UNIVERSITI TEKNOLOGI MARA

THE NEW ENHANCEMENT OF OLSR ENERGY-SAVING SYSTEM IN ADHOC NETWORK

SUHAZLAN BIN SUHAIMI

Thesis submitted in fullfillment
of the requirements for the degree of
Doctor of Philosophy

Faculty of Computer and Mathematical Sciences

ABSTRACT

In Mobile Ad Hoc Networks (MANETs), network nodes typically have short lifespans given that they are mobile, self-reconfigurable, and dependent on the battery power. To help mitigate such a problem, the Optimize Link State Routing protocol (OLSR) is considered the most appropriate routing protocol to extend nodes' lifespans. As such, this study was undertaken with the main aim to enhance the energy-saving system of MANET, with which nodes can function without failure by using a newly developed algorithm of the OLSR protocol. Specifically, the study involved the developments of three schemes, namely a new Load Balance Energy Distributed (LBED) scheme, a new enhancement energy-saving (NEES) scheme, and a New Enhanced OLSR Willingness Calculation (NEWC) scheme. Accordingly, a series of simulations was carried out to measure and quantify the performances of the LBED, NEES and NEWC schemes using the OLSR protocol. The performance criteria were based on the level of remaining battery power (measured in percentage points), energy consumption, and number of live nodes based on high data transmission rate and high mobility speed requirements. The simulations performed yielded several promising, interesting results. The new enhanced energy-saving system was able to improve the battery power consumption significantly by as much as 20%. Most promising, the mean percentage of network improvement using the new enhancement energy-saving system was 48.18%, which was significantly high compared to that of existing OSLR protocol. Such findings suggest that the new enhancement energy-saving system will be able to further improve the performance of MANETs by making such networks more stable and reliable. In addition, the new enhancement energy-saving system was applied to a number of network scenarios based on high mobility speed and high data transmission rate, the findings of which helped formulate a solution matrix. This matrix can serve as a network configuration tool to help guide practitioners (especially network administrators) in setting up appropriate mobile networks that are badly needed to establish communication in critical situations involving highly mobile nodes. Overall, the research findings suggest that the proposed new enhancement energy-saving system of the OLSR protocol can help improve the use of battery energy in MANETs through efficient distribution of energy to network nodes. Effectively, such energy-efficient distribution can help prolong the life of each node, directly improve the selection of nodes as MPR nodes, provide more alternative routes in the network, and evenly distribute data transmission tasks to all nodes. Furthermore, the findings underscore the importance of selecting appropriate levels of critical parameters (e.g., the number of nodes, size of the network space, mobility speed, and data transmission rate) that collectively will have a huge impact on the mobile network performance. In this regard, practitioners can refer to the solution matrix to select the most appropriate levels of such parameters that can help optimize the energy consumption of the battery, thus leading to a stable, reliable mobile network.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

Abbreviations	
AC	Alternating Current
ACOR	Admission Control Enable On-demand Routing
ACPI	Advanced Configuration and Power Interface
ANSN	Advertised Neighbour Sequence Number
AODV	Ad Hoc On-demand Distance Vector
API	Application Programming Interface
APM	Advanced Power Management
BATMAN	Better Approach to Mobile Ad Hoc Network
BIOS	Basic Input Output Process
CBR	Constant Bit Rate
DDR	Distributed Dynamic Routing
DHCP	Dynamic Host Configuration Protocol
DSDV	Destination-sequenced Distance Vector
DSR	Dynamic Source Routing
DST	Distributed Spanning Trees
DYMO	Dynamic MANET On-demand Routing
ESS	Energy-saving Scheme
ESSID	Extended Service Set Identification
GCC	GNU Compiler Collection
GNU	GNU's Not Unix
GOD	General Operations Director
GPL	General Public License
GSR	Global State Routing
HNA	Host and Network Association
HSR	Hierarchical State Routing
IANA	Internet Assigned Numbers Authority
ICMP	Internet Control Message Protocol
ICMP	Internet Control Message Protocol
IEEE	Institute of Electrical and Electronics Engineers

IETF	Internet Engineering Task Force
LAR	Location-aided Routing
LBED	Load Balance Energy Distributed
MAC	Media Access Control
MANET	Mobile Ad Hoc Network
MPR	Multipoint Relay
NAT	Network Address Translation
NEWC	New Enhancement Willingness Calculation
NS	Network Simulator
OLSR	Optimize Link State Routing Protocol
PDA	Personal Digital Assistant
RFC	Request for Comment
SLURP	Scalable Location Update Routing Protocol
SSH	Secure Shell
SSID	Service Set Identification
TC	Topology Control
TCL	Tool Command Language
TCP	Transmission Control Protocol
TORA	Temporally Ordered Routing Algorithm
TTL	Time to Live
UDP	User Datagram Protocol
WMN	Wireless Mesh Network
WRP	Wireless Routing Protocol
WSN	Wireless Sensor Network
ZHLS	Zone-based Hierarchical Link State
ZRP	Zone Routing Protocol

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Optimized Link State Routing Protocol (OLSR) is a table-driven proactive protocol used in Mobile Ad hoc Networks (MANETs). This protocol helps constantly maintain and update the topology of such networks. However, this constant updating requires information (which can be quantitatively immense) of all nodes in the network. Consequently, and inevitably, this protocol will experience information flooding that severely imposes a huge overhead of routing traffic, thus severely causing some initial delay in data communication. To help address information flooding, the Multipoint relay (MPR) technique was proposed to optimize the OLSR protocol.

In a MANET, all nodes rely on the power supplied by a battery to keep them running (alive), and thus optimizing energy consumption in such a network becomes an imperative (Lalitha, & Rajesh, 2014). The use of fully functional MANET is critical to managing and sustaining mobile network in life-threatening environments, which are often caused by natural disasters (such as floods and earthquakes), as the communication infrastructure of such locations may be either lacking or badly damaged (Basurra, et al., 2015; Sandeep, et al., 2015). Given this concern, many researchers have carried out a number of studies by focussing on the improvements of OLSR routing protocol to help maintain sufficient live nodes in the mobile network.

One important finding of such studies is that using OLSR will result in MPR nodes consuming more energy than the non-MPR nodes, thus rapidly depleting the available energy left in the network (Prajapati, et al., 2015). To mitigate this problem, several researchers have proposed solutions that can help such MPR nodes to consume less energy (Prajapati, et al., 2015; Patil, R.B. & Patil, A.B. , 2015 ; Belkheir, et al., 2014; Loutfi, A et al., 2014; Ouacha, et al., 2013; Guo, et al., 2011). Nonetheless, the research carried out thus far has not focussed on the level of energy use based on the willingness values that can affect the selection of nodes as MPR nodes.

1.2 Problem Statement

Issues concerning energy consumption in MANETs have been discussed with some degree of concern in the literature. Such concerns are not surprising given that nodes in such networks, which typically operates without sufficient information infrastructure, depend on the battery for their source of power. Clearly, the battery is a very valuable energy resource that should be utilized optimally such as to prevent nodes from losing their energy at a rapid rate that will ultimately lead them to die, which can render the network to be inactive. In other words, non-optimal use of the battery by the nodes will quickly deplete the available energy, thus causing energy-deficient nodes to lose their ability to communicate. With less or no electrical energy, the network will become unstable or cease to function, respectively (Palaniappan & Chellan, 2015).

In recent years, the focus of research has shifted to formulating solutions to overcome the above problem. For example, Safa et al. (2014) proposed a power-aware heterogeneous routing protocol (PHAODV) for MANETs, which takes into consideration the status of a node's energy level during route selection. In fact, this approach of heterogeneous wireless interface nodes is specifically designed for MANETs. Based on this approach, the route that consumes the least power will be selected and information about the nodes travelling through this route will be added to the routing table. In contrast, the use of the proposed approach will help ensure all nodes will share equal amount of loads, with no one having excessive load that makes it become washed-out. To prevent such occurrence, two thresholds will be used by nodes to control the rate of energy consumption such as to prevent the rapid depletion of battery energy. Moreover, an interoperability model will be used to ensure all nodes will communicate using a diverse array of transmission technologies to help improve network connectivity and extend network lifetime. Nevertheless, there are some limitations imposed by this approach that are attributed to the flooding of message activities, such as broadcast messages, route replies, and error messages, which use multiple interfaces such as Wifi and Bluetooth.

To this end, a number of researchers, including Sandeep and Satheesh (2015), have conducted studies that focus on such approach that aims to select an alternative path that can reduce the loads of individual nodes and to improve the lifetimes of such nodes at high traffic network. The underlying principle of such an approach is the sharing of network responsibilities in delivering data among efficient devices (nodes).

which can help further improve the performance of the network. Against such a backdrop, this research was carried out with the focus on reducing energy consumption via effective workload distribution among nodes in high traffic networks. However, the approach adopted in this research was confined to examining network nodes based on troop operation, not a full-scale military operation, with military aircrafts, tanks, and other moving equipment representing nodes in a military scenario. For the selected scenario, the movements of such designated nodes were divided into three main speed categories, namely low, medium and high mobility speed.

Interestingly, Fatima and Najib (2012) carried out research that focus on OLSR protocol. Specifically, their research involved the modification of the MPR selection mechanism in OLSR. Such modification was intended to help improve energy consumption and mobility management in MANETs by considering nodes' lifetimes and speeds such that each node would be able to act as an MPR. Clearly, one of the main advantages of this approach is the proper selection of an MPR set based on node mobility, one of the critical factors that has a profound impact on the network topology. Nevertheless, in contrast to velocity, the speed of a node provides no information on the direction of its movement.

The conventional energy-saving mechanism of the OLSR protocol has its share of drawbacks, notably the level of remaining energy available for network nodes is not monitored which may adversely affect the performance of the network. In light of this drawback, a new energy-saving mechanism that can help optimize the OLSR protocol is required to help solve this particular problem. Hence, identifying, developing, and testing the appropriate method to improve the energy-saving mechanism was the main objective of this research. With such an enhanced mechanism, the available energy of a battery can be constantly monitored and optimally utilized, thus improving the quality of the routing protocol.

Another major concern, which has not been fully addressed as yet, is to find the optimal values of the four elements of a network, namely the number of nodes, network area, data transmission rate, and mobility speed of nodes. These optimal values are critical to ensuring the energy consumption would be economical and the number of nodes alive would be reasonably high. Thus, a series of experiments was performed in this study by focusing on these four critical elements. Surely, the findings of these experiments would help the researcher to develop a matrix of an energy-saving mechanism, which when used in the right context can substantially save energy and improve the quality of the OLSR protocol.

Admittedly, the battery-powered nodes in MANETs have limited lifetimes that can severely disrupt data transmission; hence, such potential communication disruption served as the motivation of the research that focused on energy utilization of MANETs. Specifically, this study was carried out with the main aim to address the prevailing issue concerning the energy use in a MANET operating with the OLSR protocol. Moreover, the choice of studying such a network using the Optimized Link State Routing (OLSR) protocol was highly appropriate given the wide adoption of this protocol in many MANET applications (Clausen & Jacquet, 2003). Furthermore, from the economic standpoint, focusing the research on this protocol (which is freely available, robust, and easy-to-configure) would have a far-reaching implication for the communication industry that relies on MANETs.

1.3 Research Questions

Three (3) research questions were formulated to address the issues discussed and highlighted in the previous sections as follows:

i. How the available energy among nodes in the MANET can be distributed evenly?
ii. How the proposed technique can be effectively applied to improve the function of the OLSR routing protocol?
iii. How the performances of the proposed LBED and NEWC schemes compared to those of existing benchmarks?

1.4 Research Objectives

Correspondingly, three (3) research objectives were formulated to help address the above research questions as follows:

i. To design and develop the New Enhancement Energy-Saving scheme (NEES) and the New Enhancement OLSR Willingness Calculation (NEWC) function.
ii. To design and develop the new Load Balance Energy Distributed (LBED) scheme.
iii. To evaluate, validate, and compare the reliability and performances of the proposed schemes with those of the benchmarks.

1.5 Significance of Study

The findings of this study will provide a greater insight into the understanding of how available energy in MANETs can be optimized by introducing a new, enhanced technique for the OLSR protocol. With this novel technique, the number of live nodes in a network can not only be increased but also be sustained over a longer duration. Clearly, with a greater number of live nodes, the network will be more stable to transmit data from a source to a destination and to create more alternative paths for data transmission. Definitely, the improvements gained through the proposed technique can further enhance the reliability and readiness of the network, which is critical to dealing with highly demanding situations. Additionally, the knowledge pertaining to energy optimization of the OLSR protocol can help practitioners to improve their current practice. In particular, the proposed new techniques, namely the Load Balance Energy Distributed (LBED) scheme and New Enhancement OLSR Willingness Calculation (NEWC), can further improve network performance to a higher level.

Specifically, the findings of the research can help enrich the body of knowledge concerning energy use in MANET, especially those that run with the OLSR protocol. The following are the contributions of the study that can help improve the existing practice.

i. The new practical energy-saving mechanism can help optimize available energy to maintain and sustain a high number of live nodes.

ii. The new mechanism can be used to extend the lifetime of a battery, thus enabling the network to be more reliable and stable. This extended lifetime can be achieved as the energy-saving mechanism enables nodes to seek shortest paths that eliminate excessive consumption of energy, thus resulting in long-lasting battery.

iii. The mechanism can serve as an alternative solution to optimizing the use of energy and to maintaining a high number of live nodes in a given situation based on the high mobility speed and high data transmission rate.

iv. The proposed new solution matrix table can help manage networks by optimizing the number of nodes and network area in a particular situation. Essentially, the use of this solution matrix can help practitioners to identify the appropriate option in creating more alternative paths for data transmission, which results in better energy-saving management.

1. The stability of a functional network can be assured through improved network efficiency, as energy consumption can be maintained at a reasonable rate and live nodes can be maintained in sufficient number.

1.6 The Scope of Study

Typically, research in network is challenging from the practical standpoint given the vast network areas that need to be covered. It is therefore more practical to perform testing of new methods or techniques in simulated scenarios, the results of which would mirror actual settings. For this study, the researcher proposed, designed, and developed a new energy-saving method for the OLSR protocol with the main aim to improve the energy use of ad hoc networks. This new technique had been tested in simulated settings that yielded several important findings. Testing was carried out by comparing the performances between existing system and the proposed system by focusing on the optimization of energy use and the number of live nodes based on two important factors, namely high mobility speed and high data transmission rate. Of course, there are other parameters that can affect the performance of MANETs, but these two factors are the critical ones, which thus far have not been investigated in greater depth. As such, they were examined in this study such as to help understand their potential impacts on the performance of such networks.

1.7 Thesis Organization

This thesis consists of five (5) chapters to help readers follow the presentation of the discussion as follows:

Chapter 1 provides an overview of the background of the study, problem statements, research objectives, research questions, significance of study, and the scope of the research.

Chapter 2 consists of two main sections that provide a detailed account of the literature review. The first section focuses on the theoretical aspects of the routing protocols used in MANETs, notably the OLSR routing protocol. The second section deals with previous research on energy use in MANETs and the OLSR routing protocol.

Chapter 3 comprises two main sections that discuss the methodology of the research. The first section discusses the elements of research methodology, namely the research design, research framework, and performance evaluation and analysis of results. The second section elaborates the appropriate research tools used in the study that deals, including the requirements of the operating system, hardware, and software. This section also discusses the Ubuntu operating system, hardware, and software used for the simulations of the performances of the routing protocols.

Chapter 4 discusses the data analysis of the simulation data and the ensuing results, including the data collection and pre-processing, the performance evaluation and analysis of results, and the solution matrixes.

Chapter 5 provides a summary of the research findings, contributions to the current practices, recommendations for future research, and conclusion of the dissertation.