The Use of Taguchi Method to Determine Factors Affecting the Performance of Destination Sequence Distance Vector Routing Protocol in Mobile Ad Hoc Networks

[1]Hazura. Mohamed, [2]Muhammad Hisyam Lee, [2]Mazalan Sarahintu,
[2]Shaharuddin Salleh and [3]Bahrom Sanugi
[1]Department of Industrial Computing, Faculty of Information Science and Technology,
University Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia
[2]Department of Mathematics, Faculty of Science,
University Technology Malaysia, 81310 Skudai, Johor, Malaysia
[3]Faculty of Science and Technology, University Sains Islam Malaysia,
78100 Nilai, Negeri Sembilan, Malaysia

Abstract: In this study, Taguchi method was used to identify the several factors that may affect the performance of Destination Sequence Distance Vector (DSDV) routing protocol. The performance of DSDV routing protocol in mobile ad hoc networks were greatly influence by factors such as node speed, node pause time and traffic load. **Problem statement:** By using orthogonal experimental design and analysis techniques, the protocol performance can be analyzed with more objective conclusion through only a small number of simulation experiments. **Approach:** The performance was measured with respect to packet delivery ratio. Analysis of variance (ANOVA) was carried out to identify the significant factors affecting the response and the best possible factor level combination was determined through analysis of the signal-to-noise ratio. **Results:** It was found that the traffic load has a stronger influence on the packet delivery ratio, followed by the pause time. **Conclusions/Recommendations:** The optimal setting of the best performance is determined. The optimal setting has resulted in increased packet delivered. These findings demonstrate that Taguchi method may be valuable tool for the investigation of main effect or interactions of multiple factors in the performance of mobile ad hoc network routing protocols.

Key words: Taguchi method, analysis of variance, mobile ad hoc networks, destination sequence distance vector routing protocol

INTRODUCTION

A mobile ad hoc network (MANET) is a dynamic wireless network that can be formed with absence of infrastructure such as base stations or access points[2]. One of the main challenges in MANETs is the design of robust routing protocols that adapt to the frequent and randomly changing network topology. In recent years, a number of routing protocols have been proposed and evaluated as well. Due to the high cost of deploying and testing new mobile ad hoc networks architecture in real world, simulation is an often used tool to analyze MANETs[4]. Through simulation experiment it provides a vital alternative for conducting cheap and repeatable evaluations prior to actual deployment. However, the way they conducted the experiment is not stated clearly and the result may not be directly comparable even the used performance metrics are the same.

There are numerous routing protocols for mobile ad hoc networks have been developed under the authority of Mobile Ad Hoc Networking working group and charter of Internet Engineering Task Force (IETF). One of which is a Destination Sequence Distance Vector (DSDV)[12] routing protocol. DSDV is a one of table-driven routing protocols, which is an attempt to maintain optimal routes to all destinations at all times, regardless of whether they are needed. To support this, the routing protocol propagates information updates about a network's topology throughout the network. In DSDV each node maintains a routing table that list all available destination and routes to them. The sequence number is used to distinguish stale routes from new

Corresponding Author: Muhammad Hisyam Lee, Department of Mathematics, Faculty of Science, Universiti Teknologi Malaysia, 81310 Skudai, Johor, Malaysia.

ones and thus avoid the formation of loops. When DSDV detects a broken route, it stores the packet until the next route update at which time it tries to resend the packet. Several works on the DSDV performance were reported such as[2,3,5]. Nevertheless, the effects of the factors on the DSDV performance are yet to be analyzed. In this work, we carried out a systematic procedure to identify the effect of node speed, node pause time and traffic load on packet delivery ratio using Taguchi Experimental Design (TED). TED offers a way for the researcher to determine, before the runs are made, which specific configurations to simulate so that the desired information can be obtained with the least amount of simulating[7]. Lee[8] has been initially used of Taguchi approach to analyze and estimate the effects of MANET routing protocols performance. Subsequent works like[1,9] have been carried out.

MATERIALS AND METHODS

This research relates in identifying factors affecting DSDV performance. The ratio of message received by destination node over message sent by source node was measured. Since factors affecting the protocol performance are beyond the possibility even to be listed here, in this study Taguchi Experimental Design (TED) was used to find out the influence of the factors and their significance on the response. In this paper, three factors were considered in the protocol analysis and for each factor two levels were set (Table 1), while holding all other factors constant.

The justification of the factor levels chosen are as follow. Both node speed and pause time stress the node mobility in the network. Both values for node velocity are a minimum and maximum walking speed of pedestrian[14]. Pause time is a time, in seconds, for which mobile nodes pause before moving to another destination. The less this time is, the more active the mobile nodes are in moving. Both value choosing for pause time have a low and moderate mobility in the network. The traffic load is defined as a percentage of number of nodes acting as a source in the network. Each source transmits data at a certain value of packet sending rates, which called the packet rates.

Using the Taguchi experimental design, an orthogonal array was selected due to three factors and two levels for each factor. The selected orthogonal array for this study is the L_4 orthogonal array[12] (Table 1). The advantage of using an orthogonal array is the ability to estimates all the main factor effects and all the possible interaction where all orthogonal to one another, in a minimum of tests. This is considered an efficient experiment since much information is obtained from a few trials[10].

Table 1: Factors and levels

Label	Factors	Level 1	Level 2
A	Node speed (ms⁻¹)	0.72	1.34
B	Pause time (s)	10.00	50.00
C	Traffic load (packets/s)	4.00	8.00

For each experiment, five packet delivery ratios are obtained by repeating the experiment five times. These responses are further transformed to the signal-to-noise ratio η (S/N ratio) using the equation:

$$\eta = -10\log\left[\frac{1}{5}\sum_{i=1}^{5}\frac{1}{y_i^2}\right] \tag{1}$$

where, the packet delivery ratio y_i with larger the better response characteristic has been chosen. The overall mean value of η over the four experiments becomes:

$$\bar{\eta} = \frac{1}{4}\sum_{i=1}^{4}\eta_i \tag{2}$$

The effect of a factor is defined as the the absolute difference between the average S/N ratio of the two levels. For example, to calculate the average effect of factor A at level 1, all results of factor A at level 1 are averaged. Hence, the average effect of factor A at level 1 η_{A_1} and the effect of factor A can be written, respectively, as:

$$\eta_{A_1} = \frac{1}{2}\left[\eta_1 + \eta_2\right] \text{ and effect of A} = \left|\eta_{A_1} - \eta_{A_2}\right| \tag{3}$$

A factor with the largest effect means that it has the most significant influence on the response metric. The analysis of variance (ANOVA)[12] is used to discuss the relative effect of all factors on the response metric and to determine which factor has the highest effect. Parameters used in ANOVA are calculated by the following equations:

$$SS_T = \sum_{i=1}^{4}\left(\eta_i - \bar{\eta}\right)^2 \tag{4}$$

$$SS_j = \sum_{i=1}^{2}2\left(\eta_{j_i} - \bar{\eta}\right)^2 \tag{5}$$

$$SS_e = SS_T - \sum_{j=1}^{4}SS_j \tag{6}$$

$$\rho_j = \frac{SS_j}{SS_T}\times100 \tag{7}$$

Where:

SS_T = The sum of squares of the variance

SS_j = The sum of squares for each factor

SS_e = The sum of squares of the errors correlated to all factors

ρ_j = The percentage contribution related to each factor

The computed values for ρ_j tell us the relative importance of the three factors in determining high packet delivery ratio.

In estimating the predicted performance of S/N ratio for packet delivery ratio, only the selected level of the significant factors is used. The contribution of significant factor is obtainable by subtracting the overall mean of S/N ratio from the average effect of factor at desired level η_i. Let denotes Θ_j is a contribution of the factor j and Θ_j can be calculated as follows:

$$\Theta_j = \eta_i - \overline{\eta} \qquad (8)$$

Defining the predicted S/N ratio of packet delivery ratio as $\hat{\eta}$, the prediction equation can be written as[10]:

$$\hat{\eta} = \overline{\eta} + \sum_{j=1}^{p}\left(\Theta_j - \overline{\eta}\right) \qquad (9)$$

where, p is the number of significant factors.

Our simulation experiment was carried out using network simulator NS-2 version 2.29, which provide implementation of DSDV routing protocol. NS-2 is a discrete event simulator targeted at networking research. NS-2 provides substantial support for simulation of TCP routing and multicast protocols over wired and wireless (local and satellite) networks[13]. The simulations were carried out on an Intel Pentium IV processor at 2.00 GHz, 256MB of RAM running Linux Fedora Core 3. Each simulation experiment was executed for 300 seconds. We performed the simulations for 20 nodes networks, migrating in a 100 metre by 100 metre area. We used the random waypoint mobility model to model the mobility and the movement pattern of each node as default in NS-2. Each node has a transmission range of 30 meters.

RESULTS

Simulation experiments were done according to the experiment number shown in Frame A and was yielded the results in Frame B of Table 2. For the measured responses, S/N ratios calculated using Eq. 1 is presented in Frame C of Table 2.

Based on the S/N ratio in Table 2 and using Eq. 3, a response table was developed as in Table 3. Through this table we can evaluate the effect of each factor and obtain the best factor level combination.

To be clear, a main effect plots was used to visualize performance changes as each individual factor level is changed. Figure 1 shows the response graph for S/N ratio of packet delivery ratios. Each value along the *x*-axis corresponds to a 1 or 2 level for a particular factor. The slope of the line shift indicates the degree of particular factor has a main effect on the performance metric.

Based on Table 3 and Fig. 1, it was found that the strongest factor was the traffic load since its estimated effect was the biggest value and the degree of the slope was the highest, followed by the pause time and the node velocity. The optimal factor level combination was $A_2B_1C_2$, where the notation A_i was represents the ith level of the factor A.
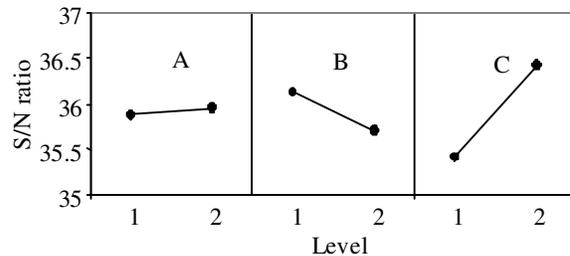

Fig. 1: Main effects plot for S/N ratio

Table 2: Simulation result

Exp. No.	Frame A Factor			Frame B					Frame C
	A	B	C	Packet delivery ratio (%)					η
1	1	1	1	54.19	73.85	58.56	62.72	56.65	35.586
2	1	2	2	74.94	65.15	64.62	66.67	55.57	36.190
3	2	1	2	75.21	78.00	71.55	58.37	63.90	36.676
4	2	2	1	48.31	58.87	60.48	57.29	70.94	35.246
								$\overline{\eta} =$	35.925

Table 3: The estimated effect of factors

Factor	η_{j_1}	η_{j_2}	$\left| \eta_{j_1} - \eta_{j_2} \right|$	Rank
Nodes speed (A)	35.889	35.961	0.073	3
Pause time (B)	36.131	35.719	0.413	2
Traffic load (C)	35.416	36.433	1.017	1

Table 4: Summary of ANOVA for S/N ratio

Factor	df	SS	ρ (%)
Node speed (A)	1	0.004	-
Pause time (B)	1	0.169	13.643
Traffic load (C)	1	1.033	85.097
Error	0	-	-
Pooled error	(1)	(0.004)	1.260
Total	3	1.209	100.000

Table 5: Optimum condition and performance estimated

Factor	Level description	Level	Contribution
Pause time (B)	10 sec	1	0.206
Traffic load (C)	8 packets sec^{-1}	2	0.508
Total contribution from significant factors			0.714
Current grand average of performance			35.925
Expected result at optimum condition			36.639

To determine which factor significantly affected the packet delivery ratio, analysis of variance (ANOVA) was performed. The ANOVA result for S/N ratio of packet delivery ratio is given in Table 4. Since the ANOVA has resulted in zero degree of freedom for error term, it is necessary to pool the factor which having less than 10% of the most effective factor[12], for correct interpretation of results. Percent contribution (ρ%) indicates the relative power of a factor to reduce variation. For a factor with a higher percent contribution, a small variation will have a great influence on the performance. From Table 4, it can be observed that traffic load has a major influence on packet delivery ratio. It can be observed from the results of ANOVA that the pooled error is less than 2%, which indicates that no important factors are omitted from the experiments.

After selecting the best combination levels of factors for the DSDV protocol, the final steps is to predict and verify the adequacy of the model for the determining the maximum packet delivery ratio. Using Eq. 8 and 9, the predicted optimum value of S/N ratio is 36.639 when optimum condition is applied and its value is in range among value obtained for any trial listed in Table 3. Table 5 shows the optimum condition and the performance estimated for the scenario being discussed. Confirmation run was conducted for further analysis by setting pause time and traffic load at their optimum levels. Since node speed (factor A) is insignificant, it

could be set at the highest node speed (A_2) to obtain high rate of packet delivery (by looking at Table 4 and Fig. 1). Three confirmations run were conducted and the actual result was 34.597 which about 5% different from the expected result.

DISCUSSION

The simulation results in previous section demonstrate that Taguchi method has given us greater insight into determine the main factor effect and the best factor combination of the DSDV performance for MANETs. The DSDV with high speed, low pause time and high traffic load yielded the higher packet delivery ratio under scenario considered in the study.

When investigate the performance of DSDV at One-Factor-At-a-Time (OFAT), Yadav and Yadav[14] found that DSDV has less packet delivery ratio when speed set at a high speed. Since finding the route requires more and more routing traffic as speed increases thus making a lesser portion of the channel useful for data transfer. They also found that for DSDV, packet delivery ratio decreases as the number of traffic sources increases. Arun kumar et al.[1] observed that DSDV performed poor in terms of packet delivery ratio in case of high mobility.

However, when investigate the effect of speed, pause time and traffic load on packet delivery ratio simultaneously, we found that the combination of high speed, low pause time and high number of traffic load give better performance in terms of packet delivery ratio. The results are some agree and disagree with the result from OFAT case and this result gives us greater insight to extend this study to other protocols.

In the current study, besides 8 runs only 4 runs of testing for the design of three factors with two levels. This is greatly reduces the number of test and increases the efficiency when involves more number of factors and levels in the study.

CONCLUSION

This study has shown the application of Taguchi method on the performance evaluation of DSDV protocol for mobile ad hoc wireless network application. The simulation experiment was successful in terms of achieving the objective of experiment, which was to quantify the main effects of potentially influential factors on the packet delivery ratio of DSDV. The analysis of the results showed that the best combination level of factors for the DSDV protocol for maximum packet delivery ratio was high node speed, low pause time and high traffic load. However, the expected performance at optimum condition was obtain

by consider only significant factors which are pause time and traffic load.

Since the selection of value level of factors is sensitive, it is important to take note that all the findings in this paper were totally based upon the factor levels considered in this study and may vary if different factor levels are used. We executed several simulations run in order to reduce potential variation in when different factors were used.

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REFERENCES

1. Bakar, S.A., S. Salleh and M.H. Lee, 2006. FRECAST: Message transmission model in dense graphs for ad hoc networks. Int. J. Simulat. Process Model., 2: 4-11. http://inderscience.metapress.com/app/home/contribution.asp?referrer=parent&backto=issue,1,14;journal,6,8;linkingpublicationresults,1:113438,1.

2. Boukerche, A., 2004. Performance evaluation of routing protocols for ad hoc wireless networks. Mobile Networks Appl., 9: 333-342. http://doi.acm.org/10.1145/1012215.1012224.

3. Das, S.R., R. Castaneda and J. Yan, 2000. Simulation based performance evaluation of routing protocols for mobile ad hoc networks. Mobile Networks Appl., 5: 179-189. http://dx.doi.org/10.1023/A:1019108612308.

4. Kurkowski, S., T. Camp and M. Colagrosso, 2005. MANET simulation studies: The incredibles. Mobile Comput. Commun. Rev., 9: 50-61. http://doi.acm.org/10.1145/1096166.1096174.

5. Lakshmi, M. and P.E. Sankaranarayanan, 2005. Performance analysis of three routing protocols in mobile ad hoc wireless networks. Asian J. Inform. Technol., 4: 1195-1200. http://www.ansijournals.com/itj/2006/114-120.pdf.

6. Lambiase, A. and S. Miranda, 2003. Performance parameters optimization of a pneumatic programmable palletizer using taguchi method. J. Robot. Comput. Integrat. Manufact., 19: 147-155. DOI: 10.1016/S0736-5845(02)00072-8.

7. Montgomery, D.C., 2004. Design and Analysis of Experiments. 6th Edn., John Wiley and Sons, Inc., River Street, USA., ISBN: 047148735X.

8. Lee, M.H., S. Salleh, B. Sanugi and S. Olariu, 2006. On the probability of route existence in mobile wireless networks. Int. J. Simulat. Process Model., 2: 222-226. DOI: 10.1504/IJSPM.2006.012649.

9. Lee, M.H., H. Mohamed and M. Sarahintu, 2008. Using taguchi's approach in determine and rank factors that affect the performance of dynamic source routing protocol in mobile ad hoc networks. Int. J. Applied Probabil. Statist., 3: 115-124. .

10. Peace, G.S., 1992. Taguchi Method: A Hands-on Approach. 1st Edn., Addison-Wesley Publishing, MA., USA., ISBN: 0201563118, pp: 224.

11. Perkins, C.E. and P. Bhagwat, 1994. Highly dynamic Destination-Sequenced Distance-Vector routing (DSDV) for mobile computers. SIGCOMM Comput. Commun. Rev., 24: 234-244. http://doi.acm.org/10.1145/190809.190336.

12. Roy, R.K., 2001. Design of Experiment Using the Taguchi Approach: 16 Steps to Product and Process Improvement. 1st Edn., Wiley Interscience, New York, USA., ISBN: 0471361011, pp: 560.

13. Fall, K. and K. Vardhan, 1995. The NETWORK SImulator (NS-2). http://www.isi.edu/nsnam/ns/.

14. Young, S.B., 1999. Evaluation of pedestrian walking speeds in airport terminals. Transport. Res. Rec., 1674: 20-26. DOI: 10.3141/1674-03.