

Perspectives and Reflections on Cloud Computing and Internet Technologies from NordiCloud 2012

Muhammad Ali Babar
Lancaster University &
IT University of Copenhagen
Copenhagen, Denmark
(+45) 7218 5107
malibaba@itu.dk

ABSTRACT

The Nordic Symposium on Cloud Computing and Internet Technologies (NordiCloud) has been found with the key aim of promoting and supporting Cloud computing and Internet Technologies research and practice in Nordic and Baltic regions. It would provide a bridge between researchers and practitioners from Nordic/Baltic countries and Cloud computing communities in other parts of the World. The first symposium was organized as a collocated event with WICSA/ECSA 2012 in Helsinki, Finland. This report summarizes the key points from the symposium based on the presented talks and discussions. It highlights some of the areas that the participants considered worth pursuing in order to help organizations to not only exploit the opportunities that cloud computing offers but also to deal with the challenges when adopting cloud computing. This report points out some of the key challenges and potential solutions that are likely to interest researcher and practitioners in Nordic/Baltic regions and beyond.

Categories and Subject Descriptors

C.2.4 [Computer-Communication Networks]: Distributed Systems
– Cloud Computing; D.2 [Software Engineering]: Miscellaneous.

General Terms

Theory, Management, Measurement, Performance, Design, Security, Standardization.

Keywords

Cloud Computing, Utility Computing, Software Services, Internet of Things (IoT), SaaS, PaaS, IaaS, Software Engineering, Tools as a Service (TaaS), Empirical Software Engineering.

1. INTRODUCTION

Cloud computing offers a significant number of mechanisms of new and innovative ways of acquiring and providing IT

infrastructures for business operations in private as well as public sectors. On demand scalability of resources without upfront investments [5, 7, 19] is considered one of the most significant attractions for adopting cloud computing for organizations of all sizes in different domains. Cloud computing paradigm enables organizations and individuals to access a desired set of IT resources (i.e., computing, storage, and network) from a shared pool based on pay per use model [6]. Cloud computing can be broadly classified into service and deployment models. Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS) are the commonly known service models; whereas public, private, hybrid, community, and virtual clouds are the categories of the deployment models. Like in other areas of the world, a large number of organizations have been adopting cloud computing.

An increasing number of Nordic and Baltic companies are facing a broad set of challenges when adopting cloud computing and/or other advanced Internet Technologies, also called Internet of Things (IoT). Some of the key challenges include fine-grained scalability monitoring and management, optimization of cloud resources, testing cloud services, requirements identifications and decision support for selecting appropriate cloud services, interoperability between cloud infrastructures, security and privacy, data location management for adhering to national and international regulations and laws. In order to help organizations to adopt cloud computing without facing significant challenges, several governmental and community based initiatives and networks have been started to promote cloud computing research, education, and training in Nordic and Baltic countries.

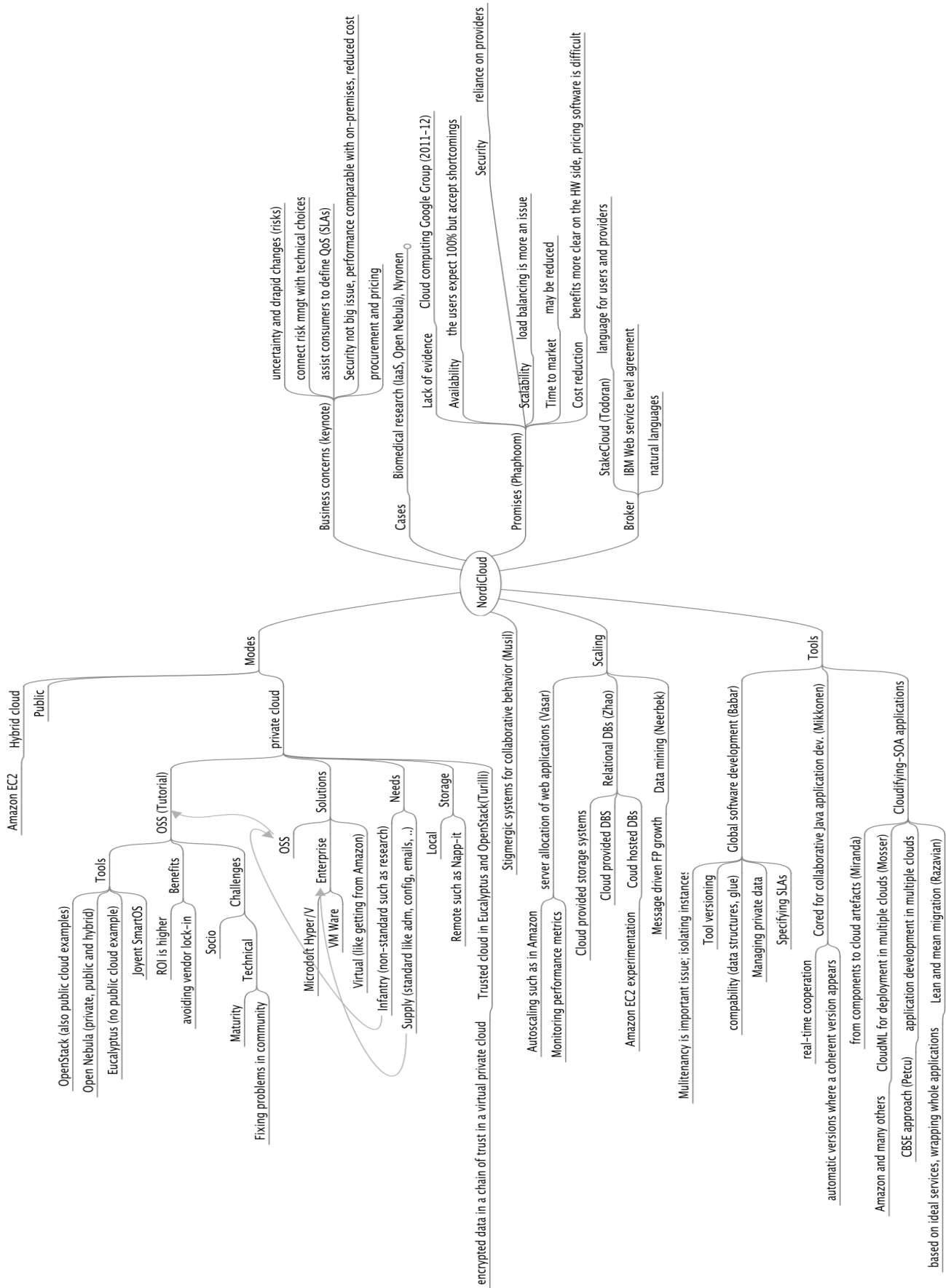
The Nordic Symposium on Cloud Computing and Internet Technologies (NordiCloud) is one of the community based initiative to provide a venue for enhancing collaboration between industrial and academic communities. The symposium also aims at providing a bridge between cloud computing researchers and practitioners from Nordic and Baltic countries as well as other areas of the world. The NordiCloud 2012 program included keynotes, invited talks, presentations of the accepted papers, and a tutorial on setting up private cloud with open source software. The scientific and networking activities during the two days symposium resulted in a huge number of perspectives on different aspects of the current and future development and use of cloud computing and Internet of Thing (IoT) in different domains that range from health care, assisted living, collaborative scientific research, smart cities, emergency response services, law enforcement agencies, and education. The reflections on the presented talks and the current trends resulted in several areas

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Figure 1: A mind map of the topics presented and discussed during the symposium (Prepared by Dr. Parastoo Mohagheghi).



where immediate research and development need to be carried out in order to enable individuals and organizations to benefit from the potential benefits of cloud computing and IoT for developing and providing IT based solutions for sustainability societies.

2. SOME OF THE PERSPECTIVES

This section provides an overview of the presented work that can be found in [2]. While the presentations were covering diverse perspectives of cloud computing including business and technical aspects, the discussions among participants resulted in categorization of the work that are described as follows:

2.1 Cloud Providers and Consumers

The first gathering of the NordiCloud had an excellent keynote talk, given by Dr. Anna Liu from National ICT Australia. Dr. Liu is considered a thought leader in cloud computing research and practice. The keynote talk focused on the business and consumer perspectives of providing and using cloud-based software and services. The talk pointed out the major concerns of customers such as privacy issues, cost, and security in deciding to migrate to cloud computing. Dr. Liu shared the experiences and impressions of Australians towards migrating to cloud and proposed a research agenda for supporting migration to cloud computing.

That talk was based on a series of case studies of migrating legacy system application to cloud. One of the key points were that security could be a perceived risk that can be considered and addressed with right processes in place such as categorizing sensitive data and applying appropriate data masking before transferring the data to cloud computing. The results of the case studies also showed a significant improvement in performance of the application after moving to clouds that can be considered as a business motive; however, there can be some specific scenarios (e.g., producing balance sheet) in which performance is negatively impacted. There were also scenarios that considered negotiable points whether or not a customer can put up with some delays. The presenter's team has also considered cost reduction as a significant result. The cost reduction resulted from savings from provision of testing environments. Consequently, the research agenda items underlined the major issues of migrating to cloud from users' perspective as guaranteeing quality of service, the fluctuations in performance due to network connections and limited visibility in control (e.g., the location of data) and proposed the need of tools/methods for managing uncertainties and rapid performance changes to address customers' concerns.

2.2 Cloud Computing and Software Development

One of the sessions was dedicated to case studies on different aspects of cloud computing such as experiences of adopting cloud solutions from particular cases. The representatives of the IT department of Nordea Bank Finland shared experiences and observations from their use of cloud infrastructure for building test environments. As of common business concerns, the main questions asked by the Nordea IT experts were "what to put on the cloud" and "why different cloud business models can be attractive". Their experiences of adopting cloud solution for test environments provided the attendees with insightful perspectives on adopting cloud computing for software development environments in financial industry as they reported how they achieved their main goals of significantly decreasing the

provisioning time, increasing number of test environments, and decreasing the IT effort in release candidates.

The talk about building a test environment using cloud computing also reported some of the most significant difficulties faced in terms of the hardship for developers to adapt to changes (e.g., new IP addresses to be used). In that regard, the audience discussed the challenges of infrastructure providers in terms of the need to provide very unique configuration for every single software company and the demands of software companies to have the minimum changes in their own configuration to migrate to cloud computing which needs to be addressed by cloud providers.

Another area which are significantly discussed in NordiCloud's first gathering was how cloud computing and Internet Technologies can be leveraged to support software engineering in terms of providing web-based software engineering tools and Tools as a Service (TaaS) based on Service-Oriented Architecture (SOA). Apart from the talk from Nordea bank on building test environments using cloud computing, there were two more talks on this topic. Chauhan and Ali Babar [3] described the need of an infrastructure to provide tools as a service specially in the context of Global Software Development (GSD). The presentation focused on the difficulties of configuring various tools in the process of software development and in particular in GSD; not only provision of unique testing environments within short time span (e.g., for mobile applications) is challenging, the factors such as culture, working habits, and paying for the license of a variety of tools used in design and architecting phases are of the concerns. Thus, providing tools as a service can be seen beneficial in many of the abovementioned issues; for example, having an IDE in the cloud as a service, would provide the possibility of artifact's traceability as well as support for real time awareness and collaboration. The provision of a sophisticated tool as a service to the remote sites that have to use the tool can be seen as a good strategy for countries where the copyright rules are not seriously being followed.

Interestingly, the collaborative cloud-based tool [8] could support the idea of Tool as a Service (TaaS). The proposed research demonstrates the provision of collaborative browser-based editor for the programmers who work together; the features such as working in parallel, embedded IM, and adding comments in the code while chatting, automatically checking the bugs using Java language can be enumerated as capabilities of the tool. The provision of this tool as a service which can be accessed at <http://cored.cs.tut.fi/> is claimed to be a faster and easier solution for programmers to start to work compared with installing all the needed libraries and framework.

Cloud brokering is another important topic covered in NordiCloud 2012. Given a high demand of industry for solutions to efficiently finding appropriate cloud providers that are addressing their particular concerns, the need of Cloud Brokers become a necessity. In that regard, the research by Todoran and Glinz [15] has focused on communication gap between cloud providers and consumers and proposed StakeCloud as a solution architecture to bridge that gap. Todoran's talk raised important points about the limitation of the current ways of describing SLAs that are the main means of communicating requirements between cloud providers and consumers. However, SLAs are usually based on natural language, hence, there is a possibility for automatically searching and matching the provided features that match to consumers' requirements. These kinds of limitations in describing

and implementing SLAs are quite significant challenges in cloud computing. The proposed architecture tends to provide an organized environment for the customers to find the most suitable providers systematically [16]. Given the significance of assisting consumers to define QoS (SLAs) that discussed by keynote, we can consider this work as an attempt to address this concern.

2.3 Stories from Trenches

This session was dedicated to presentations mainly focused on experiences of building and deploying systems by leveraging cloud-enabled technologies and the challenges encountered and solutions devised in those efforts. These presentations provided the attendees with not only inspiration for different applications of cloud-enabled technologies but also pointed out the potential areas of risks and how to manage them.

Phaphoom and colleagues [13] reported the results from an investigation focused on the perceived benefits of cloud computing for cloud users. Based on a systematic and rigorous analysis of the practitioners' discussions on a Google forum on cloud computing, the researchers identified the main areas of focus as availability, scalability, cost reduction and time-to-market. Their findings showed that while lack of availability had been the most mentioned problem, it was also tolerable if the providers could notify the users about the down times beforehand. The results also show that the load balancing is the most discussed issue regarding scalability of clouds; security is a matter of reliance on providers. While time to market is an open issue to discuss (i.e., may be reduced), cost reduction is more achievable on hardware side than software side due to difficulties in pricing.

Like many other disciplines, cloud computing has been stimulating several new and innovative ways of providing IT enablers for biomedical research. However, there are several kinds of challenges attached to using cloud computing for biomedical research, especially when highly personal and private data related issues are involved. Hence, there have been several reservations and reluctances towards the use of cloud computing in biomedical domain. However, the situation is changing slowly as a result of increasing number of success stories and guidelines. One of the case studies presented in the symposium was from biomedical domain. Nyrönen and colleagues [12] presented the observations and experiences from a case study carried out in the context of biomedical research. Their experiences showed that cloud computing provide appropriate and cost-effective solutions to data-intensive applications in biomedical domain. The presenter highlighted the challenges and solutions in the area of cloud computing where a solution is not only expected to provide appropriate infrastructure to maintain and provide the data for different analyses and experimentations but it is equally important to maintain the transparency of the backbone and simple usability due to the end users' level of IT knowledge. However, due to the criticality of the data and the nature of the competitive research, the data usually tend to be stored close to researchers' location and cannot be moved around the world. For these purposes provision of infrastructure as a service on local premises is considered a better solution.

2.4 Frameworks and Architectures

It is well recognized that knowledge-based approaches can play a significant role in systematically designing and rigorously evaluating cloud enabled applications. The knowledge-based approaches are usually focused on applying architectural styles and patterns, design tactics in order to build reference frameworks

or design reference architectures to be exploited for migrating existing or building new applications by taking the advantage of the existing reference frameworks or architectures. During the symposium, a session was allocated to the research problems and proposed solutions for building and leveraging reference frameworks and architectures for cloud-enabled applications.

One of the presentations in this session reported interesting approaches aimed at supporting scalability related issues for cloud-based relational databases. Zhao and colleagues pointed out the problem with scaling relational databases hosted in a cloud environment. One of the expectations is that the applications can monitor fine-grained scaling performance and automatically manage scaling issues. However, a cloud application may not have access to fine-grain monitoring data for supporting automatic scaling up or down. There is an important need of architectural support for automatically collecting, analyzing, and acting based on scaling polities for an application. Zhao presented a reference architectural framework for building a system to support an autonomic scaling of relational databases in cloud using well-know architectural patterns of autonomic computing – MAPE pattern. The framework has been evaluated using a modified Web 2.0 application benchmark. The presenter reported that the results from the study showed that the framework was able to provide application-level flexibility in achieving improved throughput, data freshness and monetary saving [20].

Another interesting perspective presented and discussed was how to leverage well-established area of architecting systems like component-based software development for building and providing cloud-based system. Petcu presented results from an EU project, mOSAIC, whose output had been made an open source project that is a Platform-as-a-Service based support for building component-based cloud solutions. According to this platform, a component is expected to be scalable, fault tolerant, manageable, and autonomous. Each elastic component has to be stateless and platform is based on event-driven programming style.

Another architecture-centric platform presented and discussed was stigmerg that had been designed based on the principles of indirect communication and self-organization for framing certain groups of software services. The stigmerg aimed at enabling the creation of better solution stack configurations needed to support effective and efficient development of services.

Trust in cloud computing was another important issue discussed. It is important to have trustworthy cloud computing in order to have scalable amounts of computational resources. One notable presentation on this topic was myTrustedCloud that described how to integrate trusted computing technologies into a platform of an Infrastructure as a Service (IaaS) – Eucalyptus can enable security-critical cloud based solution in industries like energy

2.5 Research to Practice

One of the best ways of creating value through high quality research activities is to have the outcomes transferred to Industry. The industrial actors can also provide inspiration for relevant research and development initiatives. The initiatives like NordiCloud are expected to provide a platform for academia and practitioners to create new opportunities of interactions and networking for leveraging existing or starting new research and development activities. Considering the importance of industrial participation and knowledge dissemination, NordiCloud program was designed to have several talks on reporting the research

performed in close collaboration with industry or where the research output had clear potential for creating immediate value for industry. Whilst such talks were scheduled in different sessions of the symposium, we decided to gather the summaries of the talks and the discussions around them in this section.

Like many other disciplines and themes of computer science and software engineering, cloud computing provides several opportunities of unique application of data mining approaches and optimization algorithms. For example, search based software engineering is considered to have several kinds of applications for cloud-enabled systems including verification and validation. One of the talks on the application of FP-growth (Frequent Patterns growth) [11], one of the best known algorithm for frequent itemset mining, was focused on extending FP-growth algorithm for developing a cloud-enabled algorithmic variant for frequently mining itemset without being concerned about scalability issue as the extended algorithm incurs very little communication and computational overhead. The extended version of FP-growth algorithm for cloud-enabled infrastructure is expected to have a wide range of applications with significantly less amount of resources required [11]; any kind of data intensive applications where data mining on a cloud scale required, huge databases of marketing campaigns, data mining for biomedical research, or contextual based delivery of services through mobile devices.

Federated cloud is another important and hot topic for research and practice in cloud computing. It is expected that Scandinavian and European industrial sectors would be more keen than their counterparts in other parts of the World not to be placed in a situation of vendor lock-In. That is why many European Union (EU) research and development projects are focused on developing solutions that can help them to avoid vendor lock-In. Most of the efforts are focused on devising some mechanisms and standardization for making diverse cloud infrastructure interoperable with little success. Miranda and colleagues [9] presented approach that leverages model-driven engineering (MDE) for modeling and developing cloud applications for which cloud providers can freely define their own cloud policies, but the users can still continue to be free to choose a cloud provider, even after the application has been developed.

One of the key design principles underpinning a large majority of the cloud-enabled application is Service Oriented Development of Applications (SODA) and Service Oriented Modeling and Architecture (SOMA) [10]. Organizations are finding it hard to migrate legacy systems to Service-Oriented infrastructures that leverage Service-Oriented Architecture (SOA). Migrating to cloud computing brings a new set of challenges and potential strategies. Mohagheghi and Sæther [10] identified some of the challenges associated with migrating applications to service cloud platforms. The identified challenges include systematically assessing the potential viability of migrating to cloud, architectural level refactoring, modifying data management schemas, addressing quality of service (QoS) and extra functional requirements, verifying the cloud-based solution and redefining business models for pay per use pricing scheme.

In the symposium, there was a presentation on migrating legacy systems to SOA based infrastructure. Whilst this talk was not specifically focused on migrating to cloud computing but many of the challenges identified and the proposed approaches can provide useful inspiration for supporting an effort to migration to cloud computing. Razavian and Lago [14] reported a lean approach to

migrating legacy systems to SOA. The work was based on an empirical study aimed at identifying the strategies for migrating legacy systems to SOA. There were important insights and useful strategies that steered discussion on the applicability of the identified strategies to migration to cloud computing. The reported findings not only highlighted the importance of empirically gathering and analyzing industrial challenges and strategies for building an evidence based body of knowledge to support migration efforts but also stimulated fruitful discussion on several questions related to understanding and making sense out of specific industrial processes and practices with the intention of making them more generic. One important point for consideration was how generic the findings from a specific industrial study can be as authors packaged their findings as a lean and mean approach to migrating legacy systems to SOA.

3. REFLECTIONS FOR THE FUTURE

The talks, questions and answers, and group discussions during the sessions and breaks resulted in potentially useful outcomes in terms of the identification and elaboration of several key points for stimulating potential areas of research and practice of cloud computing and Internet of Things (IoT) for the well being of individuals and societal sustainability. The discussions and reflections of the participants were driven by the positioning of the presented research papers and industrial experiences and lessons in the context of broader opportunities and challenges that cloud computing promises. The discussions also focused on the future work that the presenters had envisaged in their respective areas of research and practice. In this section, we describe and discuss the reflections on the presented work and the discussions as it is expected to provide some insights into the future areas of research and practice for promoting and supporting widespread adoption of cloud computing and IoT for individual, societal, and industrial advantages in Nordic/Baltic countries and beyond.

Cloud computing has provided software engineering researchers and practitioners with many interesting avenues of valuable research and development. Leveraging cloud and Internet based technologies for providing software engineering tools as a service (TaaS) [3] and browser based Integrated Development Environments (IDEs) [8] are two of the areas which appear to have significant potential for exploration. TaaS concept is not only restricted to software engineering tools but can also be suitable to any engineering or scientific discipline. It seems very intuitive to provide tools as a service rather than deploying and maintain a large variety of tools for different tasks and then trying to make them interoperate at the different layers of abstractions ranging from User interfaces, middleware, and databases. The work presented in [3] was aimed at building an infrastructure for providing TaaS. The infrastructure work has identified several areas of potential research for enabling TaaS such as tools integration, traceability, multi-tenancy, and privacy of the data used and generated by different tools. The work on Internet based IDE [8] requires to mature the research to support collaborative editing, constant builds and tests as code changes, and automated configuration management. Moreover, an extensive testing of the ideas presented provides interesting areas for further exploration. This kind of work is also expected to stimulate several interesting areas for end user evaluation.

Another area of interest from software engineering perspective is supporting migration to cloud computing. Whilst there are an increasing number of organizations which intend to migrate to

cloud computing, there is a paucity of literature on process support, guidelines, and appropriate tool support [4]. The work presented by Razavian and Lago led to interesting discussions about the usefulness and relevance of the industrial practices of migrating to SOA outside the context where those efforts have been undertaken. Their work showed how empirical methods can help in understanding industrial challenges and solutions in as technologically advanced and complicated concepts as SOA. Those kinds of research methods should be equally applicable to studies of cloud computing related topics. There was also interesting points on the need of conducting basic and applied research for developing and empirically validating risk and value driven migration strategies and decision making tool support [14]. Some of the software engineering related challenges of migrating legacy systems to cloud computing discussed during the symposium have also been observed in [1, 10]. Scalability is an important area that needs significant amount of research efforts in the context of cloud computing as there are several issues with regards to scalability (i.e., up or down) of cloud resources that need to be fully understood and appropriately addressed.

Another important area of software engineering in the context of cloud computing is requirements engineering for cloud-based services. This topic was briefly presented as a poster paper [16] but it drew significant attention as it is becoming increasingly clear that conventional methods of requirements engineering are unlikely to meet the needs of cloud providers and consumers when it comes to gathering and analyzing requirements from mostly unknown customers and finding, evaluating, and selecting appropriate cloud services to meet the needs of a cloud service consumer. Todoran and Glinz have proposed the idea of building a community marketplace, called StakeCloud, whose details can be found in [16]. This poster talk stimulated discussion about the need of major research efforts to focus on requirements engineering in the context of cloud computing in order to devise and empirically validate appropriate methods and tools. There is also a need of solid decision support mechanisms and tool support. Cloud computing users and providers need to be able to quickly align their needs and offering from several dozens, or may be hundreds of cloud service offerings as there can be several different flavors and combinations of cloud service models and deployment models. It is expected that the requirements engineering methods developed for service-oriented domain can be customized for cloud computing, however, it is yet to be seen how much the requirements engineering methods and tools for service-orientation can be leveraged for cloud computing.

Another area where significant research efforts need to be dedicated is software testing in the context of cloud computing. Ali Babar and Chauhan [1] raised the point that testing cloud-enabled software services is different to testing the traditional systems as software services can only access the virtual representations of the hardware resources that are used to perform the required tasks. That means we need to take into account how the hardware is being configured and managed. Dynamic allocation of hardware resources can cause minor but significant variations that can be sufficient to have problematic implications if not considered and addressed appropriately. For example, any change in the underlying infrastructure that is managing the virtual resources may decrease the performance of the application and cause a system failure. This may also result in increased software maintenance cost without actually any modification or new enhancement. Hence, there is an urgent need to devise and

empirically evaluate appropriate testing approaches and tools to support software testing in the context of cloud computing. This issue was also discussed during the symposium in the context of the work, whose details can be found in [17], that has reported a framework for monitoring and testing scalability of web applications. Whilst this work is an initial step in the desired direction of devising new or enhancing existing approaches and tools for testing cloud-enabled software services, there are several areas which would need immediate attention of software testing community. For example, whether or not the auto-scaling features of cloud providers work well at the coarse-grained and at the fine-grained level; availability of suitable mechanisms to support continuous testing in the wake of changing underlying hardware of new virtual instances but with the same configuration profile. Another interesting area to be explored will be cloud-based testing – building and executing software test environments using cloud computing rather than in-house IT infrastructure or availing cloud based testing services that are being offered by many companies. It can be asserted that cloud testing services will be one of the most popular services offered and used. However, organizations need to carefully evaluating and choose the relevant testing services based on their Quality Assurance (QA) strategies or they need to adjust their QA strategies and processes.

Cloud computing can also provide new ways of providing IT infrastructure for scientific research and development activities. However, there can be several types of issues that need to be considered and addressed before cloud computing infrastructure can be leveraged. Some of the top most issues can be related to privacy, security, and reliability. For example, it is quite tricky to migrate biomedical systems to public clouds when the sensitivity of the data privacy needs to be managed very carefully. One of the talk at the symposium reported how a biomedical research organization was using public cloud infrastructure. Data location knowledge and management can be the key issues that need to be addressed to support the adoption of public cloud solutions for biomedical or any other domain where data location and privacy are paramount requirements. One type of the solutions to the high data integrity problems discussed can be myTrustedCloud [18], which addresses the privacy and trust related issues in cloud computing at the OS level. This solution is expected to enable dynamic, fast and secure management of the information generated and elaborated on multiple users and providers.

Vendor lock-in is another situation which almost all kinds of organizations want to avoid. How to avoid vendor-lock-in was another important topic discussed at length as it draws a lot of attention. There is an increasing push to provide solutions that can enable interoperability and easy portability across different clouds built using open source as well as proprietary stacks of cloud solutions. One of the possible solutions proposed are focusing on building reference architectures and standards to support interoperability of different vertically integrated clouds. One of the solutions presented and discussed in the symposium was a middleware-based solution for achieving cloud application migratability and interoperability [9]. However, there is a significant work needs to be done in this direction including building and evaluating appropriate cloud foundries to support interoperability and portability.

4. RELEVANT EUROPEAN PROJECTS

The perspectives and reflections from the first gathering of the NordiCloud reported in the previous sections have helped us to identify several kinds of issues that need to be completely

understood and sufficiently addressed in order to support widespread adoption of cloud computing for supporting individuals and organizations to provide and consume IT infrastructure (e.g., storage, computing, networking) as a utility. These issues raise many researchable ideas and questions that need joint efforts of researchers and practitioners with different kinds of backgrounds and expertise; the types of joint academic and industry efforts that usually characterize research and development projected funded by the European Commission.

We have identified some EU projects whose outcomes can be expected to provide solutions to some of the issues and challenges that public and private sector organizations in Nordic/Baltic countries are facing while adopting cloud computing. Our selection of these projects was based on an analysis of the key issues discussed during the symposium in terms of the potential solutions required to sufficiently address them and the main objectives of the cloud computing related EU projects. We expect that readers will find an overview of these research and development efforts useful sources of solutions to the problems they may be trying to address or inspiration for interesting researchable issues for deriving new ideas for building consortia and project proposals for future funding calls. Following are the names, URLs, and brief descriptions of a selected set of projects aimed at providing solutions for cloud-enabled systems.

VISION Cloud (<http://www.visioncloud.eu/>) - This project is focused on providing solutions for data mobility and federation to extend the limited data migration capabilities to migrate and federate data across geographically distributed location (administrative domains). The expected solutions to be developed in this project will be architectural solutions for making processing available where the data are stored and providing a platform where data intensive services can be securely stored.

TCLOUDS (<http://www.tclouds-project.eu/>) - This project aims at providing an infrastructure for delivering cost effective, simple, and scalable computing and storage capacities for social networking applications in the areas of healthcare and energy with the desired level of security, privacy and resilience.

mOSAIZ (<http://www.mosaic-cloud.eu/>) - The main objective of this project is to provide solutions for supporting interoperability among different cloud infrastructures. The intended platform will provide a multi-agent brokering mechanism to search services matching the applications' requirements, and compose the services if a single service cannot fulfill the requirements.

Contrail (<http://contrail-project.eu/>) - This project aims at designing, implementing and evaluating an open source computational cloud where user can share resource. The project will develop a cloud platform with complete integration of IaaS and PaaS in order to seamlessly integrate resources from other cloud with constrain cloud. The users will be able migrate applications from one cloud to another without being worried about vendor locking.

VENUS-C (<http://www.venus-c.eu/Pages/Home.aspx>) - This project aims at developing a highly scalable and flexible infrastructure for enabling scientific researchers to easily deploy end user services. The project will use Azure resources available at multiple partner universities and Microsoft European divisions. It is also considering EMOTIVE and OpenNebula to incorporate open source clouds.

LOGICAL (<http://www.project-logical.eu/>) - This project aims at enhancing inter operability of logistics businesses to improve the

competence of central European logistic hubs by enabling a universal standard for cloud computing in logistics, develop beta versions and test it to realize capacity building measures and bring transitional cloud computing tools to the operational capacity.

CloudSME (<https://www.facebook.com/cloudsmeproject>) - This project aims at providing a scalable platform for providing small and large-scale simulations and targeting to provide support to end user SMEs so that they can use simulation applications deployed as SaaS model. Simulation software provider and consultant companies can quickly assemble customize solutions by using SaaS model of the platform.

EPIC (<http://www.epic-cities.eu/>) - This project aims at providing a service catalogue and cloud platform to enable every city in Europe to allow and have access to smart city services according to the requirements and budget constraints.

ECO₂CLOUDS (<http://eco2clouds.eu>) - This project aims at developing guidelines, methods and technologies for cloud computing that consider that concerns ecological concerns (e.g. CO₂ footprint). The goal of this project is to improve cloud computing architectures, and development and deployment methods for cloud based applications.

OpenBio (<http://www.eubrazilopenbio.eu>) - This project aims at developing an e-Infrastructure for supporting open access to resources (data, tools and services) in order to meet the requirements of biodiversity scientific community. The infrastructure will result from federation and integration of existing European and Brazilian infrastructure. The infrastructure will enable cost-effective and cross-disciplinary virtual research environment applications.

REMICS (<http://www.remics.eu/>) - This project is aimed at developing process and tool support for migrating to cloud computing based on a Model Driven Architecture. The project has been conceived on the premise that one of the most effective and efficient way of supporting migration to cloud computing will be to provide appropriate process and tool support for connecting the architectural model SOA with cloud and base the migration process on architectural input from users and actors.

RESERVOIR (<http://www.reservoir-fp7.eu/>) - This project was aimed at providing a generic IaaS architecture for easier development of new and existing (cloud) applications. It built framework components to ensure Service Level Agreements (SLA) that enables portable implementations of services across a wide variety of cloud providers.

EASI-CLOUDS (<http://easi-clouds.eu/>) - This project aims at providing a generic PaaS with standardized APIs similar to the RESERVOIR project. One of the key objectives of this project is to develop and assess reference architectures and implementation to support cloud interoperability at different levels of abstractions.

CloudScale (<http://www.cloudscale-project.eu/>) - This project aims to develop technological solutions for enabling service providers in different domains to analyse, predict, and resolve scalability issues. The key outcomes of the project will be tools and methods for different types of companies to be able to develop highly scale services (i.e., SaaS, PaaS, and IaaS).

MODACLOUDS (<http://www.modaclouds.eu/>) - This project aims to provide solutions for rapid development of cloud-enabled services using model-driven engineering approaches. The outcomes of the project will be different methods, decision

support applications, open source IDEs and run-time environments for the high-level design, early prototyping, semi-automatic code generation, and automatic deployment of applications on multi-Clouds with guaranteed QoS.

PaaSage (<http://www.paasage.eu/>) – This project purports to provide methodological support and a platform for developing and deploying enterprise systems that will be able to access cloud services irrespective of the underlying technologies as the technical details will be abstracted from the developers through the technology neutral platform.

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