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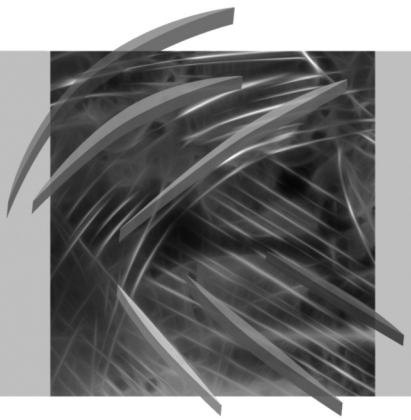

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Information Systems in Business

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APPLICATION OF CLOUD COMPUTING SOLUTIONS IN ENTERPRISES. REVIEW OF SELECTED FOREIGN PRACTICAL APPLICATIONS

Abstract: The article is focused on the issues of cloud computing solutions. It presents characteristics of cloud computing, its deployment models, fundamental architecture elements creating such a solution, proposal of Cloud-Based model for Business Organizations including virtualization. It also presents foreign practical application of cloud computing solutions provided in such enterprises as Microsoft, Google, Amazon. These enterprises are vendors of such solutions as well.

Keywords: cloud computing, Software as a Service, grid computing.

1. Introduction

Rapid development of information processes, as well as a huge dynamics of changes on the market causes that the information resources of enterprises increase from hour to hour. There exists tendency to treat them as a wealth and crucial possession of companies where these resources have key strategic significance and are indispensable to gain competitive advantage of such enterprise [Nowicki (Ed.) 2006, p. 178]. In order to gain this advantage, enterprises of all sizes have to apply modern hardware and software solutions allowing for i.e. cost reduction of business functionality, better and faster access to information resources, assurance of proper security policy, etc. Such an IT solution enabling all these features is cloud computing, called new trend in Information Technology and developing nowadays in fast pace. The aim of this article is to provide information concerning theoretical and practical background of cloud computing solutions in enterprises illustrating e.g. notion of this type of computing, basic cloud computing models, benefits and limitations resulting from its application, and also to review selected foreign examples of cloud computing practical applications such as Google App Engine, Microsoft Azure and Amazon EC2 solution.

2. The notion of cloud computing

There are many definitions of cloud computing evoked by practitioners and academic scientists specializing in the field of computing. As an example B. Furth defines cloud computing as "a new style of computing in which dynamically scalable and often virtualized resources are provided as a services over the Internet" [Furth, Escalante 2010, p. 3]. The National Institute of Standards and Technology (NIST) characterizes cloud computing as "a pay-per-use model for enabling available, convenient, on-demand network access to a shared pool of configurable computing resources (e.g. networks, servers, storage, applications, services) that can be rapidly provisioned and released with minimal management effort or service provider interaction" [Buyya, Broberg, Goscinski (Eds.) 2011, p. 4]. The deployment models, which can be either internally or externally implemented, are summarized by NIST as [Krutz, Vines 2010, p. 4]:

– private cloud – enterprise owned or leased,
– community cloud – shared infrastructure for specific community,
– public cloud – sold to the public, mega-scale infrastructure,
– hybrid cloud – composition of two or more clouds.

M. Armbrust et al. perceive cloud computing as "sum of SaaS and utility computing, but does not include small or medium sized data centers, even if these rely on virtualization for management" [Armbrust et al. 2010, p. 51]. Cloud computing is perceived as a new trend in computing and referring to the access to software and data storage in the "cloud" that is using any network such as previously mentioned the Internet. Some users perceive cloud computing as nothing new and for them it is a modernization of the time-sharing model which was widely employed in the 1960s. These developments eventually evolved to the client/server model where applications installed on different servers distribute large amounts of computing power at people's desktops and time-sharing systems are deployed [Krutz, Vines 2010, p. 1].

IDC predicts that worldwide, customers will spend $29 billion on public IT cloud services in 2011, up 30% from 2010. They claim that 2011 year will also be significant for private cloud services adoption and deployment, with IDC's preliminary estimate for 2011 worldwide spending on private IT cloud services at $13 billion [www.idcpoland.pl].

There are currently three cloud-based delivery models. In the case of Software as a Service (SaaS) a consumer uses the application, but does not control the operating system, hardware or network infrastructure. In such a case the application is controlled over the network by its users. Platform as a Service (PaaS) model allows users to host an environment for their applications. The users control the applications, but do not control the operating system, hardware or network infrastructure they use. Finally, there is Infrastructure as a Service (IaaS), where a user has access to "fundamental computing resources" such as CPU, memory, middleware and storage capacity. In the third case a consumer controls the resources, but not the cloud

infrastructure beneath them. Cloud computing relies on separating user applications from the underlying infrastructure using virtualization [Antonopoulos, Gillam 2010, p. 5]. Cloud computing has developed from technologies and business approaches that emerged over a number of years. The major building blocks range from Internet technology to cloud service providers, as it is illustrated in Figure 1 [Krutz, Vines 2010, p. 5].

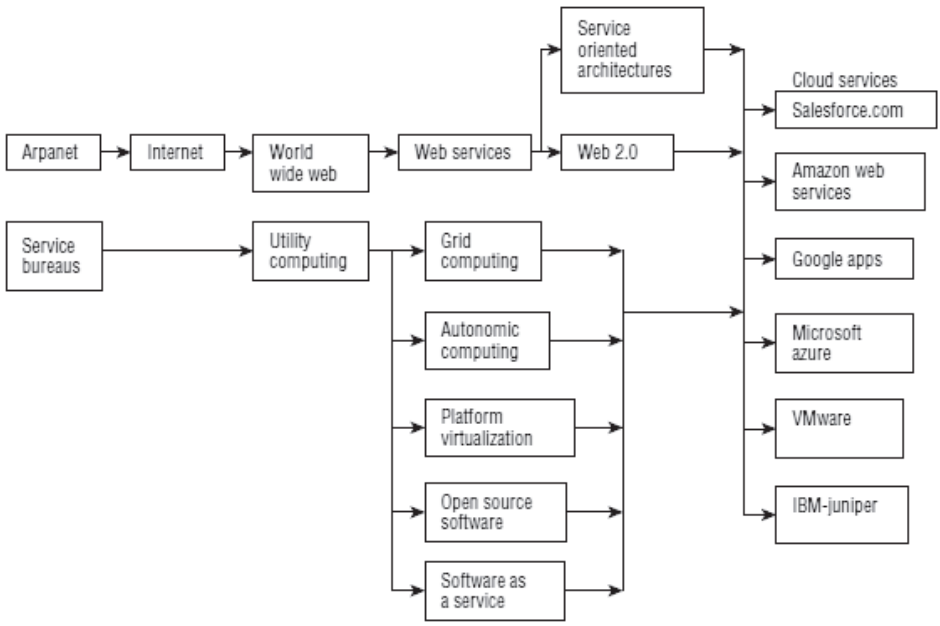

Figure 1. Origins of cloud computing

Source: [Krutz, Vines 2010, p. 5].

The key elements of cloud computing origins briefly described above include: utility computing, that is packaging and delivery of computing resources to a customer who pays for these resources as a metered service when needed [Krutz, Vines 2010, p. 6]; grid computing which refers to the concept of grid as a global connection of different and dispersed resources which can be properly managed and collaborate with each other [Ziora 2008, pp. 151–158], from the customer's point of view the place of data storage and the computers that are used for different operations are not important [Nowicki, Turek 2010, p. 299]; autonomic computing, that is functioning of a computer system without external control; platform virtualization, that is the logical partitioning of physical computing resources into multiple execution environments including servers, applications and operating systems. Virtualization is based on the concept of a virtual machine running on a physical computing platform, Software as a Service (SaaS) is a software distribution and deployment model

where applications are provided to customers as a service and are run on the users' computing systems or provider's servers, Service Oriented Architecture (SOA) is a set of services which communicate with each other [Krutz, Vines 2010, p. 6], and Web services which are based on series of connected IT solutions among which the most important are four basic standards: XML – data description and exchange format, SOAP – protocol of service call up and message transmission, WSDL – service description format and UDDI – catalogue for registering and searching of services [Rot, Ziora, pp. 210–214].

A.T. Velte, T.J. Velte and R. Elsenpeter explain the term services in cloud computing as "the concept of being able to use reusable, fine grained components across a vendor's network". This is widely known as "as a service." Offerings with *as a service* as a suffix include traits like the following [Velte, Velte, Elsenpeter 2010, p. 11]: low barriers to entry, making them available to small businesses, large scalability, multi-tenancy, which allows resources to be shared by many users, device independence, which allows users to access the systems on different hardware. Software as a Service (SaaS) is the model in which an application is hosted as a service to customers who access it via the Internet. When the software is hosted off-site, the customer does not have to maintain it or support it. Figure 2 presents examples of SaaS and Paas architecture.

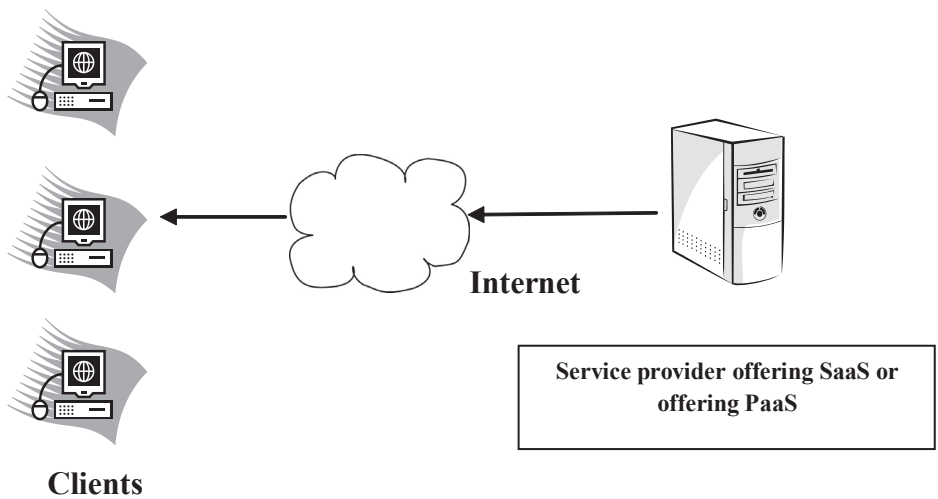

Figure 2. Example of SaaS and PaaS architecture

Source: [Velte, Velte, Elsenpeter 2010, p. 12].

Some of SaaS applications include customer resource management (CRM), video conferencing, IT service management, accounting, web analytics, web content management, etc. Platform as a Service (PaaS) is another application delivery model

which supplies all the resources required to build applications and services completely from the Internet, without necessity to download or install software. Velte et al. claim that PaaS services include application design, development, testing, deployment, and hosting. Other services include team collaboration, web service integration, database integration, security, scalability, storage, state management, and versioning [Velte, Velte, Elsenpeter 2010, p. 14]. HaaS model presented in Figure 3 allows the user to rent such resources as server space, network equipment, memory, CPU cycles, storage space.

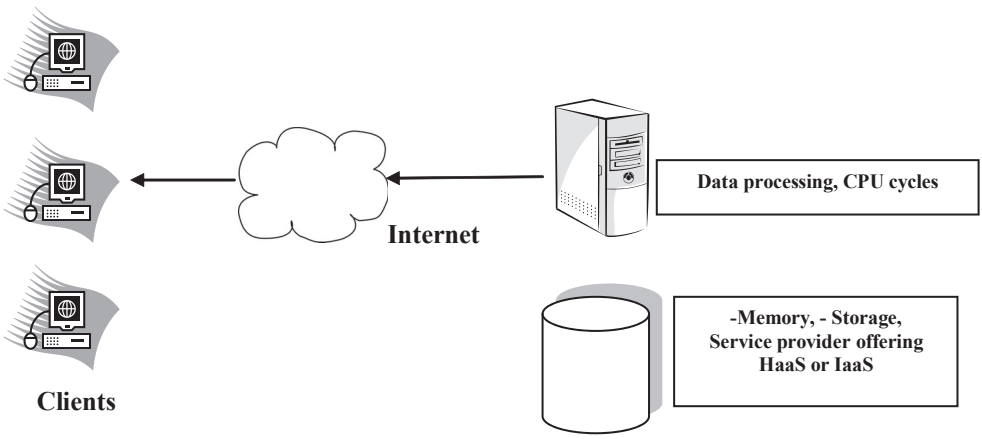

Figure 3. Example of HaaS architecture

Source: [Velte, Velte, Elsenpeter 2010, p. 12].

The proposal of Business in Cloud model was introduced by M. Hugos and D. Hulitzky as presented in Figure 4. The authors state that "cloud-based systems have well-defined application program interfaces (APIs) so each company can use service-oriented architecture (SOA) techniques to connect their internal systems to a cloud communications backbone". Cloud-based systems built with BPM, CEP, BI, and simulation gaming can come together as cloud-based management and governance models for entire industries. This could be the formation of integrated sets of real-time workflow processes that are tailored to specific vertical industries. Cloud-based trading networks would then enable the formation of entire business ecosystems. They state that "companies may be more inclined to join networks where they have some ownership and greater influence in the decision-making procedures employed by the network" and as its result fewer people are involved in the decision-making process [Hugos, Hulitzky 2011, p. 20]. "Cloud computing is an emerging paradigm, which promises to make the utility computing model comprehensively implemented by using virtualization technologies" [Babar, Chauhan 2011]. Implementation of virtual enterprises enabling SMMEs (Small, Medium and Micro En-

terprises) to respond quickly to customers' is possible thanks to the application of virtualisation technology which is one of the building blocks of Cloud computing. Through a virtual business operating environment offered by cloud computing, the SMMEs will be able to increase productivity and gain competitive advantage due to the cost benefit incurred [Mvelase et al. 2011].

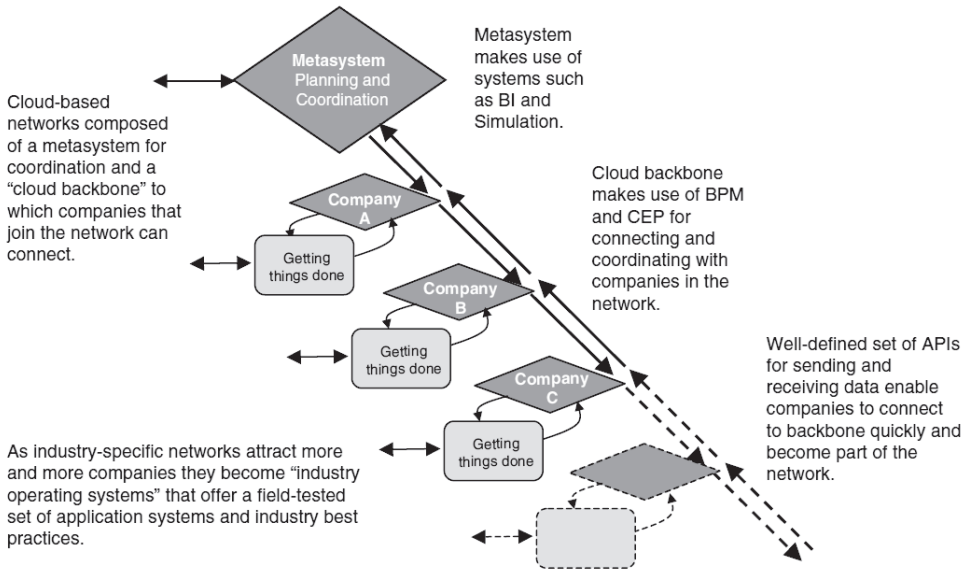

Figure 4. A cloud-based model for business organizations

Source: [Hugos, Hulitzky 2011, p. 21].

3. Benefits and limitations of cloud computing solution in an enterprise

The benefits resulting from the application of cloud computing solutions in enterprises may be divided into financial benefits meaning that IT can be purchased on a pay-per-use basis and treated as operational expenditure, with the reduced administration burden that comes with not having any server hardware to look after. M. Williams states that "the elastic and scalable nature of cloud computing supports the unpredictable cycles of expansion and contraction that businesses go through". Public cloud customers share the cost of a multi-tenanted computing infrastructure with other customers [Williams 2010, pp. 25–28]. Cost models vary between the three main service models: Software as a Service (SaaS), Infrastructure as a Service (IaaS) and Platform as a Service (PaaS), but the principle is the same. Long-term cost savings are less likely for large enterprises as they have their own economies of

scale, but many small to medium-sized businesses can benefit financially from cloud computing even in the long term [Velte, Velte, Elsenpeter 2010, p. 14]. The next financial benefit may be reduced IT management costs. Further M. Williams distinguishes technological benefits of cloud computing application in the enterprise which include rapid scalability on demand where access to a needed service is not dependent on place, which means there is possibility to access cloud computing services anywhere due to the fact that they are web based. With Software as a Service (SaaS) and Platform as a Service (PaaS) the user always gets the latest software, which means that updates are automatic. There are no costs for upgrading to the next version of any application or development platform. This solution enables backing up data off-site automatically and redundantly, setting up virtual private networks, securing web applications and patching web servers, etc. Cloud computing helps small businesses compete with larger enterprises. The service provider can offer cheaper, more reliable applications than organizations by themselves. A.T. Velte, T.J. Velte and R. Elsenpeter indicate some other benefits of SaaS including: familiarity with the World Wide Web of most employees, smaller staff, easier customization, better marketing, web reliability, security where Secure Sockets Layer (SSL) is widely used and trusted, more bandwidth [Velte, Velte, Elsenpeter 2010, p. 13]. The economic benefits of cloud adoption for small and medium-sized enterprises (SMEs) and large enterprises can be enlisted as: strategic flexibility, mentioned cost reduction, software availability, scalability, skills and staffing, energy efficiency, system redundancy and data backup [Antonopoulos, Gillam 2010, pp. 349–351]. M. Armbrust et al. mention a list of a few opportunities for growth of cloud computing, i.e. possibility to use multiple cloud providers, deployment of encryption and standardized APIs, VLANs, etc. [Armbrust et al. 2010, p. 54].

A few limitations of cloud computing solutions can be distinguished. The first is that an organization that has a very specific computational need might not be able to find the application available through SaaS, which means that companies with unique needs may not be able to find some of the components in a SaaS [Williams 2010, p. 67]. There exists also an element of "lock-in" with vendors meaning that customers might pay a provider to use an application, but once they do, they may be unable to port that application to a new vendor. Finally, SaaS also faces challenges from the availability of open source applications and cheaper hardware. If companies are so inclined, they can put their open source applications on hardware that performs better and costs less than it used to [Velte, Velte, Elsenpeter 2010, p. 15]. It is worth mentioning that cloud computing solutions are economically justified only for SMEs enterprises, which was confirmed by McKinsey Consulting research which found that a "typical" data center of a large organization can operate at significantly lower costs than what would be required to outsource it to a cloud service like e.g. Amazon's EC2 [Marston et al. 2011, p. 184]. To sum up, it is worth noticing that the risks resulting from application of cloud computing solutions include internal and

external security risks, data protection risks, cloud outages, data loss, vendor failure and lock-in.

4. Practical examples of cloud computing solutions

Cloud computing solutions are utilized by many enterprises nowadays. They are offered by such vendors as Google, Amazon, IBM, Microsoft, Sun, New York Times. The most well known solution is offered by Google Enterprise which is aimed at organizations of all sizes, and used to store customer data in multiple systems. Users are able to communicate and cooperate with Gmail, Google Calendar, Google Talk, Google Sites and Google Docs. A.T. Velte, T.J. Velte, R. Elsenpeter and M. Williams cite a few practical examples concerning application of cloud computing in mentioned above enterprises. They maintain, i.e., that technological solution called Google App Engine "enables developers to build their web apps on the same infrastructure that powers Google's own applications". They enlist features thanks to which developers can accomplish the tasks such as: one time code writing and its deployment which is crucial for dynamic provision of computing resources as they are needed; absorption of spikes in traffic – using automatic replication and load balancing, Google App Engine makes it easier to scale from one user to one million by taking advantage of "Bitable" and other components of Google's scalable infrastructure; easy integration with other Google services [Velte, Velte, Elsenpeter 2010, p. 15].

The other example of cloud computing provider may be Microsoft corporation that provides a number of cloud services for organizations of any size. Microsoft offers Azure Service platform that is hosted in Microsoft datacenters. The platform offers a cloud operating system and developer tools with industry standard protocols like REST and SOAP. The example of cloud operating system is Windows Azure which enables the development, hosting, and service management environment for the Azure Services Platform. It gives developers an on-demand compute and storage environment which they can use to host, scale, and manage web applications. Windows Azure can be used to: add web service capabilities to existing applications, build and modify applications and then move them onto the Web, make, test, debug, and distribute web services efficiently and inexpensively and reduce the costs of IT management [Kaufman, Venkatapathy 2010].

The third example worth mentioning is Amazon cloud vendor offering services on many different fronts, from storage, platform to databases. Amazon Elastic Compute Cloud (Amazon EC2) is a web service that offers resizable compute capacity in the cloud and is designed to make web scaling easier for developers. Amazon EC2 cuts the time it takes to obtain and boot new server instances to a few minutes and it allows to run Windows-based applications on Amazon's cloud computing platform. This might be web sites, web-service hosting, high-performance computing, data processing, media transcoding, etc. For database services, Amazon offers Amazon

SimpleDB providing core database functions of data indexing and querying. This service works closely with Amazon Simple Storage Service (Amazon S3) and Amazon EC2. This provides the ability to store, process, and query data sets in the cloud. Amazon Simple Storage Service (Amazon S3) is Amazon's storage solution for the Internet designed to make web-scale computing easier for developers. Amazon CloudFront is a web service for content delivery. It works in conjunction with other Amazon Web Services to give developers and businesses an easy way to distribute content to clients. Object requests are automatically routed to the nearest edge location, so the content is delivered with the best performance possible. Amazon Simple Queue Service (Amazon SQS) offers a scalable, hosted queue for storing messages as they travel between computers [Velte, Velte, Elsenpeter 2010, p. 16].

The example of Infrastructure as a service may be the New York Times. M. Williams cites that "in November 2007 Derek Gottfrid, a developer from the *New York Times*, used Amazon Web Services and a great deal of technical skill to solve a difficult problem for his employers". He states that "the newspaper wanted to make all its public domain articles from 1851–1922 available on the web free of charge, but the articles were broken up into individual images scanned from the original paper that had to be pieced together. This could be done dynamically on a website for any article, but if the website proved popular, then the web server could soon be overloaded with processes and grind to a halt. If there were static PDF copies of the articles to download, the website would not have to work anywhere near as hard, but there were 11 million articles to process and a tight and inflexible deadline to meet. Gottfrid's solution was to use open-source tools to process four terabytes of image data in parallel on 100 Amazon Elastic Compute Cloud (EC2) virtual machines, storing the resulting 1.5 terabytes of articles in Amazon's cloud using the Simple Storage Service (S3). The whole process took just under 24 hours and cost $240, paid for on the newspaper's company credit card; the 100 EC2 instances had done their job and were deleted" [Williams 2010, p. 67]. It allowed for conversion of archival articles (3 million) into new data formats using Amazon elastic compute services, rapid provisioning and higher elasticity on the infrastructure resources [Furht, Escalante 2010, p. 13].

5. Conclusion

Cloud computing solutions are utilized by more and more enterprises of different sizes and branches all over the world. The pioneers of such solutions are huge enterprises as Google, Amazon, Microsoft, IBM, which was presented in review of foreign case studies. This technology has many benefits as well as a few drawbacks mentioned in this article. Systems which base on clouds possess the ability to optimize proper resources. The clouds seem to join and use such technologies as grid services and computing, web services, and data centers.

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ZASTOSOWANIE ROZWIĄZAŃ *CLOUD COMPUTING* W PRZEDSIĘBIORSTWACH. PRZEGLĄD WYBRANYCH ZAGRANICZNYCH ZASTOSOWAŃ PRAKTYCZNYCH

Streszczenie: W artykule skoncentrowano się na rozważaniach dotyczących rozwiązań przetwarzania w chmurze. Przedstawiono charakterystykę *cloud computing*, jego modele, w tym kluczowe elementy stanowiące architekturę takiego rozwiązania, oraz propozycję modelu przetwarzania w chmurze przeznaczoną dla organizacji biznesowych uwzględniającą również wirtualizację. Zaprezentowano praktyczne zagraniczne przykłady zastosowań *cloud computing* w takich przedsiębiorstwach, jak Microsoft, Google, Amazon. Wspomniane przedsiębiorstwa są równocześnie dostawcami rozwiązań przetwarzania w chmurze.