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CLOUD COMPUTING – THE NEW IT PARADIGM

Oblak računara – nova IT paradigma

Abstract

Cloud computing is becoming the new IT paradigm. After 50 years of development, the original idea of McCarthy to deliver information technology and applications as a public service comes to life. The secret sauce of this new development is a combination of commodity components (standardized and cheap), ubiquitous Internet connectivity, and virtualization technology of computing resources. After a few years of discussion and sometimes even disputes there is finally a solid and accepted definition of what cloud computing really is. But that's not all. Cloud offerings mushroom these days: from big global offering (*Amazon, Google, IBM, and Microsoft*) to very small, focused, and highly customized solutions. Economics of the cloud are promising, in particular for small and medium businesses, and public sector. Cloud solutions enable elimination of investment costs (no upfront investments in IT infrastructure and software licenses) and significant reduction of operating expenses (50% or even more). Some special solutions, like disaster recovery in the cloud, are for the first time viable for all enterprises. Economics of the cloud come from aggregation and sharing of common infrastructure as is the case for all public services: power distribution, public transportation, telephone services. In this article, we present a underlying concept of the first cloud offering on Serbian and regional market provided through *Coming – Computer Engineering* and *Telekom Serbia* partnership. Key differentiator in comparison to global offerings is a full customization of solution to meet user's expectations and a solid support that goes as far as full outsourcing of IT operations to provider (i.e. *Coming CE*). Also, we are willing to spark discussion about community cloud solutions that can serve many institutions otherwise unable to build their own IT services. We point directly at: local (community) authorities, schools and universities, public administrative services, to name just a few. Also, we invite academic community to critically assess how reality of the cloud lives up to promises made by service providers.

Key words: *cloud computing, public cloud, private cloud, hybrid cloud, virtualization, enterprise cloud, interoperability, economics of cloud, services, information technology, infrastructure.*

Sažetak

Oblak računara postaje nova IT paradigma. Posle 50 godina razvoja originalne Mek Kartijeve ideje iz 1961. godine da se informacione tehnologije i aplikacije isporučuju kao javni servisi pojavile su se prve takve usluge na tržištu. „Tajna“ ovih usluga je u kombinaciji: standardizovanih i jeftinih komponenti, sveprisutnih Internet veza i tehnologije virtualizacije računarskih resursa. Posle nekoliko godina diskusije i, ponekad, nesporazuma, pojavila se solidna definicija oblaka računara. Ne samo to. Ponuda usluga u oblaku buja ovih dana: od velikih globalnih isporučilaca (*Amazon, Google, IBM, Microsoft*) do vrlo malih, fokusiranih i visoko prilagođenih rešenja. Ekonomičnost usluga u oblaku je obećavajuća, posebno za mala i srednja preduzeća i javni sektor. Usluge u oblaku omogućuju eliminisanje investicionih troškova (nema investicija u IT opremu i softverske licence), a realna je i značajna ušteda u operativnim troškovima (50% ili čak i više). Neka posebna rešenja kao što je rešenje za oporavak od katastrofe po prvi put postaju dostupna svim preduzećima. Ekonomija usluga u oblaku dolazi kao posledica agregacije i deljenja zajedničke infrastrukture, kao što je slučaj i sa drugim javnim uslugama: distribucijom električne energije, javnim transportom i telefonskim uslugama. U ovom članku izložen je koncept na kome počiva prva ponuda usluga u oblaku u Srbiji i region koja je nastala kroz partnerstvo *Coming – Computer Engineering*-a i *Telekoma Srbija*. Ključne razlike u odnosu na globalnu ponudu predstavljaju potpuna prilagodljivost zahtevima korisnika i solidna podrška, koja ide čak do potpunog iznajmljivanja svih IT operacija kao usluge (t.j. *Coming CE* preuzima brigu o njima). Takođe, voljni smo da pokrenemo i diskusiju o zajedničkim (komunalnim) uslugama u oblaku koje mogu biti od interesa za mnoge institucije koje nisu u stanju da sopstvenim sredstvima izgrade IT. Ukazujemo direktno na: lokalnu samoupravu, škole i univerzitete i javnu administraciju. Pored toga, pozivamo i akademsku zajednicu da se kritički osvrne na stvarnu vrednost usluga u oblaku u odnosu na obećanja koja su dali isporučio.

Ključne reči: *oblak računara, javni oblak, privatni oblak, hibridni oblak, virtualizacija, oblak za preduzeće, interoperabilnost, ekonomija oblaka, usluge, informacione tehnologije, infrastruktura.*

Introduction

In 1961 McCarthy first formulated the idea of delivering information technology and application as a public service. This idea actually copied experience from the past: railroad and public transportation, power distribution, telephone – just to name a few. It seemed very compelling but unfortunately technology was not able to deliver IT services economically. It took almost 50 years to come to current state of development thanks to Moore's law (number of elements on integrated circuit doubles every 18 months – or more colloquial: computer power doubles every year and a half). Improvements were not just quantitative. On the contrary, IT went through many development phases: mainframes (1960s), minicomputers (1970s), personal computers (1980s), Internet in the 1990s, to the latest phase – pervasive connectivity, device diversity (mobile phones, PDA, tablets, desktops) and mobility of users. Because of these characteristics this phase is named: "post PC-era".

Also, the idea of delivering IT as a service has been transformed from initial formulation through many phases: on-demand computing, autonomic computing, hosting (equipment and applications) – but failed more or less to fulfill expectations of users. Two critical components were missing:

- Standardized and cheap IT components – "commoditization" of IT
- Virtualization of IT resources (most important: virtualization of computing through enablement of virtual machines).

Pattern of commoditization of IT closely followed patterns from the past: steam machine, power distribution, and telephone. Except that the whole cycle from over a century for steam machine is shortened to a few decades for IT. Current state of affairs is clearly visible: personal computers and other devices now sell together with home appliances. And manufacturing brands are the same: *Samsung*, *LG*, etc. Server and storage businesses follow the same pattern in a bit different way – this is more than visible through lower margins and migration towards more complex service offerings – away from less profitable segments. The other side of the coin is lowering of prices of IT equipment – inversely proportional to Moore's law.

This development was nicely exposed in N. Carr article "IT does not matter" [1]. Article sparked discussion about IT role in the enterprise (once again) and we think the best part was actually discussion about commoditization of IT and its consequences.

Commoditization alone would not be enough to spark cloud computing story because vendors always find intelligent (and not so intelligent) ways to lock-in current users. Secret missing ingredient that appeared from oblivion becomes virtualization. The main idea is very simple: create illusion for a user that all resources he/she needs are always available and that the user is perfectly isolated from other users. On the other hand this illusion created a new possibility for service providers: build shared infrastructure, virtualize it, and present it to the users. This is where solution requested by the users goes arm in arm with economics of delivery.

IT as a public service

Development of information technology led for the first time to mature offering of public services capable of fulfilling growing needs of modern enterprises. Common name of broad services delivered this way is:

Cloud computing. At the very beginning of this new trend, a few years ago, there were many critics like this one: "cloud computing is nothing new; this is what we used to do for years" (L. Ellison, *Oracle*). In spite of these, new trend (and new terminology) grabs attention of IT community and many providers come to market quickly offering services under the cloud computing umbrella. Today (2012) you can hardly find anybody in IT sector not offering cloud services. Size of the company does not matter much. All sectors are active too: infrastructure, system software and management tools, application development, not to mention Internet services and hosting providers. Analysts predict this trend will continue in the following years and market will soon grow above 100 billion dollars per year [9] Also, confusion is growing regarding this new class of services. Is there any commonly accepted definition? What is the content and difference of existing offerings? What about size of the providers and cloud infrastructure? Is there any place for small companies? What is the pace

of migration, obstacles, and price? Many questions like these pop up asking for quick and clear answers. In the text that follows we shall try to clarify at least a few of them.

Cloud computing – A definition

Commonly accepted definition of cloud computing comes from NIST [3]:

“Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. This cloud model is composed of five essential characteristics, three service models, and four deployment models.”

We have to highlight a few most important consequences of this definition and current implementations: cloud services (public offering of these) enable provision of new IT resources (infrastructure elements) without investments and with lower-than-usual operating costs. Besides, no IT people training are needed; buying new licenses and implementation of provisioned resources either. This is (should be!) an easy way of extending capabilities of existing IT infrastructure of the enterprise or even fully outsourcing IT to external service provider(s). These promises are yet to be proven, but they represent the essence of cloud computing and a key test whether technology and providers will survive in the long term.

Type of cloud services

Cloud computing is commonly defined as: everything as a service. Or shortly: *XaaS*. But there are three main categories prevailing today:

- *IaaS* – infrastructure as a service
- *PaaS* – platform as a service
- *SaaS* – software as a service.

IBM includes in its own portfolio the fourth type: *BPaaS* – business process as a service (beyond scope of this article).

Infrastructure services are the most common type and probably the most mature offering today. These services can vary from very simple (plain virtual machines) to very complex offerings (like full SAP ERP landscape). The first on the market and the most visible one is *Amazon Web Services*. But other offerings mushroom these days: from very small to big ones (*IBM, Microsoft, Google, etc.*).

Customer (enterprise) using *IaaS* offering gets all needed infrastructure elements: networking resources, data storage, and computing resources in a form of virtual machines. IT administrators take these elements to build enterprise infrastructure, install application software and manage it as its own. Except for provisioning of resources this type of service resembles the most traditional way of IT infrastructure design, implementation, and maintenance. Granularity of provisioned resources makes another big difference. Traditionally, equipment was provisioned with one physical server per application – very coarse granularity. *IaaS* virtual machines are provisioned as a fraction of physical server and configured exactly for application they serve.

Service delivery models of cloud computing

At the very beginning of cloud offerings on the market it was expected that new services will concentrate around 4-5 major players (*Google, Amazon, Microsoft, IBM* and maybe a few others) who would share more or less all customers. Situation was very similar to the 1950s when it was predicted at the beginning of mainframe era that a few (maybe 5) mainframes would be enough to serve the whole world. So, this “prophecy” was nothing new and was equally wrong. It did not take too much time to evidence cloud offerings mushroom, as we mentioned at the very beginning of the article.

Leading cloud and virtualization platform vendor, *VMware* proposes a bit deferent approach: mixed environment and gradual migration from traditional to fully (someday!) cloud capable infrastructure. In the text that follows we shall give more details regarding this approach as it is now broadly accepted by IT community.

Instead of 4-5, the major cloud services are now offered using a few delivery models:

- Private cloud
- Public cloud computing
- Hybrid cloud
- Community cloud.

Underneath all four models there is virtualization layer and virtualization management infrastructure. Vendor solutions differ but conceptually this is common denominator of all solutions. Some providers even hide this kind of architectural information, but nevertheless use very similar solutions (*Google* for example).

Besides, we will mention a few obstacles providers and customers have to overcome to be able to reap benefits of cloud infrastructure.

Private cloud

In 2006 virtualization technology came back from oblivion as a mainstream trend and technology promising to transform the whole IT operations. Until then it was common to provide one physical server per application service. The result was disappointing efficiency of resource usage. CPU usage hardly went over 4-5%. Other resources were underutilized too. This trend had to be stopped because it was economically unacceptable. After initial and visible cost savings from infrastructure consolidation, it was obvious that there were many less tangible benefits: much less power and datacenter space used, easier maintenance, no vendor lock-in possible, and drastically improved uptime of services. Statistics from the field of virtual infrastructure show cost savings of 50% and more and utilization of most expensive resources (like CPU) well over 60%.

Through many very successful consolidation projects virtual infrastructure gradually and almost invisibly has been transformed from consolidation tool to platform for cloud computing services. Key for this transformation was development of management, monitoring, and automation tools.

Now with the cloud services booming it is obvious that virtual infrastructure is a “secret sauce” missing in the previous generation of hosted services offering.

This global picture was repeated locally through many (over 100) projects *Coming - Computer Engineering*

delivered to customers in Serbia and in the region. Pattern was applied successfully for small and even for very big companies with equal success.

Today we see gradual transformation of already virtualized infrastructure to private clouds of the enterprises. Private clouds enable even higher costs savings (through automation and less administration) and preparation for the next phase: hybrid solutions (to be discussed later). Companies not virtualizing datacenter resources now see stronger pressure to follow this development as quickly as possible. Otherwise, they risk staying behind for at least two generations of technology.

Public cloud

This is what is commonly seen as cloud computing: computing and storage services delivered over Internet. There are many offerings on the market today: *Amazon AWS* [4], *T-Systems*, *IBM* and many others. In spite of many similar characteristics, no two clouds are equal. Besides, interoperability among different clouds is not standardized, and it is still not possible to move services around on the fly. There is a serious ongoing debate whether hardware vendor lock-in from the past could be repeated in the cloud.

Existing services differ sharply by the existing and target customer base: from plain virtual machines for small or even individual users to enterprise solutions customized to strict customer needs. *Coming – Computer Engineering* decided at the very beginning of development to focus on enterprises: small and medium at first, large ones later, offering fully customizable services. Individual (residential) customers are not excluded, but pricing still prevents massive deployments for this class of users.

Hybrid cloud

Hybrid cloud is an extension of customer’s private cloud infrastructure. Through this customer can add resources to his own IT infrastructure, use outsourced resources as if they are his own and move services between private and public clouds at wish (finding optimal place for a service regarding performance, security, scalability, and other

criteria). Therefore, the interoperability of different clouds is prerequisite for such an operation. Key standards like Open Virtualization Format are in development and so are numerous tools like VMware vCloud Connector [5]. The tool creates a “single pane of glass” for administrator who is able to manage full set of services and move them around no matter where they are currently located.

Community cloud

Community cloud has all the characteristics of a public cloud, but it is serving limited number of users who are sharing the same policies regarding security/privacy, management or any other. It can serve, for example, a number of government institutions, university, local community (municipality). Internal users (organizations) are treated as independent entities and have management and administrative independence. For the outside world community cloud is not visible (except through carefully controlled Internet links). Therefore, through aggregation of resources belonging to many similar organizations, community cloud enables significant cost savings and build-up of qualified IT organization. Underlying technology – including virtualization, network isolation, and security appliances – is the same as for public cloud solutions.

Let us mention one of the most famous initiatives for community cloud build-up: Obama Cloud Initiative from 2009 [11]. Many more similar initiatives are in progress today. There is no sign that this wave will stop soon. Again, economic impact of the solution is a key driving factor.

Characteristics of cloud computing

To qualify market offering as cloud computing, provider has to fulfill and guarantee a few distinctive characteristics. Otherwise, solution could be qualified as traditional or at most “cloud like”. This distinction is not a cosmetic one. In essence, this is what new cloud concept is bringing to IT world. Let us take a look:

On-demand activation of services

On-demand delivery (activation) of services is probably the most distinctive characteristic of cloud computing.

Very often activation time is measured in minutes or even seconds and activation is a kind of self-service. For example (once again): *Amazon Web Services*. But even a bit longer activation time – day or two makes a big difference to traditional one – measured in weeks and even months.

Internet and private virtual network access

Cloud services started as a public service delivered over Internet (public network) and this method is still prevailing. For enterprise customers and others who need complex solutions it is now common for providers to have other means of delivery: highly isolated and protected private MPLS networks. As security over Internet could be easily compromised, secure transport services are mandatory (encrypted protocol like IPsec or SSL – out of scope of this article).

Aggregation (pooling) of resources

In order to be economically feasible, cloud computing services inherently use shared physical infrastructure (networking, storage, and computing resources). This is achieved through a profound use of virtualization technology: aggregate resources of different kind in a pool of shared resources (not necessarily of the same characteristics), and then: partition resources as it is requested by user applications (normally in very small portions compared to aggregated capacity). It's nothing new: this way we share public transportation, power supply, telephone infrastructure. To be successful, sharing of resources is to be invisible to users (i.e. users are invisible to other users) and partition should guarantee quality of services. All the other characteristics of cloud computing and the whole economics of it come from sharing of common elements and this is not possible without a full virtualization of underlying resources.

Instant elasticity

As we mentioned earlier, user services are very often just a small fraction of physical servers of which cloud infrastructure is built. But cloud brings other very interesting possibilities not seen before: to build very large applications consisting of tens, even hundreds, of instances of underlying virtual machines. And build it automatically

and almost instantly. There is famous Animoto case on top of AWS that shows what elasticity really means: adapt to user and application needs instantly. Scale up as well as scale down on demand.

Metering of resource usage

Metering usage of resources in the cloud infrastructure and be able to do precise accounting of them is another distinctive characteristic of the cloud. Cloud brings to life possibility for a user to pay resource per usage – similar to other public services (for example: telephone). This is not the only possible method of metering/payment but it is prevailing today. For enterprises and other permanent users of cloud services accounting of resources can be done on a fixed/flat basis, as a fraction of reserved resources (inaccessible to others) and on many other ways. No matter what nuances we have in mind, user is always paying for what it uses – per request or on a monthly basis.

Usage scenarios for different customer types

What are the use-cases of cloud computing? How do they differ from traditional ones? We shall give non-exhaustive list of possibilities and potential benefits.

- *Business users* – enterprises, small and medium in particular, by using cloud offerings can outsource more or less all IT infrastructure or provision a new one with no investments and lower (compared to their own) operating costs. If infrastructure cannot be fully outsourced (for whatever reason, for example, security policy of the enterprise), it can be at least partially outsourced: test and development, training infrastructure, remote backup, and disaster recovery services.
- *Public sector and government agencies* – users from this segment have very sophisticated publicly accessible applications for which cloud could represent “native” environment for secure, accessible, and economical delivery to the society.
- *Independent software vendors* – they are focused on development and marketing/sales of various business applications and not on infrastructure itself. Therefore, cloud is particularly inviting

for ISVs. Proof of concept solutions, training, demonstration of applications can be delivered from the cloud in no time wasted for provisioning, decommission and other for ISV not particularly interesting activities.

- *Hybrid solutions* – for many enterprises fully outsourced cloud infrastructure is still (and maybe never will be) the only infrastructure delivery model. It could be much more feasible to outsource part of infrastructure: for testing, remote backup and disaster recovery, even peak or seasonal load, typically batch operations (like analytics). Besides, number of publicly accessible (external) applications is growing. By the rule these are put in so-called: demilitarized zones – isolated regions inside enterprise private infrastructure. Cloud is even better isolated so these application can more securely be delivered to the users from it. This division of infrastructure to private-public is artificial. Mature cloud offering should enable interoperability of the services (applications) and transparent migration from one infrastructure to the other at user request – i.e. finding the best place to work (accessibility, economics, security, whatever user sees as a feasible criteria).
- *Events of limited duration and big projects* – traditionally IT infrastructure for such an event is provisioned well in advance, installed, and used very shortly and decommissioned – all with high costs. Usage of delivered infrastructure and hardware in particular after the event is never perfect fit and much of the investment cannot be recovered after. Cloud comes here as a rescue. *Coming - Computer Engineering* showed feasibility of such solution at Eurosong 2008 and University Games 2009, Belgrade.
- *Schools and universities* – they have to equip a huge population with personalized, functional, and secure environment for work. Instances of services and applications have to be delivered in no time, with minimal administrative efforts and very cheaply. As it is shown from recent past, traditional solutions fail quickly with millions wasted. As we

can see, cloud computing as a platform for schools and universities represents today the only viable solution. Examples from USA, Brazil and other countries show clearly why this is the case.

- *Residential users* – last but not the least. Mostly this class of users has expected to be able to surf Internet securely. But those days are over: now they expect to be able to share and backup data and valuable documents, be free of end-user computing devices, be able to use devices of different form factors – from PDAs over tablets, to desktops, to access their application from any place at any time. Cloud is very inviting regarding this but many obstacles are to be overcome: security (like for all other user categories), delivery of multimedia content with the same quality as for non-cloud solutions (its own desktops). In a few last years we have seen intermixing of personal and professional life through social networking so that a distinction of what is inside (private) and outside (public) becomes quite vague.
- *And many more* – limited only by price/performance compared to traditional solutions. All other factors (like security) will play less significant (we do not want to say unimportant) role, because in the end economy always wins.

Quality of cloud computing services

Resource metering in the cloud is a must have feature of any offering. But quality of service matters even more. Promises given by provider at contract signing have to be secured by clear definition of quality of service and measurements/accounting at the time of delivery. Without measurable quality of service anything that user gets can be considered “adequate” and also user can complain about any characteristic if acceptable values of it are not clearly set.

Therefore it is common, and we would say mandatory, to put quality of service term into service contract with cloud provider. It is done with so-called Service Level Agreement, or shortly SLA.

SLA should have at least the following elements:

- 1) *Guaranteed service availability*: defined as percentage of time services are at user disposal compared to times when they are not available (i.e. downtime). Now it is common to have this measure at the level of 99, 5% or more. Critical services are to be available for at least 99,95% of time, but real values heavily depend of user needs and usage scenario,
- 2) *Way of support and availability of support resources and qualified personnel* – normally repair time should be very short – a few hours, with most of the hardware incidents resolved automatically using high availability functions of underlying virtual infrastructure,
- 3) *Data privacy, security and protection* – it is common these days to have nondisclosure agreements signed or included in service delivery contract. Provider must guarantee protection of user’s sensitive data and documents, and prevent any leakage of them. This is commonly considered as one of the pain points of cloud computing and obstacle to broader acceptance. All user requests and measures, to be implemented to secure user data, are to be put into SLA part of the service contract. Examples from recent past show that unrecoverable destruction of user data is possible and that consequences are huge: lost intellectual property, lost reputation, in the end lost clients and maybe bankruptcy,
- 4) *Penalties of not delivering services* within the limits defined by SLA. Normally this is defined as a monthly discount for future payments. Critical incidents are to be treated with special care. It is not uncommon for users to request bank guarantees as an additional security.
Other SLA elements are to be negotiated too:
 - Planned maintenance of applications and cloud infrastructure
 - Disaster recovery procedures (in case of fire, flood, earthquake, etc.)
 - Limitations and acceptance of provider policy of service delivery
 - Licensing of software used if paid on a monthly

basis. Users now can relatively easy bring their own licenses to the cloud (without paying a new)

- Other commercial terms (way of payment, due dates, etc.).

Without solid SLA journey to the cloud, it could be full of (mostly unpleasant) surprises.

Economics of cloud computing

For any technology to survive in the long term, economics of delivery and usage are of critical importance. Graveyards are full of “promising” technologies from the past. Cloud computing does not show signs of these already forgotten solutions. On the contrary, economy of the cloud seems to be quite solid. Besides, other less tangible advantages play important roles too.

Main sources of cost savings are the following:

- 1) *Capital expenditure do not exist* (more precisely go on provider's account and are part of service price) – investments in IT infrastructure consists of the following: networking, storage, computing resources, datacenter facility, software licenses (system software like operating systems, databases, email or application software like ERP, CRM, POS and many other well-known enterprise applications). Investments in the infrastructure can be fully eliminated (or transferred to provider who has better negotiating position with vendors and shared infrastructure through economies of scale will do the rest). Application licenses can be paid on a monthly basis without upfront investments and in practice it is shown (that) aggregated price is comparable to traditional way of licensing. Additional savings come from the possibility for users having private cloud solutions to provision only infrastructure volume needed by everyday operations and to spare (use cloud instead) peak load needs which are estimated to 30% or more of “regular” infrastructure capacity. Many “extra” services can be provided this way and the cost can be shared (through provider) with others.
- 2) *Operating costs – promises for operating costs savings are very compelling* – estimate goes to 50%

and even more. What is the source of such a big improvement? Economics again come from shared infrastructure – lower costs for power supply and air conditioning, datacenter space rental and, mostly, administration and maintenance personnel costs. It is estimated (*Microsoft study*) that one administrator in a private infrastructure is managing close to 170 virtual machines – in the cloud this number goes to over 1000 (!). Besides, separation of duties in the cloud is possible with a consequence of better service and lower costs.

- 3) *Disaster recovery services* – IT manager's dream (or nightmare!) for a very long time can now become true thanks to low service costs in the cloud. This complements growing management awareness of possible consequences of disastrous events like flood, fire, earthquake, and others. Studies show (Gartner) that more than 40% of the enterprises which experienced disasters do not recover at all – in other words, stop doing business. A significant part of recovery from disaster is ability to recover IT infrastructure to serve critical applications and data. Now this can be done by provider in different (cloud) location. Is there any excuse now for not having DR plan? It seems (finally) that cloud is bringing this opportunity even to very small enterprises that were not able to provision DR solutions in the past and were exposed to above mentioned risks. Calculations (beyond the scope of the article), as well as experience of the other providers show that DR in the cloud can be delivered for a fraction of the cost (less than 15%) of traditional DR solution.

Cloud computing obstacles

In the well-known paper [2] Berkeley researchers named ten most serious obstacles that cloud computing concept and implementations have to overcome to become finally respectable, reliable, and dependable public service. We shall not go into details here. To summarize, we see a few important categories of obstacles:

- Reliability and availability of service
- Performance and scalability
- Privacy and security
- Software licensing.

Of these, we find security as the most serious one. There are two aspects of it: psychological and technological. Both should be treated with care. For many users it is difficult to overcome feeling that by moving sensitive data into the cloud they are losing control and that data leakage is only matter of time. Provider must be ready to answer concerns like this one and provide even financial guarantees that can be activated in case of failure to prevent incidents.

On the other side, technology is mature enough to enable adequate protection of sensitive data and applications. What could be questioned is provider's ability to implement security measures without holes and in an auditable way. We suggest potential user to take a careful look whether provider has adequate security policies in place and certificates like ISO 27001. For example: *Coming CE* and *Telekom* organizations and facilities passed this certification last year.

Cloud services market – global picture and global players

As it is well known, the biggest global cloud computing providers today are *Amazon*, *Google*, *IBM* and *Microsoft* along with rapidly growing number of providers of different sizes and market focus. On the other hand, *VMware* is a global cloud computing platform leader – building virtualization and cloud management tools for implementation and delivery of private, hybrid and public cloud services. Locally, on the Serbian market the first services of a kind are delivered by *Coming/Telekom Serbia* partnership.

Of service type by far the biggest is SaaS segment with *salesforce.com*, *Google* and *Microsoft* as the leaders. *SAP* and *Oracle* and hundreds of others are closely following this trend. Practically there is no application software company which is not offering at least cloud services for testing and training.

First domestic cloud for enterprise users – Coming CE and Telekom Serbia partnership

This comes as no surprise as *Coming* is recognized leader in virtualization in the region and so is *Telekom* in communication sector. Many of the services hosted in a traditional way in the past are now being transformed in cloud offering. Many virtualization projects, a few of which inside *Telekom*, represent a solid foundation for cloud computing. Very important for this development is strategic decision of *Telekom Serbia* to lean on partners of different kind in delivering innovative services to the market. In the cloud segment, *Coming CE* is the first to propose and materialize a new approach. This article aims to explain key elements of the approach and current offering.

At first services are particularly well tailored to small and medium businesses and ISVs, but the others will follow soon. Key differentiator from established global offerings is full customization to user needs and solid support from standard infrastructure services to complex outsourcing of all administrative and support duties.

Cloud for the enterprise – fully customizable solution

Generic cloud services – delivered through plain virtual machines – more or less uniform no matter what real usage could be, are just the basics no longer able to fulfill user needs. For enterprises, it would not be very serious to offer it as a solution. Besides customization, enterprise services must be carefully engineered and integrated with the existing user's infrastructure and application. Solid support and maintenance – all with reasonable price – are unavoidable part of the offer. This is the key of *Coming CE* offering to the regional enterprise customers. Let us mention some of the services delivered lately to the customers and currently under development:

- 1) *ITaaS* – enterprise outsources all IT operation to cloud provider (in this case *Coming CE*; examples: *Mona*, Belgrade; *Squadra*, Belgrade). This type of the solution is very compelling to small and medium enterprises, because they are not

- able to build and pay all technical staff they need for reliable operation of IT,
- 2) *Small infrastructure* through rental of plain virtual machines. In this case user takes the whole responsibility of IT infrastructure and application management. Provider, on the other hand, is responsible for reliable operation of cloud (virtual) infrastructure and connection endpoints,
 - 3) *Storage as a service* – service growing in popularity – enabling customers to store large volumes of data/documents reliably and securely in the cloud,
 - 4) *Backup as a service* – do remote copies of backups in the cloud. This type of service is very cost effective form of basic disaster recovery. With minimal effort provider can convert remote backup into fully functional DR solution,
 - 5) *Archiving* – besides remote copy of data, this solution includes applications too, for customer to be able to search archive and extract needed data/documents. In a way this can be treated as SaaS service type,
 - 6) *Development and testing of software* – very broad category which enables reliable and isolated development, test, and training of new or changed applications built in-house or by independent software vendor. For this purpose customer needs no infrastructure – only test data are needed and promotion of a test system to production can be done with ease,
 - 7) *Proof of concept solutions* – resembles much the previous case but differs in scope. Any new solution can be proven and stress test done without interrupting normal operation of customer's infrastructure. This is probably the preferred service for ISVs as is the previous one,
 - 8) *Public services* – so called services from demilitarized zone (DMZ) – this class of services needs full isolation from internal ones. Therefore it is quite natural to put them in the cloud. Channel between customer's productive (private) infrastructure and the cloud DMZ can be controlled, inspected and activated only when needed,
 - 9) *Internet sites and portals* – traditional segment for Internet service providers now can be freely mixed with DMZ services or isolated by customer request. There is no need any more to run them completely separately (even physically).
 - 10) *Batch processing in the cloud* – this is a natural way of processing for many advanced services like High Performance Computing or Data Warehousing (especially data mining), because cloud can scale well and provide massive parallel processing in a short time (and convert some complex analysis into real time or close to real time applications). We have in mind that in the cloud 1000 hours of one virtual machine cost the same as 1 hour on 1000 machines (not possible at all without cloud infrastructure!),
 - 11) This is just a short list of possible services in the cloud. Some of them are very innovative and were impossible or prohibitively expensive in the past.
- From the list it is obvious (having in mind economy and other factors too) that even the biggest enterprises could productively use cloud services. For the small ones, cloud finally offers economical alternative to traditional way of developing of IT infrastructure and services.

Conclusion

There are many testimonials of existing cloud computing users that evidence viability and economics of current services. Level of sophistication of cloud services is also improving. Now is the time for academic community to jump in and help in analysis to what extent early promises match with real achievements from the field. Besides, *Coming CE* and *Telekom Serbia* cloud services show clearly that cloud is not only for big players and that on the local (regional) market we can develop and put in production sophisticated cloud services. It would be interesting to predict and analyze the social consequences of this, especially in public sector for which IT infrastructure can be totally transformed by community cloud solutions.

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