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REVIEW ARTICLE

BENEFITS OF CLOUD COMPUTING IN BIOMEDICINE

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Summary

Currently, Biomedicine is characterised by a growing need for processing large amounts of data in real time. This leads to new requirements for information and communication technologies (ICT). Cloud computing offers a solution to these requirements and provides a lot of advantages such as cost savings, elasticity and scalability of using ICT.

The aim of this paper is to explore the concept of cloud computing. Firstly, the forms of cloud computing are described. Secondly, the potential benefits and limitations of Biomedicine technology are discussed. Finally, the current (present) situation of using this technology in Biomedicine in the Czech Republic from an economic point of view is analysed.

Key words: Cloud computing; benefits; limitations; bio-medicine

INTRODUCTION

Current science is characterised by a considerable growth in the ability to measure and gather data in enormous amounts that were previously unthinkable. Nevertheless, it leads to new requirements for the development, application of new methods and ICT capable of storing, transmitting and further data analysing, or potentially capable of using the data as input data for mathematical modelling (Hřebíček et al., 2012). Biomedicine is a significant area of ICT utilisation, which also needs to process huge amounts of data. In scientific calculations based on bio-medical data, they are often modelled on real world situations and changeable conditions. These problems cover a wide range of complex and very extensive units, for instance the design and implementation of automated clinical laboratories, screening facilities, multifunctional imaging centres, hospital information systems, distant monitoring, telemetry, etc. The requirements for computing power increases mainly in the evaluation of biomedical signals in real time. Using some kind of transformation like the wavelet is not difficult due to the number of steps in one subscription, but mainly for use on large real bio-medical data which requires fully parallel high performance computing. The technology, which can be used effectively in this context, is cloud computing (Huptych, 2007).

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Cloud computing should make any element of ICT infrastructure accessible as an on-demand service: virtual computers, applications, data staging area, servers and networking hardware. In addition, the infrastructure is very flexible and can be changed (Penhaker et al., 2012). Cloud computing can be seen as a form of services accessible to customers by means of communication network, as well as, all hardware and software tools used by data centres providing these services (Armbrust et al., 2009). Forrester (Forrester, 2009), a global research and advisory firm, widened the above mentioned definition so that it also covers the standardisation of ICT tools on the supplier's side, and self-service principals on the user's side. Cloud Computing is in fact a package of standardised ICT capacities (services, software solutions or infrastructure) accessible via the Internet on the basis of self-service principles and the pay-per-use model. Marks and Lozano (Marks, Lozano, 2010) consider hardware standardisation to be a necessary prerequisite for the formation of Cloud Computing. The Gartner Agency proposes a more compact view of the problem. The whole concept is based on the way of using ICT when scalable and elastic ICT tools are delivered as services to external users through internet technologies. There are five unequivocal pillars of the whole concept (Gartner, 2009):

- *Services* – customer needs and provider needs are separated by a clearly defined interface, which is called a service,
- *Scalability and elasticity* – service delivery can be progressively increased or decreased according to topical customer needs,
- *Sharing with other users* – ICT tools are accessible as a service shared by more customers,
- *Measuring by utilisation* – service utilisation is measured by means of suitably defined measurement standards, which enable charging the service based on a number of payment models,
- *Internet technology utilisation* – services are supplied to the customer via the Internet.

Two types of service models can be distinguished within the field of cloud computing: public and private. A service model is a way of providing cloud computing services to the end user. Many authors, for instance (Sarna, 2011), (Linthicum, 2009), (Mell, Grance, 2009), agree with it. The basic characteristic of public cloud computing infrastructure is accessibility to individual users or companies. The service provider must be an external entity. The same applies to the data centre from which the service is accessible (Mell, Grance, 2009). In relation to this model the so-called Virtual Private Cloud is sometimes mentioned. It is a solution that enables any organisation to create a group of separate ICT tools in a public space. According to Mell and Grance (Mell, Grance, 2009), Private Cloud is every model which makes services accessible only to the entity. The whole infrastructure can be administered by a third party or a given organisation. On the other hand, Armbrust (Armbrust et al., 2009) can see the essence of the private solution in internal data centres, which make their services accessible exclusively to their own organisation, it is not available to the public or to other entities.

From the point of view of offered services, three basic distribution models can be distinguished. Infrastructure as a Service (IaaS) – in this case the service provider pledges to provide the infrastructure. The main advantage of this approach is the fact that all hardware problems are solved by the provider. IaaS is suitable for those who own software (or a license for it) and do not want to care about hardware. IaaS examples are Amazon WS, Rackspace or Windows Azure. Platform as a Service (PaaS) – this service model offers a complex hardware and software platform. Therefore, it is sometimes called cloudware. The PaaS service usually facilitates the creation of user interfaces and includes devices and services for application development which enables designing, development, testing, implementation and hosting (Novák, 2011). The service users do not have to worry about investment or building the infrastructure for development and the subsequent operation of their applications. An example of PaaS providers are Google App Engine or Force.com (Salesforce.com). Software as a Service (SaaS) – this application is licensed as a service leased to the user. Users can purchase access to the application, not the application itself. SaaS is ideal for those who only need ordinary application software and require access from any place at any time. An example is the well-known set of Google Apps or the Cargopass System, known in logistics.

Cloud computing provides lots of advantages. For instance, savings on ICT costs, elasticity of using ICT, etc. A lot of experts agree upon the benefits listed in Table 1.

Table 1. Benefits of cloud computing.

General Benefits	
Lowering investment costs and operating costs	(Armbrust et al., 2009), (Linthicum, 2009), (Sarna 2010), (Marks, Lozano, 2010), (Goncalves, Ballon, 2011), (Velte et al., 2010), (Marston et al., 2011), (Hogan, 2008)
Utilisation of network services and the Internet, the speed of implementation	(Linthicum, 2009)
Innovative approach	(Velte et al., 2010), (Sarna, 2010), (Linthicum, 2009), (Marks, 2010), (Goncalves, Ballon, 2011), (Marston et al., 2011), (Hogan, 2008)
Environmentally-friendly approach	(Linthicum, 2009)
Lower number of ICT staff and lower ICT costs	(Sarna, 2010), (Marks, Lozano, 2010), (Armbrust et al., 2009), (Rosenthal et al., 2010), (Goncalves, Ballon, 2011), (Velte et al., 2010), (Marston et al., 2011)
Elasticity and scalability	(Armburst et al., 2009), (Rosenthal et al., 2010), (Marston et al., 2011), (Hogan, 2008)
Safety	(Velte et al., 2010)
Support of the business process	(Marks, Lozano, 2010), (Rosenthal et al., 2010)
Faster access to the market	(Goncalves, Ballon, 2011)
Shorter delivery time	(Goncalves, Ballon, 2011)
Automation of processes	(Velte et al., 2010)
Topical version of applications	(Velte et al., 2010), (Marston et al., 2011)
Energy savings	(Marston et al., 2011)
Benefits in Bio-medicine	
Central management of patient care and claims data	AT&T Intellectual Property, 2012) (Rubenstein, 2010), (Ferenchick, Solomon, 2013)
Reporting clinical data to improve patient outcomes	
Analysing chemical and biological data for drug discovery	
Meeting high performance computing (hpc) capacity needs and processing computer intensive research models such as genome sequencing	
Storing, managing, and analysing high volumes of images	
Utilisation of cloud in support of just in time management	
Viewing from virtually any location through common internet web browsers	
Accessible from laptops, tablets, smartphones and other smart devices	
No data leaves cloud and is viewable on highly-secure mobile devices	
Freedom of choice in medical image storage	
No data leaves cloud and is viewable on highly-secure mobile devices	

APPLICATION OF CLOUD COMPUTING IN BIOMEDICINE

Biomedicine is an inter-disciplinary scientific discipline. It integrates technical knowledge as well as physical sciences. Its objective is to utilise this knowledge for solving problems of basic medical sciences, clinical medicine and biology. According to the Bio-medical Engineering Handbook (J.D. Bronzino, editor; CRC Press&IEEE Press, Second Edition, 2000) it includes:

- applying engineering system analysis (physiological modelling, simulation, management) to biomedical problems;
- detection, measurement and monitoring of physiological signals (i.e. bio-sensors and bio-medical instrumentation);
- diagnostic interpretation by means of signal processing methods applied to bio-electrical data;
- therapeutic and rehabilitation procedures and instruments (rehabilitation engineering)

- substitute or body strengthening instruments (artificial organs);
- computer analysis of patients' data and clinical decision-making (i.e. medical informatics and artificial intelligence);
- medical imaging (i.e. graphical imaging of anatomic details or physiological functions);
- Creating new biological products (e.g. bio-technology and tissue engineering).
- The above mentioned facts make it clear that information technologies supporting bio-medical processes work with data in the following formats:
- discrete numerical values,
- analogue data in the form of a continual signal (e.g. electrocardiogram),
- visual pictures (e.g. radiological pictures)

At the same time, the current requirements for ICT in this area are developing in the following direction (Huptych, 2007), (Doukas et al., 2010). It is the availability of e-health applications and medical information anywhere, patient and personalised monitoring, online health and wellness tools. Requirements arise for proper realisation (Doukas et al., 2010):

- data storage and management (physical storage & availability issues, maintenance, etc.),
- interoperability and the availability of hetero-geneous resources (heterogeneous data, seamless global access),
- security and privacy (encryption and storage, transmission access control),
- unified and ubiquitous access (platforms, infrastructures, interfaces) (Microsoft, 2013).

E-Health Cloud

E-health is a very important area and opportunity, which is supported on a national and supranational level in the use of cloud computing. Between 2013 and 2020 the European Commission (European Commission, 2012) will support actions to improve the market conditions for entrepreneurs developing products and services in the fields of e-Health and ICT for well-being (Sofsian, 2006). Many different application scenarios are envisaged in electronic healthcare (e-health), e.g., electronic health records ((Rau et al., 2010), (Gematik, 2012), (Schabetsberger, 2006)) accounting and billing (Sofsian, 2006), (KV SafeNET, 2010), medical research, and trading intellectual property (Hsu et al., 2010). In particular e-health systems like electronic health records (EHRs) are believed to decrease the cost of healthcare (e.g., avoiding expensive double diagnoses, or repetitive drug administration) and improving personal health management in general. Examples of national activities are the e-health approach in Austria (Schabetsberger, 2006), the German electronic Health Card (eHC) system (Gematik, 2012) under development, or the Taiwan Electronic Medical Record Template (Hsu et al., 2010), (Baharath et al., 2013).

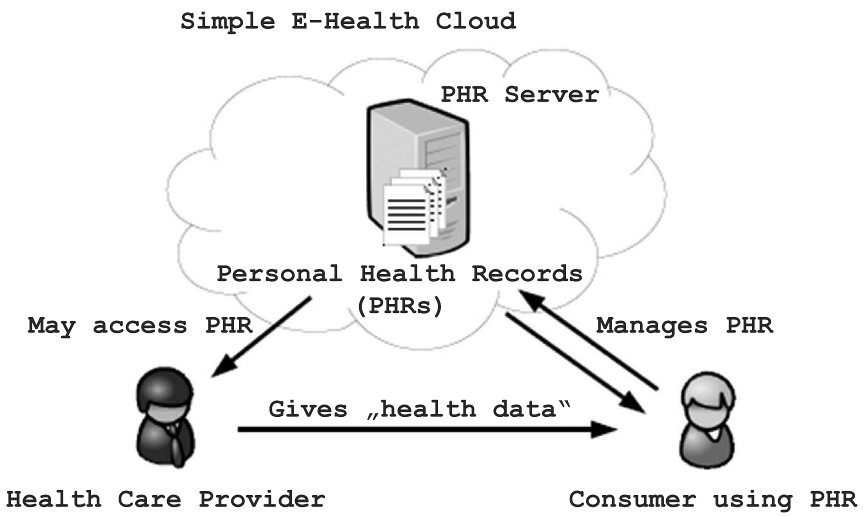

Figure 1. Simple E-Health Cloud model. Patients manage their own personal health records, source: (Löhr, 2010).

While such e-health systems promise a more cost-efficient service and improves service quality, the complexity to manage data security and privacy increases, too. The simple E-Health Cloud model is shown in Figure 1.

On the other hand, e-Health Cloud brings some limitations which are discussed in (Löhr, 2010):

(a) High cost of implementation and maintenance: the costs require investments in software, hardware, technical infrastructure, IT pro-fessionals, and training. This can result in a consid-erable cost to healthcare organi-sations in particular for small and medium sized entities.
(b) Fragmentation and insufficient exchange of patient data: in most cases small clinical or administrative systems exist as separate systems within different departments of the healthcare provider's organisation. Therefore, the patients' data exist in a dispersed state where certain portions of this data are restricted within separate departmental systems, certain clinics or areas of the healthcare organisation.
(c) Lack of regulations/laws mandating the use and protection of electronic health care data capture and communication: currently, there are no well-established laws or regulations man-dating the electronic capture of patient data in addition to laws covering the issues of protec-tion and security of this data. For example, there is no general law protecting the privacy of patients and the interchanges of their medical data between countries. The data protection standards and regulations are at different levels across countries (Rau et al., 2010).
(d) Lack of e-Health Cloud design and development standards: There are no well-established standards available for healthcare providers to use for designing and building their systems. This would include definitions of data types, forms and frequency of data capture in addition to defining how the data is obtained, stored, used and protected. More regarding existing e-health standards is available in the ITU-T technology Watch Report in (Sunyaev, 2010).

THE POTENTIAL OF CLOUD COMPUTING IN CZECH BIO-MEDICINE

The current state of Biomedicine in the Czech Republic

The development of Biomedicine is extremely dynamic as it immediately incorporates new findings and knowledge into medical and bio-pharmaceutical technologies. Explosive knowledge growth and the latest research results in this field have led to establishing new interdisciplinary research areas. Biomedicine in the Czech Republic has to solve several significant problems, namely (MEYS, 2014):

- fragmentation of the infrastructure, large infrastructure is non-existent in the Czech Republic;
- too many local interests and fragmentary objectives or too many groups of scientists located in various workplaces with minimal co-operation;

On the other hand, sufficient intellectual capacity, experience and human resources exist for a lot of technological units. Individual units achieve outstanding scientific results and participate in directing the development of scientific disciplines at least on a national level.

Cloud computing in the Czech Republic

The Czech Republic struggles with the utilisation of low level cloud computing. A survey carried out in September 2011 by Aspectio Research in coop-eration with Google Czech Republic and the Association of Small and Medium Enterprises and Crafts CZ only confirms this fact. The survey proves that a major obstacle in using new technologies in cloud is the lack of information on what the term actually means (AMSP, 2011). Almost 70% of the survey respondents had previously never heard of cloud computing and only a quarter knew its correct meaning. 16% of com-panies didn´t know this term but have been using cloud computing without being conscious of its existence.

The results of another questionnaire survey called "Utilisation of ICT in Czech companies" were similar as in previous years. The percentage of companies using cloud computing or considering its use was very low (8.17 %). The basic barriers are (Marešová, 2013):

- insufficient knowledge of cloud computing and its capabilities,
- low priority given to the usefulness of cloud computing,
- fear concerning data safety,
- dependence of operation on internet connection.

Nevertheless, according to the last prognoses of IDC, the utilisation of cloud in the Czech Republic has been on the rise. The dynamics of growth will depend on many factors, namely clear rules on service provider accountability, guaranteeing data and application portability between cloud services providers and fostering EU-wide standardisation and interoperability of cloud and cloud services.

Cloud computing in Czech Biomedicine research

In 2013 the Czech Republic joined the project called the European Life-Science Infrastructure for Biological Information (ELIXIR). The ELIXIR Project as a scientific infrastructure is organised by the means of a system of a central coordination knot and a nationally distributed knot, which enables mutual interconnection of biological data, files, tools and literary sources in the broadest sense (Vondrášek, 2013). ELIXIR is an infrastructure of worldwide significance. It enables cooperation of researchers in all scientific disciplines in natural, life sciences and also medicine (ELIXIR, 2014). At the same time, it is an infrastructure open to new members and enables cooperation on projects of international significance. On a national level in the Czech Republic, twelve significant research institutions are currently preparing a project to create the national cell, the so-called knot, which will participate in ELIXIR.

In the case of further engagement and expansion of this technology, the following opportunities open up:

- small laboratories, medical practices do not usually have internal IT staff to maintain and service in-house infrastructure for mission-critical applications such as EHRs. Therefore, eliminating the cost of new infrastructure and IT maintenance burdens can remove many obstacles in EHR adoption (Schweitzer, 2011), (Zhang, 2010). For bigger health organisations, placing data storage and the needs of IT applications in the hands of a cloud provider essentially shift the IT management burden to a third-party provider. From an IT management's point of view, cloud computing can increase the scalability, flexibility, and cost effectiveness of infrastructure,
- perhaps the strongest resistance to the adoption of cloud computing in health IT centres is related to data security (ENISA, 2011). All kinds of security measures, such as hardware, software, human resources, and management costs, are cheaper when implemented on a large scale.

CONCLUSION

Bio-medical research during the last decade includes the implementation of a wide spectrum of experimental techniques which produce a large amount of bio-medical data which need to be processed in Real Time. This requirement is not possible to observe by using only standard information technologies. Cloud services offers Biomedicine an attractive solution, helping manage resources better, and provide fluid access, viewing, and sharing of medical images across organisations, departments and providers.

Cloud computing is a technology that has been rising to prominence in the Czech Republic since 2009. Despite this fact, its current utilisation in Czech companies and institutions is still relatively low and the same applies to the knowledge of Czech companies with regard to its possibilities. From 2014 onwards, a sharp rise in its utilisation is expected. This rise should be more significant. The more significant it becomes, the more support it will receive from the Czech government and its interventions. Support for this technology comes from the EU, which has already approved a strategy whereby the objective is to better support the utilisation of Cloud Computing and to create unified rules for its utilisation by European companies.

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