CONSTRUCTION PROJECT CONTROL THROUGH WIRELESS NETWORKING

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_____

Prof. Dr. Canan Özgen
Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science.

_____

Prof. Dr. Erdal Çokca
Head of Department

This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science

_____

Assist. Prof. Dr. Yasemin Nielsen
Supervisor

Examining Committee Members

Assist. Prof. Dr. Metin Arıkan	(METU, CE)	_____
Assist. Prof. Dr. Yasemin Nielsen	(METU, CE)	_____
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ABSTRACT

CONSTRUCTION PROJECT CONTROL THROUGH WIRELESS NETWORKING

Köseoğlu, Oğuzhan Ozan

M.S., Department of Civil Engineering

Supervisor: Assist. Prof. Dr. Yasemin Nielsen

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In this thesis, the latest developments in mobile telecommunications and mobile devices are investigated in order to integrate wireless connectivity and mobile computing in construction industry core business processes on site. The research includes current technologies and implementation in the construction industry and other industries. Wireless solutions are presented in order to improve information flow, quality of data, control and coordinate business processes in construction companies. The Marmaray project in Turkey is used as a project case study to present the necessary investment and benefits gained by the contractors. This study investigates and seeks to eliminate the barriers on the way to integrate mobile technologies in the construction industry business processes.

Keywords: Wireless connectivity, mobile technologies, construction industry

ÖZ

İNŞAAT PROJELERİNİN KABLOSUZ İLETİŞİM YOLUYLA KONTROLÜ

Köseoğlu, Oğuzhan Ozan

Yüksek Lisans, İnşaat Mühendisliği Bölümü

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Bu tezde, inşaat sektöründe şantiyedeki temel iş akışlarına kablosuz erişim ve mobil bilgisayar kullanımını entegre etmek için en son gelişmiş olan mobil telekomünikasyon ve mobil cihazlar araştırılmıştır. Bu araştırma değişik çeşitte en son gelişmiş mobil teknolojileri ve endüstrilerdeki kullanım alanlarını içermektedir. İnşaat şirketlerindeki bilgi akışlarını, verinin kalitesini, iş akışlarının kontrolünü ve düzenlemesini iyileştirmek amacıyla kablosuz çözümler sunulmuştur. Türkiye'de

Marmaray projesini kapsayan, gerekli yatırımı ve müteahhitler tarafından kazanılan faydaları ortaya koyan bir uygulama çalışması yapılmıştır. Bu çalışma inşaat sektöründeki iş akışlarına mobil teknolojilerin entegrasyonu önünde bulunan bütün engelleri araştırmayı ve ortadan kaldırmayı hedeflemiştir.

Anahtar Kelimeler: Kablosuz erişim, mobil teknolojiler, inşaat endüstrisi

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LIST OF ABBREVIATIONS

AMPS	Analog/Advanced Mobile Phone System
AOC	Advice of Charge
AP	Access Point
BS	Base Station
BSC	Base Station Controller
BTS	Base Transceiver Station
CDMA	Code Division Multiple Access
CDMA 2000	Code Division Multiple Access 2000
CDPD	Cellular Digital Packet Data
CF	Compact Flash
DHCP	Dynamic Host Configuration Protocol
DoS	Denial of Service
DTMF	Dual Tone Multi-Frequency
EDGE	Enhanced Data Rates for Global Evolution
ETSI	European Telecommunications Standards Institute
1G	First Generation Wireless Technology
FDMA	Frequency Division Multiple Access
GHz	Giga Hertz
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communications
HSCD	High Speed Circuit Switched Data

ICMP	Internet Control Message Protocol
IEEE	Institute of Electrical and Electronics Engineers
IP	Internet Protocol
ISP	Internet Service Provider
IT	Information Technology
KB	Kilobyte
Kbps	Kilobit per second
LA	Location Areas
LAN	Local Area Network
MAC	Media Access Control
Mbps	Megabit per second
MB	Megabyte
MHZ	Megahertz
MITM	Man-in-the-Middle Attacks
MMS	Multi Media Messaging Service
MS	Mobile Stations
MSC	Mobile Switching Centre
NMT	Nordic Mobile Telephony System
PAN	Personal Area Network
PC	Personal Computer
PDA	Personal Digital Assistant
PDC	Packet Data Cellular
PSTN	Public Switched Telephone Network
2G	Second Generation Wireless Technology
2.5G	2.5 Generation Wireless Technology

RADIUS	Remote Authentication Dial-in User Service
RAM	Random Access Memory
RF	Radio Frequency
ROI	Return on Investment
SD	Secure Digital
SIM	Subscriber Identity Module
SMS	Short Message Service
TACS	Total Access Communication System
TDMA	Time Division Multiple Access
3G	Third Generation Wireless Technology
UMTS	Universal Mobile Telecommunications System
USB	Universal Serial Bus
UWC-136	Universal Wireless Communication -136
VPN	Virtual Private Network
WAN	Wide Area Network
WAP	Wireless Application Protocol
WCDMA	Wideband Code Division Multiple Access
WEP	Wired Equivalent Privacy
WLAN	Wireless Local Area Network

CHAPTER 1
1 INTRODUCTION

Construction is a multi-organization process with heavy dependence on communication between the parties inside and outside the organization. Project communication is becoming increasingly complicated and quick transfer of information is important from the project performance point of view.

Many construction businesses require flexibility of their personnel concerning the place and time today. Information technology and its products give the freedom of mobility to participants in the construction business. Mobile technologies and wireless connectivity can be used in construction sector in order to improve real-time data transferred during the business processes.

Mobile computing has witnessed a revolution over the last years, and many sectors now use mobile technologies and wireless connectivity. The purposes of using mobile computing are to share data instantly, reduce rework and paperwork, solve problems on site, construct accurate databases by timely and continuous collection of data, increase quality of information and decrease operational costs. However, in order to use mobile computing efficiently and effectively, mobile technologies and construction sector have to be investigated in detail. After this, the best suited technology can be used for the improvement of business processes in construction.

In this research, detailed technical information is given about the predominant mobile and wireless technologies available at the moment. Technologies and trends that can be expected to gain momentum in the near or medium future, such as 3G telecommunications and full convergence of cellular and wireless LAN, are also discussed. After the technical information, worldwide applications are explained in order to design a model for construction. The study then concentrates on integration of the information technology and mobile computing in the core business processes of construction, i.e. site processes. Detailed information is given about the construction industry and the application areas and scenarios of mobile computing and wireless connectivity.

After the detailed analysis of the mobile technologies and construction industry, the research continues with a case study, in form of the Marmaray project in Istanbul. In this case study, wireless local area network design and mobile computing in construction sites are proposed and evaluated for this particular project.

CHAPTER 2

2 MOBILE TELECOMMUNICATIONS

2.1 Mobile Phone System

The mobile phone system evolution started in the late 1970's. The efforts of Bell Telephone Laboratories resulted in development of the commercial Analog Mobile Phone System (AMPS). In this system and in the other cellular systems, geographic areas are divided into smaller areas called cells.

A Cell is the smallest unit of the mobile phone system where there is radio coverage by a particular cellular phone system. The size of the cell varies according to the geography and the number of mobile devices which are planned to be used in the cell. Cells in cities are constructed to be smaller than rural areas. Because when population density increases the number of the mobile device increases. For this reason, cells become overcrowded. To prevent this, more cells has to be constructed in cities. (Wireless Devices, Steward & Mann)

A cell site is the point from which signals are broadcast into a cell. There are four important components that allow mobile communications:

- Mobile Stations (MS)
- Base Transceiver Station (BTS)
- Base Station Controller (BSC)
- Mobile Switching Center (MSC)

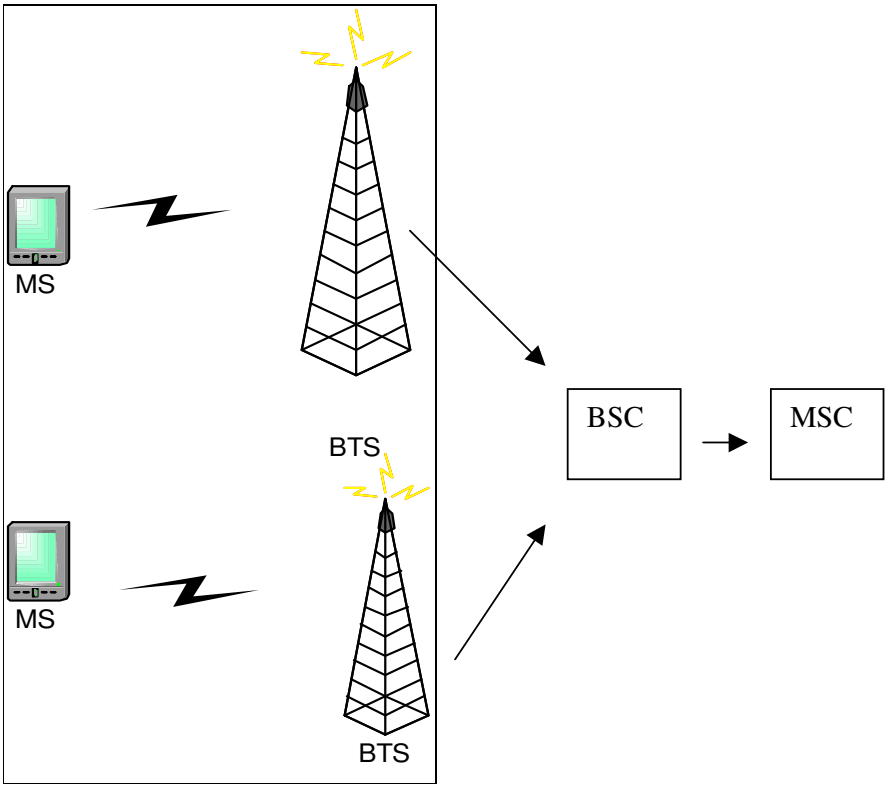


Figure 2-1 Mobile System Architecture (GPRS and 3G WirelessApplications- Christoffer Andersson)

Base Transceiver Station (BTS) is located at the cell site and composed of radio station and antennas that communicate with wireless devices.

Mobile Switching Center (MSC) is a facility which connects to Base Station Controller in order to control the switching between base stations and also acts as a connection between the cellular system and fixed telephony infrastructure.

‘ Handoff ‘ is one of the most important processes of cellular networks. During handoff the wireless device automatically switches from its current channel to a stronger channel in another cell. Handoff process works on these five steps:

- During the movement of the wireless device, the signal for the channel it is using starts to fade.
- The BTS communicating with the wireless device detects that the signal is fading and ask for handoff.
- The MSC determines which BTS has the strongest signal from the wireless device.
- MSC assigns the wireless device to the new BTS and gives a new link for device to use.
- The wireless device switches channels and begins to communicate with the new BTS in the new cell.

2.1.1 First Generation Wireless Technology (1G)

During the early and mid-1980s First Generation Wireless Systems started to be used. The two important characteristics of 1G system are analog modulation and circuit-switched technology.

1G system was designed to carry voice signals, which are analog. The systems connected to the Public Switched Telephone Network (PSTN). PSTN is an analog system which is used in every home or office today.

Switching is the other important characteristic of 1G system. In circuit switched system connection is set up between the transmitter and receiver. This connection is remained for the duration of communication. The PSTN is a circuit switched system. For this reason, 1G system is designed to be convenient with the regular telephone system.

1G system is used to carry voice signals. Analog modulation and circuit switching has some disadvantages to carry voice data:

- In circuit switching, users are billed according to their connection time.
- Wireless devices are digital devices. For this reason, converting signals form digital to analog in the device is an inefficient way.
- Transferring data is slow in 1G system.

2.1.1.1 Advanced Mobile Phone System (AMPS)

Advanced Mobile Phone System is an original cellular system which is used most part of the world. AMPS is used in United States mostly. AMPS was started to be used nearly twenty years ago. It has been successful in United States, Canada and Mexico.

AMPS is developed by AT&T Bell Laboratories in 1983. It is a 1G wireless system. AMPS is an analog modulation and circuit switched system. The spectrum division of AMPS is Frequency Division Multiple Access (FDMA). Its frequency is between 824-894 MHz.

FDMA divides the available radio spectrum by frequency. There are multiple communication channels. These multiple channels are using different frequency band. Each user gets one channel for the entire call time.

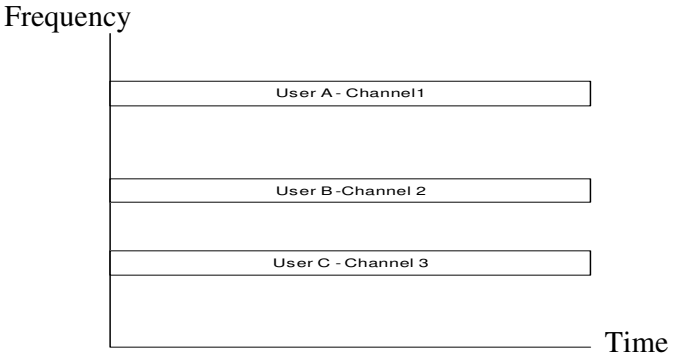


Figure 2-2 Relationship between bandwidth, time and users in FDMA (Steward & Mann–Wireless Devices)

In United States, there is a complete coverage of AMPS. For this reason, phone call can be made in anywhere by using an AMPS mobile phone. However, AMPS standard does not have enough security.

2.1.1.2 Nordic Mobile Telephony System (NMT)

Nordic Mobile Telephony System was developed by Ericsson and Nokia and started to be used in 1981. NMT was used in Denmark, Finland, Norway, and Sweden as the 1G standard cellular phone system. Moreover, it has been deployed more than 40 countries.

NMT has two versions. The original version is called NMT 450 which is operating on a frequency 450 MHz. The new version is NMT 900. This version operates on a frequency of 900 MHz. Importantly, NMT was the world's first cellular network which allows communication between countries.

NMT is an analog modulated and circuit switched system. The spectrum division of NMT is FDMA. The fist version of NMT 450 was found in 1981 and later version was found in 1986 by Ericsson & Nokia.

2.1.1.3 Total Access Communication System

Total Access Communication System called as TACS was developed in the 1980s by Vodafone. TACS basically depends on AMPS. The difference between the two system is their frequencies. TACS operates in the 900 MHz range instead of the 800 MHz range.

TACS is a 1G system which has analog signal type and circuit switched system. The spectrum division of TACS is FDMA.TACS is still in use today.

However, Second Generation technology is mostly used today's communication world.

2.1.2 Second Generation Wireless Technology

First Generation Technology has some shortcomings, such as, limited system capacity for users, poor voice quality, and limited ability to carry digital data are the most important deficiencies of the 1G system. However, a 1G technology like NMT showed that mobile communications can be extremely useful for a wide audience and also clearly demonstrated advantages of communication over international borders. For these reasons, companies have made some improvements on 1G and also developed a new technology called 2G.

1G technologies use analog encoding to carry voice messages. All sounds in nature are analog. Analog encoding seems reasonable from this point of view. However, digital encoding allows faster, more accurate and more efficient data transfers by using less bandwidth. By digital encoding the analog sound level is measured and converted into the binary numbers. These binary numbers are transmitted over the wireless network digitally and when they reach the destination, they are converted into analog form to be heard by the person.

2.1.2.1 Time Division Multiple Access (TDMA)

TDMA, also known as D-AMPS, is a 2G upgrade technology of the 1G AMPS technology. TDMA is widely used in United States. TDMA devices can be used in places where there is AMPS coverage without any TDMA coverage need. This means the wireless device will work on the 1G mode. TDMA divides the

available radio spectrum by time. Each TDMA channel can work with multiple different devices. Several users can share the channel in TDMA. In FDMA, one channel is used by only one user at a given time .However, in TDMA the capacity of the network for the user increases.

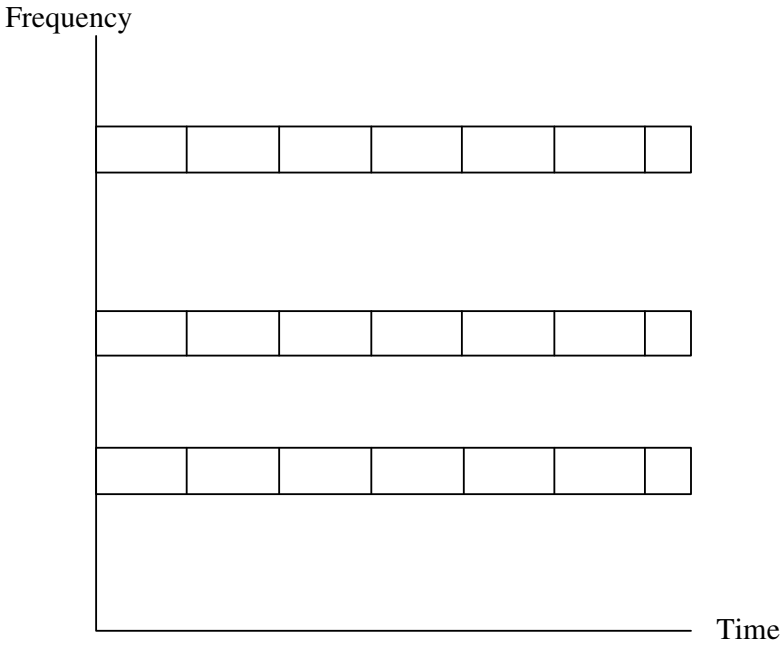


Figure 2-3 TDMA technology (Relationship between users, time and Frequency)

Each rectangular row is named as channel. It can be easily seen that there are 3 channel and 21 users totally. (Source: Wireless Devices, Steward and Mann)

TDMA is developed by Ericsson in 1991. TDMA is a digital, circuit switched technology. It is operating on the 824-894 MHz frequency band and this technology has 9.6 Kbps data transfer rate.

2.1.2.2 Global System for Mobile Communication (GSM)

GSM (Global System for Mobile Communications) was designed to support basic voice and data services. GSM resembles TDMA and FDMA in some cases. GSM is a digital technology and an important technology all around the world. GSM works by dividing the available radio spectrum into different channels like in FDMA technology. Moreover, GSM technology divides each channel into eight time slots in order to be used by eight users at the same time.

GSM technology was developed in 1991 by European Telecommunications Standards Institute (ETSI). This technology operates in three different frequency bands:

- GSM 900 (890-960 MHz)
- GSM 1800 (1710-1880 MHz)
- GSM 1900 (1850-1990 MHz)

GSM 900 consists 124 paired channels, GSM 1800 consists 374 paired channels, and GSM 1900 consists 299 paired channels. Each channel can be used by eight different users .GSM 1900 is mostly used in United States.

GSM networks have coverage area which means providing communication over that geography. This geographic area is defined by using four different levels:

- Cell
- Location Area
- Mobile Switching Centre Areas
- Public Land Mobile Network Area

Cell is the smallest area and each cell is supported by a single Base Station (BS). Every device in the network has an identity number and subscriber identity

module (SIM) in order to communicate in GSM. SIM card is inserted into the mobile device and by using identity numbers communication can be achieved.

Location Areas (LA) are composed of group of cells which are controlled by at least one BS. However, LA is controlled by only one Mobile Switching Center (MSC).

Mobile Switching Service Area consists of one or more location areas. The Public Land Mobile Network Service Area is the largest area in GSM network. This area is total geographic area where GSM network support voice and data communication.

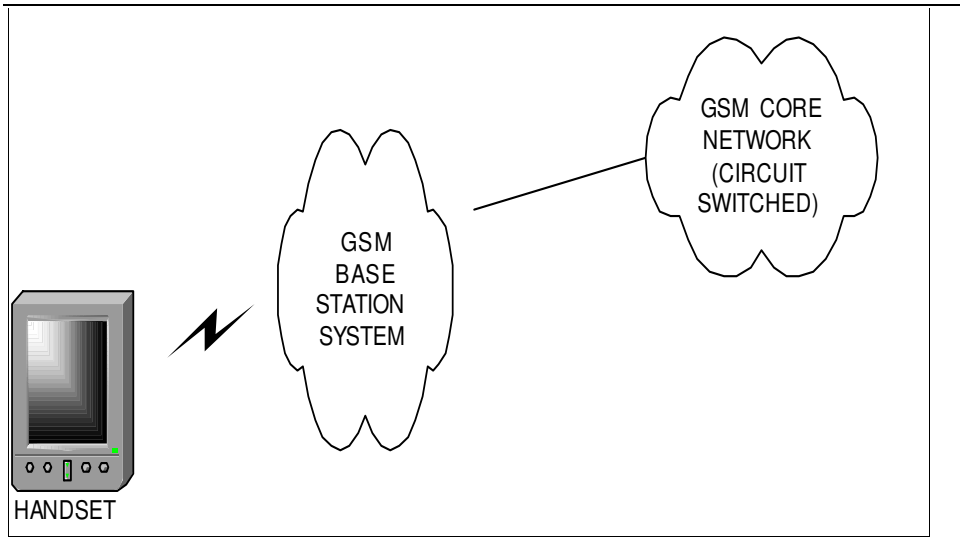


Figure 2-4 Architecture of original GSM system (The UMTS Forum , 2003)

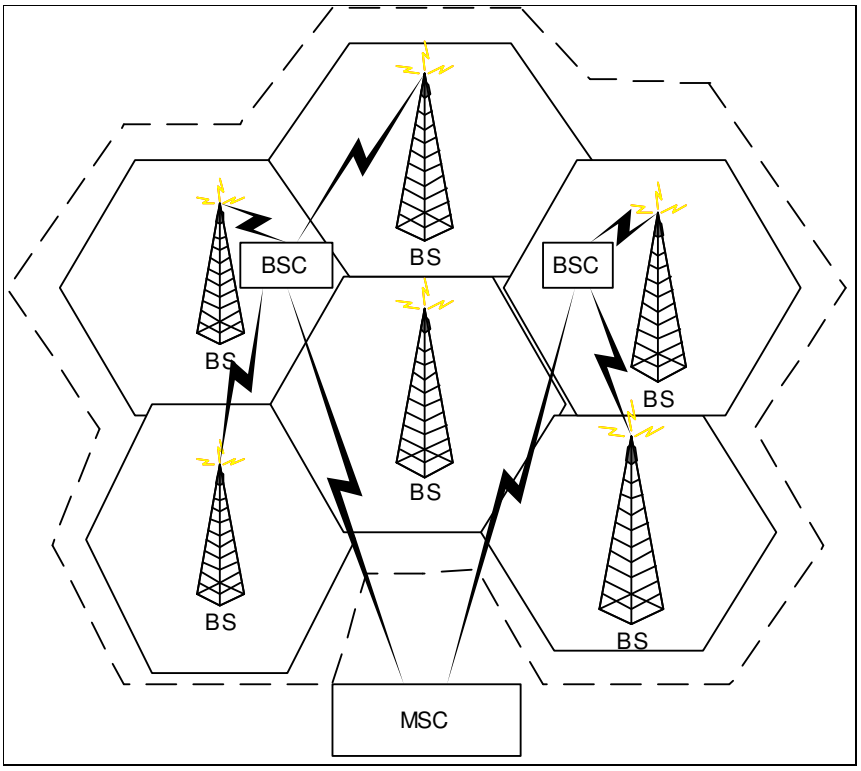


Figure 2-5 GSM Location Area which consists of several cells and all controlled by a single mobile services switching center (MSC). (Source: Wireless Devices, Steward and Mann)

2.1.2.2.1 Services Provided By GSM Systems

There are two types of services which are supported by GSM systems.

- Subscriber Services
- Supplementary Services

2.1.2.2.1.1 Subscriber Services

- **Basic Voice Telephone:** This service includes standard voice telephone service.
- **Emergency Calling:** An emergency call can be made taking bandwidth priority away from other non-emergency calls.

- **Cell Broadcast:** By using this service, user can send a (93-character) short text message to everyone within a particular cell. Cell Broadcast is mainly used for traffic warnings, weather reports and daily news.
- **Dual Tone Multi-Frequency (DTMF):** DTMF service is used in order to control devices, such as home answering machines.
- **Fax Mail:** This service enables users to store faxes in a GSM service center and send them at any fax machine.
- **Short Message Service (SMS):** SMS is the one of the most popular services in GSM. Short messages are limited to alphanumeric 160 characters in length. Characters can be words and numbers. SMS service provides delivery confirmation.
- **Voice Mail:** Voice messages for the user can be stored in a voice mailbox in the GSM network.

2.1.2.2.1.2 Supplementary Services

- **Advice of Charge (AOC):** Estimation of the charges for a particular call is given to the user by this service.
- **Barring of incoming calls:** This service avoids the mobile device receiving calls.
- **Barring outgoing calls:** This service allows users to prevent making phone calls.
- **Call Hold:** This service is used to hold the voice calls during the call time.
- **Call Waiting:** By using this service, another call waits until the other call finishes.

- **Multiparty Service:** This service allows users in order to make phone calls in a group together. Group is composed of 3 users at least and 6 users at most.

2.1.2.2.2 Today's GSM

After the launching of the first GSM networks, it became the world's leading and fastest growing mobile network technology. GSM technology is used more than 1 billion subscriber across the 190 countries of the world today. Moreover, GSM maintains worldwide the leadership being the most secure public wireless network in the world. During the last two years, 75% of the new mobile subscriptions were GSM. (Source: Global Mobile Suppliers Association)

The SIM (Subscriber Identity Module) has played an important role in the success of GSM. A SIM card per user allows the mobile operators to control billing and other information about their customers.

The top 20 mobile operators of the world were classified according to their revenues and 19 of them are using GSM networks.(Source: Global Mobile Suppliers Association)

SMS service has an important role in GSM network. Today, over 1 billion SMS messages are sent daily by subscribers around the world. In UK, over 70% of mobile subscribers use their mobile devices in order to send text messages. (Source: Mobile Data Association). The below figure shows the SMS growth between January 2000 – January 2003 around the world:

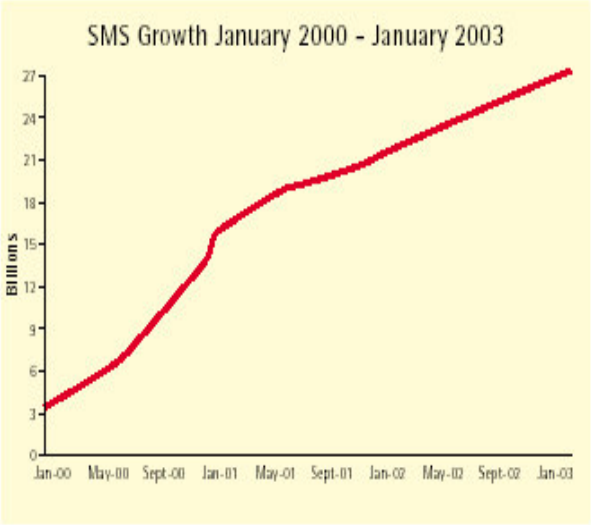


Figure 2-6 SMS Growth (Source: GSM Association)

2.1.2.3 Code Division Multiple Access

Code Division Multiple Access (CDMA) was developed by Qualcomm in 1993. CDMA is a second generation wireless standard. CDMA technology uses digital signals, packet switched and spread spectrum technology. Code Division Multiple Access (CDMA) has many advantages over FDMA (Frequency Division Multiple Access) and TDMA (Time Division Multiple Access) because of its technology. These advantages are:

- Higher security level
- Using bandwidth more efficiently
- Fewer dropped calls

FDMA and TDMA technology is straightforward. However, CDMA is more difficult to understand. CDMA uses digital signals like GSM technology. Moreover, CDMA uses spread spectrum technology to modulate the digital signal. Spread

spectrum technology was first developed for the United States military in 1940s when the military wanted to build a secure radio communication system for the armed forces.

In the below figure, non-CDMA system divides the bandwidth into seven separate group of channels. However, in CDMA all base stations and devices use the same channel.

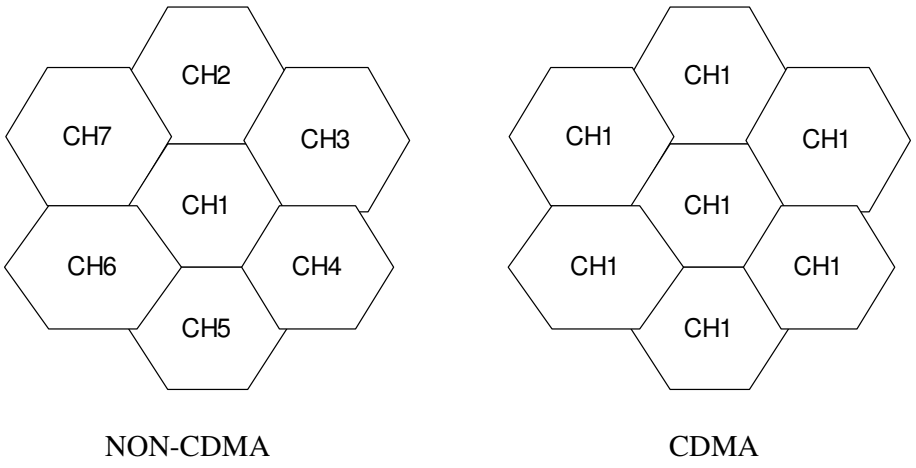


Figure 2-7 CDMA uses a single channel for the all base stations and devices in an area. (Source: Wireless Devices, Steward and Mann)

In a CDMA system, every user transmits the signals on the same frequency. CDMA can serve eight to ten times more users than AMPS in a frequency band and two times more than GSM network. CDMA systems use soft handoff, while the other systems use hard handoff. During the hard handoff in the other systems, call may drop. However, in CDMA spread spectrum technology reduces the tendency to drop calls during handoff from one cell to another.

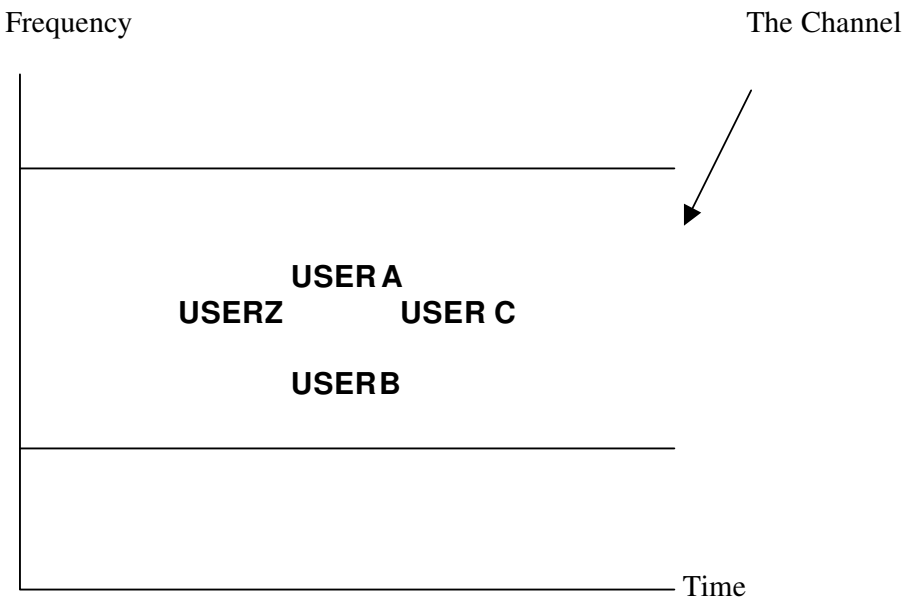


Figure 2-8 Relationship between bandwidth, time , and users in CDMA (Wireless Devices-Steward and Mann)

2.1.2.4 Cellular Digital Packet Data

Cellular Digital Packet Data (CDPD) is a digital technology which can be deployed on AMPS and TDMA networks at relatively little cost. Wireless e-mail and World Wide Web access are the major benefits of CDPD. In United States, AMPS operators made CDPD available in their networks. This is known as Wireless IP (Wireless Internet Protocol). CDPD was developed by the member companies of the Wireless Data Forum (WDF).

CDPD carries digital data on the analog AMPS network. The combined system both carries analog and digital data. CDPD uses packet-switching technology. CDPD must take digital data, divide into packets and move those packets across the AMPS network. By this way, CDPD carries more digital data load on top of AMPS. Mobile device using CDPD does not use the channel for the entire time it is active.

Device uses the channel only when it is sending a packet. The rest of the time channel can be used by the other CDPD users.

2.1.2.5 Statistics of Market Share

Figure 2.9 shows the market share of 2G networks in April 2003. As seen from the graph, market share of GSM has increased 4% during three years time .CDMA has increased nearly 0.4%. However, TDMA and PDC have decreased during this time .In 2003, TDMA had 9.4% market share and PDC had 5.2% market share. This graph shows that GSM is the leading 2G network around the world. Total number of subscribers in April 2003 was nearly 1 billion.

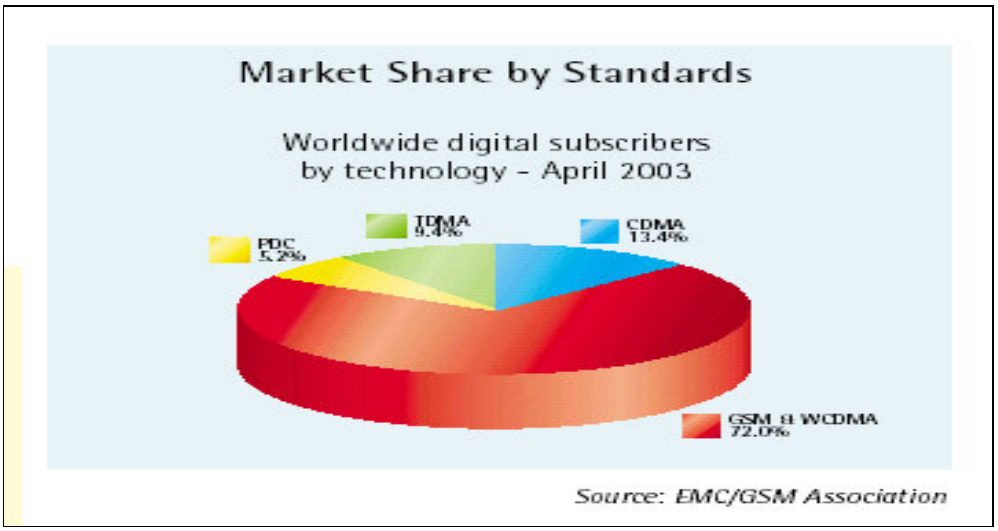


Figure 2-9 Worldwide digital subscribers by technology-April 2003 (UMTS Forum)

2.1.3 2.5 Generation Wireless Technology

During the last few years, phone companies and telecom operators have spent tens of billions dollars in order to buy third generation wireless technology (3G) licenses given by the national government. These licenses enable to provide

wireless services in a specific frequency band and in a certain geographical area. However, some of the companies went bankrupt while trying to pay the huge amounts of money. Some of the companies did not go bankrupt, but because of the economic slow down in telecom sector they could not afford to build their third generation network. For these reasons operators developed 2.5 Generation Wireless Technology (2.5G) in order to find out a cheaper solution.

2.5 G technologies were built on the existing 2G networks. These technologies have some benefits which will be used in 3G wireless technology, such as faster data transfer, enabling internet connection and continuously being on service. High Speed Circuit Switched Data (HSCD), General Packet Radio Service (GPRS) and Enhanced Data Rates for Global Evolution (EDGE) and IS-95B are 2.5G technologies. They were all designed to work on GSM networks due to its popularity all around the world as a 2G standard.

2.1.3.1 High Speed Circuit Switched Data

High Speed Circuit Switched Data (HSCD) was developed in 2000. HSCD based on GSM network and uses circuit switched technology. HSCD technology allows users to get higher data rates on existing GSM networks by using a PC card or HSCD data terminal. However, HSCD is a short term solution for the need of high speed data transfers on GSM networks. GSM divides each channel into eight time slots. By this way .GSM allows eight simultaneous users per channel. Every user gets 9.6 Kbps (kilobit per second) of bandwidth on that channel. HSCD enables a mobile device to use three time slots. The data rate became three times as much as GSM data rate and it reaches 28.8 Kbps.

HSCD is a circuit-switched technology. For this reason, the available bandwidth is consistent over the time of connection. HSCD is billed by the connect time just like in GSM network.

2.1.3.2 General Packet Radio Service (GPRS)

The General Packet Radio Service (GPRS) is a new service enabling information to be sent and received across a mobile telephone network. GPRS was developed in 2000. GPRS is a connection link between GSM and 3G wireless services and works on the existing GSM network. GPRS provides data transfer rates three times faster than GSM networks. Theoretical maximum speeds of 171.2 Kbps can be achieved by GPRS.

GSM is a circuit-switched technology. However, GPRS is a packet-switched technology. In circuit-switched, there is a dedicated circuit from wireless terminal to base station for the duration of a call. In packet-switched, data is returned to little packets and each packet is transmitted individually. GPRS packet-switching enables the network to carry more users and provide higher data transfer speeds. Moreover, GPRS has two major benefits. First, GPRS wireless terminal can be continuously online and connected to the network. Second benefit is the availability of internet access. However, GPRS is not fast enough to display video and can not display all of the web pages. On the other hand, wireless users had full access to the internet for the first time by using GPRS.

GPRS has some technical benefits. Moreover, it has some financial benefits. For example, in GSM networks, users charged for the total connection time to the network. However, in GPRS users are billed on for the data transfer not pay on the

basis of the connection time. Even though GPRS is not very cheap, billing per kB is more suitable and the mobile user therefore gains flexibility due to this billing application. However, some flat-rate billing schemes in Turkey (fixed fee per month) have been very cheap, but with a low quality service.

2.1.3.2.1 Applications for GPRS

GPRS provides different types of non-voice applications to users in order to improve the data transfer. These applications are:

- **Chat:** GPRS allows mobile phone users to develop chat groups on the internet by using their mobile devices.
- **Textual and Visual Information:** A wide range of information can be sent to mobile phone users such as sport scores, weather, news headlines, traffic location, share prices and so on. This information can be maps, graphs or visual information.
- **Still Images:** Photographs, pictures, postcards, greeting cards and presentations can be sent and received over the mobile phones by using GPRS. This service is called Multi Media Messaging Service (MMS) today.
- **Moving Images:** Using GPRS, moving images can be sent or received over the mobile phone.
- **Web Browsing:** Users can reach the internet web pages and their e-mail addresses by using the GPRS.

2.1.3.3 Enhanced Data Rates for Global Evolution (EDGE)

Enhanced Data Rates for Global Evolution (EDGE) bases on the GPRS network in order to improve the performance and efficiency of the network. EDGE was developed in 2001. EDGE is packet-switched and transfer data at 384 Kbps speed. EDGE is the last mile between the 2.5G and 3G and designed to use the same channel and time slot structure as GSM. EDGE allows the existing networks to move data faster and to use the available channel more efficiently.

Upgrading the existing GPRS network in order to build EDGE is relatively simple. An EDGE transceiver must be added to each cell and the base station software must be updated to work with that transceiver. There is no huge amount of investment in order to use EDGE network on the base of GSM and GPRS networks.

2.1.3.4 IS-95B

IS-95B is the 2.5G version of CDMA. The most significant difference between CDMA and IS-95B is speed. CDMA has maximum data rate of 14.4 Kbps. However, IS-95B can send and receive data at rate of 65 Kbps. IS-95B works on the existing CDMA network and it was developed in 1999. There is no need to replace the wireless phones in order to communicate in IS-95B network. Equipment used in CDMA networks can be used in IS-95B. This leads to less investment, but more speed.

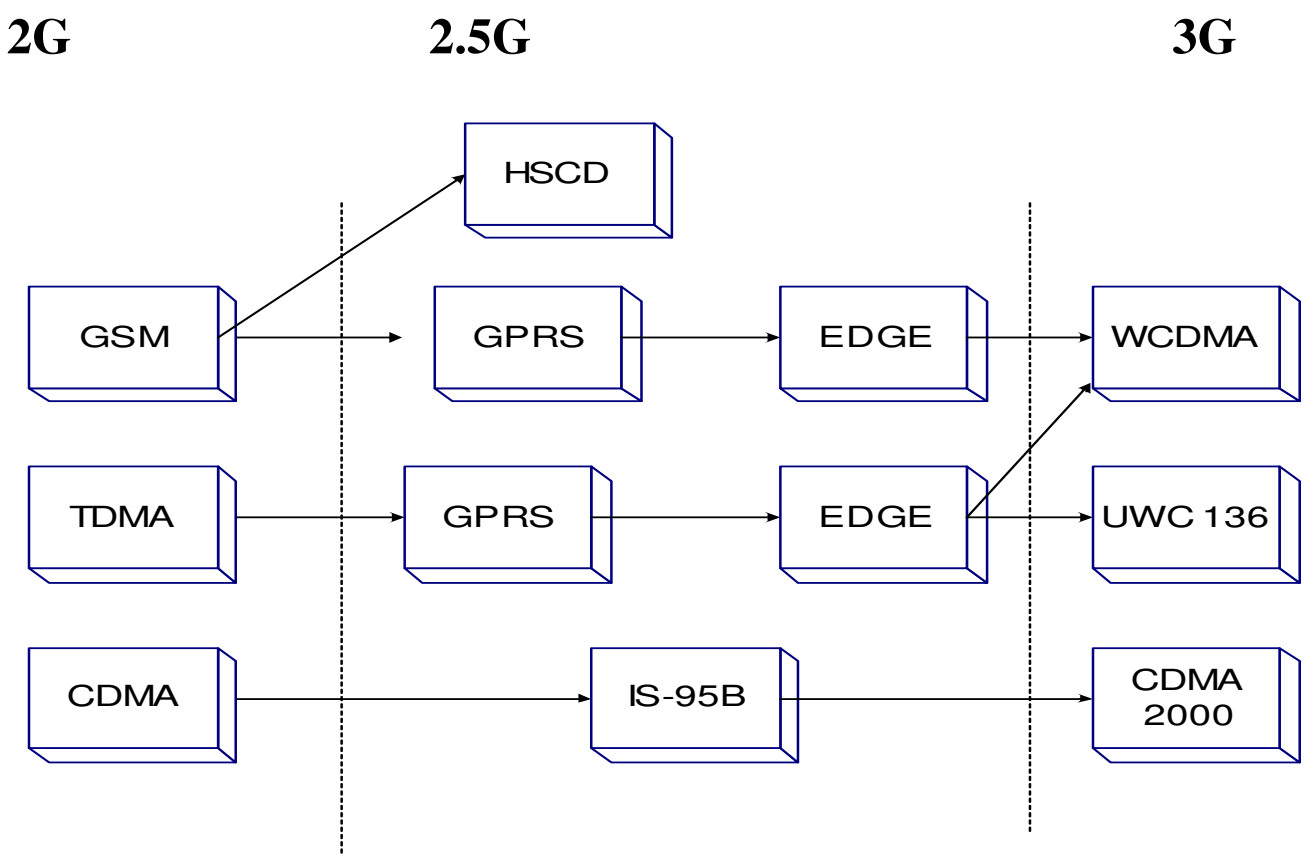


Figure 2-10 Path from 2G to 3G (Wireless Devices –Steward and Mann)

2.1.4 Third Generation Wireless Technology (3G)

Third Generation Wireless Technology (3G) includes 3G, 2.5G and 2G functionalities. Third Generation is based on CDMA. However, today's GSM technology was based on TDMA technology. Video on demand, high speed multimedia and mobile internet access are the important features of 3G. 3G services connect the wireless world with the internet world. Moreover, the data transfer rates are much faster than the existing networks. (GSMWORLD)

The 2G systems in use today transfer data at around 10 Kbps. 2.5G systems rate changes from 28.8 Kbps to 144 Kbps. 3G systems will be the faster one and the bottom data rate will be 384Kbps . Moreover, the top rate for 3G will be 2Mbps. In 3G systems, packet switched technology will be used. By this way, the mobile terminals will be connected to the network all the time. (Wireless Devices-Steward& Mann)

2.1.4.1 Wideband Code Division Multiple Access (WCDMA)/ Universal Mobile Telecommunications System (UMTS)

UMTS is Europe's name for 3G. UMTS and WCDMA are the same technologies, but they have different names. UMTS/WCDMA is a 3G technology which GSM would evolve into. This technology enables user to do same things in 2G and 2.5G wireless technology faster, efficiently and with new possibilities. For most of the 1.2 billion customers UMTS/WCDMA is the Third Generation Mobile technology.(UMTS Forum-2003, Wireless Devices-Steward& Mann)

WCDMA can transfer data at rates up to 2Mbps. Moreover, a WCDMA base station allows up to 10 times the traffic capacity compared with GSM. On the

other hand, the capital expenditure for the WCDMA network is 20%-30% less than the GSM network capital expenditure in the initial coverage phase. In terms of base station sites, 60% fewer sites are needed to achieve initial voice coverage and 40%fewer are needed for data coverage. For these reasons, WCDMA technology is a cheaper and effective alternative than 2G. (UMTS Forum-2003)

2.1.4.2 Universal Wireless Communication -136 (UWC-136)

Universal Wireless Communication is the only non-CDMA 3G standard. UWC-136 is a TDMA technology designed to provide connection to 3G for AMPS and GSM. UWC-136 adapts GPRS and EDGE technologies to TDMA systems and at the end, it will make 3G speeds and capabilities available. UWC-136 enables packet-switched data transfer rate to user up to 43.2 Kbps.

2.1.4.3 Code Division Multiple Access 2000 (CDMA 2000)

CDMA- 2000 is the preferred 3G solution for networks which are based on CDMA. CDMA 2000 requires only minor upgrades to network and small capital investment. CDMA 2000 handsets are compatible with the CDMA networks. This is an important advantage for the CDMA 2000 users. They do not need to change their mobile handsets. In CDMA 2000 technology, data transfer rate changes from 153 Kbps to 3 Mbps. CDMA 2000 does not require any new spectrum. It is designed to operate in existing cellular networks. (CDMA Development Group)

CDMA 2000 has the ability to support both voice and data services. Because of its technology, CDMA 2000 allows operators to invest in fewer cells and increase return on investment. Operators are looking forward to decrease their capital

investments during the construction of the new networks. CDMA 2000 and CDMA technology are the most efficient technologies from this point of view. (CDMA Development Group)

2.1.4.4 3G History and Crisis

There are number of stages before 3G services become established. These include standardization, infrastructure development, network trials, contracts placed, network roll out and availability of terminals. (GSM World)

The below table shows the history and stages for 3G:

Table 2-1 Timescale for 3G (GSM World)

DATE	**MILESTONE**
Throughout 1999	3G radio interface standardization took place, and initial 3G live demonstrations of infrastructure and concept terminals shown.
2000	Continuing Standardization with network architectures, terminal requirements and detailed standards.
2000	3G licenses are awarded by governments around Europe and Asia.
2001	3G launched in Japan by NTT DoCoMo
Summer of 2001	First trial 3G services become available in Europe.

Start of 2002	Basic 3G capable terminals begin to be available in commercial quantities.
Throughout 2002	Network operators launch 3G services commercially and roll out 3G.
2002/3	New 3G specific applications greater network capacity solutions, more capable terminals become available.

Third Generation (3G) mobile phone system was available in the year 2001/2. The aim for 3G is to unify the second generation wireless networks in order to develop a common standard.

Reasons for the uncertainty of 3G concepts and development: (GSM World)

- Form of mobile communications is radically changed. Many people do not understand how to make money in the non voice world.
- 3G licenses have been awarded around the world at huge costs by many governments.
- 3G is based on a different technology which is called Code Division Multiple Access (CDMA). However, 2G is based on Time Division Multiple Access (TDMA).
- Many industry experts have questioned the return on investment in 3G technology. The main point is to earn more than the capital deployed during the license acquisition and network roll out.

Another important point for 3G networks is billing strategy. The structure of 3G networks is fundamentally different from existing architecture. To create efficient

3G billing systems, operators must take all these factors into account: (International Telecommunications, March 2001)

- 3G uses packet-switched technology which means users are always connected and online.
- The expansion of the services and capacity will prevent the future overcrowding in today's second generation networks.

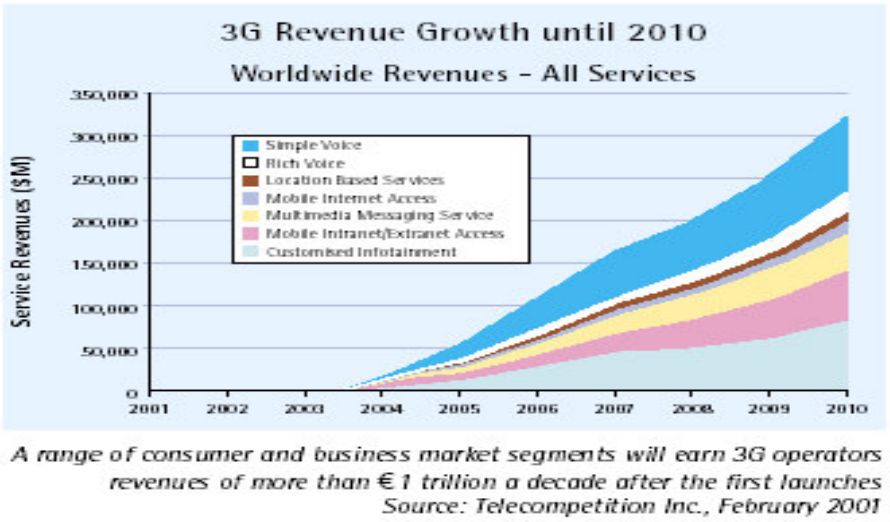


Figure 2-11 3G Revenue Growth until 2010 (UMTS Forum)

From top to bottom: Simple voice, Rich voice, Location Based Services, Mobile Internet Access, Multimedia Messaging Service(MMS), Mobile Intranet/Extranet Access, Customized Infotainment(news, sport results).

2.2 Bluetooth Networking

The growing demand for mobile networking, in 1994, the Swedish telecommunications manufacturer Ericsson began researching the possibilities of a low-cost, low-power, wireless means of communications between mobile phones and

other mobile devices. Ericsson's technology could replace the cables and communication could be achieved by the radio signals. This technology is called 'Bluetooth' today.

Bluetooth technology provides point-to-point connection and point-to-multipoint connection. In point-to-point connection, the communication is between the two devices. However, in point-to-multipoint connection, the communication channel is shared by several Bluetooth units.

In Bluetooth networking, small number of units can communicate with each other at any given time. These small groups are called 'piconets'. Piconets consist of one master unit and up to seven active slave units. There can be several piconets on a physical area and members of the various piconets communicate with each other. This larger network is known as 'scatternet'. Each unit in a piconet can communicate with the other unit in the other piconet as long as being master for only one piconet at the same time. (Bluetooth, Bakker & Gilster)

Bluetooth technology provides fast and secure voice and data communications. The range for connection is up to 10 meters and line of sight is not required .The major benefits of Bluetooth from the consumer point of view:

- Cable Replacement
- Low-cost wireless network solution
- Low power consumption
- Global Compatibility
- Instantaneous and transparent connections

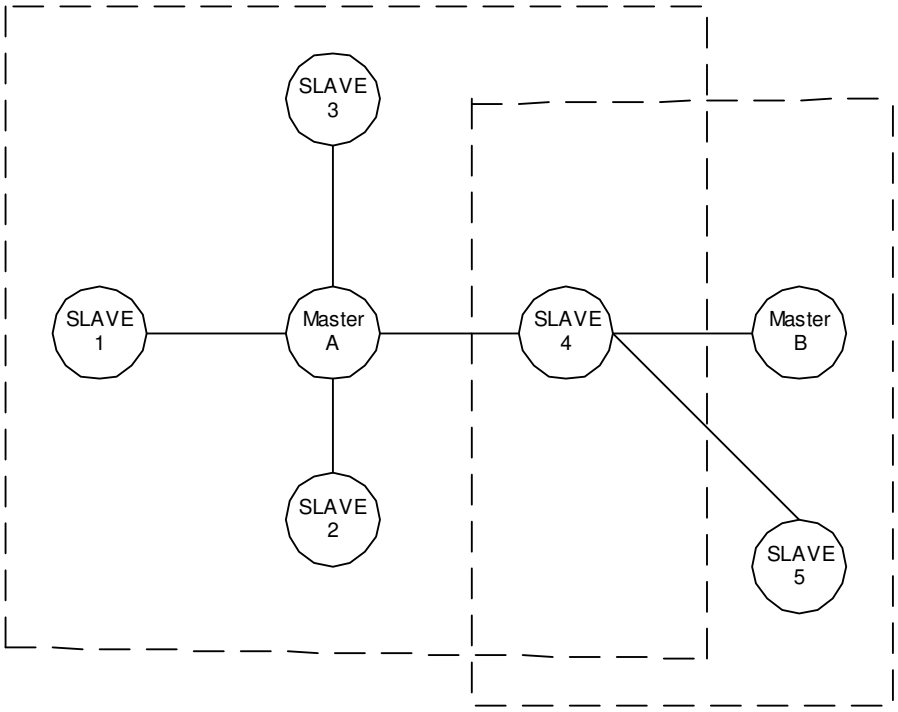


Figure 2-12 Piconets and Scatternets (Bakker & Gilster)

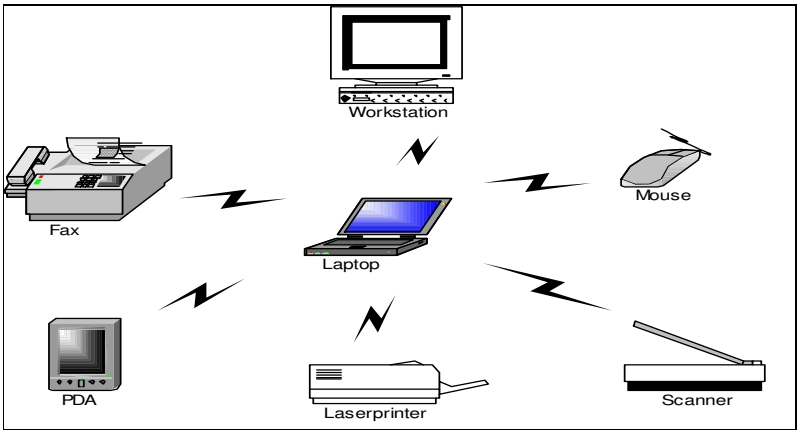


Figure 2-13 Cable Replacement

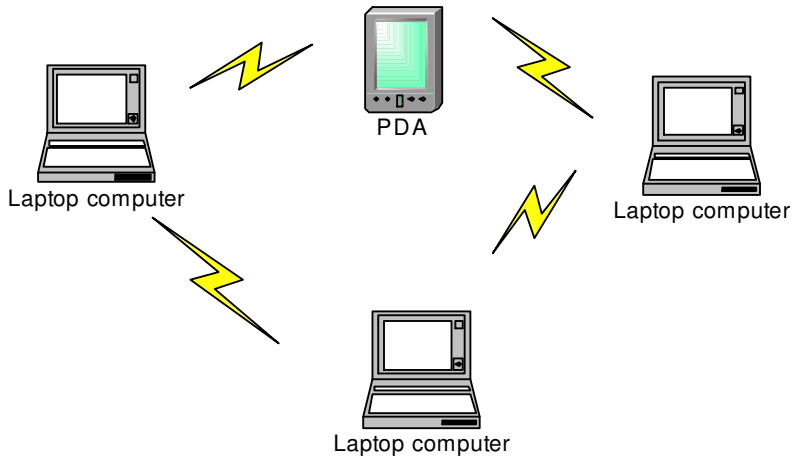


Figure 2-14 Peer-to-Peer Networking

Bluetooth technology solved the line of sight and cabling connection by using radio frequency technology to transmit data. Bluetooth uses base band transmissions. The base-band converts digital and voice data into formats that can be transmitted using a radio signal. (Bluetooth, Bakker&Gilster)

2.2.1 Bluetooth Products

Bluetooth technology is growing rapidly and various Bluetooth products were developed for consumers. Bluetooth products can add to an existing device in order to enable Bluetooth connectivity. These add-on products are:

- PC Cards
- USB adapters
- Memory Adapters
- Phone Adapters

Bluetooth PC cards are used in laptop computers. Each Bluetooth card contains radio, related electronics and antenna. The user of the computer has to insert PC card into slot on the side of the PC in order to enable Bluetooth functionality.

USB adapters are used for the same purpose, as PC cards. However, USB adapters are produced for the hardware configurations, including desktop PCs and printers.

Memory Adapters which is known as Compact Flash (CF) cards are commonly used in digital cameras and handheld computing devices. Phone Adapters are used for mobile phones in order to add Bluetooth functionality.

Bluetooth technology has some disadvantages, such the short range and the limited data transmission rate. Bluetooth range is up to 10 meters and theoretical data transfer rate is 1Mbps. (Bluetooth, Bakker & Gilster)

2.2.2 Bluetooth Usage

Bluetooth solutions create benefits for the corporations and their employees. These solutions increase the productivity and efficiency. Bluetooth technology increases the mobility of the workers. By this way, workers are not restricted with the wires. Some important global companies FedEx, Coca-Cola Australia, UPS and Palm are investing in Bluetooth technology in order to increase employee productivity and flexibility. (The Official Bluetooth Website)

Bluetooth has some limitations from the transfer rate and range point of view. Despite its limitations, Bluetooth's acceptance is growing and is predicted to increase through to the year 2007. Telecommunication companies in the United States and Europe are expecting to generate $12 billion in revenue by 2006 (Bluetooth Revenue,

2002) as a result of their investments. (The Second International Conference on Mobile Business)

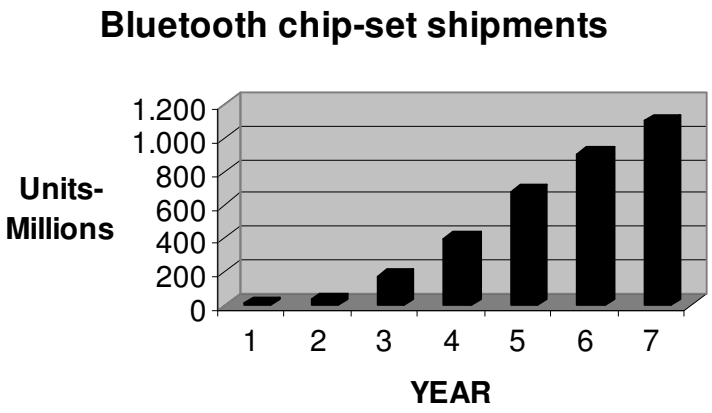


Figure 2-15 Bluetooth chipset shipments world market ,2001-2007 (www.global.umi.com ,Second International Conference on Mobile Business)

2.3 Wireless Local Area Networks (WLANs)

A network consisting of computers which are found in the same physical area is called local area network (LAN). A network which connects computers in an organization regardless of being in the same physical area is called wide area network (WAN). A local area network which uses wireless technology in order to connect computers in the network is called wireless local area network (WLAN). (Wireless LANs, Bruce& Gilster)

2.3.1 Network Components

The most common network components are workstations, servers, bridges, switches and routers.

- **Workstation:** A computer which is connected to the network.
- **Servers:** A network server is a computer which provides services to the other network computers. There are different types of servers in the networks. Some of the important ones are:
- **File Server:** This type of server controls the storage devices such as hard disks.
- **Print Server:** A computer or any other device that controls printer or printers.
- **Mail Server:** Computer which contains a system for sending e-mail to the network users on a network.
- **Application Server:** Computer which provides the software for the computers in the network.
- **DHCP Server:** Dynamic Host Configuration Protocol server automatically assigns an internet protocol address to computers on the network.
- **Hub:** A device in the network which receives signals from the computers on the network and sends signals to the computers.
- **Bridge:** Network Bridge is used to connect different networks in different buildings or in different floors.
- **Switch:** Data is sent over the network in packets. Each packet contains the address of the computer which the data is received. Switch reads the address and sends the packet to the correct destination. Switch acts as a filter to eliminate unnecessary network traffic.
- **Router:** A router in the network reads the address information in each packet and communicates with other routers using the Internet Control Message

Protocol (ICMP) to determine the best destination for each packet. (Wireless LANs ,Bruce& Gilster)

2.3.2 WLAN Components

A wireless LAN (WLAN) is a flexible data communication system as an alternative for a wired LAN in a building or campus. WLANs transmit and receive data over the air by using electromagnetic waves. (Wireless LAN Alliance)

Wireless network components are:

- **Wireless Stations:** Every computer or device that transmits or receives data over the wireless network is called station.
- **Access Point:** An access point is a device whose purpose is to receive radio transmissions from other stations on the WLAN and send them to the wired network.
- **WLAN Adapters:** Users access the WLAN trough their wireless LAN adapters. These adapters are inserted as PC cards in notebooks or PCI adapters in desktop computers, or integrated devices within handheld computers. (www.wlana.com)

2.3.3 WLAN Configurations

There are two types WLAN configurations:

- Independent WLAN
- Infrastructure WLANs

2.3.3.1 Independent WLANs

Independent WLAN configuration is the simplest one which connects a set of PCs with wireless adapters. There is no need to use access points. Two or more wireless adapters within range of each other are used in order to set up an independent network. (www.wlana.com)

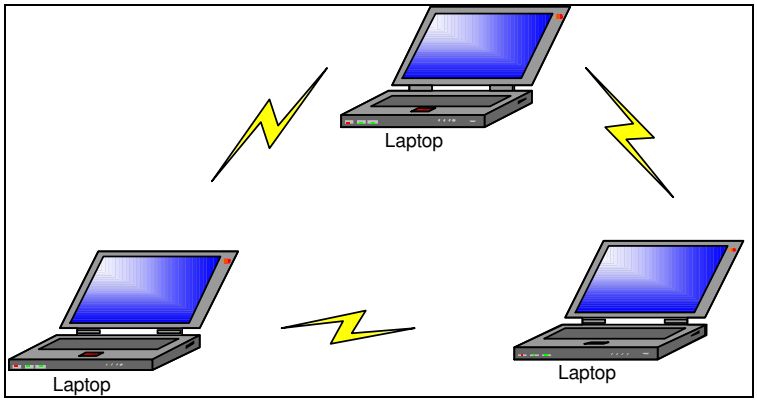


Figure 2-16 Independent WLAN

2.3.3.2 Infrastructure WLANs

In Infrastructure WLANs, many access points link the wireless network to the wired network and in this system, users can share the network resources efficiently. Access pints provide the coverage area for the wireless network in private home, an office floor, a building or in a campus.

Wireless Local Area Networks are sized according to number of access points. WLAN uses cells called microcells. Microcells in the wireless local area networks are similar to the cells in the mobile phone networks. For this reason, when the communication area increases, number of access points increases.

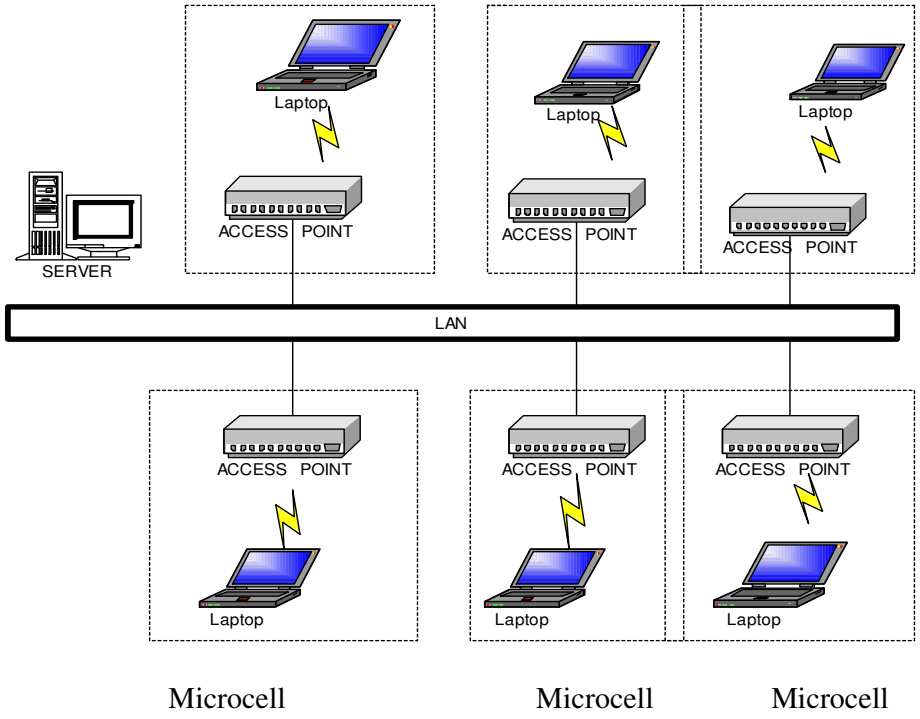


Figure 2-17 Infrastructure WLAN

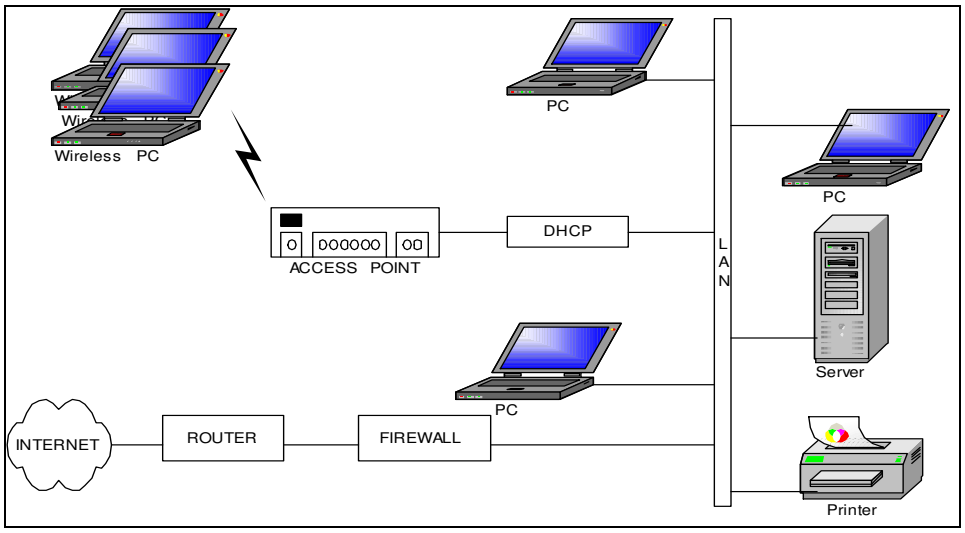


Figure 2-18 A typical WLAN (Wireless LANs, Gilster&Bruce)

2.3.4 WLAN Standards

There are a lot of organizations which exist in order to develop standards. However, two of them have the most important impact on wireless technologies. These are Institute of Electrical and Electronics Engineers (IEEE) and the European Telecommunications Standards Institute (ETSI). IEEE 802 is the standard for wireless local networks and it was developed by IEEE. The 802.11 standard defines the relation between wireless stations and their network access points. Three important WLAN standards exist all around the world. These are IEEE 802.11b, 802.11g and 802.11a.

The most widely available 802.11 standard currently is the b standard .Many of today's new notebooks are designed with 802.11b standard. Data transfer rates of 802.11b is up to 11 Mbps. 802.11b uses the 2.4 GHz radio frequency (RF). The 802.11a standard is a developing standard that costs 30 percent more than 802.11b. It uses the 5 GHz radio frequency, with a maximum data transfer rate of 54 Mbps.

Table 2-2 Comparison of Wireless LAN Standards (Intel IT White Paper, May 2003)

Characteristic	**802.11b**	**802.11g**	**802.11a**
Spectrum Type	2.4 GHz	2.4 GHz	5.2 GHz
Spectrum Congestion	High	High	Low
Performance	11 Mbps	54Mbps	54Mbps
Maximum Throughput	6 Mbps	22 Mbps	30-35 Mbps
Cost	Low	Low	Moderate
Non-Overlapping channels	3	3	12
Coverage	100 meters	100 meters	50 meters

2.3.5 WLAN Design

WLAN design is the most important part before using the wireless local area networks in the corporate networks. IT department has to investigate the needs of the company and establish a network according to the budget and break down structure of the business processes. IT department must benefit from IT tools as efficient as possible. The investment and the return on investment must be compared before the installation of the technology. For this reason, two important steps exist before the investment:

- Site Survey
- Choosing WLAN equipment

2.3.5.1 Site Survey

The most important reason to perform site survey is to define the coverage area and network size. The survey must analyze these concepts:

- Signal Coverage
- Network Capacity
- Radio Frequency
- Power Requirements

Signal Coverage in the network area is tested in order to establish the connectivity in the network and the number of access points. However, signal coverage is affected by various factors: (Wireless LAN, Bruce& Gilster)

- Linear distance from the access point(AP)
- The power of the access point
- Antennas on the access points and on the stations

- Construction Materials used in the walls, floors, and ceilings.
- The shape of the building and network area.
- Location of the area and the rooms in the building.
- Physical objects which have been added by the employees.

Another important point in the survey is the network capacity. Network capacity is determined in order to establish the number of wireless stations which will access to the network. The following information has to be obtained from the company:

- The number of users
- Organizational Structure
- Software Usage
- Expected Company Growth
- Type of Network Services (File Servers, Printers and etc.)

There is an increasing demand for devices which work with radio frequency electromagnetic waves to transmit information wirelessly. Before the investment on the wireless local area network, secure radio frequency transmission has to be tested around the network area.

The last important concept is the power requirements of the wireless devices on the network. Enough power has to be supplied to the network in order to avoid the failures in the network system. Otherwise, if there is any power failure occurs at the workstations, this situation leads to inefficient usage of the network and from the return on investment point of view, company lose money and working time.

2.3.5.2 Selecting WLAN Equipment

Selecting WLAN equipment is the last step before the network installation .IEEE 802.11b is not the only wireless standard, but it is currently most widely used standard around the world and this standard is supported by vendors which produce wireless equipment for the networks. Today, in the market 802.11b is available in the market, but in the future other standards will be more available due to their transfer speeds. The wireless local area network equipment consists of:

- Access Points
- Network Adapters for Stations(PC cards, PCI cards, USB adapters, Compact Flash cards)

Access point is the most necessary device of the wireless local area networks. Access points are the most expensive components of the wireless networks. The price of access point varies between $150 and $1500. Before the installation and investment, these has to be determined and established by the consumer: (Wireless LAN, Bruce& Gilster)

- Total Cost of Access Points
- Security
- Range and Coverage
- Availability of Technical Support
- Ease of installation, set up and maintenance

Network Adapters are used in order to connect the radio frequency link between the stations and the access points. These adapters are available in many types:

- PC cards(used mostly in notebooks)
- PCI cards(used in desktops)
- Universal Serial Bus (USB) Adapters (connected externally to the computer)
- Compact Flash Cards(used for PDA and handheld devices)

2.4 Mobile Devices

Technology is developing rapidly. During this development, mobile devices which are used in wireless networks as terminals become smaller and more complicated. The vendors produce new models and each model has more effective properties than the older models from the user point of view. The most important wireless terminals used in wireless networks are:

- Mobile Phone
- Laptops
- Personal Digital Assistant (PDA)
- Pocket PC
- Tablet PC

2.4.1 Mobile Phones

Mobile phones are the terminals of the mobile phone architecture. Mobile phones have similar properties as the wired telephones such as having earpiece, speaker, and call indicator. However, mobile phones have different properties and technological options from the wired phones. These are: (Wireless Devices, Steward & Mann)

- **Call Logs:** Allows the user to view missed calls, received calls, and call lengths.
- **Multiple Call Rings:** Most of the mobile phones enables the user to download ring tones.
- **Menu Navigation Keys:** All mobile phones have navigational menu for displaying options such as phonebook, messages, settings, etc.
- **Battery Indicators**
- **Text Messaging:** All phones in the market provide short messaging service.(SMS)
- **Color Display**
- **Voice-activated dialing:** Some phones have this option. By this technology, user can dial the number with his speaking.
- **Music Devices:** Some of the mobile phones include musical CD player.
- **PDA options:** New mobile phones provide PDA options such as detailed contact information, scheduling calendar and calculator.
- **Games**
- **Java applications:** Some mobile phones manufacturers are using Java in order to create different kinds of entertainment.

- **Connectivity:** Some mobile phone can be connected to the PCs, other phones and mobile devices by using the Bluetooth technology, serial port and infrared connections. By this way, data can be shared between the mobile phones and other mobile devices.
- **Web and E-mail Access:** By using the GPRS technology, mobile phones can access to internet. This direct access is called Wireless Application Protocol (WAP). Phones that can access the internet sites are called WAP-enabled.
- **Hands-Free:** Bluetooth or wireless headsets are used for hands-free. By using headset, user can answer the calls without touching the phone.
- **Camera and Multimedia Messaging:** High technology mobile phones provide taking photos to users and by using the multimedia messaging service(MMS) users can share the photos with the other users.

Figure 2-19 Nokia 7700 (www.nokia.com)

Features of 7700 are:

- High resolution LCD display
- Touch screen , pen based with input stylus
- On-screen keyboard

- Handwriting Recognition
- Camera, Music Player, Bluetooth, MMS
- 20-25 MB of internal memory available for contacts, text messages, multimedia messages and images.
- Memory can be upgraded up to 128 MB
- E-mail access
- Wireless Connectivity with PC
- Data transfer using EDGE, GPRS, HSCSD

2.4.2 Personal Digital Assistant (PDA)

Personal Digital Assistant (PDA) is a handheld digital organizer which stores contact information and allows users taking notes. PDA is basically used for information management. PDA has following functions: (Wireless Devices, Steward& Mann)

- **Contact Management:** New PDAs allow using e-mail, telephone options without need of any device.
- **Information Retrieval:** PDAs are used to store and retrieve information by the professionals. Today's PDAs can hold data more than 16 MB.
- **Daily Finance Management:** People use PDAs in order to keep individual financial records.
- **Mobile Conferencing:** A PDA user can participate in a conference with the other parties on the web. The mobile PDA user can demonstrate a power point presentation or distribute images on the web.

- **Vehicle Locator:** Companies which have mobile transportation can use PDAs in order to monitor locations of the vehicles and daily job reporting.
- **Network Data Access:** Mobile employees of companies can share information by using PDA over the secure network connections.

The largest PDA producer is PalmOne. Palm's latest model is explained briefly.

Tungsten C has the following features: (PALM official web site)

- Personal organizer
- Word, excel, powerpoint
- Music player
- Voice recorder
- Built-in digital camera
- Built-in voice communications
- Wireless Connectivity(Bluetooth, GSM,GPRS,WLAN)
- 64 MB memory
- Intel 400Mhz processor

Figure 2-20 Tungsten C (www.palm.com)

2.4.3 Pocket PC

Pocket PC has many types of wireless device options. The properties of the Pocket PC are much more similar to the notebook computers. Pocket PCs have large and clear full-color screens. They have larger memories than the PDAs. Some PDA manufacturers develop their own programs, but unlike Palm models which use PalmOS, Pocket PCs use a version Windows as the main software. Programs and applications such as calendar, contacts, notes, excel, word, outlook, internet explorer are all loaded onto the Pocket PCs by the manufacturers. Pocket PCs can be used in the wireless networks by using add-on cards. Today, manufacturers produce devices which have Bluetooth technology and WLAN 802.11b standard. By this way, Pocket PCs can be used in the mobile networks in companies. Using the device, mobile user can access to the corporate network, internet and share data with network users over the internet or WLAN.

The latest model of Compaq is a good example of the new technology Pocket PCs. Features of the HP iPAQ Pocket PC h5550 are:

Figure 2-21 iPAQ 5550 Pocket PC(www.compaq.com)

- Integrated 802.11b WLAN and Bluetooth technology
- Integrated biometric fingerprint reader enhances protection of device, information and network connection.
- 128 MB random access memory (RAM)
- Microsoft Windows Mobile 2003 Software for Pocket PC
- 400 MHz Intel Xscale Processor

2.4.4 Tablet PC

The latest development of the mobile computing is Tablet PC. Computer manufacturers work on the PC designs which are more lightweight and mobile. The outcome of these researches is Tablet PC. Features and the properties of the Tablet PCs are:

- Similar to a small laptop, comfortable, lightweight design holds like a book and it can be used during sitting or standing.
- Long battery life provides using in different environments for long time.
- No barrier between the user and the others .Information can easily be shared with the person nearby.
- User can use own handwriting on the screen. This leads to drawing figures, sketching and using the PC as a worksheet.
- Tablet PC gives the user freedom of movement.
- Integrated Bluetooth and WLAN 802.11b technology enable to be used in wireless networks.

Figure 2-22 Tablet PC (Compaq official site)

2.5 Wireless Security

Wireless technology gives users the freedom of mobility, more options to connect networks and capability of connect different devices to networks. However, wireless technology has more risk than the wired networks from the security point of view. For this reason, in order to design secure networks, the threats must be realized .By this way, networks can be protected from these attacks. Some of the important threats are: (Wireless Security, Maxim& Pollin)

- Uncontrolled Terrain
- Eavesdropping
- Communications Jamming
- Injection and Modification of Data

- **Uncontrolled Terrain:**

In wireless networks, there are uncontrolled coverage areas between the end points of the network. This enables the attackers to perform number of attacks to the network.

- **Eavesdropping:**

In the open and uncontrolled wireless networks, the most known problem is the unknown attackers. The unknown attacker can mix the radio signals and decode the data being transmitted. These attacks are nearly impossible to detect. Use of antennas enables the attacker to get into the system from a considerable distance away. Eavesdropping is used to obtain information about the network under attack. The basic aim is to understand the user of the network, what is accessible, what the capabilities of the equipment on the network are and what the coverage area is. This information is needed in order to attack on the network. The following figure illustrates the eavesdropping of the attacker: (Wireless Security, Maxim& Pollin)

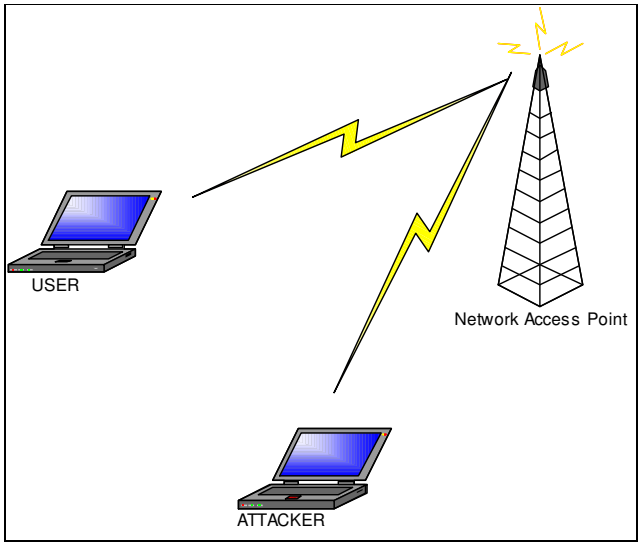


Figure 2-23 Wireless Attacker Eavesdropping on Wireless Communications

- **Communications Jamming:**

Communication link between the user and the network becomes useless when jamming occurs. Jamming the entire network can cause a denial of service (DoS) attack. The entire communication area, including base stations, access points is affected. This attack shuts down all communications in a given area. There are two types of jamming. One is the user jamming and the other is the access point or base station jamming.

In the user jamming, the user loses the connectivity and can not access the network. However, in the network access point jamming, the jamming affects the services of the users and the revenue of the telecom company. (Wireless Security, Maxim& Pollin)

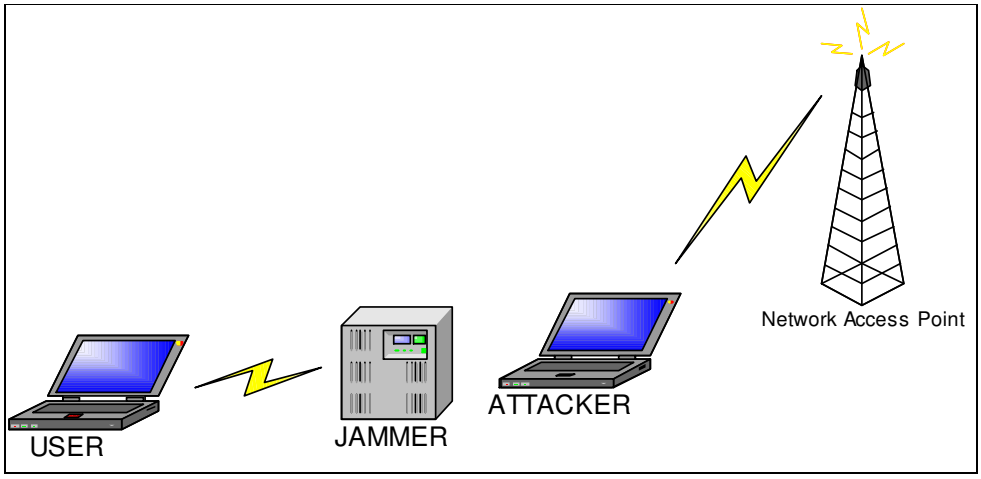


Figure 2-24 User Jamming

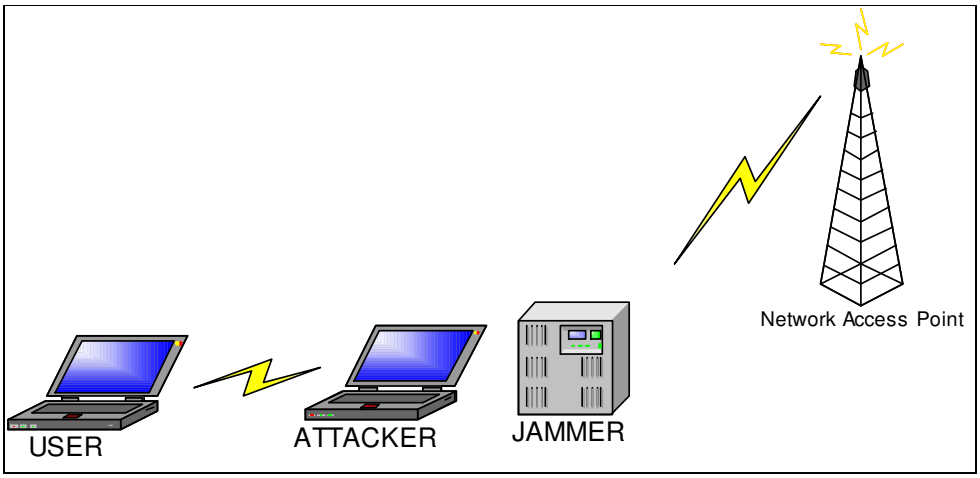


Figure 2-25 Base Station Jamming

- **Injection and Modification of Data:**

Injection attacks occur when the attacker adds data to an existing connection in order to break down the network. An attacker can control the data streams between the access point and the user by inserting packets to the user or access point. Injection attacks are similar to the Man-in-the-Middle Attacks (MITM). In the figure below, the attacker is in the position to inject data and modify communications.

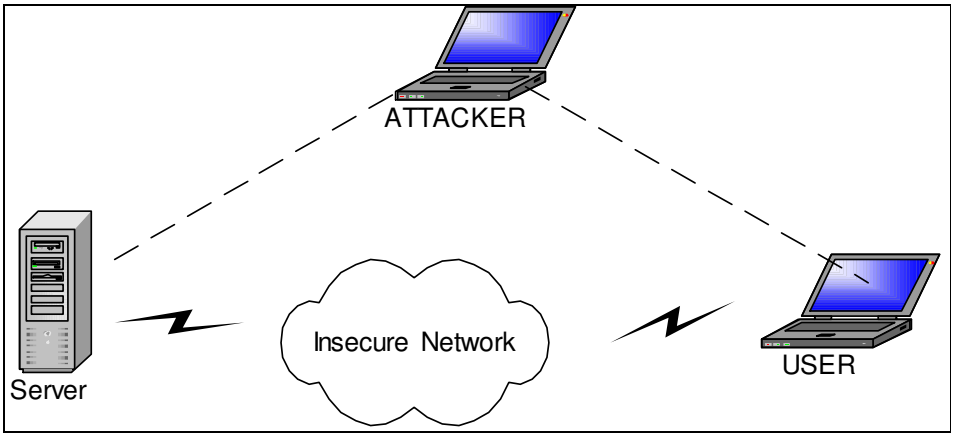


Figure 2-26 MITM attack (Wireless Security, Maxim& Pollin)

2.5.1 Security of WLAN

802.11 has provided some basic security mechanisms to prevent the effects of the potential threats. The existing 802.11 standard includes two techniques in order to secure the wireless networks: (Wireless Networks Security, Intel IT, and May 2003)

- Media Access Control (MAC) address filtering
- Wired Equivalent Privacy (WEP)

Access Points can be configured for MAC filtering, so that only users with MAC addresses are allowed into the network.

Another security protocol which is provided through the 82.11 standards is WEP algorithm. This algorithm provides protection against eavesdropping. WEP is technology for encrypting data sent between wireless stations.

These protocols may not be useful in all conditions .The items listed below are the possible precautions that can be applied:

- Place internal firewalls between the wired LAN and WLAN
- Change passwords and Internet Protocol addresses
- Prevent radio frequency leakage outside the area
- Change WEP encryption keys often
- Combine WEP with Virtual Private Networks (VPNs) for more effective protection. A virtual private network enables users on an insecure network, such as the internet or a WEP-based 802.11 WLAN, to make up a secure connection with the network.

- Establish an authentication dial-in user service (RADIUS) server on the wireless network. The RADIUS server controls and verifies the validity of the users before entering the network.

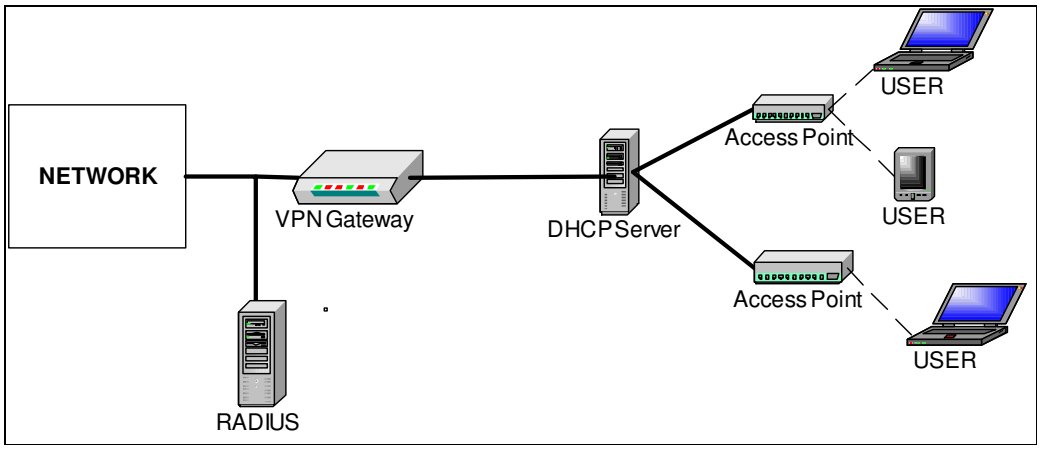


Figure 2-27 WLAN including VPN and RADIUS (WLAN Security, Intel IT)

2.5.2 Security for Wireless Devices

Another important security issue is storing data on wireless devices securely. During the design stage of the wireless devices, the possibility of the wireless devices falling into the wrong hands must be considered. The storage capacities of the wireless devices are gradually increasing and this enables the users to store huge amounts of important data. For these reasons, password-protection systems can be used by the manufacturers in order to prevent the information leakage. However, these systems can be defeated by using different types of computer programs. New technology is developing rapidly and manufacturers produce efficient backup systems for the mobile computing devices. Users can use the backup systems in order to be on the safe side when the mobile computing device

is stolen. Briefly, users have to use the wireless devices very carefully and for being in the most secure position, they must not lose their devices.

CHAPTER 3

3 WIRELESS USAGE

3.1 Wireless LAN Users

Wireless Local Area Networks (WLAN) has gained popularity in a number of different sectors, including education, health-care, manufacturing, warehousing, financial, etc. Organizations in these sectors are searching for an increase in user productivity and IT team productivity. Today, WLANs are becoming widely recognized and the market is approaching $ 1 billion revenues in U.S (Wireless LAN Alliance)

Listed below is a brief list describing the application areas and user profiles of WLANs: (Wireless LAN Alliance)

- Warehouse workers use WLANs in order to exchange information with central database and increase their efficiency.
- Doctors and nurses in hospitals use mobile devices to deliver patient information and share with the database of the hospital over WLAN.
- Students in university campuses use wireless connections in order to access information.
- Executive Managers in corporations can make quicker decisions due to the real –time available information.

Research conducted by Cisco Systems in May 2001 gives information about the wireless LAN use and users profile in U.S. There is a figure below showing the market penetration of wireless LANs by sector. This survey results are included in order to figure out the difference between the past and today.

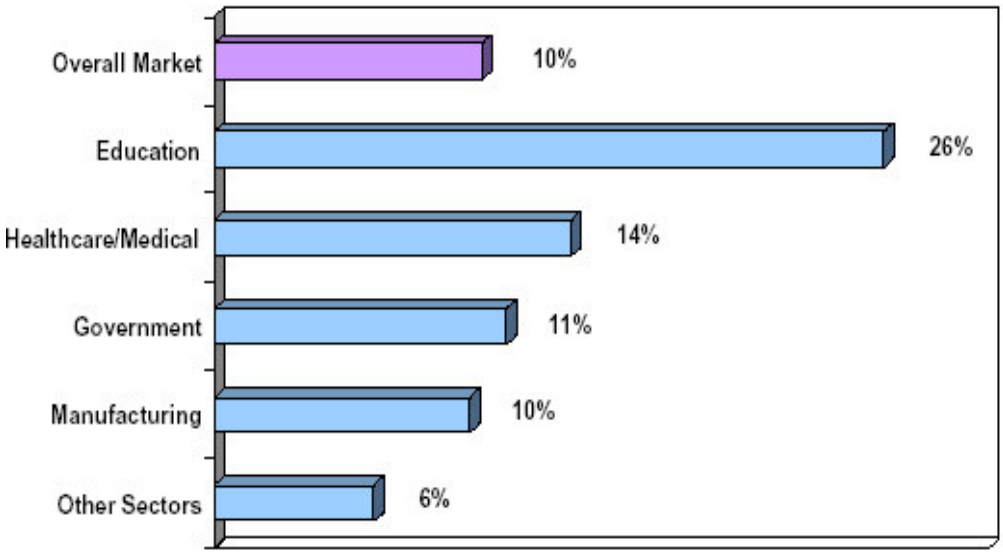


Figure 3-1 Market Penetration of Wireless LANs by sector (WLAN Benefits Study, Cisco Systems 2001)

The overall market penetration of wireless LANs in the US is nearly 10%. However, some sectors are adopting the technology faster than the overall market. As seen in the figure, these sectors are: Education, Medical, Government and Manufacturing. A recent survey which was done by Wireless LAN Alliance (WLANA) and published in 2003 gives the latest market penetration of WLANs in the sectors:

- Education: 23%
- Healthcare: 23%
- Manufacturing:21%

- Retail: 15%
- Financial:18%

The above research was based on the companies in the healthcare, manufacturing, education, retail and financial industries. It can be concluded from the both researches that WLANs are deployed more than the past.

In the education sector, university students use wireless local area networks in order to access the network from dormitories and classrooms. WLAN enables students to be more mobile and universities to reduce network costs. By this way, remote locations can be connected to the central buildings and servers.

In medical sector, companies use WLAN in order to decrease the length of hospital stay, speed up diagnostic and case analysis time, reduce hospital labor, documentation and procedural costs.

In manufacturing industry, staff are using mobile computers or pen-based tablet PCs for entering and accessing data in real-time. These mobile devices are connected to servers running software application such as inventory collection, receiving, quality control, etc. By connecting to a database directly, manufacturing companies increase the accuracy and use the working time efficiently.

Retail Industry which includes restaurants, specialty stores and prepared food stores use WLAN technology in order to get customers through check out, taking inventory. By this way, more customer attraction can be achieved and long lines can be reduced. The WLAN infrastructure provides real-time information on the ordering, collection, distribution, and sale of goods. The wireless network increases the accuracy, productivity and efficiency in retail industry.

In the financial industry, individuals within the financial companies often use portable computers to communicate with the corporate network. For this reason, wireless network within the buildings enable employees to be more flexible and mobile. This leads to time saving and increases productivity.

3.2 Public Wireless LAN Hot Spots and Users

Public places where Wireless LANs are available are called 'Hot Spots'. Hot spots are typically open for use in locations such as:

- Airports
- Hotels(including conference facilities, public area and room coverage)
- Retail locations(Coffee Shops ,Gas Stations and Restaurants)
- Stations and ports
- Community locations (Libraries ,Public Spaces)
- Shopping malls

Public WLAN Hot Spots are dramatically increasing all around the world, including in Turkey.

The graphs below show the forecast of number of public WLAN Hot Spot Locations and Users Worldwide until 2008.

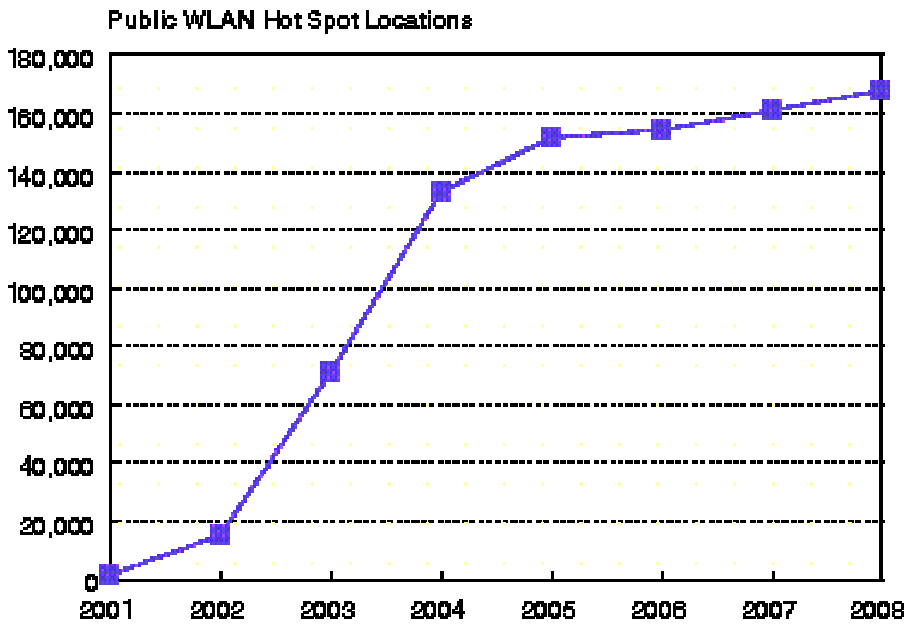


Figure 3-2 Public WLAN Hot Spot Locations Worldwide (Gartner)

Table 3-1 Detailed number of Hot Spot Locations Worldwide (Gartner)

	2001	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
Source: Gartner Dataquest (April 2003)								
Airports	85	152	292	378	423	452	476	505
Hotels	**569**	2,274	11,687	22,021	23,663	23,690	24,623	25,674
Retail outlets	**474**	11,109	50,287	82,149	85,567	77,514	74,423	**72,312**
Enterprise guesting areas	84	624	1,762	3,708	5,413	7,022	8,071	8,752
Stations and ports	-	88	623	2,143	3,887	5,041	5,959	6,722
Community hot spots	2	266	5,637	20,561	30,659	37,521	44,524	**50,363**
Other	-	240	790	1,526	2,156	2,537	2,796	2,937
Total	**1,214**	**14,752**	**71,079**	**132,486**	**151,768**	**153,778**	**160,871**	**167,265**

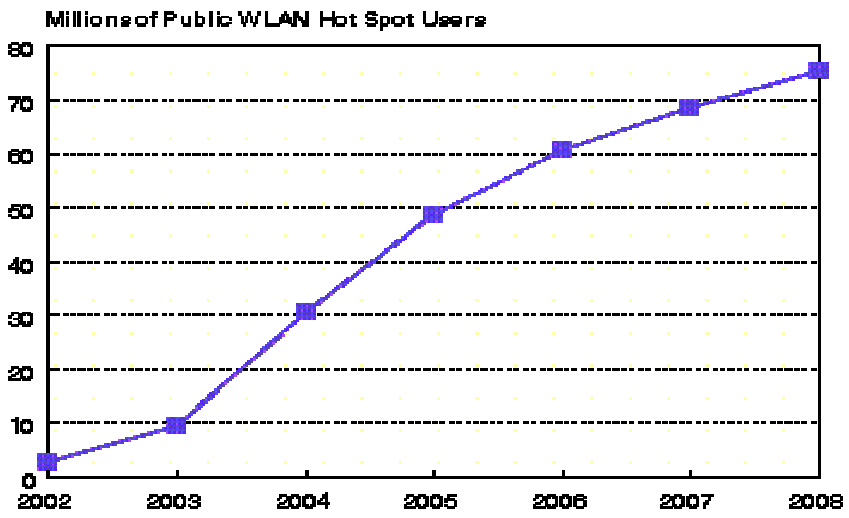


Figure 3-3 Public WLAN Hot Spot Users, 2002-2008

Table 3-2 Total WLAN Hot Spot Users Worldwide by Region (Millions.2002-2008) (Gartner)

	2002	2003	2004	2005	2006	2007	2008
Source: Gartner Dataquest (April 2003)							
North America	1.6	4.7	13.1	17.5	20.3	21.5	22.6
Europe	0.2	1.7	7.0	12.3	15.7	18.2	20.3
Asia/Pacific	0.6	2.7	9.8	16.6	21.6	25.6	28.6
Rest of world	0.1	0.2	0.7	2.2	2.8	3.2	3.8
Total	**2.5**	**9.3**	**30.5**	**48.5**	**60.4**	**68.5**	**75.3**

- As seen from the tables and graphs, number of hot spot locations and users will increase in huge amounts.
- Airports and community places will have the largest number of WLAN hot spots.

3.2.1 Wireless LAN Applications

WLANs are used for the applications in the business processes of the companies. By using the wireless network, employees or individuals achieve different types of applications. These applications were researched and a list showing the percentage use of the applications was published by Cisco Systems.

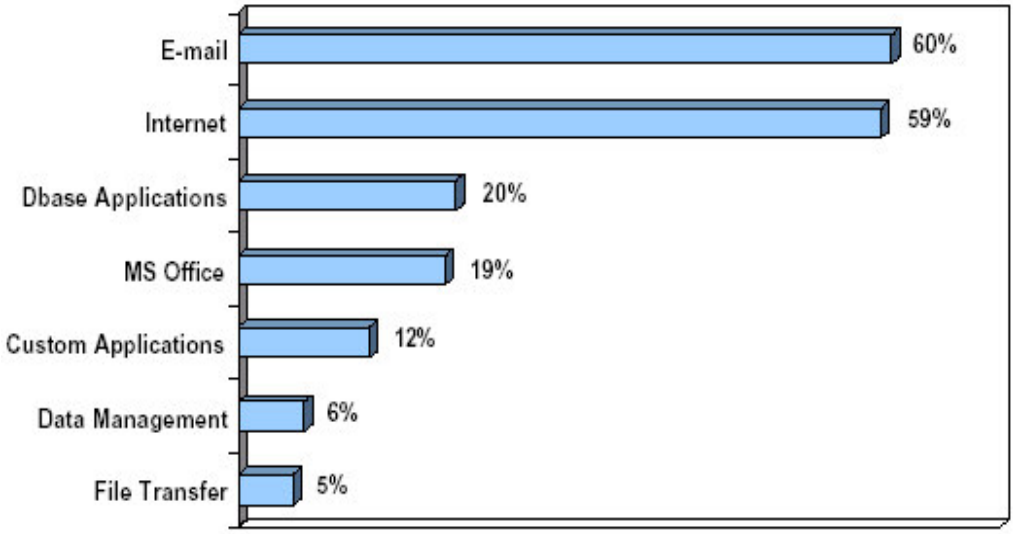


Figure 3-4 Applications WLAN used for (Cisco Systems, Fall 2001)

It can be easily understood from the figure that WLANs are used mostly for the e-mail and Internet applications. The other applications such as file transfer, data management, MS office have lower percentages. The chart suggest that users of WLAN use wireless mobile devices, such as laptops and pocket PC's, for accessing the Internet while more demanding information processing (e.g. database and Excel sheets) are done independent of WLAN access. The reason may be found in the limited functionality of pocket versions of MS office applications. As for the limited

use of custom applications, a reason may be the number of operating system standards on handheld devices. PDA-type equipment is generally split between PalmOS and Windows Pocket. On Phone-PDA type devices and smartphones there are also a number of operating systems such as Symbian, Pocket PC Phone Edition and even Linux. Without a single standard for an operating system, the development of custom applications may be limited. Another important reason may be security. IT managers may be hesitant to allowing wireless LAN in some occasions because of security issues. Finally a reason may be the data transfer rates of WLAN standards (typically 802.11b) which are acceptable for anything but the most demanding user applications, but still much slower than wired LAN and therefore unsuitable for large bulk file transfers, such as very large files and system back-ups.

3.3 Wireless LAN Deployment Case Studies

3.3.1 Microsoft Corporation

In May 1999, Chairman of Microsoft Bill Gates declared an executive challenge to IT department in order to install a WLAN within a year in Microsoft's corporate buildings in Redmond and Washington. Gates main objective was to show the efficiency and productivity of WLANs. In summer 2001, Microsoft IT Group has completed the installation of 70 buildings in Redmond and 23 remote locations internationally.

The Microsoft IT Group decided to build IEEE 802.11 WLAN standard. They started with a pilot study with 600 users. By this way, they could examine the network and would have a decision whether installing WLAN is feasible or not. The pilot study ended with the following results: (Intel IT, 2003)

- **Increased Flexibility:** 24% used the WLAN for more than six hours per day and 93% used notebook computers in new locations
- **Productivity:** 50% saved 0.5 hour to 1.5 hours per day because of the WLAN connection.
- **Usage:** 90% used wireless notebooks for e-mail and web access.

After conducting the results of the pilot survey, Microsoft started full implementation of WLAN. Microsoft invested $9 million as capital expenditure for WLAN. Today, 35000 Microsoft employees go wireless with WLAN. It is believed to be one of the largest such solutions in the world. Microsoft estimated that the return was $6.1 million per year and they decided to realize payback after 18 months.

3.3.2 Intel IT

Intel IT and Intel Finance have succeeded on linking return on investment (ROI) to productivity gains from wireless LANs (WLANS). They built a model which became the mainframe of Intel IT for deploying WLANs.

From 1998 to today, Intel started to use notebook computers up to 20 percent of employees and mobile PCs for mobile business up to 65 percent of workers worldwide. Intel IT launched a fast push into wireless networking. Because it was proven that mobility increases worker productivity and delivers a positive ROI. Some of the benefits can not be seen easily .These benefits are called soft benefits: (Intel IT White Paper, December 2002)

- Increased Flexibility: Mobility within the office , at home or any other working place

- Faster Decision-making
- Higher Employee Satisfaction
- Greater Accuracy
- Increased Productivity

Intel IT conducted a pilot study for the wireless local area networks. The reason for the pilot is to collect useful data, identify users most likely to benefit from the WLAN and show how WLANs can deliver ROI to an organization. Intel IT wanted to learn how users can save time with a WLAN by sending /receiving e-mail, accessing data, transferring files, attending online meetings and connecting to the network. Intel IT segmented its pilot user base into five categories:

- Engineering
- Manufacturing
- Sales
- Marketing
- Support

After applying the pilot study, the overall results showed that 68 percent of the respondents indicated they used the WLAN continuously or most of the time during working hours. 62 percent of the respondents preferred to use a wireless connection whenever possible. Moreover, the pilot study has some results showing the productivity and time savings.

Table 3-3 Fully Adjusted user time savings (Intel IT, December 2002)

	DailyTime Savings/User (hours)	Adjustedfor human judgement(50%)	Adjusted to reflect actual productivity gains (50%)	Net daily time savings for productivity (hours)
Engineering	1.49	0.75	0.37	0.37
Manufacturing	1.33	0.67	0.33	0.33
Sales	0.67	0.34	0.17	0.17
Marketing	1.80	0.90	0.45	0.45
Support	1.47	0.74	0.37	0.37

Table 3-4 Value of Annual WLAN Productivity Gains (Intel IT, December 2002)

	Adjusted Daily Time Savings for Productivity gains(in hours)	Hourly Burden Rate	Productivity benefit per year/per user
Engineering	0.37	$60	$5,253
Manufacturing	0.33	$40	$3,126
Sales	0.17	$55	$2,165
Marketing	0.45	$55	$5,816
Support	0.37	$45	$3,886

Table 3.3 shows how Intel IT adjusted the time to establish conservative estimates. Table 3.4 shows how Intel IT calculated the value of annual productivity gains. After calculating the value of productivity gains, Intel calculated the start-up costs for three potential WLAN deployments:

- Large (800 users) - $408,000
- Medium (150 users)- $72,000
- Small (32 Users)-$19,800

The start-up costs include initial hardware, software and labor expenses to build the WLAN.

Table 3-5 WLAN ROI over three years (Intel IT, December 2002)

	Number of Users	Net Three-Year Cost	Net Three-Year Productivity Benefit	Net ROI
Large Building	800	$400,000	$5,000,000	$4,600,000
Medium Building	150	$60,000	$1,000,000	$940,000
Small Building	32	$20,000	$300,000	$280,000

It can be concluded from the above table and pilot study results that WLAN deployment makes the company productive, efficient and profitable. As a result, the analysis shows that an average of 11 extra minutes of productivity per week will pay for a WLAN, and most WLAN users will gain much more productivity.

3.4 Wireless Use in Turkey

The three mobile operators in Turkey are:

- Turkcell - GSM900
- Telsim - GSM900
- Avea - GSM1800

3.4.1 Turkcell

Turkcell introduced mobile communication in Turkey with its GSM 900 services in February 1994 and signed a 25 year GSM license contract with the Turkish Ministry of Transportation in 1998. Turkcell has made continuous improvements to the range and quality of the voice and data communication services and increased its number of subscribers up to 19 million. Turkcell also provides GSM services internationally.

In March 2001, Turkcell launched its GPRS services across Turkey. Today, its GPRS services provide subscribers with Internet access through GPRS compatible cellular phones anywhere within the coverage area allowing subscribers data access in a mobile environment.

In July 2002, Turkcell launched its Multimedia Message Service (MMS), "MaxiMeSaj", across Turkey. This service enables subscribers to send pictures, voicemail and melody messages from their MaxiMeSaj compatible cellular phones to other cellular phones or e-mail addresses within the coverage area. (Turkcell Official Website)

Figure 3-5 Turkcell Coverage Map for Turkey (GSM World)

3.4.2 Telsim

Telsim signed a 25-year license agreement for the implementation and operation of a GSM system in Turkey in 1998. Today, the company provides coverage throughout 81 cities within Turkey, using a network of over 4,400 basestations.

Telsim has invested over 3 billion dollars in network infrastructure. By closely following all developments in the global GSM sector, Telsim aims to provide Turkey with all available services in the mobile communications industry. As a result, Telsim is able to offer a full range of GSM 900 services to its subscribers and also offers GPRS service. (Telsim Official Website)

Figure 3-6 Telsim Coverage Map for Turkey (GSM World)

3.4.3 Aria & Aycell (Avea)

Aria was established through the joint efforts of Italy's telecommunication giant TIM (Telecom Italia Mobile) and Turkey's most rooted establishment Türkiye İş Bankası for the GSM 1800 project. İş-TIM Telekomünikasyon Hizmetleri A.Ş.

signed the license agreement for Turkey's first 1800 GSM Digital Cellular Mobile Telephone System with the Ministry of Transportation. Company started to operate in 2001. Turk Telekomunikasyon A.Ş. (TT) and Aycell Haberleşme ve Pazarlama Hizmetleri A.Ş. was given the GSM 1800 operating license in 2000 and company was founded in 2001 as a telecom operator in Turkey.

On February 2004, Aria and Aycell merged in order to give birth to the new company called TT&TIM İletişim Hizmetleri A.Ş. offering GSM1800 and GPRS services under the brand name Avea. This will lead to positive consequences in the GSM market especially in view of offering even better communication opportunities by merging and optimizing the networks of the two companies. Today the two companies have a joint customer base of about 4.5 million customers representing 15% of the total market. (TT&TIM)

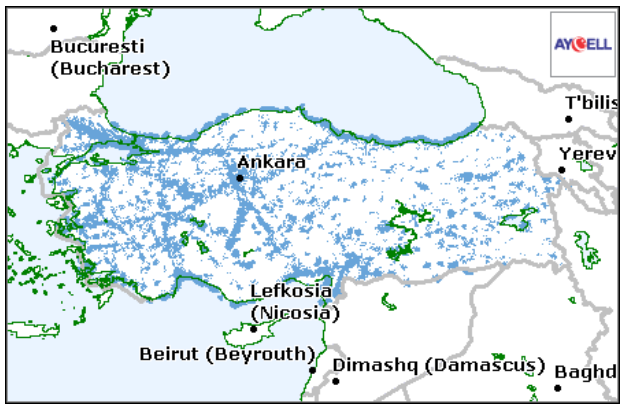


Figure 3-7 Aycell Coverage Map for Turkey (GSM World)

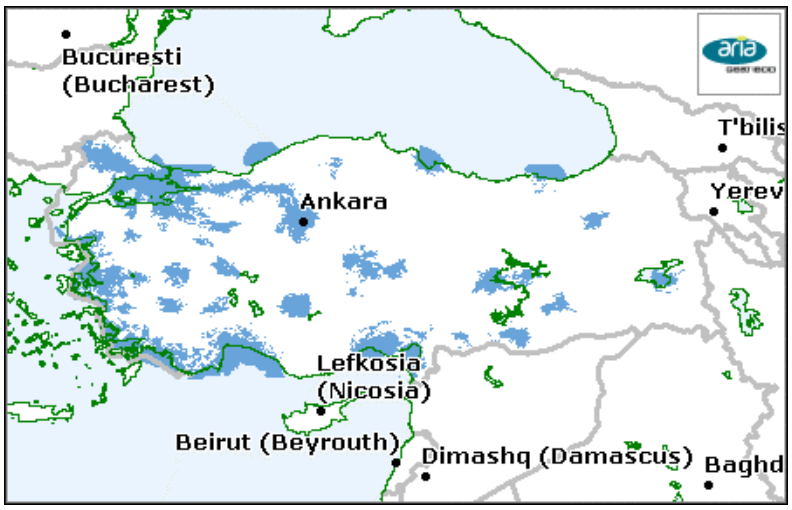


Figure 3-8 Aria Coverage Map for Turkey (GSM World)

3.4.4 GPRS Prices, 3G & WLAN

Prices of GPRS services are the most important factor determining the wireless Internet usage in Turkey. For places without WLANs, GPRS service is used in order to access the internet by using wireless devices. However, In Turkey, GPRS prices are expensive so high rates of data transfer is uneconomical. With new pricing schemes, the usage of the wireless internet could increase all around the country. This may occur in the future with the competition between the telecom operators and the efforts of the government. GPRS prices for the telecom operators are listed below: (1$ = 1.480.000 TL)

- **TELSIM :**

  900 TL (per KB)

  50.000.000 TL (for unlimited per month))

- **ARIA/AYCELL:**

  950 TL (per KB)

- **TURKCELL:**

  0-5 MB, 1.250 TL, 6.400.000 TL

  5-10 MB, 900 TL, 11.008.000 TL

  10-25 MB, 600 TL, 20.224.000 TL

  25-50 MB, 400 TL, 30.464.000 TL

  50 MB and over, 200 TL,

As a result, the most economical telecom operator for GPRS services is Turkcell today. However, the prices are expensive for the high rates of data transfers over the GPRS, and therefore not an option to a normal network.

For the wide area communications, the predominant technology around the world is 3G today. However, in Turkey, investment for the third generation infrastructure was postponed due to the political and economical reasons. Private telecommunication companies continue to work on the third generation infrastructure and they are waiting for the licenses which will be given by the government.

WLAN solutions became popular especially in this year in Turkey. Some public hot spot locations in Turkey are listed below:

- Atatürk Airport, İstanbul
- Kemer Country
- Four Seasons Hotels
- Hillside Su Hotel, Antalya
- Shlotzsky's Deli Restaurants
- Karum Shopping Center, Ankara
- Armada Shopping Center, Ankara

- İstklal Street/Beyoğlu
- Ulusoy Bus Transprotation Company Terminals
- Varan Bus Transportation Company Terminals
- Turkish Parliament, Ankara
- Turk Telekom Central Campus, Ankara
- Surmeli Hotel, Ankara
- Swiss Hotel, İstanbul
- Turgut Reisa Marina, Mugla
- Ankuva Shopping Center, Ankara
- Bilkent Hotel, Ankara
- Boss Transportation Company ,Ankara
- Club Marina, Mugla
- Turkish Treasury, Ankara
- Neva Palas Hotel, Ankara

WLAN technology will be used by more people in the near future. Hot spot locations will dramatically increase the demand and interest for the wireless access to the internet. Apart from the public hot spot locations, international and national companies started to use the wireless devices in their business processes especially in marketing and manufacturing sector. The benefits of the mobile devices are seen by the other sectors in Turkey. The following step is to use WLAN in the offices and work sites which is the subject of this thesis.

In Turkey, use of WLAN and mobile devices is sharply on the rise, following the trend seen in other parts of the developed world. People may start

using WLAN purely out of interest and curiosity, but soon they will realize a number of tangible and intangible benefits and will require access both at work and during leisure. Eventually, wireless access will be considered indispensable, like the mobile phone.

CHAPTER 4

4 MOBILE IT IN CONSTRUCTION

4.1 Need of IT in Construction

Construction industry has many parties such as design firms, contractors, subcontractors, consultants, and suppliers involved in business processes. Much research concludes that information technology has the potential for saving considerable time during the business processes by improving the quality of communication between these parties.(Rebolj, Magdic, Babic). During the last decade, different types of industries implemented IT in their business environments. This leads to great advantages in speed of operation, consistency of data generation, accessibility and exchange of information.

The majority of construction business processes are based on traditional ways of communications such as face-to-face meetings and information exchange with paper based documents. The use of information technology gives answer the need to increase the efficiency of the business processes by exchanging huge amounts of information at high speed. However, due to the historical and traditional market forces, the use of IT in construction industry is lacking behind the other industries. Construction industry has suffered for many years from difficult access to data and incomplete information. (Mohamed & Stewart, 2002)

4.1.1 Factors Affecting Construction Environment

The aim of integrating information technology into construction industry is to improve quality, competitiveness and profitability and to increase the value to clients. Construction industry is changing and developing. Some factors affecting construction industry are:

- Globalization of the Market: In many industries barriers are falling and labor has become more mobile.
- Project Complexity: Increased Project Complexity and shorter duration times greatly increase necessary communication involved in the construction industry.
- Need for faster results and decision making.
- Technological development (computers and software)
- Development of the new project management organizations, adopting novel management philosophies and having long term strategy and vision.

Information technology plays an indispensable role in order for construction to adapt to the factors listed above (Alshawi, Ingirige). The aim for the investment in information technology is to efficiently apply the current strategies and develop new strategies in order to create business value. The below figure shows and explains the seven IT implementation perspectives in the project management. These perspectives have to be evaluated before and after the investment in IT.

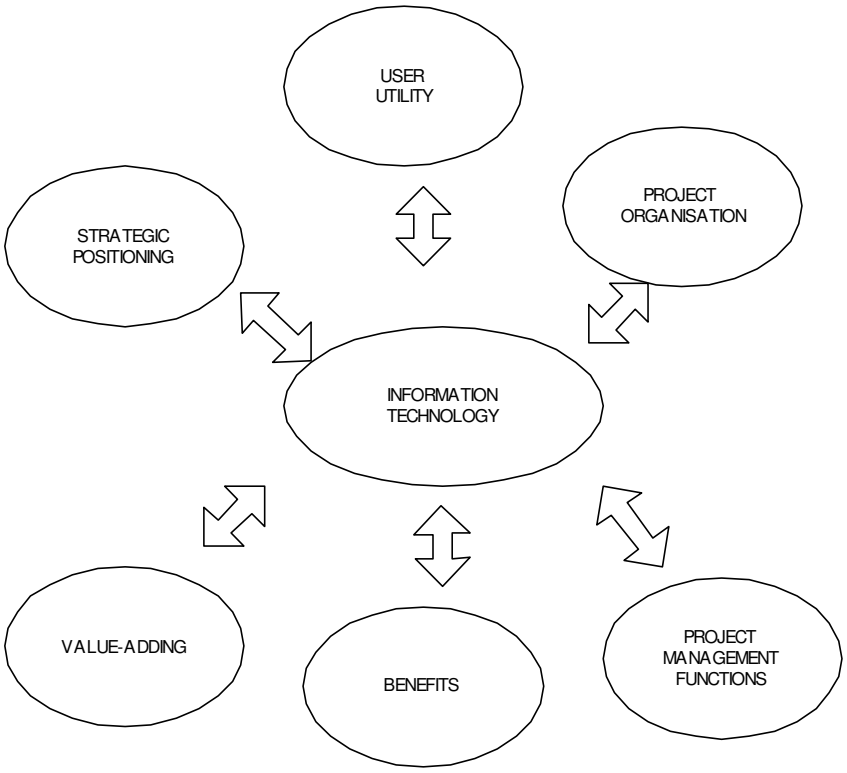


Figure 4-1 Seven IT Implementation perspectives of project centre (Tucker et al, 2000)

- **Information Technology:** IT is the centre of the framework and demonstrates the tools and their technical aspects.
- **User Utility:** Deals with satisfaction of the user and the value gained with IT use.
- **Project Organization:** The integration of parties involved in the business and their roles are concerned.
- **Project Management Functions:** Evaluates the effect of IT on project management especially in the areas of communication between the involved parties.

- **Benefits:** Tangible benefits such as time and cost savings occur due to the reduction of paperwork and rework Intangible benefits occur due to handling, manipulating and accuracy of the data.
- **Strategic Positioning:** IT investment has to be evaluated from the point of the strategic targets of the organization. IT investment leads to different strategies than before. Organization must have short term and long term strategies for implementation of information technology.
- **Value-Adding:** The relationship between IT implementation and the overall project delivery process. Vale-adding is much wider perspective than the benefits perspective. It shows the value-added to project delivery from the client's point of view. (Weippert, Kajewski& Tilley, 2002)

4.1.2 Problems and Limitations in Construction Project Management

Construction project management practices are facing various problems with lack of information technology and unprofessional information technology applications.

- **Lack of adequate communication:** Reworking and lack of integration

in the business processes are the results of the lack of adequate communication. Problems of reworking occur because of the accuracy and the timing of the information.

- **Lack of IT Knowledge and Experience:** In the construction sector,

many companies do not have a specific IT management function. In other industrial sectors IT management plays an important role on the business processes and the company‘s market strategies. This is an important deficiency. Construction companies must consider management of IT as important in order to adopt the new technological developments in their business processes.

- **Lack of Standardization in Business Processes:** In the construction

Industry, experience plays a crucial role in project management. However, there has to be standards during the data transfer and decision-making processes. IT tools must be used during the daily business processes in order to develop database for storing gained knowledge. By this way, in the same project or in the other projects the data can be used while making decisions about future applications.

- **Barriers to IT Cost & Benefit Evaluation in Construction:**

Construction organizations using traditional approaches to evaluate their IT are unaware how to measure the benefits of the IT investments (Love, 2001). For this reason, IT costs must be identified clearly before the determination of benefits. IT costs are divided into direct and indirect costs. Direct costs are classified as: Hardware Costs, Software Costs, Installation and Configuration Costs and Maintenance Costs. Indirect Costs are classified as: Employee Training, Employee Motivation, Changes in Salaries. During the investment appraisal, traditional discounted cash flow methods like Net Present Value and Return on Investment do not take into account strategic and intangible benefits and therefore fail to show the real costs and benefits of IT investment. For such reasons, IT investment has to be evaluated from both monetary and non-

monetary points of view. However, few if any construction companies enter such an exercise and IT investments are therefore done more or less on an ad-hoc basis or according to some arbitrary budget.

4.2 Application Areas of IT in Construction

Construction companies have two types of organization within their structure. These are main office organization (fig.4.2) and site organization (fig.4.3). Both of the organizations must use information technology in order to develop their business processes and share information with each other and the other parties involved in the processes.

Communication on today's construction projects has an important effect on the successful completion of the project. Information must be well coordinated in order to place in a better position to meet clients' meets and be efficient. Construction information can be divided into three categories:

- General information
- Organization-specific information
- Project-specific information

General information includes commercially available information related with the construction procedures, regulations, technical standards, etc. Organization-specific information includes all of the information available inside the construction organization such as completed project information used for reference cases. Project-specific information is related to one specific construction project and shared by the other parties involved in project.

Central database and project-specific website are the main storage areas of organization specific and project specific information. Internal information exchange (fig.4.4) between the departments of organization can be achieved by using the local networks and be stored in central database of the organization. Project-specific information can be shared with the other parties over the web and necessary information can easily be stored in project-specific web-sites. (fig.4.5)

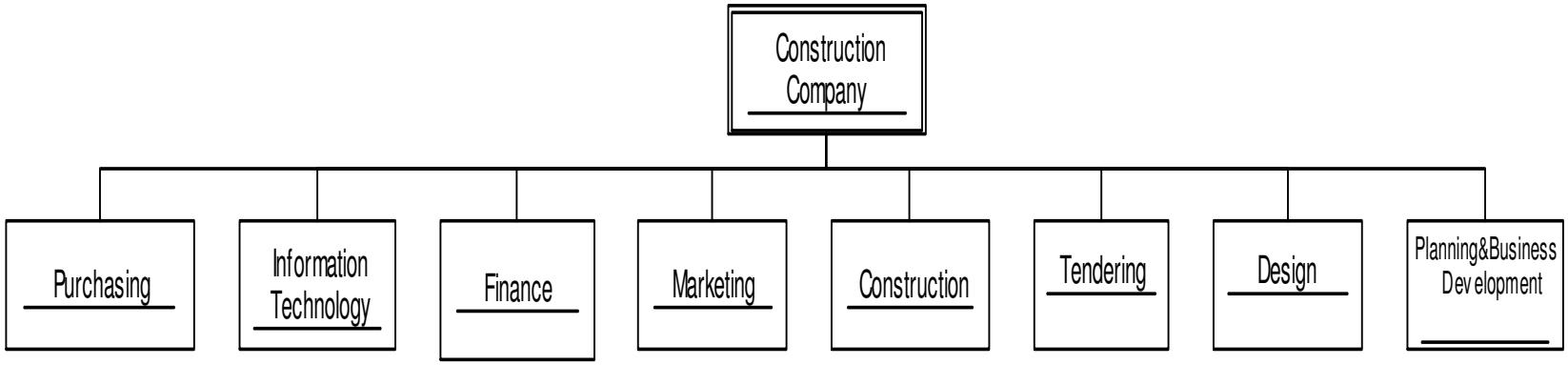


Figure 4-2 Construction Company General Organization (Expected Illustration for Construction Company)

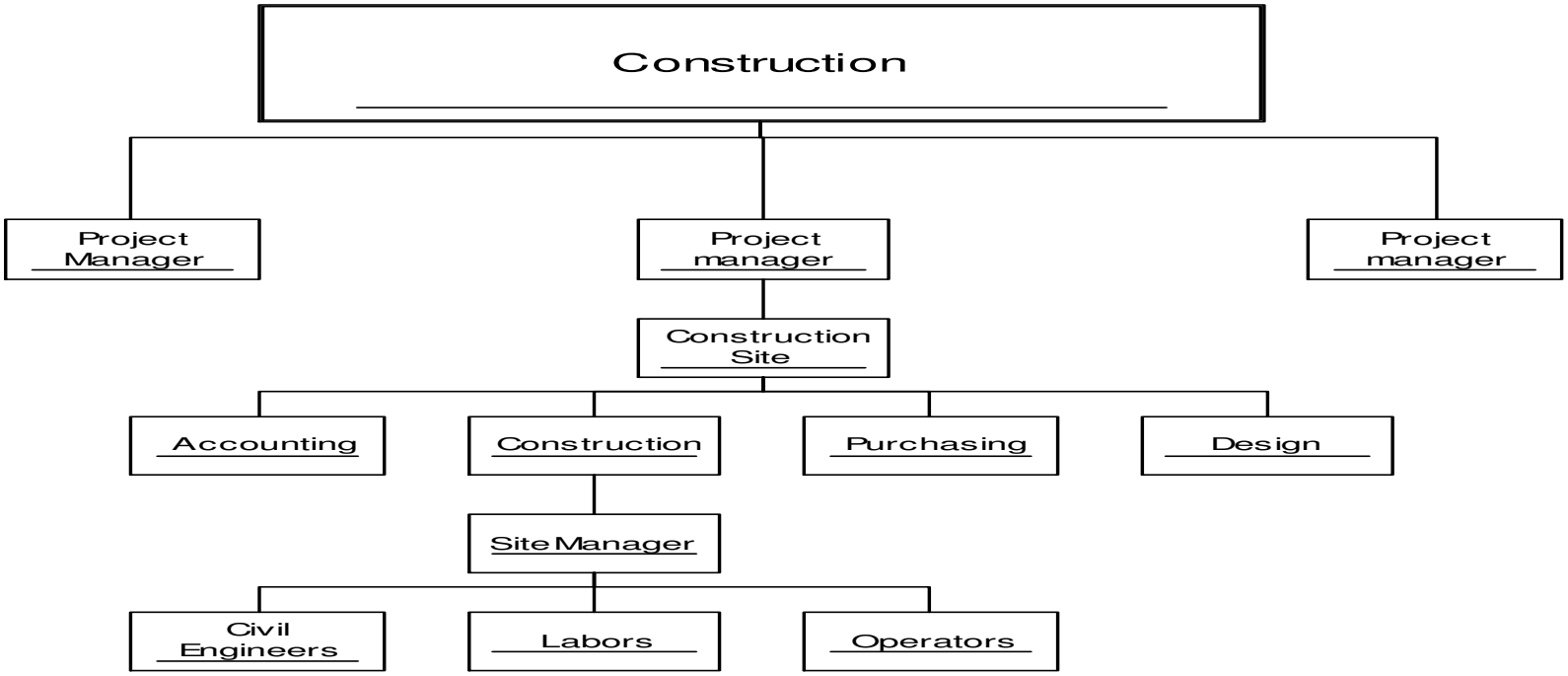


Figure 4-3 Construction Site organization (Illustration)

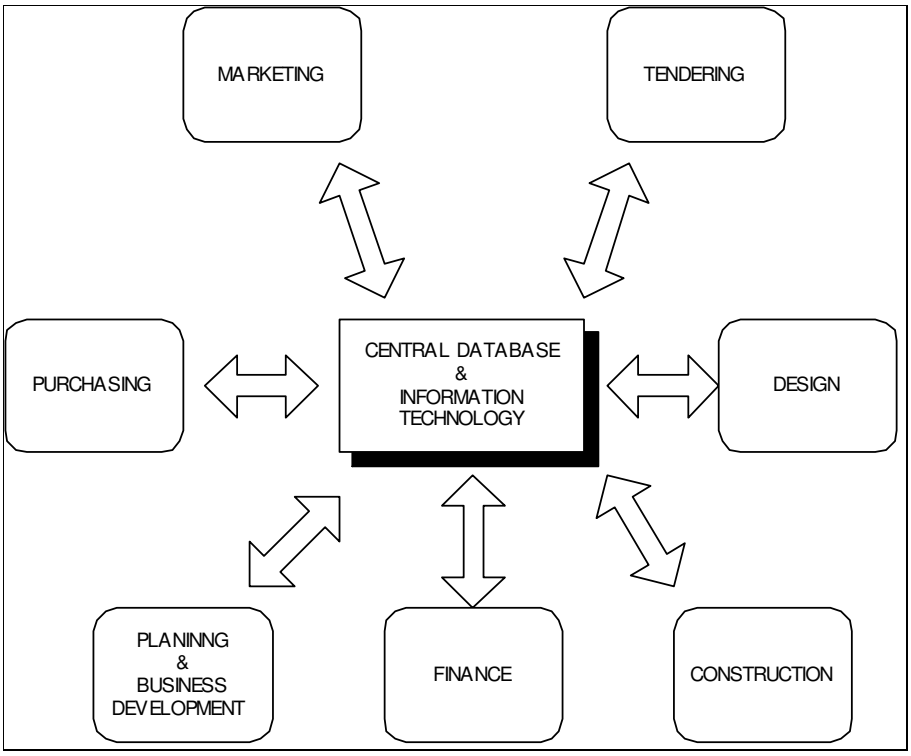


Figure 4-4 Internal Communication

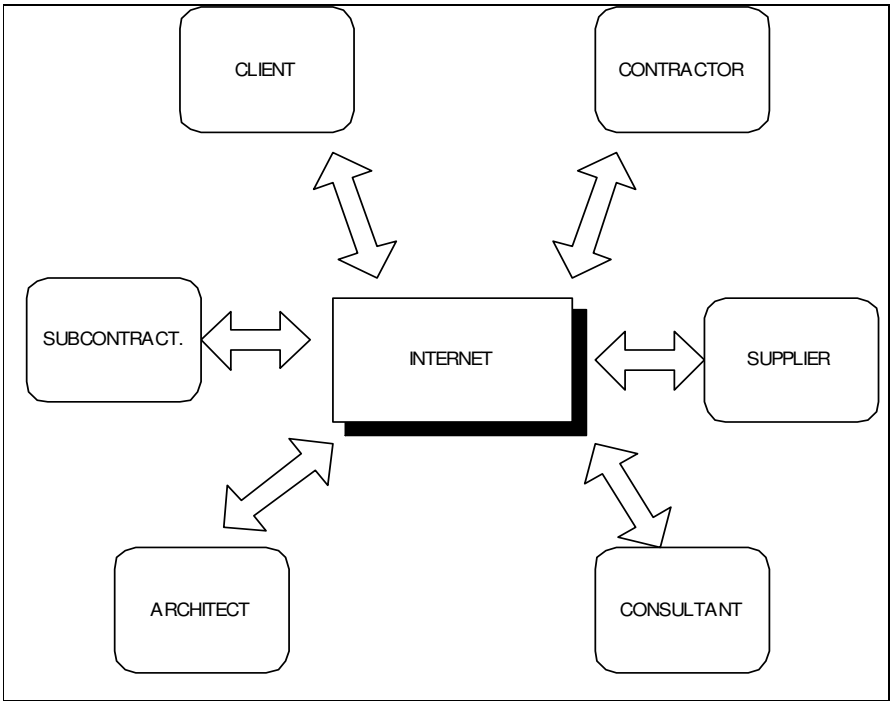


Figure 4-5 External Communication

Information technology applications and project-specific web sites give project teams and the overall organization an effective means for traditional information delivery. Computers and the Internet can be used in every process of a construction project today. As mentioned above, every department in a construction company can develop its own daily business processes using software and share necessary information with the central database and the other parties.

As a result of development in technology, new forms of communication such as networking, information sharing, database management and etc. can be used within the organizations. Moreover, the Internet provides quick information transfer accurately. Internet is a global network, which does not have restrictions on locations, time, or different computer-operating systems. On the other hand, the Internet saves money and time for construction companies by providing communication with overseas construction sites. Using the Internet, large amounts of information can be shared between sites and the head office and between other firms.

A project-specific website is an electronic project-management system which uses Internet and web pages in order to store and share project information. Project-specific websites increase the transfer speed, reduce communication barriers and improve project teamwork.(Thorpe, 2001)

Information types and documents stored in project-specific websites:

- Drawings document: Architectural, structural and special drawings.
- Contract document: Instructions, specifications and etc.
- Site photographs
- Live web cam
- Location maps of construction site

- Safety: Safety information and instructions during the production in the construction site.
- Schedule: Detailed work program, activities and materials management information.

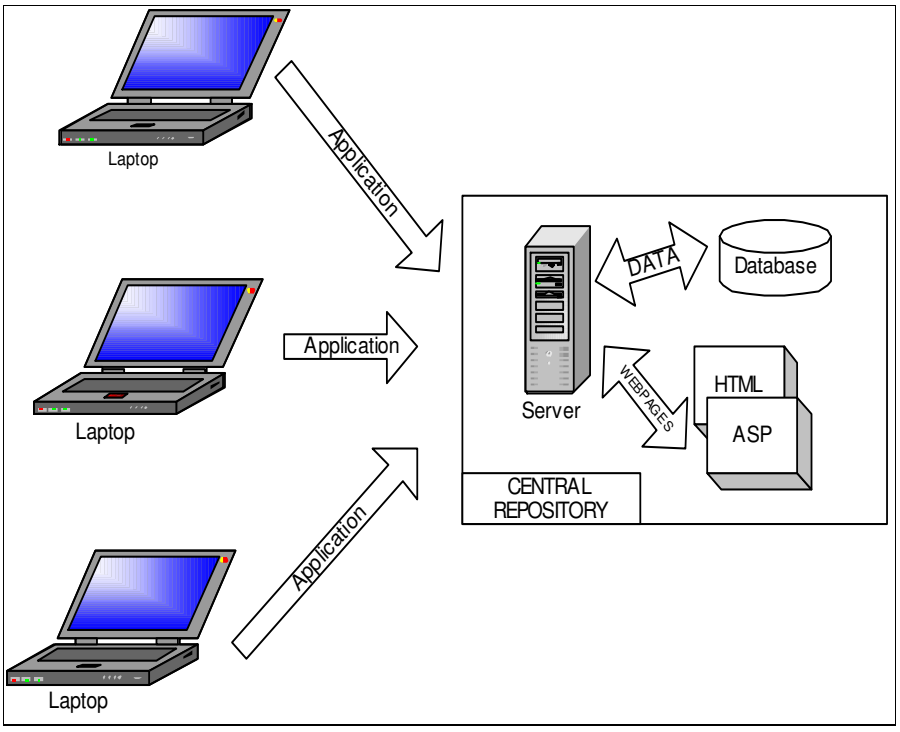


Figure 4-6 Project-specific website and central database system architecture (Dawood, Akinsola& Hobbs, 2002) (HTML: Hypertext Markup Language, ASP: Active Server Page)

Project web page improves overall project execution by managing access to the most current documentation and changes - saving valuable time and lowering the risk of costly mistakes due to using out-of-date documentation, or not knowing about the latest changes being discussed. Some of the advantages of project-specific web pages are:

- Online access to centralized project data

- Unlimited user support and access at no additional cost
- Instant e-mail notification of new files/versions, mark ups and project notes
- Reduce printing & delivery costs
- Everyone works from current plans and documents

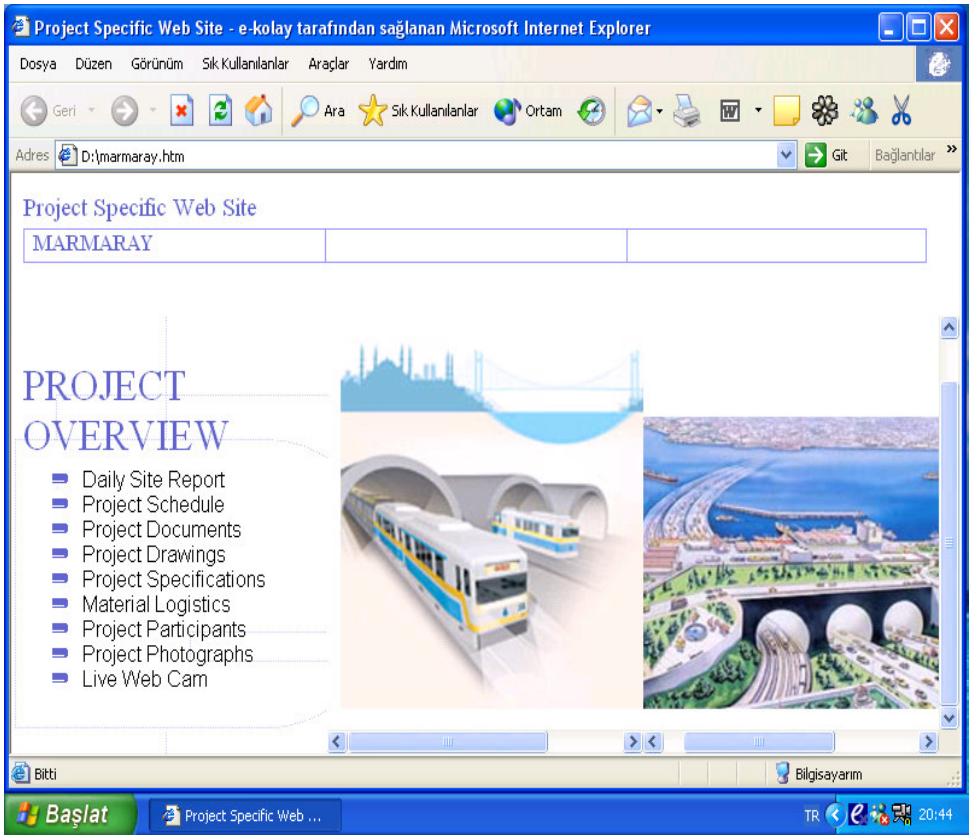


Figure 4-7 Example project website (Illustration)

4.3 Mobile Business Applications in Construction

Mobility in business is based on new available mobile technologies enabling the mobility of people and devices. Various communication service providers have begun to find new business areas to enter. New innovative services and technologies has changed the existing business processes in different sectors. Many businesses require flexibility of personnel in terms of location and time. Mobile technology can be an effective tool to enhance field force operation.

In the past, many corporations invested in information technology in order to support business processes in the office. With the advent of mobile technologies, business professionals are no longer tied to offices and information can be carried and shared out of the office. Wireless devices have ability to synchronize with real time data in a more efficient manner than traditional methods. At the moment the predominant wireless data transfer technologies can be classified according to range and data transfer rate:

- Short Range: WLAN and Bluetooth
- Wide Range: GPRS and UMTS

Table 4-1 Wireless Protocols

Mobile Technology	WLAN(802.11b/ 802.11g)	Bluetooth	GPRS	UMTS
Data Rate	11Mbps/54Mbps	1 Mbps	170 kbps	384 kbps
Coverage	Limited with numberof access points&locations	0-50m	Extensive Coverage	Limited Coverage
System Requirements	Installation of WLAN equipment	Installation ofBluetooth equipment	Telecom Operator	Telecom Operator
Cost	Hardware	Hardware components	Hardware& service fee	Hardware& service fee

4.3.1 Mobile Construction Site Activities

Construction site activities can benefit from real-time wireless communication integration in the field, just as any other work activity. By enabling instant wireless connectivity in site with the necessary handheld devices, decision making and problem solving can be made quickly reducing the need for time-consuming face to face meetings. Moreover, tedious paper work will decrease after the integration of mobility into construction site activities and communication and information flow between the site and the office become more accurate and efficient. With the right information at the right time leads to save time and make workers more productive at site. Wireless solutions and connections enable workers to achieve these applications at the construction site:

- Transfer electronic data to other site or main office by using wireless connectivity
- Record field data on a mobile device such as PDA, Pocket PC and Tablet PC
- Instant access to the corporate information
- Solve problems on site related with the project documents
- Reduce paperwork related with construction site

Mobile business solutions are used for the above applications and these applications can be used for construction site activities listed below:

- Material management
- Quality control
- Daily jobsite record keeping
- Resource allocation and control
- Safety

- Cost and schedule control

4.3.2 Scenarios for Wireless Networks in Construction

The following section describes various scenarios which were developed for wireless networking in construction industry. These scenarios are developed from literature and technology survey. Cost, speed and efficiency are the most important factors affecting the scenario infrastructure. All of the mobile networks, which were mentioned in thesis including Bluetooth, WLAN, GPRS and 3G, are all considered. The figure below shows the list of scenarios according to cost, efficiency and speed:

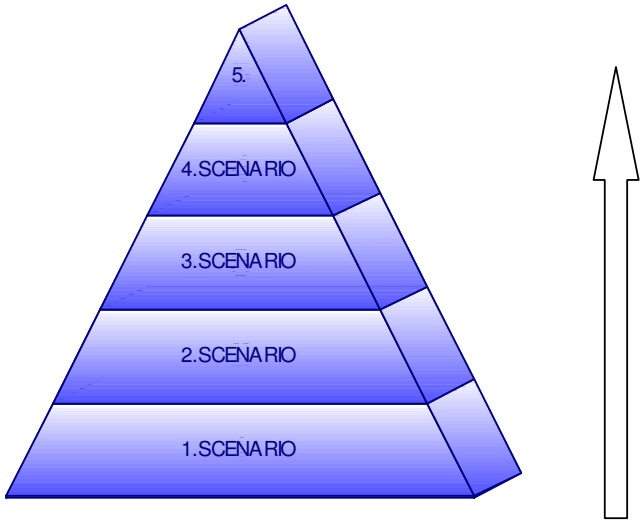


Figure 4-8 Wireless Scenario Pyramid (Cost, efficiency and speed increases in upward direction)

4.3.2.1 Bluetooth in Main Office& Site Office

Communication between Bluetooth devices can be achieved without any access point in 10 meters range. Moreover, range of Bluetooth has become up to 50 m meters with recent development of the technology. Bluetooth leads to cable

replacement and peer to peer networking in the office. The advantage of Bluetooth is its low cost. Devices can be connected by using USB adapters and add-on cards. However, short range and the low data transfer rate are disadvantages for transferring large amounts of data and wide area usage.

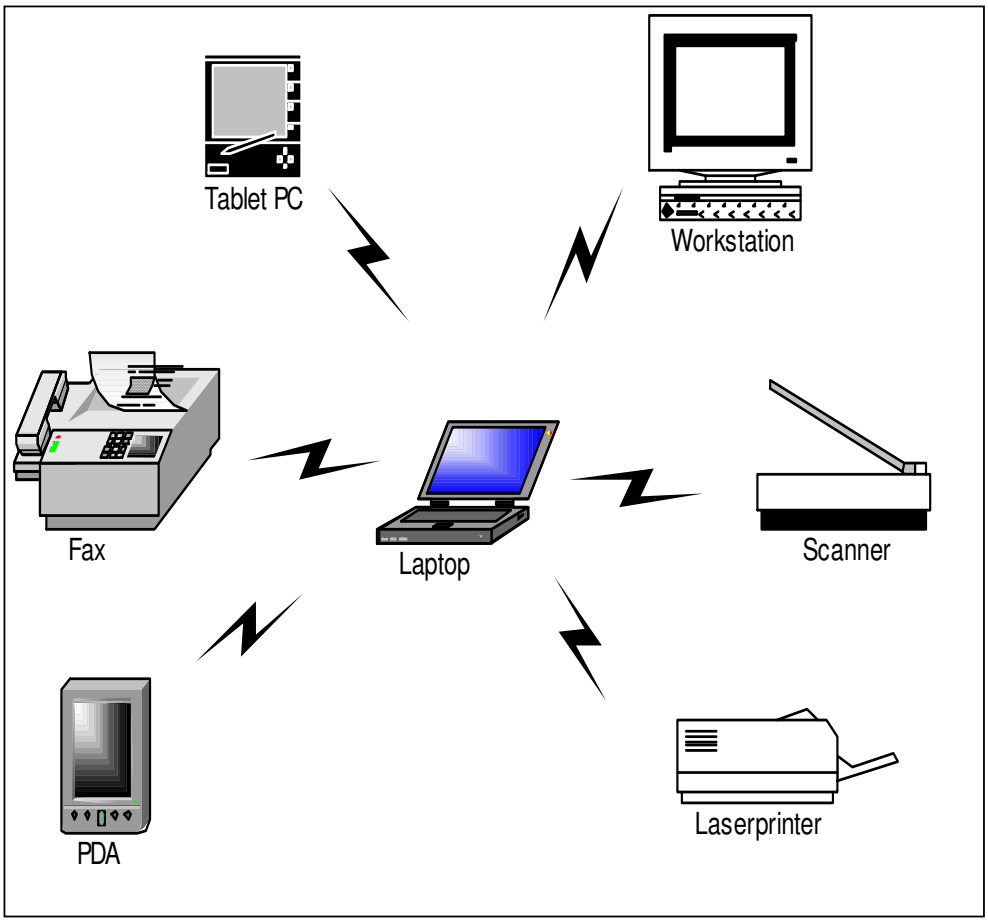


Figure 4-9 Bluetooth Networking in Office (Scenario 1)

Bluetooth networking can be used in construction site for the communication between the engineers carrying PDA or mobile phone. However, access range may be a problem in the construction site.

4.3.2.2 Bluetooth in Main Office& Site Office Wireless Equipment (PDA, Pocket PC, etc.) on Site

In this scenario, Bluetooth networking is used for communication between the devices in both of the office. In construction site, mobile devices are used in order to record job site information. Information taken from the site is daily loaded to the site office computer by using synchronization between the site office computer and the mobile device. At the end of the day, daily information is sent to the main office database and project website repository over the internet. There is no wireless communication between the construction site and the site office during the working hours. Mobile device is synchronized with the site office computer at the beginning and end of the day. Specific software designed for the mobile computing in construction site is used in these information flows.

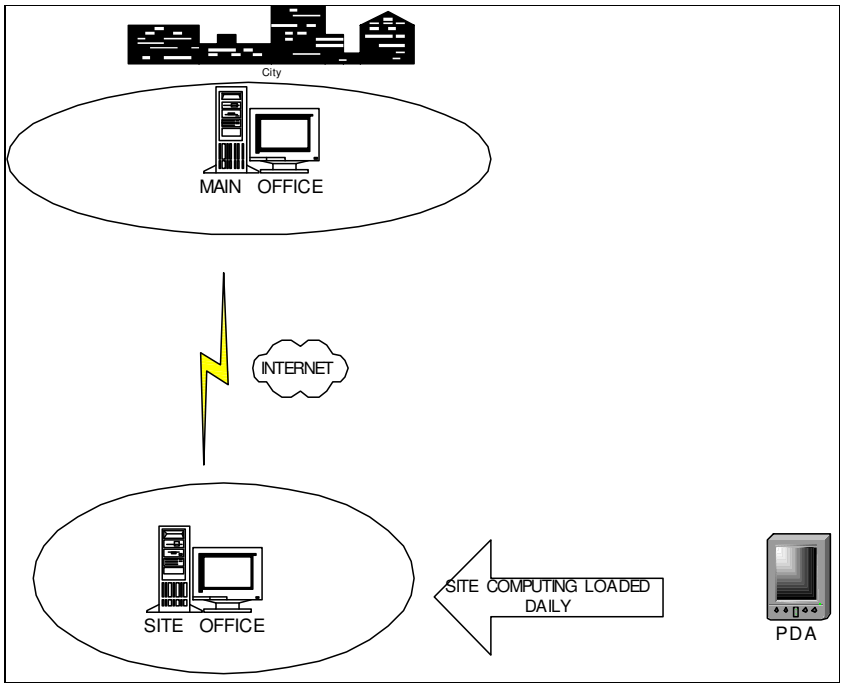
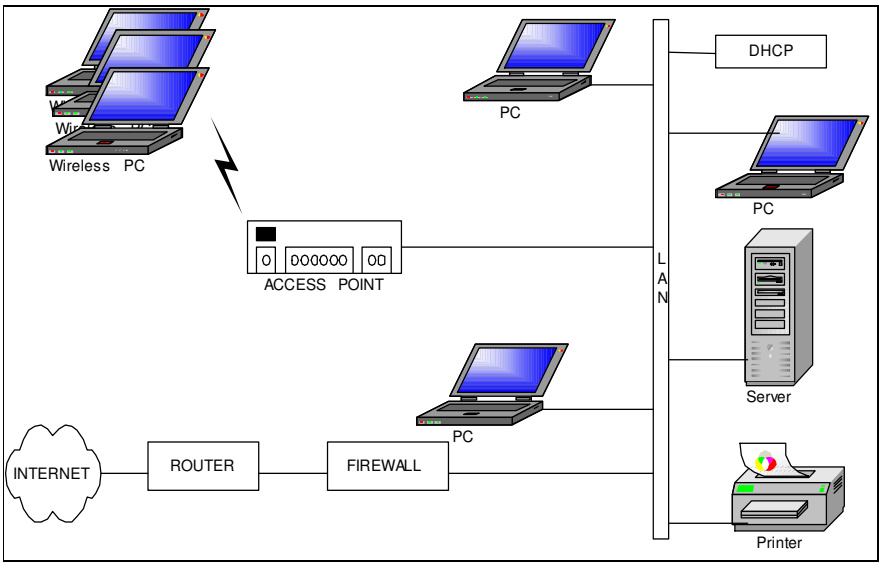


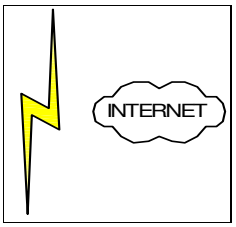
Figure 4-10 Computing On Site (Scenario 2)

4.3.2.3 WLAN in Main Office, Bluetooth in Site Office& Wireless Equipment (PDA, Pocket PC, etc.) on Site

In the third scenario, the difference is installation of wireless local area network in main office. WLAN has higher data transfer rate and wider range than Bluetooth networking. Users can access to the internet and corporate files anywhere in the main office building by using wireless connection over the access points.



WLAN CONFIGURATION IN MAIN OFFICE



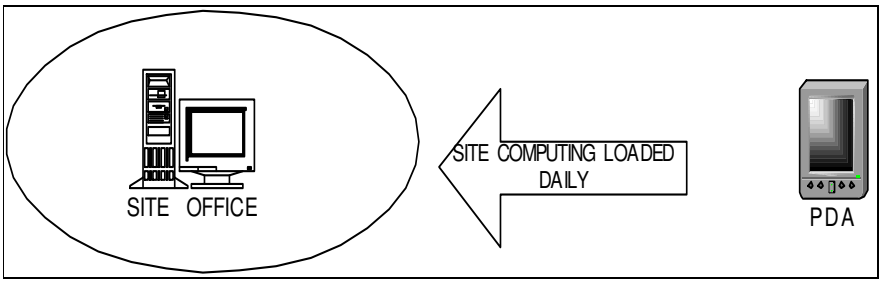
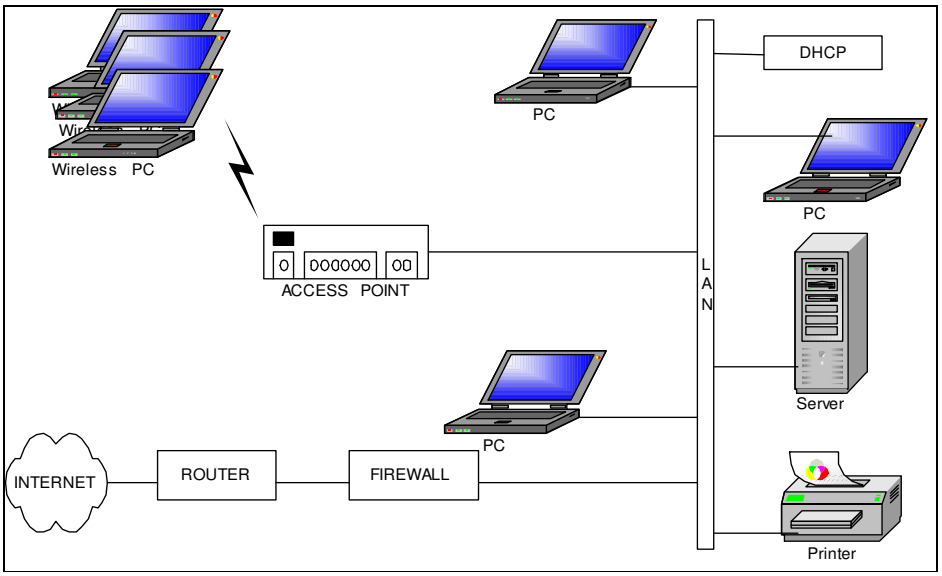


Figure 4-11 Computing On Site without networking, Bluetooth Networking in Site Office & WLAN in main office (Scenario 3)

4.3.2.4 WLAN in Main Office, WLAN in Site Office

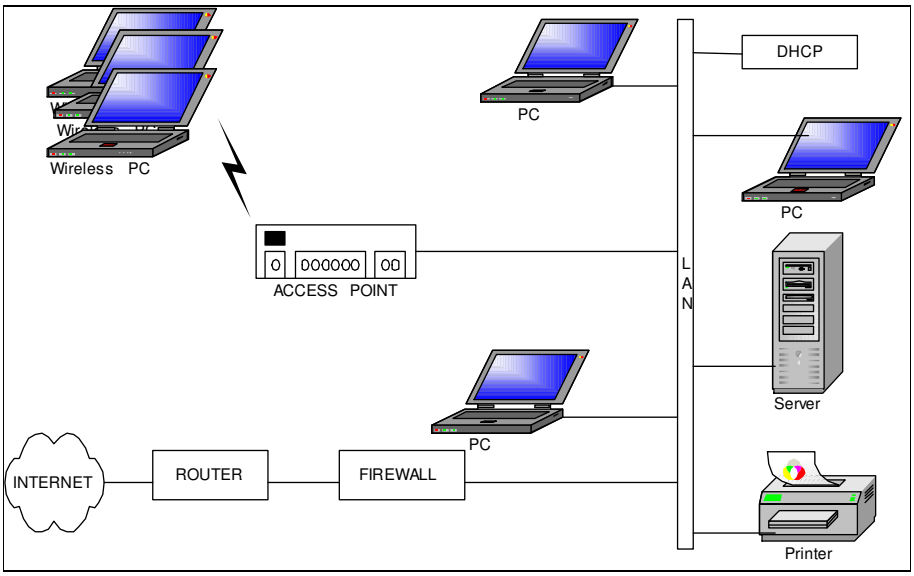
WLAN&GPRS at Construction Site

The fourth scenario is the best applicable one for Turkish contractors. Site offices and main office use WLAN for their internal business communication. The communication between the site and main offices is conducted by using specific software on the internet. Communication between the engineers in the construction site can be achieved by using mobile devices over WLAN or GPRS. Moreover, construction site mobile device users can share files with the main office and Internet. In the construction site, transferring data to anywhere else can be faster while using WLAN. However, GPRS has wide range and in remote locations, GPRS may be very useful. Briefly, both of the networking option can be used together in order to be more efficient and effective.

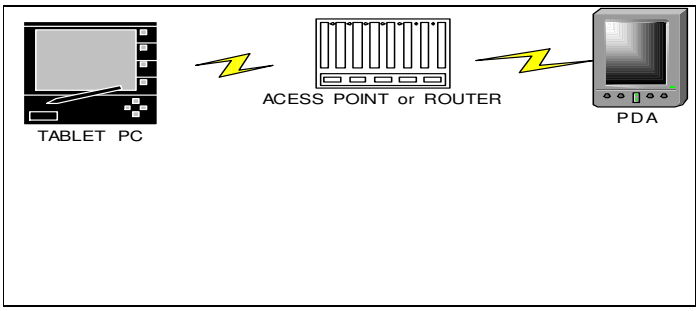


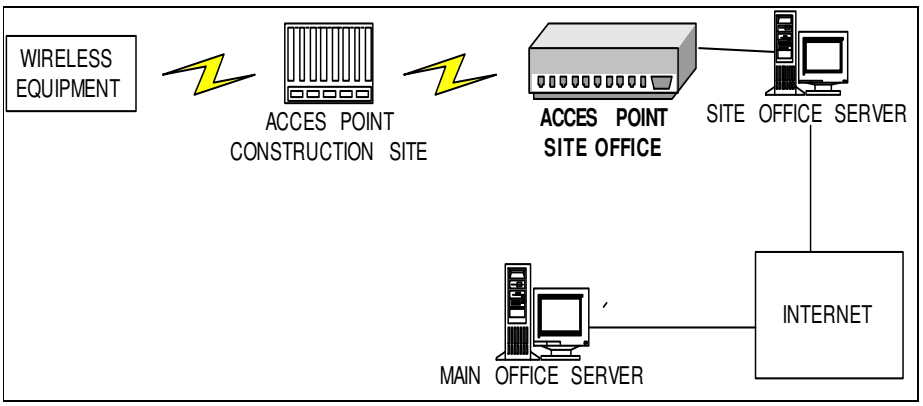
WLAN CONFIGURATION IN MAIN OFFICE

WLAN CONFIGURATION IN SITE OFFICE



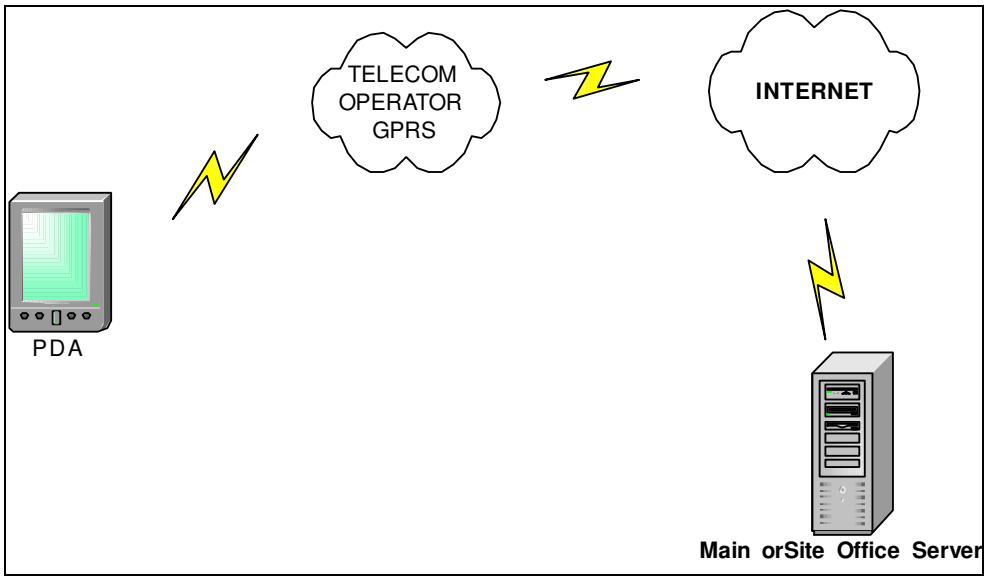
CONSTRUCTION SITE





DATA FLOW BETWEEN THE CONSTRUCTION SITE AND MAIN OFFICE

Figure 4-12 Scenario 4 (WLAN in construction site)



DATA FLOW BETWEEN MAIN OFFICE AND CONSTRUCTION SITE OVER GPRS (2.5 G)

Figure 4-13 Scenario 4 (GPRS in Construction Site)

4.3.2.5 WLAN in Main Office, WLAN in Site Office

WLAN&UMTS at Construction Site

Scenario 5 has the same infrastructure as scenario 4. However, the only difference is the telecom technology using in the construction site. In this scenario, 3G mobile technology is proposed for the position of GPRS. 3G technology has many advantages over GPRS, however today; Turkish contractors can not use this service due to the unavailability of 3G infrastructure in Turkey. Construction may benefit from 3G in the future for the wide area instant communications; however there are no plans for roll-out of 3G in Turkey.

4.3.3 Benefits of Mobile Computing in Construction

Construction is an obvious sector to benefit from real-time wireless communication due to the field work in construction site. By coordinating mobile connectivity, construction site engineers and workers have opportunity to contact with other parts of the site, managers and engineers. This way, information is shared and problems can be solved faster by instantaneously having access to information. Benefits of the mobile computing and wireless connectivity in construct ion site are:

- Reducing overhead costs (documentation, paperwork, etc.)
- Increasing productivity and efficiency of fieldworker
- Reducing travel costs
- Decentralization and rapid decision making
- Increasing speed of business processes
- Better communication and coordination in construction site
- Better record keeping and knowledge management

4.3.4 Preliminary Field Study of Mobile Devices

When looking at the applicability of new technology it is very important to separate myths and potential from realities and solutions. In this study, preliminary studies were done to evaluate the functionality of the wireless equipment. With increasing functionality (and cost), Phone-type device, PDA/Pocket PC and Tablet PC are three main types of mobile devices which would be tested. However, it was not possible to obtain a tablet PC for practical tests.

4.3.4.1 Mobile Phone

The Sony Ericsson T610 is a tri-band GSM phone with GPRS and Bluetooth connectivity. It has a color screen, camera and various organizer features such as calendar and contact manager. It features a Wireless Application Protocol (WAP) 2.0 browser for accessing suitable Internet site. It can be considered either an advanced GSM phone or a low-end smart phone.

Figure 4-14 Sony Ericsson T610 on a WAP site

With the T610 it is possible to do things like:

- Connect with GPRS to Internet through an ISP (Internet Service Provider, i.e. the telecom operator Turkcell, Telsim or Avea)
- Take photographs and attach them to e-mails
- Call or e-mail contacts by looking them up in the Contacts section.

- Synchronize contacts with a PC running MS Outlook through the connect software

The phones' e-mail client was found very user friendly and easy to set up. The quality of the camera is very low but still sufficient for general use on a construction site. The phone is not expandable with e.g. memory cards. However, despite being very rich on features and connectivity options for a phone, T610 also showed to have serious limitations. More importantly, it proved to have bugs in the software; both in the phone itself and the PC software supplied with the device.

A very serious problem was an error in the GPRS connection functionality: While connected with GPRS the phone was unable to accept incoming calls (figure 4.15). A normally functioning GPRS connection will put itself on hold during an incoming call and automatically reconnect when the call is ended. The fault was investigated through the operator (Aria) as well as the supplier. Eventually Sony Ericsson admitted that the phone had a fabrication error.

This is not unusual with mobile phones, new phone models with 'bugs' is a widespread problem. Due to fierce competition, suppliers are forced to send new models to the market as quickly as possible. Some models therefore reach the shops before being properly tested under all conditions.

Figure 4-15 Error in GPRS connection – calls not allowed during GPRS

Several other problems were experienced with the T610, there were:

- The phone crashed three times in a week, when accessing a slow WAP site. Reset could only be done by taking out the battery.
- WAP services are very slow and unreliable. Google WAP search proved useless – it constantly gave "two many results"
- Hotmail Mobile only worked with Turkcell, not Aria(now Avea)
- Polyphonic ringing tone was very hard to hear outside, and definitely too low for a construction site. There will be many lost calls if using this phone outside.
- The screen is very dark outside and since it is not transreflective it is almost useless on a sunny day.
- The newest version of “XTND Connect PC" software was downloaded from the web, but it was unable to detect the phone on infrared connection to a laptop, even thought Windows XP could detect the phone (Figure 4.16).

Figure 4-16 Bug in software in supplied with the phone – unable to detect phone

- **Conclusion phone device**

Due to the error with GPRS connection, which was determined as a fabrication error by Sony Ericsson, the phone was returned before it could be useful in a field study. For construction site use, it could be anticipated that the T610 could be used for ad-hoc reporting from site by sending e-mails with photographs taken with the built-in camera. The advantage of GPRS connection is the coverage everywhere in the country. The disadvantage of GPRS is the slow speed and relatively high cost. In general the phone seemed to have many fashion statements, such as polyphonic ring tones and color screen, some of which in some aspects makes the phone less useable on a construction site than a traditional mobile phone. Furthermore, there were many bugs in the phone and supplementary software which must be considered unacceptable.

4.3.4.2 Pocket PC

The HP iPAQ 4150 is a pocket PC featuring on-board WLAN and bluetooth. It is installed with Microsoft Windows Mobile 2003 Software for Pocket PC operating system as well as various softwares, such as pocket versions of MS Word and Excel. It has the usual organizer functions such as a contact manager, calendar with alerts when appointments are due, tasks and E-mail.

The device is extremely handy, in fact almost too small. Windows Pocket 2003 can be considered user friendly and the quality of the screen is very good in all conditions including direct sunlight. It has a secure digital (SD) port for extra storage up to 1 GB. A 256 MB SD card will cost around 75 dollars in Turkey. SD I/O cards, shortly 'SDIO' cards, are supported. SDIO is a way to support memory and I/O cards

in the same slot. Typical SDIO expansions are ethernet (LAN), modem, WLAN, bluetooth and cameras.

Figure 4-17 HP iPAQ 4150 Pocket PC

With the iPAQ 4150 it is possible to do things like:

- Synchronize appointments, tasks, contacts and other items with a PC running MS Outlook through the ActiveSync software.
- Connect wirelessly to the Internet and office network with 802.11b Wireless LAN (WLAN)
- Connect to Internet through an internet service provider (Turkcell, Telsim or Avea) by using a bluetooth phone as GPRS modem
- Use public hot spots for WLAN connectivity to Internet
- Send e-mails to contacts in the Contacts section

- Read and edit Word and Excel
- Read Acrobat and Microsoft Reader documents.

The pocket PC does not feature GPRS. Inserting an SDIO card with GPRS may seem like a solution, but SDIO-GPRS cards were found not to be available (although GPRS cards for laptop computers are available). The reason must be that in order for it to work a SIM card would have to be inserted, and this will create a space problem in the small SDIO card. However, a typical method of connecting with GPRS would be to connect with bluetooth to a GPRS phone. Two typical connection methods are shown in figure 4.18.

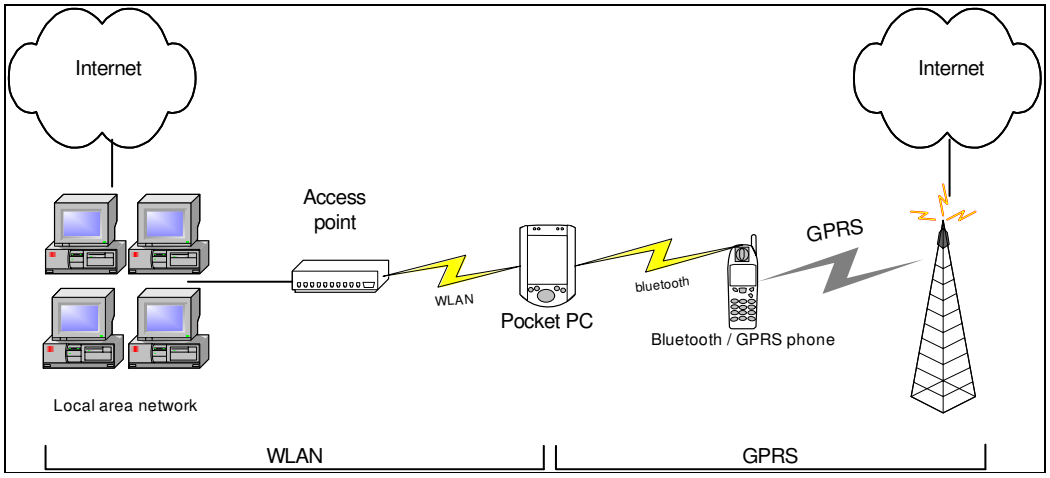


Figure 4-18 Typical wireless connection scenarios for pocket PC

The Pocket PC and phone would constitute a small Personal Area Network (PAN), which connects to the Internet through an ISP, i.e. the telecom operator. In bluetooth terms the phone-pocket PC relationship is called a 'partnership'. Where

available, WLAN will be the preferred connection protocol, otherwise there is GPRS coverage all over Turkey.

4.3.4.2.1 Security

Unauthorized access to the network is a far greater problem with wireless than with cable networks. A set of security services used to protect WLAN 802.11 from unauthorized access has been developed. The Pocket PC supports the following services:

- WEP = Wired Equivalent Privacy, a network encryption using a key to authenticate access, the most normal security technique using for example 64 or 128 bit keys
- 802.1X Certificate Enroller, support for Microsoft Certificate Servers built-in. Custom enrollment applications can be developed for Alternate Certificate Authority servers
- LEAP, an 802.1X authentication protocol developed by Cisco, requiring initial registration on a LEAP-authenticated network

Furthermore, when wireless access exists, it is important to use firewall and password protection of network resources wherever applicable. Other security measures exist. For example, the MAC address is a unique hardware identifier, and therefore a method of client tracking and authentication employed in LANs and 802.11 wireless networks. MAC filtering enables some control of devices and users, and is for example deployed in METU campus wireless network.

Handheld computing brings another security risk, since the Pocket PC enables access to the network, and may also contain confidential information. If it

falls into the wrong hands it may be misused. Pin-codes and password protection can be applied, and on some high-end models, fingerprint authentication is possible.

4.3.4.2.2 Connectivity test - Wireless Connection to Internet and a Local network

The Pocket PC was tested in a wireless network with a Linksys router / access point and two other computers. The Linksys router assigns dynamic IP addresses to the 2 computers and the pocket PC. With dynamically-assigned IP addresses getting access to the Internet with the pocket PC was almost effortless. The router enabled the 3 devices to share a METU backbone connection to the Internet. WEP authentication of 64 bit was implemented by supplying the router with a pass phrase, whereby the router would supply a key, which in turn had to be entered in all computers before being able to securely connect.

Figure 4-19 6 Linksys WLAN router / access point

Setting up access to the home network, i.e. accessing shared folders and files on other computers, took a little effort. The pocket PC accesses the local network - in this case the other two computers - through a VPN (virtual private network) connection. Network configuration in Pocket Windows 2003 OS is very

counter-intuitive compared to the full Windows. The Pocket PC has two modes of network access, 'WORK' (intended for office wireless networks) and 'ISP' (Internet). However, due to various Microsoft assertions in the operating system, the device must be in 'Internet' mode for the VPN to work, and therefore (contradictory) to connect to the other computers on the local net. In other scenarios, if an office had physical VPN or proxy servers, 'WORK' mode may work as intended, or different settings may be needed. However, this was not tested. In conclusion, setting up connections in Windows Pocket PC 2003 is therefore more difficult and more confusing than in Windows XP. Once connected, with the standard File Explorer (figure 4.20) it is possible to copy files to/from the pocket PC but it is not possible to open files located on the network. This must be considered a shortcoming, so to open files located on another computer, a file manager software called Resco File Explorer was installed. Accessing files located on the pocket PC from another computer was not possible.

Other shortcomings were:

- Due to the VPN connection, the pocket PC does not identify itself in a Windows domain or workgroup.
- Installing programs must be done from a PC connected to the Pocket PC and ActiveSync software running.

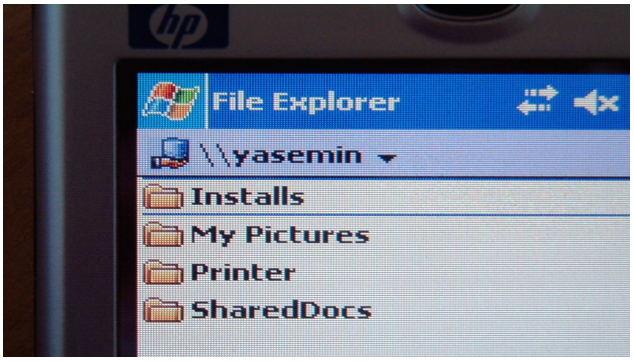


Figure 4-20 Accessing shared drives on the local network

At METU there is a campus-wide wireless LAN. Access to METU wireless LAN requires that the hardware, i.e. MAC, address of each wireless network interfaces is informed to METU Computer Centre, which will then grant access to the wireless network. This network was also tested, and basically found useless (unable to connect) except in few locations where there were obvious line-of-sight to the antenna on Engineering building. Other public hot-spots, such as Armada Shopping Centre, were tested and found to work without problems although connections times were sometimes slow, and not 'instantaneous'.

Over a WLAN 802.11b infrastructure speed of file transfers was acceptable. The Pocket PC synchronizes to a PC running Microsoft Outlook and ActiveSync. The usual connection method is a USB cradle, but it was also possible to synchronize over infrared beam or the WLAN. Synchronization over WLAN works only when a VPN connection is set up, but otherwise without any special adjustments, and a 'mobile schedule' could be set to synchronize manually or automatically depending on peak times set by the user. In a WLAN environment, USB or infrared must therefore be considered unnecessary for daily use. Synchronization over wireless LAN could be beneficial in case synchronization must take place while the Pocket

PC user is on site. For example, meeting requests (a function in Outlook) can be sent from the Pocket PC.

A GPRS connection to Turkcell was established through the infrared link and a mobile phone. The alignment of the infrared ports phone-PC makes it an unsuitable solution for situations where high mobility is needed. Speed was found acceptable for most websites but not for transfer of data. It was not possible to test a GPRS connection over a bluetooth phone.

- **Conclusion Pocket PC**

Handheld computing and wireless networking suit each other extremely well. A wireless LAN gives many added dimensions to using a Pocket PC and using WLAN feels effortless and convenient. WLAN can be set up by power users, while advanced security or VPN settings may best be done by dedicated IT staff..

Synchronizing and access to Internet are effortless, while setting up access to the local network requires a little bit of effort. Connection speed over WLAN is satisfactory for file transfers. However, accessing media files located on the network, such as video having high bit rates, seems to have problems. Battery life suggests that charging once per day will be sufficient for work on a site.

4.3.4.2.3 Limitations of Pocket PC

The following limitations with the 4150 were experienced:

- Device does not seem suitable for use in wet weather conditions without some sort of casing.

- Screen seems very small to anything but the simplest use. In case special site software is used much zooming/panning may be needed to access the needed information.
- The stylus is very small and easy to lose.
- Web sites that use HTML 4.0, animated images, and Java applets may not work correctly in Pocket Internet Explorer without additional software.
- Sending emails to domains outside METU failed. The same problem was experienced with the T610 phone, suggesting this is a problem with the ISP (Turkcell and Aria).

During the concluding stages of this study, vendors have started bringing integrated cellular/ Wi-Fi devices to market. Some of these are marketed as highly advanced phones, such as Motorola CN620, a 802.11a/GSM device that will be able to leverage new integrated cellular/WLAN enterprise architectures. The new trend is being constantly online, instead of just available. HP has marketed various devices, like the iPAQ 6153 and iPAQ h6340 pocket PCs, which can handle voice and data on GSM/GPRS, Wi-Fi and Bluetooth networks. They can function as phones through a seat of headphones.

For Turkey this development has little importance since integrated celluar/WLAN networks are not offered by any operator yet. The availability of such devices does therefore not change the circumstances of the case study, which is presented in the next chapter.

CHAPTER 5

5 MARMARAY PROJECT-CASE STUDY

Marmaray is an important and prestigious project for Turkish government and contractors. This project includes different types of tunneling methods and construction business which have numerous site activities. Construction will continue simultaneously in different parts of European and Anatolian side. This fragmentation result in development of construction sites and these construction sites have to be coordinated with each other and with site offices. Moreover, instant information sharing and communication have great importance on the coordination. Tunnel projects under the ground have difficulties due to distances between the site office and construction site. Especially, in Marmaray, there will be construction sites in both sides of Bosphorus. Wireless network design in tunnels and construction sites is the best solution for sharing documents, accessing the data and controlling project details during the construction due to its mobility, coverage and high data transfer rate.

5.1 Project Brief

The Gebze-Haydarpaşa and Sirkeci-Halkalı commuter rails upgrading and railway Bosphorus tube crossing construction in Istanbul, shortly the Marmaray project, was chosen as a case study to explore feasibility of implementing wireless networking on construction sites. The tender for Contract BC-1, i.e. tunnels and

stations between Yedikule on the European side and Söğütluçeşme on the Asian side, was won by the consortium consisting of Taisei (Japan), Kumagai Gumi (Japan), Gama (Turkey) and Nurol (Turkey). A groundbreaking ceremony took place on May 9, 2004, but at the time of thesis submittal the actual construction has not yet started due to various delays. The following section lists key project data.

Employer:

Republic of Turkey, Ministry of Transportation General Directorate of Railways, Harbors and Airports Construction (DLH).

Contractor:

The contractor is a joint venture consisting of TAISEI(Japan), KUMAGAI GUMI(Japan), NUROL (Turkey) and GAMA(Turkey).

Engineer:

Avrasyaconsult, a joint venture consisting of PCI (Japan), Yüksel Proje (Turkey) with among others Parsons Brinckerhoff (US) as subconsultant.

Contract type:

Design-build. The contractors design group is lead by Su-Yapı (Ankara)

Project Financing:

From Official Development Assistance (ODA) loan from Japan Bank for International Cooperation (JBIC) and partially from national budget.

Scope of Works:

The Marmaray Project comprises the upgrading of an existing commuter rail system and the construction of a new railway crossing under the Bosphorus. Contract BC-1, which is the subject of this case stuffy, consists of the tunneling parts, including 4 underground stations, the immersed tunnel under Bosphorus and ancillary structures such as bridges, tunnel portals and underground crossing. The new upgraded railway

system extends for approximately 77 kilometers, between the stations of Halkalı on the European side and Gebze on the Asian side of Istanbul.

The main work items include the construction of immersed, bored, and cut-and-cover tunnels; 4 new underground stations; modifications and improvements of 37 surface stations, new yards, workshops and maintenance facilities, upgrading of existing commuter lines under operation; renewal of all electromechanical systems, procurement of modern rolling stock, testing and commissioning, trial runs and staff training.

Contract Details:

- **Immersed Tube Tunnel Under Bosphorus:**

The immersed tunnel will extend from Sarayburnu Park of Eminönü to Salacak shoreline in Üsküdar. 1800 m long immersed tube tunnel, terminal joint structures (connections between the immersed and adjacent tunnels) and all necessary off-shore and on-shore facilities. The two rail tracks will be separated by a central wall in the immersed tunnel with 1.4 m wide emergency walkways on each side of the wall. The dimensions of the immersed tunnel are 14 m wide and 8m high. The rail track level at the terminal joint structures is 52m below sea level on the European side and 36m below sea level on the Asian side. Water depth is about 50m over the immersed tube tunnel.

- **Underground Tunnels:**

This part of the contract comprises two single-track tunnels extending from Yedikule station to the immersed tunnel terminal joint structure near existing Sirkeci station and from the immersed tunnel terminal-joint structure near Üsküdar ferry harbor to Söğütlüçeşme station.

Bored twin tunnels are 8.200 m in length 7m in diameter. Cut-and-cover tunnels are1, 800m in length and varying in shape. Deep station caverns extending 1,200 m and the use of new Austrian tunnel method may be considered.

- **Stations:**

Four each new stations will be constructed. The Yedikule, Yenikapı and Sirkeci stations are located on the European side and Üsküdar station is on the Anatolian side.

Table 5-1 Station Depths Below Sea Level

Station	**Depth Below Sea Level(m)**
Kazlıçeşme	At sea level
Yenikapı	13 m
Sirkeci	35m
Üsküdar	18m

5.2 Realities and Numbers about Marmaray Project

Table 5-2 Project Data (Construction Proposal)

Total Length	76.3 km
European Side	19.6 km
Asian Side	43.4 km
Immersed Tunnel	1.6 km
Bored Tunnel	8.9 km
Cut-and Cover tunnel	2.8 km
Maximum Depth of Immersed Tunnel	55m
Total Stations	37
New underground stations	4
Length of platforms	180m
Max. Capacity(Today)	10.000 passenger(one direction/hour)
Max. Capacity (Future)	75.000 passenger(one direction/hour)
Max. Speed	100 km/h
Average Speed	45 km/h
Time between the following trains	120-600 sec
Number of new vehicles	670
Total transportation time	185 minutes
New transportation time	104 minutes

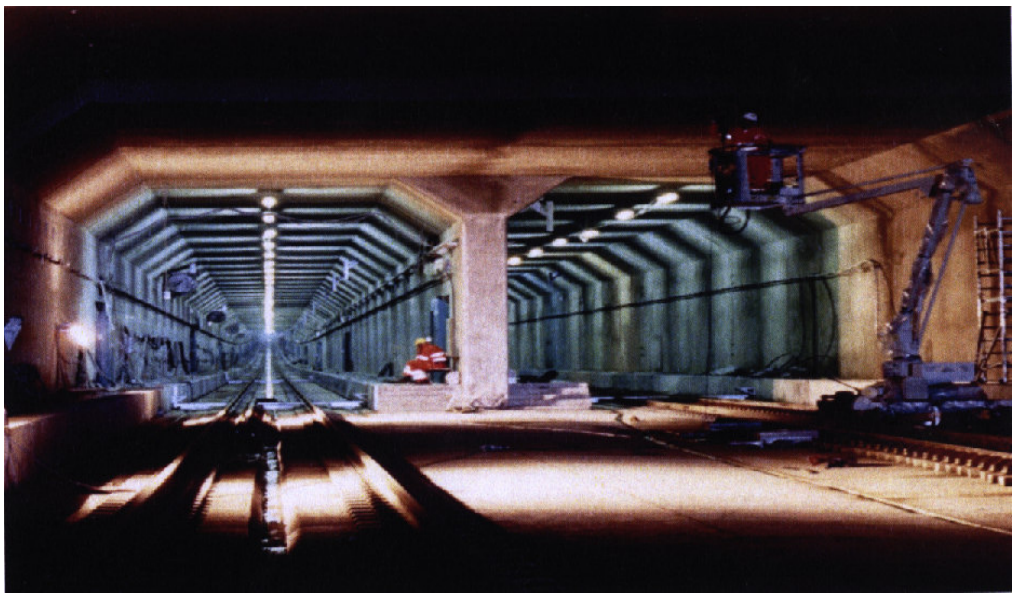


Figure 5-1 Photo Similar to Marmaray Tunnels (Construction Proposal)

Figure 5-2 Map of Marmaray (Construction Proposal)

5.3 The Overall Execution of the Works

In the construction proposal the contractor is committed to design, plan, carry out and complete the project safely and on schedule in accordance with the requirements given in the drawings, specifications and the terms and conditions of the Contract, to the full satisfaction of the Employer and the Engineer. In order to achieve the above objectives, sufficient coordination with the Employer and the Engineer should be maintained throughout the project period. (Construction Proposal)

5.3.1 Common Work Items

Large scale construction work will be carried out both on-shore and off-shore. Communications among all related parties and sufficient information including detailed work procedure is essential to complete the construction work conforming to the requirements of the Engineer.

5.3.1.1 Earthworks

The earthworks will be performed in accordance with the relevant Specifications and Drawings. Detailed execution plans for each main earthwork item will be submitted to the Engineer. During the earthwork execution, the following activities will be always monitored and controlled. (Construction Proposal)

- Excavation
- Backfill&Banking
- Hauling Work

5.3.1.2 Concrete Work

During the concrete work, these points have to be monitored and controlled:

- Control of Compressive Strength of Concrete
- Material Control
- Control of Concrete Batching & Mixing
- Control of Concrete Placement
- Formwork
- Re-bar Work

5.3.2 Specific Work Items

Work Items are listed below:

- Dredging and Disposal
- Immersed Tunnel
- Construction of Terminal Joints
- Tunnel Boring by Means of Tunnel Boring Machines(TBM)
- Deep Stations
- Cut-Cover Tunnels
- New Austrian Tunneling Method(NATM)
- Construction of Bridges
- Building Works(Underground Station, Finishes)
- Electrical and Mechanical Works

5.3.3 Mobile Computing in Marmaray Project & Wireless Local Area Network Design

Wireless Local Area Network is designed for the tunnels between Kazlıçeşme-Yenikapı (1,870m),Yenikapı-Sirkeci (3,343m), Üsküdar-Söğütlüçeşme (4,620m) and over the ground for construction sites(fig.5.3). A wireless LAN network was designed according to the project details. The network cost is assumed over the project drawings. For this reason, the cost and the network plan can be a little bit different during the execution of the project.

There will be five construction site offices and a main site office. In every site office, Construction Company will have computer servers and the wireless network will be connected to these servers. In the underground tunnels during the project execution, there will be at least 50 users. 10 users will be between Kazlıceşme-Yenikapı, 20 of them will be between Yenikapı-Sirkeci and 20 users will be between Üsküdar-Haydarpaşa. For the mobile computing in the construction sites and underground tunnels, these are necessary and by evaluating the cost of these items, mobile computing and wireless connectivity cost can be calculated in Marmaray Project:

- WLAN equipment and installation cost
- Mobile Device Cost (Pocket PC, Tablet PC, etc.)
- Software Cost
- Cost of Information Technology Team which is responsible for the configuration and development of hardware, software and the overall computer system in the project.

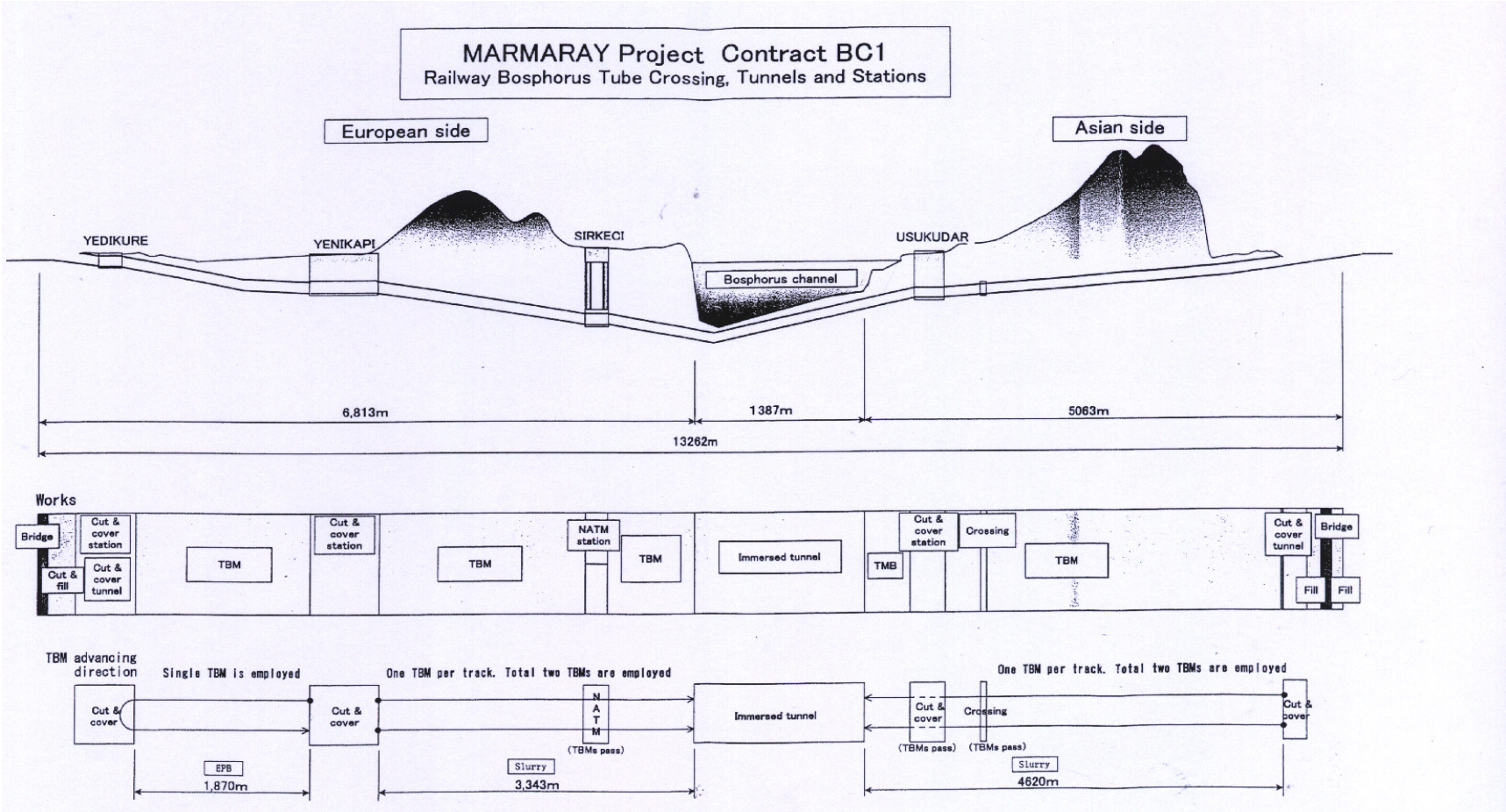


Figure 5-3 Sectional Views of Marmaray Project (Project Proposal)

5.3.3.1 Mobile Computing in Marmaray Project

Wireless connectivity and mobile computing in construction site enable controlling of project business processes in real time, thereby decreasing time losses and paperwork in the current system. In the existing system of work, engineers on site use note taking methodology in order to receive information from site and connect with the site office by using walkie-talkie voice system. In the proposed system, engineers use mobile devices in order to control the business processes and information can be shared with the both site and main office without any delay by using WLAN and the Internet. Moreover, they can discuss any point about the process on the network, make videoconferencing by using their mobile devices without leaving their positions on the construction site and send live videos from the construction site to the site office, main office or anywhere else. Every problem in the construction related with the design or anything else can be shared with offices instantaneously and if a solution is agreed it can reach to the engineer on site immediately. There are some items which are related with the execution and management of business processes. Wireless connectivity and mobile computing can be used efficiently and effectively for these items:

- Progress control
- Proper execution of the works according to technical specifications and design requirements
- Defects notification and eliminating the defects with the consultants, specialists and employer
- Changes in the scope of work
- Cost savings and resource allocation during the execution of the works

Advantages of Using Wireless Connectivity and Mobile Computing:

- Progress control: By using the mobile devices, controlling the progress according to the project schedule instantaneously and daily reporting from construction site.
- Proper execution of the works according to specifications and design requirements: Wireless connectivity and mobile computing eliminate the time loss caused by paper based documents on site and lead to data exchange between site and office.
- Defects notification: During the construction site trip in tunnel projects, defects can be properly investigated and necessary information from construction site can be saved into the mobile computers. Moreover, defect notification process will be more accurate and parties can reach the real time information instantaneously.
- Changes in the scope of work: In underground tunneling projects, there may occur different cracks during the construction. These cracks have to be monitored and controlled by the experienced engineers. Moreover, detailed decision making has to be done and necessary precautions have to be taken instantaneously. Mobile computers having webcam can send instantaneous photos and videos from construction site to office in order to make proper decision making and follow the changes in the scope of work.
- Cost savings and resource allocation: Labor, material and equipment can be controlled and coordinated by accessing the real time information from construction site efficiently and this leads to save money during construction.

5.3.3.1.1 Proper Execution of the Works

Proper execution of the works according to technical specifications and design requirements is the objective of any construction site. In the current system (fig.5.4), site engineers use paper based drawings and specifications during construction in order to check production. However, theoretical drawings and real application may differ. At that time, engineers on site and in the design office or site office have to share information. Moreover, the only way for the information sharing is to use voice system or leave the current position. There is no way to visualize the problem related with the technical specifications or drawings. This system leads to time loss and ineffective working conditions.

In the proposed system (fig5.5), engineers on site work with mobile computers in order to control the execution of the project and share information with the main or site office. There is a decreased need to work on the paper based documents. Mobile computing on site and wireless connectivity to the offices increase the mobility of field staff, decrease time losses and rework on the paper based documents. At the end of the working day, engineers transfer the information and necessary data to the file server in the site office and load the necessary information to their mobile devices for the following working day. During the work hours in the construction site, engineers and operators can share any file over the network. In the proposed system, construction activities can be completed within the budget and on time. Moreover, data from the construction site can be followed by managers continuously. The construction company gains competitive advantage because of controlling and coordinating their business processes more efficiently and effectively.

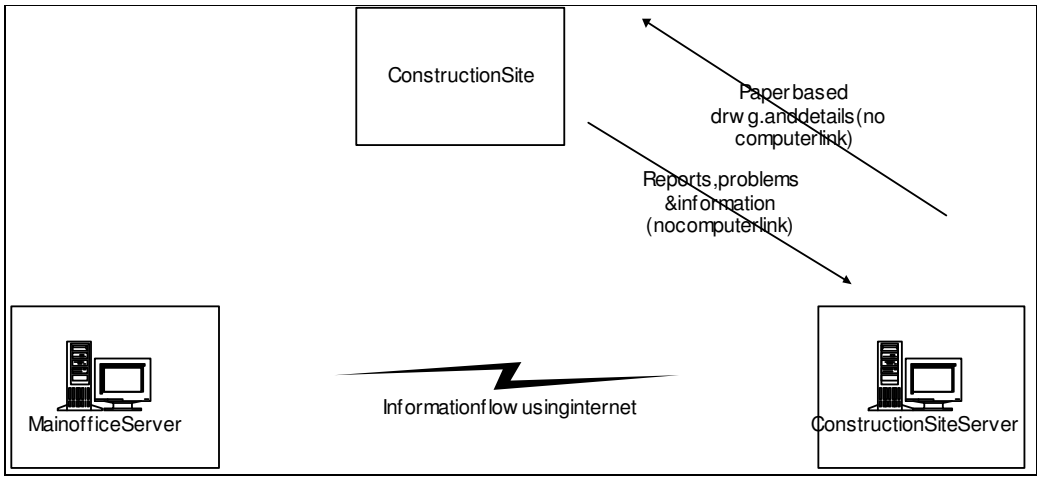


Figure 5-4 Traditional system of data flow to/from site

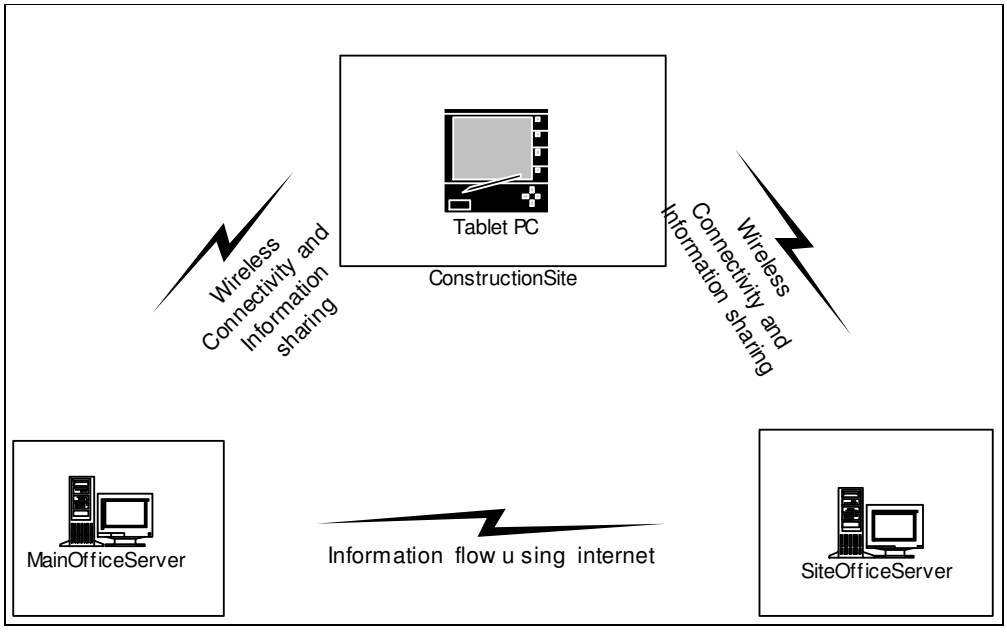


Figure 5-5 Proposed system of data flow to/from site

Controlling the construction according to design documents and drawings in the construction site is an important process for quality, cost, time and execution of the construction project. In this business process, construction company is responsible for the production in the construction site and contractor's site engineers have to follow the construction continuously in order to complete the project on time, within the budget and to satisfy the clients needs.

In the controlling of the construction for the appropriateness to design documents and drawings, there may arise some problems related with the conditions of the project. These problems have to be solved in an efficient way in the construction site. Otherwise, completing the project on time and within the budget is impossible from the contractors' point of view. Problems during the control of construction according to design documents and drawings are:

- Missing document and drawing in construction site
- Sophisticated drawing
- Need of more detailed design
- Differences between the design and the real application and need of decision making

In the traditional system, paper- based documents are used during the control of the construction according to design requirements. Computer aided design drawings are sent to site office from main office over Internet protocol and engineers receive paper-based drawings from site office.

In the proposed system, Tablet PC's are used instead of using paper-based drawings. Computer aided drawings and design documents are sent to site office and engineers save the necessary design documents and drawings into their portable PCs.

Table 5-3 Comparison of solutions in the traditional and proposed system

Problem	Solution(Traditional System)	Solution(Proposed System)
• Missing document • Need of detailed design	• Back to site office(Time Loss)	• Access to WLAN and Internet over the access points in site by using the portable PC and receive the documents and drawings.
• Sophisticated drawing • Decision making& Differences between design and application	• Back to site office for face-to-face meeting • Site trip for investigating the situation	• Sketching on the drawing in order to ask or explain the drawing and the problem, then sharing the document with site office and main office over WLAN. • Sending photos taken by webcam of Tablet PC and visualize the problem quickly. (netmeeting)

5.3.3.2 Wireless Local Area Network Design & Calculation of Overall System Cost

WLAN is designed between Kazlıçeşme-Yenikapı, Yenikapı-Sirkeciand Sırkecı-Söğütlüçeşme. However, between Sirkeciand Söğütlüçeşme immersed tube tunnel and Üsküdar station will be constructed(fig.5.8). During the design stage of WLAN, wireless connectivity in the tube tunnel is neglected because of the construction under the sea. WLAN is designed according to the directions of the tunnel boring machines. In Üsküdar station, there can be wireless connectivity expansion by using extra antennas between Söğütlüçeşme –Üsküdar. Moreover, there will be wireless connectivity in the immersed tunnel after the arrival of tunnel boring machines to the ends of tube crossing. For the wireless connectivity in the tube crossing, extra access points or bridges have to be used between the stations and tube crossing. The below figure is a network plan which illustrates the equipment used for the design, directions of tunnel boring machines and expected number of users in the tunnels. Briefly, some assumptions are made during the design of WLAN:

- Installation of WLAN hardware into Kazlıceşme, Yenikapı, Sirkeci and Söğütlüçeşme.(if it is needed, there can be extra installation for Üsküdar station)
- Tunnel Boring Machine directions are the basis on the selection of the network stations.
- Tunnel thickness is 70 cm and radio frequencies can not pass from such a thickness. For this reason, WLAN is designed for both directions of tunnel boring machines.

- Tunnels are assumed as straight during the preliminary WLAN design. However, in reality, due to tunnel cross-section along the path at least one extra access point can be used between the network stations. Extra access point costs are included in the preliminary design.
- It is assumed that each network station will have server and necessary computer hardware for the site office.
- In the design, WLAN 802.11 g standard is used.

There are two types of equipment used for the design of WLAN inside and outside the tunnels. These are directional antennas and access points. There will be at least twelve antennas and twelve access points. Here is brief information about the equipment:

High Gain Directional Antenna(ANT24-1801) :

The D-Link ANT24-1801(product code) antenna provides extended coverage for an existing wireless local area network (WLAN).Its weight is 3.5 kg and works between -40C to 80C degrees. Moreover, ANT24-1801 antenna survives up to 200km/hr wind speed. (D-Link)

Figure 5-6 Directional Antenna(D-Link)

Wireless Access Point(DWL-2700 AP):

The DWL-2700AP covers a large operating distance, providing an 802.11g outdoor WLAN which enables users to access the Internet or an organization's network. At up to five times the speed of previous wireless devices, you can work faster and more efficiently, increasing productivity. With the DWL-2700AP, bandwidth-intensive applications like graphics or multimedia will benefit significantly because large files are able to move across the network quickly. (D-Link, Official Web Site)

The DWL-2700AP is suitable for manufacturing plants, industrial sites, military bases, universities, hotels, airports and golf courses. DWL-2700 AP provides outdoor users with wireless internet access and it is designed for harsh outdoor environments. Moreover, it is capable of operating of different operation modes to meet wireless networking requirements: create a wireless LAN, wireless connect two networks and wireless connect multinetworks.

Figure 5-7 Wireless Access Point (D-Link)

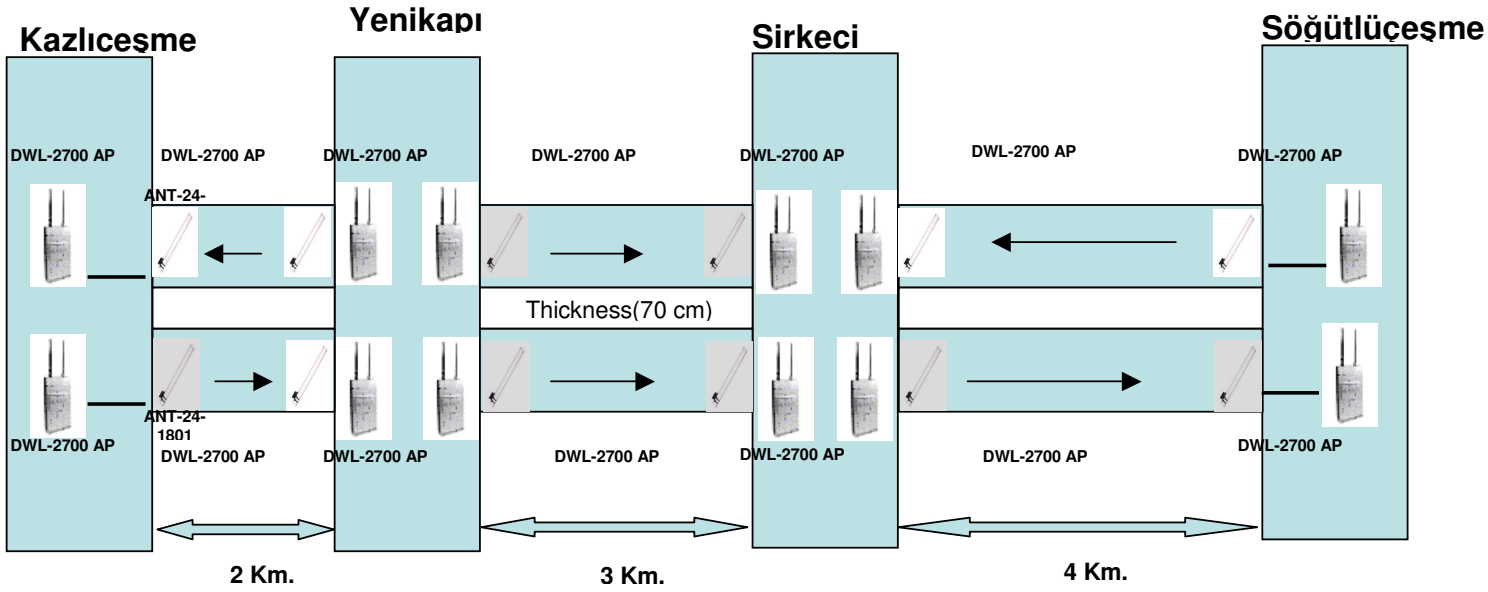


Figure 5-8 Network Plan for Marmaray Project(AVS Technology)

Overall System Cost For Marmaray Project:

- WLAN Equipment and installation Cost: 25,000-30,000 $ (Extra Equipment is included)
- Hardware Cost: At most 25 Users are assumed for the mobile computing during the project. Hardware cost includes the Pocket PC and Tablet PC cost which is nearly 30,000$ for 25 users. (20 Pocket PC& 5 Tablet PC)
- Software Cost: Software for the mobile computing can be useful for the development of database which builds the project-specific web page. For mobile computing, combined and detailed software can be used in the construction site activities. This software may include resource planning, progress control, quality control and etc. By this way, Construction Company may use the software for the all operations and for the all projects. The software cost must not be decided for the only Marmaray project cost. Because, construction company can make offer for a software which is designed for the construction project control and management in construction sites. Moreover, all the construction projects can be controlled and coordinated over the internet and local networks. Users can reach any information at any time about the current or past projects by using the database and the proposed software which is designed for mobile computing in construction sites.
- IT Team Cost : At least two engineers has to be employed by the construction company for Marmaray project and the other construction sites in order to develop a common software and integrate the mobile computing into business processes.

CHAPTER 6

CONCLUSION

The subject matter of this research is the integration of wireless connectivity and mobile computing into construction site activities. The aim was to develop a modern vision for construction management. Information technology is developing rapidly and especially wireless communication and mobile computing continue to improve business processes in sectors such as marketing and manufacturing. In engineering there has been great improvement in the field of design and structural analysis, for example. However, from a construction point of view, there has been very minor change in use of information technology. With the exception of GPS (Global Positioning System)surveying, IT has had very little influence on construction site processes, and this has caused the construction sector to lack behind other industrial sectors, who have extensively implemented IT and seen vast gains in efficiency and quality.

Strategic and IT management have an important role on the future of current construction companies. Especially in Turkey, contractors' profits have diminished since the 1990s. Moreover, the construction market does not expand like in the past twenty years. For these reasons, competition has increased. In this situation, strategic and IT management are two important factors shaping future vision and benefits of the construction companies. However, in the vast majority of Turkish construction companies, there are no real strategies for the integration of information technology for gaining competitive advantage. The construction firms typically assign the IT

department with responsibility for user support and managing the server in the main office. To break this trend, IT departments have to follow new technological developments and choose the most suitable tools integrate into the construction business processes. With the appropriate training, efficiency and effectiveness of employees will increase according to improvement in the communication and information flows.

The construction sector has numerous kinds of information flow between the parties involved in the business processes. Many of these information channels can be handled by the use of IT and telecommunication tools. By developing the necessary infrastructure in the construction company, construction sites in different locations can be coordinated from the main office and real-time data flows between the site office-construction site and site office-main office can be developed. When making IT investments, it has always been problematic to quantify the benefits in monetary values. However, tangible and intangible benefits are summarized as :

- Improved record keeping and developing historical database
- Increasing efficiency and effectiveness according to decrease in paper work and time consumption
- Accessing real, accurate and instant information
- Cost saving due to printing and delivery and disposal of documents
- Decreasing the trips to construction sites and travel costs
- Competitive advantage due to better coordinated organization
- Reputation due to the application of latest technological developments
- Cost saving due to better resource planning (material, equipment, labor)
- Better controlling and decrease cost of rework during construction

- Increasing the ability to complete project on time and within the budget according to improved control, coordinating and planning.

Certain cultural barriers must be overcome before the integration of mobile computing and wireless connectivity in the construction business. These are barriers are often related the organizational structure of the construction companies. First, construction companies have to develop organizational structures in order to follow new technological developments and use of IT tools in the business processes. An IT team must consist of engineers having experience in the construction and IT sector. The team will help the firm investing in IT tools in the most effective way and avoiding allocation of unnecessary budgets to IT. The second step is making the necessary investments.. Managers in the construction sector must be informed in detail about the latest IT integration in construction and the company must develop a long term and short term strategy with the coordination and cooperation of IT team and other departments. After developing the strategies, necessary investment can be shaped. The third step is the application of technology for the improvement of the construction business. At this stage, users have to be informed and receive the necessary training. In the development of new systems, users always show resistance because of being in the position of learning something unknown. Out of habit, the traditional systems are considered more effective. However, if users are informed in a professional way by the IT team, resistance will be lowered and users will realize the efficiency and easiness of the new system.

The case study includes a preliminary cost analysis for implementation of wireless networking on site. A wireless network covering the whole construction area represents a very minor cost item. The necessary investment for WLAN and mobile computing is negligible when the scope and budget of the project is decided.

Moreover, the design for WLAN and mobile computing in Marmaray project is feasible and applicable. Tangible and intangible benefits gained from WLAN system and mobile computing represents an importance for the construction company. In the case study, it is observed that mobile computing and wireless connectivity investment on project will improve business processes, quality of information, control and coordination of construction sites. Moreover, construction company will integrate into IT developments and gain competitive advantage in the construction market. Marmaray project is a prestigious project and using the latest technologies and improving the project control during the construction will increase the reputation of the companies involved in the joint-venture.

As a result, this research set out the scenarios and a real application scenario related with wireless connectivity and mobile computing in construction organizations. Construction sector will benefit much more than the other sectors from the mobile communications in the near future. From now on, the target must be to develop the strategy and use mobile IT in the most efficient and effective way

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