FACTORS AFFECTING THE PERFORMANCE OF DYNAMIC SOURCE ROUTING PROTOCOL IN MOBILE AD HOC NETWORKS USING TAGUCHI APPROACH

MAZALAN BIN SARAHINTU

UNIVERSITI TEKNOLOGI MALAYSIA

To my beloved mum, Aidah bt Juhaili
my father, Sarahintu b O.T Ripa
my wife, Salwah bt Mad Matar
and to all my brothers and sisters
Faridah, Roslan, Salmiah, Patmah, and Sopian.

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ABSTRACT

The performance of dynamic source routing (DSR) protocol in mobile ad hoc networks is influenced very much by several factors that define the network environment and scenario. The factors include terrain, network size, node velocity, pause time, transmission range, traffic load, and packet rates. The purpose of this research is to analyze the effects of these factors and some interactions on two performance metrics, namely routing overhead and drop rates. Taguchi approach has been applied in this study. For a preliminary experiment, L_4 orthogonal array was used to determine the effects of terrain, pause time, and node velocity on the performance of DSR. Among these factors, we found that the most influential factor on drop rates was terrain, followed by pause time and node velocity. For routing overhead, we discovered that node velocity was the most effective factor, followed by pause time and terrain. Furthermore, L_8 orthogonal array was applied to analyze the effect of all the factors above. The most important results were that the effects of transmission range, terrain, network size, packet rates, and pause time were significant on drop rates. For routing overhead, we discovered that the effects of network size, pause time, node velocity, and traffic load were significant. Finally, using suitable orthogonal arrays, the investigation was carried out to identify the effect of interactions between the significant factors. The effect of interaction between terrain and pause time on drop rates was found to be present and significant.

ABSTRAK

Prestasi Protokol Penghalaan Sumber Dinamik dalam Rangkaian Bergerak Sembarangan amat dipengaruhi oleh beberapa faktor yang menentukan rangkaian persekitaran dan senario. Faktor-faktor ini termasuklah luas kawasan rangkaian (LKR), saiz rangkaian, masa berhenti seketika (MBS), halaju nod, had penghantaran, muatan trafik, dan kadar penghantaran data (KPD). Tujuan tesis ini adalah untuk menganalisa kesan faktor-faktor ini dan beberapa interaksi di antara mereka terhadap dua metrik prestasi iaitu kadar paket yang jatuh (KPJ) dan overhed penghalaan. Kaedah Taguchi telah digunakan dalam kajian ini. Pada awal eksperimen, tatasusunan ortogon L_4 digunakan untuk menentukan kesan LKR, MBS, dan halaju nod. Di antara faktor-faktor ini, kami dapati faktor yang paling berpengaruh terhadap KPJ adalah LKR, diikuti oleh MBS dan halaju nod. Bagi overhed penghalaan pula, kami dapati halaju nod adalah faktor yang paling berkesan, diikuti oleh MBS kemudian LKR. Seterusnya, tatasusunan ortogon L_8 digunakan untuk menganalisa kesan semua faktor di atas. Keputusan yang paling penting kami perolehi adalah kesan had penghantaran, LKR, saiz rangkaian, KPD, dan MBS signifikan terhadap KPJ. Bagi overhed penghalaan pula, kami dapati faktor yang signifikan adalah LKR, MBS, halaju nod, dan muatan trafik. Akhir sekali, dengan menggunakan tatasusunan ortogon yang sesuai, ujikaji dilakukan untuk mengenal pasti beberapa interaksi di antara faktor-faktor yang signifikan tadi. Didapati kesan interaksi yang wujud di antara LKR dan MBS terhadap KPJ adalah signifikan.

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MANET	-	Mobile Ad Hoc Network
LAN	-	Local Area Network
MS	-	Mobile Station
DSR	-	Dynamic Source Routing
IETF	-	Internet Engineering Task Force
RFC	-	Request For Comments
PDA	-	Personal Digital Assistant
QoS	-	Quality of Service
CPU	-	Central processing unit
DSDV	-	Destination Sequenced Distance Vector
TORA	-	Temporally Ordered Routing Algorithm
AODV	-	Ad Hoc On Demand Distance Vector
WRP	-	Wireless Routing Protocol
CGSR	-	Clusterhead Gateway Switch Routing
CBRP	-	Cluster Based Routing Protocol
ABR	-	Associativity Based Routing
ZRP	-	Zone Routing Protocol
FUFD	-	Full factorial design
FRFD	-	Fractional factorial design
Df	-	Degrees of freedom
Df_{OA}	-	Degrees of freedom for an orthogonal array
Df_r	-	Total degrees of freedom for factors and interactions

Df_A	-	Degrees of freedom for factor A
k	-	Number of levels (values) for factor
k_A	-	Number of levels for factor A
M	-	Number of factors
SNR	-	Signal-to-noise ratio
MSD	-	Mean-squared deviation
STB	-	Smaller-the-better
LTB	-	Larger-the-better
NTB	-	Norminal-the-best
MSD_{STB}	-	Mean-squared deviation for smaller-the-better
MSD_{LTB}	-	Mean-squared deviation for larger-the-better
MSD_{NTB}	-	Mean-squared deviation for nominal-the-best
$\overline{y}$	-	Mean
y_0	-	Target value
s^2	-	Variance for sample
$Z(\Theta)$	-	Observation (in signal-to-noise ratio)
p	-	Proportion of good products in experiments
ANOVA	-	Analysis of variance
NS-2	-	Network Simulator 2
Tcl	-	Tool Command Language
OTcl	-	Object Tool Command Language
NAM	-	Network Animator
PDR	-	Packet delivery ratio
NPD	-	Number of packets dropped
g	-	Number of packets delivered to a destination
h	-	Number of packets transmitted by a source
r	-	Radius transmission range
d	-	Euclidean distance between two nodes
$E_t(r)$	-	Energy consumption for the transmission range of nodes

r	-	Radius of transmission range of nodes
pckts	-	Packets
A	-	Factor of interest
A_1	-	Sum of observations under condition A_1
$\bar{A}_1$	-	Average of observations under condition A_1
A_{effect}	-	Estimated effect of factor A
T	-	Sum of observations
$\bar{T}$	-	Grand average
S.I	-	Severity Index
CF	-	Correlation factor
N	-	Total number of experiments
N_{A_1}	-	Number of observations with factor A at level 1
SS	-	Sum of Squares
SS_A	-	Sum of squares due to factor A
SS_T	-	Total sum of squares
SS_e	-	Sum of squares for error
V	-	Variance
V_A	-	Variance for factor A
V_e	-	Variance for error
SS'	-	Pure sum of squares
SS'_A	-	Pure sum of squares for factor A
P	-	Percent influence
P_A	-	Percent influence for factor A
P_e	-	Percent influence for error
F	-	F test
$\hat{\eta}_p$	-	Predicted signal-to-noise ratio of drop rates
$\hat{\eta}_q$	-	Predicted signal-to-noise ratio of routing overhead
y_i	-	ith observation
$Y_{expected}$	-	Expected performance at original units

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CHAPTER 1

INTRODUCTION

1.1 Background

Wireless communication between mobile users has become ever more popular over the last couple of years. This is due to recent technological advances in laptop computers and wireless data communication devices, such as wireless modems and wireless LANs (Local Area Networks). This has lead to lower prices and higher data rates, which are two main reasons why mobile computing continues to enjoy rapid growth.

Mobile ad hoc networks (MANETs) are a special type of wireless networks in which a collection of mobile platforms such as PDAs, cell-phones, and laptops, which are also known as nodes, formed a temporary network without relying to any organized administration, for example base station. This network is useful in disaster recovery situations and places with non-existing or damaged communication infrastructure, where a rapid deployment of a communication network is needed. MANETs are also useful on conferences where people in the conference can form a temporary network without engaging the services of pre-existing network, for example LANs.

In this network, since some receiving nodes may be out of the direct transmission range of a sending node, intermediate nodes have to act as routers to forward packets to the receiving nodes. For this reason, some of routing protocols are necessary to make the routing decisions. These techniques include guidelines that allow nodes to discover and maintain routes to arbitrary destinations in the network. To date, there are no standard for a routing protocol for mobile ad hoc networks, instead this work continues [1].

Many studies have been carried out to improve MANETs algorithms and techniques to solve routing, for example DSDV [2], TORA [3], DSR [4], and AODV [5]. However, in this thesis, our aims are to determine and analyze the effects of several factors including interactions on the performance of DSR protocol. The DSR has been chosen because it is one of the more generally accepted routing proposed for MANETs [6]. Prior to this study, Lee [7] has performed analysis on the DSDV protocol.

1.2 Problem Statement

Recently, many routing protocols have been proposed in solving routing problems in mobile ad hoc networks [8], some of which we mentioned above.

Before employing a routing protocol in a real network, it has to be thoroughly simulated to find bugs [9] and test its reliability and robustness over a certain network configuration and scenario [10]. The DSR performance can be accessed by examining a set of performance metrics including drop rates and routing overhead [11, 12]. For instance, the routing overhead reveals the scalability of a protocol and its efficiency in terms of consuming battery power.

In addition to these performance metrics, there are also several factors which include terrain, network size, node velocity, pause time, transmission range, traffic load, and packet rates [11, 12]. These factors are always used and crucial for examining the DSR performance under a specified scenario, mobility, work load etc. These parameters along with the unique characteristics of MANETs can result in unpredictable variations in the overall protocol performance [13].

Considering the facts we mentioned above, our main problem involves determining the effects of the factors over the DSR performance system. We utilize statistical Taguchi approach to analyze the effects of the factors and some interactions on the DSR performance with regard to drop rates and routing overhead. This study can facilitate the identifications of the influential factors, and hence helping to determine if each factor has a significant effect to the performance metrics. Compiling all factors that might influence the protocol performance is inadequate. Therefore, before accepting and controlling any set of factors as appropriate, we have to determine whether or not they actually have any effect on the performance metrics of interest. This study also indirectly introduces the use of Taguchi technique as a novel approach on the investigation and prediction of MANETs and routing protocols performance, which was initiated by Lee [7].

1.3 Research Objectives

The objectives of this research are outlined as follows:

a) To analyze the influence of process parameters on the DSR performance.

b) To determine the main and some interaction effects of the factors that affect the DSR performance.

c) To rank the factors that affect the DSR performance.

d) To determine the factors that significantly affect the DSR performance.

e) To predict the performance of the DSR at the optimum conditions.

1.4 Research Methodology

Our research methodology consists of the following steps:

a) Selecting suitable matrix experiment of orthogonal array where we can study the effects of various process parameters simultaneously.

b) Finding a correct objective function to be studied which can be smaller-the-better, larger-the-better, and nominal-the-best with their corresponding signal-to-noise ratio.

c) Creating scenario files for the DSR simulations using Tcl scripts.

d) Using signal-to-noise ratio as a performance characteristic of measurement.

e) Using analysis of average effect and analysis of variance to analyze the factorial effects.

f) Using graphical methods such as response graph and interaction plot to study the behavior of the factorial effects.

1.5 Scope of the Study

This research focuses on the analysis of the DSR performance in MANETs using simulation experiments instead of real experiments or test-beds. The simulation scenario consists of a group of mobile nodes forming an ad hoc network within a small terrain such as conference hall with sparse distribution and small workload. The nodes are assumed to be moving according to the mean speed of walking pedestrian in a commercial area. Each mobile node has the transmission range of below 20 meters which correspond to any Bluetooth devices.

1.6 Significance of the Study

Results of this study would be helpful for routing designers in designing the future reactive protocols or improving the existing algorithms of the DSR protocol. This is because, by knowing the order of predominance established and the significance factors, when conducting simulations, the designers can know what parameters should be given high priority compared to others, which can act directly to improve and enhance the protocol performance.

1.7 Research Contributions

The following benefits are expected to be contributed by this study:

a) Shown the estimated effects of the factors and interactions on the DSR performance

b) Shown the rank order of the influential factors that affect the DSR performance

c) Revealed the most effective factor on the DSR performance

d) Revealed factors that have significant effects on the DSR performance

e) Shown the specific value of an optimum performance of the DSR protocol

1.8 Thesis Outlines

This thesis contains 7 chapters. Chapter 1 is the thesis introduction. It covers background of research, problem statement, research objectives, research methodology, scope of the study, significance of the study, and research contributions.

Chapter 2 discusses the mobile ad hoc networks, the properties for routing protocols, the classification of the routing protocols, and the DSR protocol. We also present some comparison of the protocols, and some previous works that are related to the DSR performance evaluations. Furthermore, we discuss the Taguchi method. It covers the theory of orthogonal arrays, the conceptual signal-to-noise ratio, analysis of variance, and the concept of additivity. We then discuss the description of NS-2 simulator used for the DSR simulation. Finally, we provide the explanation of the performance responses and provide the justifications for the factor-levels that we chosen in this study.

In Chapter 3, we use the L_4 orthogonal array to analyze the effects of the terrain size, pause time, and node velocity of the mobile nodes. We determine the effects of the factors on the performance metrics of drop rates and routing overhead.

In Chapter 4, we investigate the probability that the interaction effects between the terrain versus pause time on the DSR performance is present and significant. We show the ability of the L_4 orthogonal array to analyze the presence and significance of the interaction.

In Chapter 5, we consider seven factors that affect the performance of the DSR protocol. The factors include terrain, network size, pause time, node velocity, transmission range, traffic load, and packet rates of the mobile nodes. We use the L_8 orthogonal array to determine the significance factors over the performance metrics of drop rates and routing overhead.

In Chapter 6, the investigation is carried out to identify the probability of interactions between some of the significant factors. The interactions include the effect of terrain versus pause time and the effect of pause time versus transmission range against the DSR performance. The L_8 orthogonal array is used to analyze the presence and the significance of the interactions.

Chapter 7 presents the conclusions and discussions of this research. We also suggest some future study in this last chapter.