging ideas that were developed in the field of service-oriented architectures, grid computing, providing applications in service mode, etc. These fields were related to the development of new technologies and attempts to expand the market of information technology. Thus, cloud computing is a cross-disciplinary field and includes scientific research and developmental work, as well as market investigation and looking for new applications.

Among technical research on cloud computing, one type is research on virtualization, which is required for the organization of work with heterogeneous resources. Virtualization is the process of granting computing resources that provide some sort of advantage of the original configuration. Virtualization of resources eliminates implementation limitations, geographic location, and physical configuration of the components. Virtualized resources usually include computing capacities and data storage. An example of virtualization is symmetric multiprocessor computer architectures that use more than one processor. Operating systems are usually configured in a way such that multiple processors present themselves as a single processor module. Software applications can be written to a logical (virtual) computer module. It's much easier to work this way than to work with many different processor configurations.

A significant factor in the development of the SaaS model of cloud computing is the occurrence and wide availability of high-speed Internet connections, which provide the possibility of an intensive exchange of data with computers belonging to the cloud.

Web 2.0 technologies allow the performance of functionally complex web applications in browsers and do not load application on local PCs.

Internet services that provide access to data through special program interfaces, allowing one to process data online, appear to be extremely useful as well.

For the PaaS model, its direct predecessors are the distributed computing technologies used, in particular, by Google and Yahoo. When Google decided that these technologies could be made available for mass developers, it released Google App Engine. Salesforce.com, which is based on CRM (Customer relationship management), again developed the Force.com platform, which give potential consumers ample opportunities for the completion of products for the purpose of their adaptation. These possibilities were enough to create completely independent appli-

cations; as a result, Force.com, which should be moved to the class of PaaS platforms, appeared.

Another source of cloud computing is open source software, which began to play a significant role in the early 2000s. As G. Reese said, "the success of Amazon Web Services was possible only thanks to free licenses that do not bind users with unnecessary restrictions and do not require license payments for each processor or for each instance of the software installed" [4].

OPEN-SOURCE CLOUD COMPUTING SYSTEMS

The use of open sources is essential for the proliferation of cloud computing. Closed sources were the main risk in cloud computing: the delegation of authority in the field of information and communication technology makes customers worry about the possible consequences of overly severe conditions of service or providers leaving the market. Programs are not stored on users' computers, and users not only cannot store them, but also are not able to keep them if providers go out of business.

All these factors lead to the situation that while market competition is growing, not only dissolution of proprietary solutions, from which Amazon Web Services, Salesforce.com, and Google started, occurs, but even ordinary software systems with closed sources, where users can obtain a copy of the software and operate it after providers leave the market.

Thus, a common situation in cloud computing is the search for a new compatible service, in case of the loss or failure of a provider. This virtually eliminates the danger of a monopoly in this area.

An additional advantage of open-source software is the inevitable openness of data formats, which makes it easier to transfer data, backup data, and even the transfer of cloud solutions to their own information infrastructure if a company considers that the risk of working with cloud systems is unacceptable.

The first commercially successful open-source platform was the Eucalyptus IaaS-system, which was created during a research project at the University of California (Santa Barbara, USA). This system was still not completely open: some features were only available to those who purchased plug-ins and source codes were not published. In the summer of 2010 the OpenStack project was announced with the aim of increasing the degree of openness of systems. Despite the fact that this project has not yet been fully completed and its features cannot yet compare with Eucalyptus, the popularity of the project has already surpassed the latter. Among the lesser-known open IaaS-systems CloudStack (Cloud.com) and OpenNebula should be noted, although they generally have the same drawbacks as Eucalyptus.

Unlike IaaS systems, in PaaS systems, success in moving to open sources is less noticeable. Only Cloud Foundry by VMware may be noted. This system enables customers to develop scalable applications in their chosen system from a given list. The list includes Spring, Ruby on Rails and Node.js. Effective means of porting an application from platform to platform are implemented. According to VMware Press, Cloud Foundry can work in different environments, from Amazon Web Services to the PC of a developer.

STAGES OF DEVELOPMENT OF CLOUD COMPUTING

According to experts, the development of cloud computing has three logical stages [5].

At the present time, the first stage of cloud computing is coming to an end. This phase began in 2007, when the cloud systems were introduced by companies that took risks to rapidly enter the market and radically improve the effectiveness of their development. Here, cloud computing is used primarily in IT projects with a return on investment in a relatively short term, no more than 2 years.

This phase will have finished when the volume of proposals exceeds the market requirements and the active process of mergers and take-over bids of manufacturing companies begins. This process has already begun; therefore, we can say that the second stage is starting, viz., market consolidation and market entry by more conservative participants, in this case the number of suppliers is becoming reduced due to increased competition. The number of commercial offerings is increasing. At the second stage, the basic part of the projects will be projects with returns on investment of from 3 to 5 years.

It is possible that in 2 or 3 years the third stage, in which cloud computing will achieve mass distribution and become the main line of development of information technology, will start. Then the market will be dominated by a few large companies.

In December of 2010 Microsoft published an annual report on cloud technologies in small and midsize businesses [6]. This report argues that the use of clouds will become one of the main trends of IT development in this sector in the next 3 years. In all, 39% of all companies are going to connect to at least one SaaS-service within 3 years (today these companies are at 29%).

The number of such decisions will nearly double in most countries over the next 3 years. The transition to cloud computing will occur gradually; some time small and midsize companies will use a hybrid model of traditional and cloud IT solutions. The authors believe that cloud providers will make a profit from these teamwork services.

Perhaps these estimates are too optimistic and reflect the pattern of development of the IT market only in countries where cloud computing has started

Cloud computing standardization

Organization	URL	Sphere of activity
Cloud Security Alliance	http://cloudsecurityalliance.org/	Security standards in cloud computing
Cloud Standards Customer Council	http://www.cloudstandardscustomer-council.org	Security standards on behalf of users
Distributed Management Task Force (DTMF)	http://www.dmft.org/standards/cloud	Standards of corporate and cloud computing resources
IEEE	http://standards.ieee.org	Standards of interoperability and implementation of cloud systems
National Institute of Standards and Technology (NIST)	http://www.nits.gov/itl/cloud	Definition of cloud computing; requirements for the use of cloud computing in the public sector in the USA
OASIS	http://www.oasis-open.org	Updating of WS*, SAML, XACML, and KMIP standards for cloud computing
Open Cloud Consortium (OCC)	http://opencloudconsortium.org/	Standards of cloud computing and its compatibility
Storage Networking Industry Association (SNIA)	http://www.sina.org/cloud	Cloud Data Management Interface (CDMI)
Working Group on Cloud Computing in the Open Group Organization	http://www.opengroup.org/cloudcomputing/	Standard models aimed at eliminating provider lock-in

to be used throughout big business and government agencies, such as in the USA and the UK.

The report in [6] noted that 82% of the respondents from 3258 companies that employ up to 250 employees across 16 countries worldwide said that buying cloud services from a provider with a local presence was critical or important.

PREDICTIONS OF MODELS FOR DELIVERING CLOUD SERVICES

Like many other new areas, the division into models is associated with the early stage of development, lack of common approaches, and the existence of many developers who do not even have knowledge of the work of their colleagues.

The above classification of models for providing cloud services is also not the only one and some experts use other divisions. In particular, Dell, which has recently introduced its own strategy for the development of cloud computing, prefers its own classification based on the specifics of its own solutions: "Compute as a Service," "Storage as a Service," and "Virtual Desktop as a Service." There are also models that are associated with rental services: "Hardware as a Service" and "Infrastructure as a Service," which indicates that the framework of cloud computing is not strictly defined yet.

We can expect that the division of cloud computing into IaaS, PaaS, and SaaS models will become a thing of the past in the near future. This is shown by a noticeable blurring of the lines between IaaS and PaaS models: in particular, such well-known products as Windows Azure or Amazon Web Services cannot be clearly attributed to one of these models. Naturally, it is too early to say what will replace them. Experts propose a variety of scenarios. The most popular prediction is the concept of "Everything as a Service."

Most recently, high expectations are held for iCloud, a free service, which was announced by Apple. According to some reports, this service may become the most widely used cloud computing service [7]. Today, the service is available in beta mode and for developers only. For users, iCloud will be opened in the autumn. According to its developers, iCloud stores user content and delivers it to all user devices using the Push wireless technology [8].

DEVELOPMENT OF STANDARDS FOR CLOUD SERVICES

The development of a certain IT area requires an exact description of its borders, in particular, the development of standards and the establishment of generally accepted terms. Experience shows that in information and communication technologies attempts to create standards begin approximately 3 years after the birth of a new technology. For cloud computing, such works have already started. The development of standards is occurring in many organizations. The organizations and the directions of their activity are listed in the table.

While it is difficult to judge how quickly standards and generally accepted terminology will prevail, further limited success in this area will be useful to coor-

dinate the efforts of developers, identify the most promising cloud computing technologies, etc.

The most important and serious initiative in the field of standardization of cloud computing is the IEEE initiative, which began two projects on cloud standards. The first standard, IEEE P2301, is associated with the specifications for creating interoperable cloud systems, and the second, IEEE P2302, contains basic information and recommendations to ensure the interoperability and portability of cloud systems.

Developing common standards for the protection of personal data is still far from complete. In Russia, recommendations for data protection are less elaborated than in most developed countries; thus, data processing abroad may not complicate, but simplify the use of cloud computing [9].

CONCLUSIONS

Any innovative initiative requires at least the following preconditions for its implementation: public interests and needs, economic empowerment, and the availability of technological developments. For cloud computing, all these prerequisites are available. Potentially interested users are individuals and small and midsize businesses. Large companies and government organizations at this stage cannot be considered as consumers of cloud computing for reasons of information security. For users of the first group, the economic expediency of using information technology based on cloud computing is obvious; there is no need to buy expensive software and hardware for the storage of large amounts of data. There is, however, the problem of information security under the new conditions when processing and data storage occurs in the "cloud," i.e. outside of the computer systems of the users. The task of preventing unauthorized use of information is one of the principal task for implementing the concept of cloud computing. According to many experts, such as the Vice President for Information Technologies of Mobile TeleSystem (MTS, Russia) [10], this is especially important for the Russian IT market due to an insufficient level of information security.

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