EXPERT SYSTEMS IN A CLOUD COMPUTING ENVIRONMENT MODEL FOR FAST-PACED DECISION MAKING

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Contribution to the state of the art
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Abstract: In this paper the use of cloud computing technologies and expert systems will be analyzed. Furthermore, the use of expert systems in a cloud computing environment will be addressed. Specifically a Cloud-Based Expert System (CBES) model for decision making will be presented. The mentioned model will include the model's infrastructure and its application. In addition, a theoretical approach will be used as a basis for the research and analysis. The CBES model offers effective, fast and reliable support for individuals or organizations when it comes to fast-paced decision making.

Keywords: cloud computing, environment, CBES model, decision, expert system.

INTRODUCTION

In modern society, information technology has become a necessity. The Internet has revolutionized social interactions and the way of how people communicate. Furthermore, globalization and the age of digitalization have brought dynamic and fast information distribution. People can easily send, receive and share digital content. Cloud computing can be defined as a highly scalable virtual resource development model [18]. In addition, cloud computing technologies provide a wide set of options for flexible data storage. Nonetheless, cloud environments can "evolve" in various ways. Workflow scheduling research based on Modified Critical Path (MCP) and Dynamic Critical Path (DCP) algorithms can be used inside the cloud environment [9]. Likewise, expert systems can be implemented as well as other applications [16]. This kind of integration and use of expert systems depends on the structure and purpose of the cloud computing environment.

Expert systems are computer systems which emulate the decision making process of a human expert [17]. It has a very wide application in medicine, decision-making models, diagnostics and other types of services [21]. Expert systems can be integrated as a part of a cloud computing environment. Moreover, detailed and massive databases can enrich expert systems in the cloud environment. This can be achieved through real-time storage in the database with knowledge from experts. In addition, the added data is available to other users almost instantly [16]. Similarly, other services and applications can be provided alongside expert system support. Cloud computing environments are known for their flexibility and scalability [2]. Together, with expert systems, a model for fast-paced decision making can be created. In the modern business world, the dynamic markets require a fast decisions regarding product distribution, product manufacturing and achieving goals. Similarly, in medicine, in the automotive industry and manufacturing processes, effective di-

agnostics are important for good and fast decision making.

In this paper, a model of an expert system in a cloud computing environment for fast-paced decision making will be presented. The model includes the infrastructure of the cloud computing environment and the expert system model. Furthermore, details of the expert system, cloud platform and information flow patterns will be defined and presented. The paper addresses three main concepts. First, the principles and applications of expert systems will be defined. Second, the cloud computing environment will be presented. This includes the characteristics, architecture, advantages and disadvantages. The third section of the paper defines the elements of the model and shows the main concept of expert system implementation with cloud computing environment for fast-paced decision making.

This *Cloud-Based Expert System* model (CBES model) can improve the effectiveness of decisions and drastically reduces execution and decision making time.

Furthermore, the paper addresses the main concepts of cloud computing deploy models. In addition, software architectures and other types of cloud computing will be reviewed. The main goal of this paper is to present the possibilities of expert system use in a cloud computing environment. Furthermore, the benefits for small and medium enterprises (SME) are defined as well as the overall positive influence on society. The paper is motivated by the concept of decision making efficacy and the major role of cloud computing and expert systems in society. The presented CBES model offers an insight to the possibility of expert systems use in a cloud computing environment.

Expert systems and diagnostics

Expert systems are defined as tools which are capable to understand problems from a specific subject. The system uses acquired and available "knowledge" from databases to solve problems [12]. The "expertise" comes from experts who have knowledge about a specific subject. Furthermore, an expert system uses the experts' knowledge in order to solve a given problem [21]. Expert systems are based on two basic concepts. First, on an expert's knowledge which is not algorithmically organized, is stored into databases of the system. From here, the data is processed and used by the user through the user interface [11]. The second concept includes the expert's knowledge storing into the procedural system. This procedural knowledge can be modified and it generates new knowledge based on facts from the procedural system [11].

Expert systems can be presented as an intelligent "consultant" in a specific subject. The knowledge that an expert system contains is collected from one or more experts from one specific field. However, there are situations when expert systems can contain knowledge from two similar fields that together form a synergy [3] [11]. Known expert systems are:

- MYCIN, developed by Stanford University and is used for bacterial infection and antibiotics therapy diagnosis [19];
- MACSYMA, developed by Martin and Fateman and it is used for symbolic solving of differential and integral calculations [6];
- EXPERT, developed by Weiss, Kulikowski and Safir, and it is used for glaucoma diagnosis [4];
- CADUCES, developed by Pople, Myers and Miller, and it is used for internal statistics [14];
- GRAPH developed by Cvetković and others and it is used for medical diagnostics [7].

Expert system development includes one or more experts from whom the knowledge is collected. Problems may occur when the experts cannot present their knowledge in an adequate way. When developing an expert system, there are basic steps which are used for development. These steps are [11]:

- conceptual design;
- collecting knowledge;
- system development;
- estimating performance;
- estimating acceptability;
- demonstration of the prototype;
- revision and further development;
- expert system realization.

The main components of an expert system are the knowledge base, working base or database, inference mechanism and connection with the user [11]. The knowledge base includes knowledge from experts and this type of knowledge is presented as declarative knowledge [11]. The working database contains "initial" data and "flowing" data as well as facts which are connected to objects from the prob-

lematic field. The inference mechanism contains two main components. The first one is the execution mechanism and the second one is the control mechanism [15]. Without the inference mechanism the expert systems would be nothing more than a standard database. In addition, all knowledge from the database is processed through the inference mechanism [11] [15]. The simple scheme of an expert system is shown in Figure 1.

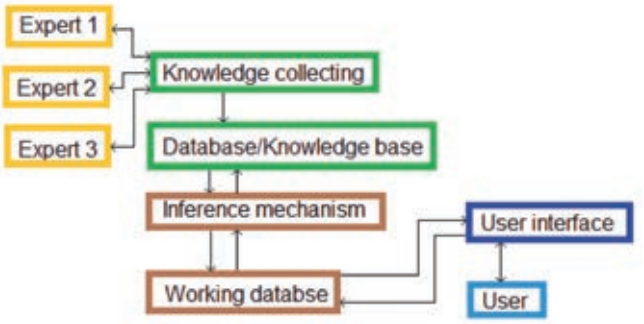

Figure 1. *Expert system scheme*
(Source: own)

One expert or more can store knowledge into the database for knowledge collecting. Next, the data is stored into the database and it is processed within the inference mechanism. Through the working base and user interface the user can access the processed data/knowledge.

Expert system can be used for diagnostics, medicine, debugging, monitoring, decision making and other. In this paper a decision making model will be presented in a cloud computing environment. The goal is to show the possibility of effective fast-paced decision making in a dynamic working environment.

The advantages of expert systems are ease of maintenance and rapid prototyping. The disadvantages of expert systems manifest as knowledge acquisition problems, performance when using tools as Lips and database integration for early expert systems [11].

In the next section, cloud computing technologies and cloud computing environment will be addressed. Further, the CBES model will be presented.

Cloud computing environment

Cloud computing can be defined as Interned based computing. This type of computing shares processing resources and data to computers or other devices. Furthermore, this kind of sharing is on demand. The main concept is based on the Internet, and the majority of the connected devices are through the Internet, thus making it very flexible and convenient [20]. The main web services delivered from the cloud are [16]:

- Communication-as-a-Service (CaaS)
- Infrastructure-as-a-Service (IaaS)
- Monitoring-as-a-Service (MaaS)
- Platform-as-a-Service (PaaS)
- Software-as-a-Service (SaaS)

Communication as a Service (CaaS) can be defined as an outsourced communications solution [20]. CaaS providers manage necessary hardware and software which are required for delivering VoIP services, Instant Messaging, Video calls and other types of communications [16] [20]. CaaS platforms are flexible and scalable. This is important for big organizations that need a manageable growth in their IT sector. Providers can usually handle peak loads when it comes to providing resources [22]. The main advantages of CaaS are shared costs with other vendors, remote management of the infrastructure and all-around communication support [16].

Infrastructure as a Service (IaaS) usually provides a virtualization platform as a service. The necessary computer hardware and software for such platforms are routers, firewalls, internet connectivity and platform virtualization machines. This type of equipment is expensive, thus providers sell the resources as virtual platforms for individuals or organizations [16] [20]. The main benefits of IaaS are ready access to preconfigured environment which is based on Information Technology Infrastructure Library (ITIL), has the latest technology equipment, secured computing platforms, manageable service-demand peaks, valleys and lower costs [16].

Monitoring as a Service (MaaS) provides security for business, enterprise and even government platforms. MaaS offers protection and security against internal and external threats [16].

Platform as a Service (PaaS) provides dynamic, secure and broad platforms for applications, downloads, developers, IT managers, and others. Businesses can focus on innovation, while the PaaS offers the infrastructure [16]. In addition, PaaS includes security options for various sectors in an organization.

Software as a Service (SaaS) includes applications that are ran on virtual platforms, from where

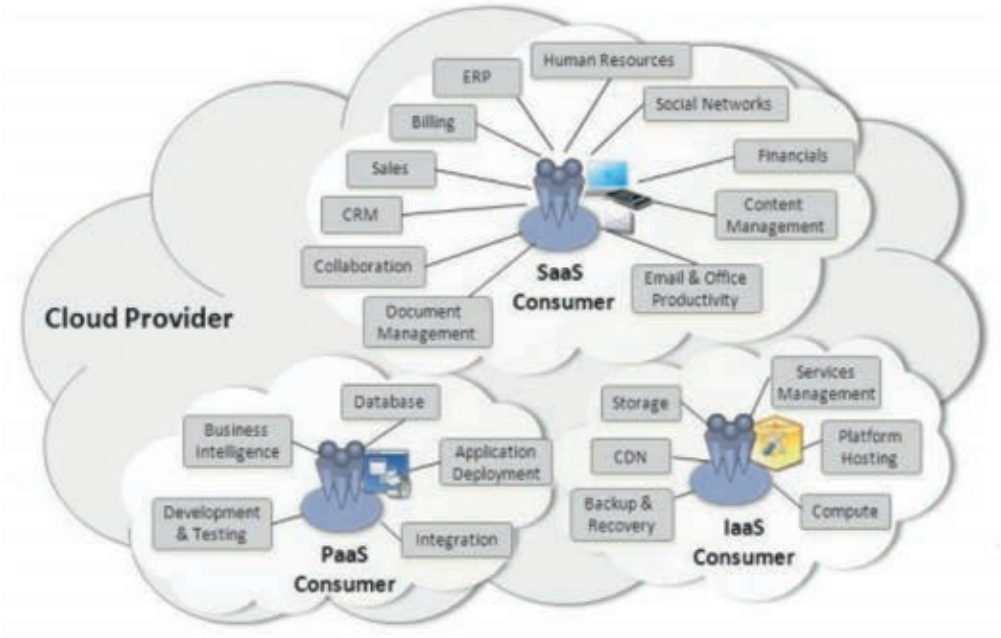

Figure 2. *Options that SaaS, IaaS and PaaS offer to the consumers (Source: Bahrami & Singhal, 2015).*

users can access the functions of those applications [16] [20]. Therefore, SaaS provides a secure platform where resource "hungry" software can run "smoothly" and process the input which has been entered by the users.

The above mentioned cloud web services are usually brought down to IaaS, PaaS and SaaS. Nonetheless, the MaaS and CaaS are sometimes defined as a part of the SaaS or IaaS. Figure 2. shows the options that a SaaS, PaaS and IaaS consumers have in the cloud [1].

In Figure 2., it can be seen that PaaS provides business intelligence, databases, development and testing, integration and application deployment to the consumer. IaaS provides storage, SDN, backup and recovery, services management, platform hosting and computing resources for the consumer. Third, the SaaS provides ERP, Billing options, human resource management, social networks, financial report control, content management, email and office productivity, document management, collaboration CRM and sales options to the consumer.

Characteristics of cloud computing are improved agility of organizations, cost reductions by providers, infrastructure is provided by a third party, location independence, wide-range compatibility of devices, easy maintenance of applications, monitored performance, increased productivity, improved reliability, scalability and elasticity and improved security [17].

The main advantages of cloud computing environments are flexibility, disaster recovery, automatic software updates, free capital-expenditure, increased collaboration, work from anywhere, document control, security, competitiveness and environmentally friendly [16] [17] [18] [19]. Flexibility is manifested as the possibility of growth within the cloud platform without fluctuating bandwidth and resources. In addition, when businesses want to add new users and use more resources, there are little or no "freeze" loads at peak points.

Disaster recovery in a cloud environment is cost effective and lets small and medium enterprises (SME) secure their valuable data in case of data loss, fire or power surge. Furthermore, files and applications are backed up and secured from malicious attacks or other types of attacks. Automatic software updates are a big deal for SMEs, because a lot of them do not have the financial resources to hire IT administrators. Suppliers can take care of software updates remotely without the need to be physically present in the organization where the computers and devices are located.

Capital-expenditures are much lower compared to traditional servers. Companies do not need to buy high-end computers. Cloud computing environ-

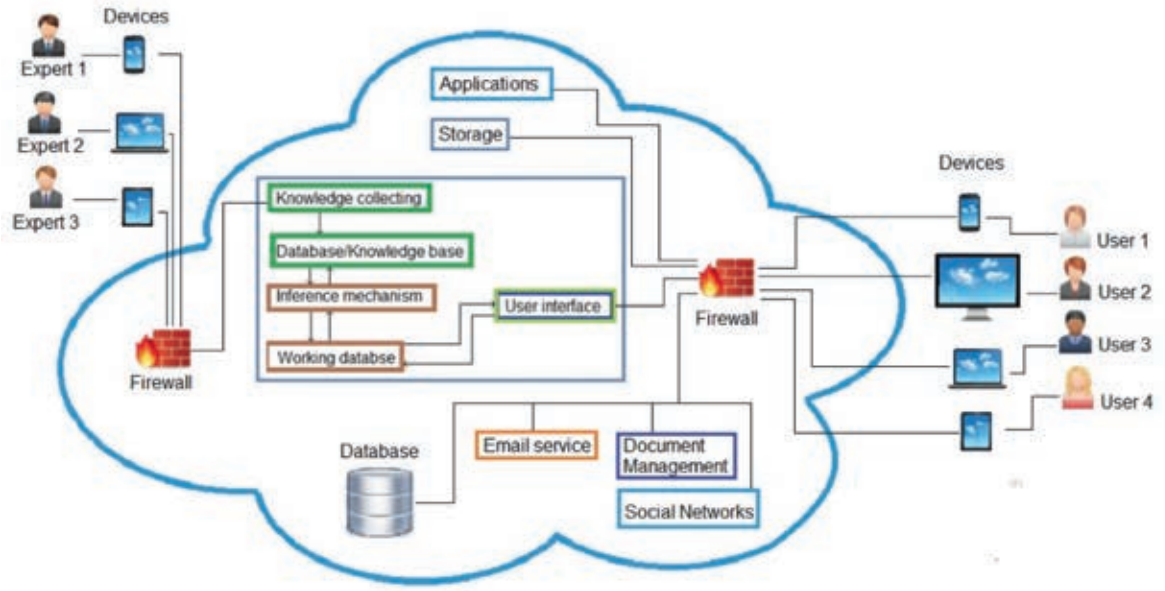

Figure 3. *Cloud-Based Expert System CBES model*
(Source: own)

ments offer resources through the internet so basically the main expenditure is the acquisition of devices through which the cloud platform is accessed. Increased collaboration is manifested as free, fast and effective file, data and profile sharing among the users of the cloud platforms.

Furthermore, working from anywhere is enabled through the Internet. Users can access crucial files at the right place and at the right time. Security protocols "defend" the user from external threats. In addition, cloud computing offers easy document control. Users can access, create, share, distribute and publish documents to other users who have authorization to access those documents. Security is indeed important, thus cloud computing environments offer a secured database where all files are stored, and in the situation of a malfunction of the device from which the cloud is accessed, the cloud simply stores the data, and there are no losses.

Competitiveness is presented as the possibility of SMEs to act faster and more effectively than big enterprises. Dynamic markets ask for fast decisions, and cloud computing offers exactly that. A dynamic information distribution gives necessary support for decision making. In addition, cloud computing platforms can serve more clients with the same infrastructure, while the traditional infrastructures are bordered only to the company that implemented them. Therefore, using cloud computing services is more environmental friendly.

Security risks and threats are present in the cloud computing environment. These security risks should be addressed through standardized security and risk management processes [20] [21]. The mentioned research papers [20] [21] are focused on risk management and similarly, cloud computing environments contain a protocol and precise calculations for risks and security threats.

In the next section, the CBES model will be presented. The section includes the scheme of the model, the necessary infrastructure, elements, users and application in practice.

CBES model

The Cloud-Based Expert System (CBES) model is a platform in a cloud environment where an expert system is implemented with the main purpose for fast-paced decision making. The model includes an expert system, applications, storage options, document and email management, database beside the ones in the expert system and social network connectivity. Furthermore, firewalls are implemented as a form of protection from unauthorized access and security risks and threats. The model is shown in Figure 3.

Figure 3. shows the CBES model. The expert system's knowledge collecting element is connected

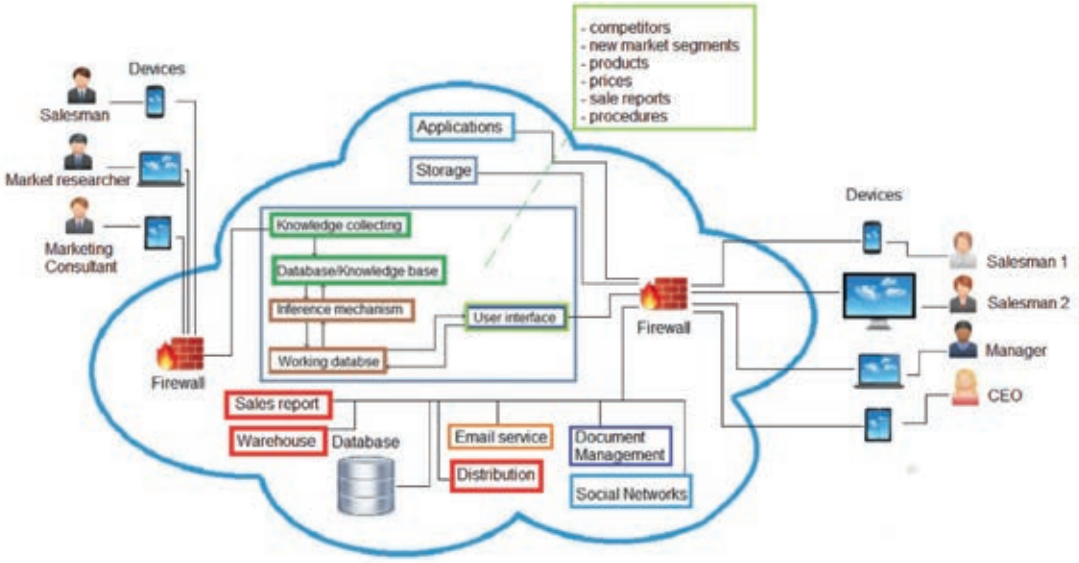

Figure 4. *CBES model on the example of a printer selling company*
(Source: own)

with a firewall. Further, an expert or more experts through internet connection and their devices can store knowledge into the knowledge colleting element of the expert system. This, however, does not mean that there is no starting knowledge in the expert system, in the contrary, the expert system should be "ready to go", but additional information and data can be added/stored by the expert through their devices. The firewall secures the connection, therefore not allowing unauthorized persons access to the knowledge collecting element of the expert system. The whole expert system is in a cloud computing environment.

The users access the cloud with their devices through the Internet. Similarly to the experts' access protocol, the users also connect to the cloud computing environment through a firewall. This firewall ensures security from threats and unauthorized log-ins.

Furthermore, the cloud environment contains a database separated from the expert system, an E-mail service, document management applications, social network profiling and additional storage. These resources enable the users to communicate important information and share crucial data for decision making.

The basic concept of the model is that the expert system contains knowledge about structural and fresh information about the market, about the products, prices, sale reports, documents, procedures, time necessary for a procedure completion and the hierarchical structure of the organization or company. When there is a rapid and fast development of new trends, the expert system is storing new info from the experts. In addition, the users can acquire information from other sources and together with the expert's system diagnose a fast, good and effective decision can be made.

The implementation process is not different from other cloud deployment models. The cloud environment can be private, public or a hybrid cloud. An expert system can be implemented in any of the mentioned deployment models. A crude example of the implementation can be shown on a company that sells printers. The CBES scheme for this kind of company is shown in Figure 4.

Figure 4. shows how a cloud-based expert system can be used for fast-paced decision making in a printer selling company. The users are the salesmen, managers and the CEO. The cloud environment includes applications, storage, sale report software, warehouse inventory software, distribution planning, e-mail services, document management, social network integration, firewalls and the expert system.

The experts are or can be salesmen, market researchers or marketing consultants. The information in the knowledge base of the expert system contains information about the competitors, new market segments, products, prices, sale reports and

other procedures. When there is a turbulent atmosphere on the market and the management needs to make a decision about a new shipment to a specific market segment, the expert system can diagnose the best option and outcome of a certain shipment. In addition, the salesmen and manager and CEO as well, can, based on their personal experience and the expert's system diagnosis, make a good decision and define further actions.

Through the cloud computing environment and expert system support, the decision making process is drastically reduced. Costs are reduced and information distribution is more effective compared to traditional information distribution techniques [22] [23] [24].

Conclusion

The facts presented in this paper clearly show that IT technologies are the future in communication and long distance services. Cloud computing environments will become a crucial part of organizations. Expert systems are a great addition to the business "arsenal" of companies in specific fields. Furthermore, it can be concluded that expert systems in a cloud environment provide a fast and effective support for decision making. In addition, the purpose of an expert system in a cloud environment can be different, and it depends on the function of the cloud. If medical diagnosis is needed, an expert system could be implemented into a cloud platform which is used in a hospital. Reduced costs, flexibility, scalability and security are more than enough reason to consider expert systems and cloud computing environments for business decision making and/or other functions. In addition, cloud platforms offer stable resources and stability.

The CBES model is not an innovative technology, rather than an innovative approach to a developed and already widely used technology. Organizations and enterprises, as well as SMEs, can benefit from this type of cloud deployment. For further research, it is recommended to address companies who had implemented expert systems and/or cloud platforms and analyze the company's improvement first hand. Until then, the CBES model stays as feasible and effective model.

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