Cloud Computing Technology for Collaborative Information System in Construction Industry

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Abstract

The fragmentation, poor integration and adversarial relationships among players in the construction industry has been one of the main barriers of the successful construction project delivery contributing to negative influence on project objectives. There are many processes, organisations and people involved within the construction industry. Enhanced collaboration with construction parties in supply chain and with the project stakeholders is significantly vital to maximise the productivity, enhancing the efficiency and effectiveness. Furthermore, construction projects require intensive efforts and processes which is often a challenge to provide the parties within the construction industry to access the accurate information and efficient communications through the reliable, competent and appropriate networks. The purpose of this paper is to investigate the construction collaboration tools along with concepts of cloud computing and context-awareness. The findings in this research are based on a thorough review of the comprehensive literature on IT, computing and construction. Consequently, this study sets out to introduce and develop the concepts of potential innovative collaborative tools, such as Context-Aware Cloud Computing Information Systems (CACCIS), for facilitating the construction supply chain processes and networks by enhancing the opportunities for achieving better competitive advantages within the construction industry. Firstly, it is hoped that this study will lead to improved construction collaboration to enhance the competitive advantages within the construction industry. Secondly, it presents the new visions of construction industry integration and most significantly collaboration in an efficient way that will ultimately improve the productivity, efficiency and the effectiveness of construction industry.

Keywords: Construction Industry, Construction Collaboration Tools, Cloud Computing, Context-Awareness.

Introduction

Fragmented, complex and non-integrated environment is often relates with construction industry. A major challenge facing the construction projects is to integrate, support and facilitate a multidisciplinary team of stakeholders working with supply chain parties and project stakeholders on achieving the common goal of a project. They must work collaboratively to improve the productivity, effectiveness of construction management, and efficient utilisation of resources in order to guarantee the success of construction projects in achieving their specific objectives. These specific objectives are mostly in achieving determined project time, allocated cost, quality and safety of the construction projects. Since several years ago, the construction industry has brought a lot of efforts to an increasingly competitive significant concern to implement techniques, technologies and tools that can reduce project duration and cost along with improving productivity, efficiency and effectiveness. It should be noted that within the dynamic construction industry whereas clients as significant part of the construction supply chain are requesting for better value of money, higher quality, shorter construction cycle times and access to the up to date information, produced at any point in the project life cycle within the construction supply chain (O'Brien et al., 2011 and Aziz et al., 2006). Although there have been a variety of technological advancements

arisen within the construction industry (Anumba et al., 2008 and 2006; Sze-wing et al., 2008 and Acar et al., 2005), but still there are many challenges in existing construction processes resulting from poor access to the right information at the right time for effective decision-making and from a general communication breakdown between project participants that could contribute to lack of collaboration and integration with in the construction supply chain parties and project stakeholders (Xuan et al., 2007; Peansupap et al., 2006 and Kondratova et al., 2003).

Quality, quantity and timing of information are significant elements in construction projects which can either hamper or assist the successful consequences on project objectives (Garza et al., 1998).Moreover, according to Anumba et al., (2008), construction is an information intensive industry, while as, information delivery is the key to better management within the construction supply chain including the implementation of construction projects. Also, it is vital for cost savings, efficient and effective decision making and a key for success. Modern project management approaches and tools have been evolved in order to overcome problems in construction management. The use of project management tools in construction management has been widely known (Milosevic, 2003). All of these techniques and tools are a key facilitator for efficient and effective collaboration among the construction industry parties.

In order to overcome the mobile and information intensive nature of construction projects, the unstructured and dynamic nature of the construction projects, difficulties and hazards existed within the construction industry will necessitate the use of intelligent ways such as adapting the cloud computing to support the construction industry. As stated by Goscinski and Brock (2010), cloud computing is a new business model wrapped around new technologies, such as virtualisation, applications (Software as a Service (SaaS)), platform (Platform as a Service (PaaS)), and hardware (Infrastructure as a Service (IaaS)). Therefore, this research effort is to discover the concepts and benefits of the cloud computing application within the construction industry such as by grounding up the approach of context-awareness cloud computing in the construction industry.

Firstly, this paper presents how construction collaboration technologies can assist the construction professional parties in managing construction projects more effectively. It also presents the variety definitions, delivery models and types of cloud computing. The third part of this research demonstrates the enabling technologies as Context-Aware Construction Collaboration Tools. The potential of Context-Aware Cloud Computing Information Systems (CACCIS) as a proposed collaboration tool will be illustrated in part four of this research. Finally, the conclusion develops ways to enhance the potential opportunities offered to the construction industry by collaborative technologies and tools.

Construction Collaboration Tools

Since the early 2000's, many researchers have sought to implement techniques, technologies and tools which reduce project duration and cost whilst improving quality, productivity, efficiency and effectiveness. Within the dynamic construction industry, clients, as a significant part of the construction supply chain, are requesting better value for money, higher-quality products, shorter construction periods and access to valid and up-to-date information at any time in the project life cycle (O'Brien et al., 2011). As asserted by Barthelmess (2003), collaboration in a project requires those involved to communicate and be aware of each other's activities. Moreover, collaboration requires successful and efficient sharing of knowledge, negotiation, coordination and management of activities (Lang et al., 2002). On the other hand, the unstructured, dynamic and complicated nature of projects, their difficulties, threats and risks, are associated with the construction industry. Thus, in order to overcome the mobile and information-intensive nature of construction projects the use of creative and intelligent ways for collaboration will be necessary. Consequently, cloud computing is a significant potential tool to support the construction industry and its currently available collaboration tools such as desktops, internet networks, tablets, smartphones and laptops. Therefore, this research will propose the development of a context-aware construction collaboration tool (Application) for the successful effective implementation of cloud

computing in the construction industry that could be utilized by the supply chain parties and project stakeholders. The next part of this research will present the variety concepts of cloud computing including the definitions, delivery models and types of cloud computing.

Cloud Computing

Cloud computing is the latest technology that is being developed by the IT industry as the next revolution that will influence on how efficiently and effectively could the internet and information systems operate and are used by the world at the bigger picture. Table 1 illustrates the various definitions of cloud computing.

Table 1: Definitions of Cloud Computing

Author(s)	**Definition**
Voorsluys et al., (2011)	A new computing paradigm which offers a huge amount of compute and storage resources to the masses.
Mell and Grance (2011) and Cloud Computing (2010)	Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources.
Sultan (2010)	The IT capabilities that are requested, provisioned, delivered and consumed in real time over the internet.
Goscinski and Brock, 2010	A new business model wrapped around new technologies, such as virtualisation, applications (Software as a Service (SaaS)), platform (Platform as a Service (PaaS)) and hardware (Infrastructure as a Service (IaaS)).
(Sharif, 2010)	As a technology that has the potential of changing how the internet and the information systems are presently operated and used.
Misra et al., 2010; Sultan, 2010; Erdogmus, 2009 and Bittman, T.J., 2009	A collection of disembodied services accessible from anywhere using any mobile device with an internet-based connection.
Armbrust et al., (2009)	As both the applications delivered as a service over the internet and the hardware along with systems software in datacenters that provide those services
Erdogmus (2009)	A pool of highly scalable, abstracted infrastructure which is capable of hosting end-customer applications that are billed by consumption.

According to Table 1, to simplify the concept, cloud computing can be defined as basically the sharing and utilization of applications and resources within a network environment to implement the business without any concerns regarding to the ownership, management and maintenance of the network's resources, applications and services. Furthermore, according to Zhang et al., (2011), applications on smartphones traditionally are constrained by limited resources such as low CPU frequency, small memory and a battery-powered computing environment. Therefore, cloud computing technology could be a significant alternative for solving these issues. It should be noted that this technology could be applied to overcome the mentioned issues and constraints asserted by Zhang et al., (2011) via smart phones, tablets and etc.

There have been four delivery models, (deployment models) of cloud computing identified which are: public cloud, private cloud, community cloud and hybrid clouds whereas, Armburst et al. ., (2009) defined public cloud as when it is constructed in a pay-as-you-go manner to the public (open system for any users) and a private cloud when the internal datacenters of a business are not made available to the public (close system due to only access of special users). The two other delivery models are community and hybrid, which is related to a cloud that is controlled and used by a group of organisations that have shared interests (community cloud), and the hybrid cloud is a combination of a public and private cloud that interoperates (Mell and Grance, 2011 and Cloud Computing, 2010).

Three broad types of cloud computing according to Mell and Grance (2011), P.Y. Thomas (2011), Cloud Computing (2010), Reeves (2009) and Kim (2009), Hoover and Martin (2008) and Foley (2008), are defined as follows:

(1) ***Infrastructure as a Service (IaaS):*** The consumer via the cloud providers uses fundamental computing resources such as processing power, storage, operating system, networking components such as firewalls or middleware. Amazon web services are a good instance in this category;

(2) ***Platform as a Service (PaaS):*** The consumer uses a hosting environment for their applications. They control the applications that run in the environment (and possibly has some control over the hosting environment), but does not control the operating system, hardware or network infrastructure on which they are running. Google AppEngine, Amazon's S3, EC2 offerings and Microsoft Azure are good examples of this category and;

(3) **Software as a Service (SaaS):** The consumer uses an application, but does not control operating system, hardware or network infrastructure on which it's running. On the other hand, in the utilisation of SaaS a provider licenses an application to customers as a service on demand, through a subscription, in a "pay-as-you-go" model. Examples of this category includes Zoho Office, Microsoft WindowsLive, variety of Google Apps include Gmail, Dropbox, Google Talk, Google Calendar, Google Docs (for word processing and spreadsheets), YouTube, SlideShare, Amazon, Facebook, twitter, flickr, and virtually every other Web 2.0 application is a cloud application in this sense.

One of the significant benefits of cloud computing is that it provides scalable access to computing resources and information technology (IT) services. This innovative and accessible resource is an integration of hardware and software which organizations or individuals can utilise, anywhere in the world via the internet. Additionally, it will ground the opportunity to penetrate and disseminate the computing resources and information technology (IT) services through the world industries such as construction industries that if appropriately implemented and adapted it will ultimately enhance the productivity, efficiencies and the effectiveness of the construction industry. The following part of this research will discuss on the definitions and concepts of context-aware computing.

Context-Aware Construction Collaboration Tools

Information communication technologies (ICT) are reaching to their main target of developing an environment in which anyone can easily access any information they may need at anytime and from anywhere (cloud computing). On the other hand, the cost reduction of information delivery has drawn the construction industry into an ocean of unmanageable amounts of information (both useful and useless). Therefore, it is important to provide useful information, merely for a specified user, at a given time and according to the user's context (context-awareness). On the otehr hand, the adaptation of information communication technologies (ICT) technologies and tools in construction industry is slower compare to other industries. Aziz et al., (2006) asserted that there is limited application of context-aware technology in the construction industry. Furthermore, there are valuable opportunities via evolving the significant enabling technologies of CAID (Context-Aware Information Delivery). Additionally, Aziz et al., (2009) stated on some of the enabling technologies for CAID which were classified into: location-based services, ubiquitous computing, sensor networks, Radio Frequency Identification (RFID) and profiling technologies.

Awareness of a user's context (such as user role, task, preferences, location, site conditions and etc) in mobile construction applications will enhance the effectiveness of project delivery by providing information and services relevant to a particular context (Fathi et al., 2009). Therefore, context-awareness of users could provide efficient and effective information, communication and services throughout the entire construction supply chain to enhance the success of construction projects. The following part of

this research will briefly discuss on the proposed system of integrated context-aware cloud computing within the construction industry.

Architectural System of Context-Aware Cloud Computing Information System (CACCIS)

Beside the characteristics of great fragmentation, the similar information is exchanged, processed, manipulated and disseminated throughout the construction industry. Consequently, drawings are re-drawn, lists are re-entered, quantities are re-counted and materials are ripped out and replaced unnecessarily and etc. These mentioned examples of unproductive workflows will all be contributors to a declining productivity. Therefore, the significant objective is to enhance the early coordination and communications along with improving the collaborations via bringing the parties within the construction project supply chain together much earlier as such the same way that design/build brought the architect and contractor together at the project's onset due that any modification one party makes will affect the entire process of construction project; thus, creating constant communication and inefficiencies. Consequently, it is hoped that by proposing the system of context-aware cloud computing (open share collaborative tool), allowing all project stakeholders and supply chain parties including the design team members, owner, architects, contractors, suppliers, engineers and consultants to collaborate more accurately and efficiently than traditional approaches and processes. It is justified that this system will be in overall, more efficient and effective rather than other systems, models and approaches such as 3D-4D-5D, BIM, Integrated Project Delivery (IPD), Virtual Design & Construction (VDC) and etc. Implementation of this system will result to an enhancement in productivity, efficiency and effectiveness within the construction industry. Moreover the two significant elements of this system as discussed in previous sections of this research includes context-awareness and cloud computing.

Context-awareness is the awareness of a user's within the environment context (such as location, roles and responsibility, identity, preferences, calendar, noise, type of network, time, weather, site conditions, available bandwidth, interests, network type, task, activity, quality of services and network characteristics) which if implemented could enhance the effectiveness of construction industry by providing the most efficient and valuable information and services relevant to a particular context. On the other hand, the other significant element of this system is cloud computing. As discussed in this research, cloud computing is a technology that uses the internet and central remote servers to maintain data and applications. Furthermore, cloud computing allows consumers and businesses to use applications without installation and accessing to their personal files at any computer with just an internet access. This technology allows for much more efficient usage of information technology services over the internet at a dramatically lower cost and with dynamic scalability by centralizing storage, memory, processing and bandwidth.

Cloud computing architecture can be divided into two sections: the front end and the back end. They connect each other through a network. The front end is the side the computer user or client sees. The back end is the cloud section of the system. According to Figure 4, front end includes the client's (users) computer such as desktops, netbooks, laptops, tablets, mobiles and smart phones along with a web based application required to access the cloud computing service. It is also known as cloud computing interface. Services like web based e-mail programs are also cloud computing interface such as Gmail, Yahoo Mail, Hotmail and etc which are all examples for cloud computing. On the back end of the system, there are various application servers and data bases (includes data storages) systems beside the server engine (processing server) that create cloud of computing services.

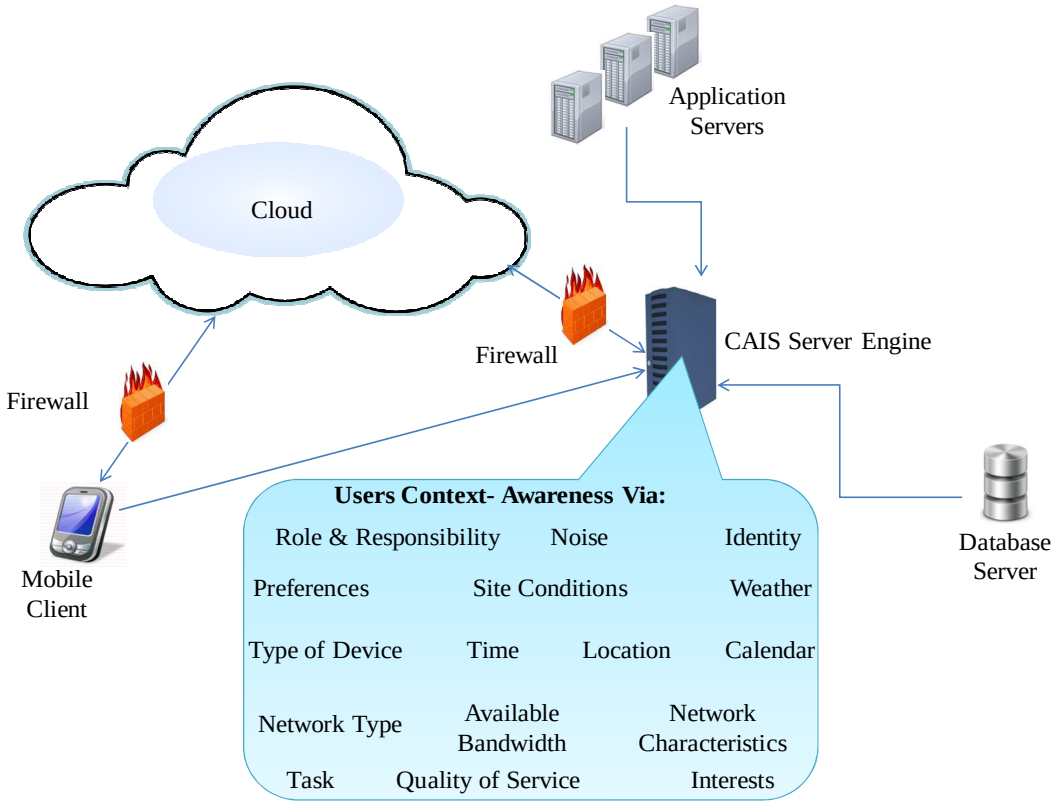

Fig 1. Context-Aware Cloud Computing Information System (CACCIS) Architecture

Fig 1 illustrates that all the data will be received by application servers and database servers which, in turn, will be sending the information to the Context-Aware Information System Server Engine (CAISSE) to process the information. The CAISSE will then send back the relevant information to the users based on selected contexts. Basically, the CACCIS architecture consists of four main components:

(1) The Mobile Client: A mobile device (smart phones and mobile computers) which is able to transmit data and information to the CAIS server engine through the cloud. Also, the client will receive the information from the cloud;

(2) The Firewall: In this system, two firewalls have been proposed which the first one is between the CAIS server engine and cloud and the second between the cloud and the mobile client. It should be noted that these firewalls are for the security of the data and information which will be transmitted and received by the devices;

(3) CAIS Server Engine: The data which is received from application servers, database servers and mobile clients will be processed by the CAIS server engine. In this phase, many features of the users based on the context defined, such as location, roles and responsibility, identity, preferences, calendar, noise, type of network, time, weather, site conditions, available bandwidth, interests, network type, task, activity, quality of services and network characteristics (user context-awareness) will be selected; and

(4) The Cloud Server: All the user information which is generated through the CAIS server engine will be transferred through the cloud with authorization through the firewall. Furthermore, this information will then be manipulated and disseminated to the mobile client through the cloud.

There are three categories of cloud computing: Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS).

Having context-aware applications (such as the location and activity context) allows the application to present information and services that are relevant to the construction supply chain parties. The context-aware application supplies information and services based on the construction supply chain parties current location by using the Global Positioning System (GPS) for the outdoor location coordinates and a Wireless Local Area Network (WLAN) for the indoor location coordinates. The location coordinates (latitude, longitude and altitude) are then transmitted from the mobile client (mobile client with GPS and WLAN capabilities) to the CAIS Server Engine (CAISSE) through internet (including the wireless network: WPAN, WLAN, WMAN and WWAN).

According to Omar et al., (2009), although a variety of mobile and context-aware applications already exist, there are still major shortcomings for the potential users. Most of the developed systems are research prototype demonstrator based that have only been evaluated in small field trials with a limited scope of usage. The limitation for a bigger usage is impossible for the two following reasons. Firstly, mobile guides might have restrictive hardware requirements like a specific type of PDA (Personal Digital Assistant), the availability of GPS (Global Positioning System) functionality or client-side software installations. However, new generations of mobile devices such as smart phones and tablets having larger display sizes, more standardised browsing capabilities and higher speed broadband data transfer will ease these hardware requirements. Secondly, the availability of extensive and accurate resource data is another limitation. Moreover, due to rapid deployment of wireless communication technologies such as Wireless Personal Area Network (WPAN), Wireless Local Area Network (WLAN), Wireless Metropolitan Area Network (WMAN) and Wireless Wide Area Network (WWAN) the opportunities for construction industry organizations to offer services to construction supply chain parties and construction project stakeholders within construction industry along with portable wireless devices (i.e. tablets, laptops, smart phones, netbook computer and etc) are growing. Therefore to mitigate and overcome the adverse consequences of these issues mentioned, this research have proposed the Context-Aware Cloud Computing Information System (CACCIS) as the most valuable construction collaboration tools that will ultimately drive the construction industry to achieve efficient and effective competitive advantages. The last part of this research will ground down a brief overview of the significant points which was discussed and concluded within this research.

Conclusion

The nature of the construction industry is unique among other major industries. Although this industry is mostly one of the early adopters compare to other industries, but it is usually slow to adopt the current collaborative tools and technologies. Furthermore, the construction industry is more projects based which consists of many players with different organizational cultures and objectives. Therefore, in order to achieve successfully the project goals in a timely, effective and efficient manner, the selection and implementing the appropriate construction collaboration tools for the construction supply chain parties and project stakeholders are critically vital. On the other hand, the expanding complexity of construction processes and the supply chain necessitates the increasing amounts of data and information which requires to be exchanged during the construction process.

Overall, this paper has reviewed valuable collaborative tools and technologies as a subset of information and communication technology (ICT) which provides the ability to communicate and exchange data and information easily, efficiently, effectively and accurately at anytime, within anywhere and in any place that is hoped to provide major benefits for the construction industry. These collaborative tools and technologies which is discussed in this paper includes cloud computing and context aware computing. Currently, the advances in affordable mobile devices such as smart phones and tablets, enhancements in

wireless network transfer speeds and improvements in mobile application performance has facilitate the cloud computing technology as a powerful potential to enhance information management within the construction industry. It is resulted that context-awareness could be integrated with cloud computing in order to ensure the delivery of applicable and reliable information with enhancing the collaboration of construction supply chain and project stakeholders.

Consequently, this study efforts in introducing and developing the concepts of potential innovative collaborative tools such as Context-Aware Cloud Computing Information System (CACCIS) for facilitating the construction supply chain processes and networks with enhancing the opportunities for achieving better competitive advantages for construction industry. Finally, the study presented in this paper is a preliminary survey and is a part of an ongoing research, which will eventually attempt to further enhance the practices and implementation of cloud computing as one of the significant innovative construction collaboration tools.

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