UNIVERSITI TEKNIKAL MALAYSIA MELAKA

CORRELATED SURVIVABILITY ANALYSIS MODEL FOR MANETS

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A thesis submitted
in fulfillment of the requirements for the degree of Doctor of Philosophy

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DECLARATION

I declare that this thesis entitled "Correlated Survivability Analysis Model for MANETS" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ....

Name : AZNI HASLIZAN BT AB HALIM

Date : ....

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Doctor of Philosophy.

Signature : ……………. ....

Supervisor Name : PROF MADYA DR RABIAH BT AHMAD

Date : …………………….. ....

DEDICATION

To my beloved husband and sons

ABSTRACT

Mobile ad hoc networks (MANETs) rely on collective nodes effort which requires node to be in cooperative behavior to continuously offer network services. Furthermore, node in MANETs shows correlated node behavior due to topology changes, node misbehavior or security attacks in which poses a significant impact on network survivability. However, correlated node behavior is not reflected as one of the metric in analyzing network survivability with current survivability models. The models did not represent real life scenario with the assumption made on individual node behavior. This limitation resulted inaccuracy when analyzing network survivability. To overcome the limitation of current research, this thesis presents a new network survivability analysis model which captures correlated node behavior to depict node behavior in MANETs and proposed a way to minimize the impact of correlated node behavior. Firstly, before network survivability analysis is modeled, a better understanding of dynamic characteristics of node behavior and its correlated behavior need to be studied and modeled. In this thesis, a merging of semi Markov process and Susceptible-Infection-Remove (SIR) epidemic theory is proposed to stochastically model correlated node behavior. To capture correlated node behavior, correlated degree is proposed in the model as a new metric to measure the impact of network survivability under correlated node behavior. Correlated node behavior model leads to a better understanding and prediction of the critical condition and the speed of spreading correlated node behavior to entire network. Network survivability under correlated node behavior is analyzed based on statistical method of multivariate survival analysis in medical research. The modification of Cox Proportional Hazard regression model in particular correlated hazard function is proposed to analyze the probability of correlated node behavior and to determine variables that significantly influence network survivability. The result on regression analysis shows energy consumption and correlated degree are the most significant variables that influence network survivability. Furthermore, probability of network survivability also can be determined. A new algorithm of topology formation is proposed with correlated degree metric to mitigate the impact of correlated node behavior on network performances. The simulation result shows that, with the new algorithm, energy consumption in MANETs can be balance which prolong node life time and increase network survivability. In addition, new algorithm also prevents network topology from partitioning. With new survivability analysis model, the status of network can be precisely measured and countermeasure can be done earlier to prevent network disruption.

ABSTRAK

Rangkaian ad hoc bergerak (MANETs) bergantung kepada kerjasama sekumpulan nod untuk menawarkan perkhidmatan rangkaian. Nod MANETs juga menunjukkan berlakunya korelasi tingkah laku nod disebabkan oleh perubahan topologi, salah laku nod atau serangan keselamatan di mana ia memberi impak yang sangat besar kepada kemandirian rangkaian. Walaubagaimanapun, korelasi tingkah laku nod tidak diambil kira sebagai salah satu metrik di dalam model menganalisa kemandirian rangkaian yang sedia ada. Model ini tidak menunjukan keadaan sebenar dengan hanya mengandaikan tingkah laku nod berlaku secara individu sahaja. Kekurangan ini menyebabkan kemandirian rangkaian tidak dapat dianalisa dengan tepat. Untuk mengatasi masalah ini, tesis ini menghasilkan model menganalisa kemandirian rangkaian dengan mengambil kira korelasi tingkah laku nod dan cara untuk meminimumkan impak korelasi tersebut. Pertama, sebelum kemandirian rangkaian dimodel, pemahaman terhadap tingkah laku nod dan cara terjadinya korelasi amatlah penting untuk diketahui. Di dalam tesis ini, penggabungangan di antara konsep semi Markov dan model epidemik "Susceptible Infection dan Remove" (SIR) dicadangkan di dalam model stokastik tingkah laku berkorelasi. Darjah korelasi (correlated degree) dicadangkan di dalam model untuk menunjukkan berlakunya korelasi sebagai metrik baru untuk mengukur kesan kepada kemandirian rangkaian. Model ini juga dapat memberi petunjuk tentang pemahaman dan ramalan pada keadaan genting. Ia juga dapat menentukan kepantasan tingkah laku korelasi ini tersebar ke seluruh rangkaian. Kemandirian rangkaian MANETs semasa situasi korelasi dianalisa menggunakan statistik kemandirian multivariate yang dipakai di dalam bidang perubatan. Berdasarkan model Cox Proportional Hazard regression, fungsi bahaya berkorelasi (correlated hazard function) diperkenalkan untuk menganalisa kebarangkalian berlakunya situasi korelasi dan untuk menentukan pembolehubah yang mempengaruhi kemandirian rangkaian. Keputusan analisa kemandirian rangkaian menunjukkan penggunaan tenaga dan darjah korelasi adalah pembolehubah yang paling penting dalam mempengaruhi kemandirian rangkaian. Satu algoritma baru untuk pembentukan topologi dicadangkan dengan menggunakan metrik darjah korelasi bagi memperbaiki kemandirian rangkaian MANETs apabila berlakunya tingkah laku korelasi. Ini penting untuk mengenal pasti nod genting dan berpotensi untuk berlakunya situasi korelasi. Penggunaan algoritma yang baru menunjukkan penggunaan tenaga di MANET dapat diselaraskan di mana ini akan memanjangkan jangka hayat nod dan meningkatkan kemandirian rangkaian. Algoritma ini juga dapat mencegah rangkaian dari berlakunya pecahan. Dengan adanya model analisa kemandirian rangkaian ini, status rangkaian dapat diketahui dengan tepat dan langkah balas dapat dilakukan untuk menghalang berlakunya perpecahan rangkaian.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

FIGURE	TITLE	PAGE

LIST OF APPENDICES

LIST OF SYMBOLS

m	-	Malicious
c	-	Cooperative
s	-	Selfish
f	-	Fail
r	-	Radius
d	-	Node degree
A	-	Probability of dropping
B	-	Probability of forwarding
C	-	Probability of injecting
D	-	Probability of loss
t	-	Time
S	-	Susceptible
I	-	Infection
R	-	Removed
P_{ij}	-	Transition probabilities from state *i* to *j*
CDF	-	Cumulative Distribution Function
CTM	-	Correlated Transmission Matrix
T_{ij}	-	Sojourn time from state *i* to *j*
$\mathbb{F}$	-	Transition time distribution matrix
$\tilde{\pi}$	-	Steady-state transition probability distribution
$E[T_{ij}]$	-	Expected sojourn time from state *i* to *j*
δ	-	Susceptible rate

β	-	Infection rate
λ	-	Remove rate
N	-	Number of node
$\omega(e)$	-	Weight function
Ω	-	Set of node behavior
$Z(t)$	-	Stochastic process
X_n	-	Embedded Markov chain
a_{uv}	-	Adjacent matrix
ψ	-	Correlated degree
θ	-	Critical condition threshold
$S_{uv}(t)$	-	Survival function
$h_{ij}(t)$	-	Hazard function
$H_{ij}(t)$	-	Cumulative hazard function
$h_C(t)$	-	Hazard function for node in cooperative state
$h_M(t)$	-	Hazard function for misbehave node
$h_w(t)$	-	Correlated hazard function
Dst_u	-	Euclidian distance node u
ψw	-	Diagonal matrix of $W(t)$
$D(t)$	-	Node degree matrix
$W(t)$	-	Weighted matrix
$W_cSet(u)$	-	Correlated cooperative set
$\omega_{uv}(t)$	-	Correlated node cooperativity
λ_2	-	Eigenvalue

LIST OF ABBREVIATIONS

ACM	-	Association for Computing Machinery
AODV	-	Ad hoc On-Demand Distance Vector
CTC	-	Correlated Topology Control
DoS	-	Denial of Service
ICT	-	Information and Communication Technology
IEEE	-	*Institute of Electrical and Electronics Engineers*
MANETS	-	Mobile Ad hoc Networks
MOSTI	-	Ministry of Science, Technology and Innovation
MTTF	-	Mean Time to Failure
QoS	-	Quality of Services
RFID	-	Radio-frequency identification
SAODV	-	Secure Ad hoc On-Demand Distance Vector
SIR	-	Susceptible-Infected-Removed
SLR	-	Systematic Literature Review
SRP	-	Secure Routing Protocol
TPM	-	Transition Probability Matrix
VANETS	-	Vehicular Ad Hoc Networks
WSN	-	Wireless Sensor Networks

LIST OF PUBLICATIONS

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CHAPTER 1

INTRODUCTION

1.1 Introduction

The usage of wireless technology has tremendously increased due to the rapid proliferation of wireless lightweight devices such as laptops, PDAs, wireless telephones, and wireless sensors. It started in the early 2000s when mobile devices converged with web services to deliver information at the fingertips (Kumar & Mishra 2012). Since then, the technology has changed the way people work, live and think. Now that wireless technology offers high-rate data transmission services provided by the current 4G networks, the usage and the dependence on mobile networks are becoming unpredictably high. There is no doubt that wireless devices offer convenient and flexible network access for the users to communicate anytime and anywhere in the areas covered by the networks. Thus, the dependency of wireless device claims for high level of reliability, survivability and security on transactions supported by wireless distributed systems.

Wireless networks infrastructures are formed by routers and hosts. The routers are responsible for forwarding packets in the network and the hosts may be the sources or the sinks of data flows (Nicholals & Lekkas 2002). In wireless networks, the routers may be static or mobile. Static routers use an access point to connect to the backbone networks. On the other hand, mobile routers use a device known as a mobile node as a router. The network with a static router is categorized as infrastructure-based and the network with a mobile router is categorized as infrastructureless. Nowadays, researchers are more interested in the infrastructureless network or better known as a wireless ad hoc network such as the Mobile Ad hoc Networks (MANETs), Wireless Sensor Networks (WSN), RFID and the Vehicular Ad Hoc Networks (VANETs). This is due to the demands on the frequently connected applications offered by these networks. A report by the Ministry of Science, Technology and Innovation (MOSTI) Malaysia under the Strategic ICT roadmap (2008) highlighted that the wireless ad hoc network is one of the Malaysian government's initiatives towards ubiquitous network society. Figure 1.1 below shows the classification of wireless network in detail. The focal point of this PhD research is in the area of MANETs. Hence, this section focuses on the discussions related to the issues of MANETs.

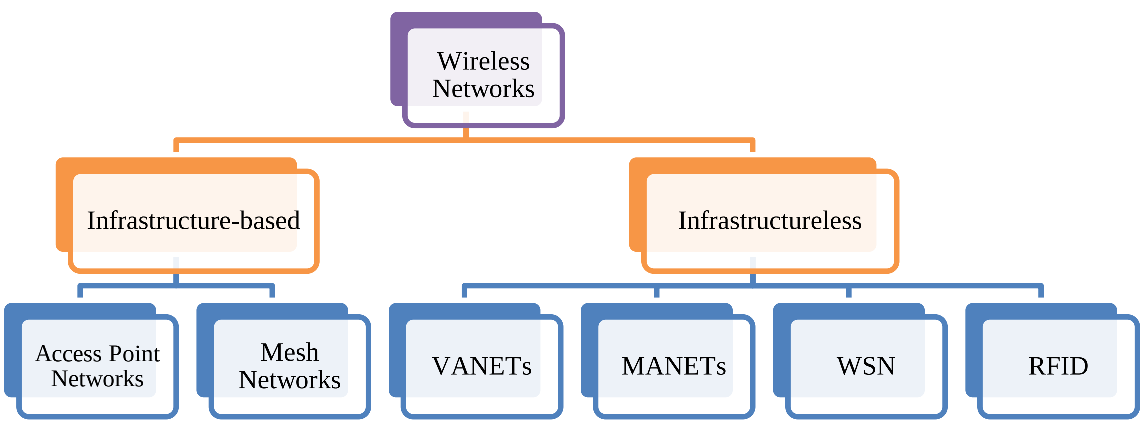

Figure 1.1 : Classifications of wireless networks

1.2 Mobile Ad Hoc Network Characteristics

The mobile ad hoc network (MANETs) is an example of a wireless distributed system. It composes of autonomous system of mobile routers and associated hosts connected by wireless links (Sharma & Ghose 2010) . The objective of MANETs is to provide ubiquitous platform for user-friendly easy access connections in daily life for a knowledge society (*K*-society). Figure 1.2 shows MANETs topology for communication.