

Development of a Mobile Computing System to improve
Construction Management for multiple and divergent civil works
in the telecommunications network

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Abstract

The development of a Mobile Computing System to improve Construction Management for multiple and divergent civil works in the telecommunications network (MCSCM), is descried. The development processes of MCSCM linked practically many research findings and examined the recent technologies to select the best solution for the system requirements. Research undertaken in this dissertation highlights the benefits from applying mobile computing systems in construction management and shows the abilities of mobile computing systems for transferring and sharing projects' information in real-time from construction sites where conventional IT doesn't help in this regard due to the nature of construction environment. The aspects of the construction projects in telecommunications network, such as multiple tasks with short duration for each task, multiple participants from different organizations and separated workers in divergent locations, led to investigate and apply many important issues in mobile computing such as device capabilities detection, mobile web services, latency and wireless network performance. MCSCM is applied and tested to determine whether all system functions has been successfully achieved and the degree of satisfaction of the end-users. The project's overall objectives is evaluated and recommendations for the further research are suggested.

Acknowledgements

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Introduction

Saudi Telecom Company (STC) is a leading telecommunications services provider in Saudi Arabia. It provides both wireless and fixed telecommunications services over a vast network that covers wide areas in Saudi Arabia. In each district in Saudi Arabia, STC has one Network Construction Department (NCD) that is responsible for constructing fixed telephone networks for company's clients. Although this project concerns one of these departments which is in Taif district, the current processes, problems and practices are similar in all departments. Therefore the system provided by this project can serve all Network Construction Departments in STC.

The main objective of NCD projects is to expand the telephone network within the existing network coverage or in new areas to meet the growing demand for the telephone services. Due to this growing demand, NCD usually conducts many projects in divergent locations in the same time. Typically, each project has several civil works such as cutting the asphalt, excavating, extending and jointing telephone cables, filling the trench and re-asphalting. NCD has several contractors who receive project documents from the construction department. These documents include design specifications and implementation plans (Gantt chart). NCD assigns one inspector for each contractor. It is the responsibility of the inspector and project manager in NCD to ensure that the contractor is working to schedule and specifications. Each task within the projects has a short duration (some tasks takes only a few hours) and the inspector must see and inspect every task before the next task starts.

Managing such construction projects in this environment with such conditions is a challenging task and requires effective tools to share and transfer the projects information in real-time among the projects' participants. The current method is simply that the contractor sends a daily log of his activities by fax to the construction department and then the fax is submitted to the particular inspector. This method is not effective because there are limited times for each task and there are a lot of tasks, therefore the inspectors must be at location on exact time, so any delay for any reason will distemper the inspectors and affect negatively on the quality, time and cost of the project. Also it is very difficult to check if the contractor does the project according to the Gantt chart. Therefore there are no references in the construction department for comparing the actual work with planning. Such information is very important to improve the planning in the future. Development of a mobile computing system to inform, in real-time, the inspector about what activity has been started and what activity has been finished for each project with the contractor, and at the same time record the actual start time and finish time of each activity, would be a very useful asset and solve the current construction management problem in CND.

The research undertaken in this project was focused in the area of the current problem in NCD which is the current poor communication tools for sharing and transferring the information between contractors, inspectors and construction manager. Therefore the research answered the following questions :

Why sharing and transferring the projects information from and to construction sites is important for construction management?

How a mobile computing system can meets the needs of construction management for sharing and transferring the projects information?

Analysis of the system requirements was conducted to understand the needs of my client. Then an investigation of the current practice, tools, and technology in design and implementation of the components of the mobile computing system took place. The findings of the research review were helpful for choosing the best solution for developing a mobile computing system that can improve construction management in NCD, consider the conditions of telecommunications network projects and work effectively in such environment.

The structure of the dissertation is presented as follows:

Chapter 1: Need for Mobile Computing System in Construction Management

This chapter clarifies the meaning of mobile computing and its benefits and applications, then discusses the nature of construction management and how the IT systems can improve its outputs and processes. This chapter investigates areas where conventional IT succeed or failed in improving the construction management, and also the ability of mobile computing for supporting construction management in some areas where conventional IT doesn't provide effective solutions. Findings presented shows that mobile computing systems can be considered as an effective solution for sharing and transferring information in construction environment.

Chapter 2: System Requirements

This chapter analyses the current processes in NCD and describes the construction management environment in telecommunications network projects. It starts by an overview of the telecommunications network and the types of civil works in NCD projects. This chapter shows the need for mobile computing systems to improve the current processes and solve construction management problems. The chapter presents also an initial depiction of the proposed system.

Chapter 3: Mobile Computing Technologies

The three components of mobile computing systems - devices, networks and platforms - are discussed. The discussion includes brief development history, technology types and usages of each component. The chapter also presents some considerations when choosing database systems in mobile computing. Findings presented show the most important issues, elements and

criteria that must be considered by mobile computing developers when designing and implementing a mobile computing system.

Chapter 4: Mobile Computing Development Frameworks

This chapter complements the previous chapter to investigate the current practice, tools and technology in design and implementation of wireless applications through research into architectures, frameworks and tools that can be used for designing and implementing mobile computing applications

Chapter 5: System Design and Implementation

All findings from chapter 1, 2, 3, and 4 feed into this chapter which is the practical aspect of this project. The research chapters reflect on choosing Global System for Mobile Communications (GSM) network, Wireless Application Protocol (WAP) platform and designing and implementing the system to work with all mobile devices types. Oracle database system was chosen also as a result of research chapters. This chapter presents the database design, the design framework, and the system architecture is provided in both high level and low level.

The chapter provides detailed description of how the system was implemented including description of algorithms, sample of coding and screenshots.

Chapter 6: System Testing

This chapter discusses the type of tests adopted for testing, including issues that should be considered when testing a mobile computing system. It presents the results of the two types of test used which are system test and acceptance test.

Chapter 7: Evaluation and Conclusion

Provides critical evaluation of the overall project against the initial objectives given in the Terms of Reference. Attention is given to my client and the extent to which the final product satisfies his needs. This chapter concludes with a summary of the project, and also the lessons learned from the project experience. Recommendations for future development, and finally suggestions for areas of further research are given.

Chapter 1

Need for Mobile Computing Systems in Construction Management

1.1 Introduction

The construction industry seeks continuously for technologies that can reduce project time and cost, and improve productivity and performance (Rebolj et al., 2002). Information Technology (IT) is one of these tools which has to be used effectively to assist construction managers to do their tasks in such a way that the construction project meets its overall objectives as defined by the scope, time, cost and quality. However, as will be seen in this chapter, conventional IT doesn't offer appropriate solutions for transferring and sharing projects' information in real-time from construction sites due to the nature of construction environment. The client of this project, Network Construction Department (NCD) in Saudi Telecom Company (STC), currently used IT systems in all construction projects phases but there is no tool used in construction sites to record projects' information and transfer, in real-time, these information to project's participants. The aim of this chapter is to explain the importance of this information for construction management and how mobile computing can contribute in this regard.

To do so, firstly, the definition of mobile computing and benefits and applications of mobile computing is presented to provide a contextual view of the concept of mobile computing and its success in many sectors. A brief discussion of the Information used in construction industry and the role of IT in construction management improvement is presented in order to explain how mobile computing system can be employed as an effective solution for construction management.

1.2 What is Mobile Computing

There are many definitions of "mobile computing" in literature; Sharad G, (1999) defines "mobile computing" as computing activity associated with portable computing devices and their mobile users. Nilsson M. and Ryding B. (2002) states that Mobility or mobile computing describes where a device like a mobile phone, personal digital assistant (PDA) or smart phone can connect to a network (e.g. LAN, internet) or a computer to synchronise applications and information. Ryding D. et al (2000) argues that Mobile computing does not only involve mobile computing devices but also the mobile networks- or wireless network- to which these devices are connected.

Basically, "Mobile Computing" can be defined "is a system that enables people to access and exchange data anywhere- within a wireless network coverage- and any time- with mobile devices.

- Anywhere: user can access and exchange information from any place either from office or from off-site. This advantage adds a significant value to the workers who work in sites that haven't conventional IT infrastructure such as construction sites.
- Anytime: user can access and exchange information when he need to do that. This advantage adds value to information that needs to be handled timely.

Mobile, ubiquitous, nomadic and pervasive computing are used by researchers to refer to computing that uses small portable devices and wireless communications networks (R. K. Ghosh, 2005). Figure 1.1 below shows the distinction between them based on the types of network.

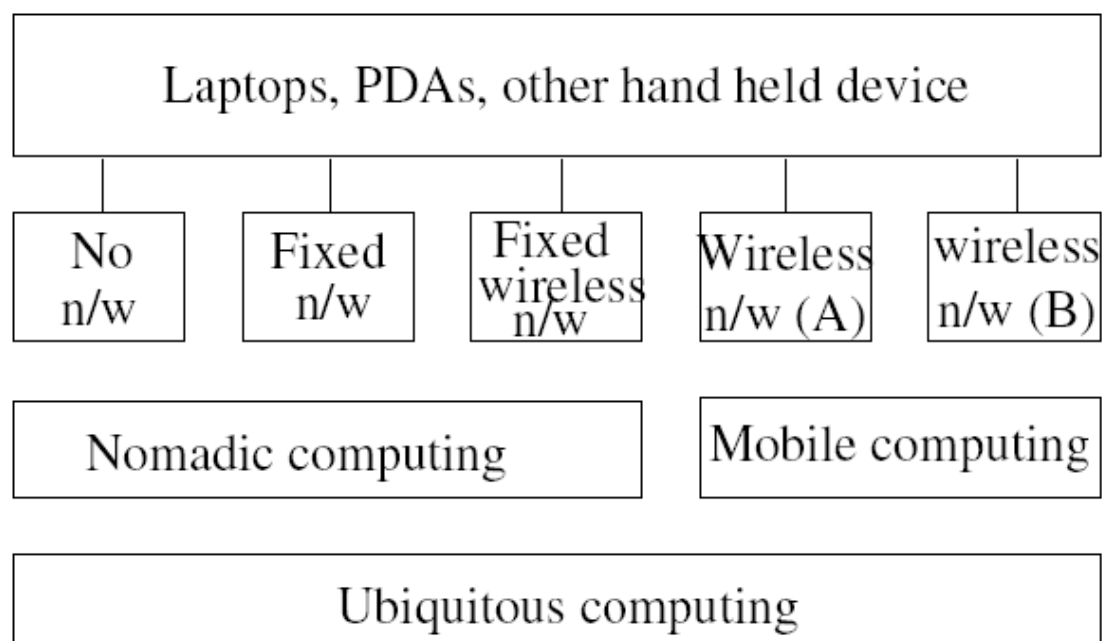


Figure 1.1 (R. K. Ghosh, 2005).

There are many technologies used to build a mobile computing system. These technologies will be discussed in chapter 3. However, choosing appropriate technologies depends somehow on the type of application environment and these technologies differ from one application to another. Therefore, before discussion of the use of mobile computing in construction management, it is important to know the benefits and applications of mobile computing in general.

1.3 Benefits and Applications of Mobile Computing

Although mobile computing applications have recently had a significant impact on many business environments, they are not fundamentally new. Instead, they add mobility as an add-on feature to the existing IT applications (Amjad, 2004, MobileInfo, 2006). In other words, mobile computing can be added to any existing IT application but the benefits depends on to what extent the application needs to add mobility features or the degree of mobility in the application.

Mobile computing has succeeded in many sectors such as e-Commerce, e-Government, health services, security and emergency services, Financial Industry and Airline Industry.

Amjad (2004) provides the following example to illustrate how mobile computing supports sales; salesman can access information from the field through his mobile devices. This real-time access enables salesman to deliver the last and updated quotes and he can ensure that items are in stock and can be delivered on time. Yankee Group expected that investment in mobile computing for sales support jump from \$132 million in 2002 to \$825 million by the end of 2006.

According to a global survey of 309 executives on mobile computing conducted by the Economist Intelligence Unit (EIU), and Nortel Networks (EIU, 2004) , 84% of the companies using wireless solutions say they are beneficial for flexible and remote working, while similar proportions believe they have a real impact on workforce productivity and team collaboration.

The NOMAD Project (NOMAD, 2004) is a good example for the success of mobile computing in e-Government. The Project is supported by the Office of the Deputy Prime Minister in UK, and owned by Cambridgeshire County Council. Its objective is to create, under one umbrella, a comprehensive set of deliverables to assist any local authority in the UK wanting to establish a mobile computing system. The deliverables covers all aspects of realising a mobile computing operation such as researches, business case design, technical planning, technology selection and Evaluation and benefits realisation. According to the report of NOMAD Project in 2004, there are three key ways in which implementing mobile computing helps to save cost. They are:

1. Reduced Operating Costs
 - Reduced cost of paper and mailings
 - Reduced number and cost of repeat visits
 - Reduced time and cost associated with document handling, correcting errors and dealing with customers' queries and complaints
2. Improved field employee productivity
 - More number of services
 - More productive field time
 - Less time spent visiting to and from offices to collect or submit data.
3. Faster project life cycle
 - Reduced cycle time, from project assessment to settlement.

Table 1.1 shows the findings of the NOMAD project for the impact of mobile computing in terms of cost reduction:

National Annual NOMAD Cost Reduction & Efficiency Savings by Type of Implementation		
	Low (£m)	High (£m)
Highways	3	8
Parking Services	19	56
Care Financial Assessments	8	17
National Total: All Authorities	30	81

Table 1.1 (Source NOMAD (2004))

Table 1.2 shows the findings of NOMAD project for the impact of mobile computing in terms of service improvement:

Service Improvement	Performance Measure	Impact of Mobile Computing
Faster response to service requests	Time taken for completion of non-urgent housing repairs	Reduced from 45 days to 12 days
	Turnaround time for processing benefit claims	Reduced to 48 hours
Reduction in appeals and complaints	Percentage of call backs following financial assessment	Reduced from 80% to around 1%
Reduction in paperwork	Reduction in correspondence sent to benefit claimant	Reduced by over 80%

Table 1.2 (Source NOMAD (2004))

Caldwell D. and Koch J (1999) conducted interviews with Chief Information Officers, senior human resources executives, general managers, team leaders, and mobile workers in each of ten diverse organizations, to investigate whether the nature of work and organizations was changing as a result of the growing use of mobile computing. They report that mobile computing provides improved customer service, faster decision making, and the “leveraging” of skill in a knowledge-based workforce.

1.4 Information Technology Applications in Construction Management

As seen in the previous section, mobile computing application is not new, rather it can be integrated with the existing IT applications. Therefore, it is important to know the current IT applications in improving construction management before adding mobile computing solutions. In this regard, Hendrickson (1998) states that in order to make meaningful improvements for construction management, we must first understand the construction industry, its operating environment and the institutional constraints affecting its activities as well as the nature of project management. For this reason, a brief description of construction management objectives is introduced first, in order to know how IT assisted to achieve them.

1.4.1 Construction Management Objectives

According to the Construction Management Association of America (CMAA), “Construction Management is a professional service that applies effective management techniques to the planning, design, and construction of a project from inception to completion for the purpose of controlling time, cost and quality” (CMAA, 2006) . Walker (1984) defines construction project management:

“Construction project management is the planning, control and coordination of a project from conception to completion (including commissioning) on behalf of a client. It is concerned with identification of the client’s objectives utility, function, quality, time, cost and the establishment of relationships between resources. The integration, monitoring and control of the contributions to the project and their output, and the evaluation and selection of alternatives in pursuit of the client’s satisfaction with the project outcome are fundamental aspects of project management”.

Berman G. (2002) states that construction management requires a number of skills relating to the knowledge of construction process, and knowledge of the design process, and the fundamentals of general and project management.

Based on the definitions above construction management needs to control and manage the three factors for the success of any project which are time, cost and quality, in all project phases. In other words, it is possible to improve construction management by developing the current tools, methods or adopting new technologies to control and manage project’s tasks according to schedule, budget and the standard specifications. In this regards, we agree with Hendrickson (1998) that “construction quality and cost can be improved with the adoption of new technologies which are proved to be efficient from both the viewpoints of performance and economy” .

There are many methods used in construction management in all stages of the project life cycle such as Gantt Chart, Network Planning, Critical Path Method (CPM) and Program Evaluation & Review Technique (PERT). The goal of these methods is for mobilising and organizing human resources, materials and technologies to achieve the project by minimal cost, time and effort. (Mohammed, 1996). Today, all of these methods are computerized by many software applications available in the market such as MS Project and Primavera.

1.4.2 Information Used in Construction Industry

The construction industry involves many participants and organizations such as Owner, general contractor, subcontractor, material suppliers and government, who have all communicated to exchange information during the life cycle of a project. In addition, inside each organization there are many specialists from different disciplines such as designer, inspector, accountant, site

engineer and project manager. Fischer M. and Kunz J. (2004) states that the major opportunity for improving the design and construction of facilities lies at the interfaces between disciplines

Bowden S. (2005) outlines a number of literature that attempts to categorise/identify construction information as in the following table:

BT (1995)	Murray and Thorpe (1996)	De La Garza (1998)	Scott (1995)
Technical	Confirmation of Verbal Instructions	Requests for Information	Contract Documents
Commercial	Technical Queries	Materials Management	Working Drawings
Management	Site Instructions	Equipment Management	Progress records and plans
Control	Subcontractor Site Instructions	Cost Management	Financial and Measurement Records
	Dayworks	Schedule and Methods	Quality Records
	Requisitions	Site Record Keeping	Safety and Accident Records
	Site Programmes	Submittals	Amendments to the contract
	Method Statements	Safety Records	Plant and materials Records
	Sketches	QA/QC	Contractual Claims
	Drawings	Future Trends	Miscellaneous
	Drawing Administration		
	Application for Payment		
	General Correspondence		
	Photographs		
	Video		

Table 1.3 (Source: Bowden S. (2004))

Kwakye (1997) identifies construction information according to information producer, in which phase information is produced, the form of information and information user.

Information producer	Project phase	Form of information	Information user
Client	Conception	Brief	Architect
Architect	Feasibility	Report	Client
	Design	Drawing	Client, Quantity Surveyor, Engineer, Contractor
	Construction	Revised drawings	
	Commissioning	As-build drawings	Client
Engineer	Design	Drawings	Architect, Quantity Surveyor, Contractor
	Construction	Revised drawings	
	Commissioning	Operating/ Maintenance Manual	Client/ Ultimate users

Quantity Surveyor	Design	Cost estimates and Bill of quantities	Architect, Client
	Construction	Cost Report, Final Account	Architect, Client, Contractor
Contractor	Construction	Progress Report, Contractual Claim	Architect, QS, Client
	Commissioning	Maintenance Manual	Architect, Client
Material Supplier	Construction	Material Availability, Supply Report	Contractor

Table 1.4 (Source: Kwakye (1997))

The available information technology solutions and software applications play an important role for processing, storing and exchanging all information that is created during the life cycle of a construction project. The following categories are an attempt for grouping these applications (Sun M.& Howard R., 2004 , Forcada N., 2005):

- Computer Aided Design and Visualization.
- Building Engineering Applications.
- Computer Aided Cost Estimation.
- Planning, Scheduling, Site Management.
- Computer Aided Facilities Management.
- Business and Information Management.

The following table provides examples for each Category and in which phases they might be used:

Category	Examples	Project Phase
Computer Aided Design and Visualization.	AutoCAD, Microstation, ArchiCAD, MiniCAD, FastCAD	Design
Building Engineering Applications	ATEAN, CARGASW	Design
Computer Aided Cost Estimation	Esti-Mate, Manifest, FBS-Estimator, PRESTO	Feasibility, Planning
Planning, Scheduling	MS Project, Primavera	Planning, Construction
Site Management	JobMaster, ICON, GEST, Presto Control	Construction
Computer Aided Facilities Management	2MAINTAIN, ARCHIBUS/FM, FM Works	Maintenance
Business and Information Management	ISS-software - Document Management, BTBuilder	All phases

Table 1.5

As mentioned early, the aim of all IT applications is to meet the objectives of construction management which are to reduce or control project time and cost, and improve productivity,

performance and quality. Information that is produced from the sites during the construction activities, such as actual start time and actual finish time for each activity, are very important for the construction manager to make appropriate decisions such as the following:

- Comparing actual project progress against the plan
- Checking the quality by visiting the construction site during implementing the tasks
- Ensuring that the inspectors or site engineers are available in the sites.

Recording Information that is produced from construction sites on paper and then entering them in systems such as that in table 5, may cause loss of information. In addition, some information will be useless when there is a delay in transferring them from the time in which they occurred. According to Davidson & Moshini (1990), Bowden S. (2005) states that the cost of construction can be reduced by 25% through the efficient transfer of information. Conversely, poor or missing information can readily lead to project delays, uneconomical decisions, or even the complete failure of the desired facility (Rebolj et al., 2004).

Mobile computing solutions in construction management will now be discussed, highlighting the weakness of conventional IT for transferring and sharing projects' information in real-time from construction sites.

1.5 Mobile Computing Solutions in Construction Management

Although Information Technology has a significant impact in improving construction management, studies and researchers have stated that the construction industry has lagged behind other industry sectors in terms of applying information technology. The reasons for this has been discussed in many researches in terms of differences between construction environment and other environments (Rebolj et al., 2004, Kunz J. 2004, Nilsson M.& Ryding B. 2002) These reasons can be summarized as the following:

1. Construction industry has complex processes and activities compared to other sectors.
2. There are many Participants, organizations and specialists in construction project each has special needs, perspective and using their own proprietary solutions.
3. Conventional IT solutions required an infrastructure which is not found in construction sites.
4. Construction sites and locations of production are dispersed and more reactive environment than any other sectors, where unplanned changes to work regularly occur.
5. The workers at construction sites are in continuous movement as there is no suitable situation to access or exchange information in a timely manner.

For the first reason, IT continuously contributes to supporting the construction processes and activities by converting any proven tools or techniques, such as Gantt Chart, PERT and CPM, into computer based activities. Also software, such as in table 1.5, supports the construction

process such as design, cost estimation and controlling, planning and management of human and physical resources and information management.

For the second reason, there are many researches and studies which address the problems of the large number of participants in construction projects, by developing information systems, models and frameworks to integrate project information and leverage information across participants, disciplines and organizations through all project phases. Web Based Project Management Systems can be considered as a solution for integrating and sharing project information.

The last three reasons are where the mobile computing systems can make important improvements in construction management. The problem can be identified in circumstances and types of works in construction sites that make it difficult to transfer and exchange information through traditional IT. As shown in table 1.5, there are many applications used in construction phase. But all of these applications are used within offices where IT infrastructure and PCs are readily available for the users.

As discussed in section 1.3, the benefits from applying mobile computing systems depends on to which extent the application needs to add the mobility feature or the degree of mobility in the application. It is clear that the degree of mobility is very high in construction sites. Therefore mobile computing system is the best solution due to its ability to allow accessing, sharing and exchanging information anytime and anywhere.

1.6 Summary

The need and use of mobile computing in construction management has been investigated. The outcome of this investigation has shown that applying mobile computing system in construction management -like other environments- can be added to the existing IT applications to allow the users to access, share and exchange information during mobility.

The nature of construction management has been discussed including its information, IT applications and participants. This discussions led to an understanding of how mobile computing can contribute for achieving construction management objectives.

Mobile computing system not only enhances the existing IT applications to meet the objectives of construction management but also offers appropriate solutions for transferring and sharing projects' information in real-time from construction sites where conventional IT doesn't help in this regard due to the nature of construction environment.

Having considered the use of mobile computing in construction management in general, chapter 2 will be more specific by analyzing the processes of construction projects in telecommunications network

CHAPTER 2

System Requirements

2.1 Introduction

An objective of this project was to analyse the system requirements. This objective was achieved by conducting interviews with construction department staff in Saudi Telecom Company (STC) company and by reading relevant STC practices. In addition, my personal experience in the telecommunications network as a project manger help me in analyzing the current system.

This chapter presents the results of this analysis and shows the need for mobile computing systems to improve the current processes and solve construction management problems in NCD. The chapter starts by an overview of the telecommunications network and the type of construction activities. Then a description of the current processes and problems. Finally an explanation of the proposed solutions are presented in textual and diagrammatical manner.

2.2 Telecommunications Network Overview:

Saudi Telecom Company (STC) offers a full range of Telecommunications services, such as voice, internet and media, for more than 14 millions subscribers. These services can be provided to clients wirelessly or by extending cables to locations of subscribers (fixed network). There are more than 3.5 millions clients, in many cities and wide areas, who use fixed telecommunications network. This project are applied on the fixed telecommunications network in one medium city where the number of clients is 150,000 . Constructing the fixed network involves many civil works such as cutting and scratching the asphalt, excavating, extending cables etc.

The telecommunications network uses two types of technologies ; copper network technology and optical fiber network technology.

Copper Network: it is the network that uses the copper cables to provide the services to the subscribers. The following are the main parts in this network:

Exchange: It is a building that contains the switching equipment of the telecommunications network. All primary cables originate from here and are distributed to the outside network.

Copper cabinet: A small room manufactured from special material and placed in a safe area in the street. Cooper cabinet contains blocks where the primary copper cable is connected with the secondary copper cable.

Primary Cables: Copper Cables that connect the exchange and subscriber's cabinet.

Secondary Cables: Copper Cables that connect subscriber's cabinet to the subscriber's distribution point.

Subscriber's Distribution Point: A small box placed on the wall of the subscriber and connects the secondary cable with the subscriber's telephone line .

To provide telecommunications services over copper network, we need to construct two different types of networks; secondary network and primary network each of them has special design specifications and they may construct in the same project or separately.

Optical Fiber Network: it is the network that uses the optical fiber cables to provide telecommunications services to subscribers directly or to a Remote Access Node RAN (electronic cabinet). The electronic cabinet can convert the digital signal comes from the fiber cables to the analogue signal then the signal will be carried by the copper cables to the copper cabinet. In case of the optical fiber not reach to the subscriber directly, we have to use copper cables from RAN to copper cabinet as shown in figure 2.1.

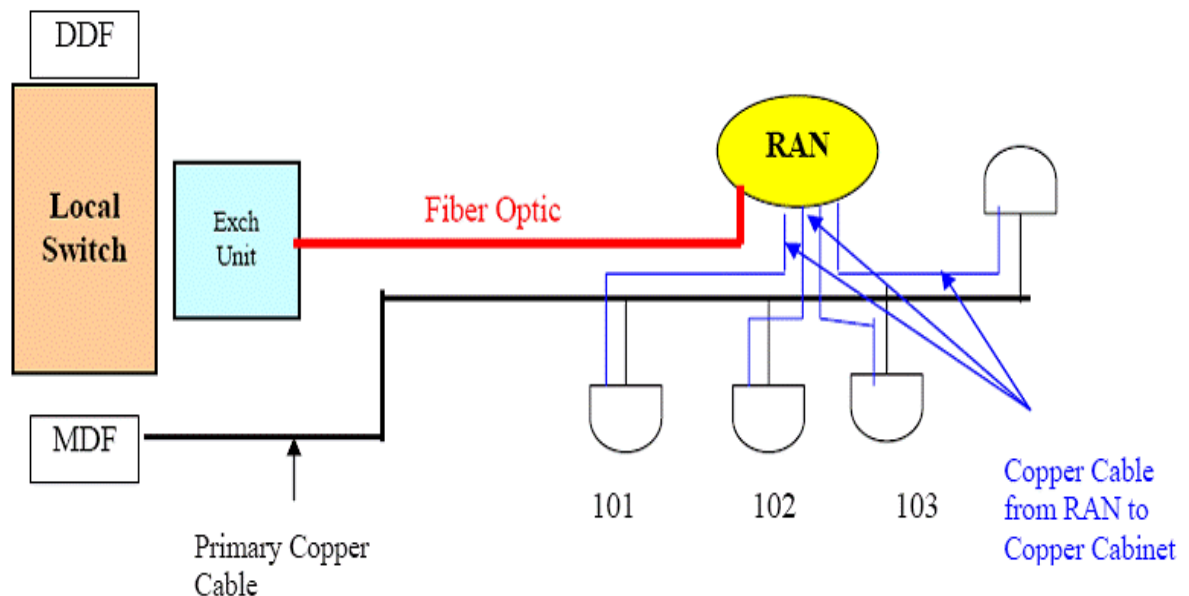


Figure 2.1

2.3 Types of Civil Works

Although specifications of design and construction differ depending on the type of technology and network used in the telecommunications projects, the types of civil works are mostly similar. For example, all projects may require cable trench but the dimensions on the trench differ from copper technology to fiber technology and from secondary copper network to primary copper network. The most civil works used in the projects of the telecommunications network are listed below:

1. Cutting and scratching the asphalt.
2. Excavating the trenches.

3. Extending the cables.
4. Jointing cables.
5. Filling the trenches.
6. Re- asphaltting.
7. Installing the cabinets
8. Installing the distribution points
9. Installing and Concreting the ducts.
10. Installing the manholes.

It is not necessary that all projects contain all tasks above. For example, some areas have already telecommunications network infrastructure such as cabinets, ducts and manholes, so we need only trench, cables and distribution point. The projects' tasks may be **sequence** or **overlapped**. Sequence tasks occur in small projects where the telecommunications services will be provided for few locations in a small area and there is only one trench line. The figure below shows how the Sequence tasks occur.

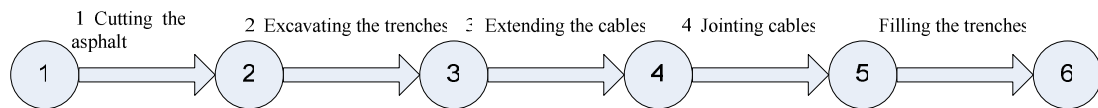


Figure 2.2

Figure 2.3 below shows the overlapped tasks where the trench line is too long. The figure below illustrate that the tasks are overlapped. For example when cutting asphalt is finished in first part we can start excavation the trench in that part while cutting asphalt is started in the second part.

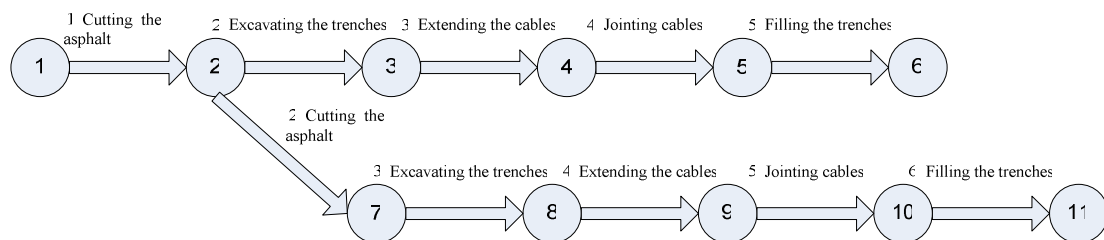


Figure 2.3

Sometimes the project covers wide area, so the project starts from more than one point, therefore more than one construction line and overlapped tasks could be in same project

2.4 Current processes

Service orders comes to the network units in the STC from the planning unit which is responsible for planning network's projects based on demand forecasting. Service orders may also comes from client request. These orders may be within existing network coverage or a new

area where the telecommunications services are not yet provided. When the order reach to the network unit, the engineers in the engineering department make a project contains an appropriate design with an approximate cost for constructing the network. Each project takes a unique number. If the project approved by the quality engineer and the department manager, then it will be sent to the Network Construction Department (NCD). Then projects manager in NCD makes schedule for each project and distributes them to the contractors and assigns one inspectors for each contractor. The inspector must see and inspect every activity before the next activity starts. It is the responsibility of the inspector to ensure that the contractor is working to schedule and specifications. The contractor sends a daily log of his activities by fax to the construction department and then the fax is submitted to the particular inspector. When the project completed, the inspectors make a final invoice for contractor works based on the items' prices of the contract.

2.5 Current problems

All activities in section 3.3 are computerized except the activities of the mobile workers in the site where there are no conventional computers and IT network. As seen in Chapter 1, for effective construction management, the project manager needs a lot of information about what actually happened in the sites. Currently, it is very difficult for the project manger to check if the contractor and inspector does the tasks according to the schedule. Therefore there are no references in the construction department for comparing the actual work with planning. Such information is very important to improve the planning in the future

The current practice is inefficient, sending the daily activities of contractors by fax prone many errors in terms of the exact time of each activity and also some activities may not happen according to daily schedule because of unexpected reasons. When these errors happen, the inspectors can't see and inspect the activity, so there are two possible procedures; the contractor doesn't close the activity and wait the inspector to see the works, or complete the work and the inspector may accept the work without knowing what exactly happened, in some case, the inspector may request from the contractor repeat the work. Both previous procedures are conflicting with the strategy objectives of the STC Company because the most important strategy objectives are:

- Providing service to customers in a timely manner.
- Producing high quality services.

The reasons of the current problem can be summarized into the following

- **Multiple Tasks**

The contractor may conduct approximately 10 projects in the same time. Every project has different tasks with limited duration. Although some tasks may take only one hour such as jointing cables, it is very important for the project manager and inspectors to ensure such tasks are done according to schedule and specifications.

- **Multiple Participants**

There are many Participants in network projects, department manager, project manager, inspector, site engineer and project manager of the contractor and labors. In addition, the number of contractors is from four to six and they may be changed every contract.

- **Divergent Workers**

Because of the STC works continuously to offers its services for the clients in any place in the country, locations of network projects are in divergent areas. The service order are expected to be in any place even in areas within the existing network coverage because the spare lines in the distribution point of the subscriber might be occupied in any time. For this reason the mobile workers are always separately in many areas.

2.6 The Proposed Solution

Many interviews were conducted with construction manager, engineers and inspectors in construction department in STC (STC is the sponsor of this project). They are aware the current problems and understand the role of the proposed mobile computing system in solving the problem. They also requested some requirements after the idea of the proposed system was introduced to them.

We can say that the core of the problem is the current poor communication tools for sharing and transferring the information between contractors, inspectors and construction manager. Fax machine and emails which are currently used don't help much in such environment. This problem delayed the projects, reduced the quality and increased the cost.

The basic idea of the proposed solution is to use mobile application designed for mobile devices of contractors and inspectors and connect with server and desktop computers in the construction department. The figure 2.4 below illustrates the proposed system and the interaction between its components:

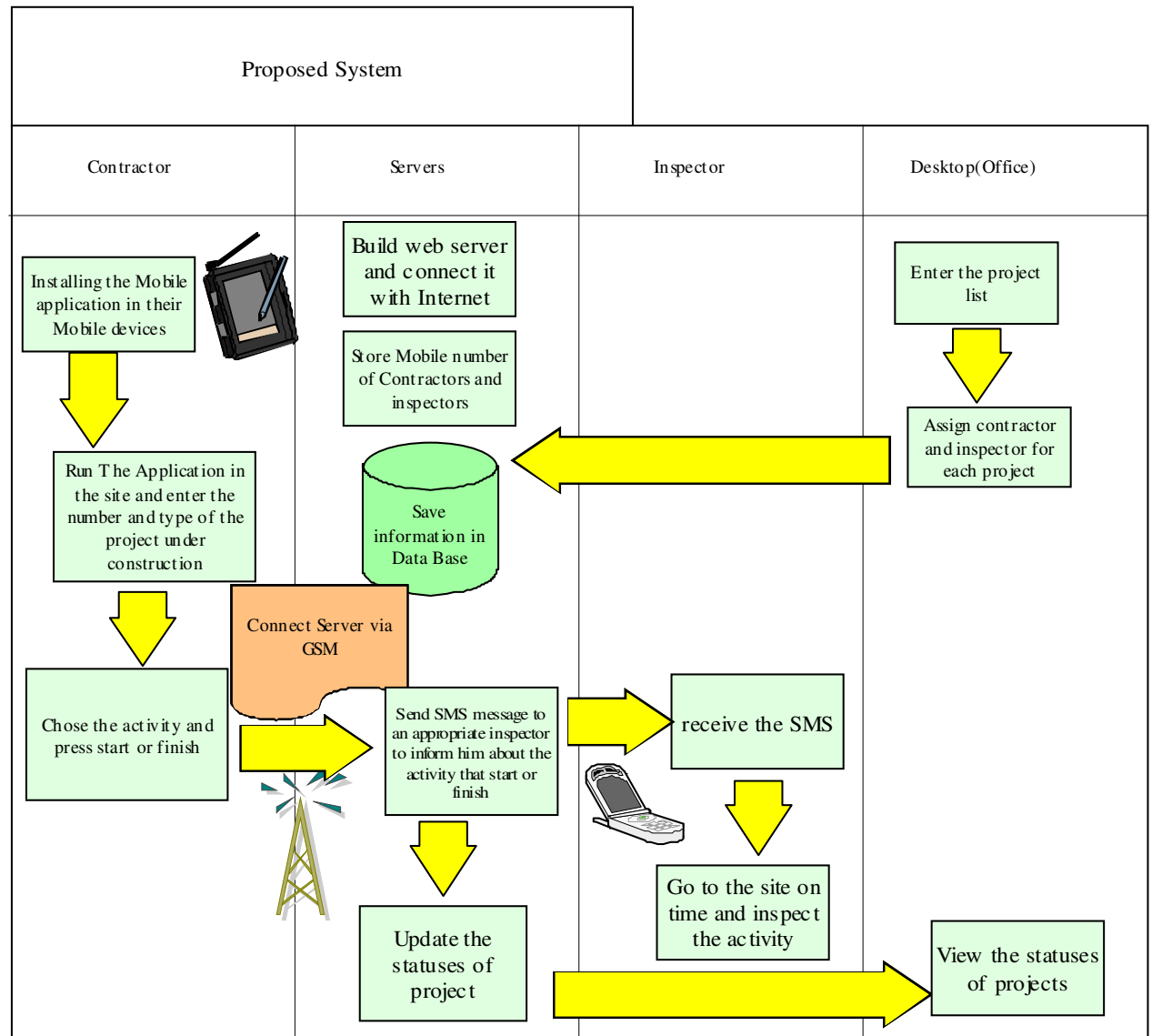


Figure 2.4

The proposed system is an integrated mobile computing system and will allow the mobile devices of contractors and inspectors to send and receive projects' information wirelessly. This will be achieved through a General Packet Radio Service (GPRS). The proposed system will join the following parts:

- Mobile devices of contractors.
- Mobile devices of inspectors.
- Server
- Desktop PC.

The interaction takes place through a secure Internet connection

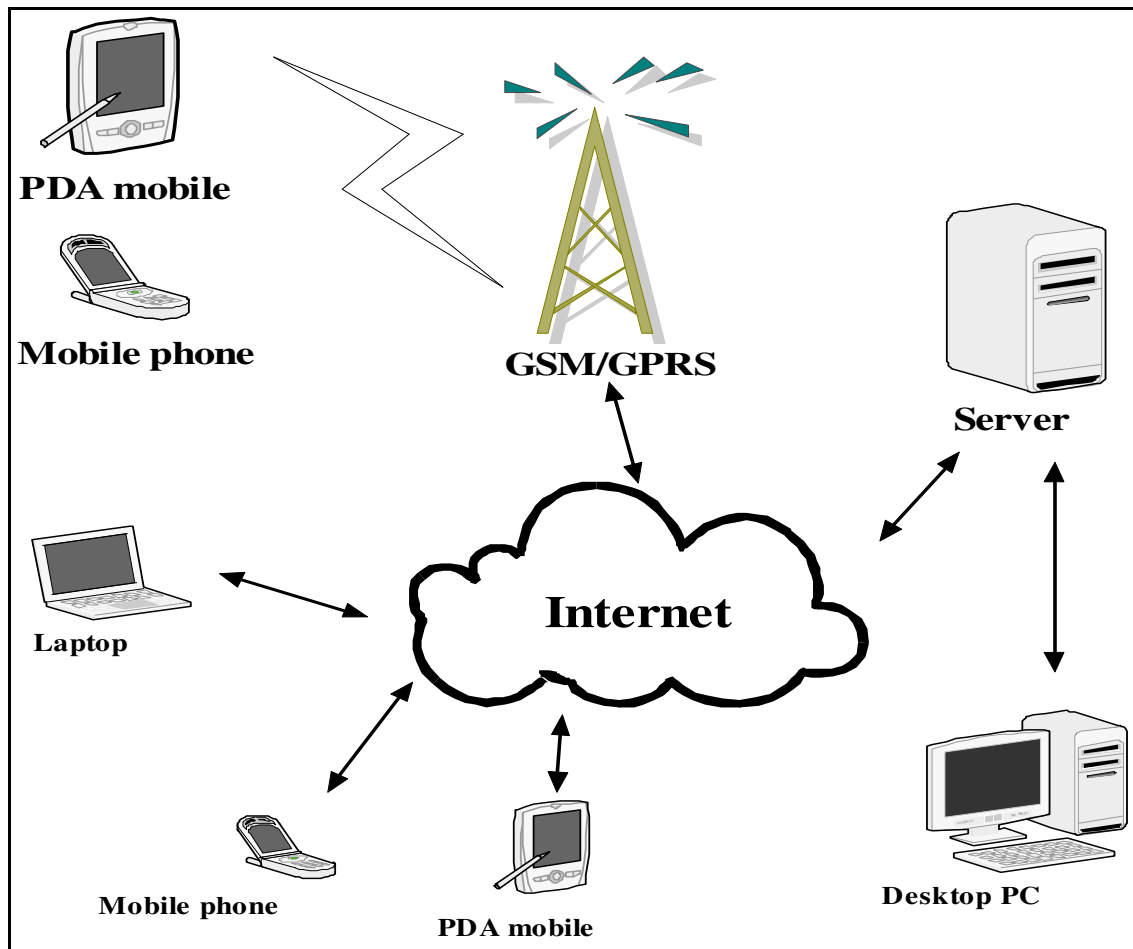


Figure 2.5

1. Mobile devices of contractors:

The proposed system will allow the contractors to use their mobile Devices to do the following functions:

- Enable the contractor to enter project number
- Enable the contractor to enter project type (Primary, Secondary and Optical fiber).
- Enable contractor to enter the activity name (Cutting asphalt, Excavating, Extending cables etc)
- Allow The activity information to be sent to the server.



2. Mobile devices of inspectors:

SMS message will be sent to inspectors.

That message contains the project number, project location, contractor name and the activity that has been started or finished.

This information can help the inspector

to be at the location of the project to inspect the current activity.



3. The server:

The PC server will contain an appropriate database management system to store the information of projects' activities such as expected start time, expected finish time, actual start time and actual finish time. The database should also include the information of contractors, inspectors and project managers.

The PC server will also contain an appropriate application server to deploy the application over the internet and allow communications with client PCs and mobile devices.

4. PC desktop:

It connects with server and view the information of projects such as actual start time, actual finish time, task duration, contractor name and inspector name. This information will improve project management, support decision-making and improve future planning. Also the user will enter all the required information of projects, contractors, inspectors, etc., through the desktop PC.

The figure below shows the use case diagram for the proposed system. It shows how the user (actors) will interact with the system to perform the system functions.

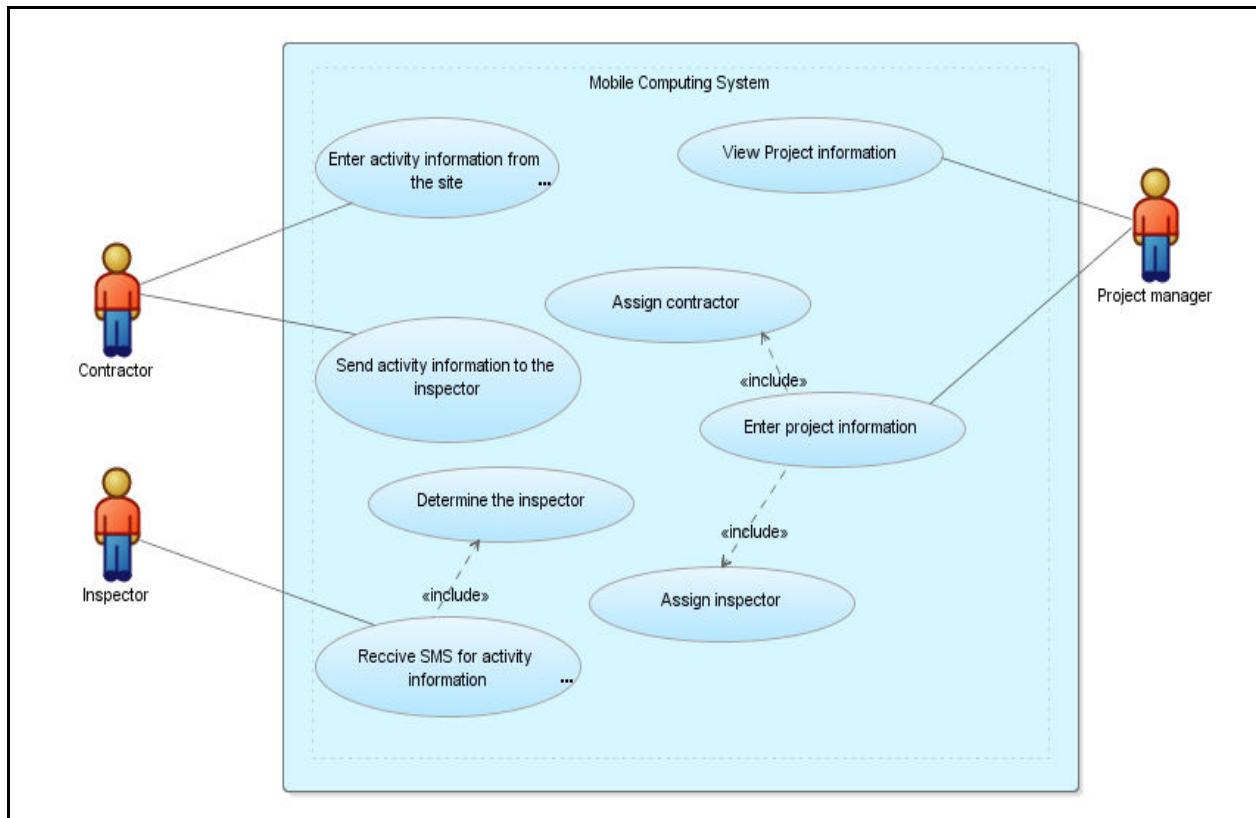


Figure 2.6 :Use Case Diagram

The proposed mobile computing system will build to meet the previous system requirements. The analysis of the current processes led to explore many potential improvements. Some of them are listed below

- Allow the inspectors and the contractors to access the STC practices and specification from sites.
- Allow the contractors to receive the project documents from the web site
- Allow to send and store pictures for site activities as MMS messages
- Provide quality check lists for activities and allow the inspectors to access these lists from sites.

Although these improvements will be left to future work, the system should be developed to be able to provide these requirements in future.

2.7 Summary

The current processes in the construction department of the telecommunications network have been analyzed with discussion of the current construction management problems and the proposed solution. It is clear that the core of the problem is the current poor communication

tools for sharing and transferring the information between contractors, inspectors and construction manager. The chapter has been proposed a mobile computing system to solve the current problem in NCD and improve construction management. This proposed system will offers a solution to share and transfer project's information among sites and office wirelessly.

The results of this chapter will be considered for designing and implementing an appropriate mobile computing system that meet the needs of the users. In order to built the desired system, the current practice, tools, technology in design and implementation of mobile computing system must be investigated. Therefore the next chapter researches on mobile computing system technologies.

Chapter 3

Mobile Computing Technologies

3.1 Introduction

It was shown in the system requirements chapter that there is a need for a mobile computing solution that allow the users to access, share and transform project's data from sites and among the projects' participants. This solution will solve the current problems and improve the management of construction projects in NCD. This solution can't be achieved in an efficient manner without knowing mobile computing technologies and how to choose the most appropriate technologies with respect to the system requirements. So the objective of this chapter is to investigate the current practice, tools and technology in design and implementation of wireless applications.

In general mobile computing systems contain three components; mobile devices, mobile computing platforms and wireless networks. The various types of these components are discussed in detail referring to their roles in designing and implementing wireless applications. Discussion includes brief development history, technology types and usages of each component.

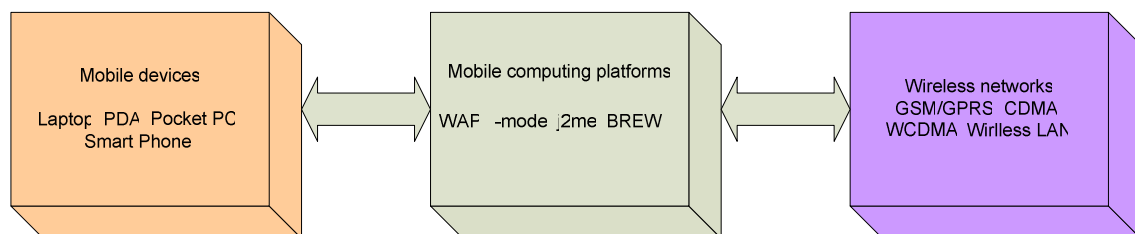


Figure 3.1: Mobile computing components

Databases management systems is essential part in any distribution system including mobile computing. This part is discussed briefly with respect to mobile computing considerations.

3.2 Devices

In the 1950s, the transition to 12 volt automotive electrical systems gave rise to a large number of 12 volt devices, such as two-way radios (Wikipedia ,2006). These devices was used in specific systems and for a small number of users such as taxicab radios and two way radios in police cruisers. In 1993, Modern mobile devices began with the Apple Newton, followed by the Palm Pilot in 1996 (MLEEO, 2005).

There are a variety of types of mobile devices such as handheld, Personal Digital Assistant (PDA) and smart phone, each with different features, purpose and functions. As the result of the general purpose of mobile device which is enable the users to communicate with other and share information anywhere and anytime, a mobile device needs to be small enough to move around and to be fitted in user's pocket. This led to the following limitations:

- Limited processor: currently, the processor in mobile devices is not as powerful as in desktop PCs.
- Limited memory: most mobile devices have limited memory and some devices do not have a persistent storage of their own.
- Limited input: most mobile devices do not have keyboards. Even if some of devices types have a keyboard, it is limited in size.
- Small screen. This effects display and colour resolution
- Battery with limited lifetime

These limitations must be considered by mobile application developers and they have to consider also the variety of types of mobile devices that may be used for their applications. Sometimes users requirements involve choosing specific device types. In our case where there are many Participants from different organizations, different types of mobile devices are expected. But some recommendations could be provided to the users for choosing a durable device type that can operate efficiently in construction sites.

GPRS class of the mobile devices is the most important specification when choosing mobile devices for mobile computing system. GPRS classes refer to the slots allocated for uploading and downloading data (Nokia, 2006). For example, GPRS Class 8 (4+1,5), the number 4 refers to the maximum number of slots that can be used for downloading. The number 1 refers to the maximum slots that can be used for uploading. The number 5 refers to the maximum number of slots that can be used at any one time, both uploading and downloading. Therefore we can say that GPRS Class 10 (4+2, 5) is faster uploading than Class 8 while Class 8 is appropriate for browsing or reading email more send. At this moment Class 32 (5+3,6) is the maximum download performance while Class 12 (4+4,5) is the maximum upload performance.

3.3 Wireless Networks

Just as the capability of mobile devices, wireless network types and connection can be considered as one of the mobile computing constraints. Issues, such as network coverage, speed, capacity, reliability and latency, effect on choosing a network type or/and provider that meet the functionality and performance requirements of the mobile application. there are many types for

wireless networks such as Bluetooth, Wi-Fi, WiMax, GSM and Satellite. The table 3.1 below compares various types of wireless networks in terms of speed and coverage

Wireless Network		Max Data Rate Speed	Coverage
Bluetooth		1 Mbps	10 m
Wi-Fi		54 Mbps	100 m
WiMax		30 Mbps	50 Km
GSM	2 G	172.2kbps	Coverage area of provider network
	3 G	2 Mbps	Coverage area of provider network

Table 3.1 compares various types of wireless networks

Although network capability such as speed and coverage must be appropriate for the system requirements, wireless applications should be also designed to work efficiently with network capability. Figure 3.3 below illustrates the relationship between network's speed, network technologies and wireless applications

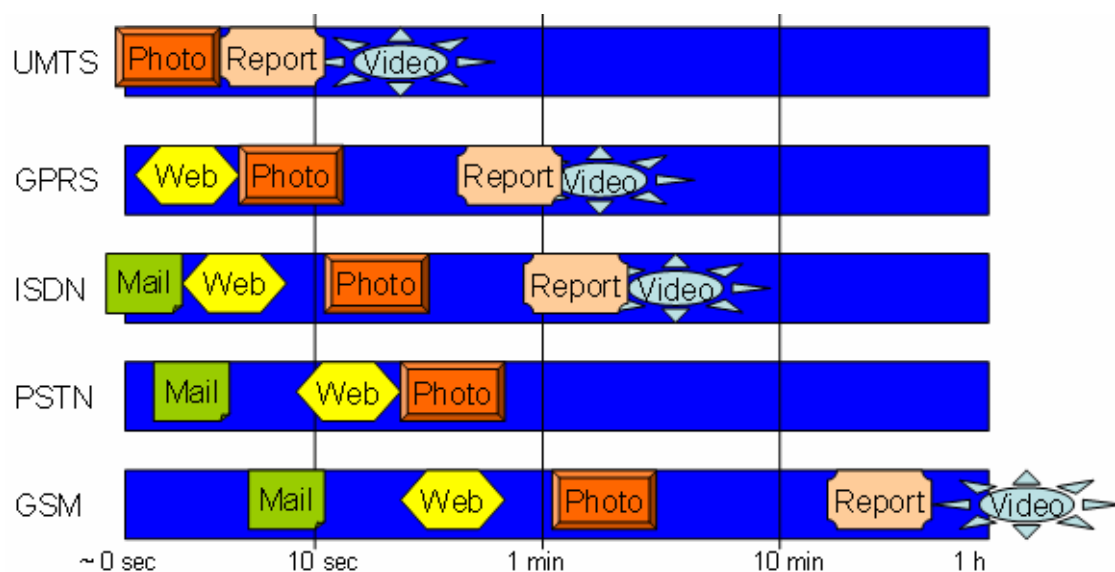


Figure 3.3: (source: <http://www.mobilkomaustria.com>)

3.3.1 History of Wireless Networks Development

The following is a discussion of the principles and history of wireless networks development

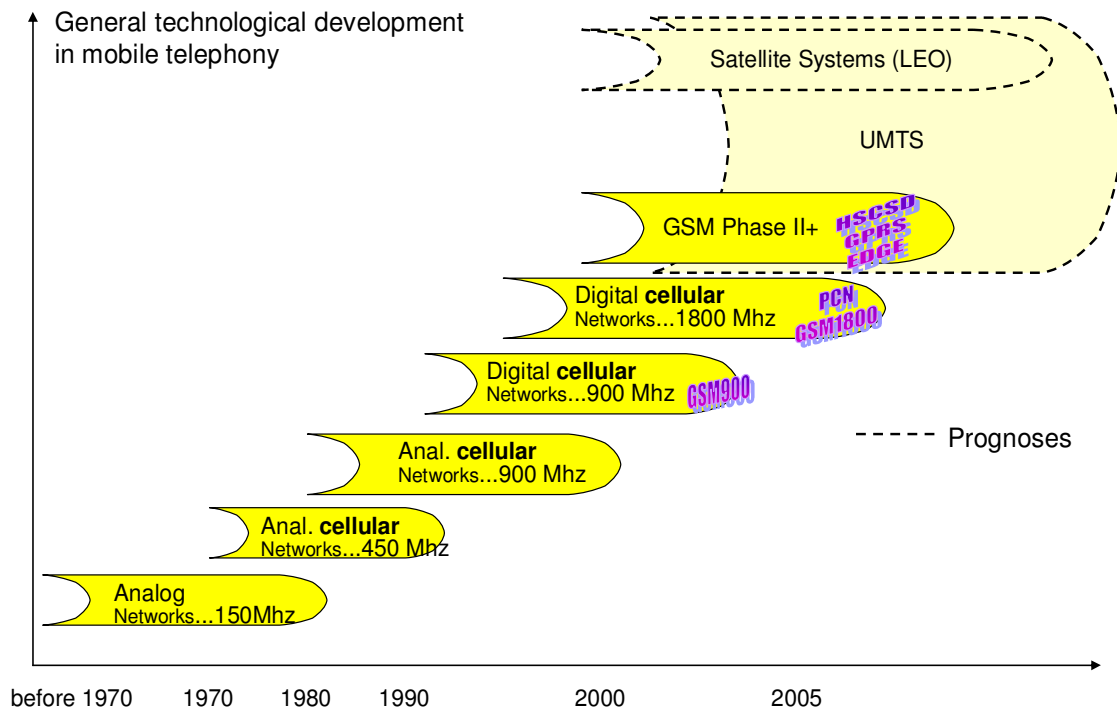


Figure 3.4: Development wireless networks

- **First Generation**

1G is short for first generation of wireless telephone technology. It uses analog radio signal with 150 MHz frequency and up. There are two keys improvement in 1970s led to emerge 1G systems; the microprocessor and the digitization of the control link between the mobile phone and the cell site (ITU, 2006)

The first commercial service based on 1G was introduced in Saudi Arabia on September 1st 1981 (UTMS, 2006). The name of that system is Nordic Mobile Telephone NMT. 450 MHz in NMT network was introduced in 1986. The range of cell size in an NMT network is from 2 km to 30 km. NMT network can provide simple data transfer. Data and Messaging Service DMS provided by NMT is similar to SMS in GSM. Mobitex is another wireless technology which was introduced Canada in 1990. Mobitex runs at 900 MHz and it was the first wireless network to provide always on (packet-switched) (Wikipedia, 2006).

- **Second Generation**

2G the main difference between 1G and 2G is that the networks in 1G uses analog signal while 2G networks uses digital signal. Also 2G systems digitized not only the control link but also the voice signal (ITU, 2006). There are three access technologies; Frequency Division Multiple Access (FDMA), Time Division Multiple Access (TDMA) and Code Division Multiple Access (CDMA). The first one FDMA has been used for 1G analog systems while the others used in 2G. The Difference between these three technologies is based on the type of multiplexing used (how several digital data streams or analog signals are combined into one signal).

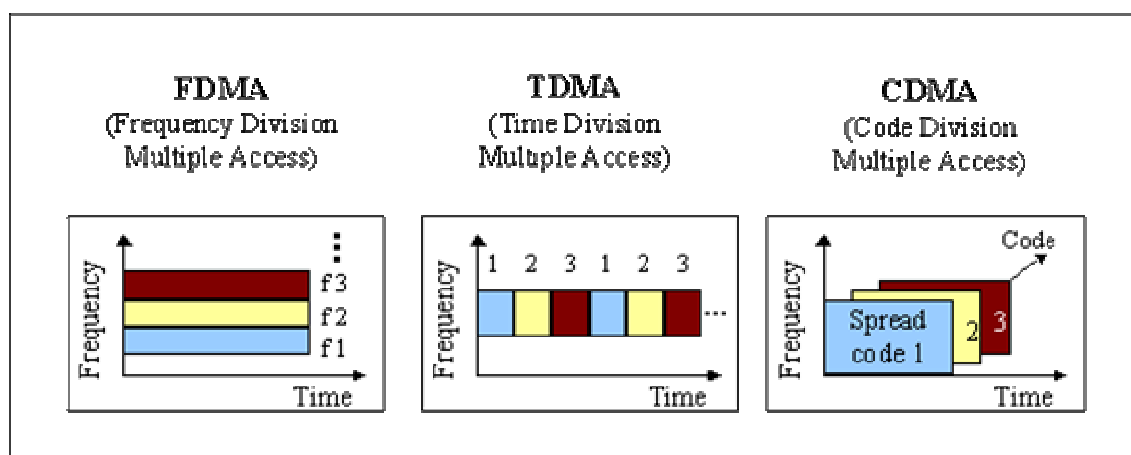


Figure 3.5: Access technology (ITU, 2006)

Standards of G2 systems are based on TDMA or CDMA technologies. The following table shows these systems and in which regions they are pervasive.

System	Multiplexing technology	Regions
GSM	TDMA	Worldwide
iDEN	TDMA	More than 19 countries including Saudi Arabia
TDMA IS-136	TDMA	Throughout the Americas, particularly in the United States and Canada
CDMA IS-95	CDMA	Americas, South Korea and India
Personal Digital Cellular (PDC)	TDMA	Japan

Table 3.2

From table 3.2, there are two systems currently offered in telecommunications Saudi market by deferent providers. GSM provided by two companies; STC and Mobily.

iDEN System (Motorola's integrated Digital Enhanced Network) is provided by Bravo Telecom Company in Saudi Arabia. Currently Bravo's network cover six cities in Saudi Arabia. Bravo made a 15 year Build-Operate-Transfer (B.O.T) agreement with Saudi Telecom Company (STC).

GSM was developed in 1980s by pan-European initiative, involving the European Commission, telecommunications operators and equipment manufacturers (ITU, 2006) . It is now the most popular standard for mobile phone. According to the GSM Association (2005), GSM is used by over 2 billion people across more than 212 countries. The European Telecommunications Standards Institute was responsible for GSM standardization (ITU, 2006). GSM standards released General Packet Radio Services (GPRS) in 1997. GPRS is a standard adopted by GSM operators based on packet-switched technology enabling high-speed data transmission which may reach to 115 kbit/s. (ITU, 2003). It allows mobile users to connect to the internet through

an installed application on the mobile device, deliver emails and surf web site by using WAP (Wireless Application Protocol) or other standards.

When using GPRS in mobile applications, it is important to know its limitations. Theoretically, Maximum the GPRS speed rate is 172.2kbps using all 8 timeslots. But in reality the speed rate depends on mobile devices (as mentioned in section 3.2) and/or networks constraints. Networks use 200Mhz radio channels. Each 200-MHz radio channel is divided into eight time slots one time slot supports one voice user, but for packet data, GPRS can combine up to four time slots. Each time slot can support 13Kbps (Rysavy P. , 2000) . Therefore achieving GPRS speed between 30kbps-40kbps is more realistic.

- **Third Generation**

3G is short for third generation of developments in wireless technologies. International Telecommunication Union (ITU) uses the term ITM-2000 (International Mobile Telecommunications-2000) to refer to the global standards and technical specifications for 3G. There are two major partnership projects in ITM-2000; 3rd Generation Partnership Project (3GPP) and 3rd Generation Partnership Project 2 (3GPP2). Universal Mobile Telecommunications System(UMTS, developed by European Telecommunication Standards Institute) is based on WCDMA as underlying technology and uses 3GPP standards. WCDMA is wideband and uses Code Division Multiple Access (CDMA) multiplexing method to achieve high speed transmission. Another standard in 3G family is CDMA2000 which similar to WCDMA and standardized by 3GPP2 based on IS-95 standards (the first CDMA-based digital cellular standard).

However, 3G offers two speed rates; 114kbps-384 kbps for high-mobility and high coverage and 2 Mbps for low-mobility and low coverage. Amjad (2004) states three examples of data rate based on the level of mobility; data rates of 144 Kbps at driving speeds, 384 Kbps for outside stationary use or walking speeds, and 2 Mbps indoors. Although recently both two providers in Saudi (STC & Mobily) offers 3G services, their networks, at the moment of writing, do not cover all areas because it is still a new service.

3.3.2 Network Providers

Choosing a network provider must be carefully evaluated in relation to system requirements (Nettech ,1999). Mobile computing developer have to evaluate each of the following criteria when choosing a network provides:

1. Network Coverage: does the provider has enough base stations in all areas that required For the mobile application ?
2. Network Capacity: what are the peaks of congestion during the day hours? And

Comparing these peaks with the usage times of the mobile application

3. Network Reliability: What is the percentage of network downtime? How quickly can it fix things when something goes wrong?
4. Network Latency: how much time it takes between sending a message and Receiving it?
5. Technical Support: What are its technical support hours? And What is its response time?
6. Reporting: what types of reporting and statistics the network operators can provide. Such as peak times, downtime percentage, etc

3.4 Mobile Computing Platforms

Mobile applications can be implemented using either; Browser Based Applications or Downloadable Applications (Montelius J. (2004), Reza B. (2005)):

1. Browser Based Applications: mobile application placed on the server and can be accessed by using browser software clients. Examples for the platforms that support browser based applications:

- Wireless Application Protocol (WAP)
- i-mode

2. Downloadable Applications (client-side processing) : Mobile application can be downloaded in mobile devices and the devices' processor used to run the application and execute some computing tasks while the server executing the others. In case of standalone applications, the application can be executed on the devices without needs for server and network connectivity. Examples for the platforms that support Downloadable Applications :

- Java 2 Micro Edition (J2ME)
- Binary Runtime Environment for Wireless (BREW).

3.4.1 Wireless Application Protocol (WAP)

“An open, global specification that empowers mobile users with wireless devices to easily access and interact with information and services instantly.” www.wapforum.org
According to recent research, the number of mobile internet users will reach 934 million by 2007 (Choi B. et al, 2005) . Users need to access internet content and data services by their mobile devices. In addition, developers need to develop applications that can run over different wireless network technologies and mobile device types. As the result of this, WAP is developed to meet the requirement of wireless terminals and it's based on the existing WWW Architecture and protocol (Kulmala H., 2000).

WAP provides an universal standards framework for accessing, presenting and delivering information and services from wireless devices. The WAP Forum was founded in 1997 by

Phone.com, Ericsson, Nokia and Motorola. Today there are more than 200 members including the major handset manufacturers, network operators, and software companies. (MobileInfo, 2006). WAP provides a gateway act as a converter between wireless and wired domains by using a set of protocols (Pashtan A., 2005). WAP gateway shield the mobile application developers from this converting and they should not have to know the underlying network details (Amjad U., 2004).

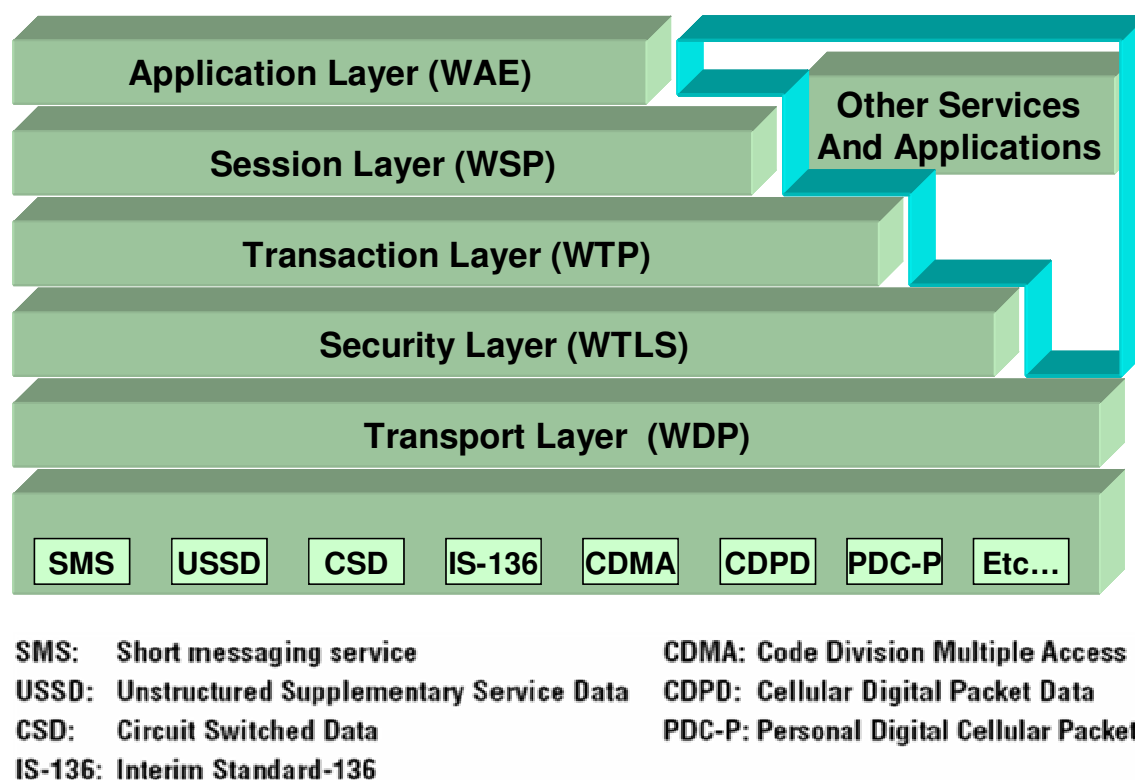


Figure 3.6: WAP Architecture (source www.sergiochacon.com/)

WAP protocols consider the constraints of mobile devices such as small size, limited CPU, memory, power and input, etc. Constraints of wireless networks is also considered by WAP such as less bandwidth than wireline, high latency, low capacity and reliability.

There are many issues with respect to the constraints of the mobile devices and wireless networks, addressed by WAP. The WAP standard defines a Wireless Application Environment (WAE). WAE includes three main elements (Amjad U., 2004); (1) A markup language called Wireless Markup Language (WML) which is suited to the constraints of mobile devices. (2) Specification of a microbrowser in the wireless terminal. (3) A framework, the Wireless Telephony Applications (WTA) specification, to allow access to telephony services such as call control, messaging, etc.

WML is derived from XML and describes content and format for presenting data on small wireless devices. There is also a scripting language WMLScript to make the WML pages more dynamic.

XHTML MP (eXtensible HyperText Markup Language Mobile Profile) is the markup language defined in WAP 2.0. It is a subset of XHTML and comes after WML to bring together the technologies for mobile Internet browsing and that for the World Wide Web (developershome, 2006). By using XHTML Mobile profile, developer can use the same technologies to develop both the web and wireless version of the internet application. Also the WAP 2 mobile device can be used to access XHTML MP, WML and WMLScript web pages. XHTML MP is designed to support the limitation of screen, processor and memory in mobile devices by removing some features in XHTML that are unsuitable for mobile devices.

3.4.2 i-mode

i-mode is a service provided by NTT DoCoMo company which is Japan's leading wireless communications operator. I-mode was launched in February 1999 in Japan to allow subscribers to access email and the internet from mobile devices. The number of i-mode subscribers reached more than 46.4 million in March 2006 and this number is expected to reach 47.9 million in March 2007 (DoCoMo, 2006). Although most of the subscribers are in Japan, i-mode is currently gaining momentum in the US and in other parts of the world (Amjad, 2004).

As WAP, i-mode architecture contains a gateway act as the interface between the GPRS mobile network and the internet (Pashtan A., 2005). The micro-browser in i-mode compatible devices makes a wireless request to the gateway before the web content present on mobile phones of the users.

i-mode is packet-switched which is in principle "always on" when the users are in the area of the i-mode signal. I-mode pages use cHTML (compact HTML is a subset of ordinary HTML) as the markup language while WAP uses WML.

3.4.3 J2ME

J2ME is the java platform for consumer and embedded devices, resource-constrained computing devices such as mobile phones, pagers, personal organizers. It is not a product or programming language. It is a combination of technologies and specifications available by Sun Microsystems. J2ME is a client-side processing that allows to implement the downloadable mobile application where the application is downloaded and installed on the mobile device (Montelius J., 2004). Also J2ME adapts existing java language but for handheld and embedded devices. J2ME is one of the three platforms editions. The other platform editions are Java 2 Standard Edition (J2SE) for conventional desktop application and Java 2 Enterprise Edition (J2EE) for enterprise

computers with an emphasis on server-side development using Enterprise JavaBeans (EJBs), web applications, servlets and JavaServer Pages (JSP) and Extensible Markup Language (XML).

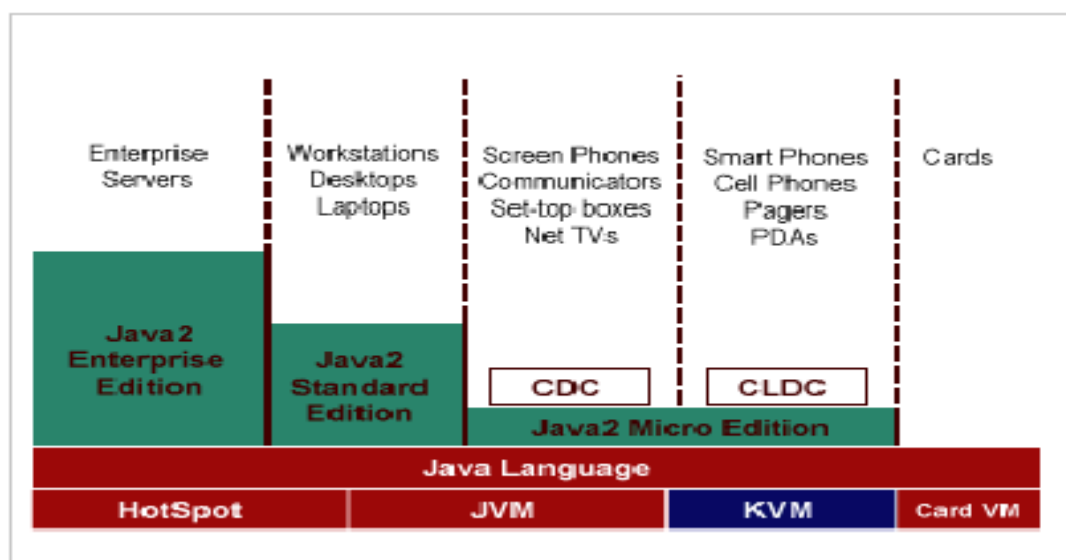


Figure 3.7: Java 2 Platforms

J2ME is platform independent, i.e. it can work with a variety of operation systems and types of mobile devices.

3.4.4 BREW

Binary Runtime Environment for Wireless (BREW) is another wireless application platform developed by QUALCOMM company. BREW has been successful in American wireless communication market. BREW is a client-side processing like J2ME but BREW is also a business system (Kaasin J., 2002)

QUALCOMM distributes, manages and sells BREW applications by allowing users to select, purchase and download mobile applications, over-the-air and any applications they purchase will appear on the monthly bill of the network operator. The price is then split between the operator, the developer and QUALCOMM (Kaasin J., 2002).

BREW-enabled device users can query BREW Distribution System (BDS) for applications that it can download. BREW environment can answer that query by filtering the applications that can run on the user devices based on the device's capability (Kochhar J., 2003).

3.5 Databases in Mobile Computing Systems

Mobile applications can use the existing Data Base Management Systems (DBMS) to perform the traditional functions of database management such as providing users an abstract view of

data without knowing how the data is stored and maintained, managing concurrent access to data, enforcing information security by preventing unauthorized access and providing backup and recovery. Today, it is possible to do DBMS functions from mobile devices such as PDA and pocket PC. Many commercial DBMS works in this trend such as Syware, Oracle Lite and Microsoft SQL Mobile. In this case the previous constraints of wireless networks and devices must be taken into account.

Normally, mobile computing system does not stand alone; rather, it must be tightly integrated into an existing system (Extended Systems, 2006) and it provide services and solution for businesses that have already IT infrastructure which includes DBMS. In construction management, there are many information that used in different stages in the construction lifecycle (Nilsson M., 2002) such as information of participants, organizations (contractors, suppliers, engineers, inspectors) and information of project itself such as design specifications, contract items and scope of work (in our case, these information already exist in Oracle database system). Therefore, recreating this information will consume much time and effort and be prone to errors. Since, it is importance to develop a mobile computing system that can integrate with existing database and IT infrastructure.

Databases in mobile computing may deal with new issues and challenges that was not there in traditional distribution systems. As the result of mobility in mobile computing where users have mobile terminal (Sköld M., 1997), databases deal with management of location data, mobile users information and frequent disconnections. In 1997, Imielinski T. & Badrinath B. (Imielinski T. & Badrinath B., 1997) expected that mobility will have a similar impact on data management as distribution had on data management. From the mid 1990s to present, the impact of mobility in data management has been seen clearly as the result of rapid growth in mobile terminals and wireless networks.

Mobile querying and moving-object indexing are other important issues, in regard to mobile databases, that have been discussed in many research papers (Hu Q. L. at el (2000), Breunig M. at el (2004), Jensen C. at el (2004)) Although these topics are beyond the scope of this project, They will be considered in future when adding some functionality to the system such as determining locations of mobile users (inspectors and contractors) or assigning inspection task to the nearest inspector from a particular project.

Chapter 4

Mobile Computing Development Frameworks

4.1 Introduction

The investigation of the mobile computing system components, which was discussed in the previous chapter, was the first step towards achieving one of the objectives of this project which is investigate the current practice, tools and technology in design and implementation of wireless applications. This chapter complements the previous chapter to achieve that objective through research into architectures, frameworks and tools that can be used for designing and implementing mobile computing applications.

4.2 Mobile applications and Software Development Processes

The most important question for developing a mobile computing system is that “do the architectures, frameworks and tools that used in software development processes, can be applied for mobile application development?”. Frameworks and tools used in developing software systems in general, are based on the architecture of the system and the architecture of the system should be selected based on the user requirements. Reza B. (2005) states that “one of the most prevalent mistakes in designing software systems in general, and mobile software systems in specific, is that architecture is done as an afterthought to a group of products and frameworks selected”. Therefore, before selection frameworks and tools for developing a mobile computing system, the system architecture should be selected. Amjad U. (2004) defines wireless system architecture as an architecture that consists of the components (network components such as wireless access points, platform components such as WAP gateways, and application components such as mobile databases), what they do (connect with the user, translate content, provide needed data), and how they interface/interact with each other. This definition is suitable for high level which can be used to draw the key design ideas.

Because of mobile applications are inherently distributed network-based systems, mobile architecture are inherently network-based computing architectures (Reza B. ,2005) and the most popular network-based architectures is Client-Server Architecture.

4.3 Client-Server Architecture

Client/Server is a computational architecture that involves client processes requesting service from server processes (Kristol D. and Montulli L , 2000).

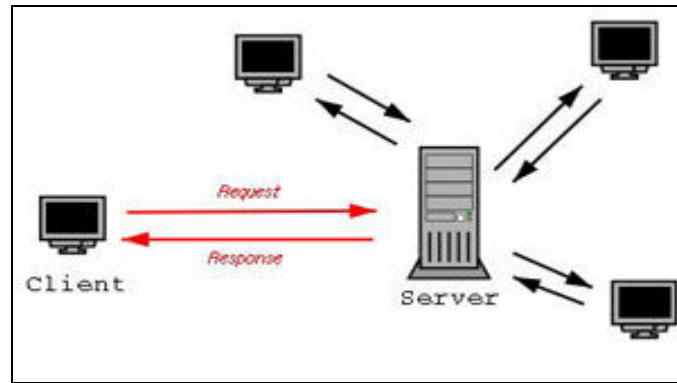


Figure 4.1 Client-Server Architectures (Source www.progdevo.com/database/client-server.html)

The design of client-Server system doesn't reflect the physical computers on the system. It should reflect the logical structure of the application being devolved. (Nilsson M. and Ryding B. ,2002). Simply , client-server model involves two distinct programs ; one reside in client machine and requests services from the another program which is resided in server machine. There are two mechanisms that allow the clients machines to communicate with server machine in order to request a specific service. These mechanisms are thin-client/server and thick-client /server. In a thin-client all of processing and data management is carried out on the server. The client is responsible only for running the browser software. In a thick –client , the client executes some tasks and the server executes the others. Reza B. (2005) argues some difficulties of having thick client for mobile devices such as the restricted resource for mobile devices such as limited power, processor and memory also the deployment and provisioning problem for example how developers distribute software to such a wide range of devices with variety of platforms. However selecting any one of these mechanisms effects on selecting frameworks and tools for developing a mobile computing system. For example when system requirements involves thin-client/server model, mobile applications developers have to select one of the platforms that support browser based applications that mentioned early in section 3.4

The most important issue in Client-Server Architectures is that which tasks should be done on the client side, and which on the server side. There are two Architectures; 2-tier and N-tier. In 2-tiers Architecture, the presentation layer and the business logic is spread across to the clients and the server becomes just a database server. In N-Tier Architecture, the Presentation layer is located on the client device and the Business Logic layer on a application server and the data layer on a database server. Einav J (2007) defines these layers as the following:

- **Presentation layer:** is the layer responsible for displaying user interface.
- **Business layer:** is the layer responsible for accessing the data tier to retrieve, modify and delete data to and from the data tier and send the results to the presentation tier. This layer is also responsible for processing the data retrieved and sent to the presentation layer.
- **Data layer:** is the database or the source of the data itself.

Normally, N-Tier Architecture often have several components (software) such as application server, web server, database server , etc (Gao R. , 2005).

When designing a system based on Client-Server Architectures, the developer should make a clear distinction between different layers in order to separate them between client side and server side. One proven design pattern called Model-View-Controller (MVC) used by developers to separate between the components of application code. The MVC framework will now be discussed.

4.4 Model-View-Controller (MVC)

Model-View-Controller began as a framework developed by Trygve Reenskaug for the Smalltalk platform in the late 1970s Fowler M. (2003). The Model-View-Controller (MVC) pattern separates the modeling of the domain, the presentation, and the actions based on user input into three separate classes Burbeck S. (1992). Azamsharp (2005) defines the roles of MVC as the following:

- Model: The model manages the behavior and data of the application domain, responds to requests for information about its state (usually from the view), and responds to instructions to change state (usually from the controller).
- View: The view manages the display of information.
- Controller: The controller interprets the mouse and keyboard inputs from the user, informing the model and/or the view to change as appropriate.

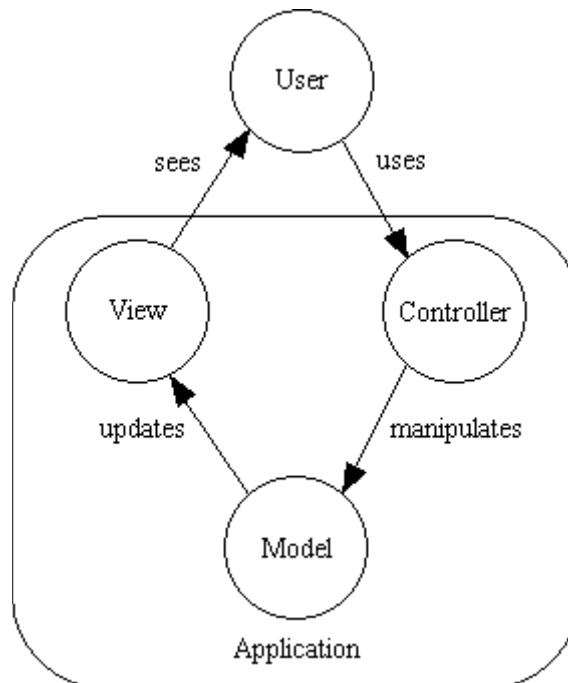


Figure 4.2 - The basic MVC relationship (source: <http://www.tonymarston.net/php-mysql/model-view-controller.html>)

There are many benefits from applying MVC architecture which repeated in many articles. The Separation application of layers allows the developer to change, replace, maintain or modify an MVC component without re-writing the entire application. Also it allows different developers to work in different parts of the application. In addition, some application components such as user interfaces can be used in many applications. In mobile application, MVC allows for switching the user interface from PC application to mobile application and still using the underlying controller and model layers because a single model and controller layer can support more than one view at the same time (Dorsey P. et al, 2004). MVC can meet the criteria of the good mobile application architecture that set by Amjad (2004) which is “a good architecture should be able to tolerate technology changes and be flexible and scalable to handle different and new users “.

MVC has been adopted by many programming languages, platforms specifications and industry standards such as ASP.NET, Python, perl and Java Platform Enterprise Edition (Java EE). Next section will discuss Java EE which is one of the most popular platform and widely used in distributed applications.

4.5 Java Platform Enterprise Edition (Java EE)

Formerly known as Java 2 Platform, Enterprise Edition or J2EE up to version 1.5, it is a platform from Sun Microsystems and provides a set of coordinated technologies and practices that enable solutions for developing, deploying, and managing multi-tier, server-centric applications (Sun Microsystems, 2007). Multi-tier Java EE applications is based on Model-View-Controller framework which can be mapped to Multi-tier Java EE applications as shown in the figure below:

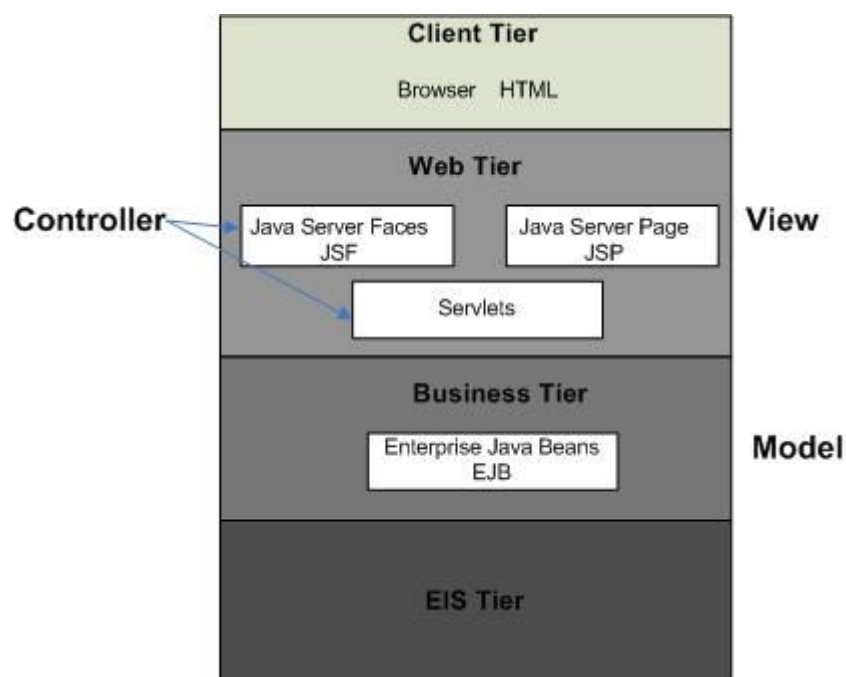


Figure 4.3 Mapping MVC Architecture to Java EE

The three tiers; client tier, web tier, and business tier can be separated in different machines as shown in Figure 4.4 below:

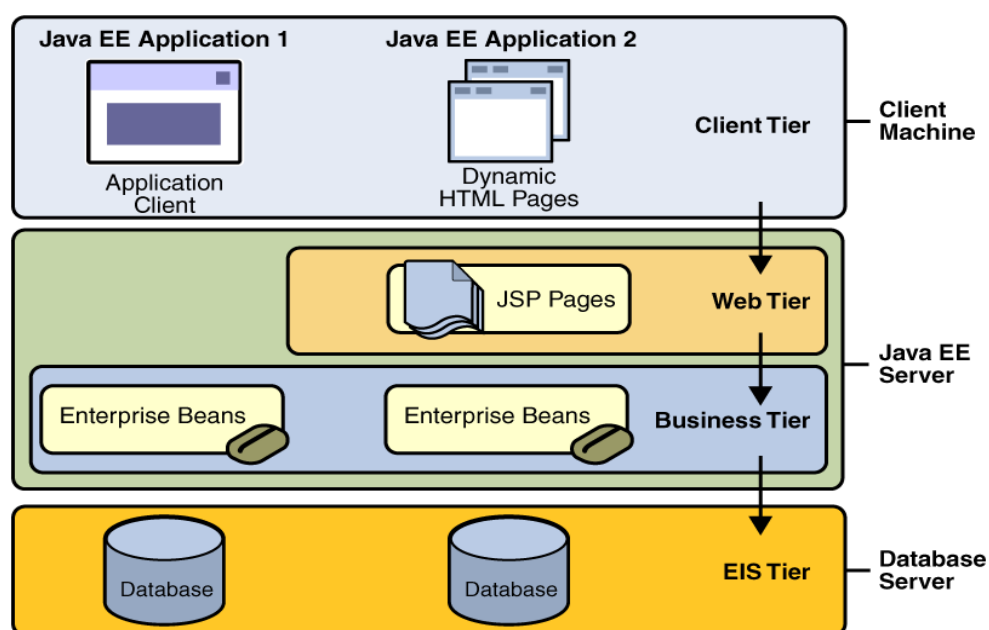


Figure 4.4 separation multitiered applications (Source *The Java™ EE 5 Tutorial*)

Servlets are java classes files that are stored in Java EE server. Each Servlet act as controller by receiving a request from the view, communicating with the model to process the request and forwarding the result of processing to the appropriate view. Servlets are coded entirely in java and therefore portable and offer a bytecode “compiled” runtime version (Dorsey P. at al, 2004).

Java Server Page is An extension to the Java servlet technology that mixed HTML and Java code in the same source file. JSP allows to dynamically generate the web content, which is normally HTML page, in response to a Web client request. At run time Java EE server convert JSP into java servlet (.jsp to .java file) and then the servlet is compiled into bytecode (.class).

Java Server Faces is the latest technology after Servlets and Java Server Page. Although Servlets and JSPs are extremely useful, handling many common tasks for developing web applications. JSF can help simplify these tasks and provide a rapid solution for developing web applications (Ericsson ,2006). JSF offers this solution by providing a standard set of UI components that is encapsulated in JSP tag libraries, binding UI components to business logic and allowing developers and venders to share UI components with others (there are many JSF component kits, such as MyFaces from Apache and ADF Faces from Oracle). Although JSF can be considered as a whole framework technology , it can act as controller in MVC because it validates values, invokes business logic, and uses JSP for displaying results.

Enterprise Java Beans EJB is the official technology from Sun Microsystems for creating business services (the code that fulfills the purpose of the application). It is held in EJB container in business tire and collect data and present it to the view and controller. EJB supports both transient and persistent objects. A transient object is called a session bean, and a persistent object is called an entity bean (Thomas A. , 1998). The third bean type is Message-Driven Beans

Session beans: Performance a business task for a client

Entity beans: Represents a business object that exists in a database. an entity bean instance can be considered as a row of data

Message-Driven Beans: Receives asynchronous Java Message Service (JMS) messages

One of the most Advantages of EJB is to improve the productivity of application developers by allowing them to focus on writing the business logic and EJB automates the use of complex infrastructure services, such as transactions, thread management, and security checking (Thomas A. , 1998 , Krastev A and Galletly J, 2003). But its specification is too large and complex Krastev A and Galletly J (2003) states that the EJB technology has the potential to produce a more complex and costly solution than necessary. This disadvantage is a direct corollary of the complex specification.

Another technology for creating business services is ADF Business Components (ADF BC) which is one of Application Development Framework (ADF) technologies provided by Oracle company. ADF is an end-to-end application framework that builds on Java EE standards and

open-source technologies. Because of ADF is based on the Java EE design pattern MVC, it provides a clean separation of business logic, page navigation, and user interface. The figure below shows ADF Architecture

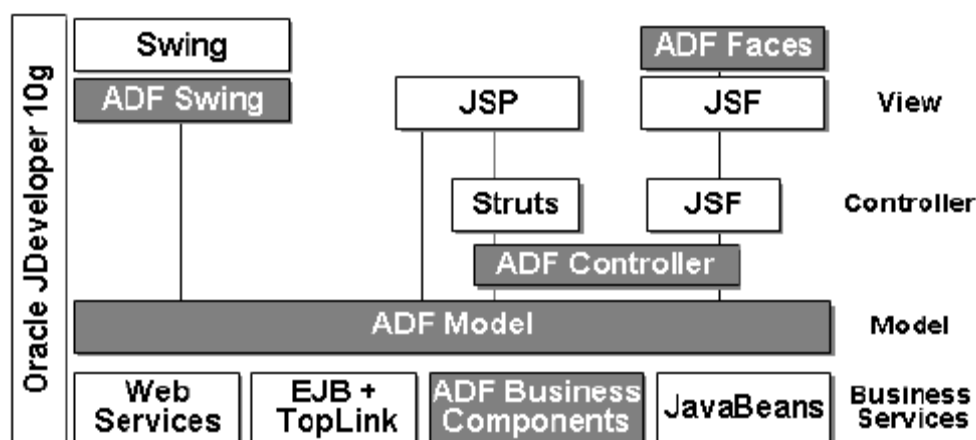


Figure 4.5 ADF Architecture

As shown, ADF supports Java EE technologies and also provides its own solutions such as ADF BC. This allows developers to choose the appropriate technology for their applications. There are two main advantages of ADF BC: that it saves the developers the difficult task of coding Java Database Connectivity (JDBC) by automated mapping of Java objects to database objects and provides easy hooks for binding user interface components (Dorsey P. et al, 2004). However, EJB is better for developers who need to develop business services without using vendor-specific-library or who are comfortable with EJB technology.

There are three components in ADF BC:

Entity Object: An entity object represents a row in a database table.

Application Module: An application module is the transactional component that UI clients use to work with application data.

View Object: A view object represents a SQL query and simplifies working with its results.

4.6 Applicable of Java EE in Mobile Applications

As previously stated, Java EE is used for developing multi-tier, server-centric applications. It is a proven platform (Vawter C. and Roman E., 2001) that has been used in many client-server applications such as web applications and adopted by many Application Server vendors such as WebSphere, Tomcat, WebLogic and JBoss. As mentioned early, mobile applications are client-server applications when the mobile device (client) connects to the server through a wireless network. Therefore, Java EE can be used for developing the mobile applications when taking into account the aspects of mobile applications. In this regard, JSP in web tier generates HTML for web client while there are other mark up languages supported by different mobile devices types.

such as WML, XHTML MP and cHTML. In other words, unlike normal PC, not all mobile devices support HTML and we need to customize the view layer and present the appropriate web content format for a variety of devices.

Many solutions have attempts to solve this problem. All these solutions revolve around one idea; detection of the user-agent of the requesting device and then generate an appropriate view for that device. The following are some of these solutions

4.6.1 Oracle ADF Mobile:

Oracle ADF Mobile is based on JSF and ADF Faces. It allows the developers to use over 60 of the standard ADF Faces components each of them rendered appropriately for small-screen mobile devices. ADF Mobile detects the user-agent of the requesting device. Based on this value, the pre-populated device repository is queried and then the characteristics of the device are inserted into a bean called `adfFacesContext` (Darringer P. , 2005). Then the applications query that bean to determine the attributes of the device such as screen width and height, etc. ADF mobile then customize the view elements such as number of rows in a table based on device attributes.

ADF Mobile doesn't generate mark up languages based on device attributes. Therefore, at the moment of writing, ADF Mobile solution is offered only for three mobile device categories PDA, Telnet, and Ask. For that, we can not provide this solution for mobile applications that require different types of devices with different mark up languages.

4.6.2 Wireless Abstraction Library (WALL)

It is a Java tag-library that deliver the best possible mark-up language for the requesting device by querying another XML file called Wireless Universal Resource File (WURFL). WURFL is a is an XML configuration file works as repository of wireless device capabilities. WURFL is a open-source project its goal is to describe the capabilities of common wireless devices around the planet and provide a simple API to programmatically query the capability repository (palowireless, 2006) .

First, WALL detect the user-agent for the requesting device and query the WURFL to figure out which mark-up the requesting device prefers then issue appropriate mark up language tags depending on the capability of that device (Passani, L., 2006).

WALL document can be inserted into a JSP file that located in the web tier in Java EE server. Therefore, this solution addresses the aspect of the mobile applications and allows to develop them in Java EE servers by just modifying the View layer to serve a variety of mobile devices

and in the same time still dealing with Model and Controller layers in the same way with PC web applications

4.6.3 Mobile JSF Kit from Ericsson

“The Mobile JSF Kit provides just such a JSF library, MobileFaces, which implements a reference solution for mobile device-specific rendering for mobile applications based on Java EE. MobileFaces can render different page content for different end devices based on one JSF page” (Ericsson, 2006). MobileFaces consists five components; Renderkits for XHTML-MP/WML, Device Manager, Content Filter, Media Adaptor, Script Renderer.

The Device Manager is a component of MobileFaces that responsible for collecting and providing the device features. It contains five java classes; DeviceDataFactory, AbstractDeviceDataFactory, DeviceDataFactoryRI, DeviceData and DeviceDataImpl. The Device Manager detects the attributes of the requesting device such as screen width and height and markup language and provides these attributes for other components of MobileFaces. The device manager uses WURFL's Java API and xml file to do its task.

Renderkits is responsible for rendering the JSF pages with UI components to standard markup language pages. Mobilefaces library contains a class called “MobileRenderKitFactory”. this class will check the markup language attribute from the Device Manager for the requesting device and decide to use HTML, WML or XHTML-MP renderkits. In addition, the standard JSF tags can be used and Renderkits in MobileFaces will render JSF for mobile devices. This means that MobileFaces allows to create one JSF page for different end devices.

4.7 Summary

It has shown that Client-Server architecture and Model-View-Controller framework can be used for designing and implementing mobile computing systems. Java EE tool, which is based on Model-View-Controller and offers solutions for Client-Server applications can be used also in mobile applications, with some amendments due to the aspects of mobile applications. The proposed solutions that offer these amendments has been discussed.

Chapter 5

System Design and Implementation

5.1 Introduction

Mobile Computing System for Construction Management (MCSCM) was designed and implemented to achieve the practical objectives of this project. The goal of MCSCM is to improve the construction management in Network Construction Department (NCD) and solve the current project management problem in NCD which lies in the lack of a system that can be used from construction sites to record projects' information and transfer, in real-time, these information to project's participants. The importance of such information for Construction Management was discussed in Chapter 1, which also explains that mobile computing system, in general, does not stand alone; rather, it can be added into an existing system.

From the system requirements which were analyzed in Chapter 2, projects' information that need to be transferred from construction site, in NCD case, are project number, task name, actual start time and actual finish time. MCSCM transfers, in real-time, these information to project's participants and inserts them into the other projects' information which are currently used in the existing systems in NCD. The aim of this chapter is to discuss how MCSCM was designed and implemented to do its functions. Firstly, summarization of the findings of the research chapters are presented to show how these findings feed into the practical aspect of the project.

5.2 High-Level Design

The analysis stage has produced an initial depiction of the system design through figure 2.4 and figure 2.5. The research that followed the analysis stage led to provide a mature design for the system. Although some components, technologies and procedures in the initial depiction still been adopted in the final solution, the research in chapter 3 and chapter 4 turned to study all possible alternatives and their relationship to the system requirements and thus led to choice the way in which the system was designed and selection the components' types of the system. In addition, the research led to understand the issues that should be considered by developers when choosing or designing the components of the system. One of these issues is that the user requirements must be determined first then the architecture of the system must be created based on these requirements and finally frameworks and tools selections must reflect the architecture of the system.

From chapter 2, the contactor needs to enter project number, task name, actual start time, actual finish time for each project. these projects are located in divergent areas in many cities. From

chapter 3, it is clear that the most appropriate and economical wireless network that can provide such coverage is GSM (Global System for Mobile Communications). From data rate speed point of view, chapter 3 discussed the capability of GSM in terms of data rate speed and how the mobile applications application should be leveraged to be appropriate with the speed of GSM. The figure below shows the high-level design of MCSCM.

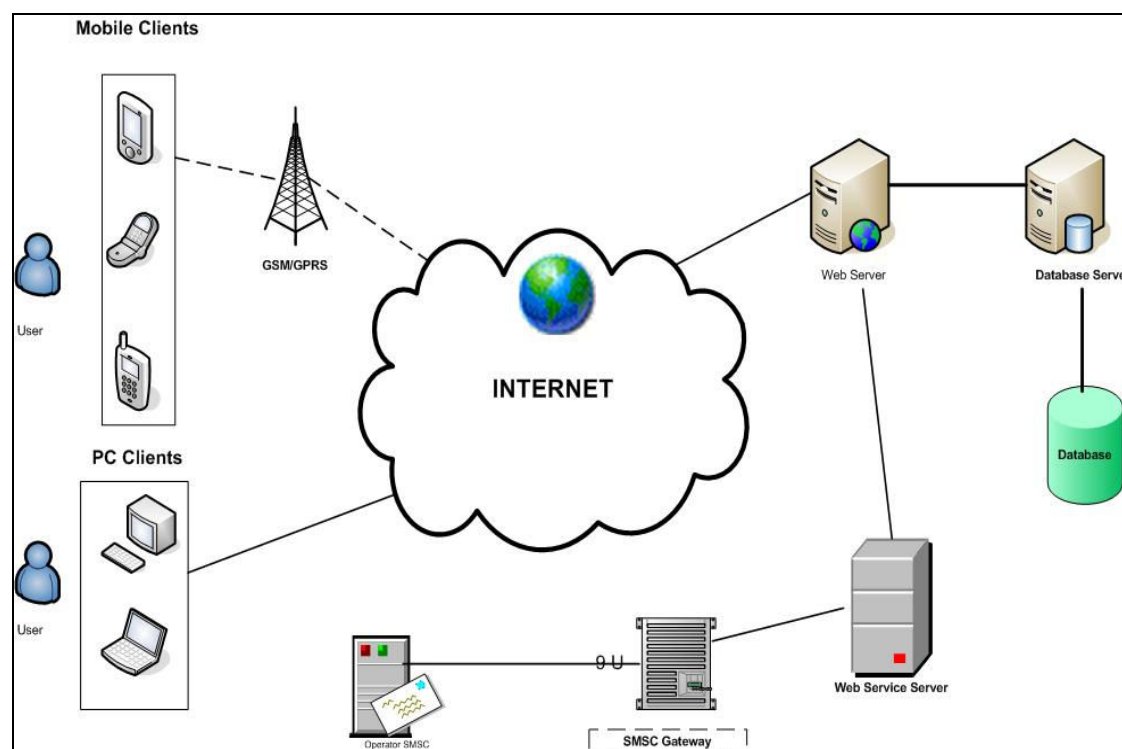


Figure 5.1 High-level architecture

GSM/GPRS connects to a gateway that act as the interface between the GPRS mobile network the wired internet. As discussed in chapter 3, the mobile applications developers should not have to know the underlying network details for converting between wireless and wired internet. Therefore this part were omitted from the system architecture. MCSCM was designed to consist a web server that connects to the internet and two other servers; database server and web service server. The database server stores and updates the database of the application. While the web services server connects to SMSC (Short Messages Service Centre) gateway of the SMS operator to provide SMS service for the application.

5.3 Technologies Selection

Chapter 3 discusses the components of the mobile computing systems and the technologies used in each components. The following are discussion about how these technologies were selected based on the findings of chapter 3.

5.3.1 Platforms

Platforms were considered first because the other components have usually been selected based on them. “Browser Based Application” were selected. Some reasons of this selection relating to the performance of mobile devices in general, been discussed in section 4.2 in context of thick – client /server architecture, some of the reasons relating to the requirements of the system However the following are the reasons for this selection:

1. In MCSCM, There are many users from more than one organization and it is difficult to download the application for every user. Also it difficult to update or modify the application in the future
2. According to the limitation of mobile device processor, power and memory. The performance of the application will be better when keeping all processing in server side
3. Platforms that support downloadable applications such as J2ME or BREW may be not supported by all types of the mobile devices of the potential users.

WAP platforms has been selected because both two GSM operators in Saudi Arabia adopt WAP and the infrastructure of their network supports WAP protocols. Another reason was that most of mobile devices in Saudi market are compatible with WAP

5.3.2 GSM Network and Provider

As mentioned, GSM network has been selected due to its coverage meets the system requirements. Another issue that were considered during design stage was the data rate speed of GSM. Based on the findings from chapter 3, although both 2G and 3G from GSM are currently available in Saudi Arabia, 3 G network for both providers (Al-jawl from STC and Mobily)does not cover all areas because it is still a new service at the moment of writing. Also most of mobile devices that currently used by the users of MCSCM or that available in the Saudi market don't support 3 G services. For that, MCSCM was designed and implemented to be work with the data speed rate of 2 G by using GPRS technology which is, as mentioned in chapter 3, realistically between 30kbps-40kbps. This means the large data volume was avoided when designing a web page for mobile devices in MCSCM.

Regarding to the provider selection, Al-jawal from STC was selected because the features of al-jawal's network meet the criteria that mentioned in chapter 3 such as coverage, capacity, reliability and latency.

5.3.3 Mobile devices

In MCSCM, where there are many participants from different organizations, different types of mobile devices are expected. So the MCSCM were designed to work properly with variety of types of mobile devices. some recommendations could be provided to the users for choosing

a durable device type that can operate efficiently in construction sites :

1. Devices should be water- resistant
2. Devices should be withstand high temperature
3. Devices should also withstand stress and shock
4. The screen should be readable in direct sunlight environment

In terms of GPRS class selecting for the devices, all GPRS classes will work in MCSCM but application will work faster When choosing a GPRS class with high uploading performance such as class 10 or 12. See section 3.2 to know more about GPRS classes.

5.4 Database Design

As mentioned in chapter 2, all current activities in NCD are computerized except the activities of the mobile workers in the site where there are no conventional computers and IT network. The main function of MCSCM is to computerized –in real time- the information that produced from construction sites. But, as mentioned many times in the previous chapters, the mobile computing systems need to be added to the existing systems. Although MCSCM not fully integrated with the existing systems in NCD, it was designed to use the similar information that currently used in NCD. It is difficult to integrate such prototype with the existing IT systems in NCD but it was designed to make this integration possible and easy in the future. For this reason, MCSCM uses the same Data Base Management System (DBMS) that currently used in NCD which is Oracle database system. Also database tables follow a similar structure used in the current database in NCD, with some elimination for any unnecessary tables and fields that were irrelevant to the needs of MCSCM. Figure 5.2 below shows the database structure

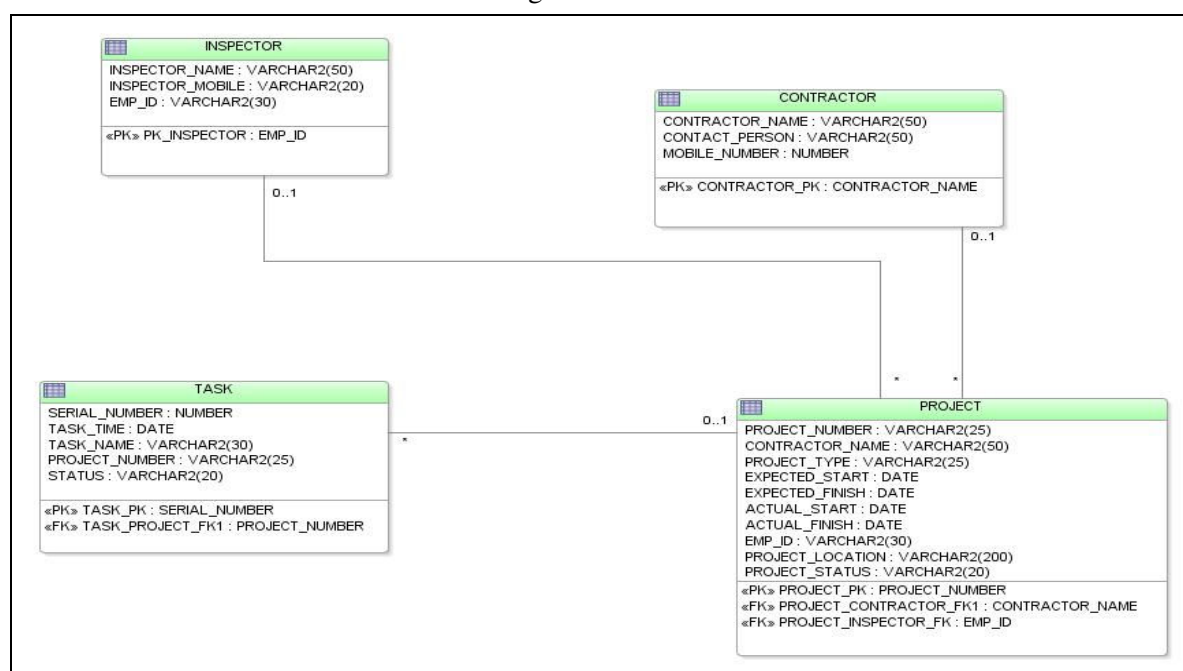


Figure 5.2 Database structure

As shown, there are four tables; CONTRACTOR, INSPECTOR, PROJECT and TASK. Figure 5.2 shows name, length and data type for each fields in the tables and the relationships between tables.

5.5 Low-Level Design

From high-level design, some MCSCM functions can be performed by enable the users to access (through GSM/GPRS) the application in the web server via the internet by using their mobile devices. Some functions can be performed by normal PC that connects to the internet. Also section 5.2.1 states that WAP platform was selected. This means that the users will use the browser software in their WAP-enabled devices to access the application in the server. Low-level design was created to select the components of the application server and describe where these components are placed and how they communicate with each other and with client side and database to perform the functions of MCSCM. Figure 5.3 below shows the low-level design of MCSCM.

The design is based on Java EE specifications (chapter 4 discusses in details these specifications) where there is a clear separation between model, view and controller. The client side may be a mobile browser or PC browser. Mobile browser may support either WAP mark up languages (WML and XHTML MP) or HTML.

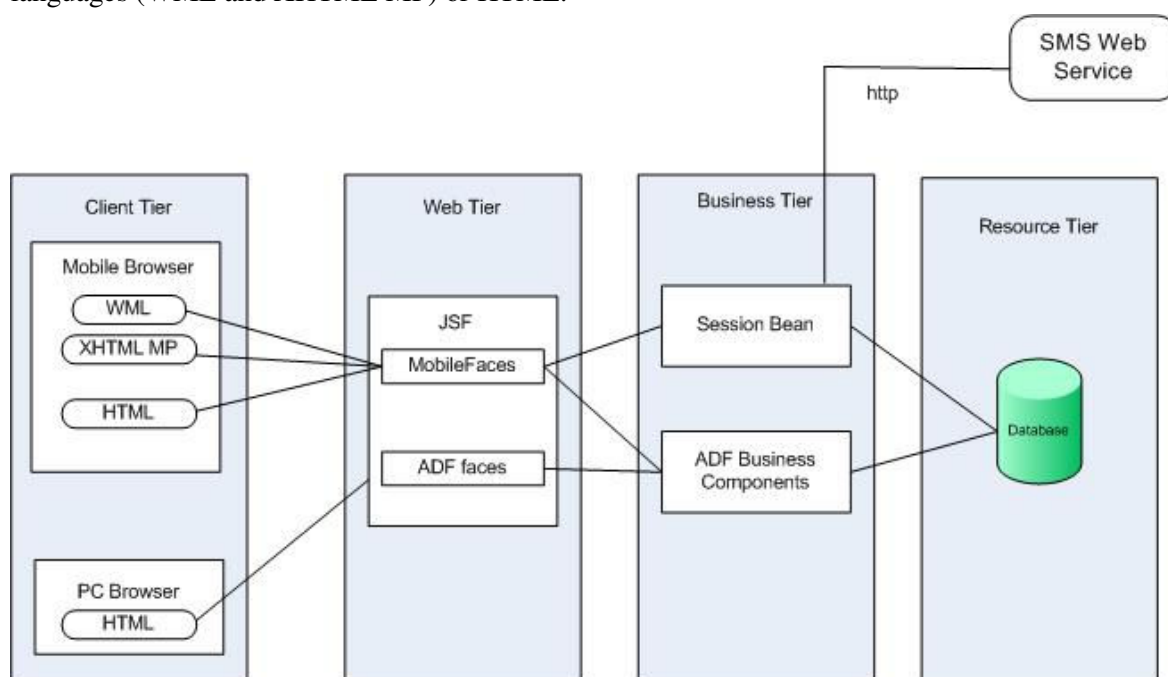


Figure 5.3 MCSCM Low-Level Design

The server side was developed by using Tomcat application server and contains two tiers; web tier and business tier. The web tier contains two technologies Java Server Page (JSP) and Java Server Faces. The functions of JSP and JSF were discussed in chapter 4. Section 5.6 discuss how they were implemented. ADF Business Components (ADF BC) was selected in business

tier in the server side for creating the business services of MCSCM. Chapter 4 discusses the advantage of ADF BC and other alternatives for creating business services. Sections 5.5 and 5.6 below describes how the web tier and business tier in the server side were implemented.

5.6 Business Tier Implementation

Business tier in the server side contains ADF BC for creating the business services (the code that fulfills the purpose of the application) of MCSCM. This section discusses how the three components (Entity Objects, Application Module and View Object) of ADF BC were implemented. The components of ADF BC represent model layer in MVC framework and implement validation and database access. The business tier contains also Session Bean used to serve clients requests and allow them to perform certain business tasks as explained below in section 5.6.4.

JDeveloper 10.3.1 was chosen as a suitable Integrated Development Environment (IDE), primarily because it is a product from Oracle and offers fully compatibility with Oracle database and Oracle Application Development Framework (Oracle ADF) (chapter 4 defines Oracle ADF). JDeveloper simplifies creating the components of ADF BC in business tier as is the case with the rest of the components of other tiers.

5.6.1 Entity Objects

Four entity objects were created “Contractor”, “Inspector”, “Project” and “Task”. Each entity object corresponds to a table in the database and represents a single row in that table for example “inspector” entity object corresponds to “INSPECTOR” table in the database and so on. each entity object has a related XML component definition file (see appendix 3) which contains metadata to determine the behavior of the java class of the entity object.

5.6.2 View Objects

There are four view objects; ContractorView, InspectorView, ProjectView and TaskView. The purpose of the view objects, as stated in chapter 4, is to represent a SQL query and simplify working with its results. SQL query columns map to the attributes of the view object. Each view objects are related to an underlying entity object and used to read, insert, update, and delete rows of data. In case of any changes in rows of data, the view object coordinates with its underlying entity objects to save modifications to data permanently. Like entity objects, the view objects are defined by XML files (see appendix)to define the SQL that retrieves the view objects data, the view object attributes, and entity object usages.

5.6.3 Application Modules

Application modules are business components that represent particular application tasks. The following are the screen shots of MCSCM tasks:

1. To view projects information, add new project and view the tasks of a project:

Project Number	Contractor Name	Inspector Id	Project Type	Expected Start	Expected Finish	Actual Start	Actual Finish	Project Location	Status
0623000000	Bin Dafrah	Zaydi A	secondary	Jan 20, 2007	Jan 24, 2007	Jan 20, 2007	Feb 1, 2007	TIFS Cab. 135 Um Al-Suba'	Close
0623000001	Bin Dafrah	Zaydi A	primary	Jan 21, 2007	Jan 25, 2007	Feb 13, 2007		TCEN Cab. 100	Open
0623000002	Easa Al-Easa	Gthamy M	Fiber	Jan 23, 2007	Feb 1, 2007	Jan 23, 2007		Hada Cab. 10	Open
0623000003	Taqniyat Al-Masharee	GHamdi A	Secondary	Feb 1, 2007	Feb 8, 2007	Feb 9, 2007		TIFS Cab. 30	Open
0623000004	Al-Mothry	Shanbry H	Fiber	Feb 27, 2007	Mar 5, 2007			HAWI 005:010	
0623000787	Taqniyat Al-Masharee	Moshtak H	Secondary	Feb 20, 2007	Feb 21, 2007	Feb 20, 2007	Feb 20, 2007	HAWI 016:053	Close
0623000815	Taqniyat Al-Masharee	Moshtak H	Secondary	Feb 13, 2007	Feb 16, 2007			Hawi Cab. 069	Open
0623000816	Taqniyat Al-Masharee	Thabaty T	Secondary	Feb 20, 2007	Feb 21, 2007	Feb 20, 2007	Feb 20, 2007	HAWI 039:055	Close
0623000817	Taqniyat Al-Masharee	Moshtak H	Secondary	Feb 20, 2007	Feb 21, 2007	Feb 20, 2007	Feb 20, 2007	HAWI 023:237	Close
0723000098	Taqniyat Al-Masharee	Moshtak H	Secondary	Feb 21, 2007	Feb 22, 2007	Feb 21, 2007	Feb 21, 2007	HAWI 072:075	Close
0723000136	Taqniyat Al-Masharee	Moshtak H	Secondary	Feb 21, 2007	Feb 22, 2007	Feb 21, 2007	Feb 21, 2007	HAWI 092:020	Close
0723000142	Taqniyat Al-Masharee	Moshtak H	Secondary	Feb 13, 2007	Feb 15, 2007	Feb 13, 2007	Feb 20, 2007	Hawi Cab. 064 near asmak Al-romanah	Close

Figure 5.4

The user can add new project by pressing on “Add New Project” button as shown in the following screen:

MCSCM Add new Project

* Project Number: 0723000020

Contractor Name: Easa Al-Easa

Inspector Id: [Empty]

Project Type: Abdulwahid Al-Zaydi

Expected Start: Ahmad Al-Gamdi

Expected Finish: Mohammed Al-Gethamy

Project Location: Fahad Al-Thumally

Buttons: Save, Add New

Figure 5.5

The user can query about the tasks of any project by pressing the button “View Tasks” in figure 5.4, the following screen will appear then he can enter the project number to view the information of all tasks in that project as shown below:

MCSCM View Tasks

View Tasks

Enter Project Number

Project Number 0623000000
Contractor Name Bin Dafrah
Inspector ID Zaydi A

Task Name	Task Time	Status
Permissions	Jan 20, 2007	Start
Permissions	Jan 20, 2007	Finish
Cutting asphalt	Jan 20, 2007	Start
Cutting asphalt	Jan 23, 2007	Finish
Trench	Jan 23, 2007	Start
Trench	Jan 23, 2007	Finish
Extending cables	Jan 23, 2007	Start
Extending cables	Jan 30, 2007	Finish
Jointing cables	Jan 30, 2007	Start
Jointing cables	Feb 1, 2007	Finish
Filling trench	Feb 1, 2007	Start
Filling trench	Feb 1, 2007	Finish
Re- asphaltting	Feb 1, 2007	Start
Re- asphaltting	Feb 1, 2007	Finish
Ready for service	Feb 1, 2007	Finish

Figure 5.6

2. To view and edit inspectors information:

MCSCM Inspectors Information

Inspector Name	Inspector Mobile	Inspector ID
Abdulwahid Al-Zaydi	+966504701690	Zaydi A
Ahmad Al-Gamdi	+966504701466	GHamdi A
Mohammed Al-Gethamy	+966504701281	Gthamy M
Fahad Al-Numarry	+966504701729	Nmarry F
Fahad Al-Thumally	+966504701739	Thmally F
Hashem Moshtak	+966504701662	Moshtak H
Tariq Al-Thabaty	+966504701696	Thabaty T
Harith Al-Shanbry	+966504701679	Shanbry H

Edit

Abdulwahid Awad Al-Zaydi
azaydi@stc.com.sa

[Home](#) | [Proj](#)

Figure 5.7

3. To view contractors information:

MCSCM Contractors Information

Contractor Name	Contact Person	Mobile Number
Bin Dafrah	Raja Khan	966501320985
Easa Al-Easa	Khalied Hosain	966553071015
Al-Najdeen	Nor Al-Dain	966509355592
Taqniyat Al-Masharee	Abdulrahman Al-Thabaty	966506781781
Al-Mothry	Saeed Alem	966507770295

Abdulwahid Awad Al-Zaydi
azaydi@stc.com.sa

[Home](#) | [Proj](#)

Figure 5.8

4. To send the task information (from construction sites) from mobile devices:



HTML MP mark up language



WML mark up language

Figure 5.9 MCSCM generates different mark up languages

There are four application modules represent the above tasks which are ProjectInformation, InspectorInformation, ContractorInformation and TaskInformation. Each application module aggregates a particular view object instance that retrieve the data needed by the client to accomplish the application's tasks. Like other business components, the application modules are partially defined by XML files. The application modules also defined by java classes which includes methods that required by the application modules (see appendix 3).

5.6.4 Session Bean

MCSCM allows the users to enter the project number and selects the task name from the menu and selects task' status from radio button (see figures 5.9) after the users presses on "Send" button , two threads will be created; first the information of the project will be sent to the application module " TaskInformation" in the business tire on server side which then will communicate with the database to save these information in TASK table in the database. In the second thread the information will sent to the session bean "ProjectBean" which then will communicate with "MobileNumber" application module to query the database about the mobile number of the inspector and the location of the project .MobileNumber application module contains two view objects to perform the query from the database. The following code in ProjectBean shows how to retrieve the mobile number of the inspector and the location of the project from the database through MobileNumber application module and view objects:

```
String amDef = "mcscm.model.MobileNumber";
String config = "MobileNumberLocal";
ApplicationModule am =
Configuration.createRootApplicationModule(amDef, config);
ViewObject vo = am.findViewObject("InspectorMobile1");
ViewObject vo1 = am.findViewObject("InspectorForProject1");
ViewCriteria vc1 = vo1.createViewCriteria();
ViewCriteriaRow vcr1 = vc1.createViewCriteriaRow();
vcr1.setAttribute("ProjectNumber",project);
vc1.add(vcr1);
vo1.applyViewCriteria(vc1);
vo1.executeQuery();
while (vo1.hasNext()) {
Row curUser = vo1.next();
empId = (String)curUser.getAttribute("EmpId");
}
ViewCriteria vc2 = vo1.createViewCriteria();
ViewCriteriaRow vcr2 = vc2.createViewCriteriaRow();
vcr2.setAttribute("ProjectNumber",project);
vc2.add(vcr2);
vo1.applyViewCriteria(vc2);
vo1.executeQuery();
while (vo1.hasNext()) {
Row curUser = vo1.next();
location = (String)curUser.getAttribute("ProjectLocation");
}
```

```
ViewCriteria vc = vo.createViewCriteria();
ViewCriteriaRow vcr = vc.createViewCriteriaRow();
vcr.setAttribute("EmpId",empId);
vc.add(vcr);
vo.applyViewCriteria(vc);
vo.executeQuery();
while (vo.hasNext()) {
    Row curUser = vo.next();
    mobileNo = (String)curUser.getAttribute("InspectorMobile");
}
```

once these information received from the database, ProjectBean instances a message object from Message.java class:

```
Message message = new Message(mobileNo, task, status, project,location );
```

messagingPeople is the SMS web service provider for MCSCM. Message class uses messagingPeople API to connect to the messagingPeople gateway via HTTP. SMS reviced by the inspector is similar to the figure below:



Figure 5.10 MCSCM send sms to the mobile users

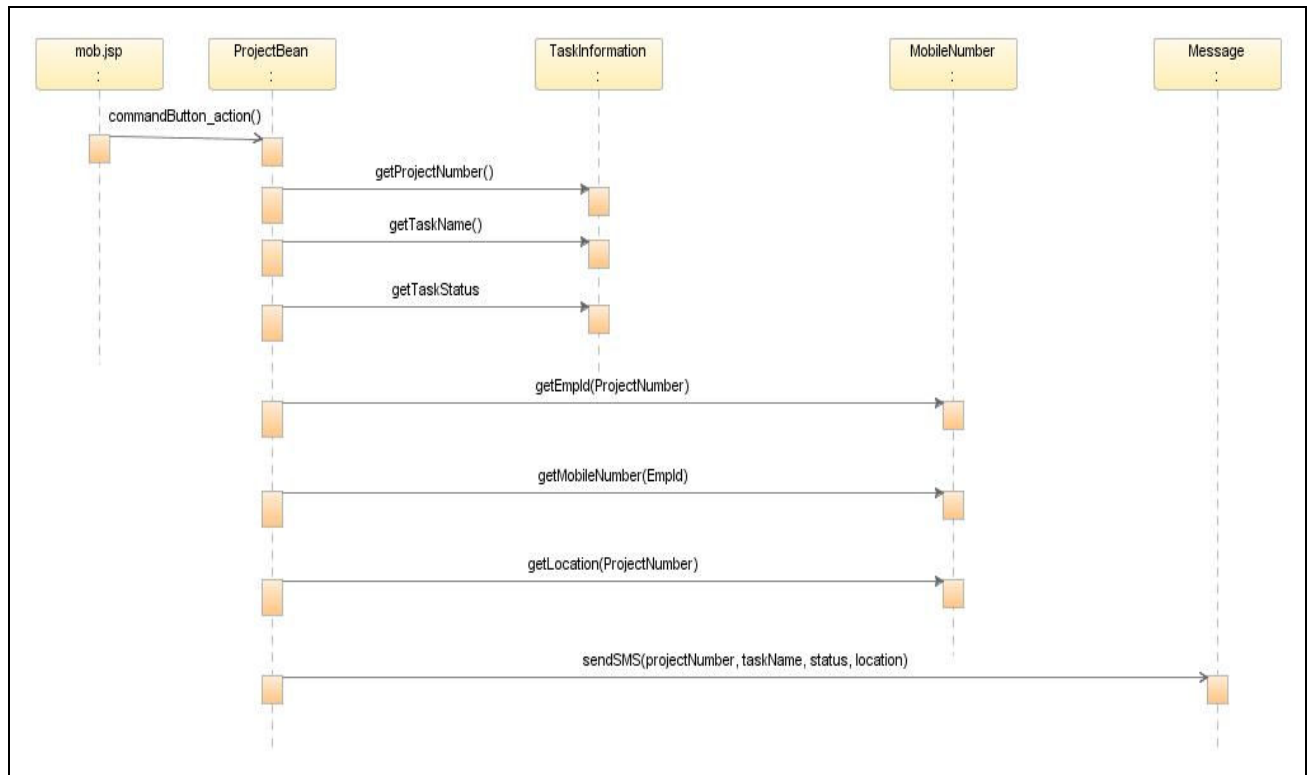


Figure 5.11

As mentioned the previous chapter , The construction projects in telecommunications network have multiple tasks with short duration for each task (some tasks may take only less than one hour such as jointing cables), the time that takes between sending a message and receiving it, become very important in terms of system performance, especially when considering the number of the users and the time that the inspector needs to reach to the construction site. As stated in chapter , network latency is one of criteria that was evaluated during choosing the network provider. In system implementation, the adopted design patterns assists to increase the system performance by executing multiple system functions in one asynchronous transaction. This reduces reduce time consuming and minimizes the number of calls between mobile clients and wireless network and also between the three system's servers.

5.7 Web Tier Implementation

The web tier was implemented to fulfill two purposes: to present user-interface component and to handle user interactions with the application. Because of MCSCM was designed based on MVC design pattern, the user-interface code (**View**) is separated from handling the user interactions (**Controller**). Java Server Faces framework provides this separation.

5.7.1 Handling the User Interactions

For controlling, two xml files was created; web.xml and faces-config.xml. The web.xml file registers servlets, defines servlet initialization parameters and define custom tag library location. For example, Java Server Faces framework provides a unique servlet (javax.faces.webapp.FacesServlet). All requests handled by FacesServlet and it was declared in /WEB-INF/web.xml as the following :

```
<servlet>
  <servlet-name>Faces Servlet</servlet-name>
  <servlet-class>javax.faces.webapp.FacesServlet</servlet-class>
  <load-on-startup>1</load-on-startup>
</servlet>
<servlet>
```

The faces-config.xml used to define the navigation rules between pages. For example the following are the code that used in faces-config.xml to navigate from ProjectInformation.jspx (figure 5.4) to newProject.jspx (figure 5.5) when the user presses “Add New Project” button:

```
<navigation-rule>
  <from-view-id>/app/ProjectInformation.jspx</from-view-id>
  <navigation-case>
    <from-outcome>addNew</from-outcome>
    <to-view-id>/app/newProject.jspx</to-view-id>
  </navigation-case>
```

This file also used to define the managed beans.

5.7.2 Java Server Faces UI Components

JSF offers a standard set of UI components, such as the "HTML" component, allowing the developer to build Web user interfaces using these pre-built user-interface. As mentioned in chapter 4, JSF API allows developers and venders to create custom JSF UI Components and share UI components with others. ADF faces from Oracle and MobileFaces from Ericsson are example of such custom JSF UI Components. Both components were used in developing UI of MCSCM.

5.7.3 ADF faces

All JSP pages that can be accessed by PC browser that supports HTML, are implemented by using ADF faces. ADF faces offers a rich library for web applications with more sophisticated

UI components. For example The ADF Faces table that used in ProjectInformation page (see figure 5.4) supports paging and sorting on any column. ADF faces also allows to refresh data without causing the entire browser page to refresh. These features not available in the standard JSF. The following code provides an example of how ADF Faces table tag was used in InspectorInformation page (see figure 5.5):

```
<af:table value="#{bindings.InspectorView1.collectionModel}"
          var="row" rows="#{bindings.InspectorView1.rangeSize}"
          first="#{bindings.InspectorView1.rangeStart}"
          emptyText="#{bindings.InspectorView1.viewable ? 'No rows yet.' : 'Access
Denied.'}">
  <af:column headerText="#{bindings.InspectorView1.labels.InspectorName}"
              sortProperty="InspectorName" sortable="false">
    <af:outputText value="#{row.InspectorName}"/>
  </af:column>
  <af:column headerText="#{bindings.InspectorView1.labels.InspectorMobile}"
              sortProperty="InspectorMobile" sortable="false">
    <af:outputText value="#{row.InspectorMobile}"/>
  </af:column>
  <af:column headerText="#{bindings.InspectorView1.labels.EmpId}"
              sortProperty="EmpId" sortable="false">
    <af:outputText value="#{row.EmpId}"/>
  </af:column>
</af:table>
```

5.7.4 MobileFaces

As shown in figure 5.9, MobileFaces in the web tier generates different mark up languages that supported by different mobile devices types such as WML, HTML MP and HTML. MobileFaces uses the standard JSF tags; JSF core tag library and HTML tag library. These two library is imported by writing the following code line at the top of mob.jsp (mob is the page that used for mobile devices in MCSCM -see figure 5.9)

```
xmlns:h="http://java.sun.com/jsf/html"
```

```
xmlns:f="http://java.sun.com/jsf/core"
```

Then the following line is to import the MobileFaces tag library:

```
xmlns:m="http://www.ericsson.com/sn/mobilefaces"
```

Although MobileFaces uses the standard JSF tags, some components, such as doctype and body tag, are different from HTML to XHTML-MP/WML. Therefore these hard-coded HTML codes should be replaced with MobileFaces components as the following table:

Standard JSF tag	MobileFaces tag
<!DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 4.01 Transitional//EN">	<m:doctype/>
<html> & </html>	<m:html> & </m:html>
<body> & </body>	<m:body> & </m:body>
&	<m:h3> & </m:h3>

Table 5.1 (Source Ericsson (2006))

As stated early in chapter 4, WURFL is a is an XML configuration file works as repository of wireless device capabilities. To get device features from WURFL, Two java classes are used; WURFLDeviceDataFactory.java and WURFLReader.java. These classes are contained in the Mobile JSF Kit from Ericsson available at:

http://www.ericsson.com/mobilityworld/sub/open/technologies/open_development_tips/tools/mobile_jsf_kit

WURFLReader is used to read the device features from the WURFL data file. The following code lines in WURFLDeviceDataFactory illustrates how WURFLReader read from WURFL and set the result in DeviceData calss in the Device Manager (see section 4.5.3):

```
String useragent= request.getHeader("user-agent");
WURFLReader reader = new WURFLReader(useragent);
DeviceData device = new DeviceData();
device.setProperty(DeviceData.DEVICE_NAME, reader.getName());
device.setProperty(DeviceData.USER_AGENT, useragent);
device.setProperty(DeviceData.MARKUP, reader.getMarkup());
device.setProperty(DeviceData.SCRIPT, reader.getScript());
device.setProperty(DeviceData.SCREEN_LEVEL, reader.getScreen());
device.setProperty(DeviceData.IMAGE, reader.getImages());
```

WURFLDeviceDataFactory is Registered in mfaces-config.xml:

```
<factory>
<!--custom device factory-->
<device-data-factory>
com.ericsson.sn.mobilefaces.demo.device.WURFLDeviceDataFactory
</device-factory>
</factory>
```

MobileRenderKitFactory class checks the markup language attribute from the Device Manager and then decides to use HTML, WML or XHTML-MP renderkits. So, the standard JSF tags are used in mob.jspx and these tags will be rendered by the XHTML-MP and WML renderkits in MobileFaces, to XHTML-MP tags or WML tags.

As mentioned early, MobileFaces allows to create one JSF page for different end devices including normal PC. This means, by another words, that it is impossible to develop all pages in MCSCM by using MobileFaces and its library will generate an appropriate markup language based on the requested client. But I preferred to take advantage of ADF Faces' features that previously mentioned because MobileFaces working only with the standard JSF tags. It's good for developers to see in the future cooperation between Oracle and Ericsson enable them to combine the advantages of MobileFaces and ADF Faces.

5.8 Summary

MCSCM has been design and implemented based on the research findings and system requirements. The system has taken into account the needs of the users and the aspects of the construction projects in telecommunications network, such as multiple tasks with short duration for each task, multiple participants from different organizations and separated workers in divergent locations. MCSCM not only solve the construction management problem in NCD but also exceeded expectations of my client. Tests conducted on the system will now be discussed in the next chapter

Chapter 6

Testing and Evaluation

6.1 Introduction

This chapter describes the testing of the MCSCM and the evaluation of the project's overall objectives. The chapter provides a description of the three types of tests (system test, usability test and acceptance test) that were applied during the testing stage, including the techniques that were used to conduct the test and the results of these tests. An evaluation of the project is provided by an evaluation of each objective set out in the Terms of Reference detailed in Appendix.

MCSCM has been subjected to the experiment for three weeks with the aim of testing and taking observations and impressions of users and has been the formation of a team with one project manager, one contractor and two inspectors.

6.2 System Test

The purpose of system test is to test the system works as a whole to see if the system does what it is expected to do. Black box technique was used to compare actual against expected outputs for various sets of valid and invalid input data. The test inputs were sequences of user actions and the interactions between system's components. All test cases were derived from system requirements and use cases. The tables below shows the results of the test cases.

1. Viewing project information

Test case	Expected result	Result
Press on "Project Information" from the main menu	ProjectInformation.jsx shall appear represent the Project table from the database (see figure)	OK
Press on "Inspector Information" from the main menu	InspectorInformation.jsx shall appear represent the Inspector table from the database (see figure)	OK
Press on "Contractor Information" from the main menu	ContractorInformation.jsx shall appear represent the Contractor table from the database (see figure)	OK

2. Adding a new project

Test case	Expected result	Result
Press on "Add New Project" button from	Screen in figure shall appear represent	OK

ProjectInformation.jpsx		
Press on pop up list of “Contactor Name” field	All contractors’ names shall appear in the list	OK
Press on pop up list of “Inspector Id” field	All inspectors’ names shall appear in the list	OK
Press on “Save”	A new row shall be inserted in “Project” table in the database. “Save” button shall be inactive	OK
Press on “Add New”	A new empty table shall appear.	OK

3. Viewing the tasks of the project

Test case	Expected result	Result
Press on “View Tasks” button from ProjectInformation.jpsx	Screen in figure shall appear represent	OK
Enter a project number in “Project Number” text field and press “View Tasks” button	Tasks information of the project shall appear	OK

4. Sending task’s information

Test case	Expected result	Result
Enter web address in the browser of a mobile that supports XHTML MP mark up language	The mobile web page shall appear like figure	OK
Enter web address in the browser of a mobile that supports WML mark up language	The mobile web page shall appear like figure	OK
Enter project number “0623000000”, select task name, select “Permissions” task, select status and press “Send” button	Actual start field in ProjectInformation.jpsx page (figure) shall be filled with the date which was at the moment when pressing the button	OK
	Status field in ProjectInformation.jpsx page (figure) shall be change to “Open”	OK
	A SMS contains the following text “ A Permissions task has been started in project no. 0623000000 in , shall be sent to the mobile number of the inspector with Id “Zaydi A” who responsible for that project	OK
	The task information shall be inserted to the ‘Task’ table in the database	OK
Enter project number “0623000000”, select task	Actual finish field in ProjectInformation.jpsx page (figure) shall	OK

name, select “Ready for Service” task, select status and press “Send” button	be filled with the date which was at the moment when pressing the button	
	Status field in ProjectInformation.jsp page (figure) shall be change to “Close”	OK
	A SMS contains the following text “ A Permissions task has been started in project no. 0623000000 in , shall be sent to the mobile number of the inspector with Id “Zaydi A” who responsible for that project	OK
	The task information shall be inserted to the ‘Task’ table in the database	OK
Enter project number “0623000002”, select task name, select “Trench” task, select status and press “Send” button		OK
	The task information shall be inserted to the ‘Task’ table in the database	OK

6.3 Usability Test

There are many usability-related issues with mobile applications. The most usability issues that are unique to mobile applications, can be divided into two areas (Reza, 2005):

1. The capabilities of the mobile devices that provides GUI access to the web content such as scrolling, input mechanisms, power consuming and screen size.
2. the limitations of the wireless network such as connectivity problems, data speed rate and time for response.
3. The use of mobile applications under mobility conditions of the user such as movement, lighting and harsh climate.

The usability test considered the above areas through inclusion in the certain tables that were designed to record the feed back of the users during the test stage. The following are summarization of the results:

1. Network:

Test	Measurement Unit	Results			
		Excellent	Good	Medium	Poor
Connectivity success	Number of successes	More than 90 % √	from 70% - 90 %	from 50 % - 69%	less than 50%
Time for connection establish	Min	less than 0.5 min	from 0.5 - 1 min √	from 1-1.5 min	more than 1.5 min
Time for response	Min	less than 0.5 min	from 0.5 - 1 min √	from 1-1.5 min	more than 1.5 min

2. Mobile devices and conditions:

- Size of the mobile web page for the size of the screen:

■ Suitable □ Unsuitable

- Clarity and size of the components of the mobile web page

■ Suitable □ Unsuitable

- Impact of the application on the mobile device energy

□ Consumed ■ Unconsumed

Usage	Very easy ^s	Easy	Difficult	difficult Very
Entering the values	√			
Navigation between the components	√			
Sending information	√			
The use of the application during movement			√	
The use of the application in direct sunlight environment		√		
The use of the application in the harsh climatic		√		
The use of the application during the voices		√		

6.4 Acceptance Test

The purpose of this test is to check whether the customer is satisfied with the final product or not. The aim of this project is to improve the construction management in NCD. Therefore, attention has been given to my client to take his impression about the effectiveness of MCSCM in achieving this goal. The following table is a summary of the information taken from users around the contribution of MCSCM to improve the construction management

Result	Very useful	Useful	Unhelpful	Don't Know
Follow-up projects	√			
Reduce field visits	√			
Raising productivity	√			
Quality assurance	√			
Time management		√		
Decision-making	√			
Planning		√		
Project completion		√		
Billing			√	
Reporting		√		

6.5 Summary

This chapter covers the testing phase of the project. the results of different types of test has been outlined. The system test indicated that all the functions of the system has been successfully achieved. In usability test, the results showed that the system compatible with the limitations of the mobile devices and the wireless network, as well as the real conditions for the operation of MCSCM in the field. Finally, the acceptance test indicated that my client is satisfied entirely with the final product and its effectiveness in improving his work.

Chapter 7

Evaluation and Conclusion

7.1 Introduction

As presented in the previous chapters, research into the use of mobile computing in construction management and the results of the system requirements analysis led to the development of a Mobile Computing System for Construction Management (MCSCM) in the telecommunications network. It has been discussed also that the investigation of the current practice, tools, technologies in design and implementation of wireless applications led to choice an appropriate design and implementation in respect of the nature of the telecommunications network projects.

The aim of This chapter is to assess the project overall by providing an evaluation of each objective set out in the Terms of Reference detailed in Appendix 1. Finally, An summar are presented includes the lessons learned from the project experience and some suggestions for further work.

7.2 Success against the Initial Objectives

In order to assess the project, the initial objectives, as set out in the project Terms of Reference (Appendix 1), were used as the main determinant of success. Evaluating each objective to see whether it has been meet, provided a good way to measure the project's success. follows is An assessment of the project objectives.

1. To research the use of mobile computing in construction management.

Chapter 1 presented the findings from research into the use of mobile computing in construction management in general. The research touched on three main axes; (1) what is mobile computing (2) The nature of the construction industry (3) information and systems used in the construction industry. Of particular interest was the ability of mobile computing system for transferring and sharing projects' information in real-time from construction sites where the conventional IT doesn't help in this regard due to the nature of construction environment. The findings showed that the mobile computing systems have to be added to the existing IT applications in construction management, to allow the users to access, share and exchange information during mobility.

2. To analyse the system requirements.

Processes of construction projects in telecommunications Network Construction Department (NCD) were analysed in chapter 2. A critical discussion showed the problem in NCD lies in the current poor communication tools for sharing and transferring the information between contractors, inspectors and construction manager. Chapter 2 presented how this problem can be solved by using a mobile computing system.

3. To investigate the current practice, tools, technology in design and implementation of wireless applications.

Chapter 3 investigated and discussed the three components of mobile computing system- devices, wireless networks and platforms. Findings showed the most important Issues, elements and criteria that must be considered by mobile computing developers when design and implantation a mobile computing system. These findings were very useful in designing the high level architecture for MCSCM. Chapter 4 investigated the architectures, frameworks and tools that can be used for designing and implementing mobile computing applications. So it complemented chapter 3 to achieve this objective and its findings led to create the low level architecture for MCSCM.

4. To investigate and choose an appropriate database.

Chapter 1 and 3 discussed that mobile computing systems should be integrated with the existing database and IT infrastructure. Oracle DBMS was selected in order to allow MCSCM to integrate with the current systems in NCD. Also the database design in chapter 5 used the similar information and structure that currently used in NCD with some elimination for any unnecessary tables and fields that were irrelevant to the needs of MCSCM.

5. To design and implement a mobile client/server application.

This objective was the practical part of this project and it was achieved through development processes of MCSCM. It was developed based on the system requirements and findings from the research chapters. Java EE tool, which is based on Model-View-Controller frame work and that Client-Server architecture was selected for designing and implementing MCSCM.

6. To test the final system.

The system was tested by using three types of tests; system test, usability test and acceptance test. the results of test showed that all the functions of the system has been successfully achieved and the system compatible with the limitations of the mobile devices and the wireless network, as well as the real conditions in the field. Also the results showed that my client is extremely pleased with the with the final product.

7.3 Summary

This dissertation provided mobile computing system as a solution for the construction management in the telecommunications network projects. Providing this solution involved dealing with many issues related to mobile computing and its contributions in improving the construction management processes. The research in this dissertation and development processes of a mobile computing system for telecommunications network environment, presented a good example of how choosing the research and studying carefully the environment in which the mobile computing will be produced, will effect in choosing an appropriate technologies, design and implementation.

The solution provided by this project allow me to learn many invaluable skills and knowledge such as:

- Oracle database system
- Web application
- Mobile web application
- Mark up languages for mobile devices such as WML, XHTML for MP
- Mobile web services
- Server side technologies such as Java Server Page (JSP) and Java Server Faces (JSF)

The impression and the feed back of my client about the system was very encouraging and will be a great incentive for me to continue research and development in the field of mobile computing.

Although I tested the system by using three different types of tests, further long-term tests such as stress test, scalability test and performance test is required. Such tests can't be done during this project due to time and manpower constraints but they could be done in the future. Continuing on the research path would also involve applying more mobile web services such as Location Based Services (LBS) in construction management. Applying LBS will enhance the functionalities of MCSCM by determining the location of the mobile users and assigning the project's tasks based on their locations.

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