

Mobile Cloud Computing for Enterprise Systems: A Conceptual Framework for Research

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Abstract—In the recent years two trends have influenced our daily life: mobile devices and cloud based services. Complex enterprise systems have been moved to the cloud. The integration of mobile devices and cloud based enterprise applications offers new possibilities in terms of innovative products or processes or it increases the mobility and flexibility of the workforce

This integration has several effects on the company as a whole, whereas four central aspects can be identified, the management, the organization, the user and the technology.

In this paper we present a conceptual framework that offers guidance for further research in this field. We also derive topics for further research. From a stakeholder's perspective the framework focusses on the customer of services

Index Terms—business data processing, cloud computing, mobile computing, organizations, usability

I. INTRODUCTION

Recent technological development opened up two technological streams: First, with the proliferation of cloud computing, organizations have been able to get access to an unprecedented increase in computing power and resources. Now organizations can move their enterprise systems to the cloud and use them as cloud based services. Second, mobile devices already play an important role in our daily business and the market for those devices and their applications has been growing rapidly [1].

The integration of the technological developments, mobile computing and cloud based enterprise systems leads to a significant change the way how communication takes place. Eventually it will shift people towards new working models supported by services and the related data should be available and accessible anywhere, anytime, from every device, inside or outside the company. This is a new way to support the informational requirements of employees and offer more flexible working models [2] while improving the overall performance of organizations. As a next step it is inevitable to integrate customers and partners [3].

The implementation of cloud based services in an organization however is not only a technology-related task. Rather, it affects the organization as a whole, the related business process and those people inside and outside of the organization that have to use these information systems. Until now – to the best of our knowledge – research has put little attention on this field. As a starting point this contribution introduces a conceptual framework that integrates central aspects in the context of mobile cloud computing and enterprise systems. Finally we conclude with

highlighting four different directions for future research that will guide our research and that will hopefully inspire the research of others in the field.

II. RELATED CONCEPTS

In this section we introduce the concepts that we will relate to in the conceptual framework in section III below.

A. Mobile Computing

Mobile computing refers to small and powerful devices that enable mobility in wireless networks to support computing on the go [4].

For our discussion it is important to highlight some aspects that are essential for the provision of an acceptable mobile work environment: Scalability, security, efficiency, usability and performance are important regarding mobile applications [5].

To implement a productive mobile information system, it is crucial that mobile solutions can be integrated into the existing system landscape, into the IT infrastructure and into processes in an easy and accurate way.

When developing mobile applications one has to take into account some restrictions that are inherent in mobile devices. Basically, mobile devices span a large number of different devices with heterogeneous platforms. Compared to personal computers or laptops the size of the screens is usually small and the variation of the screen sizes is usually rather high. Furthermore the interaction with the system can depend on different factors, e.g. location, bandwidth or remaining energy [6].

B. Cloud Computing

The US National Institute of Standards and Technology (NIST) defines cloud computing as “a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction” [7].

This definition portrays cloud computing in the following dimensions:

Six characteristics: on-demand self-service, broad network access, resource pooling, rapid elasticity, and measured service.

Four deployment models: private Clouds, community Clouds, public Clouds, and hybrid Clouds.

Three service models: Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS).

In more detail these main characteristics can be described as follows:

On-demand self-service: computing resources can be acquired and used at any time without the need for human interaction with cloud service providers. Computing resources include processing power, storage, virtual machines etc.

Broad network access: resources can be accessed over a network using heterogeneous devices such as laptops or mobiles phones.

Resource pooling: cloud service providers pool their resources that are then shared by multiple users. This is referred to as multi-tenancy where for example a physical server may host several virtual machines belonging to different users.

Rapid elasticity: a user can quickly acquire more resources from the cloud by scaling out. They can scale back in by releasing those resources once they are no longer required.

Measured service: resource usage is metered using appropriate metrics such monitoring storage usage, CPU hours, bandwidth usage etc.

A specific type of cloud environment, primarily distinguished by ownership or access is represented by cloud deployment models

Public Cloud: a public cloud can be accessed by any subscriber with an internet connection and access the cloud space.

Private Cloud: a private cloud is established for a specific group or organization and limits access to just that group.

Community Cloud: a community cloud is shared among two or more organizations that have similar cloud requirements.

Hybrid Cloud: a hybrid cloud is essentially a combination of at least two clouds, where the clouds included are a mixture of public, private, or community

The cloud service models represent specific, pre-packaged combinations of IT resources on different levels.

IaaS supplies a set of virtualized infrastructural components such as virtual machines (operating system with computational power) and storage on which customers can build and run their applications.

PaaS are programming environments and run-time frameworks offered by the provider. Usually additional application building blocks and predefined functions can be used in order to improve the development of cloud based services. Those applications can also be hosted on those platforms. *PaaS* platforms usually offer tools to support the software development process from visualizing first ideas, the development and testing as well as the provisioning of the applications.

The SaaS model enables cloud providers to offer application software as on-demand services. Because clients acquire and use software components from different providers, crucial issues include securely composing them and ensuring that information handled by these composed services is well protected.

C. Mobile Cloud Computing

Mobile Cloud Computing is a novel computing mode which provides cloud based services to users through the internet and mobile devices [3].

A definition which includes more specific characteristics of cloud computing and mobile computing proposes mobile cloud computing as “a rich mobile computing technology that leverages unified elastic resources of varied clouds and network technologies toward unrestricted functionality, storage, and mobility to serve a multitude of mobile devices anywhere, anytime through the channel of Ethernet or Internet regardless of heterogeneous environments and platforms based on the pay-as-you-use principle” [4].

Basically mobile devices can interact with cloud services by using a web browser or native applications. Those applications, which are often called apps, are programs which are developed especially for mobile devices. Usually several versions of the same app are required, mainly depending on the operating system of the device. However, it is often difficult to manage and use the installed apps in an efficient way.

Recently, various applications based on mobile cloud computing have been developed and are served to users with applications available in the area of mobile commerce, mobile learning, mobile healthcare, mobile gaming and other applications to manage, share or store personal contents [8]. Examples for such personal information management systems are email, calendar, dictionaries, communication and messaging systems, maps and navigation systems, voice search or social media platforms [6].

The market for mobile applications and services is still growing as mobile applications play an increasing role in business [8]. Mobile business apps, which help and support employees with specific tasks, are seen as highly beneficial [5, 9].

D. Enterprise Systems

Enterprise systems are systems that span functional areas, focus on executing business processes across the company, and include all levels of management [10].

Enterprise resource planning systems, supply chain management systems, customer relationship management systems, and knowledge management systems the four typical types of enterprise applications.

The recent development in cloud computing has triggered the development of enterprise systems as cloud services. Special emphasis has been put on enterprise resource planning systems and customer relationship management systems, which are considered crucial for the future of the organization to be successful.

E. Cloud Enterprise Systems

Cloud enterprise systems are different from enterprise systems that are installed on-premise. From a technical perspective access to the system is achieved via a cloud provider using predefined interfaces. From a managerial perspective only those components and modules are used which are relevant to the business. Companies only need to pay what they use, thus there is no need to purchase the whole enterprise system [11]. This offers enterprises more flexibility, agility and they are able to concentrate on their core businesses.

F. Mobile Cloud Enterprise Systems

Based on these developments, the next step is to bring cloud based enterprise systems on mobile devices. The complexity of the functions and processes implemented in enterprise systems is usually higher compared to already

available mobile cloud based systems like mail or calendar.

Thus, the design of a mobile version of an enterprise system must be different from versions running on devices having more resources in terms of memory, computational power, size of screen, etc.). Nevertheless there must be a seamless integration of all devices in an enterprise system.

G. Stakeholders in Cloud Computing

Vendors and consumers are the two stakeholders in a rather traditional approach in the provision of enterprise systems. Besides vendors and consumers the ecosystem of cloud computing encompasses additional stakeholders which are infrastructure providers, platform providers, aggregators or brokers [12–14].

Customer purchase services through various distribution channels, for example, directly from the service provider, through a platform provider or broker.

III. CONCEPTUAL FRAMEWORK

As a starting point for further research a comprehensive conceptual framework has to be developed. This conceptual framework comprises four perspectives namely the technology, the user, the organization and the management to explore the characteristics of mobile cloud based enterprise systems.

Technology: The technological aspects have to cover the fields of cloud computing, mobile computing and enterprise computing. Based on the main characteristics of cloud computing broad network access is a prerequisite which has to be provided by customers.

Cloud services are based on the principles of the internet and they are offered through interfaces, thus the related tools and technologies like HTML, XML, SOA, etc. must be available in the company to work with these standards. If companies want to build their own services on the basis of cloud services, the corresponding programming models in combination with the supporting tools have to be introduced.

The integration of mobile devices generates additional technical issues, like the requirements that originate from the development of apps or other restrictions that are inherent in mobile devices.

User: A positive user experience plays an important role in the users' acceptance of information systems and can hence be regarded as a success factor [15]. In general user experience covers every aspect of the interaction of users with a product or service that influence their perception. Detailed definitions and a comprehensive discussion of the dimensions of user experience can be found in [16].

Organization: The organizational perspective encompasses items such people, structure, business processes, politics, and culture. Implementing a new information system or services often requires and results in significant changes to be made within an organization. [14, 17]. Organizations have a structure that is composed of different levels and job specialization. Business processes consist of a set of rules and regulations that guide employees [10].

When it comes to the introduction of mobile cloud based enterprise systems the main challenges are often more closely related to the organization and are often difficult to treat [18].

Management: There is a plethora of literature on management in organizations [19, 20].

According to Stroh [20] management has to fulfill five general functions namely planning, organizing, coordinating, leading, and controlling. Planning means to decide what has to happen in the future and how these decisions have to be implemented by making plans. Ensuring that the required resources are available in order to implement the plans is called organizing. The coordinating activity creates structures which enables an organization to fulfill the goals. In times of uncertainty leading has to decide what has to be done in specific situations. Finally controlling has to check and compare the actual situation against planned situations.

Management usually acts on three hierarchical levels: strategic, tactical and operational. On the strategic level decisions about future directions and goals for the entire organization have to be made. The tactical management provides a framework for the operational level, derived from strategic guidelines. The operational level is primarily concerned with the day-to-day decisions.

IV. RESEARCH DIRECTIONS

These four aspects are highly interrelated and one cannot be explored without the others. Management activities are required to mentor and promote all activities.

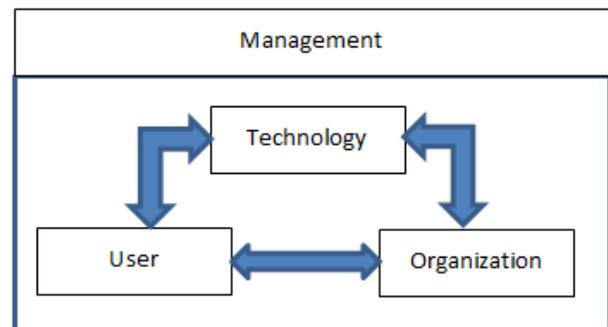


Figure 1. Interrelated Dimensions of Framework

The proposed conceptual framework provides a basis for further research. Due to the close interrelations between the four aspects no one can be treated in isolation. Based on this framework the following research directions can be derived, user-centric, technology-centric and organization-centric.

A. Technology-centric Research

Besides wireless internet connections mobile devices offer a variety of communication capabilities, above all Near Field Communication (NFC) and different standards of Bluetooth, especially Bluetooth Low Energy, also called Bluetooth 4.

The different ways of communication, other features of mobile devices like GPS or cameras and related mobile applications can be combined. In a further step data can be collected and integrated with mobile apps and then combined with cloud services. This offers new opportunities for enterprises in different fields, like customer care, product maintenance or fast and accurate communication with customers and suppliers.

The integration of different information systems on different levels, like integration of data or functions leads to new technical requirements. Concerns like security, priva-

cy or identity management issues also have to be addressed with technical solutions.

The central management of mobile devices as well as new trends like “bring your own device” has to be taken into consideration.

B. User-centric Research

The challenges of mobile interaction design are changing permanently due to the fact that mobile devices are constantly evolving. Thus methods and standards have to be further developed accordingly. Besides the design of software the interaction with all other elements of an information system (e.g. sensors from products in case of maintenance) has to be taken into consideration in order to improve user experience.

The development of design guidelines for apps, benefits and drawbacks of responsive or adaptive web design compared to mobile-dedicated systems, gesture-control or models for measurement is an option for further research.

C. Organization-centric Research

Introducing mobile cloud based enterprise services will change roles and responsibilities in an organization. These services are bought from providers therefore less technical workforce is required. On the other side new roles will emerge, like managers for the different types of services, service architects or staff that is responsible for service orchestration. These new roles are also responsible to add value to the organization.

This will impact the skills of employees in business units. They have to develop an understanding on how these kinds of information systems work and what kind of possibilities they offer. As a consequence this will change the organizational structure as well as internal and external processes.

D. Management-centric Research

Cloud based mobile enterprise systems open new possibilities for innovative products and business models, new ways to organize production processes. As a consequence this will have effects on the way we work and collaborate.

Further research to develop and adapt process models to introduce cloud based mobile systems that cover all phases, e.g. strategy, analysis, concept, development, implementation and operation, is needed.

Developing robust decision models to select systems that cover all related aspects like technology, finance, people and organization is required to improve decision making processes. New trends like “Everything as a Service” demand quick and precise decisions.

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