www.itcon.org - Journal of Information Technology in Construction - ISSN 1874-4753

FUTURISTIC CONSTRUCTION COMMUNICATION INFRASTRUCTURES: SECURE AND SAFE WITH NO WIRES

PUBLISHED: August 2009 at http://www.itcon.org/2009/34

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SUMMARY: *Wireless technology is already available and used in several industrial sectors. In the next few years it is envisaged that the technology will mature and converge with other technologies providing the ability to communicate and exchange data and information easily and effectively anytime, anywhere, and in any place. Alongside this, security technology will grow and mature providing a safe information technology (IT) networked environment. Where these two technologies combine, they will provide major benefits for the construction industry, particularly in the design, construction and operational stages of new build projects. This paper will explore the positive impacts that can be achieved from a secure and wireless IT infrastructure. This will be carried out through an in-depth analysis and investigation of current and future wireless and security technologies. The paper will also explore their impact on the construction industry through a series of scenarios with practicing professionals. This will provide the opportunity to demonstrate practical problems in day-to-day communications and how the technology can provide appropriate solutions. The foreseen industrial impact will be to promote wireless communications as a safe and secure medium for construction organisations. This will also provide the opportunity for enhanced collaborative working and information sharing throughout the supply chain and the various construction processes. Additionally, this will also help promote confidence in the use of the technology so that wireless communication systems become an integral part of work operations in the future.*

KEYWORDS: *Wireless networks, IT Security, Communication*

REFERENCE: *Strachan R, Stephenson P (2009) Futuristic construction communication infrastructures: secure and safe with no wires, Journal of Information Technology in Construction (ITcon), Vol. 14, Special Issue Next Generation Construction IT: Technology Foresight, Future Studies, Roadmapping, and Scenario Planning, pg. 526-539, http://www.itcon.org/2009/34*

1. INTRODUCTION

While advances have already been achieved concerning improved communication within the construction sector, the expanding complexity of construction projects has resulted in increased amounts and types of information to be communicated throughout the construction process (Peansupap and Walker, 2006a, Wong, 2007). However, despite the technological advancements made within construction, (Acar, et al 2005, Anumba et al, 2006, Anumba, 2008, Sze-wing et al, 2008) problems often persist concerning the lack of timely and accurate communications during construction processes, and their integration with the supply chain and project stakeholders (Peansupap and Walker, 2006, Xuan and Yuanzhang, 2007).

Coupled with the requirements of communication is also the reluctance within the construction industry to embrace the technology to solve many of the perceived problems (Thompson, 2005). This relates to construction organisations and their access to the required expertise, the implementation and operation of communication networks, and associated costs (Williams and Williams, 2007). Additionally, there is the concern of untimely communication technology breakdowns at critical stages of projects, and the every increasing fear of security and intrusions to data networks. The construction industry produces products which are essentially large, diverse, and geographically dispersed, both nationally and internationally. It is therefore essential that efficient communications systems become an integral part of construction organisations' IT infrastructures (Kirisci et al, 2004).

2. COMMUNICATIONS IN CONSTRUCTION

Efficient communications in the construction sector has become of increasing importance owing to the complexity of the data and information transfer needed from inception to the completion of projects (Wu and Yao, 2008). An individual project itself has substantial information constantly passing from company offices to site, and also to the client and professional advisors, other stakeholders and participants in the supply chain (Baxevanaki, et al 2001, Adriaanse and Voordijk, 2005). Moreover, this complexity of data traffic and its transfer increases in magnitude as companies are invariably carrying out projects concurrently, and for some organisations, this occurs in both national and international markets. The volume and complexity of data and information communications are therefore vast.

While the technology is available to support communications, many construction organisations adopt an ad-hoc approach to its use. By tradition, the industry is very practical in terms of construction, and hence both formal and informal communications are both important forms in communication processes (Dainty, et al 2006). While information in the form of design details, contractual arrangements, variations, costs and value are formally documented and communicated to relevant parties, equally important are the communications of mobile workers and the instructions communicated to the point of production where time and progress are paramount to ensure planned project completion (Bowden and Thorpe, 2002, Shohet and Frydman, 2003, Won-suk and Skibniewski, 2008). Technology use should therefore, provide for efficient communications at all levels of the communication process in order to achieve the concept of any place, any time, anywhere information (Siddiqi et al, 2007, Yuan and Kamara, 2008).

3. EMERGING COMMUNICATION TECHNOLOGIES & THEIR SECURITY

To be effective it is essential that the construction industry communicates information electronically (Bowden, et al 2006, Rowlinson and Croler, 2006). There are now a wide range of communication technologies to support this exchange, and over the next few years it will become increasingly easier to do this without wires (Gajendran and Brewer, 2007, Chen and Kamara, 2008). Alongside this, developments in the reliability and security of these systems will ensure communication can happen safely and effectively.

3.1 Communication technologies

Many homes now have wireless routers enabling Internet access from a range of devices including laptops, wireless enabled PCs, mobile phones and games devices such as PlayStation Portable (PSP) (Doherty, 2002, Warren, et al 2008). One type of wireless communication now readily available is known as 'wi-fi'. It is based on the IEEE 802.11 set of standards (IEEE, 2008) and allows wireless communication between an access point (wireless router) and a number of devices over a distance of 50 – 200m. It is also being used increasingly in the workplace to provide wi-fi access across an organisation's site. In recent years, the cost of wi-fi products has fallen and although still slightly more expensive than the wired equivalent, cost has become less of an issue. However, performance can still be an issue especially when used for transferring large volumes of data such as those associated with multimedia information and when there are a large number of users. There are methods to alleviate the performance issues but these usually involve installing multiple devices for which there is a cost implication.

Wi-fi is just one wireless technology. It sits in the middle of the spectrum of wireless technologies. To one side there are other wireless technologies that cover shorter distances such as Bluetooth, Zigbee and Radio Frequency Identification (RFID). On the other side covering greater distances are technologies such as WiMAX, Satellite, Free

Space Optics (FSO) and 3G. Fig 1 illustrates the transmission range and data transfer rate for some of these current wireless technologies.

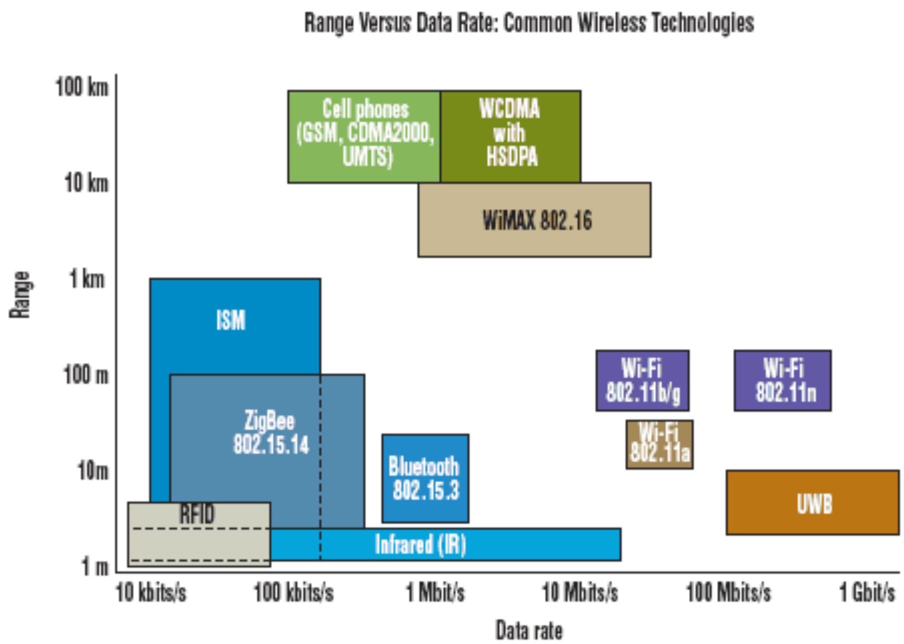

FIG 1: Range and data rate of wireless technologies (Source: (Electronic Design, 2008))

At the lower rate of transmission and shorter distance are three wireless technologies that are of particular interest to the construction industry:

- Bluetooth: a short range wireless technology available now on many devices ranging from mobile phones to monitoring devices, PCs and headphones. This technology allows small amounts of data to be exchanged relatively easily over short distances (<10m) and between multiple devices. There is no need for a central controller (Tutorial Reports, 2008);

- Zigbee: this is a short range wireless technology for stabling a Wireless Personal Area Network (WPAN) between computers and related devices. Based on specifications from the IEEE 802.15 Working Group Zigbee is designed for remote controls and sensors, devices that have low data rates, low power consumption but long battery life. Zigbee is aimed at the 'intelligent' home market providing an enhanced wireless technology eliminating the need for line of sight between the remote and the device it operates e.g. TV and TV remote (De Nardis and Di Benedetto, 2007).

Radio Frequency Identification (RFID): dubbed the intelligent replacement for the barcode, RFID allows automatic and unique identification of key components, devices, people through the use of a small wireless tag. These tags can range from a long life 'dumb' tag that only transmits an id to a shorter life but more intelligent tag capable of receiving information as well as transmitting it. The tags can be automatically recognised by hand held devices or larger devices situated on entry points to and from a particular site e.g. on doors, gates, and the resulting id stored and analysed in software as required (Glover and Bhatt, 2006).

For longer distance communication there are three main options for wireless communication – satellite, mobile cellular technology, and more recently WiMAX. Satellite communication has been in existence for several years, and can provide world wide coverage but can be very costly to run and can also suffer from performance problems. Mobile cellular technology has evolved in recent years with many areas now providing third generation (3G) technology. 3G technology provides faster access and is designed to support data as well as voice applications.

WiMAX is based on the IEEE 802.16 wireless standards and is intended to support long distance wireless communication (5 – 30 miles) at high speed. It is already being rolled out in a number of areas across the globe. A further wireless technology often quoted is 4G (Fourth Generation). This form of broadband mobile communications is still in the design stage but is expected to provide high speed multimedia communication facilities to replace 3G services and is likely to utilise both WiMAX and wi-fi as part of the underlying technologies to support this.

A challenge to the construction industry is how to exploit these technologies for competitive advantage. Each technology has its own strengths and weaknesses and thus its effectiveness will vary according to the application and environment in which it is being deployed. There are a number of key criteria which can be used to characterise these technologies. However it should be noted that there are often tradeoffs between these different criteria. For example, a wi-fi network could have performance problems due to the number of users. Installing more wireless access points or antennae could help alleviate these problems but would have a cost implication. A further example is that a wireless network can be secured but this requires extra processing of the information and can slow the network down leading to performance issues and sometimes scalability issues.

The key criteria can be defined as follows:

- Cost (both set up and ongoing costs);
- Performance including throughput rates;
- Reliability;
- Security;
- Scalability;
- Coverage;
- Mobility;
- Ease of Installation & Management;
- Application Services and Use.

3.2 Securing your communication

Security remains a high area of concern for wireless communications. There have been well publicised cases of ‘eavesdropping’ and ‘hacking’ into wireless systems. There are, however, security measures that can be put in place to reduce these threats and this forms the discussion for the following section.

Easttom (2006) identifies three important questions:

1. How is information safeguarded?
2. What are the vulnerabilities to these systems?
3. What steps are taken to ensure that these systems and data are safe?

These questions are still applicable whether the underlying communication system is wired or wireless. It is important to be realistic in any assessment of the threat to the system. Threats can be broadly classified into one of three areas:

- Malware. This is malicious software that can attack a system. Examples include viruses, Trojan horses, keyloggers and spyware. Preventative measures include antivirus software;
- Intrusions. This includes any attack on the system to gain unauthorized access including hacking, and social engineering;
- Denial of Service (DoS). This type of threat is designed to prevent access to the system and on wireless systems, can include blocking the airwaves with a jamming signal. Another example is flooding the targeted system with false requests, thus preventing legitimate requests getting through.

Any assessment of the system needs to examine vulnerabilities in the system. Automatic preventative measures can be put in place such as antivirus software, encryption software, authorisation software but education of those using the system is also essential. A number of recent and well publicised loss of ‘private’ information has been through a lack of basic security awareness amongst employees rather than due to breaches in the online security system.

In terms of security there are three basic elements: **encryption, authentication** and **authorization**. Encryption is securing data and information so that even if someone gains access to it, they cannot understand it. Authentication means ensuring that the user/system/device is who they say they are and authorization ensures that the user/system/device has access to the areas they should have access to and no more or no less. If these are all addressed, the system should be secure. Mechanisms are now available for all of these elements on a wireless system but as stated earlier, there are often tradeoffs between security and other criteria thus it requires a certain level of judgement to assess the severity of any threats and compare this to the cost and impact of any resulting security breach and the time, cost and effort involved to secure the system fully. For example, setting up a temporary ad hoc mobile network to exchange information and data for an on-site meeting may require very few security measures whilst a long term wireless network set up to support exchange of financial information, costings and building specifications on-site may require a much more rigid set of security measures.

4. CONSTRUCTION ORGANISATION SCENARIOS

In order to assess currently technology use within construction, data on construction organisations' communications and technologies were collected from two construction companies working within the United Kingdom. Data related to operations at company level and project level. Two construction projects currently being constructed, one by each company, were used as part of the scenarios. Interviews were held with company personnel at various levels of management which included IT directors, IT department staff, and at project level, project managers, site managers, planners and surveyors. This provided the opportunity to obtain information on technology use and its application from head office to site level. Company and project scenarios are detailed below.

4.1 Scenario 1

The first scenario was based on an organisation that carries out general building works. The company also specialises in housing which includes new build in addition to refurbishment, repair and maintenance. The turnover of the company is in excess of 150 million GBP per annum and it employs over 1000 staff, both technical and administrative. The organisation is sufficiently large to have its own IT department with IT staff supporting networks, software usage and maintenance of bespoke company software. The main server is located at head office utilising an ADSL and operating MPLS to support TCP/IP and voice. The network structure consists of LANs and MANs sub-nested and interconnected within a WAN infrastructure. The use of firewalls and filters with propriety virus software at desk top level provides the required security at all levels of operations. Software use compliments the type of work the company carries out and includes kitchen design software, CAD, Causeway and SharePoint, project management applications, and general applications software.

To support the supply chain, third party software is used to support day to day ordering of resources. A number of bespoke systems are also in operation developed by the IT department to suit specific business operations within the company. No security problems or intrusions have been experience to date, or at least, none the company are aware of, and this relates to the company’s entire operations including over 200 sites connected to the network infrastructure.

The main communication problems experienced in the company relate to efficiency of communications, the duplication of work items and details, and data storage by construction personnel. Information flow is also seen, at times, as problematic, particularly down the chain of command from senior management down to contract management, site management, surveyors and general foreman working on sites. The company makes use of collaborative software with its back end functionality, but improvements need to be made to this to gain the required benefits.

The company is continually looking for greater efficiencies in order to become more lean in its operations. The company also realises that it is not at the cutting edge of technology use, but is always looking at IT developments to see if any products will provided a competitive edge. Strategic decisions in relation to this are dealt with by the IT director. The use of wireless technologies is not used extensively with the organisation and not at site level. The company do make use of 3G and smart telephones for site staff to browse and view e-mail and web mail.

The construction project considered as part of the scenario was a typical sheltered accommodation development for a housing association, consisting of flats, community area and restaurant. The project was valued at over 5 million GBP with a construction period of 40 weeks. The appointed professionals to the project included an architect, professional quantity surveyor and consulting engineers. The company, as main contractors, employed their own supervisory staff with all employed trades being domestic and specialist sub-contractors. Wired PCs and laptops were used on site with installed e-mail, CAD and project management software. Communications on variations to design and constructions details were requested from the architect via e-mail. This was also the case with communications and instructions to sub-contractors and suppliers. Immediate required information and speedy communications in relation to the procurement of resources and information was carried out by the use of DECT telephones.

4.2 Scenario 2

The construction organisation in the second scenario is a major building contractor operating in both public and private sectors of the industry. The company carries out general construction work in addition to civil engineering works. The company has an annual turnover of some 200 million GBP and employs over 800 staff. The company has an IT department with an established IT strategy and structure together with annual IT budget. The company has an established WAN network installation at head office linking other regional offices and utilises both intranets and extranets. The company has several on-going multi-million pound projects with wired connections to site. The larger projects have their own site server with networked computers in the site offices, with a wired link to head office. The company have a comprehensive intranet for employee access and the supply chain is serviced by suppliers and sub-contractors who are, in the main, preferred partners. The company operates a tight system in terms of security with firewalls, and a hierarchy of permitted entry with protection codes and authorisation access.

The project considered as part of the scenario was a multi-storey block of luxury flats and offices with parking facilities and retail outlets at ground level, with a value of over 15 million GBP. The procurement of materials and components was dealt with by the procurement department from head office. This was a complex project, and owing to site restrictions involved just-in-time delivery of materials and off-site fabrications. Many of the suppliers were geographically dispersed and many of the materials and components were imported from the EU. IT facilities and communications on site were though networked PCs and laptop computers link to the site server. Communications and construction-related software were available to site staff through the site network for project management and cost management purposes. Wireless communications on site were through staff PDAs which were used for recording progress information and general construction information. PDAs were connected to site computers for downloading and communicating to head office. PDAs were also used to receive and send e-mail while out on site, and particularly when staff were located at the top of the multi-storey structure inspecting and supervising operations. The project manager indicated that IT facilities and communications on the project were operating fine with the exception of the volume of e-mail messages received by site staff. There were no current plans to install wireless solutions to their IT infrastructure. Fig. 2 reflects the infrastructure used by the two organisations.

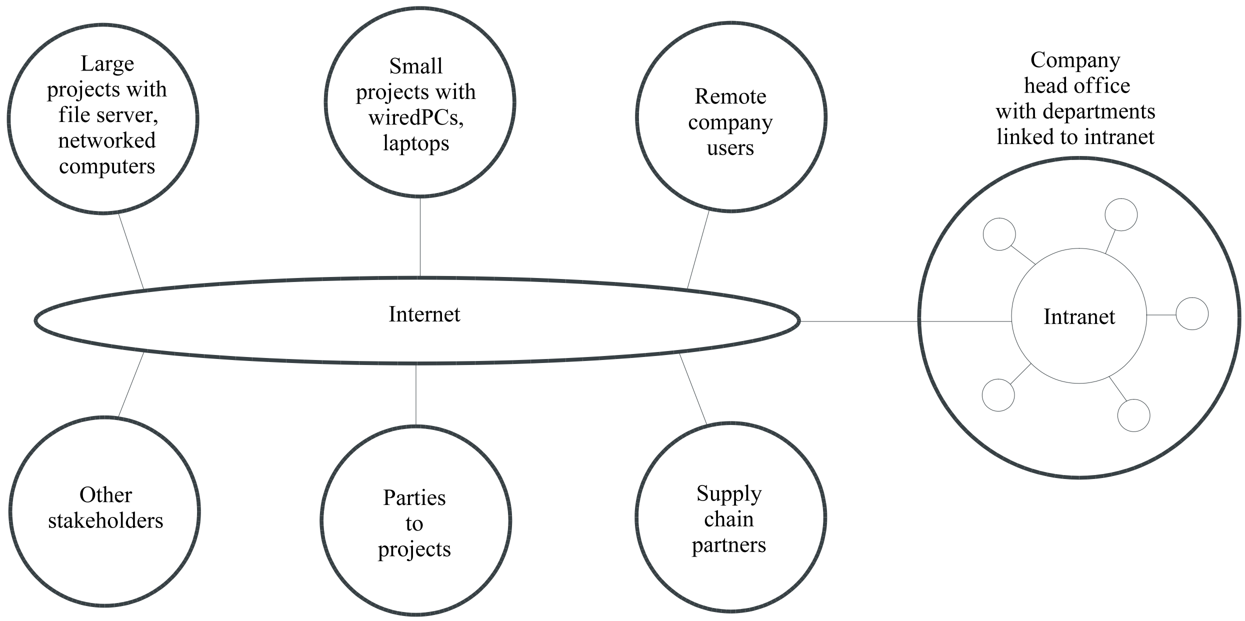

FIG 2: Typical wired communications infrastructure of medium-sized construction organisations

5. BARRIERS TO WIRELESS COMMUNICATIONS

Information was also obtained from the two scenarios on the use of wireless communications. The major barrier to wireless solutions was identified as authentication on sites. Companies have not found a solution to this in terms of wireless access, particularly where users are not able to obtain a valid digital certificate. Additionally, many problems have been experienced with digital phones and wireless signals, particularly in relation to interference. The other concern was ultimately, speed, or the lack of it, and this was seen as problematic.

One of the main potential applications for wireless technologies was seen to be during meetings on projects, particularly when staff move from one office to another in a sister company within the group. It was considered ideal to be able to take a laptop and hot desk and connect up to the other company wirelessly.

Security was not seen as a problem, even with a wireless installation. The main criteria influencing the adoption of a wireless solutions was seen as mobility, and not because potential solutions are cheap and fast. Mobility in an open office environment would ideally facilitate hot desking and connectivity and is viewed as a major reason for adopting a wireless solution. It may be useful across sites, but it would depend on the nature of the site. It is not a case of one size fits all. A wireless solution may work well on one site but not on another. One IT manager suggested, "If a building or site can be wired, why would you use wireless? Speed and reliability are grey areas and a wireless solution may not be worth the expense". Cost and speed versus security is always an issue, and it is a matter of getting the balance right.

On the issue of implementation it would not be appropriate to install an unsecured wireless network. Simple wireless security such as WEP is fine for a temporary wireless solution but in large corporate organisations it is not adequate. There is a need for robust authentication including digital certificates and this has related cost implications. On the issue of trading cost against performance or security, it was considered in the IT field that "you pay for what you get" and that costs would increase in order to get a more secure and faster system.

With regard to the initial investment, it depends on what a company is trying to achieve. It is recognised that in order to deploy a new technology, it requires a feasibility study, development and roll-out, plus the accompanying resources and so there are always time and cost implications. Admittedly, a mobile solution could be re-used and possibly expanded.

With regard to a solution becoming out-of-date, much will depend on requirements. Construction organisations tend not to be high flyers or at the cutting edge of technology. Current wired installations are a proven solution. They may become out-of-date, but they work. An out of the box solution is generally satisfactory for what construction organisations do. Systems have to be replaced or written off eventually and much depends on cost. There is a need to look at cost in terms of turnover before making a decision on investment or replacement.

There is also the situation within the construction sector where organisations do not have a current ICT infrastructure in place, but may be in the process of considering technological use to support current business operations. In these instances it is debatable whether such organisations would move, initially, to a wired solution or opt directly for a wireless implementation.

The structure of the construction industry is large and diverse with its most substantial sector represented by small and medium-sized organisations (SMEs). Many of these organisations are engaged in small scale developments or repair and maintenance work where the majority of those employed are directly involved in work operations. The very nature of such work may not immediately highlight the use of ICT as a priority, but the small scale contracts of short duration coupled with the constant requirements of mobility to maintain work continuity would suggest that mobile and wireless solutions would be ideally suited to their needs. It is this sector of the industry where wireless solutions would prove beneficial.

However, as with most SMEs operating at this level, other barriers may prove inhibitive. The fear of ICT may be such that they remain devoted to mobile solutions only. The lack of knowledge and expertise within their organisation may also feature, as would the need for training of staff, time to implementation, cost and the necessity of a speedy return on investment (ROI). Thus the rate of adoption by these organisations will depend much on advances in technological developments to provide ease of use, speed, security and the identifiable benefits linked to improved productivity and service to clients. If such sureties could be communicated and delivered by the ICT industry, the rate of adoption of wireless technology would undoubtedly increase.

6. FORESIGHT – CREATING AN AGILE INDUSTRY

Foresight is defined as "*the systematic process of developing a range of views of possible ways in which the future could develop, and understanding these sufficiently well to be able to decide what decisions may be taken today to create the best possible tomorrow"*(James, 2001). Technology foresight can be viewed as a number of systematic investigations drawn together to help plan the technology and science that will create innovation and improvements in the quality of life. Using a lightweight foresight technique it is possible to draw on the above research to highlight a number of important communication requirements for the construction industry. These have been used to form the basis for two examples illustrating how wireless technologies can be key enablers for the construction industry. The examples both use the same underlying wireless technology but it is deployed in two quite different ways to meet the differing business requirements.

6.1 Example 1: the mobile workforce

The first example is based around a mobile workforce. The research above has highlighted the need for 'mobility' including 'hot desking'. Typically this example would be an employee of a construction industry. During their working day, they might usually be based at the head office but during certain times they could be working out on a construction site, at a third party supplier's office or even at a regional office. In any of these cases, the employee may need connectivity to communicate, access or transfer information and data from the head office. Because this data and information may be of a sensitive nature, it is critical that in this case, the system is secure. Taking the key communication criteria highlighted earlier it is possible to identify the key requirements for this example. Table1 illustrates these.

Table 1: Communication requirements for example scenarios.

Communication Criteria	**Requirements for Example 1**	**Requirements for Example 2**
1. Cost	*Medium set up* *Low running costs*	*Medium – High set up as equipment can be reused* *Very low running costs*
2. Performance	*High volume, low delay*	*Low volume, low delay*
3. Reliability	*High*	*High even though may be in noisy environment*
4. Scalability	*System needs to be available in different locations*	*System needs to adapt to local needs/changes*
5. Coverage	*Typically < 250m from wired network*	*Varies depending on size of construction site*
6. Mobility	*Low*	*High*
7. Ease of Installation & Maintenance	*May be complex to set up initially. Easy to use once set up*	*Must be easy to set up and use, as users connect on adhoc basis*
8. Applications & Use	*Link to Head Office* *Secondary use – local links*	*Peer to Peer networking at locality*
9. Security	*High*	*Low*

From this, a potential system can be identified to meet these requirements. The distance over which wireless transmission is required are within a single site and therefore wi-fi technology would be an appropriate wireless technology. High security is required. Virtual Private Networks (VPNs) can be used over both wired and wireless networks, providing a secure 'tunnel' between the end user and the central system irrespective of the underlying technology. Wi-fi, 3G, 4G and WiMAX could all be possible wireless technologies over which a VPN can be used. With more and more wi-fi access points able to support VPN functionality, and an increase in the number of handheld devices that support a number of different wireless technologies such as wi-fi, WiMAX and 3G/4G, a mobile secured system is becoming a reality. Fig. 3 illustrates a potential system where each of the sites have fast wired links to the internet and thus to each other.

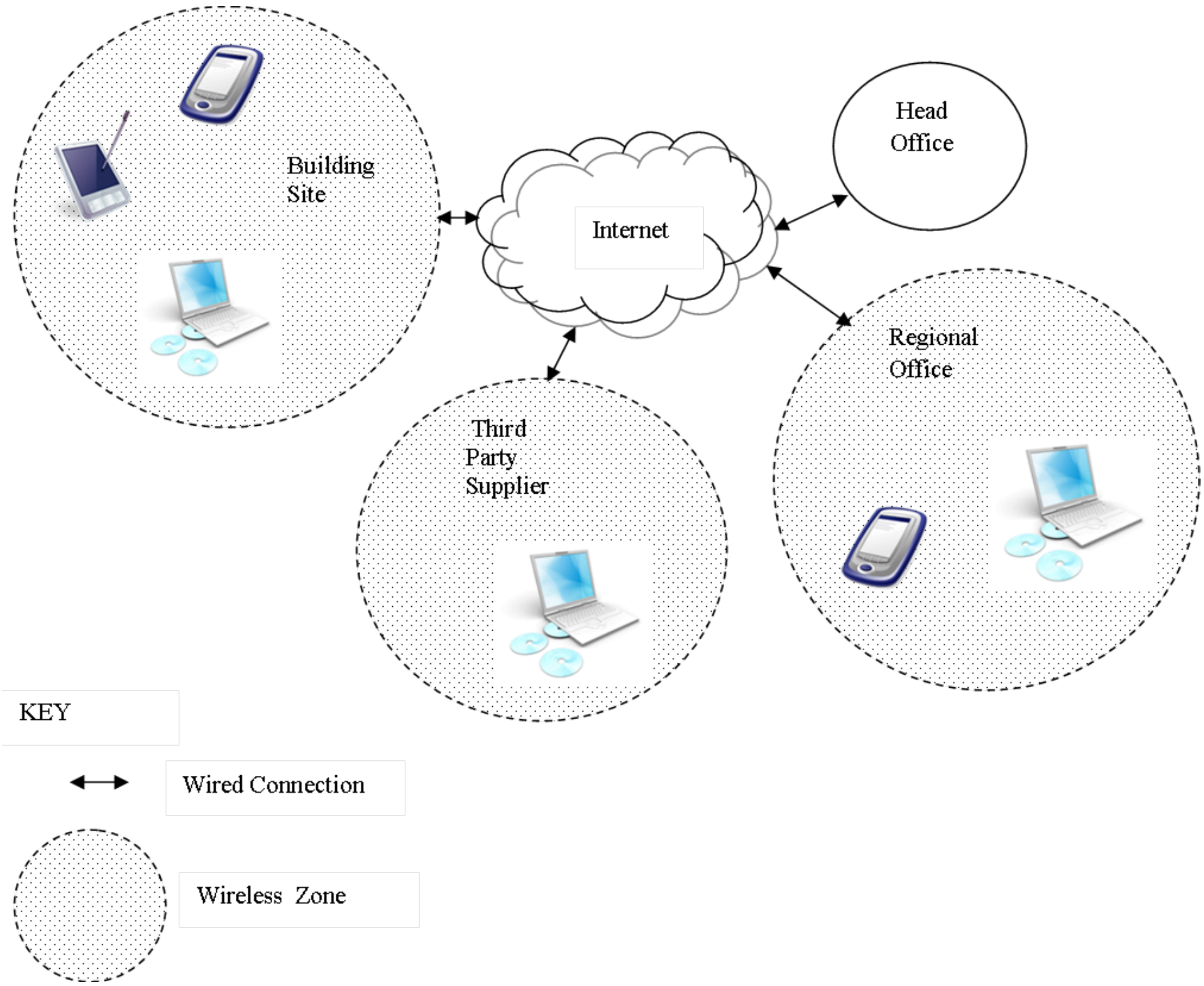

FIG 3: Example 1 – the mobile workforce

However, on site, each of the remote sites employs wi-fi wireless technology and VPNs to provide a wireless zone, allowing mobile workers to link into the main wired network and internet easily and securely. The use of VPN would require careful set up but once set up, mobile workers could move easily around each site and from one site to another whilst still retaining connectivity to the head office. Such solutions are in use in other sectors such as education and business and commerce. The wireless zones can also be set up to allow differing levels of access – a low level security access providing an open network solution and a high level security access via the VPN to allow authorised access such as access to the Head Office systems, data and network.

6.2 Example 2: the wireless mesh construction site

The second example is based around a construction site itself. Here the need is to provide connectivity across the site easily and quickly to allow different employees to communicate with one another and the site office. It could also allow visitors to the site temporary connectivity for file transfer, and other communication needs. One of the main issues is that of signal interference. A robust solution to this is the use of a mesh wireless network. It also provides a simple 'out of the box' solution that can be reused on another site. A mesh network such as this can be based on wi-fi technology similar to Example 1 but the set up is very different. In this case access points would be set in ad-hoc mode and a 'self-learning' routing algorithm employed so as devices and their corresponding users 'roam' around the network, the network learns where these devices and users are now positioned enabling routing to take place seamlessly. Security on such a system is harder to provide but this was not seen as a major requirement for on-site internal communication. Such a system can also be linked typically using a wired solution to the Internet. This network would provide a simple wireless communication facility for both on site staff and visitors, allowing documents to be easily exchanged and shared. Such systems are gaining widespread use in third world countries where there is no 'wired' infrastructure readily available (Johnson, et al 2007). Table 1 also illustrates the main communication requirements for this example.

Each of the above examples illustrate that wireless technology can be employed currently to support communication needs within the construction industry. However wireless technologies need to be evaluated and deployed in line with the main requirements for each set of communication needs. This is because there are still tradeoffs between the different criteria. Example 1 provides a secure mobile solution but it would need investment in time, training and resources to set up. Each wireless zone can be expanded but it would involve a set up each time. In Example 2, a reliable and quick wireless solution has been provided. Once set up this system could easily be transported to a new site with relatively minimal set up costs. The trade off here is that security would be minimal.

As wireless technologies converge and security solutions develop, the construction industry should see a wireless solution that meets all their differing needs, providing communication facilities quickly, easily, securely and with no interference. Already wireless internet access in the home has moved from a few years ago when it was a difficult to achieve process, and people generally needed to call in an expert or have some expertise themselves to a situation where the wireless router comes preconfigured and provides an almost 'out of the box' solution. Development is still needed to provide a similar system albeit on a larger scale to suit the differing needs of business and industry.

6.3 Business benefits of wireless communications and security

Whilst generic benefits of wireless technologies are identifiable, certain characteristics make wireless solutions ideally suited to construction. These can be identified as:

- Increased efficiency of communications provides the fast transfer of project information within contracting organisations and also between project participants and stakeholders.
- The constant connectivity of construction personnel working on a project without the need for wired connections to access networks.
- Greater support for mobile workers at various locations on a project who can be networked without the need for dedicated equipment.
- Savings in time through instant communication of production-critical information delivered to the work face.
- Realisation of the continuous benefits of innovative technology and developments to support competitive business operations and services to clients.
- Repeatable, scalable and secure wireless solutions to support project portfolio management.
- Reduced cost in relation to wired solutions with cheaper installation and maintenance costs.

7. WIRELESS INFRASTRUCTURES – THE NEXT STAGE

The research carried out so far has indicated that the construction industry is making use of wired technology and some wireless technologies with a good degree of success. The large corporate organisations require technological solutions that are secure and robust. There is also the need for solutions that are rapid to deploy and allow mobility. Currently wired solutions do not provide this. Wireless can provide a solution here although care needs to be taken to ensure the chosen deployment meets industry needs. Fig. 4 shows a proposed framework for translating business requirements into a final implementation.

It is clear that there is scepticism about the effectiveness of wireless technologies and thus the next stage of development is to provide a more comprehensive framework for wireless deployment with practical examples of successful implementation. It is essential that the construction industry works with the suppliers of wireless technology to ensure that it is fit for purpose.

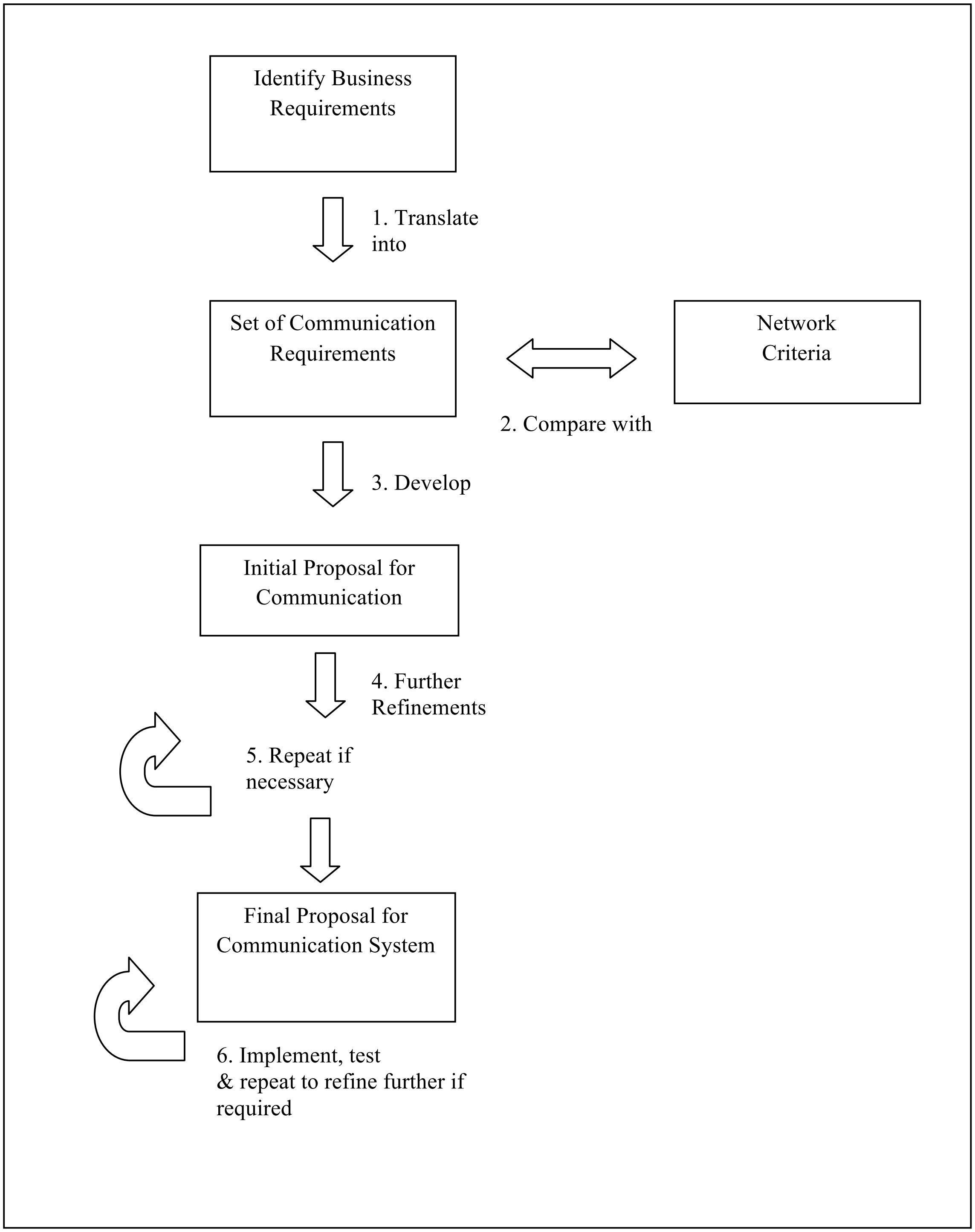

FIG 4: Framework for producing a wireless infrastructure

8. CONCLUSIONS

The expanding complexity of construction projects means that increasing amounts of data and information need to be exchanged during the construction process. This paper has reviewed a range of wireless technologies and examined the security threats and preventative measures. An analysis of the needs of the construction industry was established through in depth interviews with personnel within two different construction organisations. This provided the basis to highlight two different example scenarios where wireless technologies could be successfully deployed to provide a solution to the needs of the industry. It is clear that there are positive benefits to using wireless technologies now but there is not one solution that will meet all the differing needs of the industry. The industry can learn from other sectors that already deploy wireless solutions. Dissemination of examples of good practice and the development of a framework to assess specific needs and ensure the correct solution is deployed would be very valuable. With convergence of the wireless technologies, and ongoing development in security, further integration is expected, allowing one solution to meet more varied needs. It is important that the construction industry works with the technology providers to ensure the providers understand their needs and developments are in the appropriate directions.

9. REFERENCES

Acar E. Kocak I. and Sey Y. (2005). Use of information and communication technologies by small and medium-sized enterprises (SMEs) in building construction, *Construction management and economics*, Vol. 23, No. 7, 713-722.

Adriaanse A. and Voordijk H. (2005). Interorganisational communication and ICT in construction projects: a review using metatriangulation, *Construction innovation*, Vol. 5, No. 3, 159-177.

Anumba C. J. Aziz Z. Ruikar D. Carrillo P. and Bouchlaghem D. (2006). Intelligent wireless web services for construction: a review of the enabling technologies, *Automation in construction*, Vol. 15, No. 2, 113-123.

Anumba C. J. Pan J. and Issa R. R. A. (2008). Collaborative project information management in a semantic web environment, *Engineering, construction and architectural management*, Vol. 15, No. 1, 78-94.

Baxevanaki L. Bozios T. and Mathes I. (2001). Mobile user support for the construction industry, *Journal of the institution of British telecommunications engineers*, Vol. 2, No. 3, 123-129.

Bowden S. and Thorpe A. (2002). Mobile communications for on-site collaboration, *ICE proceedings: civil engineering*, Vol. 150, special issue 2, 10-16.

Bowden S. Dorr A. Thorpe T. and Anumba C. (2006). *Mobile ICT support* for construction process improvement, *Automation in construction*, Vol. 15, No. 5, 664-676.

Chen Y. and Kamara J. M. (2008). Using mobile computing for construction site information management, *Engineering, construction and architectural management*, Vol. 15, No. 1, 7-20.

Dainty A. Moore D. and Murray M. (2006). *Communication in construction: theory and practice*, Taylor & Francis, Oxon, England.

De Nardis, L. and Di Benedetto, M. G. (2007). Overview of the IEEE 802.15.4/4a standards for low data rate Wireless Personal Data Networks, *Proceedings of the 4th Workshop on Positioning, Navigation and Communication,* 22 March 2007, 285 – 289.

Doherty P. (2002). The future of controls is wireless and small, *Networked Controls*, July, 40-42.

Easttom C. (2006). *Computer Security Essentials*, Pearson Education Inc, New Jersey.

Electronic design (2008). *Figure showing Range versus Data Rate: Common Wireless Technologies*, Available at http://electronicdesign.com/Files/29/11412/Figure_01.gif, Last accessed 15/10/2008.

Gajendran T. and Brewer G. (2007). Integration of information and communication technology: influence of the cultural environment, *Engineering, construction and architectural management*, Vol. 14, No. 6, 532-549.

Glover, B and Bhatt, H. (2006). *RFID Essentials: theory in practice*, O'Reilly Media Inc.

IEEE. (2008*). IEEE 802.11 Wireless local area networks: the working group for WLAN standards*, Available at http://www.ieee802.org/11/, Last accessed 15/10/2008.

James M. (2001). *Australia 2020: Foresight for our future*, Science, technology, environment and resources group, Research Paper 18 2000-01, Parliament of Australia.

Johnson D. et al. (2007). *Building a rural wireless mesh network: A do it yourself guide to planning and building a Freifunk based mesh network*, Wireless Africa, Meraka Institute, South Africa, Version 0.8.

Kirisci P. T. Hribernik K. A. and Dikici C. (2004). A wireless solution for mobile collaboration on construction sites, *International workshop on wireless ad-hoc networks*, Oulu, Finland, 166-171.

Peansupap V. and Walker D. H. T. (2006). Information communication technology (ICT) implementation constraints: a construction industry perspective, *Engineering, construction and architectural management*, Vol. 13, No. 4, 364-379.

Peansupap V. and Walker D. H. T. (2006a). Innovation diffusion at the implementation stage of a construction project: a case study of information communication technology, *Construction management and economics*, Vol. 24, No. 3, 321-332.

Rowlinson S. and Croler N. (2006). IT sophistication, performance and progress towards formal electronic communication in the Hong Kong industry, *Engineering, construction and architectural management*, Vol. 13, No. 2, 154-170.

Siddiqi J. et al. (2007). Secure ICT services for mobile and wireless communications, *International journal of mobile communications*, Vol. 5, No. 5, 572-589.

Shohet I. M. and Frydman S. (2003). Communication patterns in construction at construction manager level, *Journal of construction engineering and management*, Vol. 129, No. 5, 570-577.

Sze-wing L. Mak S. Lee B. L. P. (2008). Using a real-time integrated communication system to monitor the progress of quality of construction works, *Automation in construction*, Vol. 17, No. 6, 749-757.

Thompson J. (2005). Building IT foundations: construction industry, *Managing information strategies*, May, 64-69.

Tutorial Reports. (2008). *Resources including wireless tutorials on Bluetooth, Zigbee and RFID*, Available at http://www.tutorial-reports.com/wireless, Last accessed 15/10/2008.

Warren P. Davies. J. and Brown D., editor. (2008). *ICT futures: delivering pervasive, real-time and secure services*, John Wiley & Sons Ltd, Chichester, England.

Williams M. D. and Williams J. (2007). A change management approach to evaluating ICT investment initiatives, *Journal of enterprise information management*, Vol. 20, No. 1, 32-50.

Wong C. H. (2007). ICT implementation and evolution: case studies of intranets and extranets in UK construction enterprises, *Construction innovation*, Vol. 7, No. 3, 254-273.

Won-suk J. and Skibniewski M. J. (2008). A wireless network system for automated tracking of construction materials on project sites, *Journal of civil engineering and management*, Vol. 14, No. 1, 11-19.

Wu Y. and Yao N. (2008). Framework system design of construction project document management during the initial phase based on WBS, *Proceedings of 3rd international conference on wireless communications, networking and mobile computing*, Shanghai, China, 5243-5246.

Xuan Z. and Yuanzhang, L. (2007). The impact of ICT on supplier-buyer relationship in different types of supply chain, *Proceedings of 3rd international conference on wireless communications*, Beijing, China, 4689-4692.

Yuan C. and Kamara J. M. (2008). Using mobile computing for construction site information management, *Engineering, construction and architectural management*, Vol. 15, No. 1, 7-20.