

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

SU SHAW BANK

UNIVERSITI TEKNOLOGI MALAYSIA

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 diperolehi 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.

TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	DECLARATION	ii
	DEDICATION	iii
	ACKNOWLEDGEMENTS	iv
	ABSTRACT	v
	ABSTRAK	vi
	TABLE OF CONTENTS	vii
	LIST OF TABLES	xii
	LIST OF FIGURES	xiii
	LIST OF ABBREVIATIONS	xix
	LIST OF SYMBOLS	xxiv
	LIST OF APPENDICES	xxvi
1	INTRODUCTION	1
	1.1 Introduction	1
	1.2 Motivation of Research	4
	1.3 Objective of Research	7
	1.4 Methodology of Research	8
	1.5 Contribution of Research	11
	1.6 Organization of Thesis	13
2	LITERATURE REVIEW	15
	2.1 Introduction	15
	2.2 Telemedicine System	15
	2.2.1 The Definition of Telemedicine	16
	2.2.2 The Brief History of Telemedicine	16

2.2.3 The Application of Telemedicine	18
2.2.4 The Need for Multimedia Communication Technologies in Telemedicine	19
2.2.5 Telemedicine over Various Multimedia Communication Technologies	20
2.2.5.1 Telemedicine via POTS	20
2.2.5.2 Telemedicine via ISDN	20
2.2.5.3 Telemedicine via ATM	21
2.2.5.4 Telemedicine via Internet	22
2.2.5.5 Telemedicine via Mobile and Wireless Communication Technologies	23
A. Telemedicine via Cellular Technology	25
B. Telemedicine via WAP	27
C. Telemedicine via 3G	28
D. Telemedicine via WLAN	30
2.2.6 The Challenges of Telemedicine Issues	31
2.2.6.1 Safety and Standard	31
2.2.6.2 Confidentiality and Privacy	32
2.2.6.3 Latency	32
2.2.6.4 Reliability	33
2.2.6.5 Cost of the Telemedicine System	33
2.3 PDA in Telemedicine System	33
2.3.1 The Brief History of PDA Technology	34
2.3.2 PDA in Telemedicine Application	34
2.3.3 The Challenges of PDA in Telemedicine Application	44
2.3.3.1 Expectation of Performance	44
2.3.3.2 Limited Input Method	45
2.3.3.3 Small Screen Size	45
2.3.3.4 Battery and Processor Power	45
2.4 The Selection of Technologies in Telemedicine Design	46
2.4.1 Comparison of WLAN and Bluetooth	46
2.4.2 Comparison of Palm Handheld and Pocket PC	47

2.4.2.1	Cost of the PDA	48
2.4.2.2	Corporate Standard	48
2.4.2.3	PDA Trend in Market Share	49
2.4.2.4	The Openness of the Developer Tool and SDK	49
3	THE DESIGN AND MODELLING OF MOBILE TELEMEDICINE SYSTEM	51
3.1	Introduction	51
3.2	The Overview of the Designed Architecture	52
3.3	Patient Unit	55
3.3.1	MedSim 300B Patient Simulator	56
3.3.1.1	Hardware Layout of Patient Simulator	56
3.3.1.2	RS 232 Connection	58
3.3.1.3	IDC Serial Control Program	60
	A. Configuration Panel	61
	B. Command Select Panel	62
	C. User Interface Control Buttons	63
3.3.1.4	Conditioning Circuit Design	69
	A. DC Power Supply Design	69
	B. The Design of Amplification Circuit	70
	C. The Design of Filtering Circuit	71
3.3.2	GDS-820C Digital Storage Oscilloscope	75
3.3.2.1	Hardware Layout of Oscilloscope in Emulating Medical Equipment	75
3.3.2.2	Software Implementation of Oscilloscope	76
3.3.3	Intel CS 330 PC Camera	76
3.3.3.1	Hardware Layout of the PC Camera in Emulating Medical Equipment	76
3.3.3.2	Software Architecture of the Camera	77
3.3.4	Smart Electronic Stethoscope	81
3.3.4.1	Hardware Layout of the SES Application	81
3.3.4.2	Software Architecture of the SES Application	82

4	THE DEVELOPMENT OF INTERACTIVE DATA COMMUNICATION APPLICATION	84
	4.1 Introduction	84
	4.2 OSI Network Model	85
	4.2.1 Palm OS Network Architecture	87
	4.2.2 Window Socket Network Architecture	89
	4.2.3 Development Tools	90
	4.2.3.1 Development Tools of Palm OS Platform	90
	4.2.3.2 Development Tools of Microsoft Windows XP Platform	93
	4.2.3.3 Development Tools of Wireless Networking Devices	94
	4.3 IDC Client Software Design and Development	96
	4.3.1 The Basic Structure of Palm OS Application	96
	4.3.2 The IDC Client GUI	101
	4.3.2.1 The GUI of Main Form	101
	4.3.2.2 The GUI of Status Form	104
	4.3.2.3 The GUI of Patient Select Form	105
	4.3.2.4 The GUI of Patient Edit Form	107
	4.3.2.5 The GUI of Patient Details Form	108
	4.3.2.6 The GUI of Password Form	110
	4.3.3 Patient Database	111
	4.3.4 Net Library Operation	115
	4.3.5 RFB Protocol	119
	4.3.6 The Handling of Rectangles	122
	4.3.7 The Handling of Different Scales	129
	4.3.8 The Handling of Pen Events	131
	4.3.9 The Handling of Key Events	134
	4.4 IDC Server Software Simplification and Development	135
	4.4.1 The IDC Server GUI	135
	4.4.2 The Windows Socket Network Operation	136
	4.4.3 The Handling of Rectangles	138
	4.4.4 The Handling of Different Scales	139

4.4.5	The Handling of Mouse Clicks	140
4.4.6	The Handling of Keyboard	140
5	RESULTS AND ANALYSIS	142
5.1	Introduction	142
5.2	The Result of Signal Conditioning Circuit	144
5.3	The Hardware Layout of Performance Test	146
5.3.1	The Hardware Layout with Patient Simulator	146
5.3.2	The Hardware Layout with Oscilloscope	147
5.3.3	The Hardware Layout with PC Camera	148
5.3.4	The Hardware Layout with Stethoscope	148
5.4	The Result and Analysis of the Performance Test	149
5.4.1	The Result and Analysis of Latency Test	149
5.4.2	The Result and Analysis of Reliability Test	151
5.4.3	The Result and Analysis of Power-consumption Test	152
5.4.4	The Result and Analysis of Mobility Test	153
5.4.5	The Result and Analysis of Signal-quality Test	153
5.4.6	The Result and Analysis of Scalability Test	154
5.4.7	The Result and Analysis of Simplicity Test	154
5.4.8	The Result and Analysis of Interoperability Test	155
5.4.9	The Result and Analysis of Security Test	156
6	CONCLUSION AND FUTURE WORK	157
6.1	Conclusion	157
6.2	Suggestions for Future Work	159
	REFERENCES	160
	Appendices A-G	178

LIST OF TABLES

TABLE NO	TITLE	PAGE
2.1	Mode of Operating of Telemedicine Applications	18
2.2	Wireless Technologies in Telemedicine Applications	24
2.3	Comparison between IEEE 802.11b and Bluetooth	46
2.4	Differences in Philosophy	47
2.5	A Sampling of PDA Prices of December 2002	48
3.1	The Description and Functions of RS 232 Pin Out on DB-9 Connector	58
3.2	The Configuration Options of IDC Serial Control Program	62
3.3	The Selected ECG Waveform in Serial Control Program	63
3.4	The Description of Functions in OpenPort Function	65
4.1	OSI Network Layers and Description of Layer Service	86
4.2	The Sequences of the Mouse State for the Three Mouse Actions	131
5.1	The Methods of Performance Test in Various Criteria	142

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE
2.1	The relation among E-health, Telehealth and Telemedicine	16
2.2	Comparison of Wireless Technologies in Data Rate and Mobility	24
2.3	Multiple Base Stations Positioned in a Hexagon Cellular Network.	25
2.4	Structure of the WAP-Based Telemedicine System	28
2.5	System Flow of the 3G Mobile Teleconsultation System	29
2.6	Poket Doktor System Architecture	35
2.7	Intensive Care Unit Ubiquitous Monitoring Overall Architecture	36
2.8	Architecture of the Wireless Telemedicine System	37
2.9	Block Diagram for the PDA-based ECG and BP Telemonitor	38
2.10	Principal Components of the Continuous Event Recording System	38
2.11	Block Diagram for Telemedicine Instrumentation Package in Mobile Station	39
2.12	Block Diagram for Telemedicine Instrumentation Package in Fix Station	39
2.13	Architecture of the Ubiquitous Mobility in Clinical Healthcare	40
2.14	System Architecture for Cardiac Monitoring using PHIMS	41

2.15	The Overview of System Architecture for Indoor Telemedicine	42
2.16	Architecture of the proposed system	43
2.17	Design architecture of Transmission System	43
2.18	The Feature List versus User Experience	44
2.19	Changes in PDA Market Share	49
3.1	An Overview of the System in Interactive Data Communication between PDA and Medical Equipments	53
3.2	The Integration of the Proposed Method in Common Hospital Network Architecture (Refer to Figure 2.7).	55
3.3	The Samples of Medical Equipments in PDA Performance Evaluation	55
3.4	The Illustration of MedSim 300B Patient Simulator	56
3.5	The Hardware Layout with Patient Simulator	57
3.6	The RS232 Pin Out on DB-9 Connector for DTE	58
3.7	The RS232 Pin Out on 6 Pin Din Female for DCE	59
3.8	Part of the Circuit Diagram Connected to DCE RS-232 Connector	59
3.9	The Proposed Connection between DTE and DCE	60
3.10	The GUI of the IDC Serial Control Program	61
3.11	Data Packet Corresponding to the ASCII Character A	61
3.12	The Program Flow of the OpenPort Function	64
3.13	The Program Flow of the Worker Thread	66
3.14	The Program Flow of the WriteData and ReadData Functions	68
3.15	The Schematic of the Typical DC Power Supply	70
3.16	Three Stages of Non-inverting Amplifier Circuit	70
3.17	The Schematic of Six Order Butterworth Low Pass Filtering Circuit	72
3.18	The Hardware Layout of Oscilloscope in Emulating Medical Equipment	75
3.19	The GUI of FreeView Software	76

3.20	The Hardware Layout of PC Camera in Emulating Medical Equipment	76
3.21	The WinMain Function in IDC Video Capture Program	77
3.22	The Main Window Procedure in IDC Video Capture Program	78
3.23	The Window Message of Create in Initialize Video Window	78
3.24	The GUI of IDC Video Capture Program	79
3.25	The Video Resolution, Start Capture and Stop Capture Menu Actions	80
3.26	The Hardware Architecture of SES Application	81
3.27	The Software Design of SES Application	82
4.1	OSI Network Reference Model	86
4.2	The Palm OS Network Model Compared to the OSI Network Model	88
4.3	The WinSock Model Compared to the OSI Network Model	90
4.4	The PDA of Palm Tungsten C	91
4.5	The IDE of CodeWarrior Development Studio for Palm OS 9.3	91
4.6	Debugging Tools - Palm OS Garnet Simulator and Palm Reporter	92
4.7	The IDE of Microsoft Visual C++ 6.0	93
4.8	Wireless-G Broadband Router and Wireless-G USB Network Adapter	94
4.9	Infrastructure Mode of Wireless Network	95
4.10	Ad-Hoc Mode of Wireless Network	95
4.11	The Flow Chart of PilotMain Function	97
4.12	The Flow Chart of AppStart and AppStop Functions	98
4.13	The Flow Chart of AppEventLoop Function	99
4.14	The Flow Chart of AppHandleEvent Function	101
4.15	The GUI of Main Form	102
4.16	The Flow Chart of MainFormHandleEvent Function	103

4.17	The GUI of Status Form	104
4.18	The Flow Chart of StatusFormHandleEvent Function	105
4.19	The GUI of Patient Select Form	106
4.20	The Flow Chart of PatientSelectFormHandleEvent Function	106
4.21	The GUI of Patient Edit Form	107
4.22	The Flow Chart of PatientEditFormHandleEvent Function	108
4.23	The GUI of Patient Details Form	109
4.24	The Flow Chart of PatientDetailsFormHandleEvent Function	109
4.25	The GUI of Password Form	110
4.26	The Three Regions in Palm OS RAM	111
4.27	The Flow Chart of OpenPatientDB Function	112
4.28	The Flow Chart of ArrangePatientList Function	113
4.29	The Flow Chart of LoadPatientRecord Function	113
4.30	The Flow Chart of SavePatientRecord Function	114
4.31	The Flow Chart of ClosePatientDB Function	114
4.32	The Net Library Architecture	115
4.33	The Procedures of Using NetLib in IDC Client Application	115
4.34	The Flow Chart of Open Network Function	116
4.35	The Flow Chart of Send and Receive Function	118
4.36	The Enhanced RFB Protocol Diagram	120
4.37	The Drawing Style of Hextile Encoding on PDA Rectangle	122
4.38	The Drawing Style of Hextile Encoding on a Rectangle of PDA Screen	123
4.39	The Drawing Style of Sub-Encoding (0) on a Tile inside PDA Screen	124
4.40	The Drawing Style of Sub-Encoding (1) on a Tile inside PDA Screen	124

4.41	The Drawing Style of Sub-Encoding (2) on a Tile inside PDA Screen	124
4.42	The Drawing Style of Sub-Encoding (8) on a Tile inside PDA Screen	125
4.43	The Drawing Style of Sub-Encoding (12) on a Tile inside PDA Screen	125
4.44	The Drawing Style of Sub-Encoding (14) on a Tile inside PDA Screen	126
4.45	The Drawing Style of Sub-Encoding (24) on a Tile inside PDA Screen	126
4.46	The Drawing Style of Sub-Encoding (26) on a Tile inside PDA Screen	127
4.47	The Flow Chart of HandleRFBServerMessage Subroutine	127
4.48	The Flow Chart of HandleHextileEncode Subroutine	128
4.49	The SendScaleFactor and UpdateViewablePortionSize Subroutines	130
4.50	The ProcessPenUpDownEvent and ProcessPenMoveEvent Subroutines	132
4.51	The Flow Chart of SendKeySequence Subroutines	134
4.52	The GUI of IDC Server Property	136
4.53	The Procedure of Configuring Windows Socket Network	136
4.54	The Series of Processes after the Frame Buffer Update Request	138
4.55	The Series of Processes after the New Scale Factor Request	139
4.56	The Series of Processes after the Pen Event Request	140
4.57	The Series of Processes after the Key Event Request	141
5.1	The Graph of Gain versus Frequency in Conditioning Circuit	144
5.2	The Eight Selected ECG Waveform Generated by Patient Simulator	145

5.3	The Hardware Layout of Patient Simulator in Emulating Medical Equipment with PDA	146
5.4	The Hardware Layout of Oscilloscope in Emulating Medical Equipment with PDA	147
5.5	The Hardware Layout of Web-Camera in Emulating Medical Equipment with PDA	148
5.6	The Hardware Layout of Electronic Stethoscope with PDA	149
5.7	The Frame Speed versus Distance when Testing on Four Emulating Equipments in both Infrastructure (AP) and Ad-Hoc (AH) Mode	150
5.8	The Frame Speed versus Distance in Four Equipments for Infrastructure Mode	151
5.9	The Frame Speed versus Distance in Four Equipments for Ad-Hoc Mode	151
5.10	The Idle-frequency versus Distance in Four Equipments for Infrastructure and Ad-Hoc Mode	152
5.11	The Battery Level versus Time in the Four Equipments	152
5.12	The Accessibility versus Distance in the Four Equipments	153
5.13	The Identifiability in Eight Selected ECG Waveforms	153
5.14	The Satisfactory Level in Viewing Quality for Four Viewing Scales	154
5.15	The Satisfactory Level in User-friendliness for Four Designed Forms	155
5.16	The Satisfactory Level in Switching Conveniency for Four Equipments GUI	155
5.17	The Protectiveness of IDC Application in Different Security Mechanism	156

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
μF	-	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

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
A	Equation Derivation of Conditioning Circuit	178
B	Photograph of Conditioning Circuit	184
C	MedSim 300B Patient Simulator Remote Commands	185
D	The GUI Layout of Medical Equipments	188
E	Questionnaire Form	189
F	Results of Performance Test	192
G	Published Paper	197

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.