Using Voice over IP and a Wireless Network to aid Collaboration in the Construction Industry

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ABSTRACT: This paper looks at how the use of Voice over Internet can benefit the construction industry. The technology has advanced to enable the use of a wireless network allowing a custom wireless network to route communications on a construction site. The network on the construction site can be linked to a corporate network to allow seamless communications of both voice and data between the head quarters of a company and the construction site.
The paper looks at the technologies required to accomplish such a goal and identifies the potential benefits and barriers in the construction industry.

1 INTRODUCTION

Voice over Internet Protocol (VoIP) is a technology that has been under-utilised, and is seeing a resurgence of interest (AT&T, 2004). This interest lies in the advancement of network technology and the lowering costs of network equipment. The VoIP model is being adopted in favour of the traditional digital PBX systems within the office.

The Wireless network is also a new addition to most corporate networks. It allows mobility for the workforce to move around anywhere within the range of the antenna allowing them access to the network. The wireless technology has been proven to allow for greater data transfer rates and is constantly being improved to incorporate Quality of Service (QoS) (IEEE, 2004). What this means is that there is an opportunity to allow voice traffic to run over a wireless network which connects to the main fixed network. Running voice over a wireless setup can give the advantage of offering voice communication to remote workers piggy-backed on an existing IT infratructure, therefore seamlessly allowing them to communicate with the rest of the network as if they are sitting at their desk.

The construction industry is such that projects are sporadic, and run over several months, with different companies coming together to work for a specific goal. Communication between the different parties is crucial to the successful completion of the goal, and the most effective means of communication is the voice. Currently the mobile phone is the tool that is used most frequently when on site, but this can mean very costly communication bills for the company. Utilising a wireless network and tunnelling into their own corporate network, a mobile worker could utilise their wireless device to communicate with the rest of the team, and stakeholders in the project.

This paper will look at the feasibility of setting up such a system; the technology that is available today, and what future technology will help. The benefits will be explored as well as the potential for failure.

2 THE CONSTRUCTION PROJECT

The Construction industry is purely a project-based industry. The projects are worked on by, most often, multi-disciplinary groups. These groups consist of members from different companies, members from the supply chain, and customers, who all have an input into what is required for the completion of the project. Communication across team members is crucial to the success of the project. Increased collaboration between the different team members is often hindered by the fact that they are not all located under one roof. As they belong to different companies, they work in their own offices, which may not even be in the same country. Project methodologies have changed from the original over the fence type of project, where each department worked completely separate from the other, to a more involved project methodology in which all members of the team come together to plan, therefore cutting down the time and costs involved. This method is known as concurrent engineering, and it has stimulated a lot

of interest. Concurrent Engineering embodies methodologies such as multi-disciplinary teams, parallel scheduling of activities and cross-functional problem solving (Anumba et al., 1997). Information Technology plays a crucial role in supporting this collaboration. The use of extranets is ever expanding with companies able to have a common location on the internet to meet and share information and documents. The different members of the project team can collaborate in the design process; discuss topics on a message board and share drawings as well as other crucial documents.

Information sharing specifically on the construction site is also of great importance. The UK construction industry has defects which cost at least £20 billion to repair or rebuild (BRE guidance). Poor communication on the construction site is the cause of some of these defects, with poorly detailed drawings, operatives being given incorrect instruction or technical information not being available. Access to project resources such as team members and project data is increasingly important to cut these losses.

3 COMMUNICATION TECHNOLOGIES ON THE CONSTRUCTION SITE

Different information needs have been identified on the construction site. The research identifies the typical information tasks taking place (De La Garza et al., 1998). Out of the tasks identified, the following were highlighted to have voice as the most important format for information transfer:

- Design and intent clarification
- Contract specification
- Work package information
- Means and methods questions
- Implementation problems

Many different wireless technologies have been tested on the construction site including different infrastructures and communication devices (Bowden, 2002, Meissner et al., 2001, Beyh et al., 2004 and de la Garza et al., 1998). The COSMOS and MICC projects tested various technologies on the construction site. The MICC project identified the DECT (Digital Enhanced Cordless Telecommunications) technology to be suitable for the construction sector due to its reliability. The DECT system, though does have problems with standards, and cannot match the bandwidth of other technologies such as the wireless LAN (Local Area Network).

When identifying the various communication methods available, researchers have identified certain characteristics which should be looked into (Beyh et al., 2004):

- Benefits in terms of the nature of information that need to be transmitted including voice, data, video, web collaboration, etc.
- Access to all members forming the project teams including site workers, gangers, and foremen
- Reliability, availability and quality of service
- Cost of service including network administration, maintenance and upgrade
- Availability of terminals and users' devices such as mobile handsets

Many of these technologies have been reviewed with an emphasis on data communications. Data communications that would occur on the construction site usually require less bandwidth than voice communications and are less demanding on network resources. The remit of this paper is to investigate the wireless LAN as it proves to be of relative simplicity and provides the correct infrastructure for carrying voice and even video. The impact of such a system is highlighted as it could allow access to information and contact with remote experts from a construction site (Miah et al, 1998).

3.1 Wireless networks in construction

The use of a data network on a construction site has gained momentum with the increased use of IT within construction. The move towards a paperless office has found its way onto the construction site, with a move towards a paperless job site

The wireless network has gained increased popularity as it provides the benefits of being connected to a network without the hassle of any wires, making the user mobile. The wireless network works with radio waves, and there currently exist three popular standards produced by the Institute of Electrical and Electronics Engineers (IEEE) which are in use today. The main difference in these three standards is the bandwidth they offer. The IEEE 802.11b was the first to have widespread adoption and offers a bandwidth of 11Mb/s. This has been updated with the IEEE 802.11g standard which manages to reach 54Mb/s at the same frequency of 2.4 GHz. Some vendors have managed to increase this bandwidth utilising their own propriety software. The IEEE 802.11a standard offers the 54Mb/s but at a higher frequency of 5 GHz. This has the advantage of a less crowded airspace providing a much more stable connection.

Figure 1 shows a sketch of three different networks that can be integrated together; the Hybrid network consists of LAN, WAN and 3G (cellular) networks (Xu, K. et al., 2005). The WLAN requires radio base stations (network access points) that manage the sending of data to and from the wireless clients. All these networks can be integrated, as they

all utilise the common TCP/IP communication protocol.

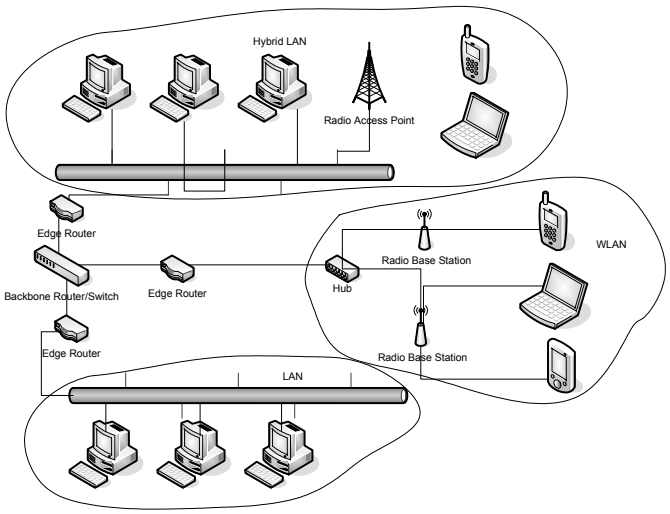

Figure 1 A sketch of integrated networks (K. Xu et al., 2005)

Wireless networks have been tested on construction sites primarily for data exchange. One such test ran with tablet PC's on a construction site connected as thin clients via a wireless network (Ward et al. 2004). The wireless network on a construction site can be set up relatively easily, and is scalable to cover large distances. The network can be set up to mimic the traditional cellular network, with access points marking the centre of each cell. This way, the network could be enlarged with an increased number of access points being 'daisy-chained' together as shown in figure 2 (De la Garza et al., 1998, Ward et al., 2004). Installing a wireless network on a construction site is very different to a traditional office. The outdoor environment is a great factor, with the effects of weather and dust which mean that the wireless technology should be rugged enough to cater for that.

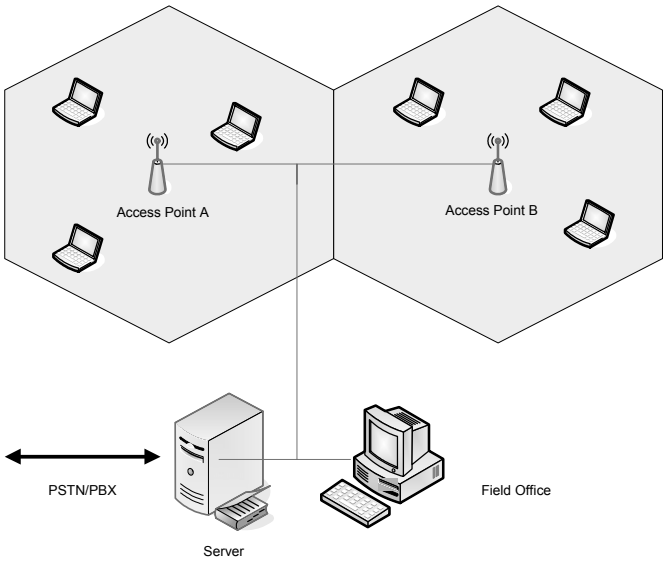

Figure 2 A WLAN network with access points (De la Garza et al., 1998)

With tests of wireless networks on construction sites, the researchers have used standard wireless equipment in rugged containers to keep them secure in the construction environment. Manufacturers of wireless equipment have developed systems specifically for the construction industry that are capable of withstanding the conditions on site. Theses systems can be installed and daisy-chained like ordinary wireless systems which have been identified. Figure 3 shows an example of such equipment. This specific device works with the 802.11b standard with a maximum throughout of 22Mb/s and a claimed range of up to 10 miles (CII).

Figure 3 Orinoco Outdoor Router

Issues identified with the wireless setup included obtaining power for the wireless access point. This was resolved by connecting the access point to a rig's power supply, therefore bypassing the need for a battery (Ward et al., 2004). Device battery life has been identified as a problem with measures to reduce battery consumption including placing the device on standby.

The placement of the wireless access points can also provide some difficulty on a construction site. An American construction company, Webcor, installed a wireless access point on the crane hovering over the construction site. This wireless network gave engineers and crew's access to blueprints and the ability to easily coordinate projects (Shim, 2004).

4 VOIP IN CONSTRUCTION

Voice over the Internet Protocol is the process of sending voice traffic over the data network, therefore combining the data and telecoms network into one. Industries around the world have seen an increased adoption rate of VoIP systems. They represent cost savings with a greater feature set. Construction firms have also begun implementing the VoIP solutions within their offices. One such company is Facchina Construction who deployed an IP-PBX system. With the installation of VoIP within their offices, companies such as Facchina Construction are identifying the construction site as further uses of the technology (Hagendorf Follet, 2004). The costs of setting up both a data line and telecoms line is reduced with the removal of the telephone

line. In addition on an IP based system, a user would carry the same number from site to site, therefore simplifying the communications process.

Transmitting voice over a wireless network, although a very new technology, has had success in the indoor market. Companies such as Vocera are supplying the hospitals in America allowing for hands free instant communication amongst hospital staff. The Vocera network utilises the 802.11b standard for the wireless network. This setup is unique as the company has produced specific communication devices which allow for one touch calling (Vocera, 2004). The Vocera solution also encompasses voice recognition. This is necessary for the one touch dialling, whereby the user asks for a particular person or job role, the server then interprets this and connects to the resulting person. This technology could be applied in the construction field, although the one touch dialling may prove to be difficult to work with on a noisy construction site. Figure 4 shows the network structure with the Vocera solution. The diagram highlights the ability to link the voice solution with other applications, as all data is run over the same network using common standards. This is the case with any VoIP solution. The power of the VoIP solution is therefore enhanced with the ability to converge it with other applications to enhance collaboration.

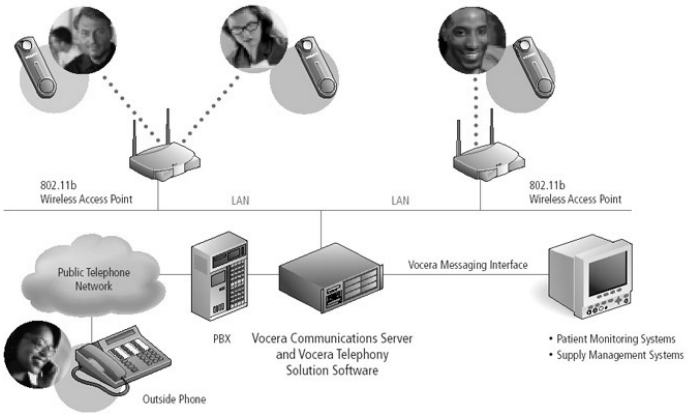

Figure 4 Vocera Networks Solution (Vocera, 2004)

5 ENABLERS AND BARRIERS

Many issues pertaining to the use of these new technologies on the construction site have been investigated by various authors. There have been frameworks identified to enable the construction industry identity their readiness to accept this technology. One such framework is the IPTCS framework (Beyh et al., 2004). The IPTCS framework suggests a methodology to help the increase in adoption of VoIP in construction. These include

- Users' involvement and education
- Existing telecommunication means assessment
- IP Telephony technology assessment and benchmarking, and
- Technological alternatives

Tackling the issues identified in the framework would prove to reduce the barriers from within the construction industry in adopting this and any other new technology.

The main advantage of implementing a VoIP solution in the construction site is that of cost savings. The WLAN setup is unlike others which have been reviewed as it does not require any on going fees (De La Garza et al., 1998, Beyh et al., 2004). The WLAN is set up and managed by the client, not a third party operator. The level of control can be considered as both an advantage and also a barrier to the WLAN. The level of control is a benefit as the network can be tailored from site to site, although this tailoring requires skilled personnel which would be an extra cost on the project. The ability to move the setup from one site to the next provides cost advantages for the industry. A large amount of investment on the technology is not required, as the same equipment can be used from one project to another.

Research investigating the time taken to communicate information on a construction site highlights the cost savings achieved in terms of productivity and time from switching to a wireless network compared with traditional communication methods (De La Garza et al., 1998). The research highlights the benefits of the WLAN for data transfer, which alone would argue a successful case for the implementation. Using this new infrastructure for voice would therefore not add an extra cost, as the infrastructure setup for data transmission would be used.

In terms of barriers that exist in the construction industry, research has shown four categories, which include technical, financial, cultural and organisational (Beyh et al., 2004). These barriers coincide with barriers that would exist in many other industries, but are exacerbated by the lack of the construction sector to adopt innovation, the large scale and scope of the construction industry, and the difficulty of introducing technology into areas which are not the optimum conditions for its use.

6 VOWIFI TECHNOLOGY CONSIDERATIONS

6.1 Reliability

The wireless network initially started off offering low bandwidth rates, but as technology has progressed, the bandwidth offered has increased to those comparable to the wired LAN. Research into the use of the wireless network has shown that although the wireless network is capable of handling the data rates, packet loss and congestion can occur,

causing delays in the information being sent (Barberis, A. et al., Xu, K. et al., 2005). This delay in sending information could lead to extensive delays in a voice call over the network. With the total latency of a voice call recommended to not exceed 150 milliseconds by the International Telecommunications Union, this could lead to a very poor service for a user.

The method to minimise the disruption is to effectively manage the loss. This issue was addressed on the wired networks with the development of new algorithms to pass data. These new algorithms would provide more efficient ways to signal a problem and correct it. Solutions such as variable vocoding depending on network conditions, Adaptive VoIP (AVoIP) have been proposed to manage the traffic on the network (Berberis, A. et al., 2001). Other solutions attempt to manage the amount of data on the network by selectively sending data. This solution would only send data when a user spoke, or the volume of the sound exceeded a certain level.

Packet loss on a wireless network can occur for a number of different reasons above and beyond the traditional reason of congestion. The wireless network has to cope with hand-offs, fading channels, congestion and transient random errors to name a few (Tsaoussidis, V. et al., 2002). The management of these different issues calls for a method of identifying the actual problem, rather than assuming it is one type and attempting to apply a solution. These issues have been addressed and novel solutions which identify and manage the problems have been introduced. The only drawback is that the different manufacturers are building their own solutions in their own hardware as no set standard in dealing with these issues exist. This poses a problem for the consumer as the choice of hardware is limited as different hardware would be utilising different methodologies in handling errors, deeming these error handling features useless. Standards are to be released attempting to resolve many of these issues which, when included, would make the task of choosing equipment a less daunting one.

6.1.1 Quality of Service

Quality of Service is a general term given to a host of different methods to achieve this aim. The key aim is to keep the network reliable. For each issue that arises, different tactics can be used to solve the problem. Some problems require use of the bits that are sent over the network, and the fact that these bits are being used for error checking rather than actual data can have an adverse effect.

With the use of Quality of Service, which uses more bandwidth to make sure that the packets reach their destination, the reliability of VoIP is comparable to the traditional PBX system. Packet labelling through Multi-Protocol Label Switching allows the network to identify data packets from voice and video packets, therefore granting higher priority to these packets. (AT&T, 2004) This will guarantee the throughput of the voice traffic on the network making sure there are no interruptions of the voice call.

The wireless network IEEE 802.11e standard is set to introduce QoS as one of its standards. Many vendors who supply wireless technology for VoIP have implemented their own solutions, but as soon as the IEEE 802.11e standard is ratified, this will be implemented on all of the available hardware.

6.1.1.1 TCP Schemes

Standard TCP does not contain any sophisticated congestion control system. As highlighted earlier, this can cause problems on a wireless network, as all packet losses cannot be associated to one problem, and the problem is usually not related to the types of problems occurring on the wired network. By not identifying the problem the most effective algorithm to correct it cannot be applied.

Many different TCP schemes exist that attempt to manage packet loss situations on the networks. Newer schemes such as TCP New Jersey, one of the new proposals, have been shown to improve the level of packet loss utilising a number of methods (K. Xu et al., 2005). The important point to note is that the wireless network and networking technology in general has not been stagnant. All these issues which arise from utilising the wireless network for more than just data are having an impact, and resolutions are being created.

6.1.1.2 Roaming

When a user moves from one access point to another, it has to re-authenticate itself to the network. This can take well over 100 milliseconds, exceeding the recommended levels immediately (Greene, Tim. 2004). This issue has been looked at by many of the vendors and is also being looked at by the IEEE standards working group. The different vendors have created bespoke solutions for the problem, each one managing to work well, but limiting the choice for the customer to choose different setups. The different solutions vary from a centralised authentication server to a pre-authentication method on all access points when a user is authenticated on one (Cohen, B. 2004). The IEEE 802.11r working group is working on a standard method to solve this problem, but this may take some time. For now, one of the available solutions would have to be employed to create a successful voice over wireless setup.

6.1.1.3 SIP

The only way for different systems to recognise the traffic as voice traffic is for the industry to utilise

standards. The standard that is being adopted by most of the VoIP industry is called Session Initiation Protocol (SIP). SIP is a signalling protocol designed to establish sessions on the internet for multimedia and voice communication. The use of standards gives the benefit to the consumer to purchase whatever equipment he/she desires and all should work together seamlessly. The lack of the available standards causes many problems and means that more hardware will have to be replaced to adopt the new standard. There may be issues with some networks, in trying to get the voice traffic past a firewall, and there may also be problems with some routes that utilise Network Address Translation (NAT). This is because with NAT IP addresses are masked, and different ports utilised, therefore making it difficult for the voice traffic to reach its destination (Higgins, Tim. 2004).

Some of the key advantages of SIP are as follows (Melinat & Kelly, 2002):

- SIP is an Internet Protocol, it can facilitate the integration of communication applications with other web-based applications.
- SIP does not rely on any type of network.
- Using SIP, new applications can be easily added without the need to rely on one specific vendor.

6.1.2 *Wireless Device*

The wireless device that is used for placing this call would for the time it is connected and making this call be using a lot of battery life. Specific Wi-Fi phones have been created that have an improved battery life, but power usage becomes more complex if a PDA is used, as the device is not used specifically for voice calls, but other applications, which use up power. The solution to this is improved battery technology, lower consumption chips, and also the network technology. A Wi-Fi device need not always be connected to the wireless network, as the user may not require the use of the network at all times, therefore switches with power management facilities have been produced by vendors to manage this. Specific firmware is required on the client device to allow for connections to be made, but it effectively reduces the power used on the client device (Griffith, E. 2004).

6.2 *Security*

Security is a fundamental issue when dealing with VoIP. This issue is of greater significance with the wireless network. The wireless network is inherently insecure as anyone with a wireless network card can attempt to connect to the network when they are in range.

Existing wireless devices may only utilise the Wireless Encryption Protocol (WEP) along with MAC address authentication. There is still a security vulnerability though, as static WEP security is weak, and if a MAC address is cloned, a new device can connect on the network and cause disruption (Griffith, E. 2004).

These issues are constantly being improved upon, with WPA (Wi-Fi Protected Access) and the newer WPA2 (Wi-Fi Protected Access 2) standards being incorporated into the IEEE 802.11i standard offering a greater level of security. The WPA2 standard is relatively new and is being incorporated on the newer access points which are being released.

Security of the voice packets being relayed from sender to receiver can also be achieved through extra encryption algorithms. This process can be achieved fundamentally because the data is sent as packets on the network which can be manipulated in the same way as traditional data. Therefore when the voice data has gone through the vocoding process, it can run through further encryption algorithms to prevent unwanted tapping of the voice communication. Of course, the receiver would require a decryption algorithm to decode the voice packets.

6.3 *Specialist Hardware*

In order to utilise a wireless network for voice calling, the specific hardware to establish a wireless connection is required. Different types of hardware may be required to achieve the set of reliability and security needed for the call to be achieved with acceptable quality. There are two options in terms of device hardware that can be taken. The first uses a generic solution, with a wireless enabled device such as a PDA or Wi-fi enabled laptop can be used, the second is using specifically built wireless VoIP handsets, such as the Vocera solution identified earlier.

6.3.1 *PDA*

The Personal Digital Assistant (PDA) has been introduced into the construction industry as a data device. Its speed, memory capacity, communication possibilities, reliability, small size and long power independence, as well as its level of hardware and software standardisation, gives the PDA a powerful potential in the information chain of a construction project (Cus-Babic et al., 2000).

The PDA connected to the wireless network can work as a ‘soft phone’. All the functions that would take place on a desktop VoIP phone would have to be programmed in software for the PDA to manage before it passes on the data. Companies such as Skype have already produced software for the PDA, but that utilises the internet to establish the call via their gateway.

The advantage of using a PDA, or generic wi-fi device is that the one device can be used for much more than voice. All communications can be unified

through one device. The PDA is a versatile piece of equipment, with selected add-ons it can be used as a video recorder, as a bar-code scanner and as a diary. This presents a powerful opportunity for a mobile or field worker, as no longer would they have to use several devices, and carry them around; the one device will suffice.

6.3.2 VoWLAN Phone

Special Wi-Fi handsets have entered the market, which have all the hardware necessary to process a call in-built. The advantage of this sort of phone is with the hardware. The hardware would have been specifically designed for the task of establishing a voice call. The PDA software would attempt to mimic what the hardware would be doing, but having specific hardware results in a much more powerful device.

7 CONCLUSION

This paper identified that voice communication is essential for all the industries to operate and work effectively. There are many tools around which aid collaboration, such as the extranet and project discussion groups, but voice communication can never be replaced. What can be done, however, is that the voice communication can be improved to allow for reduced costs and increased collaboration.

VoIP was identified as a technology that could aid the construction industry which relies heavily on communication with different members of a team, and the different members of the supply chain. The reduction in cost is reason enough to move to VoIP, but there are a great many other advantages that can be realised with its implementation. There can be an increased capacity to collaborate as the different modes of communication can be converged in one location, giving rise to greater productivity.

VoWLAN was investigated with a view to be utilised on a construction site. The very nature of a wireless network lends itself to a construction site as no wiring is required, and one can be setup relatively quickly. The PDA can be utilised to act as a 'soft phone' allowing for communication of data and voice on a single device. Connecting a mobile device such as the PDA would give the user access to project information as well as project members whilst on the construction site. The PDA can be used as a multi-function device as it is now powerful enough to carry out most of the functions of a laptop.

The varying issues with regards to implementing a VoIP solution on a LAN and WLAN were investigated, with a view to look for solutions that have been implemented. Issues regarding security are becoming less of an issue as new standards become available which introduce higher security levels. Issues of service quality were investigated, and again these issues are being tackled with the standards bodies. VoIP is not 100% perfect, and there is still room for improvements, but despite the complexities in introducing such a system, most companies have found the move to be beneficial.

The VoWLAN setup can be effectively utilised on a construction site, or even within an office to allow for communication on the move or in remote locations for a relatively minimum charge. The VoWLAN has been implemented in many other industries, but not tried in construction, and there is no reason why it shouldn't. In fact it is something that would give great benefit to the construction industry. What remains is for the construction industry to adopt it and find more applications that can merge with the voice communication to further enhance the collaboration process.

8 FURTHER RESEARCH

Further investigations into the various technologies would prove beneficial to the construction industry. Identifying the feature sets which are most suitable for the industry and also identifying areas where VoIP can be merged with other applications to further enhance the collaboration process.

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