CONSTRUCTION SITES COMMUNICATIONS TOWARDS THE INTEGRATION OF IP TELEPHONY

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SUMMARY: *Over the past decades, construction firms have been using several off-the-shelf telecommunication tools and techniques to provide the communication means necessary to their mobile personnel on the jobsite. It is obvious that two-way radio transceivers such as walkie-talkie were the de facto standard adopted within the industry at first sight and for many years for very good reasons i.e. inexpensive, ease of installation, etc. Today's rapid expansion and advancements in the telecommunications field are changing the way people communicate. Moreover, while legacy systems including wired, mobile and wireless technologies are offering a wider range of communications to the construction industry, this is not without constraints; such constraints could be of a technological and financial nature, limiting their availability to a particular class of users in certain circumstances. Furthermore, it is well known that the construction industry is information intensive and all teams involved in a given construction project are dispersed. The need to communicate with one another must be done in an effective, financially affordable and easy to use way that should satisfy the project requirements. An alternative to such traditional systems is the use of IP (Internet Protocol) Telephony communications instead. This new and emerging technology could offer to the construction industry as a whole, benefits and values that are absent in the traditional telecommunications systems. This paper provides a summary of the telecommunications means and technologies used in construction with an overview of the advantages and drawbacks of each technology. It also describes the new communication paradigm that is the IP Telephony and its potential use at the jobsite. This includes the presentation and description of a generic integrated framework which utilizes existing technologies but its implementation offers increased benefits. The various modes of communications are described under this common framework and the paper outlines some of the implementation issues, including the business case for such an improved way of working. This paper is part of a research project undertaken by the authors at the University of Salford.*

KEYWORDS: *IP telephony on construction sites, IPTCS framework, construction site communications, mobile computing in construction, ICT, VoIP*

1 INTRODUCTION

The UK's construction industry is a significant contributor to the national economy accounting for eight percent of the Gross Domestic Product (GDP) and employing over one million nine hundred thousand people (NAO, 2001). However, construction sites are often perceived as being adversarial places in which to work, leading to lower productivity and poor industry image (Egan, 1998). Sir John Egan, in his "R*eport of the task force to the deputy prime minister on the scope for improving the quality and efficiency of UK construction*" further states that substantial changes in the culture and structure of the UK construction are required, including those related to working conditions and use of technology. Noteworthy, adequate communication means are highly important to the personnel on the move where clear and consistent messages need to be managed in support of teams, business and construction projects' objectives. It is reported that "with a large mobile workforce that is expected to travel and to move on from one site to another, effective communication is one of the strategic tools available for gaining employee commitment, improving morale, increasing productivity, quality and safety and introducing new technologies" (Preece *et al.*, 1998). All parties involved in a construction project are producers, suppliers and consumers of information. Hence, owners, designers, contractors, suppliers, and construction managers will benefit substantially from having the means to deliver and access to information wherever and whenever they need to (Bakeren & Willems, 1993). Therefore, in order to improve the transmission speed of information between the site office, the Head Quarter and the supply chain, efficient communication systems and resources are required. Such improvement in communications is further expected to achieve significant reductions of construction costs (Baldwin *et al.*, 1996; Davidson & Moshini, 1990) and is believed to trigger better optimisation of the different communication resources put in place. The widespread of advanced mobile systems and applications observed in recent years is undoubtedly playing a major part in the amelioration of the communication flows between construction teams. However, circuit-switched based telecommunication systems i.e. the Public Switched Telephone Network (PSTN) and the Global System for Mobile communications (GSM) are to some extent found to be expensive (du Preez & Pistorius, 2002; Ermel *et al.*, 2002). In addition, their coverage, in some cases, may not reach the remote areas of construction sites. This situation could lead to the use of alternative technologies which are cheaper (i.e. cost of equipment, installation and operations), rapidly deployable and more efficient. Internet Protocol (IP) Telephony is one such technology that could benefit the construction industry as a whole, and provide efficient communication means to workers on the move. Yet, its implementation within such industry has not been observed due to several barriers that were recently investigated and uncovered through field works conducted by the authors between April and October 2003 with a number of construction firms, telecommunication operators, IP Telephony Service Providers (ITSPs) and equipment vendors in the UK.

This paper is organised as follows: Sections one and five provide the introduction and conclusion respectively. Section two is a summary of the telecommunication systems and technologies used in construction with emphasis on their most observed advantages and pitfalls. Section three describes a new communication paradigm known as Internet Protocol (IP) Telephony technology and discusses its potential use in construction. This includes the presentation and description of a generic integrated framework (section four) which utilises existing technologies (i.e. the Internet), but its implementation offers increased benefits. The various modes of communications are described under this common framework and the paper outlines some of the implementation issues, including the business case for such an improved way of working.

2 CONSTRUCTION SITES COMMUNICATIONS

It is observed that the main communication issue in construction is to provide a method to exchange data between the field operation and the field office (De la Garza & Howitt, 1998). Typically, the field office is located in a trailer within close proximity to the field operation. The foreman or supervisor in the field needs to be free to roam within the boundaries of the field operation. Also, the information needs under consideration are time critical to assist in maintaining or improving the efficiency at the jobsite. Construction firms generally use a varied number of traditional communication systems and services on an ad-hoc basis. However it is often difficult to establish a clear picture of the capability of these systems due to the variance in the nature, volume and requirements of the construction projects' communications. Table 1 thereafter provides a review of some of the most commonly used communication systems in construction and stresses on their advantages and drawbacks. This review is intended to assist construction firms in their preliminary choice of an adequate communication solution for their remote projects

Table 1: Review of the telecommunication systems in construction

Technology	Advantages	Disadvantages
Cellular/Mobile GSM: Global System for Mobile communications GPRS: Global Packet Radio System AMPS: Advanced Mobile Phone System	• Voice/Data transfer • Familiar technologies • Instant availability • Roaming • Miniaturised terminals • Well established	• Full dependence on the Service Provider • Communications costs are difficult to control (SOFTEX, 2001)
DECT Digital Enhanced Cordless Telecommunications standard that provides a general radio access technology for wireless telecommunications, operating in the preferred 1880 to 1900 MHz band (Ochsner, 1997).	• Voice/Data • No License required • High speed data: up to 552 Kbit/s with migration to up to 2 Mbit/s • High reliability through reserved frequency band resulting in no	• Limited coverage

Technology	Advantages	Disadvantages
Technology available in over 110 countries (Ochsner, 2002)	interference problems for industrial applications	
Voice VPN This consists of registering the mobile phones within the same service provider who provides the Voice VPN (Virtual Private Network) at a pre-agreed rate.	• Voice/Data transfer • Cost Control • Communications with other networks i.e. GSM, PSTN are supported	• Full dependence on the Service Provider for coverage and Quality of Service (QoS) • Costs are governed by length of calls
WLAN A wireless LAN is one in which a mobile user can connect to a local area network (LAN) through a wireless (radio) connection. A standard, IEEE 802.11, specifies the technologies for wireless LANs.	• Voice/Data transfer • Unlimited Free voice calls between devices • External communications cost control • Well established technology • High bandwidth data transfer	• VoIP Quality of Service (QoS) issues • WLAN devices i.e. wireless IP Phones are mainly made for indoor use • Short coverage perimeters may involve higher number of Network Access Points (NAPs)
PMR Private Mobile Radio is a term used to broadly cover all forms of 2 way radio systems.	• Well established technology • Coverage: up to 15 miles in ideal conditions	• No data transfer • Short length conversations • Internal communications only • Handsets are bulky
Advanced PMR This interfaces to the PSTN to provide access to external voice communications	• Coverage up to 15 miles in ideal conditions • Voice/data supported	• Limited data transfer • Bulky handsets • Number of simultaneous calls limited by the number of channels available
TETRA Digital European system developed as an upgrade to the analogue PMR. TETRA is a set of standards developed by the European Telecommunications Standardisation Institute (ETSI) that describes a common mobile radio communications infrastructure throughout Europe	• Voice/Data supported (ETSI, 2002) Cost control • Communications with other networks i.e. GSM, PSTN are supported	• Not yet a well established technology
Low Earth Orbit (LEO) Satellite	• Universal coverage • Voice/Data supported • Quick deployment for services	• Very expensive per minute calls and subscriptions • Bulky Handsets
Geostationary Earth Orbit (GEO) Satellite A satellite receiver is necessary to provide a direct connection to the Geostationary Satellite and enable information to be passed onwards. A WLAN is also required to connect to personnel on construction sites.	• Good coverage with the satellite footprint • Voice/Data communications supported • Quick deployment • Supports high level encryption schemes • True Broadband is easily achievable delivering high speed "Always on" access to the internet	• voice transmission delay • Coverage issues inside buildings • Communication is not always reliable, however, some providers offer a Service Level Agreement

The rapid growth of handheld computing devices in recent years has marked the beginnings of a real mobile communication capability (Kinns, 2002). Some of the technologies listed in Table 1 may offer to people on construction sites the opportunities to communicate using handheld devices (i.e. PDA) and wearable computer systems. These systems could allow field workers, through the use of telecommunication facilities to access information and contact remote experts (Miah *et al.*, 1998). The speed of data transmission, coverage range, availability of service and cost are very important factors to be considered when procuring a communication solution. However, building equipment and communication devices used on construction sites can initiate interference that affects radio transmissions. Exception is made to the Digital Enhanced Cordless Telecommunications system (DECT) which appears to be a strong technology that offers high reliability through reserved frequency band resulting in no interference problems for such industrial applications (Ochsner, 2002). The Construction industry is benefiting from this technology through the Mobile Integrated Communications in Construction solution since 1999 (see section 2.1). DECT technology is certainly moving to larger markets, lower costs and new applications. As for the wireless network solutions (i.e. IEEE 802.11) they operate over shorter range which may increase the number of Network Access Points (NAP) to maintain a larger coverage area. However they offer much greater transmission speeds necessary to the exchange of data communications. Satellite communications, although they provide universal coverage useful for areas that lack of terrestrial infrastructures, they are often associated to a very high cost of operations, service and maintenance.

Mobile communications technologies, as stated earlier in this paper, are in constant developments; an example to this is the advent of the Universal Mobile Telephone System (UMTS) based on the core of the GSM network architecture along with the GPRS and satellite technologies. The UMTS offers video, voice and data communications through mobile devices and signals the move into the third generation (3G) of mobile networks. It also addresses the growing demand of mobile and Internet applications for new capacity in the overcrowded mobile communication sky. The new network increases transmission speed up to 2 Mbps per mobile user and establishes a global roaming standard.

2.1 Mobile Integrated Communications in Construction (MICC)

The project MICC was conducted between September 1995 and February 1998 by a consortium of four European construction companies: Bouygues (France), Balfour Beatty & Tilbury Douglas (United Kingdom), HOCHTIEF (Germany) and DRAGADOS (Spain). This consortium was willing to publish a set of tested specifications to allow workers on sites to access voice and data services for the first time (Deguine *et al.*, 1999). MICC solution is centralised in a movable communications container (Fig. 1) and its architecture is based on DECT technology supporting services for more than one company based on Site Multi-Organisational Network (SMON). The design of the mobile communications container was made according to construction sites users needs gathered from face to face enquiries through interviews conducted in different European countries. The aim of developing such a communications container was to allow personnel on construction sites to use advanced Information and Communications Technology (ICT) facilities in order to quickly have the information they need at their fingertips during a construction project.

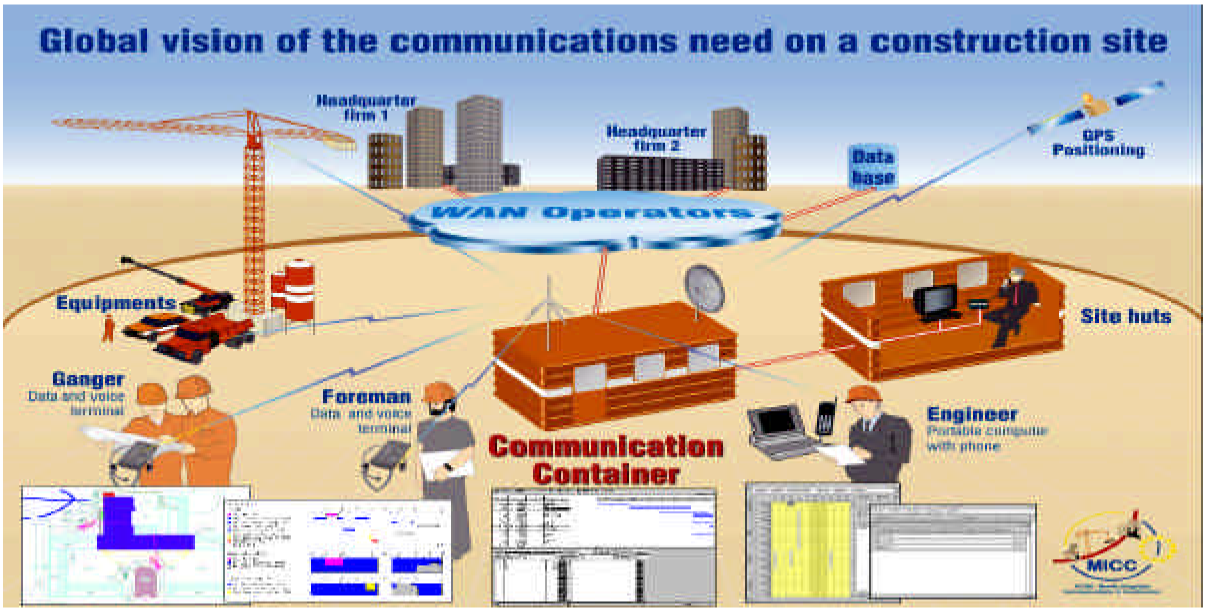

FIG.1: Global vision of the communications need on a construction site (Deguine et al., 1999)

The communication container provides the following services:

- Voice: Telephony services with PBX supporting DDI (Direct Dial In) functions.
- Data: Support of IP (Internet Protocol) access from mobile terminals and site based terminals to server based either in site offices, on corporate Intranets or on the Internet.

Four scenarios of construction sites were further identified as shown in Table 2:

Table 2: Identified Scenarios and typical figures - Source: (Deguine et al., 1999)

	No. Sites	**No. Companies**	**No. Persons**	**Distance**
Scenario 1 (Urban Area): Building Concrete	1	Several dozens	Hundreds	< 600 meters
Scenario 2: Road or Railways	Several	< 5	< 1000	Up to 30 Km
Scenario 3: Tunnels	1	< 10	< 100	Up to 3 Km
Scenario 4: Industrial (Metallic structure) or Airport	1	Several dozens	> 1000	Up to 4 Km

The technologies presented in Table 3 below were identified and researched against the abovementioned scenarios:

Table 3: Technology evaluation against the identified Scenarios - Source: *(Deguine et al., 1999)*

Construction Site Type	**DECT**	**GSM**	**W-LAN (DATA)**	**TETRA**
Adequate to Type-1	Excellent	Poor	Good	Moderate
Adequate to Type-2	Moderate	Good	Moderate	Excellent
Adequate to Type-3	Excellent	Good	Possibly Excellent	Good
Adequate to Type-4	Moderate	Good	Moderate	Excellent

GSM, DECT and TETRA solutions were candidates to solve most of the construction site communication problems. However, DECT was finally selected and site tested due to the following advantages:

- No license required
- European wide frequency band, and
- Unsophisticated network deployment

On the other hand, DECT data services using the same infrastructure have not been implemented because of a lack of standard and products in 1999. The technology has evolved since then, and more applications are being implemented worldwide (Ochsner, 2002). However, the proliferation of Next Generation Networks (NGNs) such as 2.5G (i.e. GPRS) and 3G (i.e. UMTS) could significantly decrease the need for heavy equipments, and the rapid access to these generic technologies is likely to decrease the use of specific and costly solutions (i.e. MICC and COSMOS).

2.2 Construction Sites Mobile Operations Support (COSMOS)

COSMOS is a European funded project carried out between September 1998 and May 2001. It has focused on construction sites lacking a permanent network infrastructure. Its main objectives were based on the considerations that traditional network infrastructures, systems, and tools are inadequate for frequent and ubiquitous handling of information that are centrally stored at the company's Head Quarter (HQ). Furthermore, the frequent remote access to the information involves very complex processes at the construction site level, calling for an integrated information system and thus for efficient communications within the construction site and the HQ. Such communications should be supported from any site location and with different kinds of devices. COSMOS applications are browser-based and reflect typical business and engineering process of construction companies such as management of suppliers and subcontractors, management of equipment, control of technical drawings, quality audit accomplishment, progress monitoring, control of resources, and user management (Meissner *et al.*, 2001).

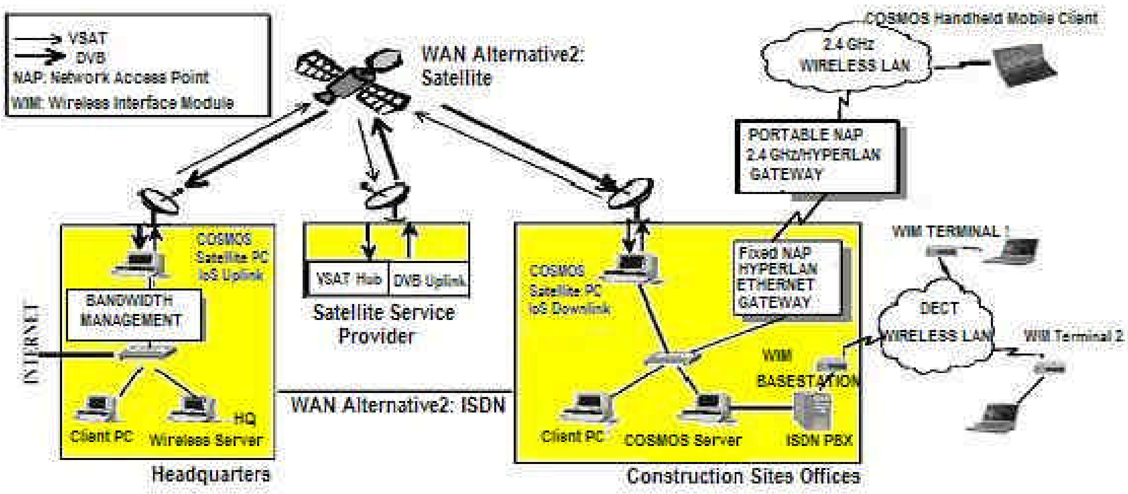

FIG. 1: COSMOS General Architecture

3 IP TELEPHONY COMMUNICATIONS

Not so long ago the Internet used to run on phone systems, but now, phone systems are running over the Internet bringing tremendous savings in communications expenses by means of voice and data consolidation such as IP (Internet Protocol) Telephony or Voice over IP (Goncalves, 1999). The Internet has benefited from a number of different fundamentals compared to legacy networks, such as the tremendous progress of computing technology and globalization (Sinnereich & Johnston, 2001). The research, academic, engineering and business communities have massively contributed to the advancement of the IP (Internet Protocol) capabilities. Thus, the applications that run over the Internet core technology are numerous. The result of these contributions is an Internet that uses consistent protocols on a global basis and equally well suited to carry data, voice, and video. IP Telephony refers to communications services such as voice, facsimile, and/or voice-messaging applications that are transported via the Internet, rather than the Public Switch Telephone Network (PSTN). The basic steps involved in originating an IP call are conversion of the analogue voice signal into digital format and compression/translation of the signal into IP packets for transmission over the Internet; the process is reversed at the receiving end.

3.1 Brief history of IP Telephony

The possibility of voice communications travelling over the Internet, rather than the PSTN, has first emerged around 1995 but was plagued with poor voice quality and substantial delays. Noteworthy, prior to 1995, there were research activities of transmission of voice signals over packet networks in the late 70's and early 80's. In the late 70's there was discussion and experiments with packetised voice over ARPANET, the predecessor of the Internet using IP and specialised coding and packetising equipment (Gold, 1997). In 1996 the first inter-networking trials between IP network and the PSTN were made and in 1997 the Delta Three launched the first phone-to-phone service for commercial use (Koistinen & Haeggstrom, 1998).

3.2 IP Telephoy basic networking architecture

There are three basic scenarios materializing IP Telephony communications; one is known to be the pioneering scenario that has given birth to the IP Telephony market. This is known as Computer-to-Computer or PC-to-PC telephony (Fig. 3). The remaining scenarios are PC-to-Phone and Phone-to-Phone.

FIG. 2: PC-to-PC architecture

PC-to-PC was the first generation of IP Telephony services (ITU, 2000). Users equipped with multimedia computers, with both ends simultaneously connected to the Internet, could initiate a voice and/or video session. Special commercial H.323 (see section 3.3: IP Telephony Standards and Protocols) compatible software such as Microsoft NetMeeting embedded in all Windows operating systems manage the compression and decompression of the speech in order to make the communication session available to both ends.

The second IP Telephony scenario which is known as PC-to-Phone has become possible around 1996. A user with a multimedia equipped PC can call a regular phone in virtually any location in the world. To terminate the call into the PSTN network, a VoIP (Voice over Internet Protocol) Gateway is set between the IP network and the PSTN (Fig. 4). PC-to-Phone communication is more complex than simple PC-to-PC resulting from the fact that calls need to be billed and routing arrangements negotiated, including interconnect payments in the distant location where applicable.

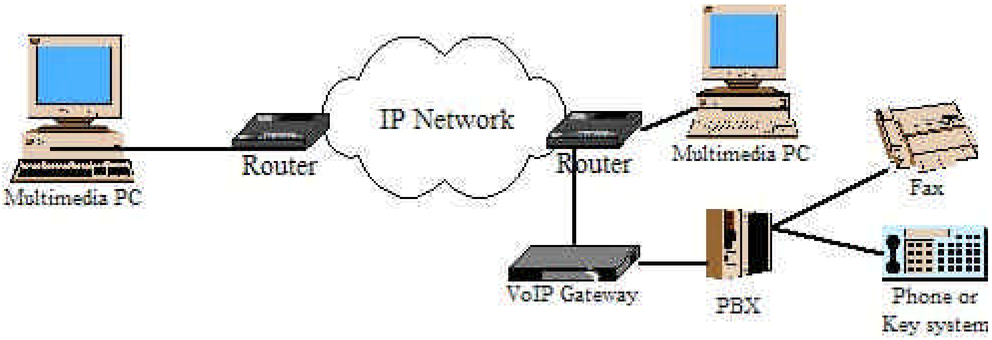

FIG. 3: PC-to-Phone architecture

The third and very important segment of the market which encompasses most commercial services is the Phone-to-Phone communications over Internet Protocol network (Fig. 5). This has been commercially available since around 1997. Phone-to-Phone indicates that users at each extremity are using conventional phones. VoIP Gateways are required at both ends. They are transparently set up to transport the voice, fax and video traffic over the IP network in order to terminate it to, or initiate it from the PSTN. This is by far the most common and best used scenario which will generate exciting new revenue opportunities for service providers and networking vendors alike. This architecture represents the baseline for future development of IP Telephony.

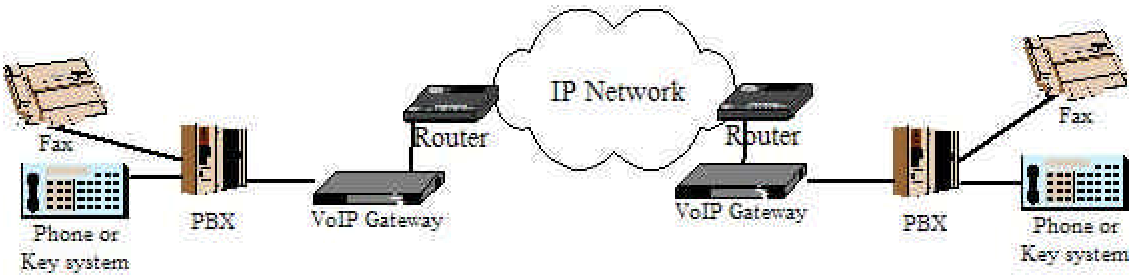

FIG. 4: Phone-to-Phone architecture

Also, there are other possible architectures of IP Telephony such as Web-to-Phone and Phone-to-PC which are not described in this paper. The interconnection between the PSTN and IP Telephony networks applies to Telcos who wish to converge between both Circuit-Switched and Packet-Switched technologies to provide convenient and cost effective telecommunication services to corporate and private users. The global interconnection architecture requires legacy equipment, VoIP Gateways and/or IP PBXs (Private Branch Exchange). Fig. 6 illustrates this interconnection architecture.

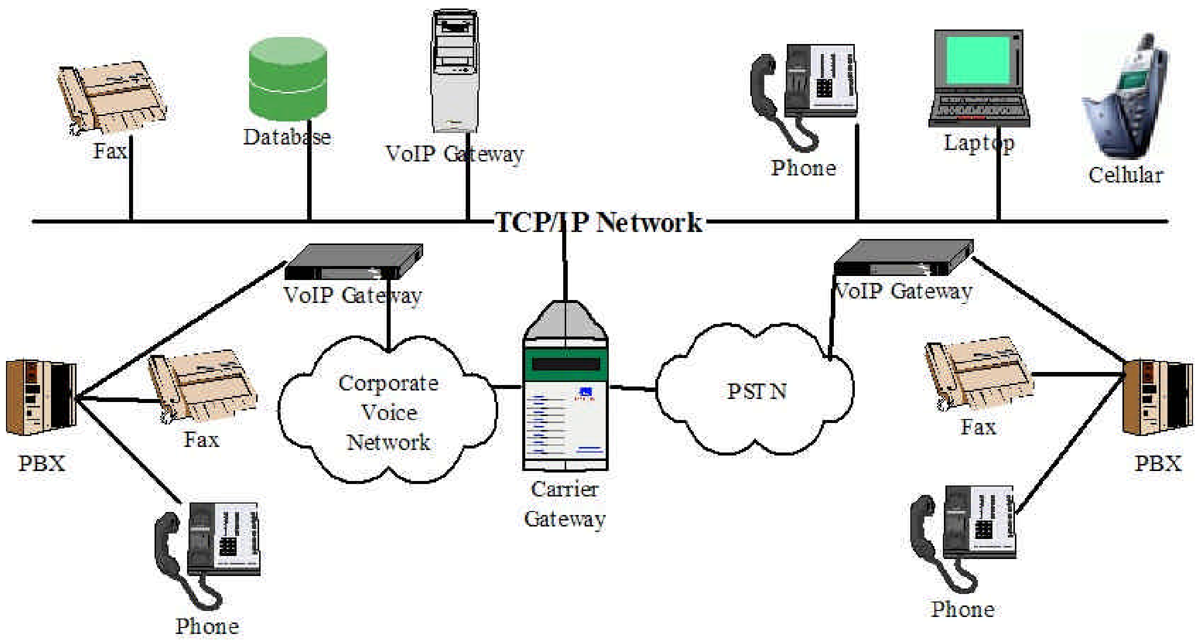

FIG. 5: VoIP and PSTN Interconnection architecture

3.3 IP Telephony standards and protocols

Standardization can eliminate customer lock-in, enable the innovation of new technologies, and maintain the competitiveness of the Internet Telephony equipment market. Two fundamental signalling protocols are set for voice over IP communications: H.323 of the International Telecommunication Union (ITU-T), and the Session Initiation Protocol (SIP) of the Internet Engineering Task Force (IETF).

The H.323 belongs to a series of communications standards called H.32x of the ITU-T. The first version approved in 1996 was primarily set for communication over Local Area Networks (LANs) and does not provide a guaranteed Quality of Service (QoS). However, in order to assure an appropriate level of communications between IP Telephony terminals (Phones, PCs, etc.), Gateways, and Gatekeepers from different vendors the standard is regularly updated and the most recent version (v5) was released in 2003 (IMTC, 2004).

The SIP standard was developed by the Multiparty Multimedia Session Control (MMUSIC) working group of the IETF which was first announced in 1996 (Sinnereich & Johnston, 2001). SIP is based on HyperText Markup Language (HTML) and is more lightweight than H.323. This protocol was originally designed for multimedia conferencing over the Internet. In addition to SIP, two other signalling protocols are considered as parts of the SIP architecture: Session Description Protocol (SDP) and Session Announcement Protocol (SAP). Some of the key advantages of SIP are summarised as follow (Melinat & Kelly, 2002):

- SIP is network indifferent; SIP based applications can be delivered via Frame Relay, ATM (Asynchronous Transfer Mode) or IP backbones.
- Since SIP is an Internet Protocol, it facilitates the integration of communication applications with other web-based applications.
- Using SIP, features can be introduced and supported at the endpoints (similar to PC clients). This reinforces the IP Communications model whereby applications can be easily added to the network without being intrinsically tied to a single, underlying vendor.

3.4 IP Telephony applications, benefits and market forecast

IP Telephony-based communications have begun in the early 1998. Vendors have encouraged this phenomenon by adding IP capabilities to their PBXs. In the absence of such IP PBX, a separate VoIP gateway was necessary to add Packet Telephony capabilities to the corporate network. Soft PBXs could replace more expensive proprietary ones with equipment based on industrial PC platforms. The interface of the soft PBX to common wire phone lines was done through Computer Telephony Integration (CTI) hardware that had been developed for call centres and other Interactive Voice Response (IVR) applications (Rinde, 1999). The IP PBX market is forecast to experience massive growth over the next few years. The mix between traditional circuit switched and packet switched IP peripheral equipment continues to shift in favour of the latter. In the span of a few years IP stations have increased from less than 1% to almost 16% of total PBX shipments (Sulkin, 2003).

Although, home applications have massively contributed to the explosive growth of IP Telephony since its early introduction into the market in 1996, the business use of this communication means is also growing at fast pace. There is a general consensus within the communications industry that Voice-over-Internet Protocol (VoIP) is the technology driving the next generation of enterprise telephone systems (MITEL, 2001).

According to IDC (2002), the enterprise IP Telephony market for new equipment will be US$880.56 million by 2005, with IP Telephony growing by 35 percent from 2001 to 2005. Allied Business Intelligence (Kharif, 2001) predicts that VoIP market revenue is projected to increase to US$7.6 billion by 2006, from US$2.6 billion in 2000. The emergence of packet-driven networks will improve operational efficiencies, reduce costs and boost overall profit margins (Sabat, 2002). IP Telephony optimizes data network functionality by running converged data, voice and video applications over a single infrastructure. It’s now possible to equip users with individual IP handsets, which work and act like traditional phones that plug directly into network switches to deliver enhanced integration with the data network. Applications such as desktop video conferencing, desktop message management for phones, faxes and e-mail, and plug-and-play phones that are as portable as laptop computers are designed to reduce costs, while protecting existing investments and quality of service. The benefits of IP Telephony can therefore be summarised as follow:

- Integrates all types of employee and customer contact streams (voice, data, fax and video) onto a single network, for enhanced productivity and improved service
- Provides a platform for productivity-enhancing applications such as Unified Messaging, collaborative data sharing in real time, and networked video
- Reduce line charges, network costs, and IT expenses by letting voice traffic travel at no added cost over data lines and equipment, without requiring significant restructuring of existing networks
- Simplify operations management by consolidating traffic onto one network.

3.5 Potential use of IP Telephony in construction

The 1990s have seen a technological shift in the construction sector from IT driven solutions to IT enabling ones. The industry, however, has become frustrated with the failing of IT as many companies have invested in the wrong technologies without addressing business needs (Aouad *et al.*, 1999). Business needs in a construction project concern all parties forming an alliance from different professions such as architecture, civil engineering, quantity surveying, structural engineering, project management, building surveying, etc. where effective communication is a fundamental factor for project success.

At the jobsite, communication can take place through different media and technologies including satellite, terrestrial, mobile, wireless and wired systems. The choice of an effective communication means must look at the:

- 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

The potential use of IP Telephony is growing rapidly in both business and private sectors. Enterprises are beginning to take advantage of converged communication networks today through the implementation of IP private branch exchange (PBX), IP Centrex, and similar IP communication solutions. These solutions allow enterprises to carry their voice and data traffic on a single IP network, calls within a company’s wide area network (WAN) are carried on the data network as VoIP (Melinat & Kelly, 2002). Converged networks also enable numerous administrative efficiencies for the enterprise. Within a construction project, a site office can benefit from 'plug-n-play' IP phones bringing ease to network configuration. At the Head Quarters, other "plug-n-play" IP devices or entire branch systems can be added to the corporate network which will automatically notify of their presence, resources, capabilities and dialling plan information to the network. A construction firm with internationally dispersed offices can benefit from IP Telephony resources to build up an entire virtual communication network rapidly and seamlessly. Theoretically, any IP telephony network can support as many nodes as the construction firm wishes to add to the network as these nodes could be internationally located wherever Internet connectivity is available. IP Telephony systems and networks can be managed remotely via the web from virtually anywhere in the world rendering their administration a less hassle for the enterprise.

4 IP TELEPHONY ON CONSTRUCTION SITES (IPTCS) FRAMEWORK

Internet Protocol Telephony on Construction Sites (IPTCS) Framework (see Fig. 7) is a set of commonly integrated variables established in the aim of enabling the use of IP Telephony Technology in the UK's construction industry by means of identifying the implementation barriers, investigating existing telecommunication technologies, and providing critical and strategic recommendations for the integration process.

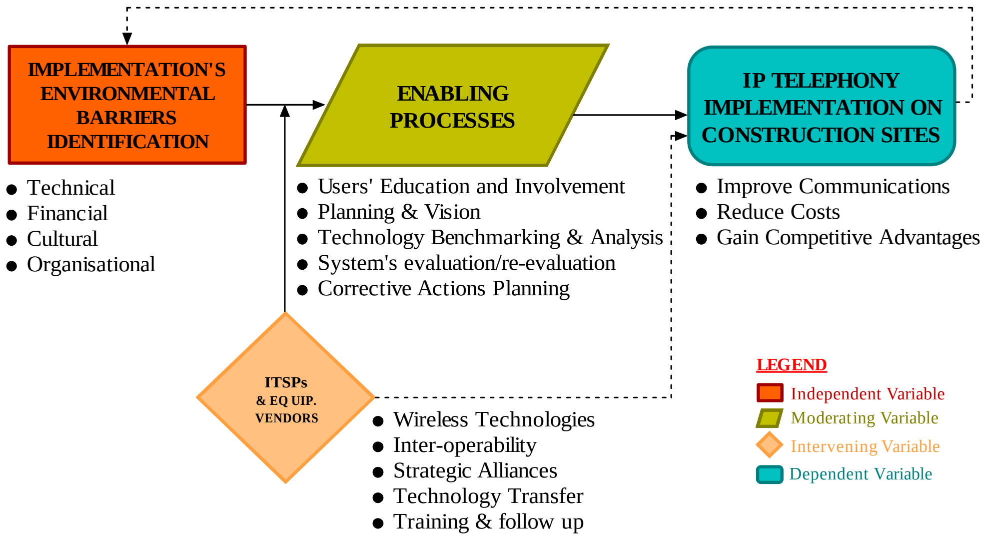

FIG. 6: Internet Protocol Telephony on Construction Sites (IPTCS) Framework

4.1 The development of the IPTCS Framework

The IPTCS Framework development was achieved during two stages: 1) Pre-field Investigations stage, based on assumptions, theories and literature analysis, and 2) Post-field investigations stage, based on a holistic approach deducted from the empirical research findings such as surveys and interviews conducted with a number of construction firms, Internet Telephony Service Providers and equipment vendors in the United Kingdom (Beyh & Kagioglou, 2004a). The authors, in the early stage of development, have established a number of assumptions where possible causes and effects retarding the use of IP Telephony were most likely to occur. The use of assumptions in this particular situation has the advantage to leverage the development of a new model or framework when no similar studies are available to establish its variables (Chen, 1976; Elam, 1979). In this regards, it has seemed essential to the authors to emphasise on the question dealing with the nature of the barriers preventing the use of IP Telephony by the UK's construction industry. Hence, the "Implementation Barriers" as shown in Fig 8 appeared to be encountered at different levels such as technical, financial, cultural and organisational. The following sub-sections discuss these barriers in detail.

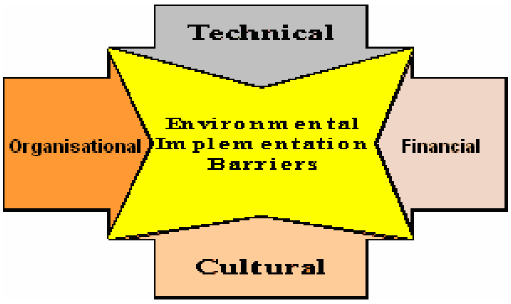

FIG. 7: IP Telephony Implementation Barriers

4.1.1 Technical Barrier

The impact of successful, widespread adoption of advanced ICTs in the construction industry could be very significant. In fact, with the increasing accessibility and affordability of communication technologies, the emergence of globally-based virtual organisations operating in knowledge-driven markets from geographically remote locations could more often take place (Bower *et al.*, 2001). However, at the present time there are still numerous reasons due to which, ICT applications have not yet reached their full potential in the construction sector. One impediment for many people and firms is for example "the fear of technology" as 10-15 % of the population will retire out of the industry before they ever embrace technology (Stark, 2002). Noteworthy, IP Telephony was only recently introduced to the business community for basic services offerings i.e. voice communications. Also several technical considerations such as network security (Wen-Chi Chen et al., 2001), Internet bandwidth requirements (Janssen & D., 2002), voice transmission delays (Schulzrinne & Rosenberg, 1999) and lack of suitable users' devices (Beyh & Kagioglou, 2003; 2004b; McPhillips, 1999) are essential concerns for decision makers for considering its implementation.

Furthermore, in order to drive construction firms to look closely at the adoption of IP Telephony, wireless technologies system developers and equipment vendors must meet several concurrent goals to overcome the technical barriers preventing its integration into today's demanding construction sites environments. Despite the recently observed technical improvements in IP Telephony [i.e. Wireless IP Telephony over PDA (Linden & Blom, 2002) and the Cisco's 7920 wireless IP Phone (Cisco, 2003)], its integration could however remain compromised. Therefore, in order to overcome such integration barriers, the following factors must be taken into full consideration as identified by Beyh & Kagioglou (2004a):

- Wireless XoIP (Voice, Video and Data over Internet Protocol) devices must be robust, water proof, resistant to dust and shock, and equipped with adequate and self sufficient power supply similar to the traditional systems' conditions
- XoIP features and services must exceed the capabilities of traditional and conventional phone systems
- Sound quality along with the transmission of video communications must meet an appropriate level required by the information need under consideration on construction sites.
- Mobile and wireless devices from different vendors must be interoperable, rapidly implemented (i.e. plug-and-play enabled) for seamless deployments
- Internet bandwidth must be prepared to meet IP Telephony usage requirements i.e. 15kb/s per voice channel guaranteed through Quality of Service (QoS) settings.

The transmission of communications over IP networks is synonymous to packet loss, delay and jitter issues (Chen & Chen, 2003; Da Costa & Sirisena, 2003). This loss of packets is significantly increased on wireless networks especially when client devices (i.e wireless IP Phones) are roaming between hot spots (Lee et al., 2003). Unlike circuit-switched communications where voice quality is consistent throughout a call, the quality of a Voice over Internet Protocol (VoIP) call can vary on almost a packet-by-packet basis (XACCT, 2001) due to the QoS performances of wireless networks. Based on this discussion, the authors conclude that:

> *The maturity of IP Telephony technology i.e. security, bandwidth requirements, lack of adequate wireless IP Telephony devices etc. and the nature of construction sites environments in general could hinder the adoption of the technology by the construction professionals and similar practitioners alike.*

4.1.2 Financial Barrier

Investing in new communications technologies and systems should have the potential to allow an adequate and rapid Return on Investment (ROI). Construction firms may not be willing to undertake new investments of the kind before taking full advantage of their existing systems. The cost of technology is believed to be an important barrier to technological innovation that a number of organisations point to when explaining their reluctance to implement wireless solutions, even though they recognise the value of their advanced applications (Stark, 2002). Such a barrier within the construction industry was also identified by Love et al. (2001) and Beyh & Kagioglou (2004a) who stated that this business like others relies on cash flow availability and thus, firms could not invest in technologies that would not bring about immediate benefits. The financial barriers they are referring to, include:

- The cost of system acquisition, requirements, and maintenance
- Investment risk
- Financial power and amount of available credit
- Cost of training and end-user education
- Losses in productivity, and
- Market uncertainty.

This discussion has led the authors to formulate a statement that:

> *Construction firms could be reluctant to the integration of IP Telephony technology because it is perceived as a new communication paradigm that would need considerable investments, but may offer the same services similar to those already found in the traditional telecommunication systems without further competitive advantages.*

4.1.3 Cultural Barrier

The cultural issues in the construction industry as a major part of influence on the development and adoption of new technologies have been well reported in the last few years (Egbu & Botterill, 2002; Fairclough, 2002; Love et al., 2001). Companies therefore must recognise that the full benefits of IT projects can only be realised as part of an overall business strategy (Bruce, 1995). Organisations that want to survive the increasingly sophisticated and competitive global marketplace will be required more and more to follow technical developments worldwide (Ashton *et al.*, 1991), this is besides a serious issue for the construction industry to follow such technological advancements at an early stage of their developments. Love et al. (2001) indicate that contractors have ignored emerging technologies which have the ability to provide significant performance improvements. This is believed to be partly due to the fact that new technologies are continually emerging and they often require significant efforts for training, test, investments and experimentation.
DIST (1998) emphasises on the difficulties in the construction industry of adopting new ICT applications by a resistance from the management to change, and a belief that the industry is doing well without it. Therefore, it may be debated that in order to be successful, a migration to, and adoption of new technologies must strongly consider looking at consequences where an attempt to change the users’ culture is likely to take place. Culture change is perceived as a complex psychological event according to Andersen (1992) who believes that “Just the thought of changing the fundamental culture or strategy of an organisation can send shock waves throughout the organisation, causing emotional and psychological stress to the individuals”. Because change is often asking people to do something different and adopt a different belief or attitude, it would be therefore necessary to analyse the organisation, the employees and their readiness for such a change prior to initiate it. Cultural issues in the construction sector could therefore affect the decision to integrate new technologies; this includes the issues arising from the preparation of the migration phase from the traditional systems to IP Telephony based systems. Network assessments or upgrade, purchase of new equipments and users’ devices, and also trainings are such tasks that could seriously affect the decision to undertake this move. IP Telephony may also need to demonstrate that combining voice and data in a system is not adding complexity and reducing resilience, and that IT staff in ordinary companies can handle it as stated by some construction firms (Beyh & Kagioglou, 2004a).

The above discussion has therefore established the following statement:

> *The unique nature of the construction industry and the reluctance of its practitioners to change, may lead in most cases to the emergence of old practices affecting or preventing the diffusion of IP Telephony communications within the industry.*

4.1.4 Organisational Barrier

This issue begins with understanding the construction teams' communication requirements and the important role that such means could play in the conduct of the field's daily construction's operations (Baldwin et al., 1996; Bowden, 2002; Cavalli, 1998; Ng et al., 2001; Preece et al., 1998). Andersen (1992) notes that "*the construction industry and its employees are being impacted by technology. The industry is affected by the use of computers; fax machines, telecommunications, new products, equipment, and robotics. Demographics clearly indicate the lack of technological skills in the upcoming work force. The educational level of employees will need to be increased to meet these challenges. Current employees will need training, retraining, and cross training to keep abreast of new technology*". Bennett and Durkin (2000) further argue that organisational change significantly influences employee commitment to the organisation especially when the perceived values of the organisation have changed. Moreover, various situations or events occurring within organisations are shown to influence commitment levels among employees. One particular situation that has received a fair amount of attention is when an employee's work environment undergoes significant changes (Meyer & Allen, 1997). The empirical investigations conducted by Beyh & Kagioglou (2004a) conclude on the organisational issues by stating that:

> *Organisational change generally caused by the introduction of new technologies may be perceived as a serious threat to the employees' commitment to migrate to IP Telephony communications within the construction industry.*

4.2 Identification of the Roles of the IP Telephony Service Providers and Equipment Vendors

Internet Telephony Service Providers (ITSPs) and Equipment Vendors (EVs) appear to have a strong effect on the adoption process. However, their contribution to IP Telephony dissemination within the construction industry is conditioned by the following parameters:

- ITSPs and EVs should demonstrate a real interest to construction firms in terms of building open solutions that fit with their working environments. This requirement is due to the fact that IP Telephony may not be for everyone, particularly organisations that have basic phone systems and need only a phone to dial out and receive calls (Chan, 2003). In this case, generic applications may not be appropriate for this category of users.
- Most organisations may have made significant investments in their existing voice, video, and data networks which they naturally need to protect. Therefore, a low-risk migration path is required from the old world (i.e. traditional systems) to the new world of IP Telephony (Cisco, 2002). The role of ITSPs and EVs in this particular situation is to develop solutions that facilitate the deployment of/or transition to IP Telephony networking in mobile and difficult environments. Such transition should be transparent to the users. It is also important that equipment, handsets, dialling plans and services including voice messaging, call restrictions, call transfer, multiparty conferencing, etc. should be similar or even easier to handle, than those naturally used in the traditional systems.
- ITSPs and EVs must be more involved in designing specific solutions by taking into consideration the unique nature of the construction industry and the integration of the sites' tools such as wearable computers and similar advanced ICT applications (Miah et al., 1998). Steps could be further established around a collaborative working body, where joint participations from the construction industry along with ITSPs and EVs, could be able to define certain parameters for the integration.

4.3 Identification of the Enabling Process

Chiesa et al (1996) identified four core processes for the development of a Technical Innovation Audit model including Concept generation, Product Development, Process Innovation and Technology Acquisition. To support these processes, they further describe the integration of three Enabling Processes: The deployment of human and financial resources, the effective use of appropriate systems and tools, and senior management leadership and direction. They describe the outcome from these processes as performance in terms of innovation and the resulting competitiveness in the marketplace.

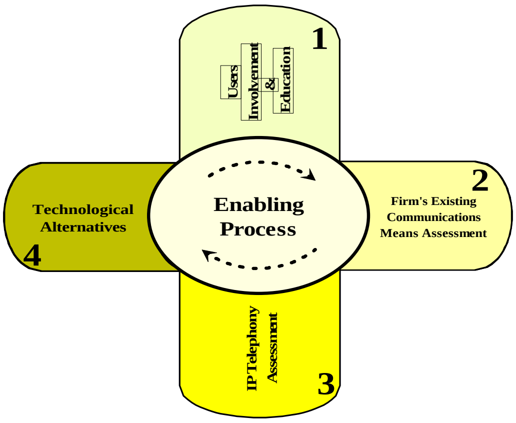

FIG. 8: IP Telephony Enabling Process

The process vs. check list (Kagioglou, 1999) involves organisational and cultural change where users' participation and education are fundamental for adopting new technologies. Drejer (2002) notes that most changes (i.e. social, economical and environmental) are directly caused by and/or related to the development, perception and use of technology. Such changes tend to transgress physical, organisational as well as disciplinary boundaries. Furthermore, four parameters where set out in the IPTCS Framework materialising the "Enabling Process" (Fig. 9) in order to accelerate the integration of IP Telephony in construction sites environment. This includes:

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

Each parameter dominates a specific part in the framework as described in the following sub-sections:

4.3.1 Users' Involvement and Education

By involving the users, at the very early stage of the integration of new technologies, a construction firm could build-up a strong interest amongst their teams to enable innovations. In doing so, the gaps between people and technologies could be significantly reduced and the fear of using/adopting such new technologies must progressively dissipate since the users could become familiar with the technologies' major strengths and weaknesses.

Noteworthy, IP Telephony like any other information technology, favours collaborative work between engineering disciplines where most of the challenges of human factors posed by their environment can be overcome by a series of team meetings during which the team jointly develop the project plan, including objectives, a detailed task network, schedule, resource and funding projections (Gunasekaran, 1999). The creation of such collaborative environment could contribute to a better understanding of the benefits of introducing new technologies, establishing integration, migration and transition plans, and maintaining strong optimisations of people and technologies alike. Hence, the involvement of the end-users should be seen as a systematic approach if there is to consider a continuous system's evaluation and communication network's sustainability within the construction organisations.

4.3.2 Firm's Existing Communications Systems/Means Assessment

The assessment and examination of the firm's existing communication systems aim at identifying the shortcomings as well as the strengths of the systems and tools in use by the personnel in the office and/or by the mobile teams on construction sites. Such assessment must be done in an effective way. By doing so, the authors suggest that, construction firms could be able to review and discuss communication issues they may have ignored in the past, and may raise questions about the capability of their existing systems. Questions as such could include but not be limited to the adequacy of the systems in terms of support to major construction teams' communications needs; systems availability and down-time ratios; issues of communicating with the entire supply chain; maintenance and running cost of existing systems, etc., and at this stage of the systems' examination, technical, financial and organisational questions should be debated in detail.

4.3.3 IP Telephony Assessment

The assessment of IP Telephony systems and the identification of its benefits, advantages and drawbacks should be naturally benchmarked with the firm's existing legacy systems. This assessment exercise aims at defining the roles upon which the interconnection between existing systems and the emerging IP telephony ones will be based (i.e. standards, interconnection, billing, etc.). It should also identify interoperability issues/parameters between equipments and services from different vendors in case that the construction organisations are tempted to integrate multiple types of IP Telephony systems. Construction firms should therefore allocate as much time and resources as it needs to perform such assessment of equipment, software, solutions and services with regards to several criteria such as interoperability, scalability, services availability, support and maintenance, training and knowledge transfer, and cost. It is an important requirement that the overall assessment should be made in a consistent and precise manner in order to avoid financial and technical mistakes where investments are likely to be made in the wrong technology.

4.3.4 Technological Alternatives

In general, the communication infrastructures are absent at the jobsites at the start of most construction projects. On the other hand, IP Telephony needs to run over packet-based networks such as ATM (Asynchronous Transfer Mode), Frame Relay or simply the Internet. However, on construction sites, these infrastructures are not always present. To overcome this issue, the IPTCS Framework suggests the design of a mobile IP Telephony Communication System to respond to such construction situations. Organisations could be able to easily and cost effectively build their Virtual Private Networks (VPN) over which, such mobile IP communication units could operate regardless of the distance and location of the remote construction sites. The development of such system is beyond the scope of this paper.

5 DISCUSSION & CONCLUSION

This paper has highlighted the traditional telecommunication means used in construction. Mobile communications is an emerging market with great potentials. However, construction firms have to consider these potentials according to their specific needs. Each of the traditional communication systems presented in this paper may provide the best solution in different circumstances but there are some key factors for a construction firm to consider prior to adopt a communication solution such as:

- Required communications means: Data, Voice and Video
- Number of entities and individuals that need to communicate together
- Nature of information to be transmitted
- Frequency of transmission: how often and when?
- Security
- Size and/or length of information
- Geographic coverage
- Site topology: Line Of Site (LOS) conditions for Microwave links,
- Cost of service
- Suitable devices (robust, waterproof, etc.) and their availability for the required tasks

Furthermore, COSMOS and MICC services (see sections 2.1 and 2.2) are both designed to respond to large construction projects communication needs. They are maintained and provided through telecommunication operators or service providers. The equipments installed at both construction sites and headquarters to run these services need dedicated technical personnel for operations and maintenance. Such situation can be associated to very high costs which may not be suitable for small or medium size projects. Moreover, construction firms could be internationally dispersed and projects may require international collaboration between the teams who need to exchange voice, data and video transmissions in a very intensive way. The achievement of such transmissions could be optimised through the integration of converged networks based on IP Telephony core components and architecture. In fact, construction sites could be seen as strategic fields to experience the benefits of using such advanced, affordable and rapidly deployable communication technology which is expected to progressively provide enterprises with myriad of new and enhanced services.

The paper has also described a framework for enabling the use of IP Telephony in construction environments. The IPTCS Framework (Internet Protocol Telephony on Construction Sites) uncovers the different barriers for implementation and provides important guidelines for the adoption of such a technology.

5.1 Future work

A Matrix based on critical implementation parameters and the findings of the empirical investigations conducted by the authors (i.e. technical, financial, organisational and cultural) will be progressively developed at the EPSRC funded Centre for Research and Innovation (SCRI) within the University of Salford to facilitate the integration of the IPTCS Framework into a construction context. The aim of the matrix is to determine whether a construction firm should implement IP Telephony or not. On the other hand, this would prevent technological clashes between the firm existing systems and those based on IP Telephony technology. To achieve the development, implementation and test of the Matrix, the authors will be seeking the collaboration with a number of construction firms, IP Telephony equipment vendors and telecommunication operators in the United Kingdom and other European countries. This phase of development is expected to commence during the second semester of the year 2004.

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LIST OF ACRONYMS

AMPS: Advanced Mobile Phone Service
DCS: Digital Cordless System
DECT: Digital Enhanced Cordless Telecommunications
GEO: Geostationary Earth Orbit satellite
GPRS: Global Packet Radio System
GSM: Global System for Mobile communication
IP: Internet Protocol
ITSP: Internet Telephony Service Provider
LEO: Low Earth Orbit satellite
PMR: Private Mobile Radio
PSTN: Public Switched Telephone Network

TETRA: Terrestrial Trunked Radio
UMTS: Universal Mobile Telephone System
VoIP: Voice over Internet Protocol
VPN: Virtual Private Network
WLAN: Wireless Local Area Network