INTERACTIVE PERSONAL DIGITAL ASSISTANT BASED TELEMEDICINE SYSTEM USING WIRELESS LOCAL AREA NETWORK

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To my beloved parents, wife, brothers, sisters, friends…

ACKNOWLEDGEMENTS

There are far too many people that have helped in this endeavour in making this thesis possible. Nonetheless, I want to mention a few people in particular. First and foremost, I would like to take this opportunity to express my sincere gratitude and appreciation to my supervisor, Ir. Prof. Dr. Mohamed Amin bin Alias. His ideas, motivation and support in the past four years steer me onto the path to accomplish this project. His consistent encouragement is invaluable in helping me to complete the work.

In addition, I wish to thank Mr. Tristan Richardson, Chief Technology Officer from RealVNC Ltd for his guidance in RFB protocol and Mr Matthew Bevan, an IT consultant from UK for his details explanation in writing remote control program for palm handheld. In particular, I wish to acknowledge the Senior Engineer, Mr. Su Shaw Hing from Tranquil Plus Technology Malaysia Sdn Bhd for his support in software development tool. I would also like to thank Mr. Toh Leong Soon for his constructive suggestions and experience sharing in hardware implementation and also Mr. Mohd Helmy b. Dollah, the PCB lab technician, for his help in building the hardware. I also wish to express my sincere appreciation to Matt Graham and Gavin Maxwell from Palm OS Technical Support forum for their fast response towards technical issues of the Palm OS Network programming and all researchers who have provided assistance at various stages. I am also grateful to Mr. Chng Heng Sun, for his support in Smart Electronic Stethoscope application.

The encouragement from my family is an important ingredient too. Special thanks to my wife, See Siew Min who is also a fellow researcher for the fruitful discussions and sharing. I also pay my tribute to my father and my eldest brother Su Biing Yueh who constantly provide me the moral and financial support. During these difficult times, my family always gets behind me. Thanks to them.

ABSTRACT

This research work is inspired by the emergence of Personal Digital Assistant (PDA) and Wireless Local Area Network (WLAN) technology which have progressed drastically over the past few years. By integrating those technologies into conventional telemedicine system, a simpler method of Interactive Data Communication (IDC) between PDA and medical equipment for wireless and mobile telemedicine system is proposed. As compared to conventional designs which were using proprietary PDA application for only particular medical equipment, a common PDA based application which enables the interoperability for different medical equipments is designed in order to contribute toward a cost-effective telemedicine system. The proposed method is based on the client-server network architecture, which is a client application developed on PDA and a server application developed on desktop. Basically, the proposed method for wireless and mobile telemedicine system consists of two parts: 1) The Patient Unit, which is set up around the patient to acquire the patients' physiological signals and video signals by interfacing to desktop. 2) The Mobile Monitoring Unit, a PDA which enables user to monitor the patient's condition anytime and anywhere within the coverage range. The physiological data are acquired from an electronic stethoscope, patient simulator, oscilloscope and PC camera. A serial control application and a video capture application are developed for patient simulator and PC camera respectively while the smart electronic stethoscope application and the Free View application are being adopted for electronic stethoscope and oscilloscope respectively to interface the desktop. The PDA user is able to monitor the physiological data remotely within the coverage of WLAN or off-site area through internet by using the client application at PDA and server application at desktop. The result shows that the IDC method achieves average 105ms in latency test with electrocardiogram waveforms, zero transmission error in reliability test, average 150 minutes in power-sustainability for power-consumption test, 97% in accessibility within 110 meter range for mobility test, 100% in identifiability for signal-quality test, 66.5%, 88.5% and 84% in satisfactory for scalability test, simplicity test and interoperability test respectively. As the conclusion, an interactive PDA based telemedicine system using WLAN has been successfully implemented in this thesis.

ABSTRAK

Hasil Kerja ini adalah didorong oleh kemunculan Pembantu Digit Peribadi (PDA) dan Rangkaian Kawasan Setempat Wayarles (WLAN) yang berkembang secara mendadak pada akhir-akhir ini. Dengan mengintegrasikan kedua-dua teknologi itu dalam sistem tele-perubatan tradisional, satu kaedah Data Perhubungan secara Interaktif (IDC) antara PDA dan peralatan perubatan untuk sistem tele-perubatan wayarles dan mudah-alih yang lebih mudah dicadangkan. Dengan membandingkan rekaan aplikasi PDA tradisional yang hanya berfungsi dengan peralatan perubatan tertentu, satu aplikasi lazim yang berasaskan PDA direka supaya membenarkan saling-operasi antara peralatan perubatan yang berlainan dan dapat menyumbang kepada sistem tele-perubatan yang lebih kos-efektif. Kaedah yang dicadangkan adalah berasaskan binaan rangkaian pelanggan-pelayan, di mana satu aplikasi pelanggan dibangunkan di PDA dan satu aplikasi pelayan dibangunkan di komputer. Pada asasnya, sistem tele-perubatan yang dirancang mengandungi dua bahagian: 1) Unit Pesakit, yang dibangunkan di sekitar pesakit untuk memperoleh isyarat fisiologi dan isyarat video dari pesakit supaya diantara-muka kepada komputer. 2) Unit Pengawasan Mudah-alih, satu PDA yang membolehkan pengguna untuk mengawasi keadaan pesakit pada bila-bila masa dan di mana-mana tempat dalam lingkungan isyarat. Data fisiologi adalah diperoleh daripada stetoskop elektronik, penyelaku pesakit, osiloskop dan kamera komputer. Satu aplikasi kawalan bersiri dan satu aplikasi tangkapan video dibangunkan untuk penyelaku pesakit dan kamera komputer masing-masing manakala aplikasi stetoskop elektronik yang pintar dan aplikasi lihat bebas digunakan untuk stetoskop elektronik dan osiloskop masing-masing dalam mengantara-muka kepada komputer. Pengguna PDA boleh mengawasi data fisiologi secara jarak jauh dalam lingkungan WLAN atau kawasan luar tapak melalui Internet dengan menggunakan aplikasi pelanggan di PDA dan aplikasi pelayan di komputer. Keputusan menunjukkan kaedah IDC yang dicadangkan mencapai masa pendam 105ms dalam ujian dengan gelombang elektrokardiogram, ketiadaan kesilapan penghantaran dalam ujian keboleh-harapan, 150 minit purata ketahanan tenaga dalam ujian penggunaan tenaga, 97% kebolehcapaian dalam ujian mobiliti untuk lingkungan 110 meter, 100% kebolehbacaan dalam ujian kualiti isyarat, 66.5%, 88.5% dan 84% kepuasan dalam ujian keboleh-skalaan, ujian keringkasan dan ujian kesaling-operasian masing-masing. Sebagai kesimpulannya, satu sistem tele-perubatan secara interaktif yang berasaskan PDA dengan menggunakan WLAN telah berjaya dibangunkan dalam tesis ini.

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LIST OF ABBREVIATIONS

1G	-	First generation
3G	-	Third generation
A&E	-	Accident and Emergency
A/D	-	Analogue to Digital
AC	-	Alternate Current
AF1	-	Atrial Fibrillation
AH	-	Ad-Hoc
AMPS	-	Advanced Mobile Phone System
AP	-	Access Point
API	-	Application Programming Interface
ASCII	-	American Standard Code for Information Interchange
AT&T	-	American Telephone and Telegraph Corporation
ATM	-	Asynchronous Transfer Mode
BER	-	Bit Error Rates
BGR	-	Blue, Green, Red
BIG	-	Bigeminy
B-ISDN	-	Broadband ISDN
BP	-	Blood Pressure
BWA	-	Broadband Wireless Access
BWIF	-	Broadband Wireless Internet Forum
CAS	-	Clinical Alarm Station
CCTV	-	Closed Circuit Television
CD	-	Carrier Detect
CD	-	Compact Disk
CDMA	-	Code Division Multiple Access
CDPD	-	Cellular Digital Packet Data
CopyRect	-	Copy Rectangle Encoding

CoRRE	-	Compact RRE Encoding
CR	-	Carriage Return
CSD	-	Circuit Switched Data
CSM	-	Central Server Monitor
CT	-	Computed Tomography
CT	-	Cordless Telephone
CTS	-	Clear to Send
D-AMPS	-	Digital Advanced Mobile Phone System
DCB	-	Device Control Block
DCE	-	Data Circuit-terminating Equipment
DECT	-	Digital Enhanced cordless Telecommunications
DIN	-	Digital Imaging Network
DSP	-	Digital Signal Processing
DSR	-	Data Set Ready
DTE	-	Data terminal equipment
DTR	-	Data Terminal Ready
ECG	-	Electrocardiogram
EDGE	-	Enhanced Data rates for GSM Evolution
EMI	-	Electromagnetic Interference
EMR	-	Electronic Medical Record
EPR	-	Electronic Patient Record
FARMS	-	Facilitated Accurate Referral Management System
FDA	-	Food and Drug Association
FDMA	-	Frequency Division Multiple Access
FOMA	-	Freedom of Mobile Multimedia Access
FTP	-	File Transfer Protocol
GPRS	-	General Packet Radio Services
GPS	-	Global Positioning System
GSM	-	Global System for Mobile Communication
GUI	-	Graphic User Interface
Hextile	-	Hex Tile Encoding
HHD	-	Hand Held Device
HIS	-	Health Information System
HP	-	Hewlett Packard

HSCSD	-	High-Speed Circuit-Switched Data
HTTP	-	Hyper Text Transfer Protocol
I/O	-	Input/Output
IBM	-	International Business Machine
IC	-	Identity Card
ICU	-	Intensive Care Unit
IDC	-	Interactive Data Communication
IDE	-	Integrated Development Environment
IEEE	-	Institute of Electrical and Electronic Engineering
IP	-	Internet Protocol
IS-95	-	Interim Standard -95
ISDN	-	Integrated Services Digital Network
ISO	-	International Standards Organization
IT	-	Information Technology
ITU	-	International Telecommunication Union
Kbps	-	Kilo Bit Per Second
LAN	-	Local Area Network
LCD	-	Liquid Crystal Display
LF	-	Line Feed
LMDS	-	Local Multipoint Distribution Service
MAC	-	Media Access Control
Mbps	-	Mega Bit Per Second
MedSim	-	Medical Simulator
MMAC	-	Multimedia Mobile Access Communication Systems
MMDS	-	Multichannel Multipoint Distribution Services
MMU	-	Mobile Monitoring Unit
MRI	-	Medical Resonance Imaging
ms	-	Millisecond
MSC	-	Multimedia Super Corridor
MSCIS	-	Model Spinal Cord Injury Systems
MSG	-	Message
MUN	-	University of Newfoundland
NASA	-	National Aeronautics and Space Administration
N-ISDN	-	Narrowband ISDN

NRIC	-	National Resident Identification Card
NSB80	-	Normal Sinus Rhythm ECG
OS	-	Operating System
OSI	-	Open System Interconnect
PAC	-	Premature Atrial Contraction
PalmVNC	-	Palm Virtual Network Computing
PC	-	Personal Computer
PCB	-	Printed Circuit Board
PCI	-	Peripheral Component Interconnect
PCM	-	Pulse Code Modulation
PCMCIA	-	Personal Computer Memory Card International Association
PDA	-	Personal Digital Assistant
PDC	-	Personal Digital Cellular
PHIMS	-	Personal Health Information Management System
PHS	-	Public Health Service
PIM	-	Personal Information Manager
POGS	-	Palm OS Garnet Simulator
POSE	-	Palm OS Emulator
POTS	-	Plain Old Telephone Service
PPP	-	Point to Point Protocol
PSTN	-	Public Switched Telephone Network
PU	-	Patient Unit
PVC	-	Premature Ventricular Contraction
QoS	-	Quality of Service
RAM	-	Random Access Memory
RAS	-	Remote Access Service
RD	-	Receive Data
RDP	-	Remote Desktop Protocol
RFB	-	Remote Frame Buffer
RFID	-	Radio Frequency Identification
RI	-	Ring Indicator
RRE	-	Rise-and-Run-length Encoding
RTS	-	Request to Send

RUS	-	Rural Utilities Services
SDK	-	Software Development Kit
SES	-	Smart Electronic Stethoscope
SG	-	Signal Ground
SLIP	-	Serial Link Internet Protocol
SMTP	-	Simple Mail Transfer Protocol
SSID	-	Service Set Identifier
SVT	-	Supraventricular Tachycardia
TCP	-	Transmission Control Protocol
TCP/IP	-	Transmission Control Protocol/Internet Protocol
TD	-	Transmit Data
TELNET	-	Teletype Network
U.S.	-	United State of American
UDP	-	User Datagram Protocol
UltraVNC	-	Ultra Virtual Network Computing
UMTS	-	Universal Mobile Telecommunications system
USB	-	Universal Serial Bus
USDA	-	U.S. Department of Agriculture
VFB	-	Ventricular Fibrillation
VNC	-	Virtual Network Computing
VTC	-	Ventricular Tachycardia
WAN	-	Wide Area Network
WAP	-	Wireless Application Protocol
WEP	-	Wire Equivalent Privacy
Wi-Fi	-	Wireless Fidelity
WLAN	-	Wireless Local Area Network
WML	-	Wireless Markup Language
WPAN	-	Wireless Personal Area Network
WSA	-	Windows Sockets Application Programming Interface
WWW	-	World Wide Web
Zlib	-	Zip Library
ZRLE	-	Zlib Run-Length Encoding

LIST OF SYMBOLS

\$	-	United State of American dollar
%	-	Percentage
*	-	Legal entry symbol
?	-	Illegal entry symbol
A_a	-	Overall gain of amplification circuit
A_{amax}	-	Maximum gain of amplification circuit
A_{amin}	-	Minimum gain of amplification circuit
A_{CL}	-	Closed-loop voltage gain
A_{CL1}	-	First stage close-loop voltage gain
A_{CL2}	-	Second stage close-loop voltage gain
A_{CL3}	-	Third stage close-loop voltage gain
A_{max}	-	Maximum gain of conditioning circuit
A_{min}	-	Minimum gain of conditioning circuit
A_o	-	Overall gain of filtering circuit
A_{o1}	-	Gain of first stage second order low pass filter
A_{o2}	-	Gain of second stage second order low pass filter
A_{o3}	-	Gain of third stage second order low pass filter
C_1-C_8	-	Capacitive Filter
C_9-C_{14}	-	Capacitor of filtering circuit
D_1-D_4	-	Rectifier Diodes
dB	-	Decibel
f_c	-	Cut-off frequency
G_{-3dB}	-	Cut-off frequency in decibel
$G_{cut-off}$	-	Cut-off frequency
G_{dB}	-	Gain in decibel
R_5	-	Adjustable Resistor
R_7-R_{16}	-	Resistor of filtering circuit

R_f	-	Feedback resistor
R_i	-	Input resistor
uF	-	Micro Farad
V	-	Voltage
α	-	Damping ratio
α_1	-	Damping ratio of first stage second order low pass filter
α_2	-	Damping ratio of second stage second order low pass filter
α_3	-	Damping ratio of third stage second order low pass filter
π	-	Constant of 3.142
Ω	-	Resistance

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CHAPTER 1

INTRODUCTION

1.1 Introduction

A person's most precious and invaluable asset in life is his health. A healthy body promotes a healthy mind, so the saying goes [1]. Aware of the importance of healthcare, which is defined as the prevention, treatment and management of illness and the preservation of mental and physical well-being through the services offered by the medical and allied health professions [2], many countries in this world are putting much effort into healthcare to improve and enhance the healthcare services. Furthermore, people nowadays are becoming increasingly proactive about looking for health information and participating in decisions about their medical care [3].

The World Health Organization at its 1978 international conference held in the Soviet Union produced the Alma-Ata Health Declaration, which was designed to serve governments as a basis for planning health care that would reach people at all levels of society. The declaration reaffirmed that "health, which is a state of complete physical, mental and social well-being, and not merely the absence of disease or infirmity, is a fundamental human right and that the attainment of the highest possible level of health is a most important world-wide social goal whose realization requires the action of many other social and economic sectors in addition to the health sector. [4]"

To achieve this ideal healthcare, it is encouraged that everyone involved, including public, healthcare providers, government agencies, pharmaceutical industries and universities has access to and shares useful healthcare information [1].

Thus, the need to provide greater healthcare access and knowledge is essential to accomplish best healthcare service.

Over the past 40 years, the Information Technology (IT) has progressed at fantastic rates. It appears the smaller packages with greater power and more versatility at a lower cost [5]. The development of IT has prompted the healthcare providers to explore the opportunities of IT in improving the quality, while simultaneously reducing the cost of healthcare. As well, consumers of healthcare want to be better informed of their health options and easy access to relevant health information. In this context, the IT is playing a crucial role in bridging the gap between providers and consumers of healthcare [6]. .

As one of the spearhead in IT, United State (U.S.) has increased the role of IT in the U.S. healthcare industry. A survey by Sheldon I. Dorenfest&Associates of Chicago estimated IT spending on health care in 2002 would be $21.6 billion [7]. Further exponential growth is expected as the industry implements further large-scale electronic medical record keeping; provides remote diagnostics via telemedicine; upgrades Hospital Information Systems (HIS), sets up intranets and extranets for sharing information and uses public networks, including the Internet and community health information networks, to distribute health-related information. [8]

In light of the importance of IT, the Malaysian government has incorporated in its primary areas for IT applications under the Multimedia Super Corridor (MSC) project, the Telehealth Flagship (Formerly Telemedicine Project). Grouped under the Multimedia Development Flagship Applications, the Telehealth Flagship has long-term objectives to support Malaysia's Vision 2020 to transform core elements of Malaysia's technology infrastructure and social systems in areas such as education or public administration, using multimedia technologies as a critical enabler in the process [1]. In other words, MSC projects explore conceptual and implementation models as regards the multimedia application on a societal basis, spearheading the post-industrial transformation of Malaysia and serving as a global test bed for innovative solutions [9].

The telehealth project aims to go beyond the traditional delivery modes of healthcare delivery and instead, provide greater access to better and higher quality healthcare to the people of Malaysia [10]. It establishes a healthcare system leveraging advanced information and multimedia technologies so as to deliver hitherto unattainable healthcare services at the individual, family and community-level. For maximum utility, such services must be accessible from the home or at least from within the individual's immediate community; a feature made practical by the MSC high-bandwidth multimedia environment [9]. The above mentioned characteristics are in line with the national healthcare vision statement as below:

> "Malaysia is to be a nation of healthy individuals, families and communities; through a health system that is equitable, affordable, efficient, technologically appropriate, environmentally adaptable and consumer friendly; with the emphasis on quality, innovation, health promotion and respect for individual and community participation towards an enhanced quality of life" [9]

In line with the vision and the infrastructural support offered by MSC allows the telehealth project not only to reach out to a wider segment of the nation but it also seeds indigenous IT research and development endeavours by way of providing a test bed for the exploitation of leading IT technology in a variety of areas, including healthcare.

Encouraged by the global trends and local government initiatives, a research on using Personal Digital Assistant (PDA) in the telemedicine (a subset of telehealth) is carried out. The research proposes a simpler Interactive Data Communication (IDC) method for wireless and mobile telemedicine system, which utilizes palm-powered PDA as the leading role in wireless monitoring of patient's physiology information. The proposed method is based on client-server network architecture. A client software application is developed on PDA while a server software application is applied on PC desktop. Two of the multimedia communication links, wireless Local Area Network (WLAN) and Internet Technology are being adopted in modelling the wireless and mobile telemedicine system. Both multimedia communication links are making use of TCP/IP in the network communication and the role of desktop serves as middleware between medical equipments and palm-powered PDA.

The unconventional designed concept of this wireless and mobile telemedicine system is the adoption of common PDA-based application as an intermediate to interface with different medical equipments. Conventionally, in the development of PDA-based telecommunication system, many researchers tend to design their proprietary PDA application for particular medical equipments. It is not only tiresome to keep changing different type of PDA software for different equipments but it is also exhausting for the limited memory of PDA. Aware of the problem, a common PDA based application by adopting enhanced Remote Frame Buffer (RFB) protocol is developed to interface with different medical equipments. Besides, the research also focuses on improving different performance criteria of the PDA in wireless and mobile telemedicine system. The performance criteria include latency, power-consumption, mobility, signal-quality, scalability, simplicity, interoperability and security.

1.2 Motivation of Research

The motivation of research is discussed in two perspectives. The first part is elaborating the motivation from healthcare perspective which will include the need for deploying WLAN and PDA technologies in telemedicine field while the second part is on improving the technical issues of both technologies.

In healthcare perspective, the figures from the U.S. presents that 195000 of in-hospital deaths per year are caused by medical errors. Twenty percent of these are due to medical staff not having immediate access to patient healthcare information. Eighty percent of all medical errors are caused by miscommunication between physicians, misinterpretation of medical records, mishandling of patient messages, inaccessible records and so forth. Therefore, the research proposes an IDC method for wireless and mobile telemedicine system which will have the potential to considerably reduce medical error.

Due to the increasing awareness of healthcare, the healthcare professional as well as the computer professional have been concerning with the twin issues of how those challenges would affect them as facilitators of IT applications development and as consumers of healthcare. In the former case, issues of concern include the design and development of applications to capture, organize, store, rationalize, and present health information, the integration of existing and emerging technology, acceptance testing and others; while in the latter these include confidentiality, ethics, privacy, security, and user-friendly interfaces [11]. Those challenges encourage and motivate healthcare professionals to provide better healthcare solution.

Besides, the costs of deploying WLAN are becoming low and continue to drop are encouraging the adoption of WLAN in healthcare services. The role of wireless WLAN in our daily activities is rapidly expanding. In addition, computers, PDA, digital information, communications and software are not only being used in routine and mundane, but have also enhanced our capability to bring distant points closer to each other. This telecommunications marvel has made it possible to access distributed resources for collecting information, processing information and dissemination of information in an efficient and cost-effective manner [12]. The emergence of small, lightweight, lower-power and inexpensive wireless terminals such as PDA contribute widespread interest in the telemedicine. By supporting links to wireless networks, this versatile and affordable device eliminate unnecessary paperwork; optimize user productivity and bring products, services and transaction points directly to the user [13]. Therefore, the advances in WLAN and PDA are shaping the adoption of both technologies in medicine.

In the adoption of WLAN, the wireless hospital LAN extends the reach and capabilities of fixed wireline LAN by bringing computing services directly to a patient's bedside. It allows physicians use wireless communicators to access patient records, manage medication, obtain lab test results in real-time and confirm diagnoses while nurses can use WLAN to place medication orders directly with the hospital pharmacy, monitor drug interactions, and check vital signs [13].

The rapid development of PDA technology has made a very strong impact in the medical field, where more than 85 percent of physicians use PDA today in US [14]. In a recent study by AvantGo, it was determined that 92 percent of physicians with PDA are using their devices for multiple activities including calendars, access to drug reference guides and reference medical journals. The study also found that 48 percent of those surveyed would like to be able to access medical reference Web sites, while 33 percent would like to write and transmit prescriptions. Another 28 percent would like to access pharmaceutical Web sites. A smaller group (27 percent) would like to be able to keep records of clinical trials. Fully 93 percent of the physicians feel that this additional information would make them more productive and allow them to provide a better level of patient care. However, it can be noticed that there are still a great need for physicians or doctors have immediate access to information on patient vital signs through the use of the PDA [14]. One of the motivation in pursuing this research in telemedicine is due to the fact that there is a need for a compact, reliable and low cost system to be used for wireless monitoring purposes such as acquisition and transmission of video images, still images and vital signs in real-time.

The full implementation of PDA based telemedicine system is turning out to be difficult to achieve at hospital level with different medical equipment system, such as PC based vital sign monitoring system, PC based MRI system, PC based ultrasound system, PC based radiology system, PC based Electronic Medical Record and others. There were different medical equipment system were interfaced to PC desktop with their proprietary GUI software. It is costly and time-consuming to prepare new GUI application on PDA for every equipment system that has direct communication with the PDA. Furthermore, the memory usage of PDA devices will be exhausted and the speed performance will be decreased. Basically, the system integration for the PDA application at the hospital level will involve many different medical equipment system components working together across the hospital network. Because these myriad components must interoperate effectively with PDA application, interoperability is the first key to success.

In the technical perspective, there are still challenges in achieving high performance rates for data transfer and problems associated with high network congestion. In comparison to wired networks, wireless networks operate in a constrained communications environment and connectivity to a fixed wired network is not always reliable, stable and secures [13]. Therefore, the design of wireless and mobile telemedicine will have to optimize between data transfer rate and reliability in the medical application.

As the result of battery and memory limitations, wireless networking handhelds are less powerful than conventional desktop computers. Moreover, despite widespread advances in WLAN technology, wireless networks support slower transmission rates and are more susceptible to security intrusions than wired configurations. In addition, wireless devices generally have smaller displays, employ non-traditional input devices ranging from a stylus to an abbreviated keyboard and lack the functional flexibility and performance capabilities of their conventional wired counterparts. Typically, wireless handhelds are limited in supporting fast transmissions. Continuous changes in wireless devices that operate in mobile environments contribute to problems in network monitoring, administration, and management. Sources of interference such as environmental noise, thunderstorms, blizzards, and line-of-sight obstructions disrupt the integrity of wireless networking operations. Moreover, wireless transmissions are subject to fading, high-bit error rates, and sporadic connectivity [13]. To overwhelm with the challenging technical issues, the design of the wireless and mobile telemedicine system needs to compromise among battery power, memory limitation, faster frame updating algorithms, higher security mechanism, flexible viewing scale, simple input solution and more reliable communication protocol.

1.3 Objective of Research

The main objective of this research is to develop a simpler method of interactive data communication between PDA and medical equipment for wireless and mobile telemedicine system to monitor the patient's physiology signals and video signals through the use of PDA in the WLAN coverage area. The summary of the research objectives is listed as below:

1. Design a simpler method of interactive data communication between PDA and medical equipment for wireless and mobile telemedicine system with

acceptable latency, longer power sustainability, flexible viewing scale, user-friendly patient GUI and better protectiveness to patient record.

2. Integrate PDA and WLAN technologies in monitoring and controlling patient's physiology signals and video signals in hospital.

3. Design a common PDA based middleware to improve the interoperability of interfacing different medical equipments with their different GUI platform.

1.4 Methodology of Research

The methodology of research is as followed:

1. Study of various multimedia links for telemedicine system
Investigation on various multimedia communication technologies which are applied in telemedicine in terms of bandwidth, power, mobility and network management is evaluated. The technologies include POTS, ISDN, ATM, Internet, Cellular, WAP, 3G and WLAN.

2. Study of Various PDA applications for telemedicine system
The previous research works about the application of PDA in telemedicine are reviewed. The pros and cons of using PDA in different manners are also identified and the characteristics of PDA are studied. The challenges of the PDA application in telemedicine are analysed.

3. Selecting appropriate multimedia communication technologies and PDA devices
After the literature review on part 1 and 2, the most suitable multimedia communication technologies and PDA devices are selected in achieving the goal of designing simpler method of wireless and mobile telemedicine system.

4. Design the architecture of the proposed method of interactive data communication between PDA and medical equipment through WLAN
The architecture of the proposed method is drafted to integrate the application of PDA, WLAN and medical equipments.

5. Deploying Patient Simulator for acquiring ECG waveforms
MedSim 300B Patient Simulator is being used to output ECG waveforms for the performance test of the proposed IDC method. An IDC Serial Control application is developed to interface the Patient Simulator with desktop through RS 232 port. The RS 232 specification of the serial port in desktop and the 6 pin Din female on Patient Simulator are studied.

6. Conditioning circuit design and simulation
The development of conditioning circuit is to amplify and filter the raw ECG waveforms output from Patient Simulator to an observable level for displaying on the desktop screen. This part involves amplification and filtering circuit design, circuit simulation, PCB drawing and fabricating, components insert and functional test.

7. Deploying Oscilloscope for capturing ECG waveforms
The deployment of Oscilloscope is to capture the ECG waveforms from conditioning circuit in the performance testing. The scope of work is to develop the cabling and connector for conditioning circuit interface and desktop interface. The PC based GUI software – FreeView application is installed on desktop for real-time displaying the signals from Oscilloscope to desktop screen.

8. Deploying PC Camera for capturing still image and video data
The deployment of PC Camera application is to capture the video and still image data for displaying on desktop screen in the performance test. The scope of work is to develop an IDC Video Capture application which is able to achieve the goal of displaying image in different scale and resolution.

9. Deploying Stethoscope for acquiring body sound signals

   The deployment of Stethoscope is to capture the body sound signals from human body to desktop. The scope of work is to install the live-plot software – SES application on desktop and records numerous set of body sound signals for the use of performance test.

10. Development of IDC Client application on Palm-powered PDA

    The scope of research in this part is the development of new IDC Client application on Palm-powered PDA. The scope of work involves the study of OSI network model, Palm OS network architecture, the development tools for Palm OS platform and the devices of both wireless network modes. In the design of IDC Client, it involves the basic structure of Palm OS programming, GUI design, Patient Database design, Palm OS Net Library programming, RFB Protocol, the handling of Rectangles, Different Scales, Pen and Key Events.

11. Development of IDC server software on PC desktop

    The scope of research in this part is the development of new IDC Server application on desktop. The scope of work involves the exploration of various server applications which is adopting the RFB Protocol and it is able to be simplified for the customized application in this telemedicine system. In the redesign of the server application, the scope of work involves the study of Window socket network architecture, the development tools for Windows XP platform, GUI design, Windows socket network programming, the handling of Rectangles, Different Scales, Mouse Clicks and Keyboard.

12. System implementation and verification

    To validate the feasibility of the proposed PDA based telemedicine system, all of the components are constructed and integrated to form the system. The tasks include the execution of Patient Simulator, Oscilloscope, PC Camera and Stethoscope, IDC Serial Control application, IDC Video Capture application, FreeView application, SES application, IDC Client application and IDC Server application to establish the wireless and mobile telemedicine system.

13. Experimental test on the performance of IDC application

The IDC application is tested in various performance criteria and the results are recorded for the analysis of performance. The performance test criteria involve Latency test, Reliability test, Power-consumption test, mobility test, Signal-quality test, Scalability test, Simplicity test, Interoperability test and Security test.

1.5 Contribution of Research

The contribution of research can be viewed in two perspective, they are healthcare perspective and technical perspective.

1. Healthcare Perspective

The proposed method of interactive data communication between PDA and medical equipment for wireless and mobile telemedicine system has its contribution as a complement system to the Teleconsultation, one of four components under the Telehealth Flagship. It shares the same goal as the Teleconsultation in utilization of multimedia technologies to facilitate consultation on healthcare between healthcare providers who are physically apart, but it has broader application which extend to the interactive data communication between medical equipments and physician or user.

The proposed method is beneficial to both patient and physician, it provides them with “any time, any place” access to medical equipments for clinical data or health database for non-clinical data. In other words, it encourages better awareness of healthcare for public and the greater access to healthcare information provides better and higher quality healthcare to the people of Malaysia

The WLAN extends the reach and capabilities of wired LANs by bringing computing services directly to a patient’s bedside and the portability of PDA provides mobility for physician without sticking in a fix location. It allows physicians use PDA to wirelessly access patient records, remote diagnosis and obtain medical equipments test results in real-time and provide around-the-clock activity monitoring. It not only contributes a non-negligible reduction in the level of psychological stress to the patient or physician, but it can potentially and substantially reducing the demand for doctors visits.

The capability of the proposed method to allow multiple accesses simultaneously to patient vital signs improves communication among physicians. As the result, the efficient and effective communications enhance the productivity of the physician and reduce medical error in hospital.

2. Technical Perspective

The research proposes a new middleware between PC based medical equipments and PDA. It is able to interface to variety of PC based medical equipment while allow interoperability of medical equipments in a PDA. Besides, it is also compatible to various PC based medical equipments which are installed on different OS platform.

The research proposes a simpler system design which is mainly made up by a pair of software applications, they are IDC server software and IDC client software. The implementation is only involving two installations—the server software on PC desktop and client software at PDA. No extra cost to upgrade the existing hardware in hospital while the cost of installing WLAN decreases recently encouraging the wide spread use of WLAN in hospital. The research suggests a low cost design concept in telemedicine system.

The research on the development of PDA client software contributes four key ingredients in improving the performance of PDA based telemedicine system. The first ingredient is to decrease the latency of IDC application by using a simplified structure of design and small application package which de facto reduce battery power consumption and lower the memory usage. The second ingredient is empowering the security and reliability of the software. It introduces four fold of protection by using SSID, MAC address filtering, WEP and D3DES encryptions methods and they are integrated in the architecture of design. In addition, all the data are only saved on server database to confirm its data integrity and avoid burdening the limited memory on PDA database. The third ingredient is to contribute more flexible viewing scales and the fourth is simpler user-friendly GUI. It applied multi viewing scales on PDA to facilitate the healthcare monitoring in a different screen resolutions. The GUI design is straight-forward and only a few buttons pressed to set up the wireless connection.

1.6 Organization of Thesis

This thesis is organised into six chapters. The content of these chapters are outlined as follows:

- Chapter 2 will firstly provide overview of the definition, history and application of telemedicine. It is followed by the investigation on various multimedia communication technologies in telemedicine, the necessity of multimedia communication technologies in telemedicine and the challenges of telemedicine issues. Subsequently, the review on the brief history of PDA technology, PDA in telemedicine application and the challenges of PDA in telemedicine is being elaborated. The last part will be discussing the selection of technologies in this research design for wireless and mobile telemedicine system.

- Chapter 3 will begin the elaboration of the proposed system for wireless and mobile telemedicine system. The elaboration goes on with the first part of the design system which is Patient Unit. The Patient Unit will include the discussion of establishment of two medical equipments which are Patient Simulator and Stethoscope, and two emulating medical equipments which are PC Camera and Oscilloscope. In these four equipments, the solutions for hardware and software interface to desktop for those equipments are being detailed out.

- Chapter 4 presents the IDC Client application for Mobile Monitoring Unit and the IDC Server application for Patient Unit. Before detailing the design of IDC application, the overview of the OSI network model, Palm OS network architecture, Windows socket network architecture and development tools for

Palm OS and Windows XP platform are carried out. In the detailing of the IDC Client application, the application is explained in eight sections, which are basic structure of Palm OS application, GUI, Patient Database, Net Library Operation, RFB Protocol, Handling of Rectangles, Scale, Pen and Key Event. Subsequently, the briefly discussion on the simplified IDC Server application which involves six sections are carried out. These sections are GUI, Windows Socket Network Operation, Handling of Rectangles, Scale, Mouse Clicks and Keyboard.

- Chapter 5 presents the results and evaluates the performance of the proposed IDC application. It begins with the test which will be carried for each performance criteria. It is followed by the results from the designed conditioning circuit. Subsequently, the hardware layouts for the performance test on medical equipment are elaborated. The last section will be discussing the results and analysis of the performance test.

- Chapter 6 concludes the works undertaken and highlights the contributions of this research. Several suggestions are provided as possible directions for future work.