UNIVERSITY OF LJUBLJANA
FACULTY OF ECONOMICS

MASTER'S THESIS

ANALYSIS OF THE IBM BLUEMIX PLATFORM IN A CLOUD

Ljubljana, January 2016 SADULOV ERMIN

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INTRODUCTION

If we look back to the industrial revolution and its impact to the world economy, the revolution itself did not take place overnight, but through waves of changes. Moving forward to the adoption of the Internet, the Internet has also developed through many waves of changes. Cloud computing has the great potential to be the following disruptive wave.

In recent years, the importance of affordable access to reliable high-performance hardware and software resources and avoiding maintenance costs and security concerns has encouraged large institution managers and stakeholders of information technology organizations and small enterprises to reorient their overall IT strategies and to shift to cloud computing (Jula, Sundararajan & Othman, 2014).

Cloud Computing has become one of the most talked about technologies in latest times and has acquired great attention from media as well as experts and analysts because of the opportunities and chances for organizations improvement. Organizations are looking to gain a better understanding of what cloud computing is, where its application makes sense in their world, and whether it's web-based infrastructure complies with strict requirements (both, internal and regulatory) for data security and process in an increasingly globalized industry. (Bowers, 2011).

With technology constantly changing, there is a need for faster, more available and accessible information. Organizations are finding that Platform as a Service (hereinafter: PaaS), which is one of the Cloud Computing service models besides Software as a Service (hereinafter: SaaS) and Infrastructure as a Service (hereinafter: IaaS), is an economical alternative to the traditional solutions. Organizations can move quicker as the need arises and can respond sooner to the technology changes. Information Technology (hereinafter: IT) people can concentrate on developing applications, tweaking existing applications, and providing support services instead of spending and wasting time on the hardware aspects of IT. This model is driving a new era of mass innovation, and that is one of the reasons why I have chosen this topic for my master thesis (Fanning & Centers 2012).

IBM Bluemix platform is the newest cloud solution provided by IBM that offer a great place for developers to develop, build, run and scale their web or mobile applications in the cloud. Bluemix is a PaaS offering based on the Cloud Foundry open source project that promises to deliver enterprise-level features and services that are easy to integrate into cloud applications. Main purpose of my master thesis is to find out what this platform actually means for developers and how it changes the way developers create applications, in which industries the platform was used for building applications, some successful stories and what are IMB's future plans considering the platform.

For that reason the main goals of this master thesis are focused on:

- To acquire an understanding and extra knowledge about Cloud Computing and PaaS technologies reviewing scientific literature in the previous mention fields;
- To understand the main purpose and usage of the IBM Bluemix platform;
- To make an analysis of the IBM Bluemix Platform, by explaining the main platform's service, concepts and architecture;
- To see how future applications can be build;
- Creating Strengths Weaknesses Opportunities and Threats (hereinafter: SWOT) Analysis by pointing internal and external factors affecting the platform;
- To observe some applications build in the IBM Bluemix platform – successful stories;
- To find out in which industries the platform showed greatest impact;
- To integrate theory and practice while analyzing the Platform.

When it comes to structural definition, the master thesis is separated in three different sections. In Section I, I am defining the Cloud Computing Approach describing the features of the technology, some components and essential characteristics, history and evolution. Then am giving briefly explanation on the Cloud Computing Deployments Models, and paying more attention on the Cloud Computing Service Models. In the second section I am considering the characteristics, features and overview of PaaS, presenting some facts about PaaS in the future and some security issues affecting the PaaS- as a service model.

The third section actually is the main part of the thesis, where I explain how exactly the IBM Bluemix platform works, what kind of services are available, how organizations and developers can create their own applications, steps for creating simple applications and in which way they can be used by their final users. Also for better understanding the platform I conducted a semi-structured interview in the IBM Innovation center in Ljubljana, where I got all necessary information and additional documentation for better understanding the IBM Bluemix platform. Obtained findings along with the documentation helped me for creating a SWOT analysis where I am focusing on some external and internal factors that may affect organizations and I am identifying platforms strengths, weaknesses, opportunities and threats.

1 CLOUD COMPUTING

Cloud Computing is noted as the next big step in the evolution of the information technology resource distributed systems, which basic concept is to separate applications from the operating systems and the hardware that runs everything, with the ability to provide organizations and end users flawlessly access to those applications (Truong, 2010). Fundamentally cloud computing allows users to access applications that actually reside at a location other than their computer or other Internet - connected device which means that organizations can approach the applications from everyplace in the world on demand through any web browser (Velte, Velte & Elsenpeter 2009).

Furthermore cloud computing technology is about separating computing resources from the remotely hosted hardware and software. On that way users may be concerned only with the service and almost never with the requirements and the needs of the platform like monitoring, maintenance and the cost of the hardware and the data center space. In other words cloud computing is (Linthicum, 2009, p.23):

- Things users do not posses
- Things users do not have to maintain
- Things user do not see and touch
- Things users pay for as a subscription fee or maybe get for free
- Expandable on demand
- Reducible on demand

It the latest time this new technology has got great attention from the media as well as from many well-known analysts and experts (Bowers, 2011), offering countless benefits, advantages and opportunities to its end users such as: the potential to change organizations business processes, deliver real-time applications, lower IT costs, access to ubiquitous storage of data and information, unlimited computing power, and market information mobilization (Oliviera, Thomas, & Espandal, 2014).

Moreover cloud computing promises to cut operational and capital costs and more important to let IT departments be more focused on strategic projects, innovation and growth instead of keeping the datacenter running. Additional benefit of cloud computing is that another (third party company) hosts users application or suite of applications, which means that they handle the cost of servers and manage the software updates, and users do not need to buy the servers or to pay for the electricity to power and cool them which will result in fewer capital expenditures (Velte et al., 2009).

1.1 Defining Cloud Computing

Cloud computing is perceived as the next step in the evolution of IT enabling organizations to get directly access to applications from anywhere in the world on demand. Cloud computing is a relatively recent term even though it was built upon some existing concepts. There are various definitions of cloud computing where each author defines this technology on different way. Some of those definitions are shown in Table 1 (Truong, 2010):

Table 1. Definitions of Cloud Computing

Definition	**Reference**
The distribution and usage of applications and resources of a network environment to get work completed without worry about ownership and management of the network's resources and applications.	Scale, 2009
User's ability to connect to software and data in the cloud on the Internet rather on their hard drive or local network.	Hammond, 2008
An approach of computing where extremely scalable IT-related capabilities are delivered as a service across the Internet to multiple external customer.	Gartner, 2008
Virtualization of resources that are fully managed and maintained by themselves.	Hartig, 2008
A sort of parallel and distributed system consisting of a group of inter-connected and virtualized computers that are dynamically provisioned and presented as one or more unified computing resources based on Service Level Agreement established through negotiation between the service provider and consumers.	Buyya, Yeo, Venugopal, Broberg & Brandic, 2009
Cloud computing embraces cyber-infrastructure, and builds upon virtualization, distributed computing, grid computing, utility computing, networking, and web and software services.	Vouk, 2008
Cloud computing is developing as a powerful computing paradigm with its purpose of efficient resource utilization and contribution to Green Information Technology.	Nanath,& Pillai, 2013

Source: D. Truong, *How cloud computing enhances competitive advantages,* 2010, p.60.

Authors of these definitions view cloud computing from different perspectives, where none of them provides an adequate and direct view of this new disruptive technology where many substantial features are missing. On the other hand the most adequate, cited and broad definition that received industry-wide acceptance was composed by the National Institute of Standards and Technology (hereinafter: NIST) (Mell & Grance, 2011):

"Cloud computing is a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (for example, networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service-provider interaction." Based on standard material presented by NIST, cloud computing is composed of **five main characteristics** (on-demand self-service, broad network access, resource pooling, rapid elasticity and measured service), **four deployment models** (private clouds, hybrid clouds, community cloud and public cloud) and **three service models** (SaaS, PaaS, IaaS).

1.2 History of Cloud Computing

When we think about cloud computing technology, we may think of situations, products, services and ideas that started in the 21st century which is not exactly the whole truth. The birth of cloud computing is really tied to the technological revolution and the birth of the internet, furthermore cloud computing, especially clouds as a concept have been around for quite some time. The idea of computing in a "cloud" traces back to the origins of utility computing, which is a concept that computer scientist John McCarthy publicly proposed in 1961 (Erl, 2013). There are quite a few debates and stories from where precisely the term "Cloud Computing" came from, but the most conventional one is that it was from the diagrams of Clouds used to represent the Internet in IT network and infrastructure designs, where the data and applications are hosted in the Cloud and the end user can access them from any location (Stark, 2012).

Cloud computing can trace it roots back in the **1950s** when organizations started using large-scale mainframe computers which were massive, occupying the entire room. Back then organizations were not in a position to afford computer for each employee because of the huge cost of buying and maintaining mainframes. The solution for that problem was "time sharing" in which multiple users shared their access to a single mainframe. The term "time sharing" stands as the premise of cloud computing (Coter, 2012).

The next happening in cloud computing history came in **1969** when the American computer scientist J.C.R Licklider helped to develop the Advanced Research Projects Agency Network (hereinafter: APRANET), the so-called predecessor of the internet. He had a vision for every person in the world to be interconnected and to access programs and data at any site from anywhere, which exactly what cloud computing allows toady to its users (Smye, 2014).

One year later, in the **1970s** IBM released an operating system (hereinafter: OS) called Virtual Machine (hereinafter: VM) that allowed admins to have multiple virtual systems or Virtual Machines (hereinafter: VMs) on a single physical mode. Using the virtualization software become possible to execute one or more OS simultaneously in a remote

environment. This system took back the 50s "time sharing" model to the next level and permitted multiple district computing environments to reside at one physical environment.

After two decades in **1990s** the internet went into a great phase of growth and began to be used from many international organizations and was also present in many households through cyberspace. Correspondingly telecommunication organizations started offering virtualized private network connections which meant it was possible to allow for more users through shared access to the same physical infrastructure (instead of building physical infrastructure to allow users to have their own connection). This innovation allowed better network balance and greater control over bandwidth usage. In the meantime, virtualization for Personal Computer (hereinafter: PC) based systems started in earnest, and as the Internet became more accessible for the users, the next logical step was to take virtualization online (Coter, 2012).

In the beginning of **2000s** with the rise of internet usage and the rapidly development of cloud computing many organizations saw opportunity to invest in this new way of working. Cloud computing had the right environment to take off, as multi-tenant architecture, highly prevalent bandwidth and universal software interoperability standards which were developed in this time. In 1999 Salesforce became the first web site whit the concept for delivering enterprise applications via simple web site. It was the first to deliver applications and software over the internet (Modi, 2014).

In the following years there were huge improvements in the cloud computing technology including many innovation, advanced services and opportunities such as in **2002** when Amazon created "Web Services" providing an advanced system of cloud services from storage to computation. Web Services was a platform for creating Web solutions that were specially designed for developers and web site owners where they could build applications and tools allowing them to incorporate many of the unique features of Amazon into their web sites which was for free of charge. And in the **2006** Amazon went one step ahead introducing Elastic Compute cloud (hereinafter: EC2) and Simple Storage Service (hereinafter: S3) as a commercial web service that allows small organizations and individuals to rent computers on which they could run their own computer applications. This introduced the Pay As You Go (hereinafter: PAYG) model to both users and the industry as a whole, and it has fundamentally become standard practice now (Salesforce, 2012).

The ideology of cloud computing increased popularity in 2007, thanks to the fast development of communication channels and a growth in the geometric progression organizations needs to expand their information systems (Arutyunov, 2012). In **2007** Salesforce.com expanded its efforts with Force.com. This PaaS let developers to build, store and run all of the apps and websites they needed to run their business in the cloud (Salesforce, 2012).

The emergence of the term began to be discussed in 2008 at one of the thematic Internet conferences. As an outcome of these discussions, there were proposed different versions of

cloud computing. 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 (Arutyunov, 2012). In **2008** Google launched the Google App Engine which was the entry of the first pure play technology organization into the Cloud Computing market. That was clearly a major step towards wide spread adoption of cloud computing. The Google App Engine brought low-cost computing and storage services which were among the lowest in the market.

In **2009** Google Apps allowed people to store documents within the cloud. In the same year Microsoft made a great step launching Windows Azzure (now Microsoft Azzure after 25 March, 2014) for building, deploying and managing applications and services through a global network of Microsoft-managed datacenters, solidifying the cloud as a market that the tech giants would be expanding and competing in it (Raghupathi, 2011).

1.3 Cloud Computing Evolution

Cloud Computing has developed through a number of phases including (Figure 1): Grid and Utility Computing, Application Service Providers, SaaS and now Cloud Computing (Stark, 2012).

Grid computing includes connecting of all the different computers merging their processing power to solve a specific problem. Each participant/user in a grid is referred as a node. With this configurations users can use other computer resources to solve problems that single computer is not capable of, including large-scale and complex calculations (such as circuit analysis or mechanical design). Some of the benefits that grid computing offers are (Bidgoli, 2011):

- cost savings
- improved reliability
- parallel processing nature
- scalability

Utility computing on the other hand can provide services on demand where users pays for computing or storage resources on an as-needed basis, similar to paying for utilities such as water, electricity, heating etc. Convenience and cost savings are two main advantages of utility computing, but this service unfortunately, does have drawbacks in the areas of privacy and security. Theft or fraud of data is a concern because the service is outside the organization's location, and cannot be controlled by the organization itself (Bidgoli, 2011).

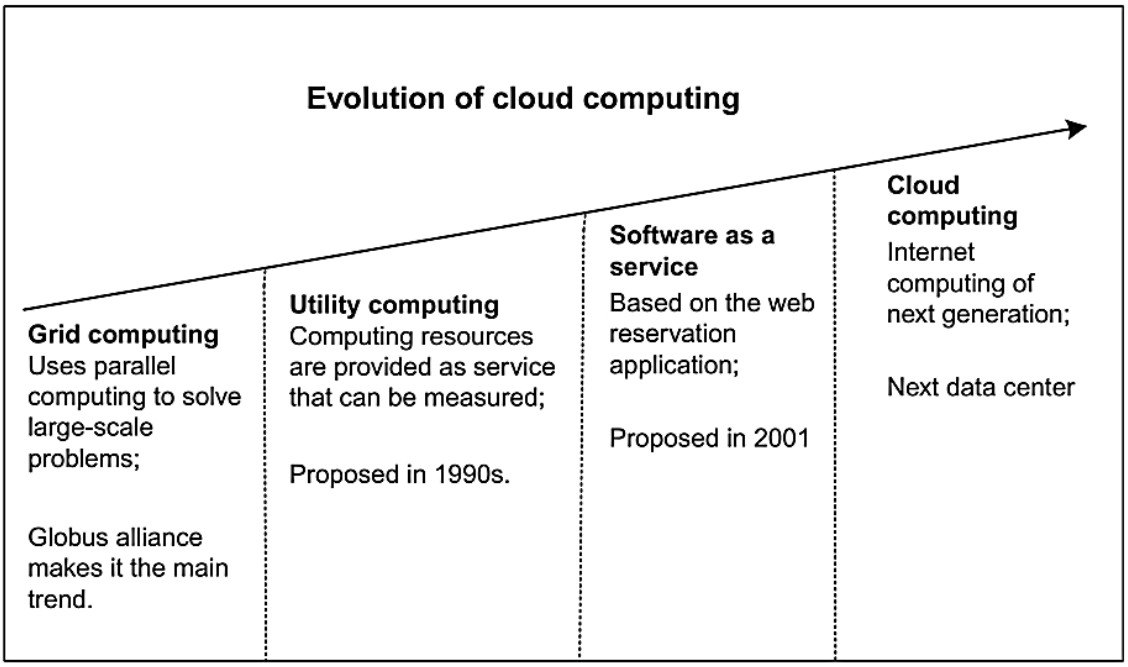
Application Service Providers (hereinafter: ASP) took the next step in creating the first wave of Internet-enabled applications that provide access to software and services for a fee.

An ASP would license a commercial software application to multiple customers which made it possible for organizations to outsource some of their IT needs, saving those organizations the time and money spent on everyday IT management (Stark, 2012).

SaaS or on-demand software, represents a model for ASPs where third party delivers software to users for a fee. The software might be for short-term or long-term use. With this delivery model, users do not need to be concerned with new software versions, updates and compatibility problems because the ASP offers the most recent version of the software (Bidgoli, 2011).

In the end **cloud computing** as previously explained is a platform incorporating many recent technologies under one platform including all previous mentioned platforms, where variety of resources can be provided to users over the internet (Bidgoli, 2011).

Figure 1. Major evolution process of cloud computing



Source: T.Wenhong & Z. Yong, *Optimized Cloud Resource Management and Scheduling: Theories and Practices*, 2014, p.4.

1.4 Essential Characteristics

According to Mell & Grance (2011, p.2) there are 5 essential characteristics of cloud computing which are listed below.

1. **On demand self-service.** A user who needs computing resources such as e-mail, Central Processing Unit - time (hereinafter: CPU), network storage, virtual storage, development platform or software service, can provide them directly in an automatic way without requiring human interaction with each service provider.
2. **Broad network access.** The broad network access provides extreme utility and enhances the scope of the benefits provided by cloud computing where users can access capabilities over the network mostly over the internet through different type of devices (mobile phones, tablets, laptops and workstations).
3. **Resource pooling.** Computing resources provided by the cloud service providers are pooled together in order to serve and to be used by multiple consumers. This is achieved by using "multi – tenancy" model where the resources are shared by large pool of users or by virtualization where virtual machines represent the physical hardware. This is made possible by having different physical and virtual resources dynamically assigned and reassigned according to consumer demand. Consumers don't have control and exact information about the location, structure and origin of the resources they are using which means that they are unable to tell the exact location where their data is supposed to be sorted. Pooling resources together enables users to enjoy economies of scale and specialization of resources.
4. **Rapid elasticity.** Computing resources can be rapidly and elastically provisioned, in some cases automatically where the users can quickly scale up resources whenever they need them and quickly scale down once there is no more need of them. To the user availability for provisioning the resources often appear to be unlimited and can be purchased any time in any quantity. This ensures that resource accessibility can rapidly rise in order to meet highest requirements at any time and can then come down to the daily requirement by releasing resources that are not required (Khalid & Shahbaz, 2013).
5. **Measured services.** Cloud computing resource usage can be measured, monitored and controlled providing transparency for both, the provider and the individual user of the utilized service. Cloud systems can control and optimize resource usage automatically by leveraging metering capability, which enables to control and optimize resource use. Typically this is done on a pay-per-use or charge-per-use basis.

1.5 Cloud Computing benefits and drawbacks

Cloud computing is now expanding like never before and it's adopted by many organizations of all shapes and sizes. Industry experts predict that this trend will continue to grow and develop more and more in the next few years. Cloud computing offers many benefits both for its users and o where they don't have to spent time supporting the infrastructure or to have additional knowledge required do develop and maintain the infrastructure. Instead of that all cloud computing users can focus on their core activities (Viswanathan, 2013). Cloud computing is a new and disruptive technology, nevertheless like all technologies it comes with both benefits and drawbacks (Aljabre, 2012).

Miller (2008, p.25-28) lists the following benefits of cloud computing technology:

- Lower Computers Costs
- Improved Performance
- Lower IT Infrastructure Costs
- Fewer Maintenance Issues
- Lower Software Costs
- Immediate Software Updates
- Better Computing Power
- Better Data Safety
- Better Compatibility Among OS
- Easier Group Cooperation
- Complete Access to Documents
- Unlimited Storage Capacity
- Newest Version Availability

One of the major benefits of cloud computing is that users don't have to buy expensive computers to run cloud based applications because those applications runs in the cloud not in the computer desktop or PC.

For that reason desktop PC doesn't need to have extra processing power or additional hard disk space, which can allow users to purchase inexpensive computers with more efficient processors, less memory and smaller hard disks. Moreover users will see better performance on their computers and devices because they will run faster with fewer installed programs and additional memory. Organizations especially the larger ones could lower their IT infrastructure costs for the reason that there is no need of additional investment in large number of powerful servers because they can use the computing power of the cloud to enhance the internal computing resources (Miller, 2008).

Less necessary hardware in the organization will lower maintenance costs immediately and basically there will be no maintenance of software because cloud applications are based elsewhere so there's no software on the organization's computers for the IT staff to maintain.

Additional software related advantages to cloud computing is that there are no issues of software cost where organizations don't have to invest in separate software packages for every single computer in the organization because software can be accessed form the cloud by the organizations employee. Also updates of the web based applications occurred automatically and are accessible the next time user logins in to the cloud. On that way users don't have to concern about keeping software up to date, because "someone else" takes care of that (Miller, 2008). As a result, the "what version of the software do I need" syndrome is eliminated (Bidgoli, 2011, p.23).

Cloud computing affords users to have an unlimited capacity of memory storage and they don't have to worry about their PC memory storage and data loss because the data in the cloud is automatically duplicated, so nothing is ever lost even if there is a situation of disk or computer crash. Besides, cloud computing technology is able to improve compatibility between operating systems, where users of OS can still be connected to the cloud and be able to share documents with users from different OS.

Cloud computing affords the capability for multiple users to collaborate on different types of documents and projects in the cloud, where each user can access to the project documents simultaneously. If one user edits or correct the document it will be automatically reflected in what the other users see on screen. Users can have universal access to their documents even if they forgot to bring the documents with them when they travel they will be always "in the cloud" and can access them anywhere, all they need is internet connection and computer.

In spite of its many benefits, mentioned above cloud computing has also its drawbacks and as a technology it comes with its set of problems and inefficiencies too, by which organizations especially smaller ones may be affected. Linthicum (2009, p.31-32) identify few drawbacks of cloud computing which are:

- Security
- Privacy
- Control
- Cost
- Openness
- Compliance

Security and privacy are the biggest issues when it comes to cloud computing. By adopting cloud computing infrastructure organizations are giving away sensitive and confidential private data and information. Data and information are not under organization's direct control and the leakage of private information may put the organization existence at risk (Tsagklis, 2013). Even while cloud computing providers support encryption, user name and password–level security, some management organization's still don't want to place important information in the clouds these days. Also cloud service vendors have to assure organizations

that they will protect their data from unauthorized users and guarantee their privacy. However cloud computing is improving in security and privacy as time goes on and probably there is no need for panicking that important data and information can be lost.

Even though there are many cost benefits regarding to cloud computing, which were previously explained, there are also many instances in which this new technology is not cost affective. Sometimes is more expensive to operate applications in clouds because of the cost of porting, special and additional features that application may require and so on, instead to operate in on premise platforms. On premise platforms is an IT resource that is hosted in conventional IT enterprise within an organizational boundary which does not specifically represent a cloud is considered to be located on premises of the IT enterprise, or on premise for short (Erl, 2013).

Openness means that cloud platforms may be proprietary in nature, and once organization had written its system using provider's language and architecture might be found cost prohibitive moving that system to other cloud providers or back into organization. Sometimes cloud computing providers may not provide the logging and auditing features that organization needs to stay compliant with, which will lead to compliance issues. But the trend is that cloud computing providers are getting better in this, understanding what the issues are, proposing compliance solutions before moving forward.

1.6 Cloud Computing Deployment Model

Based on the standard material presented by NIST there are 4 different cloud computing deployment models: public clouds, private clouds, community clouds and hybrid clouds, established primarily from the size of the network, the number of users and the security of access. Now let's briefly walk through each of these models.

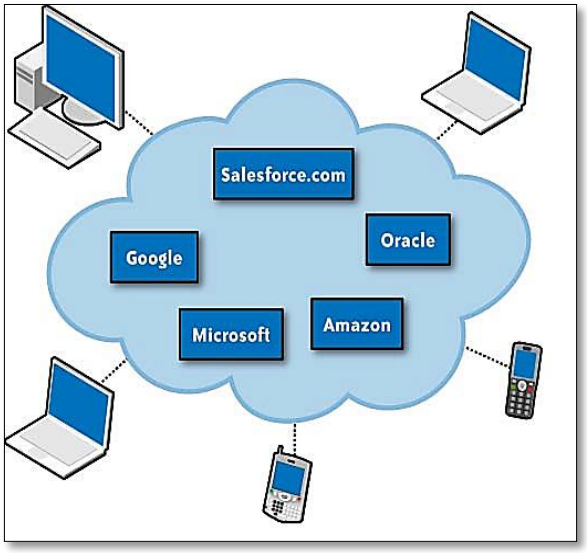
1.6.1 Public Clouds

Public clouds or external clouds (Figure 2) define the traditional meaning of cloud computing technology, where resources are dynamically provisioned over the internet, via web applications or web services coming from a third-party provider who shares scalable, dynamically available and usually virtualized resources. In a public cloud, security management and day-to-day operations are relegated to the third party vendor, who is responsible for the public cloud service offering.

The vendor has the responsibility to host, manages and operates the public cloud from one or more data centers and bills its users on PAYG basis. The service is offered and shared to a multiple users over a common infrastructure. Furthermore users are not aware of the physical

location where their software is running or where the data center is located, and with who they share the public cloud (Mather, Kumaraswamy & Latif, 2009).

Figure 2. Public Cloud



Source: T. Mather et.al., *Cloud Security and Privacy: An Enterprise Perspective on Risks and Compliance*, 2009, p.24.

One of the advantages of public clouds is the utility pricing where the users pay only for the resources they use which allow them to turn on more cloud services when there is a need to scale up and vice versa to turn off cloud services to scale down. Another benefit is elasticity where the users have unlimited pool of resources at its disposal and can configure its software solutions to dynamically increase or decrease the quantity of necessary computing resources to handle peak loads. On the other hand security and control are the biggest issues concerning public clouds because the computing infrastructures are shared between various organizations. Users must be sure that the vendor will meet their Service Level Agreement (hereinafter: SLA) for performance and uptime, and their confidential and private data and information will be protected and secured.

Also there may be lack of limited configuration because public cloud vendors have standard set of infrastructure that meet the need of the general public, and sometimes that standard infrastructure may not meet the necessities for solving user's certain problem (Kavis, 2014, p.53-55). Instead of using public clouds, users may consider to move to a private cloud. Private clouds apply similar principles as public clouds did. The extra advantage is that private clouds are deployed on a proprietary basis and are considered to have higher level of security and privacy (Turner, 2013).

1.6.2 Private Clouds

Private clouds or internal clouds are designed and build for a single user to support specific functions that are critical for the organizations success. A private cloud might or might not be hosted on the user's premises. Correspondingly, if a user implements its own private cloud on premise it may not achieve the financial benefits that service providers of private cloud can offer because there will be higher upfront costs for buying, building and managing their personal – private cloud (Williams, 2012).

The advantage of a private cloud is that it addresses the disadvantages of public cloud which were previously defined. Privacy, security and control are on the highest possible level since data is not shared among other users. Furthermore the risk about data ownership is minimalized because of the single-tenant nature of the deployment model. For on premises private cloud implementations, cloud service users have control of their own destiny because they could still manage the data center and are flexible to procure any hardware configuration they need. On the other hand hosted private cloud users are still dependent on their provider, but their resources are not shared among other users. However, by leveraging private clouds some of the core and important advantages of cloud computing such as rapid elasticity, resource pooling, and PAYG pricing may be given up.

Table 2. Private vs. Public clouds

	Private	**Public**
Location	On premise	Of premise
Connection	Connected to a private network	Internet-based delivery
Scale direction	Scale out (applications)	Scale up (users)
Maximum scale	100-1000 nodes	10000 nodes
Sharing	Single tenant	Multi-tenant
Pricing	Capacity pricing	Utility pricing
Financial center	Cost center	Revenue/Profit center

Source: J. Rhoton, *Cloud Computing Explained: Implementation Handbook for Enterprises*, 2010, p.27.

Yes, users do have actual access to a shared pool of resources, but those resources are limited to the amount of infrastructure that is bought and managed internally. This drives up costs and reduce agility because all this infrastructure have to be managed and controlled by internal resources and even if there is capacity that is not fully used it have to be paid at the end (Kavis, 2014, p. 55-56).

To sum up, private cloud leverages some of cloud computing aspects that were mentioned above. Comparing to the public cloud (Table 2), the private cloud is typically hosted on premise, connected only to a private network and scales "only" into the hundreds or possibly thousands of nodes, connected mostly to the organization through private network links. Multi - tenancy is also minimized because all applications and servers are shared within the organization. Considering the costs private clouds can bring higher costs to its users because of capacity pricing which mean that users maybe should consider another option that will provide them higher security and lower cost in the same time (Rhoton, 2010).

1.6.3 Community Clouds

In a community cloud model, organizations that have common mission, utilization needs, requirements, polices and concerns create a community and share cloud computing infrastructure among community members only. Just like the private cloud, community cloud can be owned by organization or can provide the required resources and infrastructure from a third-party service provider whose location is independent of the community premises (Jula et al., 2014). Example of such communities can be: a U.S. federal agency cloud with stringent security requirements, or a health and medical cloud with regulatory and policy requirements for privacy matters (Williams, 2012).

High security and support, lower costs and divided expenses between community members are the most significant advantages of a community cloud (Jula et al., 2014).

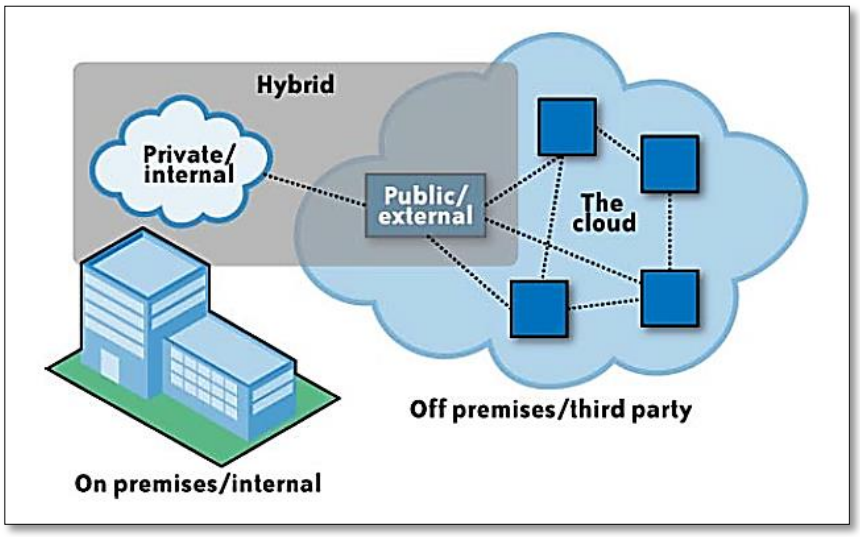
1.6.4 Hybrid Clouds

A hybrid cloud deployment represent a combination of resources of two or more separate cloud computing infrastructures (public, private or community) which endure distinctive entities that are bound together by standardized technology, that allows application and information transportability. For example hybrid cloud users (Figure 3) can use public cloud where they can run applications which does not possess very sensitive data and to get all benefits of cloud computing like resource pooling and rapid elasticity, and in the same time if there is a high risk of data ownership and privacy in public cloud they can simply leverage to private cloud (Kavis, 2014).

Furthermore an organization may decide to use a public cloud service for day-to-day computing operations, but the critical and vital organizations data would store in its own personal data center. There are many reasons for choosing hybrid clouds by organizations. One of them may be that organizations have been already made considerable investments in the infrastructure essential to provide resources in-house. Additional reason may be

addressed to the security issues of the public cloud, which is the reason why private clouds have appeared as first choices for organizations (Khalid et al., 2013).

Figure 3. Hybrid cloud



Source: T. Mather et.al., *Cloud Security and Privacy: An Enterprise Perspective on Risks and Compliance*, 2009, p.25.

1.7 Cloud Computing Service Models

The cloud can provide users with numerous service models and services. They include (Linthicum 2009, p.38-58):

- **Application-as-a-service** (hereinafter: AaaS)**.** Any type of application which is distributed over the web platform to an end user through a browser. Applications can be sold by subscription but generally free of charge, generating revenue through advertising or other ways;

- **Database-as-a-service** (hereinafter: DbaaS)**.** DbaaS offers the capability to leverage the services of a remotely hosted database which is shared among different users. Service allows users to do everything they are supposed to do with a local data base like: creating tables and setting different types of relationships among them, as well as adding, loading or deleting data. DbaaS providers provide not only basic database functions but also brand specific services such as Microsoft, Sybase, and Oracle;

- **Information-as-a-service** (hereinafter: IfaaS)**.** A standardized access of data which provides users to have access to any kind of remotely hosted information in real time;

- **Integration-as-a-service** (hereinafter: InaaS)**.** A service model that takes the functionalities of system integration and puts them into a cloud. This service enables real time exchange of information and data between organizations and third parties;

- **Management/governance-as-a-service** (hereinafter: MaaS)**.** Affords the capability to manage one or few cloud services, generally simple things such as: resource utilization, topology, uptime management and virtualization;

- **Process-as-a-service** (hereinafter: PraaS). PraaS refers to mechanisms that link many resources together, which can be hosted either remotely or within the same cloud computing resource, for creating organizations processes and solutions;

- **Security-as-a-service** (hereinafter: SeaaS)**.** An ability to deliver security services over the internet like anti-viruses, log management and even more sophisticated services such as identity management;

- **Storage-as-a-service** (hereinafter: SaaS)**.** A business model that allows smaller organizations or individual users to rent storage spaces from a large organization. Users can expand the amount of disk space available according to their requirements, and pay only for what they use. Maintenance of the hardware is eliminated because it is part of the service as well as disaster recovery system;

- **Testing-as-a-service** (hereinafter: TaaS)**.** Ability to test other cloud computing applications, internal enterprise systems or web site without requiring hardware or software resources within the organization.

However, a commonly agreed upon framework for describing cloud computing services goes by Software Platform Infrastructure (hereinafter: SPI), which stands for the **three major services** (Table 3) provided through the cloud (Mather, 2009):

- **S**aaS
- **P**aaS
- **I**aaS

Each cloud service model provides a level of abstraction that decreases the efforts required by the service user to build and deploy systems. From the Table 3 we can see the classification of the Cloud computing service models, types of services they provide for their users, flexibility, difficulty level for usage, and in the last column some scales and examples of providers offering cloud services.

Table 3. Service type classification of Cloud computing

Classification	Service type	Flexibility/ Generality	Difficulty level	Scale and example
IaaS	Basic computing, storage, network resources	High	Difficult	Large, Amazon EC2
PaaS	Application hosting environment	Middle	Middle	Middle, Google App Engine
SaaS	Application with specific function	Low	Easy	Small, Salesforce CRM

Source: T.Wenhong & Z. Yong., *Optimized Cloud Resource Management and Scheduling: Theories and Practices*, 2014, p.11.

1.7.1 Software as a Service

SaaS refers to a software or application hosted on a remote server, which provides a complete stuck of cloud services that are directly reachable by the end – users over the internet. Unlike traditional applications that users install on their computers or servers, the SaaS provider possesses the software and runs it on computers in its own data center (Rhoton, 2010). According to Jula et.al (2014) **a service is** a mechanism that permits access to one or more functionalities, where the access is applied with constraints, policies, rules, and specifics of providing the functionalities identified by the service description, through a previously prescribed interface. NIST defines SaaS as (Mell & Grance, 2011):

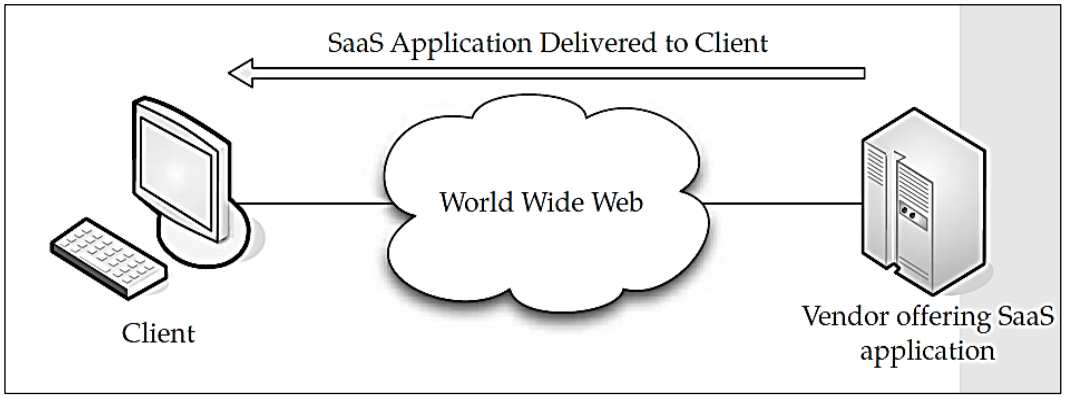
"The ability provided to the end user to use the provider's applications running on a cloud infrastructure. Those applications can be reached from different user devices like thin client interface (such as a web browser) or a program interface. The user don't have to control or manage the underlying cloud infrastructure containing storage, servers, OS, network or even separate application functionalities, with the attainable exclusion of limited user-specific application configuration settings."

From the NIST definition we can consider that SaaS users don't have to deal with software and hardware management either to install anything on their premises or to pay substantial up-front costs to purchase the software and obligatory license, because everything is already supported by the third party i.e. the provider of the service.

The SaaS provider builds applications which are accessible to numerous users through a web browser or a program interface. User just has to access the application website and can

immediately use the application or ant type of applications, which in the most cases can be customized for their own needs. All they will need is to have an internet connection and a computer device (Figure 4).

Figure 4. SaaS Model



Source: T. Velte et al., *Cloud Computing: A Practical Approach,* 2009, p.174.

On the other hand all specific details and features of each user's application are maintained in the service provider's infrastructure in a central location (Buyya, Vecchiola & Selvi, 2013).

Example for simple explanation of SaaS can be the web-based email service for instance Google (Gmail). Each mail service meets the basic conditions: the provider of the service (Google) which host all data and programs in a centralized location, providing users with access to the data and software, accessed over the internet. Even this is a simple example of SaaS, the same logic and architecture can be applied to wide – range of applications (Velte et al., 2009).

The key characteristics of SaaS software are the following (Rittinghouse & Ransome, 2009, p.53):

- One-to-many application delivery model opposite from the traditional one-to-one model;
- Accessing applications remotely via the internet;
- Access to a commercially available software from centralized location and Network based management;
- Centralized improvements and patches updates which prevent any demand for downloading and installing by a consumer.

The SaaS model provides applications for a wide range of users, which describe SaaS as "one-to-many" software delivery model. Beside the web-based email, some other typical SaaS applications are Enterprise Resource Planning (hereinafter: ERP), Customer

Relationship Management (hereinafter: CRM), Supply Chain Management (hereinafter: SCM), accounting, human resources, web analytics, web content management, payroll, video conferencing and other common business software. Organizations choose SaaS solutions for their non-core functions, for a reason because they don't have to provide maintenance, support the application infrastructure or even to hire human resources, all they have to do is to pay for a subscription fees and simply use the service over the computer network (Kavis, 2014).

SaaS applications can be divided into two major categories (Velte et al., 2009):

• **Line of business services**

Business solutions provided to organizations that are sold via subscription service, and users pay for their usage (ex. ERP).

• **Customer-oriented services**

Services offered to a general public, also based on a subscription fee but mostly of the time accessible for free (ex. Email).

There are few benefits of a SaaS model (Mather et al., 2009; Sylos, 2013):

- the third party (service provider and software vendor) hosts and manages organization's applications, which reduce the cost of application software licensing, servers, infrastructure, and hiring staff required to host the application indoor;

- a typical SaaS model can run over the existing infrastructure in the organization which does not require to invest in an additional hardware;

- SaaS applications can be used with ease since they already come with samples, explanations and best practices inside it. User can access the SaaS application via web browser, all they need is internet connection and computer device;

- SaaS allows software vendors to have completely control over their software. They forbid copying and distribution and furthermore facilitate the control of all derivative varieties of their software;

- SaaS solutions are naturally multitenant, scalable and are integrated with other SaaS offerings. Multitenancy is a SaaS feature which enables providers to centralize and sustain the effort of managing big hardware infrastructures, maintaining and upgrading applications and optimizing resources by separating the costs over the large consumer base. On the other hand user's costs constitute a minimal part of the usage fee paid for the software (Buyya et al., 2013);

- Users don’t have to deal with constant re-installing or re-configuring to get the latest version of the service because SaaS providers automatically upgrades the solution and it becomes accessible for the consumers instantly;

- In SaaS the application is already installed and configured by service provider, which allows user to provision the server for an instance in cloud and to be able to use the application in a couple of hours. These reduce time spent in installation and reduce issues and problems that may occur during the software development.

1.7.2 Infrastructure as a Service

IaaS model can almost be seen as an opposite of SaaS model, where the service provider delivers the necessary hardware resources and the underlying infrastructure required to run a user’s applications. Some service providers who have built their business on colocation services tend to offer IaaS cloud service models because they have already made significant investments in networking infrastructure designed to provide high-bandwidth connectivity for different kinds of services.

That let users to take benefit of these huge scalable networks and data centers as a part of the cost associated with building and managing their own infrastructures (Williams, 2012). According to Amin et al. (2014), **infrastructure** refers to underlying physical resources that are necessary for a system to perform its functionalities. In information systems this resources can comprise: storage, network equipment, processors and in some situations OS and database management systems.

NIST define IaaS as (Mell & Grance, 2011):

*“*The ability provided to the end user to provision storage, networks, and other fundamental computing resources being able to deploy and run arbitrary software, including OSs and applications. The user don’t have to control or manage the underlying cloud infrastructure but has direct control over OS, storage, and deployed applications. There may be limited control of select networking components like host firewalls.”

IaaS is centered on a model of service delivery that provides established, standardized infrastructure particularly optimized for the user’s application which differs from the traditional outsourcing that requires infinitive negotiations, extensive due diligence and complex, long contract vehicles. Provider-owned implementations typically include the following resources (Rittinghouse & Ransome, 2009, p.35):

- **Computer hardware** - the physical elements of the computer system
- **Computer network** - network which will allow data exchange between devices

- **Internet connectivity** - connects individual computer devices to the internet
- **Platform virtualization environment** - a platform for running client-specified virtual machines
- **SLA** - a service contract where the services are properly defined
- **Utility computing billing** - a provision model where service providers charges consumers on based on their resource usage, a consumer is charged only for the resources consumed

The main technology used to provide and implement IaaS solutions is hardware virtualization. It is a technology where one or more interconnected virtual machines regulate the distributive system on top on which applications are deployed and installed. Moreover VMs compose the atomic elements that are priced and deployed according to the particular characteristics of the virtual hardware: disk storage, memory and number of processors. (Buyya et al., 2013). The key characteristics of IaaS service model are the following (Hurwitz, Kaufman & Halper, 2009, p.17-18):

- **Dynamic scaling –** If users need more resources than planned, they can acquire them automatically and immediately from the IaaS provider;
- **Metering –** Allows IaaS providers to charge users for the resources they request via PAYG model;
- **Renting –** Instead of purchasing network, software, equipment, data center space and other resources, IaaS users can simply rent those resource as a completely outsourced service;
- **Self-service provisioning –** One of the key characteristics of an IaaS service model which allows users to access the resources like servers or networking, through a self-service portal. Users don't have to rely on IT to provide these resources for them;
- **Service levels –** Users usually sign an IaaS contract for a specific amount of storage which has some level of service guarantee. On that way they are protected and assured that the provider will to the best to provide them a flawless service.

IaaS abstract many of the tasks related to maintaining and managing a physical infrastructure and physical data center because it enables collection of services that can be automatically accessed from the web-based management consoles. Anyway administrators and developers still have some work to do like designing applications or installation and management but they don't have to deal with in house installation of physical infrastructure anymore.

There is no more spending time for purchasing, shipping and installing of the infrastructure because the virtual infrastructure is available on demand and can run immediately by calling Application Programming Interface (hereinafter: API). IaaS can better exploit IT infrastructure, also can provide more secure environment and virtual data functionalities which will allow service users to be more focused on building and managing their applications, instead of managing data centers and infrastructures (Kavis, 2014).

IaaS enables several benefits to its users such as (Buyya et al., 2013; Rittinghouse & Ransome, 2009):

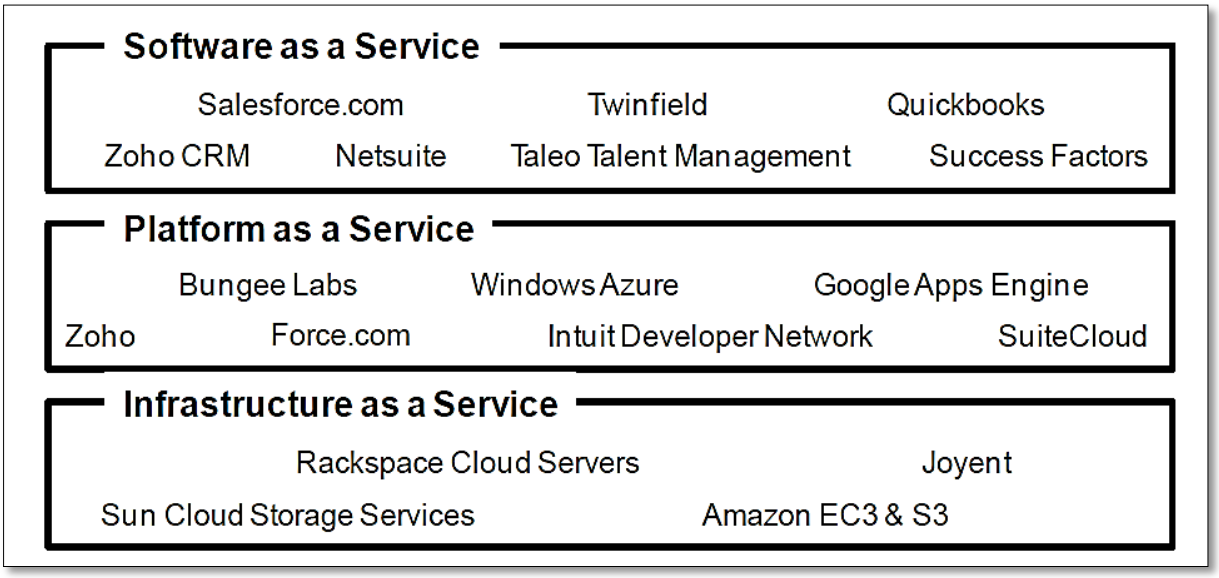
- Cost reduction, an obvious benefit to moving into IaaS, because IaaS decreases administration and maintenance costs, as well as the capital costs assigned with hardware procurement;
- Reduced cost, time and complexity for adding additional features or capabilities;
- Users can benefit of the full customization offered by virtualization to establish their infrastructure in the cloud;
- Additional services can be also provided such as: workload management, support for infrastructure design through advanced Web interfaces and the ability to integrate with other IaaS solutions;
- Access to latest technology for infrastructure equipment;
- Reduced risk by possessing off – site resources cared by third parties;
- Complete access to a preconfigured environment, which is mainly, Information Technology Infrastructure Library (hereinafter: ITIL) – based. ITIL is a customized framework of best practices designed to promote quality-computing services in the IT sector (Rittinghouse & Ransome, 2009).
- Secured, insulated and very high protected computing platforms which are frequently monitored and observed for potential damages;
- IaaS IT resources are scalable which mean that they can be used to their maximum efficiency.

2 Platform as a Service

Cloud computing and especially PaaS are terms that indicate a new improvements and development in the IT industry that are totally transforming the way how the software is designed, produced, distributed and consumed by the end user. PaaS is significant part of cloud computing architecture and unlike IaaS and SaaS, is a much more abstract concept that creates a substantial part of the cloud computing architecture.

From the following Figure 5 we can notice that the PaaS is the middle layer connecting both IaaS at the bottom and SaaS at the top layer of clouds to interface with the end users (Giessmann & Stanoevska, 2012). Basically an organization rents the hardware, storage, OS and network capacity that IaaS provides but also SaaS applications servers and software environments. That provides developers a platform on which they are allowed to load their data and start the developing applications they need (Keyur, 2013).

Figure 5. The three layers of cloud computing: SaaS, PaaS, IaaS



Source: A. Giessmann & S. Stanoevska, *Business models of platform as a service (PaaS) providers: Current state and future directions*, 2012, p.34.

A **platform** generally can be defined as a fundamental computer system that contains OS, hardware equipment and sometimes application development tools and user interfaces that create a common structure on which developers can develop and implement applications effectively and efficiently (Amin et al., 2014).

2.1 Platform as a Service description

According to Mather et al (2009, p.19) "PaaS represents a service model where the vendor through a provider's platform enables developers an application environment where they can develop applications with ease. All necessary tools and standards for development as well as all required channels for distribution and payment are developed from the provider's side. At the end provider receives a payment for providing the platform and the services".

PaaS offers the biggest influence over any other aspect of cloud computing since it brings custom software development to the cloud. PaaS as a web-based development platform can be used by external developers to develop components that can run on it. On that way they can save lots of money on a single, large-scale development project. Although PaaS provide developers the easiest way to build and deploy software on cloud infrastructure and as a service they can use it over the Internet without the need to ever install, host or to wait for new updates. Developers can provide PaaS on demand, and based on their needs they can quickly scale up and down (Jackson & Landis 2012).

NIST defines PaaS as (Mell & Grace, 2011, p.3):

"The ability provided to the user to deploy onto the cloud infrastructure, to use services, tools, libraries and programming languages supported by the service provider. In addition the user don't have control over the underlying cloud infrastructure which includes OS, servers, storage or network, but has unlimited control over the deployed applications and possibly configuration settings for the application-hosting environment."

PaaS is very important for the reason that it saves a lot of money and speeds the application development process. PaaS fundamentally reduce IT expenditures providing developers complete infrastructure needed to run their applications over the Internet. PaaS is delivered as a utility, based on a metering model where developers pays only for what they use and the service provider can spread its IT expenditure over a board base of developers. Service vendors provide off site servers excluding the necessity for large investments in hardware, maintenance and well educated staff to perform critical functions to run the system, which can divert a significant percentage of the organizations budgets from maintaining the infrastructure to create applications that deliver real business value. Also with PaaS corporate IT departments and independent software vendors can be more concentrated on innovation, developing applications and providing support services instead of spending time on the hardware aspects of IT. This model is driving a new era of mass innovation. Developers can approach unlimited computer power from any location, any time. Hence, anyone with an internet connection can create applications and deploys to the organizations whenever they are located (Fanning & Centers 2012).

There are different types of users who use the PaaS services. They can be (Jackson & Landis 2012):

- **Application administrators** – install, monitor and manage applications deployed in a cloud;

- **Application deployers** – publish application into the cloud;

- **Application developers** – develop, design and implement new application software; PaaS offers a care free environment for developers to work on their applications. They don't have to worry for configuration and maintenance of the underlying platform. By using PaaS developers just pick the features and language they want to use, match those requirements with a service provider that has them, and start coding. It's that simple. (McGrath, 2012);

- **Application testers** – test and run the entire application base on a scenario in a cloud-based environment.

PaaS platforms have many functional differences comparing to the traditional, on premise platforms. These include (Keene, 2009):

- **Multi-tenant development tool.** A cloud based studio provisions multiple developers, respectively with several ongoing projects, whereas in the traditional development tools support only one single user;
- **Multi-tenant deployment architecture**. System administrators don't have to deal with scalability when the project deploys because in the PaaS, scalability of the applications is already built and is not a concern of the initial development effort;
- **Integrated management**. Monitoring ability in the PaaS is placed into the development platform, while the traditional development platforms commonly does not concern with runtime monitoring;
- **Integrated billing**: PaaS offerings involve mechanisms for billing based on usage that are special to the SaaS world.

The traditional way of building and running on premise applications has always been very costly, complex, risky and took great amount of time. Every single solution required very specific set of hardware, a database, an OS, email, web servers etc. When the hardware and software environment were build, developers had to navigate complex developing programming platforms that were used for building their applications. In addition a team of network, database and system management experts was required to keep everything up and running. If developers were strained to change the applications that would require new test cycles before being distributed, for which again a great amount of time was spent. Furthermore specialized facilities and enormous amounts of electricity were needed to power the servers and to keep systems cool, which again leaded to extra expenditures. In the end the use of fail-over sites to mirror the data center were required so that the data could be replicated in a case of system damage.

On the other hand PaaS totally differs from the traditional way of building applications. PaaS offers a way faster and cost-effective model for application development and delivery. Importantly PaaS provide the entire infrastructure required to run applications over the internet. PaaS offering contain workflow facilities for application design, application development, security, scalability, testing, hosting, state management, virtual offices and many other services (Rittinghouse & Ransome, 2009).
PaaS has two essential parts: the platform and the service which can space out PaaS vendors from their rivals. The PaaS vendor constantly improves and maintains the software and when new configurations and updates becomes available, the vendor can instantly push them to the developers (Hurwitz, Kaufman and Halper, 2009).

2.2 Platform as a Service overview

2.2.1 Components of Platform as a Service

According to Linthicum (2009, p.54) there are a few major components essential to the PaaS notion: design, development, deployment, integration, storage and operations.

- **Design -** the capability for developers to design their own application and user interfaces;
- **Development -** the capability for developers to design, develop and test applications directly out of the platform using development tools that are provided on demand;
- **Deployment** - is the capability to test, bundle, deliver, host and access the created PaaS applications through a browser or a Web services;
- **Integration** – PaaS can also integrate applications developed on the PaaS provider with SaaS applications, or other applications that exist in the organization;
- **Storage –**the capability to enable on-demand file storage;
- **Operations -** the capability to run the application for a longer period of time, handling with backup, exception handling and many additional things that can add extra value to operations and benefits for the developers.

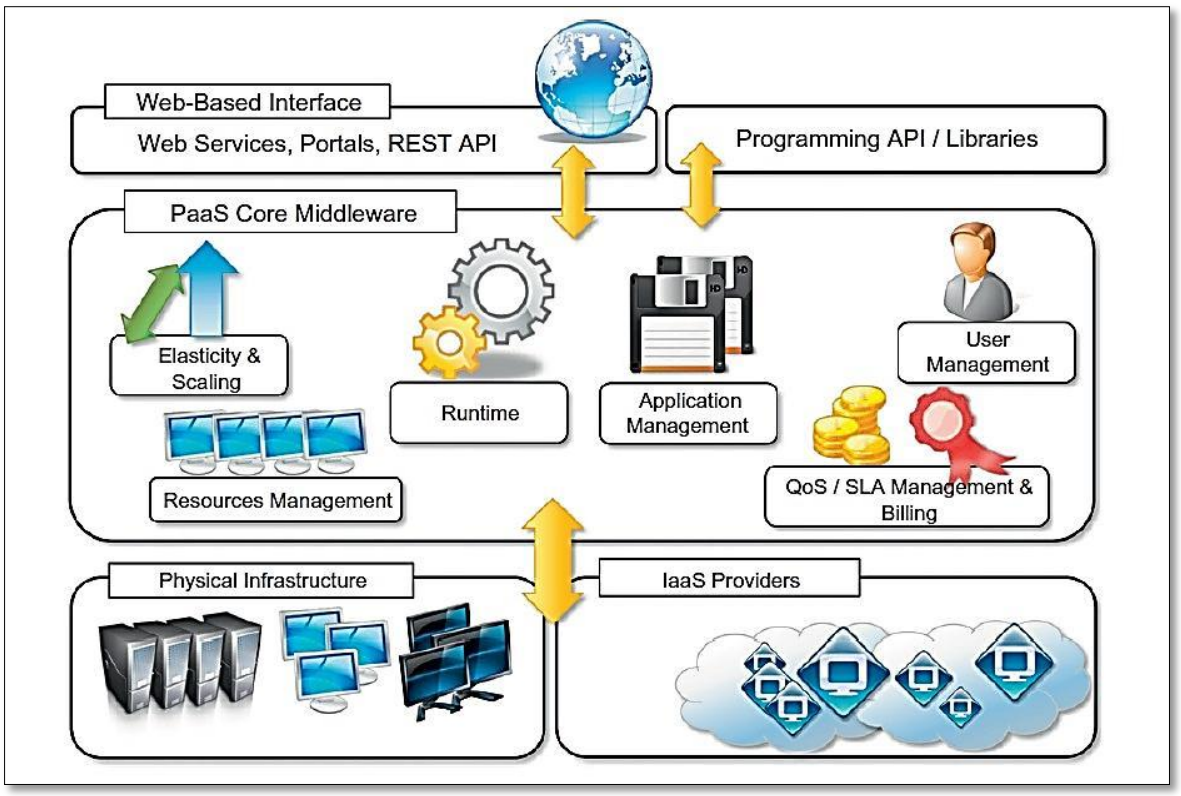
2.2.2 Features of Platform as a Service

PaaS provides many features and functions for developers bringing enough value to successfully deploy and run their applications in the cloud. A general overview of the features describing the PaaS approach is given in the Figure 6.

PaaS solutions can offer middleware for developing applications along with the infrastructure where the provider owns a large data center for executing the applications. Another alternative is to provide developers with software that is installed in the user premises where the middleware constitute the core value of the offering.

As we can see from the Figure 6, the fundamental functionality of the PaaS core middleware is the application management, which consists of set of activities necessary to construct applications. PaaS implementations also deliver applications with a runtime environment, without exposing any service needed for handling the underlying infrastructure. The process of deploying applications to the infrastructure changes in the managing systems as well as the configuration of application components and provision of supporting technologies is based on policies and agreements set by the user. In accordance with the commitments made with the developers, the core middleware is responsible for managing the resources or scaling applications that can be automatically or on demand.

Figure 6. Features characterizing PaaS approach



Source: R. Buyya et al., *Mastering Cloud Computing: Foundations and Applications Programming*, 2013, p.117.

From the user point of view, the core middleware reveals interfaces that enable designing and deploying applications in the cloud. These can be in form of programming APIs and libraries that are giving specific components for better exploiting the services offered by the PaaS environment. The particular development model decided for applications determines the interface exposed to the user. Some implementations provide a Web – based interface that is completely hosted in the cloud offering variety of services (Buyya et al., 2013).

Despite from these core features of PaaS many platform providers offer extra services which are important for applications operation, marketing and distribution. These include (Beimborn et al., 2011, p.381-382):

- Certification and Support
- Implementations
- Lifecycle Management
- Monitoring functionalities, which allows errors location and optimization potentials
- Online marketplace, that support the Independent Service Vendor (hereinafter: ISV) sales activities
- Quality Reviews

PaaS contains different solutions for developing and hosting application in the cloud. Regardless of this diversity, there are some characteristics expected to be found in any PaaS implementation. Charrington (2010) identifies some essential characteristics of PaaS solution:

- **Runtime Framework**. This framework represents the "software stack" of the PaaS model and possibly the most instinctive aspect that comes first to people's mind when they allude to PaaS solutions. PaaS runtime framework is available in different flavors, same based on Fourth Generation Programming Language (hereinafter: 4GL) and visual programming concepts and others on more traditional based application runtimes. The runtime framework executes end-user code in accordance to the policies set by both parties (the user and the PaaS provider);

- **Automation.** PaaS environment automates the process of deploying applications to infrastructure, provisioning and configuring supporting technology and application components based on SLA among the PaaS provider and the consumer;

- **Abstraction**. Platform – oriented cloud platforms are differentiated by their higher level of abstraction they provide. Comparing with the IaaS where the focus is on providing users raw access to physical or virtual infrastructure, the PaaS focus is on applications that must be supported by the cloud. On that way PaaS offer its developers a possibility to deploy, develop and implement their applications in a cloud easily enabling unlimited set of computing resources and removing the complexity of development and infrastructure configuration;

- **Cloud Services.** PaaS offerings provide application developers different types of cloud services and APIs which simplify the process of developing delivering and managing highly available cloud applications. Some of the cloud services provided by PaaS are: workload management, user identity, file and data storage, analytics and more. These services are the key differentiators among competing PaaS solutions and mostly contain specific components and capabilities for developing applications.

2. 3 Platform as a Service Elements

PaaS solution should include the following elements (Mather et al., 2009, p.20):

- Browser – based PaaS development studio solution, where the consumers don't have to install nothing on their premises to develop applications;
- High productive Integrated Development Environment (hereinafter: IDE). IDE generally supports the use of multiple programming languages, and offers a great variety of tools

and libraries for implementing, modeling, testing and versioning. Also various data systems are also provided, depending on the application domain (Beimborn et al., 2011);
- Integration with external databases and web services;
- PaaS solution must allow developers to deploy application with one click, fast and with ease they don't have to talk to a person to get their application deployed;
- A PaaS solution must afford complete monitoring tools and management of application and user activity to allow developers to have better understanding of their applications and to improve them when necessary;
- Scalability, reliability and security should be integrated into the PaaS solution in the absence of further development, configuration or other related costs;
- PaaS solution should be multitenant, without additional work, to be able to serve an arbitrary number of developers;
- PaaS solution should also support PAYG metering billing, where the consumers can pay with their credit cards online;
- PaaS solution must enable support through the entire software life cycle (development, testing, documentation and operations), and in the same time to maintain the security of source code and associated intellectual property.

2.3.1 Benefits/Advantages of Platform as a Service

There are many benefits that PaaS brings to its consumers, some of them are similar as SaaS, but also there are some additional (Hurwitz et al., 2012; Fanning & Centers, 2012; Keyur, 2013):

- Cost reduction
- Improved flexibility, ability and speed
- No maintenance costs
- Simplifying firm's IT infrastructure
- Risk reduction and less costly personnel
- Security updates and back-ups
- Access to information round the clock
- Integration with other web services

Some of the greatest benefits of PaaS are cost reduction and improved speed of development and deployment. By providing the underlying software infrastructure PaaS can reduce organizational costs and many other costs associated with: server and storage overhead, network bandwidth, software maintenance, careless mistakes, lower skill requirements etc. PaaS can also provide greater speed, flexibility and agility to the development process. That allows faster time to market by letting development teams to focus on the application development (Hurwitz et al., 2012).

There is also no maintenance cost since there is no infrastructure and the IT department instead to dealing with the problem that developers can allocates their resources to develop applications where organizations can generate its highest benefit. Moving the application to PaaS can also simplifies firm's IT infrastructure and since the PaaS provide necessary technology and tools can lower the risks and costs of application development. Time consuming tasks such as disaster recovery plans, security updates and backups are no longer user's problem because the PaaS vendor is responsible for all activities enabling developers to have up-to date and high quality services (Fanning & Centers, 2012).

In the end PaaS enables any information to be accessed and shared easily, anytime from anywhere. PaaS offer integrated organization environment, where the software as well as hardware applications using PaaS services are compatible with the most of the computer systems and telecommunication devices (Keyur, 2013).

2.3.2 Limitations/ Disadvantages of Platform as a Service

As with all cloud platforms, PaaS has also some disadvantages. If developers want to acquire the best from the cloud platform they should understand exactly what they want to achieve from the deployment and to be sure that the deployment suit their needs while achieving the maximum benefit from the cloud model. Some of the drawbacks that developers should consider while implementing PaaS solutions are (Gurudatt, Prasad & Jayant; GetCloud, 2013):

- Vendor lock-in
- Deployment to public clouds only
- Stagnant Mindset
- Not open source
- Limited flexibility
- Integration problems with in house systems and applications
- Security and privacy issues

If organization or developer wants to switch from one cloud provider to another it will be very costly, time consuming, making them dependent on a provider services – vendor lock-in. If a developer choose a certain provider, they must remain with it, unless the application is removed using the providers console and the current application is changed according to the new cloud provider where the application must be deployed. Most of the PaaS solutions target only public clouds that mandatory changes developer's mindsets before building applications on the pubic cloud begins, which is also associated with a learning curve. For that reason many organizations are not moving into PaaS because of the many other public clouds issues already explained in the section 1.6.1. Furthermore no existing PaaS solutions

are open source, which make it hardly for developers to fork the code and add additional features to share with the community (Gurudatt et al., 2011).

PaaS cannot offer the complete flexibility as IaaS and SaaS services can. For example PaaS user cannot certainly create and delete multiple virtual machines easily as IaaS user can. Subsequently developers have to put extra developing effort for designing or testing application before they deploy them for the end users. In the end problems of integration with in-house systems and applications may occur when deploying PaaS solutions, which often brings increased complexity.

Many organizations are still uncertain for having their application hosted by a third party having low confidence of security level offered by the PaaS providers. Leakage of private information and data loss increased the need some government clients or enterprises to be assured of compliance with all applicable regulations concerning security, privacy and data retention before using the PaaS services (GetCloud, 2013).

2.4 Security and Privacy Issues in Platform as a Service

According to the Cloud Security Alliance (hereinafter: CSA) report (Cloud Security Alliance

, 2013) the top 5 critical threats to PaaS security, which can be also applied into SaaS and IaaS cloud computing service models, are:

- **Data Breaches.** It is one of the top cloud computing security concerns. If the multitenant cloud service database is not appropriately designed it could allow attackers' (unauthorized) access to all organizations sensitive, confidential or protected data, which can be the worst nightmare for all Chief Information Officers (hereinafter: CIO). The attack can originate from many sources such as: fierce competitors, malevolent hackers or even from the organization insiders (employees, subcontractor or vendors). However, despite of the origin, the attack must be stopped before it causes any damage (Nissay, 2014);

- **Data Loss or Leakage.** Data stored in the cloud can be lost due to many reasons such as: malicious attackers, any accidental deletion by the cloud service provider, or natural disasters such as earthquakes, fire, flood, tornado etc. All this could lead to a permanently loss of data, unless adequate measures to data backup are taken from the user's or provider's initiative;

- **Account Hijacking.** There are many attack methods for account and service hijacking such as fraud, phishing and exploitation of software vulnerabilities. With stolen passwords and credentials attackers can have unauthorized access to critical areas of cloud computing services enabling them to compromise the availability, confidentiality

and integrity of those services (Nissay, 2014). That can allow them to eavesdrop on organizations activities and transactions, manipulate with the data, sending false information, and forward users to illegitimate sites. Organizations should be aware of those techniques and to defend with protection strategies;

- **Insecure APIs.** Cloud computing providers are offering a set of APIs or software interfaces which are used by developers to interact with cloud services. The security level of those APIs reflects on the overall security and availability of cloud services. Furthermore the interfaces must be designed on that way to prevent both malicious and accidental attempts to circumvent policy. In contrast organizations may be exposed to many security issues associated to confidentiality, accountability, integrity and availability;

- **Denial of Services** (hereinafter: DoS)**.** Attacks that prevent cloud service consumers to access their data on their applications. DoS type of attacks forces the consumer of the cloud service to utilize excessive amounts of system's resources such as memory, processor power, disk space or bandwidth making the system slow, inoperable and bogged down. This can cause frustration, increased costs and decreased productivity.

These threats have occurred as a result of the increasing popularity and demand for "as a service" products or services compared to server based technologies over the past few years. Even if there are many benefits for organizations such decreased costs and increased productivity, these approaches generated new security vulnerabilities for which organization should properly plan and prepare.

2.5 Platform as a Service Today and in the Future

In the past few years PaaS was adopted by many organizations, reaching new level of maturity each following year. PaaS has evolved to meet the needs of many organizations and now is seen as one of the best strategic ways towards innovations. Although it was firstly constructed as the middle layer lying between SaaS and IaaS service models, now PaaS is identified as a separate layer in the cloud stack. Comparing to IaaS, PaaS is less complex and more cost effective, having the capability to simplify IT department's attempts to achieve better ways of development. Currently, PaaS enables organizations to (Magalhaes, & Magalhaes, 2014):

- Improve their software development and delivery along with productivity gains
- Adopt governance best practices
- Simplified user experience
- Better quality software and software best practices
- Test automation

- Integration and fault tracking
- Reduce skill hurdles
- Rabid innovation and experimentation
- Simpler consumption of IT infrastructure and services

Golden (2014) believe that in 2015 and further it will become evident to all participants in the IT value chain that PaaS will become the future of IT especially for the developers, operations and providers. PaaS liberates developers from obligation to code low-level plumbing as part of the application development process. They will use PaaS to manage the plumbing while they put attention on the more valuable part of the application – organization functionality, instead of writing software to observe resources loads and start and stop virtual machines to support application loads. Moreover, the developer's productivity will increase because they will be able to leverage pre-configured applications environments, allowing faster application development with complex deployment topologies (Golden, 2014).

Furthermore complete PaaS solutions will include operational requirements related to version control, logging and monitoring that will result into simple operational environments, IT governance and consistent operational practices. With PaaS providers can present value based on application functionality, which is directly fixed to the business outcome for which organizations will be willing to pay a premium for. That will provide provider differentiation and higher margin services. PaaS also prevents the race-to-the-bottom pricing that is associated with pure IaaS. When one is selling undifferentiated infrastructure functionality, market process is set by providers who are most efficient or willing to absorb losses (Golden, 2014). PaaS will expand into the cloud environment, over the next few years and will continue to evolve offering simpler administrative management, support for development in multiple languages, seamless integration into applications and hybrid cloud capabilities (Magalhaes, & Magalhaes, 2014).

After providing the necessary academic literature for better and deeply understanding the Cloud Computing concept and the PaaS as a Cloud Computing service model, it is time to see how it all functions and works in the reality. The next part of the master thesis is all about how Platforms – PaaS can be used by developers. I have chosen Bluemix – the newest IBM cloud offering as a great example, which will help me to connect all theory with practice.

3 CLOUD BASED PLATFORM IBM BLUEMIX

Platform as a Service helps developers to frame and launch an application more easily than with the raw resources of an IaaS cloud offering. Bluemix is a PaaS where the user as a client only manages the applications and the data, while the rest such as: runtime, middleware, servers, storage and networking is managed by the cloud vendor IBM. That enables developers to be more dedicated and concerned on what they do the best – developing top quality applications and code writing. Moreover the system handles the back-end infrastructure without requiring the developers to spent time managing it. Also it delivers flexible capacity for bandwidth and processing as well as allows flexible capacity in terms of storage. Bluemix is a platform where developers can develop their application from concept to live in just few minutes, also they can scale the application from tenth to million users and can leverage their cloud services for their next big idea.

3.1 What is IBM Bluemix

Bluemix is one of the latest and most famous cloud offerings from IBM, firstly announced early in 2014, which enables developers and organizations in a very simple, easy and quick way to build, run, scale, manage, integrate and secure mobile and web based applications in the cloud. Bluemix offers mobile and web developer's access to IBM software for security, integration, transaction and other fundamental functionalities. Bluemix delivers enterprise-level services which can effortlessly integrate with other consumer cloud applications without additional knowledge and effort for their installation configuration and maintenance (Reyes, 2014). This platform means a lot for IBM, because this is the future of how smaller organizations can be serviced. Not that IBM is not focused to serve big organizations, but this platform is an opening to a new set of market, which means that this platform for IBM is strategic in a way to acquire new customers.

Bluemix is an open PaaS, built on a Cloud Foundry, which is an open source PaaS technology that allows developers to create applications on the cloud. Cloud Foundry is developed by over 700 developers in the open source community. Cloud Foundry abstracts the underlying infrastructure necessary to run a cloud, permitting consumers to focus only on their business and application developments. The beauty of Cloud Foundry is that it provides numerous choices for developers and organizations such as diverse kind of development frameworks, applications services and clouds (Reyes, 2014).

By using its PaaS offering, Bluemix enables greater control to application developers and provide pre-built Mobile Backend as a Service (hereinafter: MBaaS) capabilities. Bluemix simplify the application delivery through providing services that can be used immediately and hosting capabilities for internal scale development.

The platform also has cloud deployments that fit users' needs either it is small business or large enterprise in question. Consumers are allowed to develop applications in a cloud without any limit where they can connect their dedicated services to the public Bluemix services available from IBM, open source or third party providers (IBM Bluemix, 2015a).

Bluemix removes the difficulties with hosting and managing cloud based application which gives space to developers to be completely focused on application deployment. Also the platform can be automatically scale up or scale down based on application usage (Hossain, 2014).

Bluemix offers developers a numerous different services like: email, database, messaging, business rules, analytic processing, big data, mobile building blocks such as push notifications etc. This collection of services are from IBM, from third parties or from open source and can be easily integrated without any problem into developers ecosystem of services, which enables developers to compose applications rapidly through services. With Bluemix developers can enjoy many benefits that the PaaS offers like low entry costs, quick and easy application development and the possibility to pay only for what they use based on PAYG basis.

3.2 Overview of the IBM Bluemix

To gain competitive advantages and to become well positioned in the market, organizations today have to apply future oriented business models in a way to implement IT solutions faster and better that competitors. With Bluemix organizations can gain essential application development capabilities such as (Falk, Ferris, Fork, & Sauerwalt, 2014; IBM Bluemix, 2015a):

- Future oriented applications and services that can be developed, deployed and scaled faster than ever before;
- Increased user and employee loyalty through developing new born on the cloud mobile and web based applications;
- Bluemix helps organizations to avoid vendor lock in through leveraging a wide range of application services, new development tools and languages which can totally change organizations and IT processes;
- Processing power to consumers to deliver applications changes continuously
- Service and application management
- Continuous availability
- Fit-for-purpose programming models and services
- Elastic and optimized workloads

Bluemix can be helpful not only for applications developers, but also for the organizations and users (Reyes, 2014):

- **For developers**, Bluemix shorten the time necessary for creating cloud application. Developers don't have to be worried about installing software or to deal with virtual machines. Now with just few clicks developers can provision instances of their applications along with all necessary services to support them. This streamlining transfer many hours spent of setting up, configuring and maintaining into time spent on innovation and application creation.

- **For organizations,** Bluemix provides a platform that involves minimum required know-how as well as cost savings. It also provides the fast development environment where organizations need to react on user's demand of new services and features. Bluemix also provides flexibility and elasticity organizations need when their applications become used by more users.

- **For users,** Bluemix is the key that allows organizations to quickly deliver the features they request.

Bluemix offers more than a hundred software and middleware patterns that are available either from IBM, IBM Business partners or open source to help organizations and developers to develop compatible and portable applications. Moreover the platform provides an integrated experience for the developers with DevOps in the cloud, which assist them to deploy applications more efficiently and quickly. Bluemix DevOps enables developers to transfer their idea into application faster providing (Hossain, 2014):

- A built – in web IDE
- Simple integration with popular development tools such as Visual Studio and Eclipse
- Automatic application deployment services
- Team collaboration, tracking and agile planning
- Ability to manage and store code by means of Git repository

Bluemix as PaaS model provides many benefits to its consumers. Some of them are (Cox 2014):

- **Speed and simplicity.** Bluemix can decrease the downtime of redeploying applications by focusing on the DevOps model.
- **Agility.** Bluemix provides continuous availability by removing the underlying architecture and keeps the manageability of services and applications at a simple comprehensible level. Developers can be more focused on bringing organizations value, rather than on maintaining the development environment, by scaling environment elastically based on organizations request.
- **Source control.** Bluemix is integrated with several Source Control Management systems such as: Jazz SCM, Git and GitHub which provides high control over applications.

- **Different development Tools.** Within Bluemix developers can choose development tools that work the best for them and they don't have to stick to a particular tool while deploying applications.
- **Service marketplace.** Bluemix offers an open and flexible ecosystem, which lets other organizations and third parties to provide services that can be easily integrated into applications.

3.3 Bluemix architecture

With Bluemix consumers can access three types of cloud platforms (IBM Bluemix, 2015a):

- Public Bluemix Platform
- Dedicated (Private) Bluemix Platform or
- Hybrid Bluemix platform (combination of both Public and Dedicated Bluemix platform)

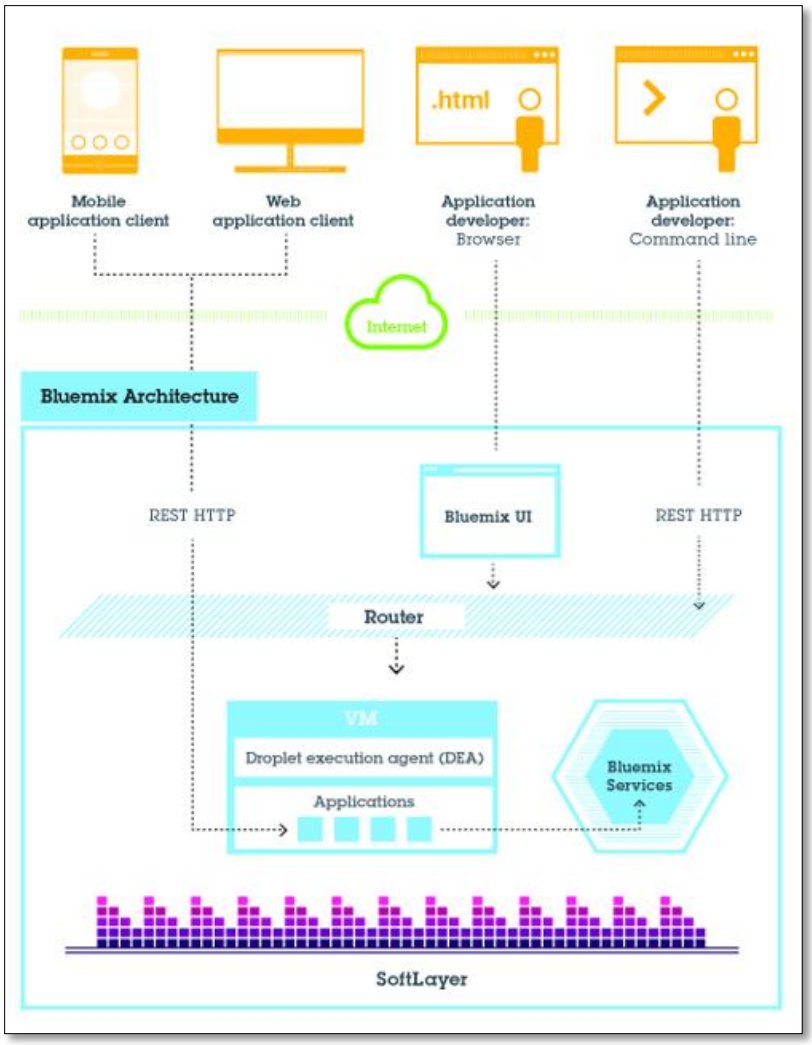
Furthermore recently IBM launched the Local Bluemix Platform which brings cloud agility to the most sensitive workloads in the user's data.

3.3.1 Bluemix Public

Bluemix Public provides all necessary resources for an application development available to the general public. Services offered may be free or offered on a PAYG model, where developers pay only for what they use. Bluemix Public provides an environment where developers can build applications and use many types of services while developing their applications. Also developers are provided with an environment where they can host applications artifacts that run on an application server. Bluemix deploys virtual containers that hosts any deployed application, by using SoftLayer that provides the highest performing cloud infrastructure available. Using the public cloud, developers can scale their applications with infinite choice and flexibility, IBM has more than 40 data centers globally, and the number is increasing daily (IBM Bluemix, 2015a).

The following Figure 7 shows the high – level Bluemix architecture. Users, which can be mobile applications, web based applications that are running externally, applications built on the Bluemix platform, interact with the Bluemix hosted applications. Clients use Hypertext Transfer Protocol (hereinafter: HTTP) or Representational State Transfer (hereinafter: REST) APIs to direct requests through Bluemix to composite services or to one of the application instances.

Figure 7. Bluemix Architecture



Source: IBM BlueMix, *BlueMix overview*, 2015.

3.2.2 Bluemix Dedicated

Bluemix dedicated is user own single-tenant Bluemix private environment which is hosted in an isolated SoftLayer instance managed by Bluemix. That is a great option for all those who want to do things in private.

In other words it is a private cloud that only the single - user have wholly access and control over the data, furthermore questions related to privacy, security, control, data redundancy or corporate policy are not more in concern with Bluemix Dedicated because the user is not sharing the platform with the general public.

Important component, which brings additional value of the Bluemix dedicated, is the connection it shares to the Public cloud instance of Bluemix. Developers have the opportunity to pull services and APIs form the Bluemix Public and use those abilities in applications that may run in the Bluemix Dedicated. Bluemix dedicated brings some extra advantages such as (Brent, 2014):

- Isolation
- High-performance networking and
- Extraordinary enterprise connectivity

There are few features associated with Bluemix Dedicated such as (Cakil, 2015):

- **Privacy**. All services and applications in Bluemix are visible and usable by developers in their private network;

- **Integration with public cloud**. Consumers have the possibility to connect their services and applications to the ones in the public cloud. This feature bring up more elasticity to consumer's applications;

- **SoftLayer Infrastructure**. Bluemix runs on a dedicated environment from SoftLayer. This isolated environment has some great features such as isolation capacities and high – speed networking;

- **Dedicated Services**. There are numerous data drives services available for consumers/developers dedicated use as: Cloudant, No Only Structured Query Language (hereinafter: NoSQL), MQLight or Structured Query Language Data Base (hereinafter: SQLDB).

Concerning security issues Bluemix Dedicated environments possess the identical security standards as a Public Bluemix in terms of physical, infrastructure and operational security. The difference is that the developer's access to the Bluemix Dedicated is controlled by their own Lightweight Directory Access Protocol (hereinafter: LDAP) policies that can be arranged by the Bluemix team when they are setting up the environment (IBM Bluemix, 2015b).

LDAP is a software protocol for enabling anyone to locate individuals, organizations and other resources such as devices and files in a network, whether on the corporate intranet or public internet (Rouse, 2008).

3.3.3 Bluemix Hybrid

Consumers can connect their dedicated services to the Public Bluemix services available from IBM and the third-party service providers. All service instances are managed and controlled by IBM. It the end developers get only one bill based on what they choose to use (IBM Bluemix, 2015a). That enables them to take an advantage of a cloud environment and still to maintain level of control that is reliable with their business needs. It is a useful approach that brings the best for the both sides.

3.3.4 Bluemix Local Platform

Recently, in early October 2015 IBM released the new Bluemix Local, which brings the power and agility of the Bluemix cloud-based platform to the organization's data center. Bluemix Local delivers many requirements for developers such as (Singh, 2015):

- Remaining data on premise
- Greater control over catalog
- Having operational view

Bluemix Local is a collaborative cloud development that offer developers an opportunity to build applications around their most sensitive data and workloads and deploy them in a personal, local on premise cloud environment. On that way developers can have direct control over the physical location of their data, without worrying over data sovereignty, performance and compliance (Singh, 2015).

As a new offering Bluemix local enables developers to write their business applications once and after that run them across their own data centers including private or public clouds. Now organizations can be ensured that certain data and applications run in certain places for regulatory compliance or other reasons (Darrow, 2015).

3.4 Getting started with IBM Bluemix

In this section I will explain how the platform works, from the first step when you get access to the platform to the final one how to build an application. As was previously described Bluemix is a place for developers to go to quickly create, deploy and manage applications in the cloud without dealing with any of the underlying infrastructure. Any developer can have access to the platform.

As a developer first thing you should do is to go to www.bluemix.net/registration/ where you can create a free trial account. Next what you should do is to give an email address and fill the form. Then you will receive a verification email and after that you can start using the platform.

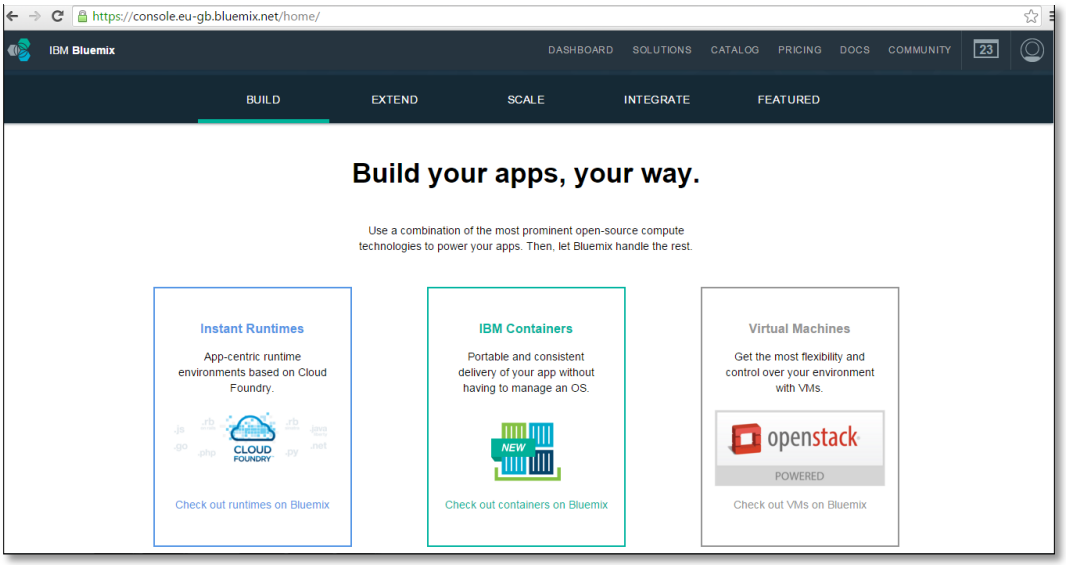
After logging in developers, can have 30 days free trial where they can have minimal access to all services and runtimes available. Developers will also have opportunity to build and code and test applications faster than never before.

As mention before Bluemix is built on Cloud foundry, which is an open source cloud platform. The approach to build Cloud Foundry applications is first to choose the runtime developers want to use and then to choose the services (both runtimes and services will be explained in details in the next section). After choosing runtimes and services developers can deploy their applications by pushing their code up and then their application is up and running.

Figure 8 represent Bluemix front page where developers can have a clear view on everything they need to start using the platform and develop applications. On the top on the front page 5 menu items are available:

- Dashboard
- Solutions
- Catalog
- Pricing
- Community and Docs

Figure 8. IBM Bluemix Platform front page



Source: IBM Bluemix Console, *The IBM Bluemix Platform online version*, 2015.

- **Dashboard.**

In fact the first time developers launch Bluemix with a trial account this is where it is going to take them (Appendix B, Figure 1). Within the dashboard number of different areas are placed. Here the current organization where developers are working in is shown, if developers use free trial version they can also see how many days of the free trial are left and can have a clear view of all settings and notifications connected with the account.

Furthermore the current status of resources is available which gives information to developers how much memory they have used and how much memory is left. At this point developers can choose whether to start building applications based on Cloud Foundry (where they can select between developing mobile or web applications), Containers or VMs. In the dashboard developers can create their own space where they can organize all their stuff and develop their own applications.

- **Solutions.**

Here developers have access to number of areas with predefined solutions, sample applications, some case studies and information inside Bluemix necessary to build their applications flawlessly (Appendix B, Figure 2). In this menu item developers can also see some samples and can try some applications related to specific topic.

- **Catalog.**

In this section all services that developers' should use for building and developing applications are placed (all services will be explained in details in the section 3.5).

- **Pricing.**

When starting Bluemix, developers have 30 days free trial version and anything they do in this period is for free. After that they have to input a credit card information's and they can continue to use the services (Appendix B, Figure 7). There are not fixed prices available because everything depends on, how many instances, how much memory and what kind of services and runtimes developers will choose prior developing their applications, in other words pricing is based on PAYG method.

Figure 9. Bluemix pricing samples

Source: IBM Bluemix Console, *The IBM Bluemix Platform online version*, 2015.

Using the cost estimation form (Appendix B, Figure 3 and Figure 4) developers can estimate the cost of the application and have a clear view of how much they should pay according to their preferences and choices. For more instances, more memory space and more developers normally the cost will be higher. Figure 9 gives three samples about how much will be the price for using the platform according to the previously mention parameters.

For example if developers choose to have 512 MB memory space, 2 instances and less than 8000 application users the price will be 18.15 EUR. To calculate additional costs for services,

containers and VMs, detailed placing calculator is available (Appendix B, Figure 5 and Figure 6) which gives a clear understanding of how much it will cost to run some application.

Moreover prices for services vary, they can be fixed or charged by usage, all services have a free tier and developers can always try them before they made the purchase (IBM Bluemix, 2015c).

- **Docs.**

All the basic services and functionalities of Bluemix are covered in documentation. Here developers can find out all the various information and necessary documentation that covers up anything connected with the platform. Based on that developers can learn more about Bluemix and build their application on their way.

- **Community.**

A place where developers can share their experiences, communicate between each other, get answers to their Bluemix questions and get support. There they can also write blogs, include videos how to use the platform, write posts about the new upgrades, submit ideas for Bluemix improvements, get information about the Bluemix events etc.

Platform's front page (Figure 9) shows that Bluemix is more than just a PaaS, IBM Bluemix beside cloud foundry offers two more infrastructure compute technology choices to deploy applications: Containers and OpenStack VMs.

3.4.1 IBM Containers

At the end of 2014 IBM have launched IBM containers which are based on the popular Docker containers. On a very high level they seems to be similar to VMs having similar advantages as fast creation of new instances but there is also a significant difference - containers virtualize the operating system and on the other hand VMs virtualize the hardware.

Furthermore there is also difference comparing to the Cloud Foundry model. Now developers don't need only to provide the applications but also the application servers/runtimes which are both included in the application. The benefit is that developers can port applications much better because for example some developers can run those containers locally, and others can run them on other on-premises environments, or the same containers can be run in the cloud which means that containers can be shipped very easily between different environments (Heidloff, 2015).

IBM Containers permits developers to deploy, manage and run application documents on the IBM deployment platform by leveraging open-source Docker container technology. Docker is an open platform used for building, shipping and running applications. The platform

provides all the necessary and common toolbox programmers need to take benefit of the distributed and networked nature of the modern applications. Beside programmers operations managers and development teams can enjoy those benefits too.

IBM containers are designed for enterprise production workloads and are securely deployed with integrated scalability and reliability. They allow consistency and portability regardless of where they run (on your laptop, organization's data center or in Bluemix server's). Containers also allows a user to obtain access to a hosted, private repository of images where they can store and manage access to images which are specific to their organization. In other words IBM containers helps developers to build and deploy containers where they can package their applications and services (Dyna, 2015).

Key capabilities of IBM Containers are follows (IBM Bluemix, 2015d):

- Completing containers communication over public and private networking
- Deploying scalable groups or single containers fast and with easy
- Integrating with DevOps pipelines for developer productivity
- Managing containers with integrated auto-recovery monitoring and logging
- Utilizing the native Docker Command Line Interface (hereinafter: CLI)

3.4.2 OpenStack Virtual Machines

VM represent an independent application environment that runs on a specific operating system which includes not only the application but services, operations and any dependencies. Each VM is an execution environment in itself that developers can monitor over functionalities available in IBM Bluemix.

Bluemix use industry-leading OpenStack software to run and manage VMs in private, dedicated or your own on-premises cloud. With VMs developers can have the most control over their applications and middleware, enabling significant flexibility to tune applications (IBM Bluemix, 2015e).

With the IBM VMs developers can (IBM Bluemix, 2015e):

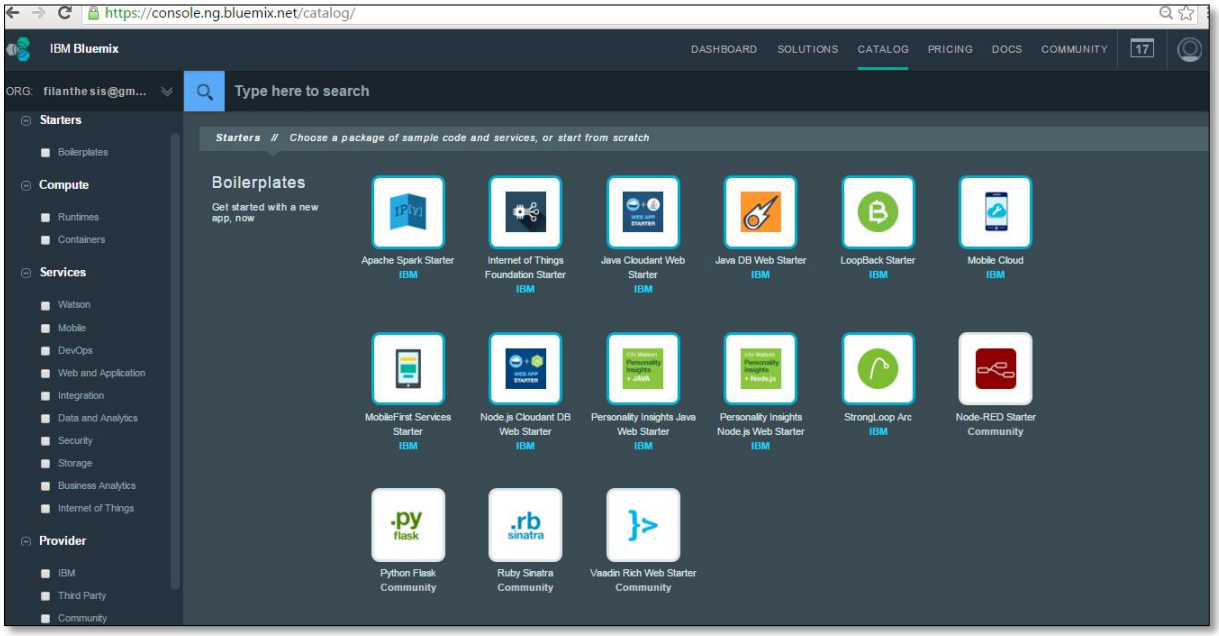
- connect VM that are deployed by them in diverse organizations
- connect VM that are deployed in different departments inside the organization
- create, deploy and manage distinct VM or VM groups
- have several VM groups inside the space of an organization

3.5 Bluemix Services – Catalog Section

Bluemix provides services that can be used by developers to deploy applications without requiring them to manage the set-up of those services. All available services are set up in the catalog in the web user interface where developers can choose from over hundreds of services for developing their applications. Some of this services are from IBM, open source and some are from third parties. Within the catalog there are many sections available:

- Boilerplates
- Runtimes
- Watson
- Mobile
- DevOps
- Web and Applications
- Data and analytics
- Integration
- Security
- Business Analytics and Internet of things

Figure 10. IBM Bluemix - Boilerplates



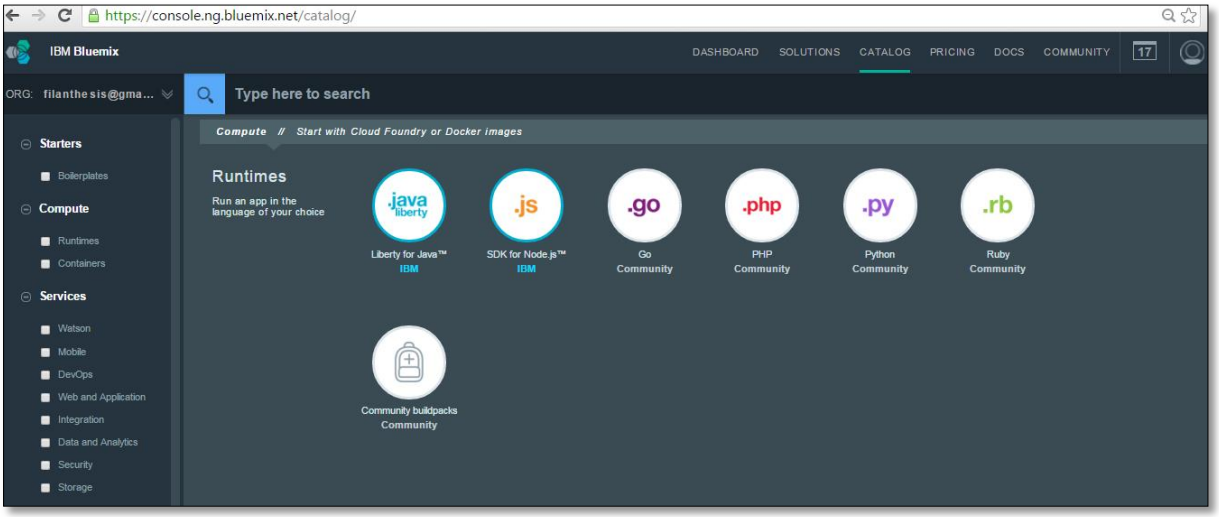
Source: IBM Bluemix Console, *The IBM Bluemix Platform online version*, 2015.

The first section is **boilerplates** (Figure 10)**.** Boilerplate is a container for an application (pre-configured solutions) which is associated with runtime environment and predefined services for a particular domain (IBM Bluemix, 2015f). On that way developers can start applications in a very quick way and run the even faster.

From the figure we can notice that number of boilerplates are available. For example Mobile Cloud is an IBM's boilerplate, which lets developers to start their mobile services for shared data, push and server-side scripting, and it includes Software Development Kits (hereinafter: SDKs) for Android, iPhone OS (hereinafter: iOS) and JavaScript. On the other hand Python Flash is a third party boilerplate which is a simple Python application that will get application up and run quickly.

Underneath boilerplates, there are the built-in runtimes with Bluemix (Figure 11). **Runtimes** allow developers to pick a language that works best for them.

Figure 11. IBM Bluemix - Runtimes

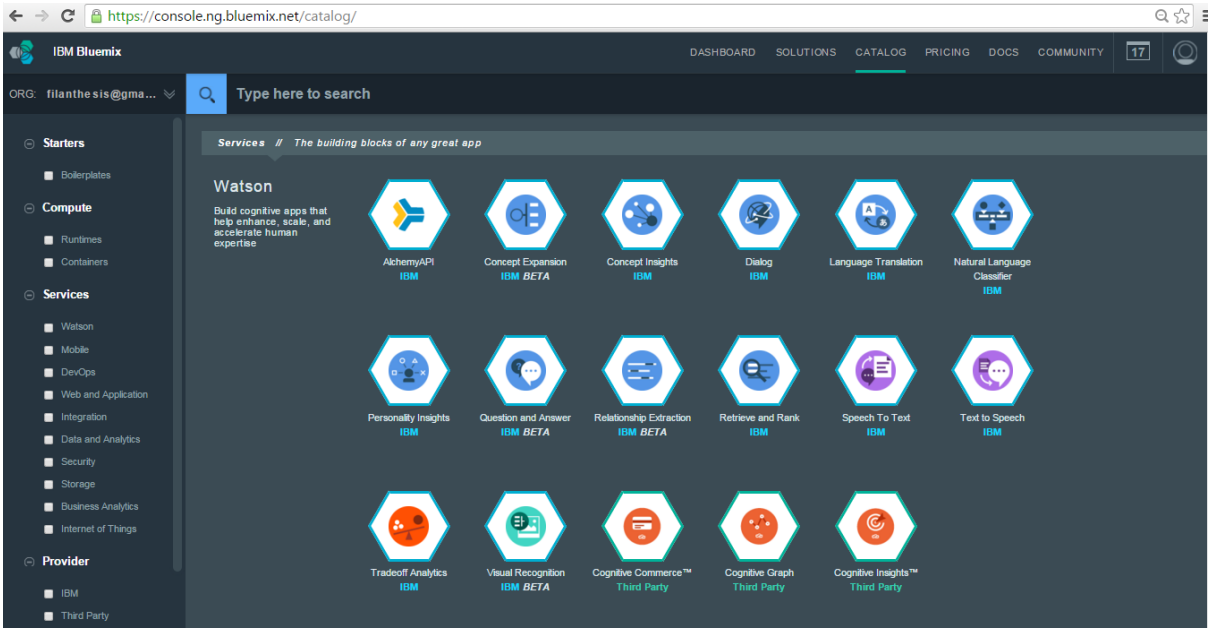


Source: IBM Bluemix Console, *The IBM Bluemix Platform online version*, 2015.

Currently there are 6 languages available: Liberty for Java, Node.js, Go, PHP, Python and Ruby on Rails. Thanks to that developers don't have to set up and manage VMs and operating systems for building applications. Because Bluemix is built on top of cloud foundry, there is a large community where there are number of build packs and different runtime languages where developers can actually go out and bring them in and actually use them with Bluemix as well.

After developer's application is running they have got an ability to bind services. Rather than having to install and configure other middleware they can just select some of the **Watson** services. They are cognitive analytic capabilities that Watson brings and there are number of Watson services exposed in Bluemix (Figure 12).

Figure 12. IBM Bluemix Watson Service



Source: IBM Bluemix Console, *The IBM Bluemix Platform online version*, 2015.

Watson is a platform that offers numerous services through REST APIs available in the cloud. Each of the services accessible on Bluemix has a free tier that allows experimentation at no cost. Many of the services at Watson are meant to help professional in their decision making i.e. to make better decisions. Instead of having one machine or instance there are many instances in the data center ready to take on work. Also Watson has a training toolset – Watson Experience Manager which permits a developers to train Watson through a number of exercises and tasks. To get started to use the services the only skill required is developers to be familiar with REST APIs (Vega, 2014).

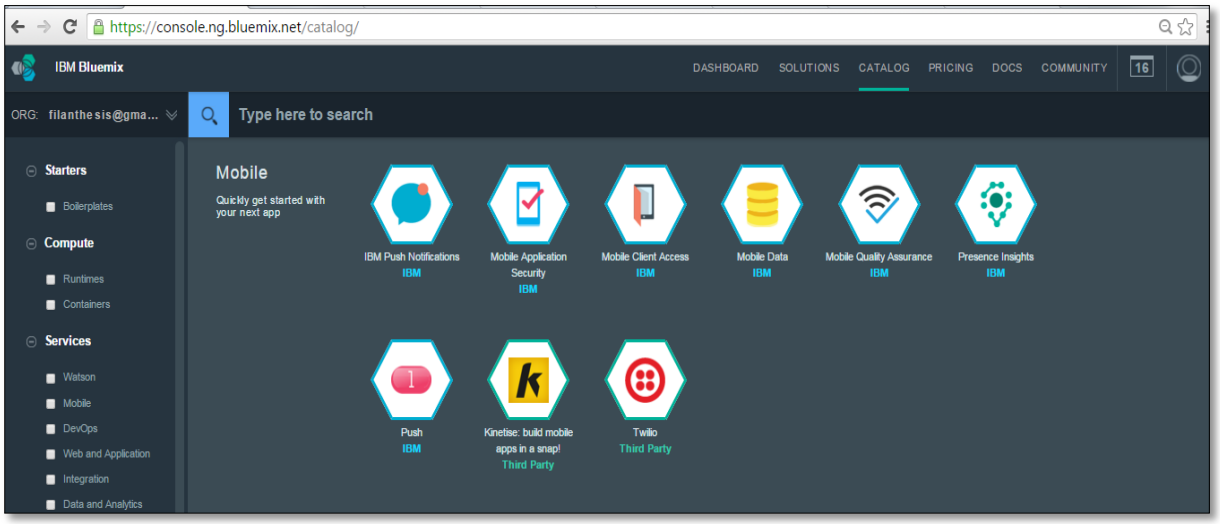
Currently there are 17 Watson services available on Bluemix, but that number is increasing as a result of constantly platforms upgrades. Some of the services are provided by IBM and some are from third parties and open source community. Some of the services offered in this section are (IBM Bluemix, 2015f):

- Language translation IBM. This service offers dynamically translation of text, news, patents and informal documents from one language to another on specific domain.

- Relationship Extraction IBM. The service maps the relationship between the components where developers can understand with ease the meaning of individual sentence and documents. Sentence components comprise parts of speech (noun, verb, conjunction, adjective etc.), and parts of functions (subjects, objects, predicates, etc.).
- Cognitive insights Third Party. Cognitive Insights is a service provided by Cognitive Scale which provides personalized and contextual commerce opportunities for organizations and developers with more relevant and actionable recommendations and helps drive commercial transactions.

Next are **Mobile** services (Figure 13). This section consist of a complete collection of backend services enabling developers to build and scale mobile applications faster. Some of the services are (Bluemix Console, 2015):

Figure 13. IBM Bluemix Mobile Services



Source: IBM Bluemix Console, *The IBM Bluemix Platform online version*, 2015.

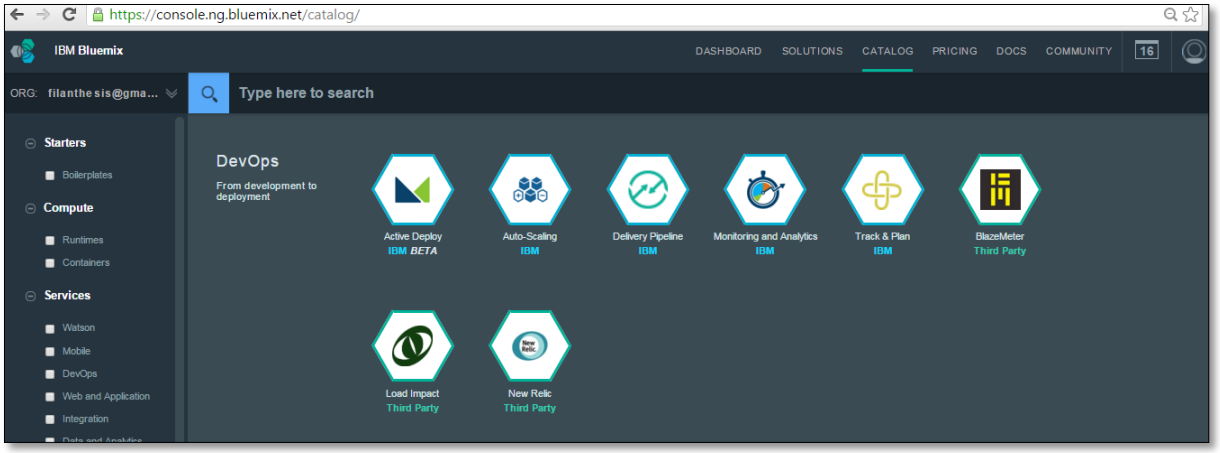
- Mobile Application Security IBM. With this service developers can have basic application security framework. On that way they can have control access from the mobile applications and can block unwanted access to be sure that unauthorized devices cannot reach their Mobile Cloud Services and data.
- Push IBM. Developers can push information to all applications users or to a specific set of users and devices - both iOS and Android at a right place and time.
- Twilio Third Party. This service designed by third parties can give opportunity to developers to build application that can integrate voice, messaging and voice over internet protocol into their mobile and web based applications

In the catalog menu developers can also select some of the **DevOps** services (Figure 14). DevOps services provides an online set of tooling to plan, manage and deploy applications

enabling complementary mobile quality and application performance monitoring. That also allows developers to collaborate and work locally on the same project (Bluemix, 2015).

If developers wants to gain the visibility and control they need over their application they may choose Monitoring and Analytics service which can help them to understand the performance and availability of the applications components. On the other hand New Relic service can lets them to see application performance from end user experience, through servers and down to the line of code (IBM Bluemix, 2015f).

Figure 14. IBM Bluemix DevOps Services



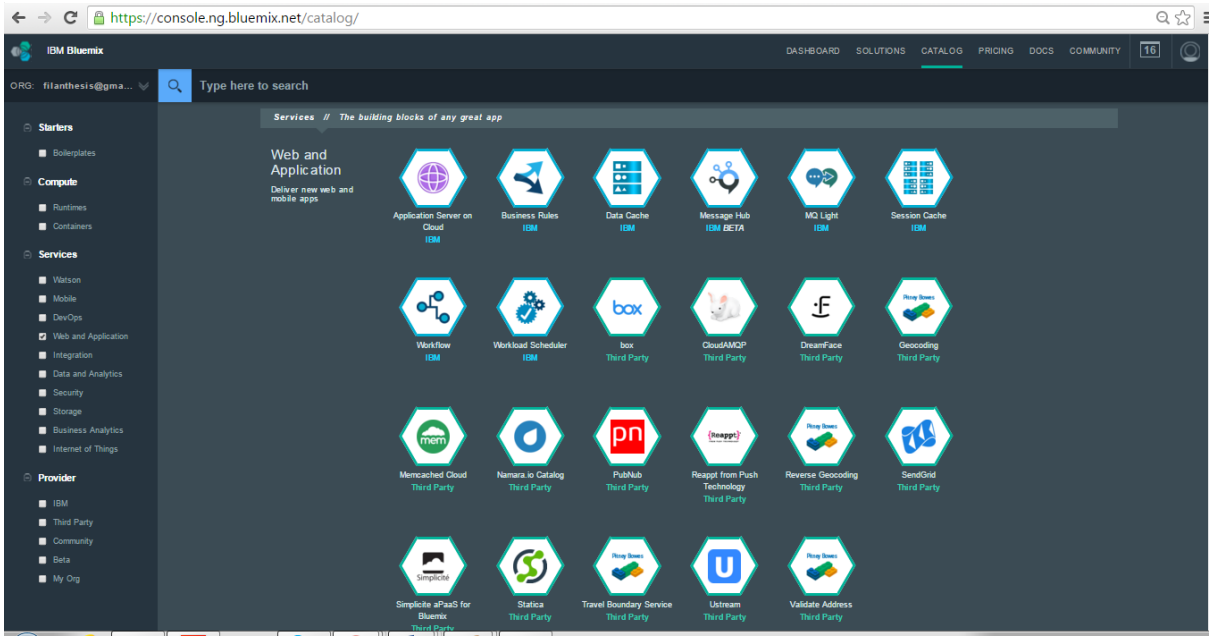
Source: IBM Bluemix Console, *The IBM Bluemix Platform online version*, 2015.

With **Web and Application** Services (Figure 15) developers have a number of services that can help them to create their own web application on Bluemix. This services enables developers to increase productivity, simplify management and orchestrate process and business rules (IBM Bluemix, 2015f). Currently there are 23 services available in this section, but the number of services is constantly rising.

Some of the services I want to point out are follows (IBM Bluemix, 2015f):

- Business Rules IBM. This service enables developers to spend less time testing and recording when organization policy changes occur. The service also minimalize developers code changes by keeping application logic isolated from organizations logic.
- Message Hub. Scalable, high throughput and distributed service that initiate developers on premise and off premise cloud technologies.
- SendGrit Third Party. With this service developers can have simplified email delivery. That may relieves them from the cost and complexity of maintaining email systems.

Figure 15. IBM Bluemix Web and Application Services

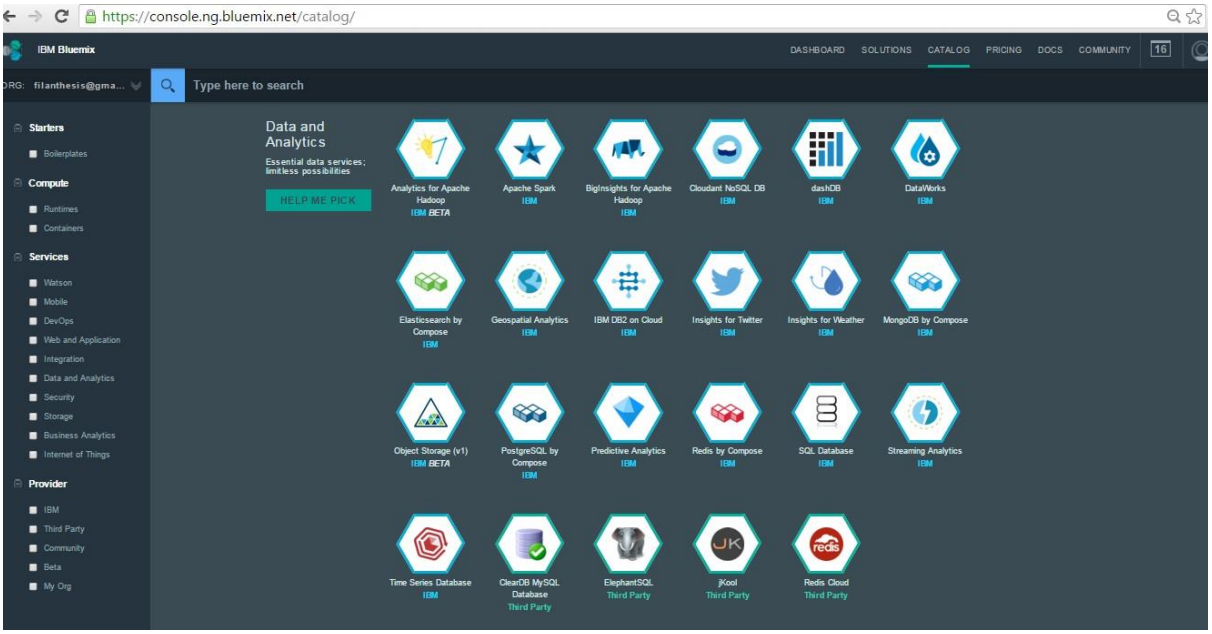


Source: IBM Bluemix Console, *The IBM Bluemix Platform online version*, 2015.

Furthermore developers now have possibility to create integrated cloud databases and analytic services. They can build data driven applications and analyze the data in one central place with the services available in **Data and Analytics** section (Figure 16). Bluemix provides full access to 23 integrated cloud databases & analytic services such as (IBM Bluemix, 2015f):

- Insides for Twitter IBM. The service provides real-time processing of twitter data streams and configurable through of rich set of query parameters and keywords.
- MQ Light IBM. With this service developers can develop responsive and scalable applications with fully managed messaging provider in the cloud. It also allows applications to quickly integrate with applications framework through easy to use APIs.
- jKool Third Party. jKool is Software as a Service that provides real time visualization for data-at-rest or for data-in-motion.

Figure 16. IBM Bluemix Data and Analytics Services



Source: IBM Bluemix Console, *The IBM Bluemix Platform online version*, 2015.

Besides all services mention above there are also other services in the catalog menu available for developers to build applications (IBM Bluemix, 2015f):

- **Integration Services** – A range of powerful services for securely connecting to data and services whenever they reside.
- **Security Services** – Services to protect access to applications and workloads.
- **Business Analytics Services** – Access to all insights to all types of data by using IBM Embeddable Reporting to embed analytics into Bluemix applications.
- **Internet of things** – Access to numerous case studies connected with the platform. Place where developers can set up and manage their connected devices and access all live and historical data with their applications.

Important to note that not all Bluemix services are available in every region. All services are accessible in the USA, but some of them may not be available in Europe and Australia region. Appendix C consist of list of all IBM Bluemix services and their availability by regions.

3.6 Steps for deploying applications in Bluemix

Now deploying application is easier than ever before. Bluemix platform offers developers to deploy their applications with ease. Important thing to know is that only software developers and those who are writing software's for a living can create applications using the Bluemix platform because after choosing selected runtimes and necessary services the coding part comes next where developers have to write their codes associated with the application.

Those are the following steps for deploying simple application using Bluemix platform:

1. In a browser type https://bluemix.net, the link will get you to your default location (US South, United Kingdom or Sydney).
2. Click Log In and then enter all your login information on the IBM id Page (Figure 8) and then click sign in, and the you will see the dashboard (Appendix B, Figure 1).
3. Click Catalog (Figure 11)
4. From Boilerplates section select Node.js Cloudant DB Web Starter (Figure 11)
5. Select a name for your application, the host name information will be automatically entered and must be unique on Bluemix. (You can do that by entering a name with your organization name or initials to make the name unique). (Appendix D; Figure 1).
6. Click create and after a short time your application should be running. If it is not start the application by clicking the route. (Appendix D; Figure 2)
7. After creating your application you can control your application by adding any service you need from the catalog, also you can increase instances and add more memory space if necessary.
8. After your runtimes and services are available and running you need to write codes. (writing codes takes the majority of time)
9. Write codes by choosing Eclipse Tool by Bluemix, CF Command Line Interface or GIT repository (Appendix D; Figure 2).
10. Push the codes

3.7 SWOT Analysis of the IBM Bluemix Platform

After explaining and understanding how the platform works, and what kind of services are available for developers to develop great applications I continued my research by conducting SWOT analysis to find out more about the internal and external factors affecting the platform and the organization at all.

SWOT analysis can help organizations to define the possible risks and rewords when observing potential for a new business or product. Acronym SWOT stands for Strengths, Weaknesses (internal factors), Opportunities and Threats (external factors), and it is an analytical framework, which can increase organization's awareness to face great challenges and to find most encouraging new markets. SWOT analysis is a great technique for information organization, giving solutions, pinpointing roadblocks, highlighting opportunities and a great way to improve organizations operations and decision making (Goodrich, 2015).

For conducting my SWOT analysis I performed the following steps:

- First, before beginning the SWOT analysis I did my own research about the organization and the IBM Bluemix platform in a cloud in order to understand the PaaS market and to find out information which will help me to create the analysis;
- Then I have conducted a semi structure interview in IBM Innovation center in Ljubljana with Mr. Bernard Grum (IBM Cloud - Ecosystem Development SEE). All information I got from the interview helped me to understand what the platform actually means for the organization, some problems the platform have or may have in the future, what the platform means for developers, platform's benefits and limitations, platform's customer base etc.
- Information I got from my own research and the conducted interview helped me to make a synthesis of the internal data and to list platforms weaknesses and the strengths and also to collect the external data with which I can identify platform threats and opportunities.
- In the next step, after listing external and internal data in the table I explain why listed data is included in the analysis followed by briefly description on each data.

Table 4 presents my findings about the strengths and weaknesses that are currently present within the Bluemix and the opportunities and threats that platform faces by its external environment.

Table 4. IBM Bluemix SWOT Analysis matrix

STRENGTHS	WEAKNESSES
• Constantly Platform updates and adding new services • Offers numerous tools for developers to choose • Simplicity, Speed and Agility • Rapid adoption to OS changes	• Limited availability • Can be used only by developers • Internet dependency
OPPORTUNITIES	**THREATS**
• Well know and recognizable brand • Easy Integration • Changes of customer behavior	• Commodity • Regulations • Time on market

3.7.1 Analysis of IBM Bluemix Internal Strengths and Weaknesses

One of the greatest platforms strengths is that the platform is constantly upgraded with additional services, back-ups and updates. I personally think that this is very important strength because that creates a great advantage for all developers to have plenty of services available for developing applications. This also brings all new set of tools that developers can choose. Having constantly upgrades they can be in hand with the newest improvement in IT and can use that directly into their applications.

In order to give a short note how the organization is serious regarding the platform and how they constantly invest in platform's improvement, here is the timeline of all announcements of new IBM Bluemix services and updates during October 2015. This is very important for any developer because on that way they can be assured that they will be always updated with the latest version and don't have to worry about what is new and what are the trends because Bluemix brings to them directly.

- October 29, 2015

Event Hub Service was announced. The service brings events that are generated together by on premises systems or in myriad web services in one centralized cloud – based system. For example developers will receive notification automatically if someone uses an ATM to withdraw cash from their bank account (Hamann, 2015).

- October 27, 2015

Apache Spark Service was announced. With the new service developers can have new levels of flexibility in analyzing large data sets and discover new insights to transform their business (Raida, 2015).

- October 23, 2015

Insights for weather Service was announced. The service include real time weather updates for present weather conditions (temperature, humidity, pressure etc.), 24/7 forecast, daily forecast for 10 day period, data and information for the last 24 hours and more (Kossowsky, 2015).

- October 20, 2015

Availability for IBM **Object Storage** (in beta version) for Bluemix was announced. The service enables developers to access and store unstructured data content and develop applications around their data content (Amanuddin, 2015).

- October 19, 2015

General availability of **Predictive Analytics Service** on Bluemix was announced. The new service offers possibility to developers and data scientists to work together in a way to integrate predictive capabilities into their applications. On that way intelligence – driven applications can be developed which will make smarter decisions, solve tough problems and improves user's lives (Badzak, 2015).

- October 15, 2015

Beta version of IBM **Message Hub** as Bluemix service was announced. The service provides messaging for all platform services, enables developers to build applications in a micro services framework and steams data to analytics engines. Also the services allows developers to connect with other Bluemix services and stream data to analytics to realize powerful insights (Lampkin, 2015).

- October 9, 2015

General availability of **Streaming Analytics** service was announced. The new service can perform real – time analysis on data – in motion for production of developer's applications. Another improvement that IBM brings into this service is that the service has the ability to

enhance integration with other services, and availability developers to choose the size of their own instance (Branson, 2015).

- October 1, 2015

Bluemix local was introduced and IBM containers were launched in London.

Additional strength is that Bluemix platform offers Simplicity, Speed and Agility to developers. Platform is not complex and it is very easy to understand. It shorten the time for developing applications, and it is giving a developers an infrastructure where they can concentrate only in developing great applications. Bluemix can decrease the downtime or redeploying applications by focusing on DevOps model. Furthermore Bluemix provides continuous availability by eliminating the underlying infrastructure and keeps the manageability of services and applications at simple and understandable level. One more strength that is listed in the table is that Bluemix can rapidly integrate and adapt to OS changes, which brings one more advantage for the platform.

One of the platforms weaknesses is its limited availability. The platform in available only in 3 sites: in USA - south, Europe and Australia (Appendix C). That may be a huge problem because if there are sensitive financial data inside the applications developers cannot run them on Bluemix (for ex. in Serbia) because in Europe there is only one site and to get infrastructure from other region developers need to access second sites in Europe where the Bluemix is running so they could built the cluster, the problem here is that the data is not leaving European Union. IBM don't have additional site for the rest European countries that are not part of the European Union, yet. That means that data can be run only inside European Union. Furthermore, if some developers come from other region that is not supported by the platform, for example from Russia eventually they cannot use the platform for developing applications and according to me this is one of the major weaknesses, which may power developers to use PaaS service from other service providers.

Unfortunately this platform can be used only by developers who are doing codes for a living, in other words anyone who doesn't have coding knowledge cannot use the platform because in the end after selecting all services and instances for the applications, the final part comes and that is writing the codes and push them in. Bluemix is a cloud solution and all cloud solutions depends on the internet connection. This is the first condition for starting and using the platform and any crash or losing the network connection can have negative impact of the developers work because this may delay deploying their applications.

3.7.2 Analysis of IBM Bluemix External Opportunities and Threats

One of the greatest opportunities regarding Bluemix is the organization's brand. IBM have a long successful history and it is present in the IT industry for decades. That bring security and trust from its customers. Furthermore IBM is the leader regarding to security, the organization has the best position at the Gartner's Magic quadrant, which makes them leaders for providing greatest security for their customers. Using the public cloud, developers can scale their applications with infinite choice and flexibility.

One of the major problems with PaaS as a cloud model is integration with in-house systems or third parties. This problem is eliminated with Bluemix because anyone can use the platform without locking it to IBM. The platform is built on open stack, and whatever runs of open stack runs of Bluemix. Because other vendor choose a lock in model, the integration to have innovation is much bigger.

According to Bernard Grum from IBM Innovation center in Ljubljana, one more potential opportunity may be the changes of customer behavior. For example corporate would think that the cloud is not secure, not reliable and inexpensive while the consumer would consider cloud to be cheap. This are 2 customers sections that have completely opposite way of thinking. In future this will get closer so small customers will start asking about security, they would start asking about reliability and enterprise or any support. When this mindset changes and make it clear that with cloud is not all about the price but the quality of the service you are doing then it will be a great development for IBM because they have the trust and security. This is the opportunity that will happen in the future because all the trends are going on that way. Moreover in the moment this in not the factor that decides here, still the price is a big factor.

Regarding the external factors there are three threats that may have negative impact on the platform and those are: regulations, time to market and fear that the platform will become a commodity. Concerning regulation that may be big threat because there can be some rules issued by executive authority or regulatory agency of a state/country government that cannot apply in favor to the Bluemix platform. For example Russia will not allow financial data to go outside of the country at all. And because of that IBM need to build new site in Russia but they don't have that yet, and now that can be also a limitation.

Another threat is coming from the competitor's time on the PaaS market. Competitors have been on the cloud market much longer. If we take Amazon as an example they are on the cloud market for more than 10 years. IBM is in the market 1 year and a half year with Bluemix and 3 years with SoftLayer. That means that competitors have already created strong customer base and expertize that may threat the platform now and in the future. Also there are a lot disruptive startups and IBM will never know when they will hit them with better or advanced service.

The last threat that is treating the platform is that PaaS and the Bluemix platform may become commodity. Here is a great explanation for that threat. IBM does not work on cost efficiency, it works on values in a term of creating value for the customer. Operational excellence and value for the customer does not walk hand in hand.

Here is one example for that. Operational excellence – car X which you have for 10 000 EUR and for that amount of money you get everything. Value for the customer - if you consider this to be the only tool then everything is ok. It's not save, do not drive very fast, probably will not get heat and that is ok because you as a customer compromise on the real value. And for example if you put in comparation to this car XY which is 30-40% more expensive than X, there may be some different perception to this.

In this situation you are already looking at value because it is a safer car, it is much more convenient to drive it is much more modular and clear, but it is more expensive. But if this is the only commodity, if everyone wants the same then you have everybody buying X and everyone is looking at X. All organizations will start to build model like X, also XY will start to build same model to compete with X and some other vendors will do the same, to produce the strict and the same model to compete with X because X is successful. Then this will be the problem because for IBM this is not the market where they are excellent, they are not able to strip down to compete. IBM constantly looks and orient in innovation. Innovation is where the organization is good at, in terms of building commodity (X as an example) IBM is not good at. So if this is becoming pure commodity market then this may be big threat for IBM.

3.8 Bluemix Applications

Bluemix was launched in 30 June 2014 and till now there were more than 1 million registered users. This is huge growth especially for IBM. IBM is not used to work with more than 10 000 clients per country. Usually IBM is working with 100 customers per country, sometimes less, sometimes more. That means that there are dozens of applications that were built under Bluemix platform.

Bluemix clients comes from different industries such as: finance, technology, retail, healthcare, education etc. There are many solutions built using IBM's Bluemix Platform as a Service. Some of the applications/solutions build under the Bluemix platform are follows (Taft, 2014; IBM, 2015):

- Vaadin Java Dev Tool.
- Diffusion Softare.
- Revenue Scout.
- AnswerHub.

- Diabetizer.
- Bluemix solution in MIET.

Vaadin Java Dev Tool.

The tool was designed for creating interactive applications that run in a Web browser without any plug-ins. Vaadin hosts its reference applications within Bluemix cloud based platform instead deploying them through organization hardware. That enables developers to stay more responsive and simplify the processes. Vaadin is a Java developer tool that is utilized everywhere from internal business applications and single day prototypes to space applications and yearlong built – outs. The application is used as a management or back-office dashboard for fortune 500 and organizations in the public sector.

Diffusion Software.

Diffusion software is available on IBM Bluemix, and it main purpose is to deliver enterprise application performance in the cloud, eliminating the complexities of not only delivering data over unreliable networks but also on-premises deployments. That enables developers to build engaging, responsive and real-time mobile applications that completely satisfy user experience and rapidly scale as business demands.

Revenue Scout.

Revenue Scout is a cloud-based revenue protection system for water, gas, power, electricity and other utilities. The application addresses the main pain points of utilities experienced around the world, due to inconsistencies in user data that cascade into collection, metering and billing deficiencies. The application preforms by leveraging data analytics, mobile field force management and dynamic workflows to point out areas of revenues leakage and recover money that would have been lost. With Revenue Scout measuring, Return Of Investment (hereinafter: ROI) is easy because the application measure, highlight and records revenue recovered or saved in a daily basis.

AnswerHub.

AnswerHub is a knowledge management software platform that helps organizations to create online communities either for public or private use. The applications was developed by DZone which is a global community of technology experts and professionals. The main purpose of the software is to help internal site developers or external customers cooperate through customized knowledge-sharing communities.

AnswerHub persistently search for new technologies in a way to expand its product development. As AnswerHub used and explored the opportunities and capabilities of the Bluemix environment, the organization also found extra tools and services within the Bluemix catalog that could support all their future improvement in a terms of test, deployment and product development. The great thing for them about Bluemix is that the platform makes it very easy to connect to additional services. The benefit they get from Bluemix is powerful cost effective environment, unlimited set of services and applications which enable AnswerHub to create new communities in hours rather in weeks.

Diabetizer.

Diabetezer Ltd. & Co.KG is an IBM business partner that focuses of making life easier for diabetics by offering tools that help their patients to track vital health details. They (together with IBM innovation center in Switzerland) developed the mobile application myDiabetizer which pulls and aggregates relevant sugar levels, fitness and nutrition information allowing patients to track this data and share it with physicians through generated reports. The application was designed using the IBM Bluemix environment.

The integration capabilities and flexibility of the SoftLayer and Bluemix platform helped Diabetizier to accelerate deployment and development timelines for new capabilities and services. As a result of all this the organization was able to cut its operating costs by 30%. On the other hand the physicians and patients have strong and clear insight into diabetic's health, reassuring better care options.

Bluemix solution in Meerut Institute of Engineering and Technology (hereinafter: MIET)**.**

Bluemix also offers numerous solutions to its users. MIET is one of the leading engineering institutions in India. They recognized the benefits and future of cloud computing and wanted to incorporate into their environment and between their students. For that achievement the institution needed resources and experts to implement the principles and technology. MIET collaborated with IBM career education program and developed a private cloud environment that included the IBM Bluemix platform for faculty training and student education.

MIET and IBM worked together and established the IBM software Lab for Cloud Computing at the institution, which is a private lab for education. The platform provides developers the ability to explore and experiment with a variety of IBM, third party and open source services for testing and implementing of different types of applications. With IBM's knowledge and support, the MIET faculty got the background needed to integrate cloud-based application development education into the institute's plethora of technology curricula, additionally advancing the depth and breadth of learning opportunities for its students.

CONCLUSION

PaaS is a one of the three Cloud Computing models, which enables developers to frame and launch applications more easily comparing to the raw resources of an Infrastructure as a Service cloud offering. A great real example for PaaS is a Bluemix platform - IBMs internal project built from internal innovation which became one of the greatest IBM products. Bluemix is a PaaS where the user as a client only manages the applications and the data, while the rest such as: runtime, middleware, servers, storage and networking is managed by the cloud vendor IBM. The platform was generally available on 30 June 2014 and it is an enormous importance for the organization because it is the future of how to service small organizations and a strategic way to acquire new customers. From it announcement till today platform does not differ a lot, actually the platform grows enormously in a terms of constantly adding new services and tools.

In the first part of my master thesis I have explained many benefits that users can get by moving to cloud computing and deploying PaaS services. Many of those benefits and even more are available within the Bluemix platform. Developers do not have to pay for maintenance costs, risk is not reduced but eliminated, and there is a great support in terms of security and privacy, constantly updates and back – ups. Developers have access to all necessary information and can communicate between each other, share ideas and finding solutions for their problems. Another additional benefit is that the platform can integrate with any type of services because it is built on an open standards and any service that is built under open standard platform can work within Bluemix. That leads to additional benefits that this platform can bring to developers and differentiates from competitors.

Most of PaaS services that are provided by large vendors are private and proprietary having their own set of standards and their own set of rules. On that way migration from one platform to another is difficult and developers need to have migration services, and maybe can happened migration to not be possible at all. What IBM did as a large vendor, it build the platform on an open standards, so if developers don't want to work with IBM they can move to any vendor offering the same public standards that are accepted in the world. Basically, if developers are not satisfied with Amazon web services they need to invest a lot in to migration and there is always a risk that this may not work. With IBM they can go to Heroku or any other vendor that use an open stack as a standards. All that means that with Bluemix lock in is eliminated. This is one of the things that is specific to Bluemix.

On the other hand security and privacy are the main problem concerning PaaS and cloud computing. Bluemix as PaaS solution showed that is very strong regarding to that issue. IBM is the leader recording to security bringing highest possible level of security of its customers. Prove for that is organization's position at the Gartner's Magic quadrant for security, which makes them leader in the industry. Everything that organization sell is done internally, they are constantly reinventing and acquiring new organizations in the field of security and

privacy. That means that the platform is completely secure and all drawbacks that PaaS can eventually bring to developers are completely eliminated.

According to the platform's SWOT analysis that I create one of the main strengths that platform faces are: constantly platform updates and adding new services, numerous tools and services available for developers, simplicity, speed, agility and rapid adoption to OS changes. On the other hand there are some weaknesses that may limit the platform and those are: limited availability, usage only by developers, internet dependency and countries regulations. Because IBM is a well-known and recognizable brand brings great external opportunity for the platform in a terms of reliability, security trust and privacy.

There is big number of data centers availably worldwide and the platform can easily integrate with other services which gives one more opportunity to the platform over competitors. The only threat that may Bluemix face is that all this cloud "think" may become commodity but IBM is completely oriented to innovation and there will be always a way to differentiate with the rest in the industry. Last but not least, in a period on a year and a half there have been more than a million registered users on Bluemix which is a great success for IBM. That is one more prove that the organization have strong customer base, a customers who believe in the product and its benefits.

After analyzing the Bluemix platform which included evaluating theoretical literature connected with PaaS and cloud computing, registering as a platform user and being in direct touch with the platform functionalities and having all documentation provided by IBM, I can conclude that the IBM Bluemix is platform for developers to build their solution and develop their applications. As an acceleration environment Bluemix frees developers from the burn of setting up the environment where they develop their applications, giving them space to focus on developing and deploying excessive applications.

The platform offers many benefits and eliminate drawbacks that PaaS brings in terms of privacy and security, it is easy to use and possess number of services and tools that developers can use and furthermore shorten the days for developing applications from weeks to hours. The platform possess very strong strengths and opportunities that go over its weaknesses and threats. It is a great solution for any developer who want to develop flawless application without worrying about the underlying infrastructure because everything is already managed by the IBM. Bluemix is the future on a way how small and big organizations can use PaaS to develop cloud solutions and acquire new customers.

REFERENCE LIST

1. Amanuddin, R. (October 20, 2015). IBM Object Storage beta for Bluemix in now available. Retrieved November 11, 2015, from https://developer.ibm.com/bluemix/2015/10/20/object-storage-beta-for-bluemix-is-now-available/
2. Arutyunov, V. V. (2012). Cloud computing: Its history of development, modern state, and future considerations. *Scientific and Technical Information Processing*, *39*(3), 173-178.
3. Badzak, M. (October 19, 2015). Predictive Analytics for Bluemix brings machine learning to every developer. Retrieved November 11, 2015, from https://developer.ibm.com/bluemix/2015/10/19/announcing-predictive-analytics-bluemix/
4. Beimborn, D., Miletzki, T., & Wenzel, S. (2011). Platform as a service (PaaS). *Business & Information Systems Engineering*, *3*(6), 1-384.
5. Bidgoli, H. (2011). Successful introduction of cloud computing into your organization: A six-step conceptual model. *Journal of International Technology and Information Management*, *20*(1), 21-37.
6. Bowers, L. (2011). Cloud computing efficiency. *Applied Clinical Trials*, *20*(7), 45-46, 48-51.
7. Branson, M. (October 9, 2015). Streaming Analytics is ready to perform your real-time analysis in production. Retrieved November 11, 2015, from https://developer.ibm.com/bluemix/2015/10/09/streaming-analytics-is-ready/
8. Brent, J. (2014, November 20). BlueMix Dedicated and Enterprise Cloud Platforms. Retrieved April 2, 2015, from https://developer.ibm.com/bluemix/2014/11/20/bluemix-dedicated-cloud-platform/
9. Buyya, R., Vecchiola, C., & Selvi, T. (2013, May 16). *Mastering Cloud Computing: Foundations and Applications Programming.* USA, MA: Elsevier Inc.
10. Buyya, R., Yeo, C.S., Venugopal, S., Broberg, J., & Brandic, I. (2009). *Cloud computing and emerging IT platforms: Vision, hype, and reality for delivering computing as the 5th utility*. USA, MA: Elsevier Inc.
11. Cakil, B. (2015, March 7). IBM BlueMix Dedicated to your data privacy. Retrieved April 2, 2015, from http://thoughtsoncloud.com/2015/03/ibm-bluemix-dedicated-bluemix-is-now-yours-alone/
12. Charrington, S. (2010, February 22). The essential characteristics of PaaS. Retrieved February 23, 2015, from http://cloudpul.se/posts/the-essential-characteristics-of-paas.
13. Cloud Security Alliance. (2013, February). The Notorious Nine Cloud Computing Top Threats in 2013 – Report. Retrieved March 4, 2015, from https://cloudsecurityalliance.org/research/top-threats/#_overview
14. Cooter, M. (2011, September 9). *Ultimate Guide to Cloud Computing.* London: dennis Publishing.

15. Cox, D. (2014, May 2). Top 5 benefits of IBM Bluemix. *Online Article.* Retrieved March 27, 2015, from http://thoughtsoncloud.com/2014/05/top-five-benefits-ibm-codename-bluemix/
16. Darrow, B. (2015, October 1). IBM puts Bluemix everywhere. Retrieved October 26, 2015, from http://fortune.com/2015/10/01/ibm-bluemix-local/
17. Dyna, M. (2015, June 19). IBM Containers: A Bluemix Runtime Leveraging Docker Technology. Retrieved October 29, 2015, from https://developer.ibm.com/bluemix/2015/06/19/ibm-containers-a-bluemix-runtime-leveraging-docker-technology/#comments
18. Erl, T., Puttini, R., & Mahmood, Z. (May, 2013). *Cloud Computing: Concepts, Technology & Architecture*. US: Prentice Hall.
19. Falk, W., Ferris, C., Fork, M., & Sauerwalt, R. (2014, March 10). Accelerate Development of New Enterprise Solutions for the Cloud with Codename BlueMix. Retrieved October 29, 2015, from http://www.redbooks.ibm.com/redpapers/pdfs/redp5011.pdf
20. Fanning, K., & Centers, K. D. (2012) Platform as a Service: Is It Time to Switch? - *The Journal of Corporate Accounting & Finance*, *23*(5), 21-25.
21. GetCloud Services. (2013, July 24). Benefits and Drawbacks of PaaS. Retrieved March 3, 2015, from https://www.getcloudservices.com/blog/benefits-and-drawbacks-of-paas
22. Giessmann, A., & Stanoevska-Slabeva, K. (2012). Business models of platform as a service (PaaS) providers: Current state and future directions. JITTA. *Journal of Information Technology Theory and Application, 13*(4), 31-54.
23. Golden, E. (2014, October 25). PaaS is the Future of IT. *DevOps Journal.* Retrieved March 4, 2015, from http://devops.sys-con.com/node/3218034
24. Goodrich, R. (2015, January 1). SWOT Analysis: Examples, Templates & Definition. Retrieved November 9, 2015, from http://www.businessnewsdaily.com/4245-swot-analysis.html
25. Gurudatt K., Prasad K., & Jayant G. (December 2011) Cloud Computing-Platform as Service. *International Journal of Engineering and Advanced Technology*, *1*(2) 2249 – 8958.
26. Hamann, M. (2015, October 10). Announcing Event Hub: Simple connectivity to streaming data. Retrieved November 11, 2015, from https://developer.ibm.com/bluemix/2015/10/29/announcing-event-hub-on-bluemix/
27. Hammond, S. (2008). Cloud computing: IT of the future or powder puff? Enterprise Innovation. *The journal of business*, *4*(5)33-34.
28. Hartig, K. (2008, June 2). What is cloud computing? *Cloud Computing Journal.* Retrieved January 21, 2015, from http://cloudcomputing.sys-con.com/node/579826
29. Heidloff, N. (2015, August 21). How Docker Containers relate to Cloud Foundry in IBM BlueMix. Retrieved October 29, 2015, from http://heidloff.net/nh/home.nsf/article.xsp?id=20.02.2015092308NHEBUJ.htm
30. Hossain, S. (2014, April 21). What is IBM Bluemix? Retrieved March 26, 2015, from http://thoughtsoncloud.com/2014/04/ibm-codename-bluemix/

31. Hurwitz, J., Kaufman, M., & Halper, F. (2009, October 30) *Cloud Services for Dummies* – IBM limited edition. USA, NJ: John Wiley & Sons, Inc.
32. Hurwitz, J., Kaufman, M., & Halper, F. (2012). The Business Benefits of PaaS in Cloud Computing, Hybrid cloud for dummies. Retrieved February 26, 2015, form http://www.dummies.com/how-to/content/the-business-benefits-of-paas-in-cloud-computing.html
33. IBM (2015). *Case studies.* Retrieved December 13, 2015, from http://www.ibm.com/cloud-computing/bluemix/case-study/
34. IBM Bluemix. (2015a). *Bluemix Overview*. Retrieved October 15, 2015, from https://www.ng.bluemix.net/docs/overview/index.html
35. IBM Bluemix. (2015b). *Bluemix Dedicated.* Retrieved October 15, 2015, from https://www.ng.bluemix.net/docs/
36. IBM Bluemix. (2015c). *Develop Bluemix For free.* Retrieved October 15, 2015, from https://console.ng.bluemix.net/pricing/
37. IBM Bluemix. (2015d). *IBM Containers for Bluemix.* Retrieved October 17, 2015, from https://www.ng.bluemix.net/docs/containers/container_index.html
38. IBM Bluemix. (2015e). *IBM Virtual Machines (BETA).* Retrieved October 17, 2015, from https://www.ng.bluemix.net/docs/virtualmachines/vm_index.html
39. IBM Bluemix. (2015f). *Catalog Section*. Retrieved October 20, 2015, from https://console.ng.bluemix.net/catalog/
40. IBM Bluemix Console. (2015). The IBM Bluemix Platform online version. Retrieved November 1 – 5, 2015, from https://console.ng.bluemix.net
41. Jackson, K, J., & Landis, C. (2012, January) Platform as a Service (PaaS) What Is It? Why Is It So Important? Retrieved February 26, 2015, from http://www.slideshare.net/kvjacksn/njvcvirtual-global-paas-white-paper
42. Jula, A., Sundararajan, E., & Othman, Z. (2014, June 15). Cloud computing service composition: A systematic literature review. *Expert Systems with Applications*, *41*(8), 3809-3824.
43. Kavis, J. M. (2014, January 28). *Architecting the Cloud: Design Decisions for Cloud Computing Service Models (SaaS, PaaS, and IaaS)*. USA, NJ: John Wiley & Sons, Inc
44. Keene, C. (2009, March 26). What is Platform as s Service (PaaS)? Retrieved February 20, 2015, from: http://cloud.dzone.com/articles/what-platform-service-paas
45. Keyur S. M. (2013, March). Analysis of Cloud Computing Security Considerations for Platform as a Service, *International Journal of Computer and Communication Engineering*, *2*(1), 197-200.
46. Khalid, A., & Shahbaz, M. (2013). Cloud computing technology: services and opportunities. *Pakistan Journal of Science, 65*(3), 348-351.
47. Kossowsky, Y. (October 23, 2015). IBM Insights for weather available in Bluemix. Retrieved November 11, 2015, from https://developer.ibm.com/bluemix/2015/10/23/ibm-insights-weather-available-in-bluemix/

48. Lampkin, V. (October 15, 2015) IBM Message HUB is now on Bluemix. Retrieved November 11, 2015, from https://developer.ibm.com/bluemix/2015/10/15/ibm-message-hub/
49. Linthicum, S. D. (2009, October 9). *Cloud Computing and SOA Convergence in Your Enterprise: A Step-by-Step Guide Paperback*. Boston: Pearson Education Inc.
50. Magalhaes, R., & Magalhaes, M. L (2014, March 5). Platform as a Service (PaaS) in 2014. Retrieved March 3, 2015, from http://www.cloudcomputingadmin.com/articles-tutorials/paas/platform-service-paas-2014.html
51. Mather T., Kumaraswamy S., & Latif S. (2009). *Cloud Security and Privacy: An Enterprise Perspective on Risks and Compliance (Theory in Practice).* USA, CA: O'Reilly Media, Inc.
52. McGrath, P.M. (2012, January 24). *Understanding PaaS.* USA, CA: O'Reilly Media, Inc.
53. Mell, P., & Grance, T. (2011, September). The NIST Definition of Cloud Computing, Recommendations of the National Institute of Standards and Technology. Retrieved February 26, 2015, from http://csrc.nist.gov/publications/nistpubs/800-145/SP800-145.pdf
54. Miller, M. (2008). *Cloud Computing: Web-Based Applications That Change the Way You Work and Collaborate Online*. Indianapolis: Queh Publishing.
55. Modi, J. (2014, December 26). Cloud Computing History. Retrieved January 21, 2015, from http://thetechstuffs.com/2014/12/26/cloud-computing-history/
56. Naghavi, M. (2012). Cloud computing as an innovation in GIS & SDI: Methodologies, services, issues and deployment techniques. *Journal of Geographic Information System*, *4* (6), 597-607.
57. Nanath, K., & Pillai, R. (2013). A model for cost-benefit analysis of cloud computing. *Journal of International Technology and Information Management*, *22*(3), 95-II.
58. Nissay, P. G. (2014, January 28). Top Cloud Security Threats. Retrieved March 4, 2015, from http://www.porticor.com/2014/01/top-cloud-security-threats/
59. Oliviera, T.,Thomas, M., & Espandal, M. (2014, July). Assessing the determinants of cloud computing adoption: An analysis of the manufacturing and services sectors. *Information & Management, 51*(50), 497-510
60. Raghupathi, K. (2011, February). 5 Key Events in the history of Cloud Computing Retrieved January 21, 2015, from http://cloud.dzone.com/news/5-key-events-history-cloud
61. Raida, A. (October 27, 2015). IBM Analytics for Apache Spark Available on Bluemix. Retrieved November 11, 2015, from https://developer.ibm.com/bluemix/2015/10/27/ibm-analytics-for-spark-available-on-bluemix/
62. Reyes, T. A. (2014, June 29). What is IBM Bluemix? IBM's Open Cloud Architecture implementation based on a Cloud Foundry project. Retrieved March 15, 2015, from http://www.slideshare.net/ibmdeveloperworks/cl-bluemixfoundrypdf

63. Rhoton, J. (2010). *Cloud Computing Explained: Implementation Handbook for Enterprises*. USA and UK, Recrusive Limited.
64. Rittinghouse, J., & Ransome, J. (2009, August 17) *Cloud Computing: Implementation, Management, and Security*. US: CRC Press.
65. Salesforce. (2012). Official Salesforce website. A complete History of Cloud Computing. Retrieved January 21, 2015, from http:// www. salesforce.com/uk/social success /cloud-computing /thecomplete-history-of-cloud-computing.jsp
66. Scale, M.E. (2009). Cloud computing and collaboration. *Library Hi Tech News, 26*(9), 10-13.
67. Singh, A. (October 2, 2015). Bluemix Local: Architectural Overview. Retrieved October 5, 2015, from https://developer.ibm.com/bluemix/2015/10/02/bluemix-local-architectural-overview/
68. Smye, B. (2014, April 25). A Brief History of Cloud Computing. Retrieved January 21, 2015, from http://www.business2community.com/cloud-computing/brief-history-cloud-computing-0858476
69. Stark, C. (2012, March). The History of Cloud Computing. Retrieved January 21, 2015, from http://www.cetrom.net/blog/the-history-of-cloud-computing/
70. Sylos, M. (2013, September 18). Top five advantages of software as a service (SaaS). Retrieved February 10, 2015, from http://thoughtsoncloud.com/2013/09/top-five-advantages-of-software-as-a-service-saas/
71. Taft, K.D. (2014, October 15). Five Innovative Apps Built on IBM's Bluemix PaaS. Retrieved December 13, 2015, from http://www.eweek.com/developer/slideshows/five-innovative-apps-built-on-ibms-bluemix-paas.html
72. Truong, D. (2010). How cloud computing enhances competitive advantages: A research model for small businesses. *The Business Review, 15*(1), 59-65.
73. Tsagklis, I. (2013, April 23) Advantages and Disadvantages of Cloud Computing – Cloud computing pros and cons. Retrieved January 30, 2015, form http://www.javacodegeeks.com/2013/04/advantages-and-disadvantages-of-cloud-computing-cloud-computing-pros-and-cons.html
74. Turner, S. (2013). Benefits and risks of cloud computing. *Journal of Technology Research, 4*, 1-7.
75. Vega, N. (2014, November 3). Top 38 questions about the Watson Services on Bluemix. Retrieved 5 November, 2015, from https://developer.ibm.com/bluemix/2014/11/03/watson-webinar-qa-responses/
76. Velte, T., Velte, J., & Elsenpeter, R. (2009). *Cloud Computing: A Practical Approach.* US: McGraw- Hill Osborne Media.
77. Viswanathan, P. (2013). Cloud Computing – Is it Really All That Beneficial? Advantages and Disadvantages of Cloud Computing. Retrieved January 30, 2015 from http://mobiledevices.about.com/od/additionalresources/a/Cloud-Computing-Is-It-Really-All-That-Beneficial.htm
78. Vouk, M.A. (2008). Cloud computing – Issues, Research and Implementation. *Journal of Computing and Information Technology, 16*(4), 235-246.

79. Wenhong, T., & Z Yong, Z. (2014, October 23). *Optimized Cloud Resource Management and Scheduling: Theories and Practices*. USA, MA: Elsevier Inc.
80. Williams, B. (2012, July 5). *The Economics of Cloud Computing – An overview of decision makers*. USA: Cisco Press.

APPENDIXES

TABLE OF APENDIXES

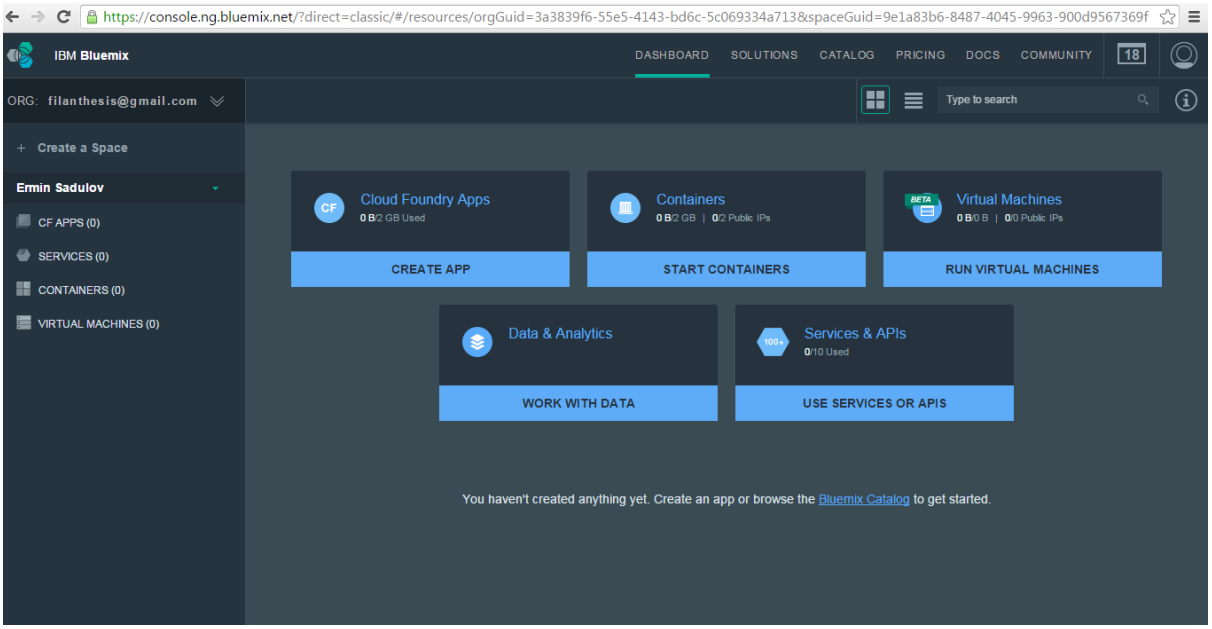
Appendix A: List of Abbreviations

APRANET	Advanced Research Projects Agency Network
4GL	Fourth Generation Programming Language
AaaS	Application As A Service
API	Application Programming Interface
ASP	Application Service Providers
CIO	Chief Information Officer
CLI	Command Line Interface
CPU	Central Processing Unit
CRM	Customer Relationship Management
CSA	Cloud Security Alliance
DbaaS	Database As A Service
DoS	Denial of Services
EC2	Elastic Compute cloud
ERP	Enterprise Resource Planning
HTTP	Hypertext Transfer Protocol
IaaS	Infrastructure As A Service
IDE	Integrated Development Environment
IfaaS	Information As A Service
InaaS	Integration As A Service
iOS	iPhone Operating System
ISV	Independent Service Vendor
IT	Information Technology
ITIL	Information Technology Infrastructure Library

LDAP	Lightweight Directory Access Protocol
MaaS	Management As A Service
MBaaS	Mobile Backend as a Service
MIET	Meerut Institute of Engineering and Technology
NIST	National Institute of Standards and Technology
NoSQL	No Only Structured Query Language
OS	Operating System
PaaS	Platform As A Service
PAYG	Pay As You Go
PC	Personal Computer
PraaS	Process As A Service
REST	Representational State Transfer
ROI	Return of Investment
S3	Simple Storage Service
SaaS	Software As A Service
SCM	Supply Chain Management
SDKs	Software Development Kits
SeaaS	Security As A Service
SLA	Service Level Agreement
SPI	Software Platform Infrastructure
SQLDB	Structured Query Language Data Base
SWOT	Strengths Weaknesses Opportunities Threats
TaaS	Testing As A Service
VM / VMs	Virtual Machine / Virtual Machines

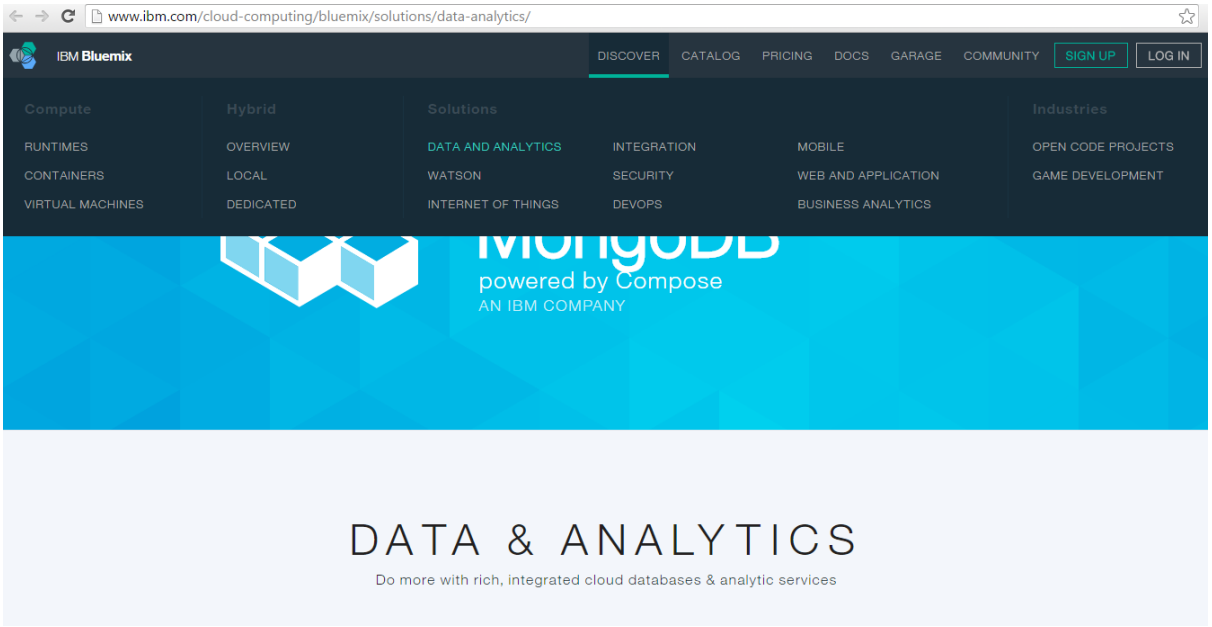
Appendix B: Getting into Bluemix

Figure 1. Bluemix Dashboard Menu



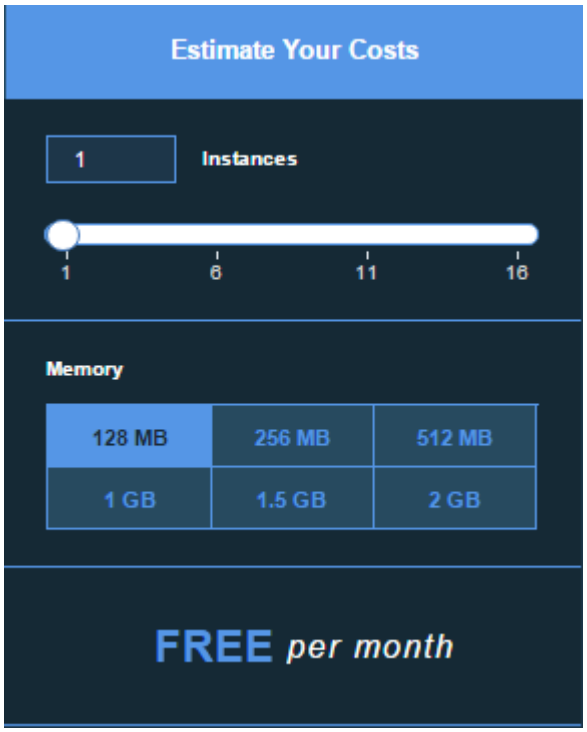
Source: IBM Bluemix Console, *The IBM Bluemix Platform online version*, 2015.

Figure 2. Bluemix Solutions Menu



Source: IBM Bluemix Console, *The IBM Bluemix Platform online version*, 2015.

Figure 3. Bluemix cost estimation form – Pricing menu



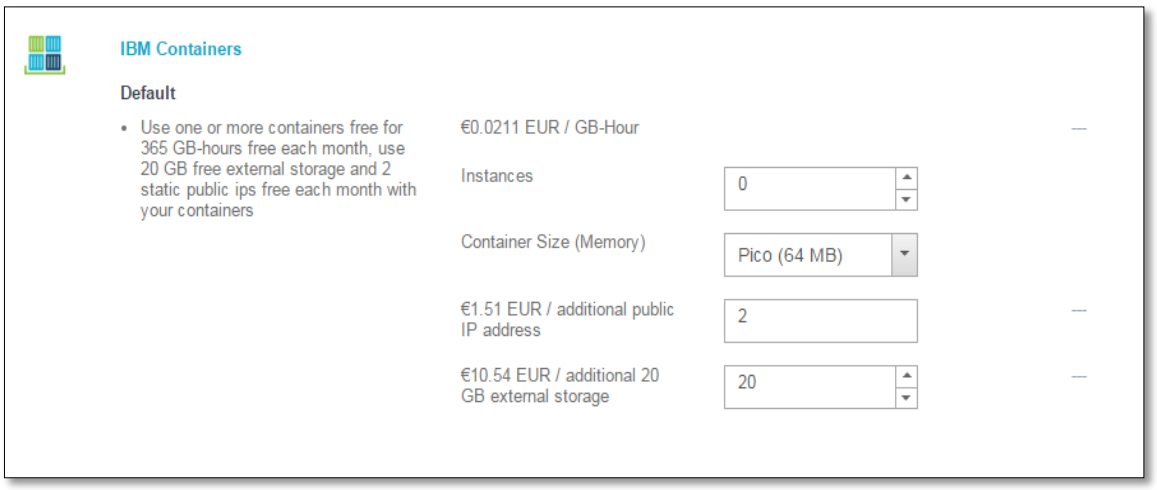
Source: IBM Bluemix Console, *The IBM Bluemix Platform online version*, 2015.

Figure 3 demonstrate the calculating form for pricing the Bluemix platform. Here developers can chose as much instances as they need and memory space and based on this settings the cost will be automatically adjusted. For example If developer choose to have 3 instances and 1MB memory space the price will be 93.89 EUR on a monthly basis (Figure 4).

Figure 4. Bluemix cost estimation form – Pricing Menu

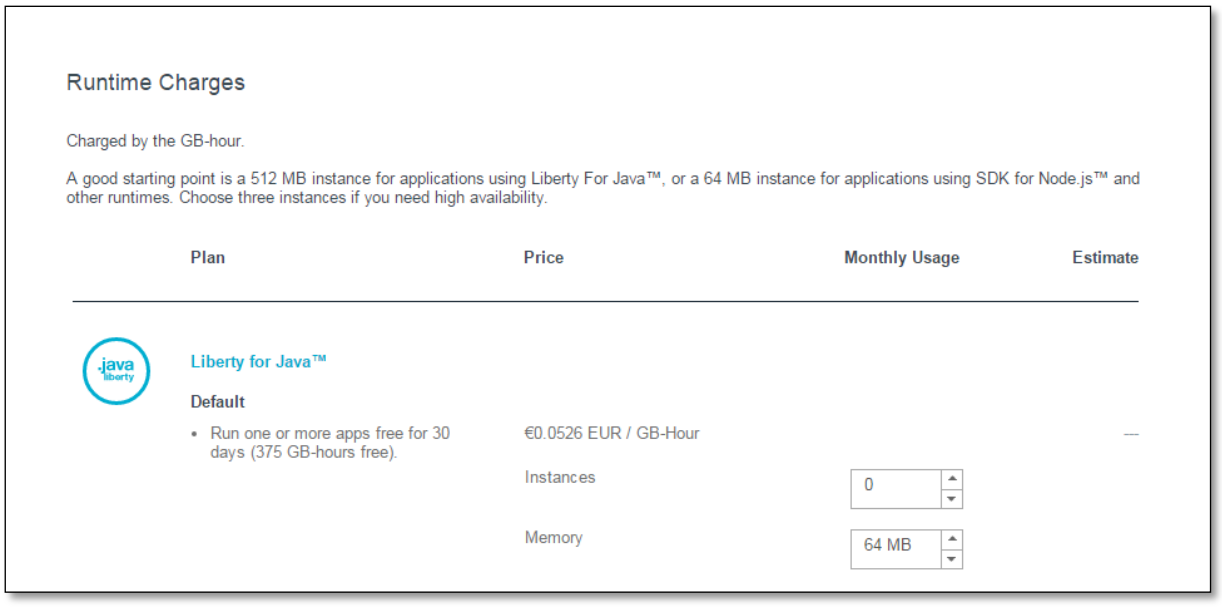
Source: IBM Bluemix Console, *The IBM Bluemix Platform online version*, 2015.

Figure 5. Detailed pricing calculator for IBM Containers



Source: IBM Bluemix Console, *The IBM Bluemix Platform online version*, 2015.

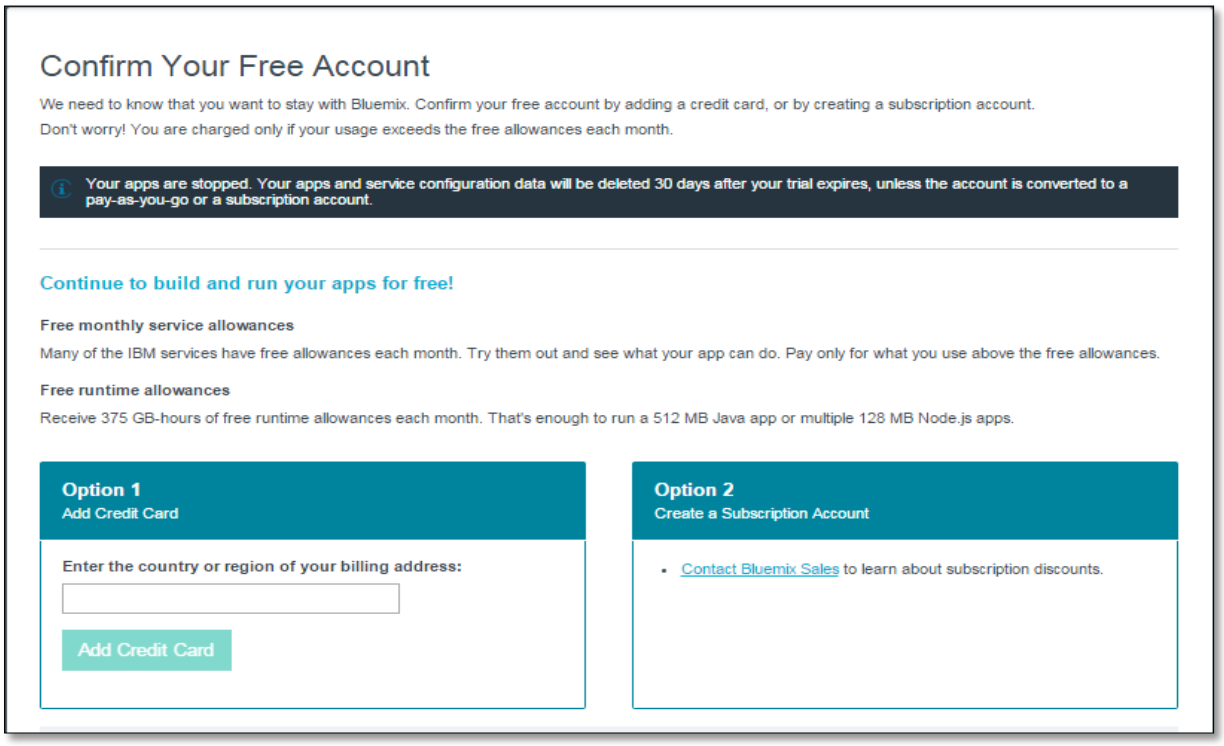
Figure 6. Bluemix Runtime Charger



Source: IBM Bluemix Console, *The IBM Bluemix Platform online version*, 2015.

Figure 7.

Confirming free Bluemix account by adding a credit card after free trial expiration



Source: IBM Bluemix Console, *The IBM Bluemix Platform online version*, 2015.

Appendix C: List of all IBM Bluemix Services and their availability by regions

Table 1. List of IBM Bluemix services and their availability by regions

IBM Bluemix Service	Service Availability by Region		
	USA	Europe and UK	Australia
Active Deploy	Yes	No	No
AlchemyAPI®	Yes	Yes	Yes
AppScan® Dynamic Analyzer	Yes	No	No
AppScan Mobile Analyzer	Yes	No	No
Analytics for Apache Hadoop	Yes	No	No
API Harmony	Yes	Yes	Yes
API Management	Yes	Yes	Yes
Application Server on Cloud	Yes	Yes	Yes
App Sec Manager	Yes	No	No
Auto-Scaling	Yes	Yes	Yes
BigInsights®	Yes	No	No
Business Rules	Yes	Yes	No
Cloud Integration	Yes	Yes	No
Cloudant® NoSQL DB	Yes	Yes	Yes
Concept Expansion	Yes	Yes	Yes
Concept Insights	Yes	Yes	Yes
Connect & Compose	Yes	Yes	Yes
Containers	Yes	Yes	No
dashDB™	Yes	Yes	Yes
Data Cache	Yes	Yes	Yes
Delivery Pipeline	Yes	Yes	Yes
Dialog	Yes	Yes	Yes
Digital Content Checker	Yes	No	Yes
Document Conversion	Yes	Yes	Yes
Document Generation	Yes	Yes	No
Elastic search by Compose	Yes	Yes	Yes

(Table Continues)

(Continued)

Embeddable Reporting	**Yes**	**No**	**No**
Gamification	Yes	Yes	Yes
Geospatial Analytics	Yes	Yes	No
Globalization	Yes	No	No
IBM DataWorks	Yes	Yes	No
Identity Mixer	Yes	Yes	Yes
Insights for Twitter	Yes	Yes	Yes
Insights for Weather	Yes	Yes	Yes
Integration Testing	Yes	Yes	No
Internet of Things Foundation	Yes	No	No
Language Translation	Yes	Yes	Yes
Message Hub	Yes	Yes	No
Message Resonance	Yes	Yes	No
Mobile Analyzer for iOS	Yes	No	No
Mobile Application Security	Yes	Yes	No
Mobile Client Access	Yes	Yes	Yes
Mobile Data	Yes	Yes	No
Mobile Quality Assurance	Yes	Yes	Yes
Monitoring and Analytics	Yes	Yes	No
MongoDB by Compose	Yes	Yes	Yes
MQ Light	Yes	Yes	Yes
Natural Language Classifier	Yes	Yes	Yes
Object Storage	Yes	No	No
Personality Insights	Yes	Yes	Yes
Push	Yes	Yes	Yes
Push for iOS 8	Yes	Yes	No
Question and Answer	Yes	Yes	Yes
Rapid Apps	Yes	Yes	No
Regis by Compose	Yes	Yes	Yes
Relationship Extraction	Yes	Yes	Yes
Retrieve and Rank	Yes	Yes	Yes
Secure Gateway	Yes	Yes	Yes

(Table Continues)

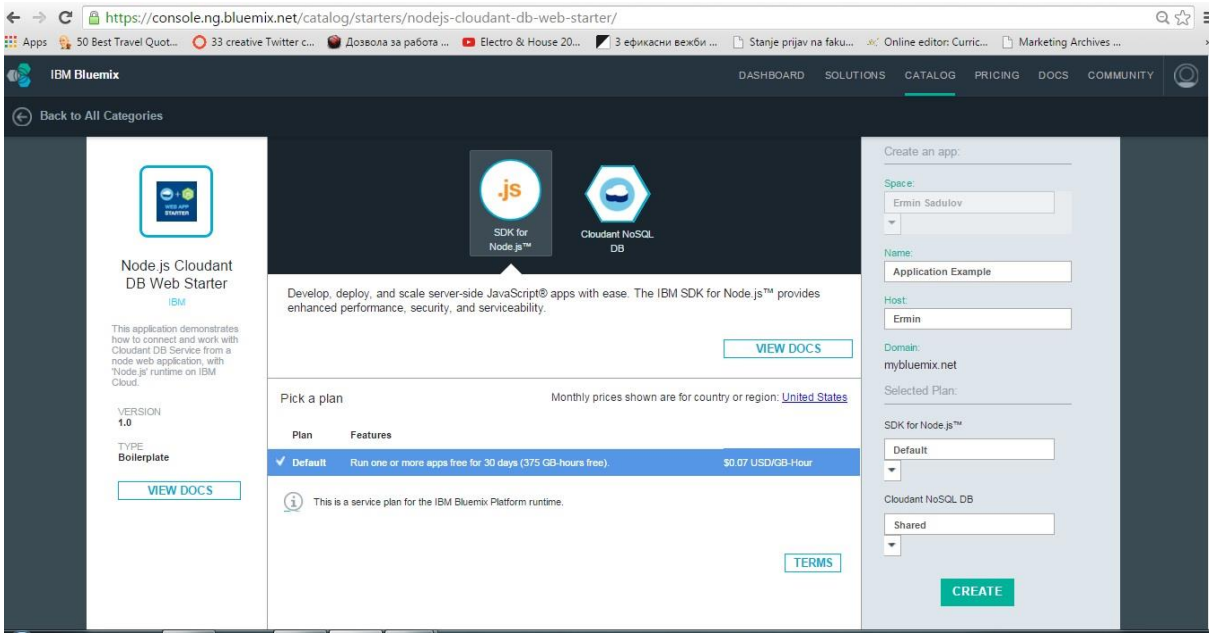
(Continued)

Session Cache	Yes	Yes	Yes
Single Sign On	Yes	No	No
1Speech to Text	Yes	Yes	Yes
SQL Database	Yes	Yes	No
Static Analyzer	Yes	Yes	No
Streaming Analytics	Yes	No	No
Text to Speech	Yes	Yes	Yes
Time Series Database	Yes	Yes	No
Tone Analyzer	Yes	Yes	Yes
Track & Plan	Yes	Yes	Yes
Tradeoff Analytics	Yes	Yes	Yes
Visual Insights	Yes	Yes	Yes
Visualization Rendering	Yes	Yes	No
Workflow	Yes	Yes	Yes
Workload Scheduler	Yes	Yes	Yes
XPages NoSQL Database	Yes	Yes	No

Source: IBM BlueMix, *BlueMix overview*, 2015.

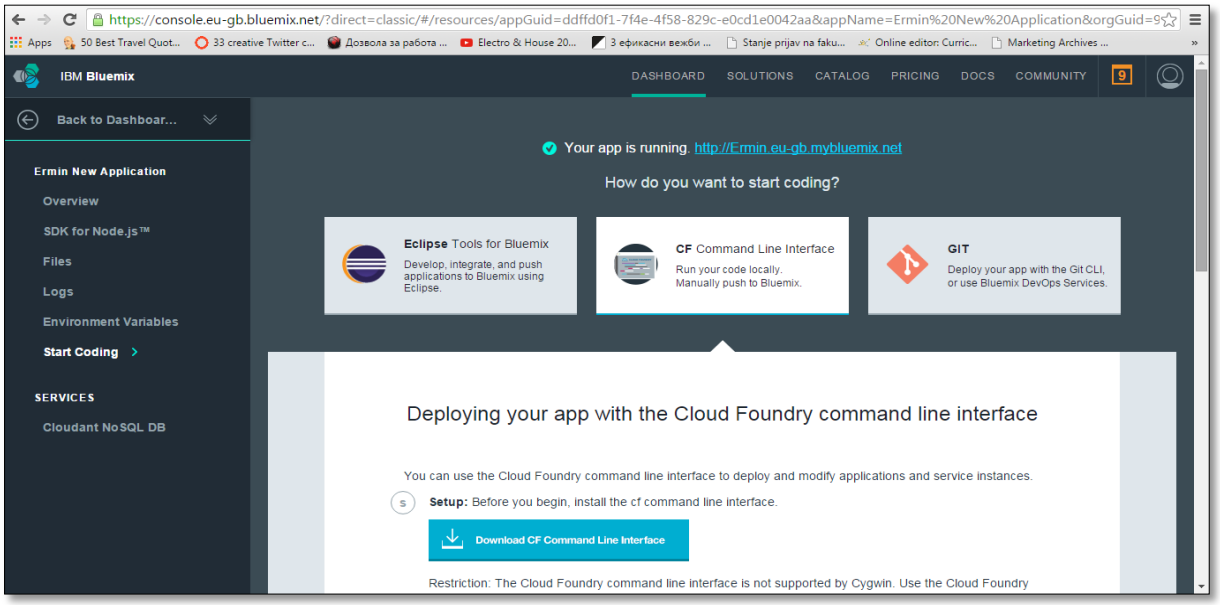
Appendix D: Deploying Applications in Bluemix

Figure 1. Naming Application in Bluemix



Source: IBM Bluemix Console, *The IBM Bluemix Platform online version*, 2015.

Figure 2. Approval that Application is running



Source: IBM Bluemix Console, *The IBM Bluemix Platform online version*, 2015.

Appendix E: The recorded interview (11.12.2015) with Mr. Bernard Grum - IBM Cloud - Ecosystem Development SEE, from IBM Innovation Center in Ljubljana, Slovenia.

1. **How was born the idea for a platform like Bluemix and how long it took to build the platform before launching the beta version?**

Bluemix is internal project built from internal innovation and it is one of the greatest IBM products. Approximately 3-9 months were necessary to build the platform before launching the beta version. The platform was generally available on 30 June 2014.

2. **What does this platform mean for IBM?**

This platform means a lot for us, this is the future of how to service smaller organizations. Not that we are not focused serving big organizations, but this platform is an opening to a new set of market, so for IBM this platform is strategic in a way to acquire new customers.

3. **How the platform differs from the beginning of its announcement till today?**

Actually the platform does not differ too much from its announcement till today. In reality it grows but the platform's idea remains the same. What is happening is that we are constantly acquiring new partners and new services. On that way innovation is continuously adding to the platform in form of new services, so basically that is the only thing that is happening.

4. **Where the major changes were made?**

Most of the major changes that were made regards to the business model and the pricing. Furthermore many of those changes connecting to the platform's business model and the pricing are still yet to come.

5. **How Bluemix changes the way developers build and develop applications today?**

Blue mix is an acceleration environment for developers and is freeing them from the burn of setting up their environment where they develop. On that way their focus is clear in the development. They are dependent yes, but they do not need to build the infrastructure. There are always dependent on their ecosystem. For example in real life that can be explained in a way if you want to come from a point A to point B, you will need the road. Without the road

you are extremely limited to what you can use and in this case Bluemix is the road and everything this road may include "petrol stations, electricity stations and everything that is included." But the car you build, you are designer of the car and you use the given infrastructure. If you build the car without the given "road" you would be very limited to what kind of car you are building because you will not have the given infrastructure and you will need to develop totally new model of how you will build that car. And of course it enforces given rules so everybody that builds the car for this roads know the basic rules and you don't drive in reverse all the time and you need to comply with regulations and in our case this is the same with Bluemix where the developers need to comply to certain regulations.

6. Are platform user's bigger organizations, SME or individual developers?

There are different types of Bluemix customers and they are coming from different industries. There are some from technology, retail, finance, healthcare etc.

7. Can you name some apps developed using Bluemix Platform? Successful stories end examples?

I can name only those that are a public reference to a Bluemix, and they can be found on the Bluemix official page under official references.

8. PaaS as a Cloud Computing service model offer many benefits, which of all them are specific for Bluemix?

In general PaaS benefits from the model are actually benefits connected to the model.

By design, IBM chose to have an open platform built on open standards, and most of PaaS services provides by large vendors are private and proprietary having their own set of standards and their own set of rules. On that way migration from one platform to another is difficult and you need to have migration services, and maybe it may happen sometimes migration to not be possible at all. What IBM did as a large vendor, it build the platform on an open standards, so if you don't want to work with IBM you can move to any vendor offering the same public standards that are accepted in the world. For me that is the major difference because, for example if you are not satisfied with Amazon web services you need to invest a lot in to migration and there is always a risk that this may not work. With IBM you can go to Heroku or other vendor that use an open stack as a standards. All that means that with Bluemix lock in is eliminated. This is one of the things that is specific to Bluemix.

Furthermore, IBM has 2 things. The first one is that IBM is the biggest developer of software services, it is a middleware in the world being in the middle between the technology in the bottom and the application on the top. IBM is the biggest provider of that of that "middleware". We have an arsenal of 3000 products which eventually will make it to Bluemix. Functionality may be different but eventually most of those services may finish in Bluemix making it the biggest playground because we are the biggest provider. But this was not enough for us, we also want to involve all of our partners, we want to open this platform to anyone. We do our innovation and we do our product development but this is a platform and it shouldn't be restricted only to IBM products, for that reason we offer third party and open source. On that way anyone can use it without locking it to us. Because that is built on open stack, whatever that runs on open stack runs of Bluemix. Because other vendor choose a lock in model, the integration to have innovation is much bigger. And other think that we have and differentiate from the others is Watson services.

9. How do you differentiate in comparison with other participants in the PaaS market?

We have a great experience working with enterprise market and we bring that expertise to the consumer market. So our expertise is the enterprise market and this is where we are good at. This is where we are leader and what we have done till now is that we have brought that knowledge and moved it to the consumer market. This is how we differentiate from other participants in the PaaS market and of course services that are result of continuous research in IBM like Watson.

10. What about the competition? Who are major competitors and how you sustain competitive?

We never talk about competition.

11. What makes you better than your competitors?

Like I explained previously of how we differentiate from the others in the PaaS market I can response that and I have already given answer to that, but what makes us better from competitors I cannot answer that because we do not talk about competition we talk about our values.

12. Security and privacy issues are one of the main problem concerning PaaS and Cloud Computing in general, how strong is Bluemix regarding to those questions?

IBM is the leader regarding to security, if you look at the Gartner's Magic quadrant we are leader for providing greatest security for our customers. Everything that we sell we use internal. We are constantly reinventing and acquiring new organizations in the field of security, so the most important think in IBM is the brand and if you have some breaches you may lose brand value and this cannot happen here in our organization.

13. What are your plans for the future? Are you planning some major changes in the platform?

We don't talk about plans.

14. What are Bluemix assets and which one is strongest?

In my opinion the strongest asset that Bluemix have is Watson services.

15. Do you have strong customer base?

Yes. Bluemix has been in production for year and a half. To my knowledge we have around 1 million registered users on Bluemix for that period of time. This is huge growth especially for IBM. IBM is not used to work with more than 10 000 Cents per country. Usually IBM is working with 100 customers per country, sometimes less, sometimes more. This is how this model is done, we approach our customers through business channel or through our partners. What differs Bluemix here is that we approach our customers directly.

16. What are advantages you have over your rival? What is main advantage that makes Bluemix different from other similar PaaS?

As we mentioned before. Strong security, powerful brand name, we eliminate lock in etc.

17. What do you need improvement on?

What we need to do in the future is we need some improvements in PaaS. Currently we have 3 sites (US south, Europe and Australian). If you have sensitive financial data you cannot run them on Bluemix because in Europe its only one site and to get infrastructure from other region you need 2 sites in Europe where the Bluemix is running so you could built the cluster, the problem is that the data is not leaving European Union. We don't have that, yet.

What we need is to have at least two sites in each region. What we need to do in terms of improvement is to build more sites for Bluemix, we have 3 which is a lot compare to competition but not enough to what we want to achieve.

18. What areas do your competitors have an advantage on?

Time on the market. Competitors have been on the cloud market much longer. If you look at amazon they are on the cloud market for more than 10 years. We are in the market 1 year and a half year with Bluemix and 3 years with SoftLayer. Also there are a lot disruptive startups and you never know when they will hit you.

19. What about drawbacks, are there any limitations regarding to the platform?

One of the limitation is that the platform as I said before is available only on 3 sites. Another drawbacks can be regulations. For example Russia will not allow financial data to go outside of the country at all, and because of that we need to build site in Russia but we don't have that yet.

20. What can be potential opportunities and threats?

Potential opportunities may be the changes of customer behavior. I can elaborate more of that now. For example corporate would think that the cloud is not secure, not reliable and the consumer would consider cloud to be cheap while the corporate thinks cloud is unexpansive. This are 2 customers sections that have completely opposite way of thinking. In future this will get closer so small customers will start asking about security, they would start asking about reliability and enterprise or any support in the country. When this mindset changes that with cloud is not all about price but it's about the quality of the service you are doing then it will be a great development for us because we have the trust and we have the security. This is the opportunity that will happen in the future because all the trends are going on that way. Moreover in the moment this in not the factor that decides here, still the price is a big factor. And when corporate slowly move that this becomes a viable model, then IBM has an excellent value proposition on hybrid cloud where you move part of the workloads to the internet and remain with the critical data inside. So again there are 2 developments that are beneficial to IBM where the competition has less credibility than IBM because of the obvious reasons.

The threats are that this may become commodity. And this is the only one threat. IBM does not work on cost efficiency, it works on values in a term of creating value for the customer. Operational excellence and value for the customer does not walk hand in hand.

Here I will give you one example for that. Operational excellence – Dacia which you have for 10 000 EUR you get everything. Value for the customer, if you consider this to be the only tool then everything is ok. It's not save, do not drive very fast, probably will not get heat and that is ok because you as a customer compromise on the real value. And for example if you say in comparation to this Citroen Berlingo which is 30-40% more expensive that Dacia. In this situation you are already looking at value because it is a safer car, it is much more convenient to drive it is much more modular and clear, but it is more expensive. But if this is the only commodity, if everyone is the same then you have everybody buying Dacia and everyone is looking at Dacia. All organizations will start to build model like Dacia, also Citroen will start to build same model to compete with Dacia and some of the other vendor will do the same, to produce the strict and the same model to compete with Dacia because Dacia is successful. Then this will be the problem because for IBM this is not the market where we are excellent, we are not able to strip down to compete. We are constantly looking at innovation, we are looking how machine can only run one liter (like Volkswagen did with the XL1, 1l per 100km) for example. Innovation is where we are good at, in terms of building commodity (Dacia as an example) we are not good at. So if this is becoming pure commodity market then this may be big threat for IBM.