DEVELOPMENT OF DECENTRALIZED INFORMATION AND COMMUNICATION SYSTEM FOR AEC

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ABSTRACT

During the transition from traditional to ICT supported engineering communication and collaboration, the type of interaction between AEC project collaborators changed. A thorough review of a number of national and European projects shows that the topology of interaction evolved from the traditional fully interconnected model where people talk to each other directly to the centralized star shaped model where collaborators talk to each other through the intermediary. The star model with the central point of interaction offers a more efficient and less complex way to manage communication although it affects the way professionals work, because it does not support core engineering processes and tasks but forces new ones. In that way, professionals are determined by the technology that they use.

This paper discusses the ongoing research work regarding the nature of the communication in the construction industry, its particularities and changes from the ICT point of view. The paper presents the theoretical backgrounds of the communication, some key barriers to the successful communication in AEC and proposes a new approach to the ICT enabled communication presenting an architecture of the informal and distributed ICT system for collaboration that was developed based on the driving technologies. The designed architecture is the outline for the developed prototype which is presented.

Keywords: communication, collaboration, Web 2.0, informal communication systems

1 INTRODUCTION

In the last decade the research regarding the communication in the field of the construction information technology was focused mainly on the shape, the content and the data type of sharing of the information with much less attention to the exchange of the information between people. Consequently, construction industry is in relatively early phase of adopting modern web-based information and communication technology, even though the Web itself has already moved deeply into its second phase.

Nonetheless, the current trends in ICT are encouraging because they focus mainly on people and processes and less on technology. The tipping point for the (engineering) communication and collaboration came with the popularity of Web 2.0 and widespread social networks that are mostly decentralized by their nature. Quickly emerging social networking applications are becoming the preferred method of communication in personal as well as in business environment. Web tools used in everyday tasks today are available free of charge and offer the desired functionalities through simple, intuitive, self descriptive and user-oriented interfaces that always work. Unlike the complex information and communication systems of the past, modern tools are oriented towards simple and effective solutions called Web 2.0. Web 2.0 represents the second generation of the World Wide Web and is characterized by the move from the classical static web pages to dynamic web services, data sharing and social networking. That is why it has quickly gained its popularity among end users. In addition, Web 2.0 services present the appropriate grounds for an efficient communication and collaboration, but they still require additional development in some fields.

The result of the development of the ICT technologies were variations of the behavior patterns of the users in domestic as well as in business environment.

The paper provides an overview of characteristics of the engineering communication and collaboration as well as the ICT technologies that shaped the AEC environment. In addition, key technological trends are outlined, system architecture is proposed and ICT communication system prototype presented.

2 BACKGROUND

One of the essential skills of the AEC professionals is the ability to express themselves clearly and concisely or in other words - to communicate efficiently and effectively. What is more, communication is arguably the most important aspect of project management since without the effective communication between the participants the AEC project cannot be finished successfully (e.g. on time and within budget). What makes communication in the AEC really difficult is the fact that construction projects are conducted in a dynamic social system where nothing is particularly stable for a very long time (Emmit and Gorse 2007). In addition, the AEC projects are affected by one-of-a-kind products and processes, uncertainty and complex interdependence.

2.1 Communication

Dainty et al. (2006) claim that the point of communication in most cases is that one person wishes another to receive information from another. Despite numerous definitions most of the engineering literature suggests that communication is essentially about the transfer of information between people. On the other hand, social studies literature defines communication as the sharing of meaning to reach a mutual understanding and to gain response. This usually involves some form of interaction between the sender and the receiver of the message (Emmit and Gorse 2007).

The communication process in engineering is usually presented with the Shannon and Weaver's model of communication (also known as the mechanical and mathematical model as well as linear model of communication) shown in Figure 1.

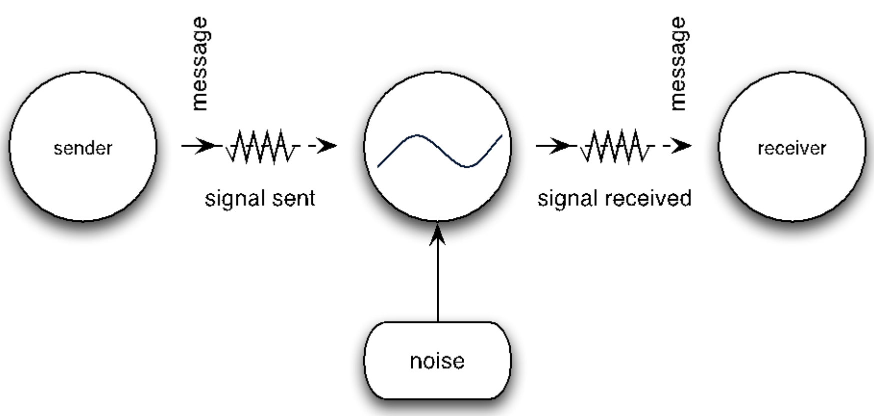

Figure 1: Shannon and Weaver's model of the communication process

The model was developed as a part of the research trying to formulate a theory to guide the efforts of engineers in finding the most efficient way of transmitting electrical signals from one location to another (Shannon and Weaver 1949). Despite many limitations of the model its simplicity and formality of the otherwise complex problem is the reason why it presents the base of the most of the communication theories and models, especially from the cybernetic tradition of the communication theories.

While there is a lack of scientific consensus on whether the linear model of communication is appropriate or not, most of the scientists agree that the levels of communication within which people are involved can be classified as follows (Dainty et al. 2006, Emmit and Gorse 2003, Emmit and Gorse 2007):

- Intrapersonal communication - internal communication processes (cognition) that enable individuals to process and interpret information.
- Interpersonal communication - direct communication between exactly two people which enables individuals to establish and maintain relationships.
- Group communication (also known as small-group communication) - more than two people communicating in order to coordinate activities.
- Multi-group communication - communication between different work groups where the sender and the recipient can be either an individual or a group.
- Mass communication - messages are sent (communicated) to a large audience.

The above classification fits directly to the classification of the communication models according to the number of nodes in the communication topology:

- one-to-one,
- one-to-many, and
- many-to-one.

With the advances in information and communication technologies the fourth model emerged:

- many-to-many.

Looking at the communication through the lens of the evolution of the connectivity of the nodes in the communication network, the development of the information and communication technologies resulted in the change from the centralized to more decentralized, fully connected network topology (see Figure 2).

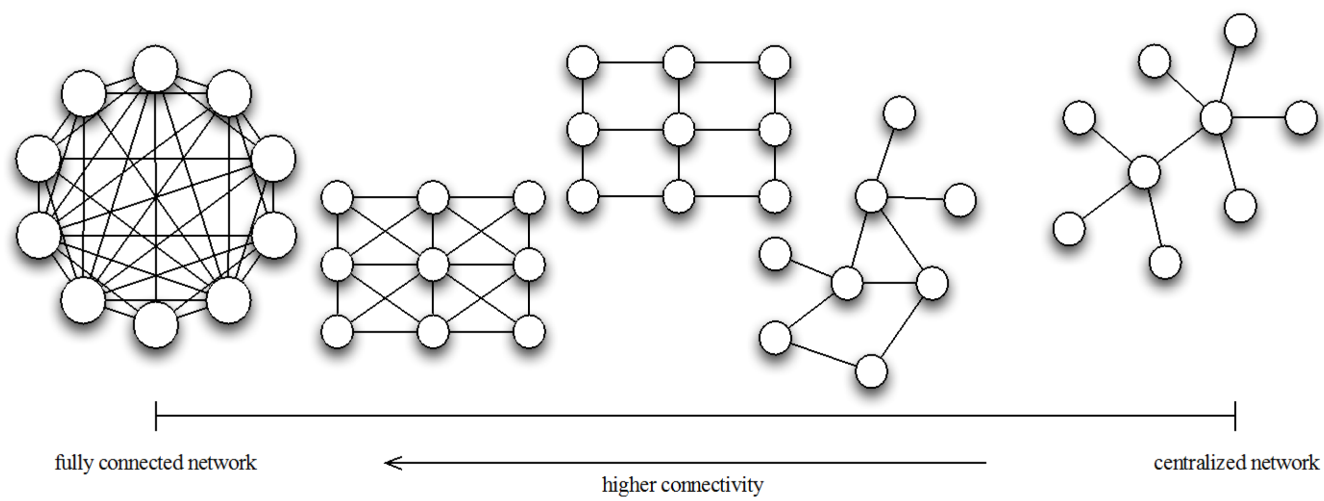

Figure 2: Network topology based on connectivity (Sanchez-Silva 2009)

2.2 Communication in construction

According to Guevara & Boyer (1981), AEC enterprises have to (in order to function effectively) introduce communication systems of different types: a) interpersonal, b) interdepartmental, and c) interorganisational. Most of the researches to date were primarily focused on interdepartmental and interorganisational communication and have not dealt with the interpersonal interaction of the AEC project participants, although the importance of formal and especially informal one-to-one communication and collaboration was emphasized many times.

The majority of the tools supporting communication and collaboration today enable one-time and just-in-case communication, but lack stronger, systematic and structured support for just-in-time connections. Most of the emerging problems are still solved in traditional ways, usually by phone, in the form of informal communication. Kraut et al. (1990) argue that informal communication is an important mechanism that helps all members of a project to achieve both production and social goals of a team. Informal communication is spontaneous, interactive and rich. That is why it is important to address the challenge of supporting informal communication with the use of I(C)T in order to provide additional channel for successful collaboration among different AEC project partners.

During the transition from the traditional to ICT supported communication the method of interaction between people changed. Instead of fully connected communication network topology where every person could talk to another directly the topology changed to centralized one, allowing members of the communication process to only communicate through an intermediary.

3 MOTIVATION

Both academic as well as business environment are trying to improve communication and collaboration among partners in construction projects for decades. Davidson & Moshini (via Bowden 2005) suggested that the efficient transfer of information can reduce the cost of construction by as much as 25%. Although ICT offers crucial benefits from the viewpoint of the communication and collaboration between people and working groups the AEC industry have not yet adapted to the requirements of the knowledge workers that would like to receive desired information at the point of activity (Bowden 2005).

Tenah (1986) illustrated that some construction companies buy packaged information systems without examining the functions and information needs of their personnel. Instead of fitting such packaged information systems to the needs of their employees the real world scenario is directly the opposite – employees have to adapt to the system. As the consequence, information system's adoption is poor despite the high investment and potential benefits.

The work with complex information system is an additional problem. Froese & Han (2009) claim that newly developed ICT technologies can not only facilitate but also complicate construction processes. In addition, they claim that the ultimate success of construction IT research and development may mostly depend on the increased ability to deal with systems complexity.

Consequently, the business information systems are changing. They are evolving from traditional tightly coupled systems to the modern loosely coupled systems following n-tier (3- or more) architecture more appropriate from the viewpoint of extensibility, usability and portability.

4 ICT SYSTEM FOR AEC COMMUNICATION 2.0

Following the extensive literature review, the ICT system requirements derived from the projects OSMOS, GLOBEMEN, ISTforCE and InteliGrid as well as new findings regarding the behavior of the Gen X and Gen Y workforce, a decentralized system architecture was designed and the prototype was built. The designed and developed prototype is filling the gap between the traditional information and communication systems used in the business environment today and the modern, simple, intuitive information and communication services used at home, usually for the communication between friends and family. The idea was built on the grounds of the Enterprise 2.0 initiative that followed the latest findings regarding technology populism and social interaction.

4.1 Driving technologies

This section describes various new and emerging information and communication technologies used in the development of the proposed communication.

4.1.1 Web 2.0

During the recent years, a phenomenon of Web 2.0 attracted a lot of attention not only on the Internet, but also in the business community. New on-line applications not only make tasks such as individual and group on-line learning, communication, collaboration and creation easier but they also have the capability of up-grading the experience by using the vast amount of information from the Internet, previous sessions and the so called collective intelligence of its users. It is considered as a next step and a major evolution of the traditional web from both the technological and social perspective. Although it is the single most used buzzword in the Internet community in the past several years there is still no official definition of what Web 2.0 actually is. The term has numerous definitions and more or less all of the authors agree that it is a trend, a perception of the direction the Web is heading, and not an object that can be created (Jewell 2007). It is an attitude towards radically open communities and communication.

It is not possible to define classic and next generation web by describing the technology. Instead, the focus has to be on the changes in human behavior that the technology enables whereas those changes are hard to describe or define. Therefore it is not surprising that it is difficult to define Web 2.0 since there is no good definition of Web 1.0 either. Both principles are more or less always presented as a comparison between each other. Tim O'Reilly (2006) proposed a Web 2.0 compact definition which was formed as follows: »*Web 2.0 is the business revolution in the computer industry caused by the move to the internet as platform, and an attempt to understand the rules for success on that new platform. Chief among those rules is this: Build applications that harness network effects to get better the more people use them.*«

4.1.2 Cloud computing

Hewitt (2008) as well as Happell (2008) recently defined cloud computing as a paradigm in which information is permanently stored in servers on the Internet and cached temporarily on clients that include desktops, entertainment centers, tablet computers, notebooks, wall computers, handhelds, sensors, monitors, etc.

The cloud is a metaphor for the Internet, based on how it is depicted in computer network diagrams, and is an abstraction for the complex infrastructure it conceals. It is a style of computing in which IT-related capabilities are provided as a service, allowing users to access technology-enabled services from the Internet without knowledge of, expertise with, or control over the technology infrastructure that supports them. Cloud computing is a general concept that incorporates software as a service (SaaS), Web 2.0 and other technology trends, in which the common theme is reliance on the Internet for satisfying the computing needs of the users. Cloud based services can be grouped into three broad categories:

1. Software as a Service (SaaS) application runs entirely in the cloud with typically an internet browser as a client,
2. attached services that present a combination of offline and online application components, and
3. cloud platforms provide cloud-based services for application development and deployment.

Cloud computing is often confused with grid computing, utility computing (Sharma 2008) and autonomic computing (Miller 2008). Many cloud computing deployments are currently powered by grid infrastructures, have autonomic characteristics and are billed like utilities, but cloud computing can be seen as a natural next step. More on driving technologies in AEC can be found in Klinc et al. (2009).

4.2 System design and architecture

The system was designed as an informal distributed information and communication system for communication and collaboration in construction teams addressing the problem of interpersonal and small-group communication. The main reason for choosing the distributed system was the good agreement between the selected design and the topology of the nodes in the communication network.

The main system was designed following classic three-tier client-server architecture (see Figure 3), which enforces the general separation of three parts: client tier (also named presentation layer or, more specifically, user interface), middle tier (business logic) and data storage tier.

The actual (implemented) architecture is slightly modified, introducing a number of smaller tiers on the level of business logic and data storage. The result is a more complex n-tier architecture with loosely coupled components and modules.

4.2.1 Presentation layer

The top-most level of the application is the user interface on the presentation tier of the system. Its main function is to translate tasks and results to something the user can understand. The system is accessible via an internet browser, which handles web pages encoded in (X)HTML language generated by web server on the layer of business logic. Calls between the user interface and web server are both synchronous and asynchronous. For asynchronous calls, Ajax web programming approach is applied.

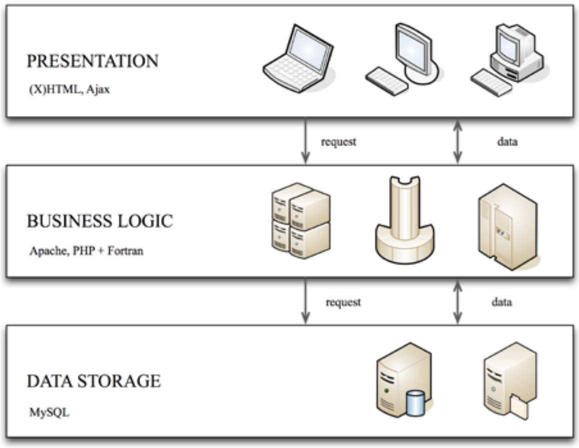

Figure 3: Underlying three-tier architecture of the system

4.2.2 Layer of business logic

The business logic layer is based on the Apache web server, running on Linux (Ubuntu) platform. Requests are handled by scripts, written using PHP programming language, which are processing input parameters, interacting with relational database, parsing results and preparing output (X)HTML pages.

4.2.3 Data storage layer

Data is stored in a relational database. It was decided to use the MySQL relational database on the basis of the excellent connectivity with the PHP programming language and the Apache web server. Another reason is the fact that it is open source software, available without charge. In the test environment, the whole system resides on one server, however the architecture is scalable so the business logic and data layer can be divided to various physical servers if such requirements emerge.

4.3 Implementation

Following the designed n-tier architecture, the developed system prototype presents the central node in the fully connected topology of the used external services. The schematic representation of the system is presented in Figure 4. The system is using a range of external components because it depends on various Web 2.0 services.

The **authentication** is handled with a RPX web service (https://rpxnow.com/) which incorporates authentication from providers like Google, Facebook, Twitter, Yahoo! and Windows Live ID, making it extremely simple for users to sign in and start using our system. It runs on RPX servers in the cloud and is accessed via simple, restful API calls.

For the **communication** among users the Twitter service, a social networking and microblogging service that enables its users to send and read messages, is used. The system is communicating with the Twitter service ecosystem via Twitter API. For the access to the Twitter data, PHP library twitterlibphp was used. Data is accessed and transferred via HTTP and GET requests. The answer is in JSON format which is parsed with various PHP scripts and eventually stored in the database.

Another component enabling **traditional communication** between users is our email component. The system is accessing emails through standard POP3 protocol. That means that the system can handle email messages from any web server allowing POP3 access. The component was developed using pop3class php class. For the email server in our architecture, Google Apps email service was used.

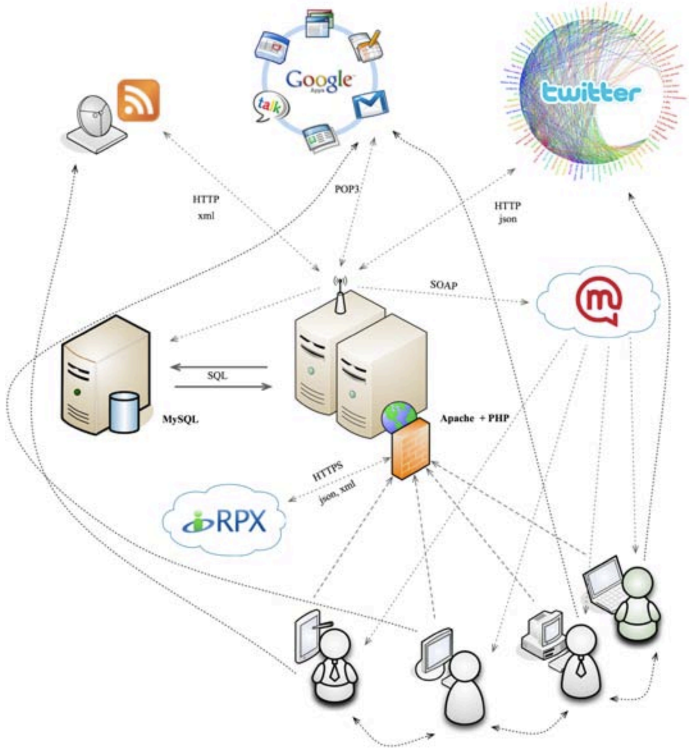

Figure 3: Scheme of the developed distributed information and communication system

To enable connectivity with the existing ICT systems, the RSS component was developed, allowing us to access, parse and store any content (information, data, …) accessible via standard RSS format. In addition, SMS gateway service of the local mobile provider was used, allowing people in the system the communication via SMS messages.

4.4 SWOT analysis of the proposed solution

A SWOT analysis was carried out using findings from the literature and results of the on-line questionnaire sent out to the domain professionals in order to analyze the strengths, weakness, opportunities and threats of the suggested approach. Analysis results are summarized below.

4.4.1 Strengths:

- modular architecture design;
- simplicity;
- low entry cost;
- support for informal communication;
- adaptable to current working practices;
- support for user enthusiasm.

4.4.2 Weaknesses:

- depends on ICT literacy and user enthusiasm;

- depends on external web services;
- no support for structured engineering data;
- informal system.

4.4.3 Opportunities

- fast sharing of data and information from the point of activity;
- additional layer of data storage;
- support for modern consumer devices.

4.4.4 Threats:

- lack of knowledge and enthusiasm of end users;
- no objective methodology for measuring benefits;
- no relationship-specific legal coverage.

5 DISCUSSION

The presented communication system architecture and the developed prototype are oriented towards the successful communication among participants in the construction projects. While the prototype addresses several issues regarding successful communication within construction projects, there are still some unanswered questions regarding the utilization and security of the external services used since the research is still in relatively early phase.

The implementation of the prototype presented in the section 3 is already complete. In the next step, efforts will be oriented towards the evaluation of the proposed architecture and the behavior of the developed prototype in a real construction project. Preliminary tests on a small scale project showed high potential, nevertheless the behavior in an uncontrolled environment of a big-scale project was not tested.

ACKNOWLEDGMENTS

The results presented in this paper are based on work supported by the Slovenian Research Agency. Their support is gratefully acknowledged.

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