THE IMPLEMENTATION OF BIOLOGICAL TUNNEL ROUTING PROTOCOL (BIOTROP) IN TUNNEL WIRELESS SENSOR NETWORK (TWSN)

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Dedicated to my beloved wife, Hasnizom binti Hassan,

and also to my beloved family, especially my mother; Khadijah binti Haji Omar,

my father; Zahar bin Samsuddin, my siblings, who have encouraged, guided and

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ABSTRACT

A sensor network is composed of a large number of sensor nodes that has expanded tremendously. The sensor nodes can be deployed in any possible applications such as environmental monitoring, industrial sensing and diagnostic, infrastructure protection, battlefield awareness and context-aware computing. In Wireless Underground Sensor Network, the sensor nodes can deploy in two conditions whether buried completely in soil or located in underground confined area like Tunnel Wireless Sensor Network. Due to difference in the implementation of experimental site, the development of a reliable communication can be an important consideration for this project. Therefore, the best routing protocol for tunnel environment named as Biological Tunnel Routing Protocol (BIOTROP) using TelosB sensor nodes is proposed. There are six sensor nodes which were deployed really in a tunnel model at a predetermined distance. The developing process of routing protocol will not neglect the basic limitation of sensor nodes like scalability of network and power transmission. This project implements the forwarding progress that is based on Packet Reception Rate (PRR), Link Quality Indicator and remaining power battery. In minimising the clarification process of network's path, the BIOTROP upgrade the capability of routing protocol in tunnel environment. Three challenging conditions were setup in experimental process such as low power transmission, all nodes appear as source node concurrently and faster transmission rate. The results have shown more than 70 percent of the transmitted data packets were successfully delivered at the base station. It is also can be implemented practically in tunnel when PRR increases more than 20 percent compared to in a free space condition.

ABSTRAK

Sebuah rangkaian pengesan terdiri daripada sebilangan besar nod pengesan yang berkembang dengan pesatnya. Nod pengesan boleh digunakan di mana-mana aplikasi seperti pemantauan alam sekitar, perindustrian pengesanan dan diagnostik, perlindungan infrastruktur, kesedaran medan pertempuran dan sedar konteks pengkomputeran. Di dalam Rangkaian Peranti Pengesan Bawah Tanah Tanpa Wayar, nod pengesan boleh digunakan dalam dua keadaan sama ada ditanam sepenuhnya di dalam tanah atau diletakkan di ruang tertutup bawah tanah seperti Rangkaian Peranti Pengesan Terowong Tanpa Wayar. Disebabkan perbezaan tapak dalam melaksanakan eksperimen, pembangunan satu komunikasi yang boleh dipercayai menjadi satu pertimbangan yang penting untuk projek ini. Sehubungan itu, Protokol Penghalaan Terowong Biologi (BIOTROP) yang menggunakan nod pengesan TelosB dicadangkan. Terdapat enam nod pengesan yang telah ditempatkan di dalam sebuah model terowong dengan jarak yang telah ditetapkan. Proses pembangunan protokol penghalaan ini tidak akan mengabaikan batasan asas nod pengesan seperti keupayaan skala rangkaian dan kuasa penghantaran. Projek ini mengemplementasi perkembangan kehadapan yang berdasarkan Kadar Penerimaan Paket (PRR), Pautan Penunjuk Kualiti dan baki kuasa bateri. Dengan meminimumkan proses mengklasifi jalan rangkaian, BIOTROP meningkatkan kebolehan protokol penghalaan di dalam persekitaran terowong. Tiga keadaan mencabar telah ditetapkan di dalam proses eksperimen seperti kuasa penghantaran yang rendah, semua nod pengesan diatur sebagai nod sumber secara serentak dan kadar penghantaran yang lebih cepat. Keputusan ujikaji telah menunjukkan lebih 70 peratus daripada paket data yang dihantar berjaya sampai di stesen pangkalan. Ia juga praktikal dilaksanakan di dalam terowong apabila PRR meningkat lebih daripada 20 peratus berbanding dalam keadaan ruang terbuka.

CHAPTER 1

INTRODUCTION

1.1 Background

There are several types of wireless communication in WSN such as Wireless Underground Sensor Networks (WUSN) and Underwater Wireless Sensor Network (UWSN). In WUSN, devices are either buried completely under dense soil, or placed within a bounded open underground space, such as mines and road / subway tunnels [1]. Sensor nodes which are deployed in mines and subway tunnels are called Tunnel Wireless Sensor Network (TWSN). In TWSN, although the signal propagates through the air, the propagation characteristics of EM waves are significantly different from those of the terrestrial wireless channels. This is due to confine space caused by the structures of the mines and road or subway tunnels [1]. This consolidate that TWSN has unbalanced communication load which leads to early invalidation of nodes close to the base station [2]. Actual tunnel cross sections are similar to a rectangle or a circle. However, the EM field distribution and attenuation of the modes in rectangle waveguide are almost the same as the circular waveguide [3].

Based on the challenging of physical condition in tunnel environment, the routing protocol must ensure the secure communication and connection to send the data from source node to base station. In this project, it is envisaged, the proposed routing protocol shall be an easier method than previous model done in various approach. This is considering ant's behavior that will try to find any way to reach the food area. Besides that, the ant agent guided also by optimal forwarding calculation to determine the best next hop neighbour.

1.2 Problem Statement

Basically, there are several general challenging for multi-hop routing in WUSN where originally the sensor nodes are manufactured to be low processing powered, low data reliability and need low energy consumption with limited computational capabilities and limited coverage. These basic limitations already challenges the implementation of sensor nodes in WUSN area like underground soil conditions monitoring in agricultural or sport fields, wall crack sensing in tunnel transportation, leak sensing in underground fuel tank and enemy aware detection in battlefield. On the other hand, there are five main factors that impact communication with EM waves underground. These factors are extreme path loss, reflection/refraction, multi-path fading, reduced propagation velocity, and noise. However, the relevant factors that occur in underground tunnel environments are extreme path loss, reflection/refraction, and multi-path fading.

The tunnel lining may contain various materials including sodium silicate, lime, silica fume, cement, and bentonite [30]. Therefore, the composition of each material can contributes more path loss due to material absorption, a major concern when using EM waves. Otherwise, underground path losses are highly dependent on the soil type and water content. In tunnel environment, the soil-wall interface introduces reflection and refraction because of the different attenuation

characteristics of soil and air. The reflected signal may improve or impair the communication performance depending on the distance between nodes. Furthermore, broadcasting waves at medium transitions will be partially transmitted and partially reflected, then also cause multi-path fading phenomenon. In certain condition that involves transmission of data from underground tunnel to ground surface, multi-path fading effect will especially be pronounced for sensors deployed near the wall surface, where the wave is close to the soil–air interface.

Although the TWSN area circles by limitations of sensor nodes manufactured setup and challenging environmental, most of researchers come with unique and special method in developing routing protocol. A lightweight routing protocol is a major scheme chosen by certain researcher to minimize the power consumption and total coding size in sensor node. Even though in reality, the detail and various problem handler schemes in proposed routing protocol will contribute inversely to tackle thousands of possibilities and unexpected risk situation. Otherwise, the researcher sets the different active time of sensor node as well as limits the number of source node to control the signal traffic. However, it is quite tough in installation process and not maximizes the sensor nodes that distributed. Therefore, the ideal routing protocol must have nature awareness, reliable in heavy source node, effective in ad hoc situation and faster transmission rate with lower power consumption. Although many kind of application occur in tunnel underground such as environmental monitoring, infrastructure monitoring, location determination, and security monitoring, the core challenging problem in TWSN is how the routes in the network maintain and reliable in multi-hop communication.

1.3 The Objectives

The objectives of this work are:

i. To design practical model of routing protocol in tunnel environment based on capability of TelosB motes in TinyOs 1.x.

ii. To adapt the Real-time Routing Protocol with Load Distribution (RTLD)'s concept in forwarding decision technique that suitable for tunnel condition.

iii. To implement the Ant Colony Optimization (ACO) method by using Forward Ant, Backward Ant and Data Ant agent to improve the probability of data packets delivered.

1.4 Scope of the Work

This research study involves several scopes. Firstly, it covers the development of the routing protocol in TinyOS environment using NesC programming language embedded in TelosB mote. The maximum numbers of hops use in this experiment are six. Therefore, the maximum number of nodes is limited to a maximum number of seven nodes. One node sets as base station node and others six nodes will act as source node as well as intermediate node. The implementation of project just focuses on tunnel environment and applies the optimization parameters to select the best next neighbour node. Finally, this project covers the development of ant agents which are Forward Ant, Backward Ant and Data Ant in the routing protocol. This project does not include the other part of the ACO technique such as the pheromone table and the data routing table.

1.5 Significance of the Study

The routing protocol developed in WSN area using two types of function nodes which are Full Function Device (FFD) and Reduce Function Device (RFD) [1] to create multi hop communication. FFD node will play two roles at the same time which are source node and intermediate node. Meanwhile RFD node just receives and forwards the data packet from source to destination. Both functions are implemented to reduce the congestion of signal in order to guarantee the data packet delivered. Therefore, proposed routing protocol challenges this limitation by setting all nodes as FFD and run in the confine region which is tunnel underground. Hence, the usage of sensor node is in fully functional condition to improve the effectiveness of sensing in any application. In addition, the proposed algorithm in BIOTROP has been developed in simple programming codes in TinyOS 1.x. So, the further improvement and study will be easier and more flexible. Otherwise, BIOTROP uses low power transmission to enhance the lifetime of sensor node in real implementation.

1.6 Contributions of the Thesis

i. Three ant agents successfully implemented in proposed algorithm although in tunnel environment.

ii. The proposed routing protocol was tested at real test bed and achieves the stable performance to guarantee data packets delivery.

1.7 Research Outline

This thesis is divided into five chapters, which describe the entire process of the research. The outline of the thesis is as follows:

Chapter 1 highlights the background of the research problem, statement of the problem and objectives of the research. It followed by research scope, significance of the study, contribution of the thesis and thesis outline.

Chapter 2 is an overview on the types of routing protocol in WSN and followed by discussion on the specification of IEEE 802.15.4. Then, it continue with the description on Wireless Underground Sensor Network (WUSN) generally and specifically on Tunnel Wireless Sensor Network (TWSN). After that, the literature review on related research works done by other researchers is viewed followed by related researches that implements in this project.

Chapter 3 discusses the details on the research process starting with discovery on the basic concept and provided facility in TinyOS version 1.x. After that, discussion followed by the details on system design of proposed routing protocol. Next, continued with the experiment test bed that divided to two subsections which are hardware component and software component.

Chapter 4 discusses the experiment result of BIOTROP that sets to two different power transmissions which are -25 dBm and -15 dBm. The comparison result for both experiment setups are analyzed detail in this chapter. In addition, the result for each node also compared in tunnel environment and free space condition.

Chapter 5 concludes the research work and gives the suggestion for future development of the related research project.

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TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	DECLARATION	ii
	DEDICATION	iii
	ACKNOWLEDGEMENT	iv
	ABSTRACT	v
	ABSTRAK	vi
	TABLE OF CONTENTS	vii
	LIST OF TABLES	x
	LIST OF FIGURES	xi
	LIST OF SYMBOLS	xiv
	LIST OF ABBREVIATIONS	xv
	LIST OF APPENDICES	xvii
1	**INTRODUCTION**	
	1.1 Background	1
	1.2 Problem Statement	2
	1.3 The Objectives	4
	1.4 Scope of the Work	4
	1.5 Significance of the Study	5
	1.6 Contributions of the Thesis	5
	1.7 Research Outline	6

2	**LITERATURE REVIEW**	
	2.1 Introduction	7
	2.2 Types of Routing Protocol in WSN	8
	2.3 IEEE 802.15.4 Specification	10
	2.3.1 Physical Layer	12
	2.3.2 Medium Access Control (MAC) Layer	14
	2.4 Overview of WUSN	17
	2.4.1 Tunnel Environment	18
	2.4.2 Challenges in TWSN	19
	2.4.3 Application in TWSN	20
	2.5 Related Research Work	20
	2.5.1 The Nonuniform Clustering Routing Protocol	21
	2.5.2 Frequency Diversity (FD) Technique	21
	2.5.3 Bounce Routing in Tunnels (BRIT)	22
	2.5.4 Reviews on Real Time Load Distribution (RTLD) Protocol	23
	2.5.5 Comparison The Related Works with The Proposed Work	24
	2.6 Biological Inspired Techniques	25
	2.7 Ant Colony Optimization (ACO)	26
	2.6.1 Method of Finding Food in Ant Colony	27
	2.6.2 Rules and Conditions	32
	2.8 Summary	33
3	**RESEARCH METHODOLOGY**	
	3.1 Introduction	34
	3.2 Structure of TunyOS 1.x	37
	3.2.1 The Value of RSSI and LQI	38
	3.3 System Design of Biological Tunnel Routing Protocol (BIOTROP)	40
	3.4 Cross Layer Design in BIOTROP	42
	3.5 Structures of BIOTROP	43

	3.5.1 Routing Management Module	44
	3.5.1.1 Optimal Forwarding Calculation	47
	3.5.1.2 Unicast Forwarding Mechanism	53
	3.5.1.3 Routing Problem Handler	54
	3.5.1.4 ACO Routing Process	56
	3.5.2 Neighbourhood Management Module	60
	3.6 Experiment Test Bed	62
	3.6.1 Hardware Component	62
	3.6.2 Software Component	66
	3.7 Summary	71
4	**RESULT AND ANALYSIS**	
	4.1 Introduction	72
	4.2 Programming Codes Size	74
	4.3 The Result's Interface	75
	4.4 Discussion on Experiment 1 at TWSN testbed	77
	4.5 Discussion on Experiment 2 at TWSN testbed	80
	4.6 Comparison between Experiment 1 and 2 Setup at TWSN testbed	84
	4.7 Free-space Condition	86
	4.8 Comparison between Tunnel Environment and Free-space Condition	88
	4.9 Summary	97
5	**CONCLUSIONS AND RECOMMENDATIONS**	
	5.1 Conclusions	99
	5.2 Recommended Future Works	101
REFERENCES		102
Appendices A – C		106-120

LIST OF TABLES

TABLE NO.	TITLE	PAGE
2.1	The Comparison of ZigBee with Two Others IEEE 802 Standards	11
2.2	Physical layer description in IEEE 802.15.4	13
2.3	Comparison between the previous works and BIOTROP	25
2.4	Simple Rule of Ant Approach	32
3.1	Overall design of experimentation	35
4.1	Comparison of code size	74
4.2	The value of PDR (%) at -25 dBm power transmission	77
4.3	The value of PDropR (%) at -25 dBm power transmission	78
4.4	The value of PRR at -25 dBm power transmission	79
4.5	The value of PDR (%) at -15 dBm power transmission	81
4.6	The value of PDropR (%) at -15 dBm power transmission	82
4.7	The value of PRR at -15 dBm power transmission	83
4.8	The value of PRR at -25 dBm power transmission in free-space	87
4.9	The value of PRR at -15 dBm power transmission in free-space	88
4.10	The value of PRR for node 1	89
4.11	The value of PRR for node 2	91
4.12	The value of PRR for node 3	92
4.13	The value of PRR for node 4	94
4.14	The value of PRR for node 5	95
4.15	The value of PRR for node 6	97

LIST OF FIGURES

FIGURES NO.	TITLE	PAGE
2.1	Routing protocols in WSNs	8
2.2	Routing topologies of (a) flat, (b) hierarchical and (c) location-based	9
2.3	Wireless Network Groups	10
2.4	IEEE 802.15.4 star and peer-to-peer	12
2.5	Operating frequency bands in IEEE 802.15.4	13
2.6	IEEE 802.15.4 operational modes	14
2.7	The super-frame structure without GTSs	16
2.8	The super-frame structure with GTSs	16
2.9	Overview of WUSN architectures	17
2.10	Topology of TWSN with nonuniform clustering	21
2.11	Top view of the measurement geometry of FD technique	22
2.12	RTLD routing protocol architecture	24
2.13	Detail Category of ACO in Routing Protocol	27
2.14	Four ants wander to get the food	28
2.15	Ant A reach the nest and laying down more pheromone	29
2.16	Two trail created by ant A and ant B	29
2.17	Each ant act with different role at this stage	30
2.18	All ants select the shortest path	30
3.1	The overall research process	36
3.2	Packet format of the LQI and RSSI	39
3.3	Proposed BIOTROP design approach	41
3.4	Cross-layer concepts in BIOTROP	42

3.5	Functional Components of BIOTROP	43
3.6	State Machine Diagram of BIOTROP	44
3.7	Routing management functional module	45
3.8	State Machine Diagram of Routing Management Module	45
3.9	The programming codes of PRR	50
3.10	Method to get *strength* value in PRR calculation	51
3.11	Method to get *lqi* value in LQI calculation	52
3.12	The programming codes of LQI calculation	52
3.13	The programming codes of battery voltage calculation	53
3.14	Node 6 meets its route to destination by Forward Ant agent	54
3.15	Base station fail to reply Backward Ant with same route to Node 6	55
3.16	Node 6 broadcast again RTR message when not receives Backward Ant	55
3.17	Visualization of Ant Agent structure	56
3.18	Forward Ant agent process	58
3.19	Backward Ant reads the table inversely	59
3.20	Data Ant sends data with same route recorded in the table	59
3.21	Neighbour table format	60
3.22	State Machine Diagram of Neighbourhood Management Module	61
3.23	TelosB block diagram	63
3.24	Front view of culvert	64
3.25	The side view of experiment setup	64
3.26	The base component for each node	65
3.27	The location of node 1, node 3 and node 5 at right edge of the tunnel	65
3.28	The location of node 2, node 4 and node 6 at left edge of the tunnel	66
3.29	Components of the *SurgeTelos* application	67
3.30	Components of the *SurgeTelosRTLD* application	67

3.31	Components of the proposed application	68
3.32	*Surge* application interface	70
4.1	The experiment setup in TWSN and free-space testbed	73
4.2	The *Surge* application interface for 2 meter in experiment 1 at (a) t= 0 s and (b) t= 300 s	76
4.3	Packet Delivery Ratio (PDR) at -25 dBm power transmission	77
4.4	Packets Dropped Ratio (PDropR) at -25 dBm power transmission	78
4.5	Packets Received Rate (PRR) at -25 dBm power transmission	79
4.6	Packet Delivery Ratio (PDR) at -15 dBm power transmission	81
4.7	Packet Dropped Ratio (PDropR) at -15 dBm power transmission	82
4.8	Packets Received Rate (PRR) at -15 dBm power transmission	83
4.9	The PRR in free-space condition at -25 dBm power transmission	86
4.10	The PRR in free-space condition at -15 dBm power transmission	87
4.11	The PRR of node 1 at two different areas with (a) -25 dBm and (b) -15 dBm power transmission	89
4.12	The PRR of node 2 at two different areas with (a) -25 dBm and (b) -15 dBm power transmission	90
4.13	The PRR of node 3 at two different areas with (a) -25 dBm and (b) -15 dBm power transmission	92
4.14	The PRR of node 4 at two different areas with (a) -25 dBm and (b) -15 dBm power transmission	93
4.15	The PRR of node 5 at two different areas with (a) -25 dBm and (b) -15 dBm power transmission	95
4.16	The PRR of node 6 at two different areas with (a) -25 dBm and (b) -15 dBm power transmission	96

LIST OF SYMBOLS

V_{mbatt}	-	Maximum battery volt
V_m	-	Maximum velocity
V_{batt}	-	Battery voltage
V_{ref}	-	Internal voltage reference

LIST OF ABBREVIATIONS

WSN	-	Wireless Sensor Network
WUSN	-	Wireless Underground Sensor Network
TWSN	-	Tunnel Wireless Sensor Network
EM	-	Electromagnetic
ACO	-	Ant Colony Optimization
RTLD	-	Real-time Routing Protocol with Load Distribution
FFD	-	Full Function Device
RFD	-	Reduce Function Device
BIOTROP	-	Biological of Tunnel Routing Protocol
QoS	-	Quality of Service
BS	-	Base Station
CH	-	Cluster Head
WPAN	-	Wireless Personal Area Network
PAN	-	Personal Area Network
LMSC	-	Local and Metropolitan Area Network Standards Committee
LoWPAN	-	Low-rate Wireless Personal Area Network
PHY	-	Physical
MAC	-	Medium Access Control
ISM	-	Industrial Scientific Medical
DSSS	-	Direct Sequence Spread Spectrum
CSMA/CA	-	Carrier Sense Multiple Access / Contention Avoidance
RTS	-	Request-to-send
CTS	-	Clear-to-send
CAP	-	Contention Access Period

CFP	-	Contention Free Period
GTSs	-	Guaranteed Time Slot
MI	-	Magnetic Induction
FD	-	Frequency Diversity
AODV	-	Ad hoc On-Demand Distance Vector
BRIT	-	Bounce Routing in Tunnel
RREQ	-	Route Request
RREP	-	Route Reply
PRR	-	Packet Reception Rate
RSSI	-	Received Signal Strength Indicator
LQI	-	Link Quality Indicator
SFD	-	Starts of Frame Delimiter
RTR	-	Request To Reply
FA	-	Forward Ant
BA	-	Backward Ant
DA	-	Data Ant
OF	-	Optimal Forwarding
SNR	-	Signal to Noise Ratio
ITI	-	Industrial Training Institute
PDR	-	Packet Delivery Ratio
PDropR	-	Packets Dropped Ratio
O-QPSK	-	Offset – Quadrature Phase Shift Keying
DSR	-	The Dynamic Source Routing Protocol for Mobile Ad Hoc Networks

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
A	Datasheet of TelosB Mote Platform and CC2420 Transceiver	106
B	Source Code of BIOTROP	108
C	Screen Shot of TinyOS 1.x Result at TWSN Testbed	114