



Faculty of Engineering

**UNDERWATER SENSOR NETWORK FOR MONITORING
APPLICATIONS**

Kuan Yee Chiang

**Bachelor of Engineering with Honours
(Electronics and Telecommunications Engineering)
2009**

UNIVERSITI MALAYSIA SARAWAK

R13a

BORANG PENGESAHAN STATUS TESIS

Judul: UNDERWATER SENSOR NETWORK FOR MONITORING APPLICATIONS

SESI PENGAJIAN: 2008/2009

Saya KUAN YEE CHIANG
(HURUF BESAR)

mengaku membenarkan tesis * ini disimpan di Pusat Khidmat Maklumat Akademik, Universiti Malaysia Sarawak dengan syarat-syarat kegunaan seperti berikut:

1. Tesis adalah hakmilik Universiti Malaysia Sarawak.
2. Pusat Khidmat Maklumat Akademik, Universiti Malaysia Sarawak dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Membuat pendigitan untuk membangunkan Pangkalan Data Kandungan Tempatan.
4. Pusat Khidmat Maklumat Akademik, Universiti Malaysia Sarawak dibenarkan membuat salinan tesis ini sebagai bahan pertukaran antara institusi pengajian tinggi.
5. ** Sila tandakan (✓) di kotak yang berkenaan

SULIT (Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di dalam AKTA RAHSIA RASMI 1972).

TERHAD (Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan).

TIDAK TERHAD

Disahkan oleh

(TANDATANGAN PENULIS)

(TANDATANGAN PENYELIA)

Alamat tetap: NO. 13, SIN THAI CHONG,

JALAN DATUK SALAU,

94000 BAU, KUCHING, SARAWAK

DR. AL-KHALID HAJI OTHMAN

Nama Penyelia

Tarikh: 6 April 2009

Tarikh: 6 April 2009

CATATAN

- * Tesis dimaksudkan sebagai tesis bagi Ijazah Doktor Falsafah, Sarjana dan Sarjana Muda.
** Jika tesis ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh tesis ini perlu dikelaskan sebagai SULIT dan TERHAD.

This Final Year Project attached here:

Title : UNDERWATER SENSOR NETWORK FOR MONITORING
APPLICATIONS

Student Name : Kuan Yee Chiang

Matric No : 14309

has been read and approved by:

Dr. Al-Khalid Haji Othman

(Supervisor)

Date

**UNDERWATER SENSOR NETWORK FOR MONITORING
APPLICATIONS**

KUAN YEE CHIANG

Thesis is submitted to
Faculty of Engineering, Universiti Malaysia Sarawak
in partial fulfilment of the requirements
for the degree of Bachelor of Engineering
with Honours (Electronics and Telecommunications Engineering) 2009

Dedicated to My Beloved Family

ACKNOWLEDGEMENT

During the course of this project, I have received the assistance of many people to whom I am very grateful.

First and foremost, I want thank to my supervisor, Dr. Al-Khalid Haji Othman, for giving me his support and advice throughout this project. His patience and guidance throughout my thesis is greatly appreciated. I am greatly indebted with his and this thesis is an acknowledgement of his tenacity and confidence in me. Thank you.

A word of thanks my beloved family for their love, care and supports during my four years study in UNIMAS.

I would also like to thank to lecturers in Electronic Department who have offered their advice during the course of my project and also helped me directly or indirectly in my thesis project. Their advice and help was especially helpful in improving my thesis.

Last but not least, I would like to thanks all technicians and all engineering faculty's staff who give me technical advice and support. I grateful gratitude also dedicated to anyone who directly or indirectly helps in making this project success.

ABSTRACT

The oceans alone cover almost three quarters (71%) of our planet and along with rivers and lakes are critical to our well-being. They must be continuously observed to detect climate changes or pollution of the environment which effects human and animal habitat, especially in this 21st century which global warming is the main issue. Recently, sensor networks have appeared as an important technique for many applications, including monitoring, measurement, surveillance and control. The idea of applying sensor networks for underwater monitoring has become more interests. In this thesis, the development of an underwater sensor that able to perform monitoring applications is described. The systems and technologies of underwater sensor network has been carried out and investigated for a better understanding. Few possible solutions of designing the system are discussed and a more suitable solution for real time monitoring is proposed. By the development of the proposed underwater sensor network monitoring system, any changing on the water quality should be able to monitor instantly by the end user, which consists of related research group or organization and society.

ABSTRAK

Lautan meliputi hampir tiga suku (71%) di planet kita, dengan sungai dan tasik adalah kritikal kepada kesejahteraan kita. Permerhatian berterusan hendaklah dijalankan untuk mengesan perubahan iklim dan pencemaran alam sekitar yang boleh mempengaruhi manusia dan habitat haiwan, terutamanya kepanasan global adalah isu utama pada kurun ke-21 ini. Kebelakangan ini, rangkaian penderia telah menjadi satu teknik yang penting dalam kebanyakan aplikasi, termasuk pemantauan, ukuran, pengawasn dan kawalan. Idea mengaplikasikan rangkaian penderia untuk pemantauan di bawah permukaan air telah menjadi semakin hangat. Dalam tesis ini, pembinaan penderia di bawah permukaan air yang boleh melakukan aplikasi pemantauan akan dibentangkan. Sistem dan teknologi untuk penderia di bawah permukaan air telah disiasat dan dikaji untuk pemahaman yang lebih mendalam. Beberapa penyelesaian yang mungkin untuk rekabentuk sistem tersebut telah dibincangkan dan sistem yang lebih sesuai untuk pemantauan berterusan akan dicadangkan. Melalui pembinaan sistem pemantauan penderia di bawah permukaan air ini, sebarang perubahan terhadap kualiti diharap dapat dipantau segera oleh pengguna, di mana terdiri daripada kumpulan atau organisasi penyelidikan yang berkenaan dan masyarakat.

TABLE OF CONTENT

Content	Page Number
Acknowledgement	iii
Abstract	iv
Abstrak	v
Table of content	vi
List of Table	xii
List of Figure	xiii
Abbreviation	xviii

CHAPTER 1: INTRODUCTION

1.1	Introduction	1
1.2	Statement of Problems	2
1.3	A Solution for Underwater Monitoring Sensor Network in Real Time	3
1.4	Project Objectives	4
1.5	Benefits on Project Application	5
1.6	Thesis Overview	6

CHAPTER 2: LITERATURE REVIEW

2.1	Introduction	8
2.2	Previous Work on Monitoring Technology	8
	2.2.1 Communication Architecture Design	9

2.2.2	Communication Protocol	16
2.2.3	Underwater Sensor Network Monitoring Applications	22
2.3	Underwater Sensor Architecture	24
2.4	Underwater Transmission Medium	26
2.5	Basic of Underwater Propagation	27
2.5.1	Path Loss	28
2.5.2	Noise	29
2.5.3	Multi-path	29
2.5.4	High Delay and High Variance	30
2.5.5	Doppler Spread	30
2.6	Challenges in Designing Underwater Wireless Sensor Network (UWSN)	31
2.7	Wireless Sensor Network (WSN) and Underwater Wireless Sensor Network (UWSN) Comparison	32
2.8	Underwater Network Topology	35
2.9	Protocols	36
2.9.1	Underwater Data Transmission Protocol	36
2.9.1.1	Frequency Division Multiple Access (FDMA) Protocol	37
2.9.1.2	Time Division Multiple Access (TDMA) Protocol	37
2.9.1.3	Carrier Sense Multiple Access (CSMA) Protocol	38
2.9.1.4	Contention-based Techniques	38

	Protocol	
	2.9.1.5 Code Division Multiple Access	39
	(CDMA) Protocol	
2.9.2	Water Surface Data Transmission Protocol	40
	2.9.2.1 Serial Line Internet Protocol (SLIP)	40
	2.9.2.2 Point-to-Point Protocol (PPP)	41
	2.9.2.3 Medium Access Control (MAC)	42
	Protocol	
	2.9.2.4 File Transfer Protocol (FTP)	43
2.10	IEEE Standard 802.11 Protocols	44
2.11	IEEE Standard 802.15 Protocols	46
2.12	Client-Server Model	48
2.13	Summary	49

CHAPTER 3: METHODOLOGY

3.1	Introduction	51
3.2	Implementation Strategy	51
3.3	Hardware Design	53
	3.3.1 Temperature Sensor	53
	3.3.2 pH Sensor	55
	3.3.3 Web Camera	56
	3.3.4 Network USB Hub	57
	3.3.5 PC / Server	58
	3.3.6 Cabling Medium	58
	3.3.7 Wire / Wireless Router	59

3.4	Design Architecture	60
	3.4.1 Using the Network USB Hub	60
	3.4.2 Using PC Act as Central Server	61
3.5	Software Development	62
	3.5.1 Visual Basic 6.0	63
	3.5.2 LabVIEW 8.5	67
	3.5.3 Database	69
	3.5.4 TightVNC	69
3.6	Interfacing Data Terminal Equipment (DTE) and Data Communication Equipment (DCE)	71
3.7	Analog-Digital Conversion (ADC) and Digital- Analog Conversion (DAC)	72
3.8	Communication between the Hardware and Software	73
3.9	Summary	75

CHAPTER 4: UNDERWATER MONITORING SYSTEM

DESIGN

4.1	Introduction	76
4.2	System Architecture	76
4.3	Hardware Architecture	78
	4.3.1 I/O Devices	78
	4.3.2 Hardware Control	79
4.4	Sensor Node Design	79

4.5	Software Architecture	83
4.5.1	I/O Module	83
4.5.2	GUI Module	84
4.5.3	Countdown Timer Module	84
4.5.4	Database Module	84
4.5.5	Software Control Module	85
4.6	Summary	85

CHAPTER 5: RESULTS AND DISCUSSIONS

5.1	Introduction	86
5.2	Underwater Sensor Network Software	86
5.2.1	Main Menu's GUI	87
5.2.2	pH Sensor's Sub GUI	89
5.2.3	Underwater Camera's Sub GUI	94
5.2.4	Temperature Sensor's Sub GUI	103
5.3	Remote Access Control Software Setup	108
5.3.1	Firewall Setting for VNC Service	109
5.3.2	Setup of TightVNC	111
5.3.3	Testing on Portal Service and Configuration	114
5.3.4	Port Forwarding of TightVNC	115
5.4	Full System Design and Operation	118
5.5	Summary	119

CHAPTER 6: CONCLUSIONS AND	
RECOMMENDATIONS	121
6.1 Conclusions	123
6.2 Recommendations for Further Works	123
6.2.1 Hardware Improvements	124
6.2.2 Software Improvements	
	126
REFERENCES	130
APPENDIX A: SOURCE CODE	155
APPENDIX B: TEMPERATURE SENSOR BLOCK DIAGRAM	156
APPENDIX C: SOME PROJECT PICTURE	159
APPENDIX D: PROJECT'S POSTER	160
APPENDIX E: NEWS ON SIN CHEW DAILY REGARDING	
ENGINEERING EXPO 2009	

LIST OF TABLES

Table		Page
2.2.2	Institutes and Researcher of MAC, R-MAC, PLAN and E-ITRC Protocol	21
2.2.3	Characteristic of Mobile UWSN for Long Term Non Time Critical Aquatic Monitoring and Mobile UWSN for Short Term Time Critical Aquatic Monitoring	23
2.4	Speed of Sound in Water	26
2.5	Available Bandwidth of Different Underwater Acoustic Channels' Ranges	27
2.7	Parameter Comparison of WSN and UWSN	33
2.10	Summary of 802.11's Characteristic	45

LIST OF FIGURE

Figure		Page
1.3 (a)	Underwater Sensor Network Block Diagram	4
1.3 (b)	Connection Diagram of the Underwater Sensor Network	4
2.2.1 (a)	Architecture for 2D Underwater Sensor Networks	9
2.2.1 (b)	Architecture for 3D Underwater Sensor Networks	10
2.2.1 (c)	AMOUR and Some Sensor Nodes	12
2.2.1 (d)	Caribou, by Bluefin Robotics Corporation	13
2.2.1 (e)	Bluefin	14
2.2.1 (f)	CETUS, by MIT Sea Grant AUV Lab	15
2.2.1 (g)	Underwater Sensor Network of 4 Sink with 10 Sensors	16
2.2.2 (a)	A MAC Protocol Using RTS/CTS Handshaking	17
2.2.2 (b)	Handshaking in PLAN	18
2.2.2 (c)	The Steps of E-ITRC Protocol	19
2.2.3 (a)	An Illustration of UWSN for Long Term Non Time Critical Aquatic Monitoring	23
2.2.3 (b)	An Illustration of UWSN for Short Term Time Critical Aquatic Monitoring	23
2.4	Internal Architecture of an Underwater Sensor	24
2.5.1 (a)	Path Loss of Short Range Shallow UW-A Channels VS Distance and Frequency in Band 1 – 50 kHz	28

2.8 (a)	Centralized Network Topology	35
2.8 (b)	Decentralized Network Topology	35
2.9.2.3	CSMA/CA Protocol	43
3.2	Flow Chart of Underwater Sensor Network for Monitoring Application Project	52
3.3.1	Ready Manufacture Temperature Sensor	54
3.3.2	USB pH Sensor with an Electrode Probe	55
3.3.3	Webcam	56
3.3.4	Network USB Hub	57
3.3.7	Wire / Wireless Router	59
3.4.1 (a)	Block Diagram of Design with the Used of Network USB Hub	60
3.4.1 (b)	Connection of Design with the Used of Network USB Hub	61
3.4.2 (a)	Block Diagram of Design with the Used of PC Act as Server	62
3.4.2 (b)	Connection of Design with the Used of PC Act as Server	62
3.5.1 (a)	The Proposed of Main Menu's GUI	64
3.5.1 (b)	The Proposed of pH Sensor's GUI	65
3.5.1 (c)	The Proposed of Underwater Camera's GUI	67
3.5.2	The Proposed of Temperature Sensor's GUI	68
3.6	DTE – DCE Interfacing	71
3.8	Flow Chart of the Underwater Sensor Network Monitoring System	74

4.2	Underwater Sensor Network's System Architecture	77
4.3	Underwater Sensor Network's Hardware Architecture	78
4.4 (a)	Sensor Node's Connection Diagram	80
4.4 (b)	Underwater Monitoring Design Concept	80
4.4 (c)	The Real Model of the Sensor Node	81
4.4 (d)	Hierarchical Design of the Sensor Node	82
4.5	Underwater Sensor Network's Software Architecture	83
5.2.1 (a)	The Data Flow of the Main Menu's GUI	87
5.2.1 (b)	GUI of the Main Menu	88
5.2.1 (c)	GUI of the Main Menu when All the Sub GUI are Closed	89
5.2.2 (a)	The Data Flow of the pH Sensor's Sub GUI	90
5.2.2 (b)	GUI of the pH Sensor when No pH Sensing Device is Detected	91
5.2.2 (c)	GUI of the pH Sensor when pH Sensing Device is Detected	92
5.2.2 (d)	Error Message Box when No Time Duration Selected	93
5.2.2 (e)	Database of the pH Sensor	93
5.2.3 (a)	The Data Flow of the Underwater Camera's Sub GUI	94
5.2.3 (b)	GUI of the Underwater Camera when No Webcam is Detected	95
5.2.3 (c)	GUI of the Underwater Camera when Webcam is Detected	96
5.2.3 (d)	Video Format Control Box	97

5.2.3 (e)	Advanced Tab of Video Source	98
5.2.3 (f)	Source Settings Tab of Video Source	99
5.2.3 (g)	Capture Source Tab of Video Source	100
5.2.3 (h)	Error Message Box when No Time Duration Selected	101
5.2.3 (i)	GUI of the Underwater Camera when Webcam Waiting Next Image Capture Event	102
5.2.3 (j)	Database of the Underwater Camera	103
5.2.4 (a)	The Data Flow of the Temperature Sensor's Sub GUI	104
5.2.4 (b)	Error Message Box when No Temperature Sensor is Attached	105
5.2.4 (c)	GUI of the Temperature Sensor when Temperature Sensing Device is Detected	106
5.2.4 (d)	Error Message Box when No Time Duration Selected	107
5.2.5 (e)	Database of the Temperature Sensor	108
5.3.1 (a)	Select Windows Firewall from Control Panel	109
5.3.1 (b)	Windows Firewall Setting for TightVNC	110
5.3.1 (c)	Add Port Properties of TightVNC	110
5.3.2 (a)	Setup for TightVNC	111
5.3.2 (b)	Server Properties Setup of TightVNC Server	112
5.3.2 (c)	Hooks Properties Setup of TightVNC Server	113
5.3.2 (d)	Administration Properties Setting of TightVNC Server	113
5.3.3 (a)	Desktop Page of TightVNC	114
5.3.3 (b)	Manage Add-ons Windows of Internet Explorer	115
5.3.4 (a)	Router Login Window	116

5.3.4 (b)	Router Virtual Server Setting Page	116
5.3.4 (c)	Setting for TightVNC Port Forwarding	117
5.3.4 (d)	Add the Created Rules to the Applied Rules Box	117
5.4	Full System of the Underwater Sensor Network	119

ABBREVIATION

A

ACK	Acknowledgement
ADC	Analog-Digital Conversion
ADO	ActiveX Data Objects
AMOUR	Autonomous Modular Optical Underwater Robot
AUV	Autonomous Water Vehicles

B

BAN	Body Area Network
-----	-------------------

C

CAT 5e	Category 5e
CDMA	Code Division Multiple Access
CSMA	Carrier Sense Multiple Access
CSMA/CA	Carrier Sense Multiple Access with Collision Avoidance
CTS	Clear to Send

D

DAC	Digital-Analog Conversion
DAO	Data Access Objects
DAQ	Data Acquisition
DCE	Data Communication Equipment
DCF	Distributed Coordination Function
DIFS	Distributed Inter Frame Space
DSSS	Direct Sequence Spread Spectrum

	DTE	Data Terminal Equipment
E		
	E-ITRC	Energy efficiency & Innovative Time Reduction Communication
F		
	FCC	Federal Communications Commission
	FDMA	Frequency Division Multiple Access
	FTP	File Transfer Protocol
G		
	GPS	Global Positioning Systems
	GUI	Graphical User Interface
H		
	HDLC	High-Level Data Link Control
I		
	IBM	International Business Machines Corporation
	IDE	Integrated Development Environment
	IEEE	Institute of Electrical and Electronics Engineers
	IP	Internet Protocol
	ISI	Inter Symbol Interference
	ISM	Industrial, Scientific and Medical
	I/O	Input / Output
L		
	LAN	Local Area Network
	LCP	Link Control Protocol
	LR-WPAN's	Low-Rate Wireless Personal Area Networks

M

MAC	Medium Access Control
MAN	Metropolitan Area Network
MIMO	Multiple Inputs, Multiple Outputs

N

NCP	Network Control Protocol
-----	--------------------------

O

OFDM	Orthogonal Frequency Division Multiplexing
------	--------------------------------------------

P

PAN	Personal Area Network
PC	Personal Computer
PCF	Point Coordination Function
PLAN	Protocol for Long Latency Access Network
PPP	Point-to-Point Protocol

R

RAD	Rapid Application Development
RDO	Remote Data Objects
RF	Radio Frequency
RFB	Remote Frame Buffer
R-MAC	Reservation-based Medium Access Control
RTS	Ready to Send
RTS/CTS	Ready to Send / Clear to Send
RTT	Round Trip Time

S

SIFS	Short Inter Frame Space
------	-------------------------

	SLIP	Serial Line Internet Protocol
T		
	TCP/IP	Transmission Control Protocol / Internet Protocol
	TDMA	Time Division Multiple Access
U		
	USB	Universal Serial Bus
	UTP	Unshielded Twisted Pair
	UW-A	Underwater Acoustic
	UWSN	Underwater Wireless Sensor Network
V		
	VB	Visual Basic
	VNC	Virtual Network Computing
W		
	Wi-Fi	Wireless Fidelity
	WPAN	Wireless Personal Area Network
	WSN	Wireless Sensor Networks
	2D	Two-Dimensional
	3D	Three-Dimensional