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VALIDATION OF PERFORMANCE ANALYSIS FOR OPTIMIZED VEHICULAR AD HOC NETWORK USING TAGUCHI METHOD

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Abstract

Vehicular Ad Hoc Network (VANET) is quite different from other ad hoc networks in term of functionality because of the variable node density, high node mobility, and unpredictable and harsh communication environment. There are two major application VANETs, namely safety applications and non-safety applications. Network optimization is one way to maintain the existing protocols and other network parameter rather than costly efforts for design and implementing new improved protocols. Motivated with the reasons to save effort of time and cost this paper presents the validation of optimized vehicular network for throughput, average delay and packet delivery ratio using Taguchi method. Highway scenario is chosen as the evaluation condition for this paper. From the performance evaluated the performance of optimized setting gives better results than non-optimized setting for both safety and non-safety applications. It is proved that Taguchi Method is applicable to optimize vehicular ad hoc network.

Keywords: Vehicular ad hoc network, network optimization, Taguchi Method, safety applications, non-safety applications

Abstrak

Rangkaian Ad Hoc Kenderaan (VANET) agak berbeza daripada rangkaian ad hoc yang lain dari segi fungsi kerana pembolehubah nod yang tinggi , mobiliti nod juga tinggi, dan persekitaran komunikasi yang tidak menentu dan sering berubah. Terdapat dua aplikasi utama VANETs, iaitu aplikasi keselamatan dan aplikasi bukan keselamatan. Pengoptimuman rangkaian adalah salah satu cara untuk mengekalkan protokol sedia ada dan parameter rangkaian yang lain dan bukan alternatif yang melibatkan kos yang besar atau mahal seperti mereka-bentuk dan melaksanakan protokol baru yang lebih baik. Didorong dengan sebab-sebab untuk penjimatan masa dan kos, kertas kerja ini membentangkan prestasi rangkaian kenderaan yang optimum untuk celusan, purata lengah baris-gilir dan nisbah penghantaran paket menggunakan kaedah Taguchi. Senario lebuh raya dipilih sebagai syarat penilaian bagi kertas ini. Dari prestasi yang dinilai prestasi tetapan optimum memberikan keputusan yang lebih baik berbanding prestasi oleh tetapan yang tidak optimum untuk kedua-dua aplikasi keselamatan dan bukan keselamatan. Melalui keputusan yang diperolehi, Kaedah Taguchi boleh digunakan untuk mencari tetapn optimum rangkaian Ad Hoc Kenderaan.

Kata kunci: Rangkaian ad hoc kenderaan, pengoptimuman rangkaian, Kaedah Taguchi, aplikasi keselamatan, aplikasi bukan keselamatan.

1.0 INTRODUCTION

In ad hoc network, nodes are communicating directly to each other without using any access point. On the contrary, Vehicular Ad Hoc Networks (VANETs) are quite different from other ad hoc networks in term of functionality because of the variable node density, high node mobility, and unpredictable and harsh communication environment [1]. In vehicular communications vehicles function as the mobile nodes equipped with on-board units (OBUs) and roads are equipped with static road side units (RSUs). Vehicles with OBUs can transfer data with each other or called inter-vehicle or V2V communications, while communications of vehicles with the roadside infrastructure is known as vehicle-to-roadside or V2I communications. VANET is targeted to provide a wide spectrum of comfort and more important is for safety applications to drivers and passengers. Irrespective of the environment, VANETs are ideate to provide a communication range of 1km with roadside units (RSUs) and other vehicles, at relative speeds up to 200km/h [2].

There are two categories of VANETs applications, namely safety applications and non-safety applications [3]. As for safety applications provide drivers information about critical situation in advance, it have crucial requirements on communication reliability and delay. The non-safety applications on the other hand are used for improving driving comfort and the efficiency of transportation system which require more throughput-sensitive instead of delay-sensitive.

There are several evaluation conditions related to transportation scenarios in VANETs such as [3]:

i) Highway traffic
ii) City traffic
iii) Intersectional traffic

On highway scenario, vehicles travel in platoon where relative speed between a vehicles and infrequent RSUs is high while relative speed between vehicles is low. Highway traffic can be evaluated for vehicles moving in same direction and also in opposite directions. A notable example of city driving scenario is it usually to be at low speed and stop-start. Compared to highway scenario, there is more number of RSUs in the city. Then, routing in the city need to be more refined with all the buildings will be large obstacles and also the driver behavior is less predictable. As for intersectional traffic scenario, there are more available RSUs but nonline-of-sight (NLOS) state conditions might occur [4].

Network optimization is one way to maintain the existing protocols and other network parameter rather than costly efforts for design and implementing new improved protocols [5]. In terms of dynamic changes of topology in VANET and requirement of to keep communicating between vehicles, deploying massive number of RSUs could be very costly. Thus, to achieve maximum performance there is a demand on optimally place minimum number of RSUs in a given region [6]. On the other hand, there is a tool called MONOPATI developed by McAuley and Manousakis (2006) from ground up, using Snealing Algorithm (SA) as a basis for hierarchy generation [5]. It emphasizes on always improve and optimize the network despite the absence of any minor or major network topology modifications. It does not depend solely on anomalies presence to attempt any changes to the parameters of the network to make it work better. This approach requires the system to be intelligent and smart enough to improve situations even on error-free environment. Motivated with the reasons to save effort of time and cost an optimization of vehicular network for throughput, average delay and packet delivery ratio using Taguchi method has been carried out. Highway scenario is chosen as the evaluation condition.

This paper is focus on the validation of optimized vehicular adhoc network using Taguchi Method that been carried out previously in [7]. The organization of the paper is as follows. Section 2 explains the Taguchi method. Results and discussion are presented in Section 3. The paper is then concluded in Section 4.

2.0 TAGUCHI METHOD

Dr. Genichi Taguchi first introduced the Taguchi method in 1960. The target of Taguchi method is to produce high quality product at a lower cost; to reduce the variation in process where a robust experimental design are involved [8].

Taguchi's method is an iterative optimization procedure based on orthogonal array (OA) which can be used to find near-optimal settings [9]. OA is an important parameter in Taguchi's method which provides a systematic way to determine the control parameters of the experimental run. Taguchi's method is widely used in manufacturing processes, then followed by other engineering fields, such as electromagnetic, power electronics and wireless communications [10]. Taguchi Method contain of three phases which is planning phase, experiment phase and analysis phase as shown in Figure 1[11].

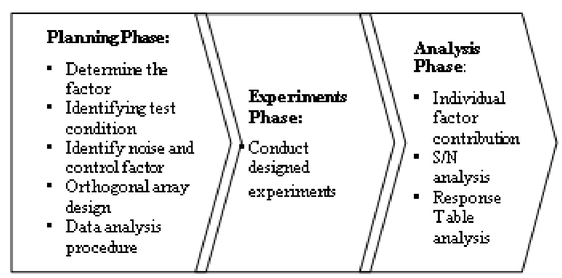

Figure 1. Taguchi Method Phase [11]

To determine the effect of each parameter has on the output, the signal-to-noise (SN) ratio needs to be calculated for each experiment conducted. The SN value representing the magnitude of the mean of a process compared to its variation. There are three types of SN ratio could be calculated depends on different types of performance characteristics.

Two orthogonal arrays being used depends on the selections of control factors and noise factors. L9 Taguchi orthogonal array design is for control factors while L4 Taguchi orthogonal array design is for noise factors.

Table 1 outlines the variations of control parameters and Table 2 is the variations on noise parameters.

Table 1 Level of variations of control parameters

	Levels		
Parameters	**1**	**2**	**3**
Packet size	512B	1000B	128B
Position of RSU	500m	250m	100m
MAC protocols	802.11a	802.11g	802.11p
Routing protocols	DYMO	BATMAN	OLSR

Table 2 Level of variations for noise parameters

	Levels	
Parameters	**1**	**2**
Number of nodes	5	30
Packet generation (ia time)	0.5	0.05
Mobility Speed	20mps	30mps

Basically in VANETs, it has two major applications that is safety and non-safety application [1]. Both need different requirement, where for safety applications demand of high level quality of service (QoS) and delay sensitive, while for non-safety require more to throughput sensitive instead of delay. Therefore, for optimal performance, the smaller-the better performance metric for delay must be taken for safety application. On the other hand, the larger-the-better performance metric for throughput should be taken for obtaining optimal VANETs design for non-safety applications.

The performance metrics being used to evaluate are throughput, average end-to-end delay and packet delivery ratio. The definition for each metrics is briefly explained in Table 3.

Table 3 Performance metrics

Name	Definition
Throughput	Total number of delivered data packets divided by the total duration of simulation time [12]. $Throughput = \frac{received\ packets\ in\ bits}{simulation\ time}$
Average End-to-end delay (Delay)	The average time it takes a data packets to reach destination from source [12].
Packet Delivery Ratio (PDR)	According to [13], packet delivery ratio is the number of packet received at the destination over the packet generated by the source. $PDR = \frac{received\ packets}{sent\ packets}$

3.0 RESULTS AND DISCUSSION

3.1 Validation of Optimized Design

From the result compiled in the previous works in [7], this paper presents the validation of optimized level of design factors for respective performance metrics.

The simulation parameter settings for evaluation are described in Table 4. The simulation is done for 300s and 5 random seed is conducted. For this simulation, the highway length is 1000m. The average of mobility speed 30mps which is equal to 108km/h. As this is the value of speed limit in major Malaysian Highway.

The performance is evaluated in two different scenarios which are in low traffic node and high traffic node. The former low traffic node consists of 5 nodes while the latter consists of 20 nodes.

Table 4 Simulation Parameter

Parameter	Value
Random Seed	5
Highway Length	1000m
Average Mobility speed	30mps
Simulation time	300s

Figure 2 displays the end of simulation process for one set of seeds. Even though the simulation time is 300s, the simulation will take around 2 hours 52 minutes to finish the simulation. Time intervals represent the time taken in between the packets to be generated.

3.2 Throughput

The network parameters used in simulation are packet size, distance of RSU, MAC layer and routing protocols. The value used to validate the optimized setting are given in Table 5, while for non-optimized setting are 512B of packet size, 250m as the distance between the RSU, 802.11p for MAC layer and OLSR routing protocols is chosen.

Table 5 Network parameters for throughput validation

Throughput	Packet size	Distance of RSU	MAC layer	Routing protocols
Optimized	1000B	100m	802.11 a	DYMO
Non-optimized	512B	250m	802.11p	OLSR

Figure 3 presents the throughput result for low traffic node for six time intervals.

Figure 4 displays the result of high traffic node. Optimized settings show better result of throughput than non-optimized settings.

3.3 Average Delay

In the case of average delay, the network parameter for packet size, distance of RSU, MAC layer and routing protocols for validation of optimized setting is set as in Table 6, while for non-optimized setting are 512B of packet size, 250m as the distance between the RSU, 802.11p for MAC layer and OLSR routing protocols is chosen.

Table 6 Network parameters for average delay validation

Average Delay	Packet size	Distance of RSU	MAC layer	Routing protocols
Optimized	128B	250m	802.11 g	OLSR
Non-optimized	512B	250m	802.11p	OLSR

Figure 5 The average delay vs time interval for low node traffic demonstrates the result for low traffic node for six time intervals.

Figure 6 presents the result of high traffic node. The results demonstrate clearly that optimized settings show better result of average delay than non-optimized settings.

3.4 Packet Delivery Ratio

In the case of packet delivery ratio, the network parameter for packet size, distance of RSU, MAC layer and routing protocols of optimized setting is set as in Table 7, while for non-optimized setting are 512B of packet size, 250m as the distance between the RSU, 802.11p for MAC layer and OLSR routing protocols is chosen.

Table 7 Network parameters for packet delivery ratio validation

Packet Delivery Ratio	Packet size	Distance of RSU	MAC layer	Routing protocols
Optimized	1000B	100m	802.11 g	DYMO
Non-optimized	512B	250m	802.11p	OLSR

Figure 7 shows the result for low traffic node for six time intervals. Figure 8 presents the result yields of high traffic node. Optimized settings show better result of packet delivery ratio than non-optimized settings.

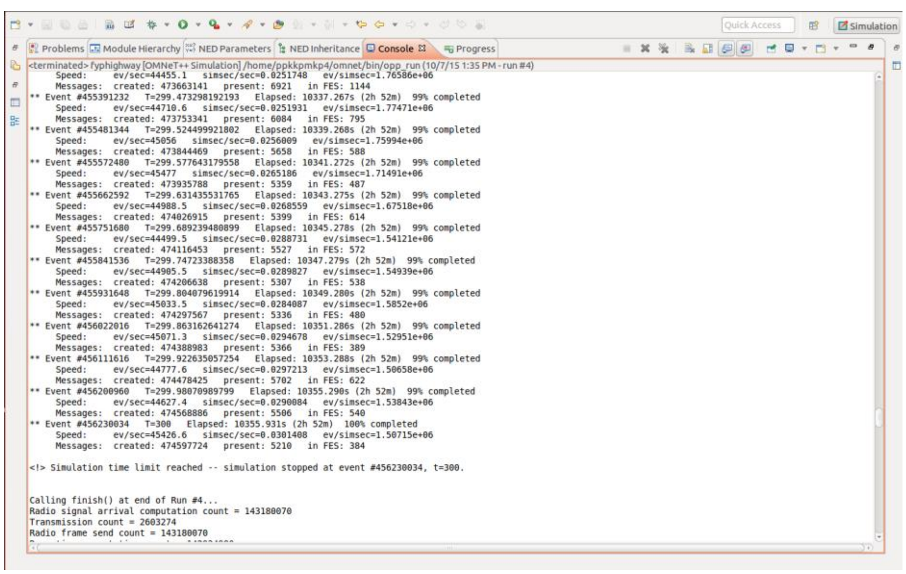

Figure 2 End of simulation process for one set of seeds

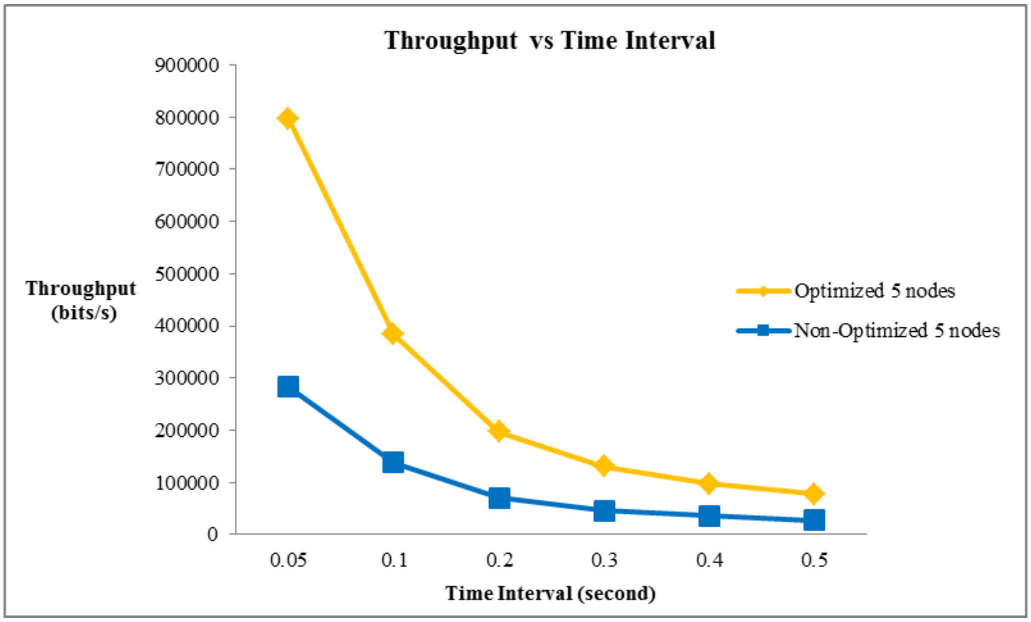

Figure 3 The throughput vs time interval for low node traffic

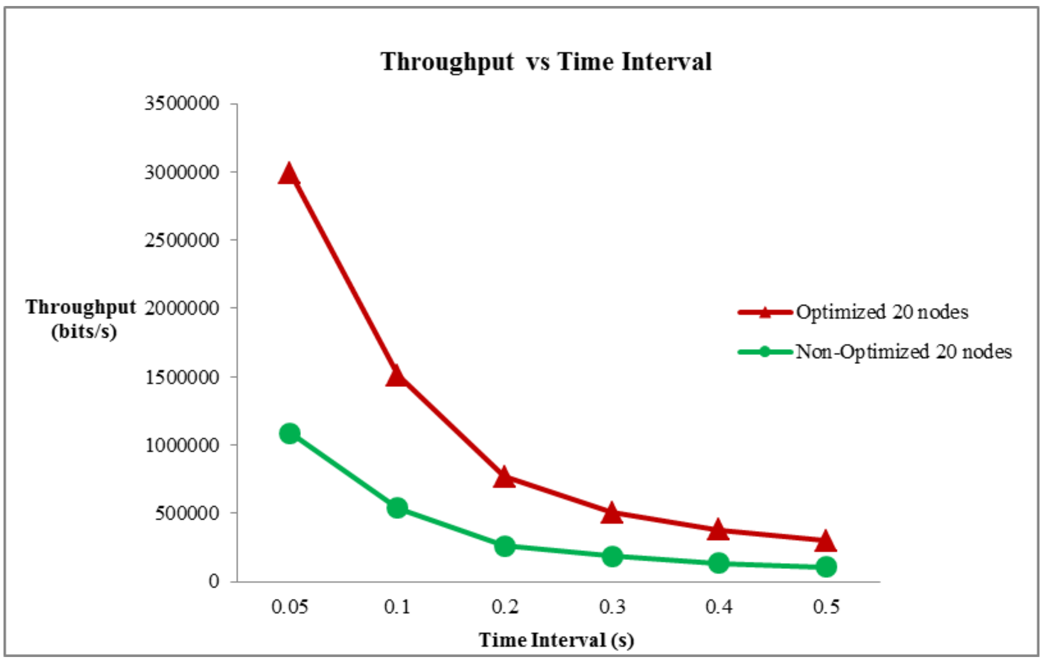

Figure 4 The throughput vs time interval for high node traffic

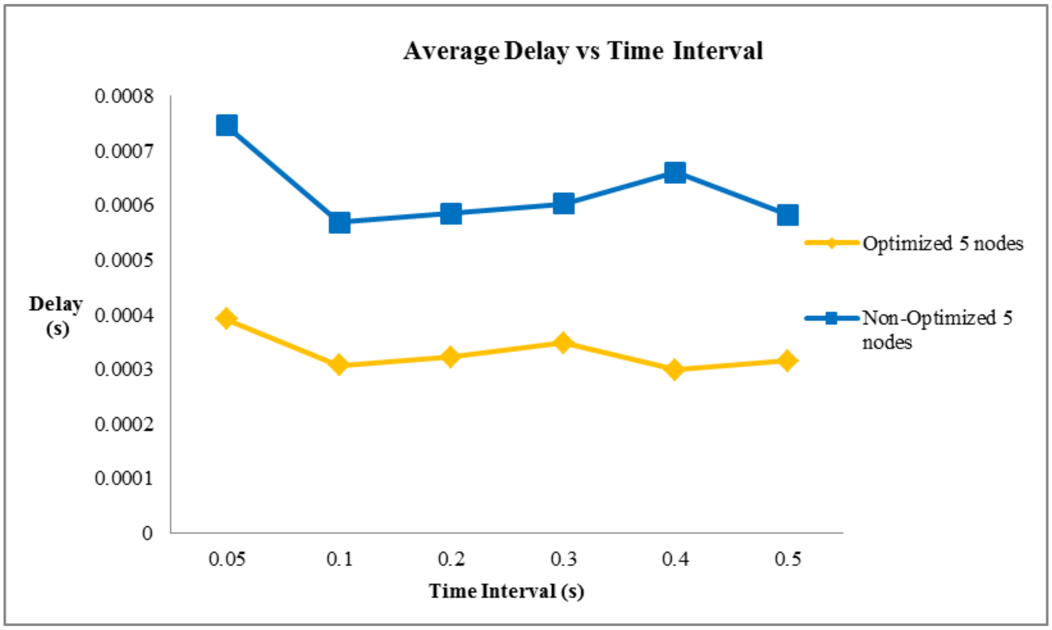

Figure 5 The average delay vs time interval for low node traffic

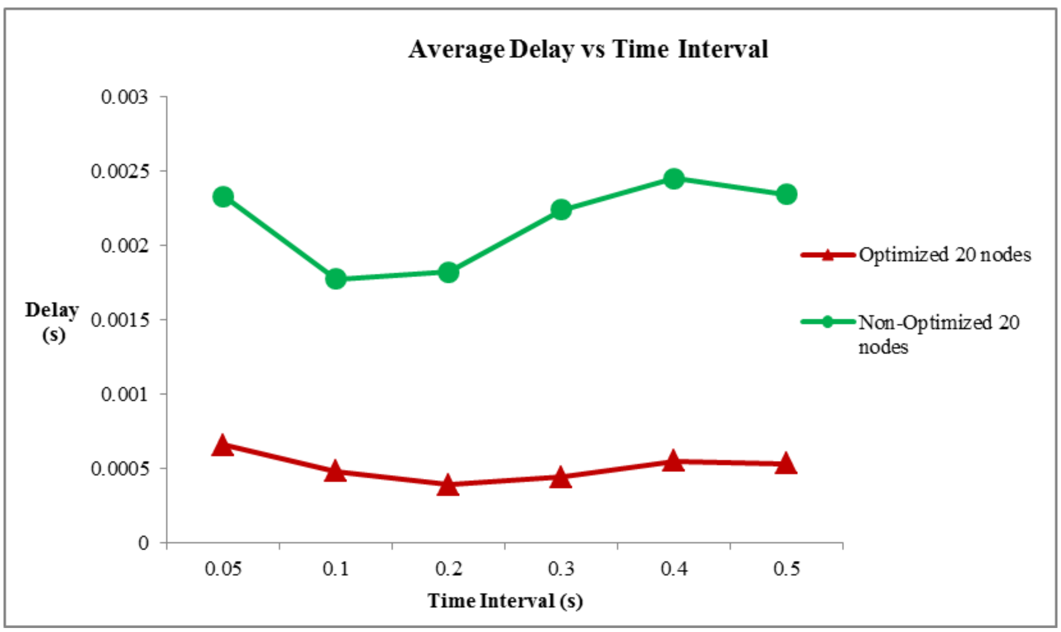

Figure 6 The average delay vs time interval for high node traffic

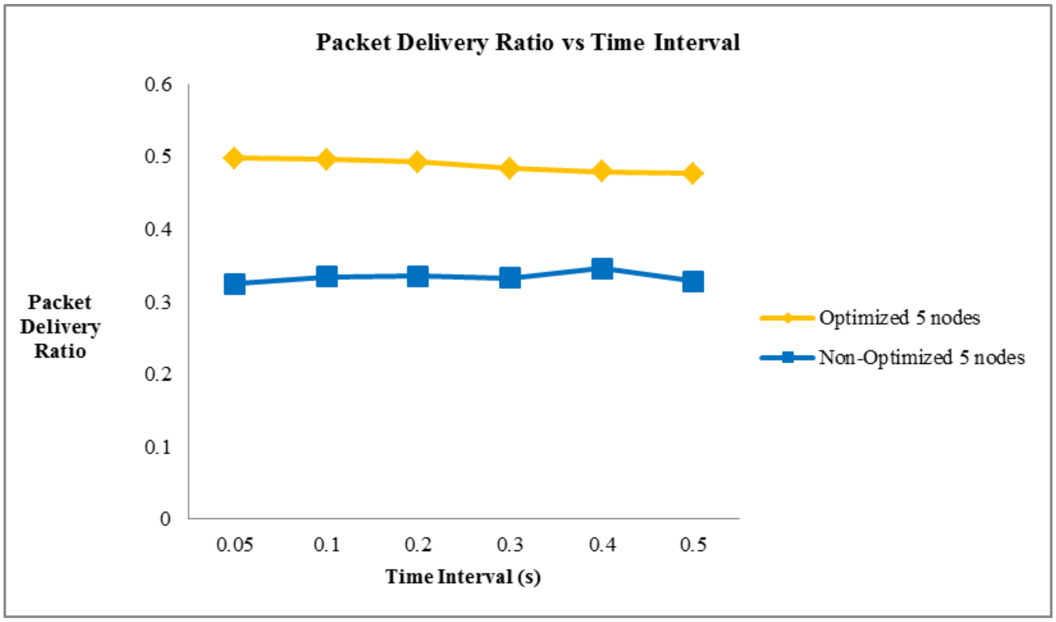

Figure 7 The packet delivery ratio vs time interval for low node traffic

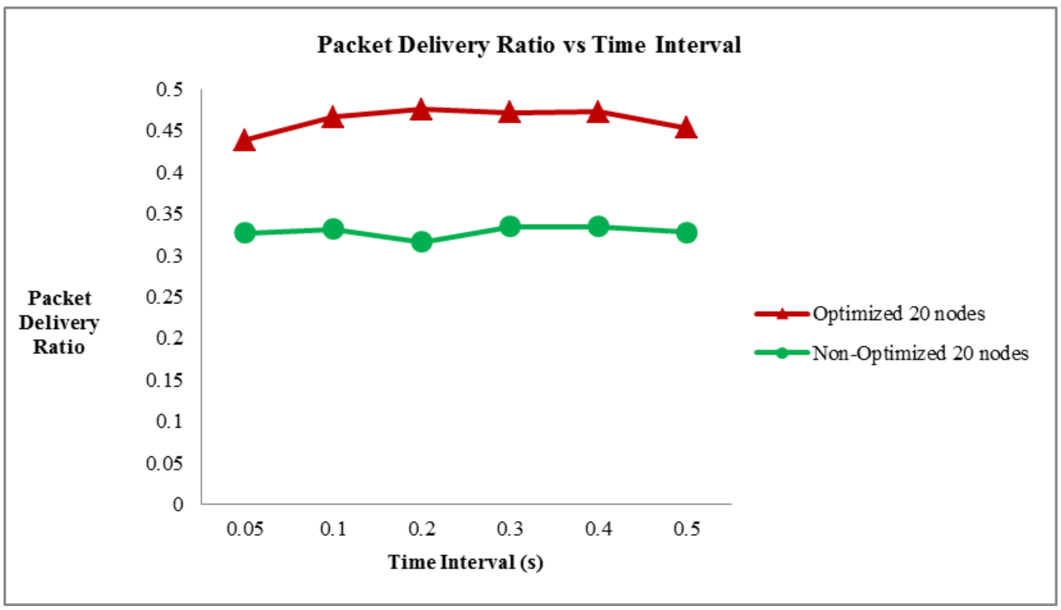

Figure 8 The packet delivery ratio vs time interval for high node traffic

4.0 CONCLUSION

From the result obtained, it shows that with different requirement of characteristic is for different applications. For safety application, since average delay is the most critical requirement, it should be implemented in best combinations of factors from taguchi method optimization. The result exhibits the optimized setting provides lower average delay than non-optimized settings. As for non-safety applications, which are looking towards maximum throughput requires different combinations of factors. Optimized setting gives better throughput than non-optimized setting. It is proved that Taguchi Method is applicable to optimize vehicular ad hoc network.

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