Position Papers of the 2013 Federated Conference on
Computer Science and Information Systems pp. 105–110

IaaS Cloud Model for e-Ordering and e-Invoicing

Kiril Kiroski, Marjan Gusev and Sasko Ristov
Ss. Cyril and Methodius University,
Faculty of Computer Sciences and Engineering,
Rugjer Boshkovikj 16, PO Box 393, 1000 Skopje, Macedonia
Email: {kiril.kjiroski, marjan.gushev, sashko.ristov}@finki.ukim.mk

***Abstract*—This paper addresses the modeling of an IaaS cloud e-Ordering and e-Invoicing solution. We have faced several challenges in the process of migration of the existing web application on the cloud, such as the reorganization of the proposed non-cloud model and the definition of the software modules that can communicate in a dynamic environment with various number of virtual machines. In the design process we have classified two kinds of software modules: static and dynamic. The classification is based on the level of required elasticity and scalability, as well as the activity that is associated with the corresponding module (tool). To finalize implementation of this idea, we have developed indicators to determine the required conditions for activation of additional cloud resources, or deactivation of involved resources. The result of this design process is a new cost effective solution with increased availability and performance compared to the non-cloud model. We have also recognized the advantages and disadvantages of such cloud solution, and discussed the characteristics that make our approach unique.**

***Index Terms*—Cloud Architecture; Cloud Computing; e-Invoicing; e-Ordering.**

I. Introduction

PROCUREMENT is the fundamental business process of each company, organization or government institution, since its basic functionality is to use or offer various products, services and/or information. Electronic procurement provides basic means to fulfill these processes, since it enables a faster, more meaningful and more integrated way to carry out corresponding purchases or sales. While electronic procurement represents a wide area of interest, authors in this paper concentrate on electronic orders and electronic invoices, as constituting parts of the post-award phase of electronic procurement.

E-Ordering and e-Invoicing are two basic processes in the e-Business area, since the essence of the business activity of a given company is the exchange of goods that another company provides. Therefore, each business process ends with a kind of an offer, order and invoice that defines the parameters of the exchange and its value.

Cloud computing, on the other hand, is a relatively new technology, which has been in use in some kind of form for decades [1]. For example, virtualization is a technique for masking the physical characteristics of computers and computer related resources, thus enabling a uniform way for other systems, applications or end-users to interact with the above mentioned resources [2]. It is arguably the biggest technology driver behind cloud computing present for almost 40 years, having a long history, starting in the mainframe environment and arising from the need to provide isolation among users [3], i.e. to enable a multi-tenant environment.

Modern computers are sufficiently powerful to use virtualization to present the illusion of many smaller virtual machines (VMs), each running a separate operating system instance [4]. Cloud computing introduces security, scalability and reliability into a group of centrally managed and virtualized physical machines. It offers scalability and elasticity on a large scale, and makes an illusion of limitless resources.

The overall research and development problem in this paper is the description of the design process to develop an IaaS (Infrastructure as a Service) cloud e-Ordering and e-Invoicing solution, although the ideas can be also exploited on other service models, like PaaS (Platform as a Service) and SaaS (Software as a Service).

In this paper, we propose a solution that can efficiently utilize the cloud resources to achieve scalable and elastic system in a multi-tenant environment for e-Ordering and e-Invoicing. The paper is organized as follows. Section II presents the related work that we found in the literature. In Section III, we lay the background for e-Procurement, with accent on e-Ordering and e-Invoicing. Section IV describes the required transformations to migrate the existing web application solution to a cloud based web services. We elaborate the pros and cons of the newly proposed model and its architecture in Section V. Section VI discusses how the model mitigates the virtualization negative impact to the performance and achieves maximum performance with the minimal utilized resources. Finally, Section VII presents conclusions and plan for future work.

II. Related Work

In this section we provide an overview of recent research in this field, and give an overview of e-Ordering and e-Invoicing solutions available on the market for general use, most frequently in the form of e-Procurement or e-Purchasing.

Today's global competitive market marshals new and innovative technologies into everyday processes. According to Boss et al. [5], procurement processes that take longer time, can be streamlined with cloud computing. The vast number of various researches has proven that public procurement conducted through electronic means can be vital to create new jobs and generate sustainable and long-term development of businesses, providing tax payers and public services' users

with best value for money, as stated by Carayannis and Popescu [6].

Research of e-Procurement in Europe, conducted by Bof and Previtali [7], provides investigative insight into various national models and their respective economic impact on both government and citizens's welfare. Trkman and McCormack [8] analyze e-Procurement benefits through related technological and organizational changes, while also estimating advantages and disadvantages of public procurement through electronic means.

Kiroski et al. [9] evaluate the development and trends for e-Government services, especially e-Procurement and its sub phases, i.e. e-Ordering and e-Invoicing. They show that the most optimal path for modeling and developing functional e-Ordering and e-Invoicing solution is to utilize all benefits of cloud computing, and particularly Software as a Service (SaaS), being today's most utilized and popular form of cloud computing. The authors have previously established the major characteristics of the existing software solutions, measured their success in implementation of the major software goals, and evaluated the level of completion of the objectives, the system should possess. The main idea is to follow international standards regarding ordering and invoicing software, and thus ensure interoperability with most European platforms [10]. In this paper we present means to enable cloud functionalities of the improved model for e-Ordering and e-Invoicing solution [11].

The ultimate goal of e-Purchasing through electronic means is to minimize the cost of producing, transporting and storing this kind of documents, to minimize cost and expenses of the procurement process. Estimates of decreased prices through electronic purchases go as high as fantastical 20 percent [12]. According to Pan-European Public Procurement OnLine (PEPPOL), if all public procurement can be accomplished through such platform, annual savings will surpass 50 billion Euros [13].

III. Background

Every company, as it begins working, regards computers and printers as basic costs of work. Then, they need to be interconnected within a company, after which servers for data storage and centralized resource management should be acquired. These steps, of course, require the involvement of trained and educated staff which will take care of installing, maintaining and servicing of the software.

While the company grows, the need for using new technologies, platforms, software and new employees who will maintain the information system arises. These additional expenses impose an additional burden on companies, regarding both the initial and system maintenance costs.

Cloud computing can help in this kind of situation, since it enables lease and use of new software only when needed, and then cancels the services or replaces them with other ones, without the obligation to change the business process structure, information technology or IT staff in the company. This is all due to the fact that everything is "on the Cloud" [14].

Advantages of using such a system based on Web service, and particularly through cloud implementation, instead of Web application are numerous, and include:

- Elasticity and scalability - resources are provided and freed according to current needs.
- Simplicity - information provided through services are very easily adaptable to a suitable form for our needs, and sometimes it is even not necessary to adapt them.
- Cost-effectiveness - using cloud services does not require additional technical staff, or additional hardware resources.
- Business agility - cloud computing enables companies to quickly start using a service, scale used resources according to actual needs, forge links to other cloud services, or stop using them altogether.
- Resiliency - clouds are built from a large number of inexpensive hardware resources, and applications are hosted in virtualized environments, thus lowering the chances to lost connectivity, functionality or even data in cases of failures in the cloud.
- Interoperability - if need arises to exchange information between different systems, web services (in case of accordingly correctly formatted attributes) can facilitate this process to great extent.

The main goal of this paper is to propose a cloud enabled model, which enables the above stated benefits, and at the same time minimizes the problems that are encountered while working on Internet.

Implementations of an e-Ordering and e-Invoicing solution through traditional provision of web services cannot offer sustainable performance since the predicted system may require huge amount of unpredictable resources only in appropriate small periods during the peak period (such as end of one year and beginning of another), while most of the time, this system requires much less predictable resources. Using server-cluster architecture to create scalable and highly available solutions [15] will only partially solve a performance peak problem since it is hard to be managed and administered. On the other hand, the software solution has to be scalable. The solution presented in previous sections can be hosted on a classic, third generation system architecture, as depicted in Figure 1. The third generation system architecture consists of three subsystems, i.e. Application Layer, Middleware and Application Domains. We can notice that there are no mechanisms for providing support in case of increased usage, hardware or network problems, and so on.

Cloud computing, as a new technology trend, provides computing resources in addition to software in form of a service [17]. Cloud providers offer on-demand illusion of infinite elastic resources using virtualization [18]. Cloud computing addresses a set of services providing scalable, QoS guaranteed, normally personalized, inexpensive computing platforms on demand [19]. Cloud billing model is similar to basic utilities billing models, i.e. it is proportional to the amount of use. Therefore, cloud computing is admissible for small

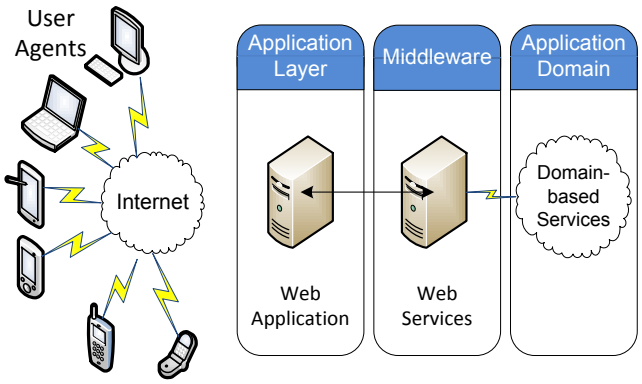

Fig. 1. Third generation architecture, using Web services [16]

and medium business enterprises, especially in the present economic crisis.

Small and medium enterprises can benefit if they migrate their e-Ordering and e-Invoicing systems onto the cloud since the cloud is capable of offering excellent flexibility and scalability of resources, storage space, computational power and network access, and most importantly lower cost. Cloud lowers the disk space requirements, and enables newest software versions and monitoring of the installation progress in each of the cloud service models, i.e. IaaS, PaaS and SaaS.

IV. Modeling the Cloud Solution

In this section we describe the required transformations to migrate an existing solution from a web application to an IaaS cloud-based solution. The cloud-based modular approach is used to realize e-Ordering and e-Invoicing software modules and tools. A new idea is introduced to enable elasticity and scalability based upon used resources, i.e., virtual machines (VMs), in a multi-tenant cloud environment.

We have faced several challenges to move the existing solution onto a cloud. The main problem concerned how to organize different software tools in modules and than schedule them on a particular VM in an efficient cost-effective architecture model. The first step was to find out which software tools need extensive processing and therefore to classify them according to the needed resources for their execution. Finally, this process will determine the scheduling of software tools into modules and map them onto various VMs.

Based on previous research and experimenting, and model developed for e-Ordering and e-Invoicing, inclusion of model's software tools into modules resulted with the following classification. The classification criteria is based on determination of processing demand and possible scheduling to a VM instance. We propose an organization of system modules into two groups: Static and Dynamic. The former is composed of the software modules (tools) that do not require increased computing power, as these modules (tools) are not utilized on a regular basis, and will not be accessed by every user. The latter refers to e-Orders and e-Invoices creation tools, and related common activities. Software modules (tools) to be

TABLE I
Proposed organization of software modules (tools).

Activity	Modules	Related Tools
Static	Management	User and web site administration tool
		Backup and recovery tool
	Usability	Creating and managing catalogues
		Customization tool
		Workflow establishing tool
		Reporting tool
Dynamic	Basic Ops.	Order creation and editing tool
		Invoice creation and editing tool
		Search and view tool
	Advanced Ops.	Invoice dispute tool
		Resolve dispute tool
		Invoice revoke tool
		Order revoke request tool
		Resolve revokes tool

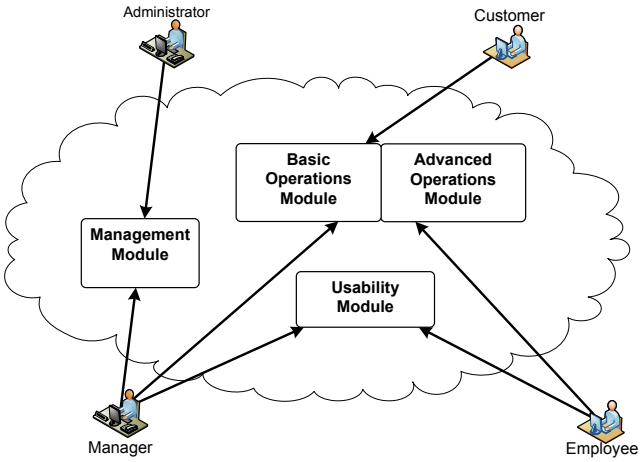

Fig. 2. Cloud-based modular approach to e-Ordering and e-Invoicing tools and modules.

realized can be clustered in relation to these requirements. The results of software module analysis are presented in Table I.

In addition to the proposed classification of software tools into Static and Dynamic groups, we have also applied a clustering method. Our deeper analysis showed that classified software modules can be implemented as four different clusters - software modules, created according to static or dynamic nature, in addition to the basic criteria for clustering as a logical group. This process will allow improved functionality, security, and access control. An example of such a implementation of modular solution can be found in [16].

The new design resulting from both the classification and clustering of software modules of e-Ordering and e-Invoicing is shown in Figure 2.

Static software modules for the proposed solution are:

- Management module - intended for Administrators and partially Managers, since main activities involve occasionally used tools for user administration, web site administration, and backup and recovery tool.
- Usability module - used by Employees to create and maintain Catalogues, and tool for forms customization. It also contains Workflow establishing tool and Reporting

tool, used by Managers and Employees to automate document creation and for reporting activities.

Dynamic software modules, which require more resources at peak times, and provide critical functionalities of the solution, are:

- Basic operations module - used by Managers, Employees and Customers alike, in order to create, edit and delete orders and invoices. It also provides Search and view tool for created orders and invoices.
- Advanced operations module - this module involves advanced activities with invoices and orders, such as disputing invoices and revoking invoices and orders, in most part by Employees and Customers. It also enables Managers to resolve disputes, and decide about revoke requests.

Figure 2 presents four different types of users. Each of those users access one or more of the indicated modules to accomplish authorized tasks. Breakdown of users and respective tasks are shown in Table II. Functionalities provided through system modules were mapped for appropriate user groups:

- The administrator can manage users, by giving certain roles to different types of users. He/she also customizes the look and functionalities on the web site. Backup and recovery are also the responsibility of the administrator.
- The manager can manage employees and customers, and customize certain global fields (tax rates, discounts...). He/she can determine the level of automation and workflow for different employees, and is able to make decisive conclusions regarding orders and invoices. The manager resolves order revocation requests. The manager can also use Search and view tool and Reporting tool.
- The employee can create order or invoice when required, and can edit them when approved by a manager. He/she can resolve invoice disputes in case he/she is authorized to. The employee is responsible for creating catalogues and linking them to orders. He/she can also use Search and view tool and Reporting tool, and track customers' payment history.
- The customer can view the catalogue and use it to create orders. He/she can also edit still unprocessed orders and require manager attention when items in question surpassing employee authority, or dispute about order/invoice content. The customer can request an order to be revoked entirely.

TABLE II
USER GROUPS FOR E-ORDERING AND E-INVOICING SOLUTION.

User Groups	Roles
Administrator	Designs the Home page
	Edits the home page fields
	Manages user accounts for managers, employees and customers
	Manages backup and recovery facility
Manager	Creates list of employees
	Manages customer accounts
	Views/analyses reports about incoming orders
	Views/analyses status reports for invoices
	Edits invoices
	Edits global invoice settings
	Edits global order settings
	Approval of invoices/orders
	Revoke invoices
	Approve revoking of orders
Employee	Creates invoices
	Edits common invoice fields
	Views status reports for invoices
	Contacts slow paying customers
	Maintain Catalogues
	View orders
	Resolve invoice disputes
	Revoke invoices
Customer	Creates orders
	View order status
	View/pay invoices
	Dispute invoices
	Request revoking of orders

V. PROS AND CONS

This section addresses a discussion of possible cloud solution's advantages and disadvantages. A great deal of both positive and negative effects is due to the nature of the cloud approach, while the solution's scope and area of application also provides for some of the possible benefits and shortcomings.

A. Advantages

This section discusses the benefits of the new proposed model and architecture. The proposed model is capable of utilizing features and characteristics offered as a solution for each cloud service layer from IaaS to SaaS. This model for e-Ordering and e-Invoicing system can be hosted onto the cloud and can use seemingly infinite cloud resources dynamically to reduce the costs and to provide better performance.

1) Elasticity and Scalability: The underlying infrastructure in the proposed cloud platform is based on VMs, all sharing a common resource pool, enabling automated utilization of more resources in peak times, and less resources (which will be routed to other VMs hosted in the Cloud) when there is no more need for them. Such benefits could be enabled through the use of data clusters, web server load-balancing, etc.

2) Simplicity: Basic services can be provided as individual services or applications. Those are:

- User access management;
- Orders, Catalogues and Invoices;
- Automated purchase lifecycle; and
- Document export and import.

Above could be provided as a simple web service or an complete web application on discretionary of the software user.

3) Cost-effectiveness: Management and maintenance of the e-Ordering and e-Invoicing solution will be a responsibility of the provider, requiring no technical staff on behalf of the service consumer different software level agreements:

- Web based solution available for purchase;
- Paying for using the service on periodical bases; and
- Per-transaction fee.

4) Business agility: Software lifecycle is provided in a few quick steps, such as:

- Companies and individuals will be able to apply for using the service;
- Administrator will be able to register new clients in the roles of managers and employees;
- Manager will be able to register new customers, as well as grant or revoke special permissions to employees; and
- Revoke order shall also permit requests for nullifying the contract for using the service.

Authorized users that are assigned with a role of Administrator will be able to disable clients, i.e. the managers and employees. A backup and recovery tool enable the users to download the documents.

5) Resiliency: E-Ordering and e-Invoicing solution is intended to run on several VMs on a specific cloud platform. A number of cloud platforms are capable of running such a software.

B. Disadvantages

There is a wide application area of an e-Ordering and e-Invoicing system, especially when most of the European countries will support the electronic procurement. Electronic documents will not just replace the existing orders and invoices, but will enable efficient usage in company's inventory systems and bookkeeping software, or in realization of the ERP (Enterprise Resource Planning) at broader sense. Non-existence of such a solution shall inquire additional initial effort for its development. On the other hand, the necessity for interoperability with an existing platform on European or world level, shall necessarily define the way such a system should be designed. Although this model for e-Ordering and e-Invoicing cloud-based solution offers significant benefits both for business and individuals, its architecture implies additional effort on resolving following challenges.

1) Service model: In this paper, the accent is mostly on presenting an IaaS solution for e-Ordering and e-Invoicing, while our future efforts will include PaaS and SaaS counterparts.

2) Interoperability: Realization of the solution in order to integrate with existing platforms. While the software is distinctive and provides unique features, it must provide an interoperability with software from other vendors and/or countries.

3) Portability: Designing software capable for migration between platforms and service providers. Solution can be developed on one platform, but it must enable fast and streamlined porting on another platform.

4) Security: Implementing security mechanisms and best practices in order to guarantee data security, integrity, and confidentiality. Financial data is one of the most sensible data in today's world, so great deal of problems may source out from lack of safety and security measures.

5) Data privacy: Catalogs, orders and especially invoices, are sensitive data and the customers require access management. Different economic operators may not gain access into one another's personified data.

6) Law compliance: Validity and legality of electronic documents, especially invoices must be compliant with governing laws for both parties' countries. Since this software is intended for multinational use, in-compliance to national governing laws and regulations is not acceptable and may incur further implications. Additionally, the private data should not leave the EU countries, regardless if they are paper or electronic.

7) Total Costs: Although cloud solutions are cost-effective, total costs may incur over-expenditure in case of excessive use. Software economic model must take into account economic justifiability for using cloud solution on agreed SLA, and not simply buying and owning the platform.

VI. Discussion

The cloud virtrual environment behaves different for the same load in differently time depending on the number of active VMs on a particular cloud node and the total number of active VMs in the whole cloud [20]. Ristov et al. [21] determined that the virtualization in cloud computing degrades almost 30% of the SOA (Service Oriented Architecture) web service performance compared to traditional "bare metal" web service hosting infrastructure with the same hardware resources. Lloyd [22] found that the performance decreases enormously for input / output intensive applications (more than 110% overhead) and decreases lightly (about 10% overhead) for CPU intensive applications. Windows Azure can achieve even superlinear speedup (speedup greater than linear speed, i.e., greater than the number of used threads and CPU cores while scaling the resources) [23].

Therefore, the real challenge is how to mitigate this relatively huge performance degradation and performance discrepancy. Migrating the existing third generation system architectures on the cloud and thus using the cloud features of scalable and elastic theoretically unlimited resources can even increase the cost, rather than to decrease it.

The most common cloud providers, such as Microsoft (Windows Azure), Google (Compute), or Amazon (EC2) offer different types of VM instances. Although the prices and SLAs (Service Level Agreements) are different for each cloud provider for the same resources, their pricing models have the common issue, that is, the price increases linearly while scaling the resources [24], [25], [26]. But many authors show that the performance is not scaling the same as the resources (and the price). The maximum speedup (performance) is limited by Gustafson's Law [27].

Gusev et al. determined that Multi-VM environment (many VMs with a single CPU core) provides up to 10 times better performance compared to the Single-VM environment (one huge VM allocated with all cores) [28]. Therefore, scaling the number of VMs (and balancing the load among them) is the better solution rather than scaling the resources in a single VM instance. The former solution is more reliable and available, because the system will continue to work if some VMs fail. Introducing a resource broker in our solution reduces the number of active VMs, thus reducing the overall cost of the solution and making it a green cloud solution.

VII. Conclusion and Future Work

E-Ordering and e-Invoicing are the most important parts of an e-Procurement business process. In this paper, we presented the design of an IaaS cloud e-Ordering and e-Invoicing model. The final goal is to efficiently and effectively utilize the cloud using scalable, elastic and theoretically unlimited computing and storage resources.

We have realized a new IaaS cloud solution, by identifying and organizing static and dynamic software modules. Dynamic modules can activate various virtual machines, forming an efficient solution.

Future work will be based on experimental research of performance of this solution and compare several other solutions. Also we plan to develop PaaS and SaaS elastic and scalable solutions.

Our proposed cloud model focuses only on a part of e-Procurement, i.e. for e-Ordering and e-Invoicing. We will continue with our research to propose a comprehend cloud model for the whole e-Procurement business process.

While proposing cloud model for partial e-Procurement solution, we are confident that proposed model can be also beneficial in other application domains, such as asset management, content delivery networks, computing, etc.

References

[1] B. Williams and G. Reese, *The Economics of Cloud Computing*. Cisco Systems, 2012.

[2] IBM, "White paper: Virtualization in education." 2007. [Online]. Available: http://www-07.ibm.com/solutions/in/education/download/Virtualization\%20in\%20Education.pdf

[3] S. Crosby and D. Brown, "The Virtualization Reality: Are hypervisors the new foundation for system software?" *ACM queue – Computer Architecture*, vol. 4, no. 10, Dec. 2006. [Online]. Available: http://queue.acm.org/detail.cfm?id=1189289

[4] P. Barham, B. Dragovic, K. Fraser, S. Hand, T. Harris, A. Ho, R. Neugebauer, I. Pratt, and A. Warfield, "Xen and the art of virtualization," *ACM SIGOPS Operating Systems Review*, vol. 37, no. 5, pp. 164–177, 2003.

[5] G. Boss, P. Malladi, D. Quan, L. Legregni, and H. Hall, "Cloud computing," *IBM white paper*, vol. 1369, 2007.

[6] E. G. Carayannis and D. Popescu, "Profiling a methodology for economic growth and convergence: learning from the eu e-procurement experience for central and eastern european countries," *Technovation*, vol. 25, no. 1, pp. 1 – 14, 2005. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S0166497203000713

[7] F. Bof and P. Previtali, "National models of public (e)-procurement in europe," *Journal of E-Government Studies and Best Practices*, vol. 5, pp. 1–14, 2010.

[8] P. Trkman and K. McCormack, "Estimating the benefits and risks of implementing e-procurement," *Engineering Management, IEEE Transactions on*, vol. 57, no. 2, pp. 338–349, 2010.

[9] K. Kiroski, M. Kostoska, M. Gusev, and S. Ristov, "Growth rate analysis of e-government development," in *Proceedings of the Fifth Balkan Conference in Informatics*, ser. BCI '12. Novi Sad, Serbia: ACM, 2012, pp. 106–111.

[10] O. Association, "About OpenPEPPOL," Feb. 2013. [Online]. Available: http://www.peppol.eu

[11] K. Kiroski, M. Gusev, M. Kostoska, and S. Ristov, "Modifications and Improvements on CEN/BII Profiles," in *ICT Innovations 2011*, ser. Advances in Intelligent and Soft Computing, L. Kocarev, Ed. Springer Berlin / Heidelberg, 2012, vol. 150, pp. 395–404.

[12] M. Singer, G. Konstantinidis, E. Roubik, and E. Beffermann, "Does e-procurement Save the State Money," *Journal of Public Procurement*, vol. 9, no. 1, pp. 58–78, 2009.

[13] PEPPOL, "Future eProcurement," Feb. 2013. [Online]. Available: http://www.peppol.eu/peppol-project/eu-wide-interoperability/future-eprocurement

[14] GTSI Group, "Cloud Computing: Building a Framework for Successful Transition," 2009. [Online]. Available: http://www.gtsi.com/cms/documents/White-Papers/Cloud-Computing.pdf

[15] J.-H. Ho, M.-Y. Luo, and C.-S. Yang, "Building a Scalable Digital Learning System on Server Clusters," *J. Inf. Sci. Eng.*, vol. 23, no. 3, pp. 803–819, 2007.

[16] S. Ristov, M. Gusev, G. Armenski, K. Bozinoski, and G. Velkoski, "Architecture and organization of e-assessment cloud solution," in *Global Engineering Education Conference (EDUCON), 2013 IEEE*, March 2013, pp. 736–743, best paper award.

[17] M. Armbrust, A. Fox, R. Griffith, A. Joseph, R. Katz, A. Konwinski, G. Lee, D. Patterson, A. Rabkin, I. Stoica *et al.*, "A View of Cloud Computing," *Comm. of the ACM*, vol. 53, no. 4, pp. 50–58, 2010.

[18] P. M. Mell and T. Grance, "SP 800-145. The NIST Definition of Cloud Computing," National Institute of Standards & Technology, Gaithersburg, MD, United States, Tech. Rep., 2011.

[19] L. Wang, J. Tao, M. Kunze, A. Castellanos, D. Kramer, and W. Karl, "Scientific Cloud Computing: Early Definition and Experience," in *10th IEEE International Conference on High Performance Computing and Communications, 2008. HPCC'08.* IEEE, 2008, pp. 825–830.

[20] Y. Koh, R. Knauerhase, P. Brett, M. Bowman, Z. Wen, and C. Pu, "An analysis of performance interference effects in virtual environments," in *ISPASS 2007, IEEE Int. Symp. on*, april 2007, pp. 200 –209.

[21] S. Ristov, G. Velkoski, M. Gusev, and K. Kiroski, "Compute and Memory Intensive Web Service Performance in the Cloud," in *ICT Innovations 2012*, ser. Advances in Intelligent and Soft Computing, S. Markovski and M. Gusev, Eds. Springer Berlin / Heidelberg, 2013, vol. 257, pp. 215–224.

[22] W. Lloyd, S. Pallickara, O. David, J. Lyon, M. Arabi, and K. Rojas, "Migration of multi-tier applications to infrastructure-as-a-service clouds: An investigation using kernel-based virtual machines," in *Grid Computing (GRID), 2011 12th IEEE/ACM International Conference on*, 2011, pp. 137–144.

[23] M. Gusev and S. Ristov, "Superlinear speedup in windows azure cloud," in *2012 IEEE 1st Int. Conf. on Cloud Networking (CLOUDNET) (IEEE CloudNet'12)*, Paris, France, Nov 2012, pp. 173–175.

[24] Amazon, "Ec2," May 2013. [Online]. Available: http://aws.amazon.com/ec2/

[25] Microsoft, "Windows azure," May 2013. [Online]. Available: http://www.windowsazure.com/pricing/

[26] Google, "Compute engine," May 2013. [Online]. Available: http://cloud.google.com/pricing/

[27] J. L. Gustafson, "Reevaluating Amdahl's law," *Communication of ACM*, vol. 31, no. 5, pp. 532–533, May 1988.

[28] M. Gusev, S. Ristov, G. Velkoski, and M. Simjanoska, "Optimal resource allocation to host web services in cloud," in *Cloud Computing (CLOUD), 2013 IEEE 6th International Conference on*, June 2013, pp. 948–949.