AN ENERGY EFFICIENT ACKNOWLEDGEMENT-BASED METHOD FOR SELFISH NODE DETECTION AND AVOIDANCE IN OPEN MANET

MEHRNAZ NIKMARAM

A project report submitted in partial fulfilment of the requirements for the award of the degree of Master of Computer Science (Information Security)

Faculty of Computing
Universiti Teknologi Malaysia

JULY 2014
This thesis is dedicated to my beloved parents for their endless support and encouragement.
ACKNOWLEDGMENTS

First and foremost, I would like to sincerely thank my lovely parents, Mahmoud Nikmaram and Mahnaz Parsa, my lovely brother Mohammad Ali, my lovely sisters Behnaz and Farahnaz and all friends for their endless love, support and encouragement. I could not have done it without you! There is no word I can find to thank you.

Then I would like to express my sincere gratitude to my supervisor Dr. Hassan Chizari for his continued support during this project. They inspired me greatly to work in this project. Their willingness to motivate me contributed tremendously to the success of this project. I have learned a lot from them and I could not have imagined having a better advisor and mentor for my Master study. Many thanks to all my lecturers, I will forever be grateful.

Besides, I would like to thank my examiners: Dr. Anazida Binti Zainal, Dr. Kamalruhnizam Bin Abu Bakar, Dr. Maznah Binti Kamat, Dr. Majid Bakhtiari and Dr. Maheyzah MD. Siraj, for their patience and insightful comments.

Finally, I would like to thank Universiti Teknologi Malaysia for their kind cooperation.
ABSTRACT

Mobile Ad-Hoc Networks (MANET) is a decentralized infrastructure with relatively low capacity of connections for communication with the special measures described as a collection of autonomous mobile nodes. In such networks, weak communication links and node mobility can lead to highly unpredictable and dynamically changing topologies. Open MANET is one of the types of MANET in which any node is able to join or leave the network. Thus, it is vulnerable in oppose of selfish nodes which they do not like to spend their resources to participate in network activities such as routing. This helps them to preserve their limited energy while they have a huge negative impact on the network performance and total energy usage. One of the category of methods to for selfish node detection and avoidance is acknowledgement-based methods. Negative Acknowledgement (NACK) is the best method for detecting and avoidance selfish node in this category. The NACK method has high level of packet delivery, and high throughput in opposed of misbehaving action. However, this method suffers from extra charge by number of routing overhead, and more energy consumption when number of selfish nodes or mobility of nodes are increasing. In this study, using the Selective Acknowledgement (SACK) a new selfish node detection method has been developed called S-NACK. This method uses SACK instead of full TCP over the NACK. The proposed method was implemented in NS2 and its performance was compared with NACK. The extensive simulation results showed that S-NACK reduces the network overhead and improves the energy consumption in comparison to NACK whereas the packet delivery ratio is almost similar at the same time.
ABSTRAK

Mobile Ad-Hoc Networks (MANET) adalah infrastruktur berpusat dengan kapasiti sambungan komunikasi yang rendah dengan langkah-langkah khas digambarkan sebagai koleksi nod yang bergerak sendiri. Dalam rangkaian-rangkaian tersebut, hubungan komunikasi dan mobiliti nod yang lemah boleh mengakibatkan topologi yang sangat tidak menentu dan berubah secara dinamik. MANET terbuka adalah salah satu jenis MANET di mana mana-mana nod mampu untuk menyertai atau meninggalkan rangkaian. Oleh itu, ia terdedah dalam menentang nod yang menyendiri dimana sumber-sumber tidak mudah dihabiskan semasa mengambil bahagian dalam aktiviti-aktiviti rangkaian seperti penghalaan. Hal ini amat membantu dalam mengekalkan tenaga yang terhad semasa memberi kesan negatif yang besar kepada prestasi rangkaian dan jumlah penggunaan tenaga. Salah satu kaedah untuk mengesan nod ini dan bagi mengelakkannya adalah kaedah perakuan berasas. Negative Acknowledgement (NACK) adalah kaedah yang terbaik bagi mengesan dan mengelakkan nod yang menyendiri dalam kategori ini. kaedah NACK mempunyai tahap penghantaran paket, dan pemprosesan yang tinggi dalam penentangan daripada menimbulkan tindakan negatif. Walau bagaimanapun, kaedah ini mengalami caj tambahan dengan beberapa laluan beban dan penggunaan tenaga yang lebih apabila bilangan nod yang menyendiri atau mobiliti nod semakin meningkat. Dalam kajian ini, dengan menggunakan Selective Acknowledgement (SACK), kaedah pengesanan nod baru yang menyendiri telah dibangunkan dan dipanggil sebagai S-NACK. kaedah ini menggunakan SACK dan bukannya TCP penuh ke atas NACK. kaedah yang dicadangkan telah dilaksanakan pada NS2 dan prestasinya telah dibandingkan dengan NACK. Keputusan simulasi yang luas menunjukkan bahawa S-NACK mengurangkan beban rangkaian dan meningkatkan penggunaan tenaga berbanding NACK, manakala nisbah penghantaran paket adalah hampir sama pada masa yang sama.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>CHAPTER</th>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>DECLARATION</td>
<td></td>
<td>II</td>
</tr>
<tr>
<td>DEDICATION</td>
<td></td>
<td>III</td>
</tr>
<tr>
<td>ACKNOWLEDGMENTS</td>
<td></td>
<td>IV</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>ABSTRAK</td>
<td></td>
<td>VI</td>
</tr>
<tr>
<td>TABLE OF CONTENTS</td>
<td></td>
<td>VII</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td></td>
<td>XI</td>
</tr>
</tbody>
</table>

## 1 INTRODUCTION

1.1 Introduction  
1.2 Problem background  
1.3 Problem Statement  
1.4 Purpose of the Study  
1.5 Research Questions  
1.6 Objective of the Study  
1.7 Significance of the Study  
1.8 Scope of the Study  
1.9 Organization of the Study

## 2 LITERATURE REVIEW

2.1 Introduction  
2.2 Mobile Ad-hoc Network  
2.2.1 MANET Characteristics
2.2.2 Advantage of MANET 13
2.2.3 MANET Applications 13
2.2.4 MANET Challenges 14
2.3 TCP over MANET 16
  2.3.1 Full TCP 16
  2.3.2 TCP TAHOE 18
  2.3.3 TCP RENO 19
  2.3.4 TCP New RENO 21
  2.3.5 TCP SACK 21
2.4 Selfish / Misbehaving Node 22
2.5 Misbehaver Node Avoidance 23
2.6 Acknowledgement Based Method 24
  2.6.1 1-ACK Method 24
  2.6.2 TWO-ACK Method 25
  2.6.3 2-ACK Method 25
  2.6.4 Selective Acknowledgment (SACK) 26
  2.6.5 Negative Acknowledgment (NACK) 28
2.7 Comparison and Discussion 29
2.8 Summary 30

3 RESEARCH METHODOLOGY
  3.1 Introduction 31
  3.2 Operational Framework 31
  3.3 Development Phase 32
  3.4 Evaluation Phase 35
    3.4.1 Network Simulator 35
    3.4.2 Simulation Setup 35
    3.4.3 Evaluation Metrics 36
  3.5 Summary 37

4 DESIGN AND IMPLEMENTATION
  4.1 Introduction 38
  4.2 Motivation 38
4.3 Designing and Implementation of Selfish Nodes 39
  4.3.1 Designing the Selfish Node 39
4.4 NACK Method 41
  4.4.1 NACK Communication Method 42
4.5 Design and Development of S-NACK 43
  4.5.1 S-NACK Design 44
4.6 Summary 45

5 FINDING AND DISCUSSION
  5.1 Introduction 47
  5.2 S-NACK Simulation 47
  5.3 Discussion 56
  5.4 Summary 57

6 CONCLUSION
  6.1 Introduction 58
  6.2 Contribution 59
  6.3 Project Achievements 60
  6.4 Future Work 61

REFERENCES 62
## LIST OF TABLES

<table>
<thead>
<tr>
<th>TABLE NO.</th>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Comparisons of ACK Methods</td>
<td>30</td>
</tr>
<tr>
<td>3.1</td>
<td>Simulation setup</td>
<td>37</td>
</tr>
<tr>
<td>5.1</td>
<td>The packet delivery ratio of NACK</td>
<td>50</td>
</tr>
<tr>
<td>5.2</td>
<td>The packet delivery ratio of S-NACK</td>
<td>51</td>
</tr>
<tr>
<td>5.3</td>
<td>Network energy analysis for NACK and S-NACK</td>
<td>52</td>
</tr>
</tbody>
</table>
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>FIGURE NO.</th>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>NACK method</td>
<td>5</td>
</tr>
<tr>
<td>2.1</td>
<td>2-ACK communication</td>
<td>26</td>
</tr>
<tr>
<td>2.2</td>
<td>S-ACK method</td>
<td>27</td>
</tr>
<tr>
<td>2.3</td>
<td>NACK method</td>
<td>28</td>
</tr>
<tr>
<td>3.1</td>
<td>Operational framework of the research</td>
<td>33</td>
</tr>
<tr>
<td>3.2</td>
<td>Framework of S-NACK</td>
<td>34</td>
</tr>
<tr>
<td>4.1</td>
<td>Simple NS2 trace file</td>
<td>40</td>
</tr>
<tr>
<td>4.2</td>
<td>Procedure of packet dropping by selfish node</td>
<td>41</td>
</tr>
<tr>
<td>4.3</td>
<td>How to apply NACK in tcl code</td>
<td>42</td>
</tr>
<tr>
<td>5.1</td>
<td>Comparing the energy efficiency of NACK and S-NACK</td>
<td>52</td>
</tr>
<tr>
<td>5.2</td>
<td>Comparing the remaining energy on forwarder nodes in NACK/S-NACK</td>
<td>53</td>
</tr>
<tr>
<td>5.3</td>
<td>A Compares of Packet Delivery Ratio between NACK and S-NACK</td>
<td>54</td>
</tr>
<tr>
<td>5.4</td>
<td>Performance of the network on S-NACK and NACK</td>
<td>55</td>
</tr>
<tr>
<td>5.5</td>
<td>Network performances based on network throughput S-NACK and NACK</td>
<td>56</td>
</tr>
</tbody>
</table>
CHAPTER 1

INTRODUCTION

1.1 Introduction

Mobile Ad Hoc Network (MANET) is composed of a number of autonomous, self-organize, resource constraint, and mobile nodes, which communicate with each other over, low capacity links. These networks suffer from lack of centralized infrastructure. The network topology in MANET is dynamic because of mobility of nodes. Therefore, the MANET suffers from dynamic and unpredictable links. Each node performs the network functions in MANET individually or collaboratively with other nodes. For example, the routing is done in collaboration with other nodes. The collaborative functions that need to collaboration of a set of nodes in network have a direct impact in network performance. MANET is employed in different military and civilian applications such as healthcare, monitoring, and so on.

In general, based on the user of MANET, it can be divided into two types including (Miranda and Rodrigues, 2002). In open MANET, there are different users with various aims; these users collaborate with each other with sharing their resources in order to gain connectivity to other nodes which are not in their communication range. In contrast, closed MANET is composed of a number of nodes with common authority controls. The nodes in close MANET act collaboratively with each other to achieve the same goal. Due to characteristics of open MANET, they are prone to appearance of misbehaving nodes such as selfish nodes. Selfish nodes can exist in the network because
of couple of reasons. First, since the communication medium is open in open MANET, mobile hosts suffer from lack of suitable physical protection, which makes vulnerable these networks to misbehavior actions. Second, most of the mobile hosts suffer from resource-constraint and performing the collaborative network functions needs to considerable amount of resource wasting such as energy, memory, and so on. Hence, some of nodes (i.e., selfish nodes) consciously don't participate in collaborative functions in order to save their limited resource. Since the MANET suffers from lack of centralized management system, detecting this selfish nodes and prevention of the misbehaviour actions is a so challenging problem in these networks.

The misbehaviour by selfish node is different from malicious behaviour. In fact, the selfish nodes use the network for own goals and they don't participate in collaborative tasks for helping to other nodes to save their own limited resources. However, their aim is not to damage the network. In contrast, the mission of malicious nodes is wasting the limited resource of other nodes to damage the network.

The Transmission Control Protocol (TCP) is one of main protocols in transport layer in protocol stack. This mission of this protocol is providing a reliable end-to-end data transmission. Due to memory constraints, packet loss is one of major problems with using TCP over MANET. While the mobile ad hoc networks suffer from losses due to errors or mobility and links. In addition, different reactions are needed for packet losses.

TCP New Reno introduced by Allman et al. (2001), to avoid timeouts in the case of multiple segments lost from the same window by staying in the fast retransmit/fast recovery phase until all the segments are correctly received. The packet losses, which are made use to a window of data, have a dramatic impact on throughput of TCP. TCP employ a cumulative acknowledgment method. In this method, the received segments which are not at the left edge of the receive window, and are not acknowledged. This situation forces the sender node to find out each lost packet and unnecessarily retransmits a correctly received segment or wait a round-trip time. Cumulative acknowledgment method suffers from multiple dropped segments. Therefore, the TCP
loses its ACK-based clock and overall throughput is reduced. To handle this problem, Selective Acknowledgment (SACK) is proposed. Using the selective acknowledgments, all successful received segments are informed to sender. Consequently, the sender needs to only retransmit those segments that actually have been lost. TCP SACK recuperates all segments lost from the current window faster than TCP New Reno by having specific information about the packets in flight and the ones correctly received (Fall, K. and S. Floyd 1996).

1.2 Problem background

Owing to MANET characteristics there are variety kinds of challenges in Ad-hoc networks such, as the nodes in MANET are energy constrained because they supply by battery. Also, open MANETs are vulnerable to selfish nodes so that the selfish nodes perform misbehaviour actions and significantly decrease the packet delivery rate. Third, transport layer such as TCP in MANET is not efficient due to several reasons specific to these networks: loss channels, path asymmetry, network partitions, route failures, and power constraints. Fourth, the MANET suffers from dynamic network topology, which handling the mobility make more overhead in different functions such as communication protocols.

According to MANET characteristics, packet dropping by selfish nodes is an abnormal action, which can drop the network performance. To deal with this problem, the selfish nodes should be detected and avoided to improve the network performance.

Hop-by-hop detection and end-to-end detection are two main approaches for detecting the selfish nodes in open MANET in order to avoid the abnormal actions and improve the packet loss. End-to-End detection methods are focused on packet mission time and forwarder will be forward incoming packet until destination. Detection and analysis are occurred on destination. In contrast, Hop-by-hop detection methods are focused on message authentication and every intermediate or forwarder can detect the
messages originality whether or not the messages come from the trusted nodes, sent to next hop or dropped by next/last hop. En-route filtering methods are well-known candidate in this category. Also, Hop-by-hop detection can be successful when it is associated with routing acknowledgement.

In MANET it is assume that all nodes cooperative work with each other in trustworthy way. Therefore, the routing and delivering a packet from source to destination is possible. However, some of nodes cannot take part in network activities due to resource limitations such as low battery. According to Buttyan and Hubaux (2008), a node that only use the other nodes resources for own benefit and doesn't help to other nodes in network activities called selfish node. If a selfish node exists in a route, routing in this route lead to packet loss and this route is called misbehaviour route. To handle the misbehaviour route, the source nodes discover the new route. However, this route may compose of a selfish node. Therefore, due to misbehaviour routes, the packet delivery ratio is reduced significantly. To detect and reduce the impact of misbehaviour routes in MANETs, several methods have been introduced in literatures. Some of the techniques use a credit-based method (Buttyan and Hubaux, 2003; Zhong et al., 2003; Wang and Li, 2006; Eidenbenz et al., 2008). The key problem of credit-based method is that these methods usually need to a hardware called tamper-resistant to protect the virtual currency or an extra payment system. The second group is techniques use a reputation-based method (Marti et al., 2000; Buchegger and Boudec, 2002; Liu and Yang, 2003). Marti et al. (2000) introduced two models for detecting the selfish node called watchdog and path rater. The watchdog use overhearing to detect the selfish nodes whereas, the path rater avoid the selfish nodes in route discover procedure. The overhearing method is not efficient to detecting the selfish nodes in MANET because the transmission is unstable in MANET to handle this problem; Liu et al. (2007) introduced an acknowledgment-based approach to overcome the weaknesses of overhearing. They propose two-hop acknowledge packets as receipts method (2ACK) in order to a node can confirm whether or not its next-hop forwards the data packets.

Negative Acknowledgment (NACK) is defined as an acknowledgment-based approach method that is focused on negative acknowledgment. NACK proposed by Jeba
and Paramasivan (2012) to prevent routing abnormal action. This method can detect misbehaviour actions based on reply ACK to last two nodes in MANET chain. In this method, each node will monitor by last two nodes. Figure 1.2 shows the quick method of NACK communications between S as the source and D as the Destination and Nᵢ as the intermediate node. Although NACK can detect most of abnormal actions in communication chain, via applying this method, network availability will be endangered. Sending reply packet to two last nodes for all incoming packets generate high overhead and needs much power and great bandwidth. Due to the characteristics of nodes, they are suffering from low power computing and low bandwidth (Jeba and Paramasivan, 2012).

Considerable factors to network availability assessment are presented as communication protocol. NACK improves the packet delivery rate in communication protocols with detecting and avoiding the selfish nodes. However, the negative feedback of NACK can be justified by its high overhead and high-energy consumption in communication Protocol. Regards to NACK nature, this method is constructed based on duplex TCP connection. Therefore, a novel solution should be designed and developed to utilize the NACK advantages, while focus on reducing the network overhead and energy consumption.

**Figure 1.1** NACK method (Sun et al., 2012)
1.3 Problem Statement

Selfish nodes in open MANET generate an abnormal behaviour. For example, in communication protocols if a selfish node is selected as a node in the path from source to destination; it will not participate in routing process to save its constraint resources. Therefore, the routing process is failed and undergoes a high overhead to discover another path from source to destination node, which may contain another selfish node in between, cause’s packet loss and a drop in the packet delivery rate. Consequently, the network performance will be significantly reduced. Detection of misbehaviour or selfish nodes in network and avoiding these nodes to prevent the abnormal actions in the routing process is one of the most important problems in open MANET. Acknowledgement based selfish node detection and avoidance approaches is most promising method to this end. Among the existing acknowledgement based approaches, the Negative Acknowledgement (NACK) method has suitable selfish node detection and avoidance results. However, the method, which is designed for this end, suffers from high overhead, which leads to high-energy consumption. Since the energy of a node is supplied by battery and the changing and replacing of the battery is too costly in MANET, enhancing the existing NACK method by low overhead mechanisms which leads to reduction in network overhead and improve the energy consumption is essential due to energy constraints node in MANET.

1.4 Purpose of the Study

The main goal of this research is to design and develop an energy efficient acknowledgement based misbehaviour node detection and avoidance method for open MANET with selfish nodes to mitigate the communication overhead and improves the energy consumption while preserving the packet delivery rate.
1.5 Research Questions

Based on the purpose and requirements of the study, the general research question is: How to design an energy efficient acknowledgement-based misbehaver node detection and avoidance method in open MANET with low overhead and good packet delivery rate?

In order to be able to answer this question, a set of research questions is presented as follows:

i. How to mitigate the overhead of different acknowledgements messages to reduce the network overhead?

ii. How to decrease the energy consumption to improve the packet delivery rate?

iii. How NACK can improved based on energy and overhead?

1.6 Objective of the Study

To attain research aim, the following research objectives have been identified:

i. To investigate current acknowledgement based misbehavior node detection method and formulating the problem.

ii. To design and develop an energy efficient acknowledgement based misbehaver node detection and avoidance method for open MANET.

iii. To evaluate and validate the performance of the proposed method.
1.7 Significance of the Study

Misbehaviour node detection and avoidance problem in MANET is a challenging problem in which usually the network performance is scarified to improve the detection rate. As in MANET nodes have limited resource of energy, finding a method, which can preserve the detection rate of misbehaviour nodes while improving the network performance metrics such as energy consumption is an important issue. This research introduces a solution to acknowledgement based misbehaviour node detection and avoidance problem in open MANET. This proposed method improves the network overhead and network energy consumption of mobile nodes while the packet delivery is almost similar to existing methods.

1.8 Scope of the Study

The scope of this study is limited to some key points as follow:

i. This research mainly focuses on acknowledgement-based detection and avoidance of selfish nodes problem in open MANET and, at the same time, improve the network overhead and energy consumption.
ii. All normal and selfish nodes are randomly and uniformly scattered in a two dimensional area.
iii. The implementation of previous and proposed methods based on DSR routing protocol.

1.9 Organization of the Study

This thesis is organized into six chapters. Chapter 1 introduces the overall plan of this research. Chapter 2 reviews the literature related to misbehaviour nodes
detections and avoidance methods and overhead suppressing and energy improvement in MANET following by Chapter 3 to present the research methodology that is conducted in this research. Chapter 4 introduces acknowledgement based misbehaver node detection and avoidance problem and proposes an energy efficient method for solving this problem. In Chapter 5, the finding and discussion presented. Finally, Chapter 6 concludes the thesis and presents the limitations and contributions of the present research.
REFERENCES


Parker, J. Discussion Record for the 1st MANET Reading Group Meeting.


Stevens, W. R. 1997. TCP slow start, congestion avoidance, fast retransmit, and fast recovery algorithms.


