Journal of Computer Science

Original Research Paper

Impact of the Smart City Architecture, Speed and Traffic Density of Vehicles on the Performances of Vanets

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Abstract: Vehicular Ad-hoc Networks (VANET) is one of the emerging and actual research fields in automotive companies and Intelligent Transportation Systems (ITS) designers. In the Smart City the presence of such networks opens the way for a wide range of applications such as safety applications, mobility and connectivity for both driver and passengers to exploit the transport systems in a smoothly efficiently and safer way. The 802.11p is a draft amendment to the IEEE 802.11 standard for vehicular communications. VANET are characterized by a dynamic topology triggered by the vehiculars mobility. In the Smart City the main problems of inter-vehicle communication are the speed, density of vehicles and the size of the buildings. For this purpose, we first examine and then display the simulation findings of the impact of different radio propagation models on the performance of vehicular ad hoc networks in terms of the characteristics of the physical layer. In our study, we have compared the performances of two routing protocols (AODV and OLSR) for three propagation model (two-Ray ground, Rice and Nakagami). We study those protocols under varying metrics such as Traffic density, Smart City Architecture (size of the scenario areas) and the mobility of vehicle. Our objective is to provide a qualitative assessment of the protocols applicability in different vehicular scenarios. These two routing protocols are simulated and compared with Network Simulator-2 under Manhattan Grid Mobility Model. To conclude, the simulation findings are to be taken as a strong reference on the three routing protocols behaviour; however, it shouldn't be considered as an exact representation of its behaviour and real environment because of several simulation constraints such as: the dimension of movement field of vehiculars, the traffic type and the simulation timing.

Keywords: Smart City, Routing Protocols, OLSR, AODV, VANET

Introduction

Vehicular AdHoc Networks (VANETs) are consisting of a number of vehicles traveling on urban streets, capable of communicating with each other (Delgrossi, 2014). The development of VANETs is backed by strong economical interests since Vehicle-to-Vehicle (V2V) communication allows sharing the wireless channel for mobile applications, to improve route planning, to control traffic congestion, or to improve traffic safety. Moreover, communication between vehicles depends on several parameters such as the transmission power, the propagation environment of the waves and the frequency used also play an important. The wave's propagation obeyed strict rules, especially in the case of obstacles between the transmitter and the receiver (Rhattoy *et al*., 2008). Among the changes a wave may undergo, we can cite: reflection, diffraction, diffusion and absorption. One key component of VANET simulations is the movement pattern of vehicles, also called the mobility model. Mobility models determine the location of nodes in the topology at any given instant, which strongly affects network connectivity and throughput. This paper is organized as follows. To approach the architecture of the city such as roads, signal fires, buildings and other obstacles in urban areas, we give three types of radio propagation models. Next, we study the concepts of routing protocols in VANET networks. Moreover, we will explain the simulation methodology. Finally, we study the impact of city architecture and radio propagation models on the performance of routing protocols in VANETs and we conclude with our conclusions.

Radio Propagation Models

In a propagation model, we use a set of mathematical models which are supposed to provide an increasing precision. Propagation radio models are three types: path loss, shadowing and fading (Arne Schmitz, et al, 2006). The path loss can be expressed as the power loss in the free space during the signal propagation. The shadowing model is characterized by obstacles on the path of the radio signal propagation. The third category is the fading which is composed of multiple path, the fast movements of transmitters and receivers. In this work, we study three propagation models: Two-Ray Ground, Rice and Nakagami.

Two-Ray Ground Model

The two ray ground model therefore considers both the direct path and a reflection on the ground. As shown in (Pranav, 2011), this model gives fairer results than the free-space propagation model when the distance is large enough. The power received by two ray ground at a distance d is calculated as follows:

$$P_r(d) = \frac{P_t G_t G_r h_t^2 h_r^2}{d^4 L} \quad (1)$$

where, ht and hr are the heights of the transmitter and receiver respectively. This propagation model is generally used by the research community in MANETs when it comes to developing and testing routing protocols. For the small distances, the two-ray ground model does not give precise results. The propagation model in the free space is instead, still used where d is small. For this model, we therefore need to calculate a threshold distance dc. When d<dc, we use the free space equation, but when d > dc, the equation (1) is used. Consequently, dc can be calculated as Equation 2:

$$d_c = \frac{4\pi h_t h_r}{\lambda} \quad (2)$$

Rice Model

In the case where the received complex signal consists of a large number of indirect paths (NLOS) having random amplitudes and phases, independent and uniformly distributed, received signal has a density of Rayleigh equation 3: The envelope of this signal follows a Rayleigh law defined by the following equation:

$$f(x) = \begin{cases} \frac{2x}{P}\exp\left(-\frac{x^2}{P}\right), & pour\, 0 \le x \le \infty \\ 0, & puor\ x < 0 \end{cases} \quad (3)$$

where, P is the average received power. In other situations, a propagation channel is characterized by several indirect paths and a direct path (LOS). As a result, the probability density of the envelope of the received complex signal obeys the distribution of Rice defined such that:

$$f(x) = \begin{cases} \frac{2x(K+1)}{P}\exp\left(-K - \frac{(K+1)x^2}{P}\right) I_0 \\ \left(2x\sqrt{\frac{K(K+1)}{P}}\right), & pour\ 0 \le x \le \infty \\ 0, & pour\ x < 0 \end{cases} \quad (4)$$

where: $I_0(x)$, is the modified Bessel function of the first kind and zero order de fined by equation 5, K, the ratio of the power received in the direct line and the average power received P.

$$I_0(x) = \frac{1}{2\pi}\int_0^{2\pi} \exp(-x\cos\theta)\, d\theta \quad (5)$$

Nakagami Model

In most cases, the Rayleigh and Rice distributions are sufficient to characterize the fading distribution of received signals in a mobile radio channel. However, some channels are not characterized either Rayleigh or Rice. For example, if the channel is characterized by two paths of comparable and stronger power than the others, the statistical expression of the received signal can no longer be approximated by the distribution of Rice. An alternative distribution to model this case is proposed by M. Nakagami. This distribution is referred to as the "Nakagamim distribution" whose probability density is given by:

$$P_r(r) = \frac{2m^m r 2^{m-1}}{\Gamma(m)\Omega^m}\exp\left(-\frac{mr^2}{\Omega}\right),\ r \ge 0 \quad (6)$$

We have $r = \left|\sum r_i e^{j\theta_i}\right|$, Γ(m) is gamma function, Ω = (r^2) and $m = \{E(r^2)\}^2/\text{var}(r^2)$ with the constraint m≥1/2. The Nakagami-m distribution covers several types of fading.

Ad Hoc Routing Protocols

Ad hoc networks are relevant in research even today due to applications involving vehicle to vehicle communication and embedded processing involving IoTs. Routing in any network can be viewed abstractly as finding and maintaining shortest-path between communicating pairs of nodes in a weighted graph. Each node maintains a preferred neighbor, which is the next hop on the path to reach a destination. Two different classes of routing algorithms have been proposed in the literature, namely, proactive and reactive (P.S., C. Nayak, 2016 and Rhattoy, 2012). In a proactive algorithm, each node maintains updated list of destinations and periodically advertises routing table to all the neighbors. This class of algorithms suffers from slow convergence. Reactive or on-demand routing algorithm, on the other hand, initiate a route discovery when a node does not have a fresh enough route to a destination it requires to reach. Flooding of route request queries can lead to congestion in network. The other problem is high latency in route discovery. VANETs are self-organized communication networks, characterized by high speed and limited degrees of freedom in node movement patterns. Such special features often make standard network protocols unusable in VANETs, which explains the growing effort in developing communication protocols specific to network vehicles. One of the critical points in developing routing protocols for VANETs is the choice of mobility models that reflect as much as possible the actual behavior of vehicle traffic. In this document, we compare the performance of two prominent AODV and OLSR routing protocols in urban environments (Vinothini and Raybin Jose, 2015).

Ad-hoc On-Demand Distance Vector Protocol (AODV)

AODV uses a route discovery mechanism. It is based on a dynamic establishment of roads by the intermediate nodes. This system is effective for networks with a large number of nodes. In order to maintain the most recent routing information between 2 nodes, AODV uses the concept of "destination sequence number". This algorithm ensures:

- Efficient use of bandwidth (minimizing the amount of control information on the network).
- Reactivity to topology changes.
- Preventing loops in the network (A.G., et al., 2016: Khatri and Rajput, 2010).

Optimized Link State Routing Protocol (OLSR)

The routing protocol OLSR is an optimized link state protocol. It is a proactive routing protocol at the IP level. OLSR offers optimal routes in terms of number of hops in the network. In a link state protocol, each node declares its direct links with its neighbors to the entire network. In the case of OLSR, the nodes only declare a sub-part of their neighborhood. The set of neighbors is called the set of multipoint relays or MPRs. The roads are built on the basis of multipoint relays. In addition, multipoint relays are used for the purpose of minimizing traffic to the broadcast of control messages in the network. OLSR uses 4 types of messages:

- HELLO: used for neighborhood detection
- TC: Disseminate topology information
- MID: Allows you to publish the list of interfaces for each node
- HNA: used to declare subnets and hosts that can be reached by a node acting as a gateway. Thus, the OLSR protocol performs two main actions:
- Neighborhood detection, by sending HELLO messages and determining the MPRs
- Topology management, performed by TC, MID and HNA messages, resulting in a global routing table in each entity

Methodology

Our study is composed of two parts, the first part studies the impact of different propagation models in order to analyze the environmental effect on VANET performance, the second part studies the performance of two routing protocols (AODV and OLSR) according to the following propagation models the two-Ray ground, Rice's and Nakagami's models. We study those protocols under varying metrics such as Traffic density, Smart City Architecture (size of the scenario areas) and the mobility of vehicle. Our objective is to provide a qualitative assessment of the protocols applicability in different vehicular scenarios. These two routing protocols are simulated and compared with Network Simulator-2 under Manhattan Grid Mobility Model (A, Rhattoy, 2012), this Model is similar to City Section Mobility Model, and he uses a grid road topology, as shown Fig. 1. This model is implemented in the BonnMotion framework (BonnMotion, 2017). The simulation span is of 200 sec. The data packet size is 512 octets. the Random Waypoint Model is considered unrealistic (Geetha, *et al*., 2008), the evaluation is done according to three scenarios, in the first scenario we have varied the density of the nodes and in a second scenario we have varied Smart City Architecture (size of the area) and in the last scenario we varied the speed of the nodes vehicles.

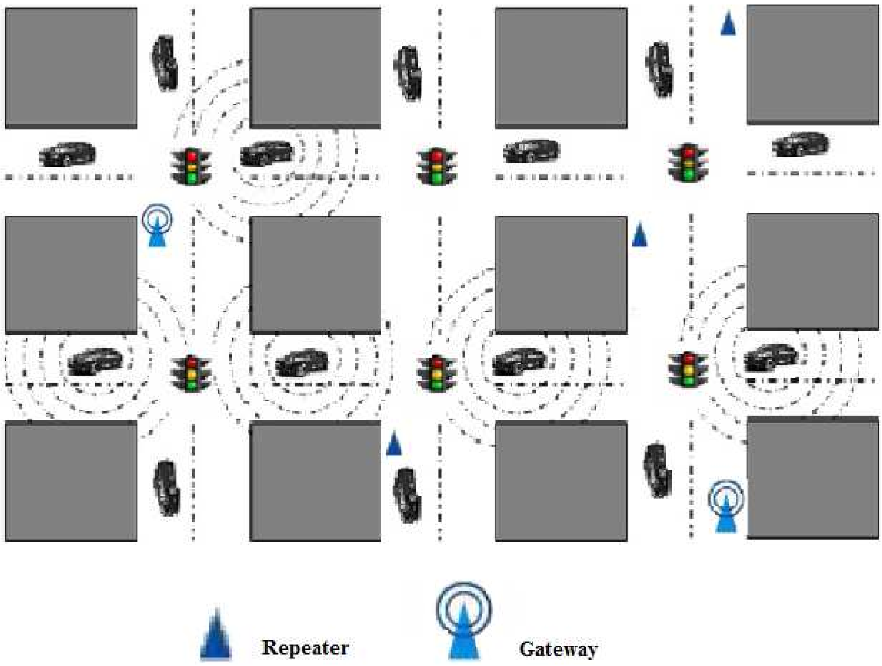


Fig. 1: Model of urban displacement

Scenario 1

In this section, we show the impact of traffic load on the performance of routing protocols. For this reason, we have varied the density of connections. Six cases were considered: 5, 10, 15, 20, 25 and 30 connections. For now, limit the maximum speed of the nodes to 10 m / sec and the architecture of the city unchanged.

Scenario 2

In this section we show the simulation results when we varying the Smart City Architecture (size of the area), without modification the number of nodes and the rest of the parameters. We selected scenario areas of 1400*700m, 1600*800m, 1800*900m, 2000*1000m and 2200*1100m. The number of nodes is set to 40 vehicles. Let's limit the nodes' maximal speed at 10 m/s.

Scenario 3

In this section, we show the impact of node mobility on the performance of routing protocols. For this reason, the packet transmission rate is set at 8 packets per second and we limit the number of sources to 10, with a maximum speed variation of the nodes, ten speed values were considered: 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10 m / sec.

Performance Indicators

In this study, we have selected just three performance indicators in order to study the routing protocols performances. They are outlined as follows: Packet delivery fraction, end average to end delay and the throughput.

Packet Delivery Fraction (PDF)

This is the ratio of total number of CBR packets successfully received by the destination nodes to the number of CBR packets sent by the source nodes throughout the simulation:

$$Pkt\_Delivery\% = \frac{\sum_{1}^{n} CBR_{recv}}{\sum_{1}^{n} CBR_{sent}} \times 100$$

The PDF is a good indicator of protocol performance; a high PDF value indicates that the majority of packages are delivered to the upper layers.

Average End-To-End Delay (AE2E Delay)

This is one of the important and critical parameters that measured the overall system performance. It can be defined as the packets per unit time interval length. On the other hand, delay represents the average delay that needs to route a packet from the source to the desired destination which depends on PDR value in the system and can be calculated as the following equation:

$$Avg\_End\_to\_End\_delay = \frac{\sum_{1}^{n} \left(CBR_{sent\_Time} - CBR_{recv\_Time} \right)}{\sum_{1}^{n} CBR_{recv}}$$

DOI: 10.3844/jcssp.2017.633.646

Throughput

The throughput is a measure of the amount of digital data transmitted per unit of time. It is measured considering the hops performed by each packet.

Results and Discussion

We study, the impact of metrics such as Traffic density, Smart City Architecture (size of the scenario areas) and the mobility of vehicle on the routing protocols.

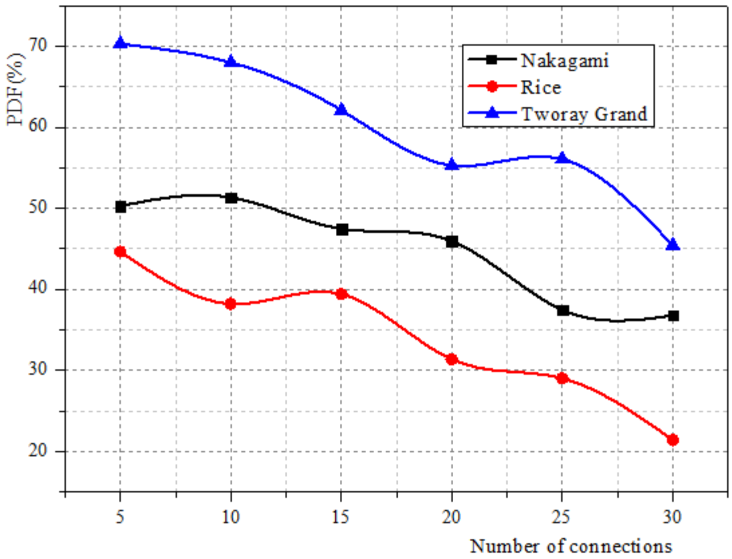
Scenario 1

In Figure 2, 3 and 4, packet delivery fraction (PDF), delay and throughput are shown respectively.

Packet Delivery Fraction (PDF)

In Figure 2, it can be seen that, the Two-Ray Grand model offers a better rate of received packets. The Rice model and the Nakagami model offer a data packet ratio significantly lower than that of the Two-Ray Grand; this is due to the fading effect caused by the management of the obstacles.

In Figure 2, it can be clearly seen that, the PDF decreases according to the density of Traffic, this is explained by, if the traffic density increases, the number of packets in the Time to life expires increases. The AODV protocol has a slightly higher PDF than d 'OLSR.



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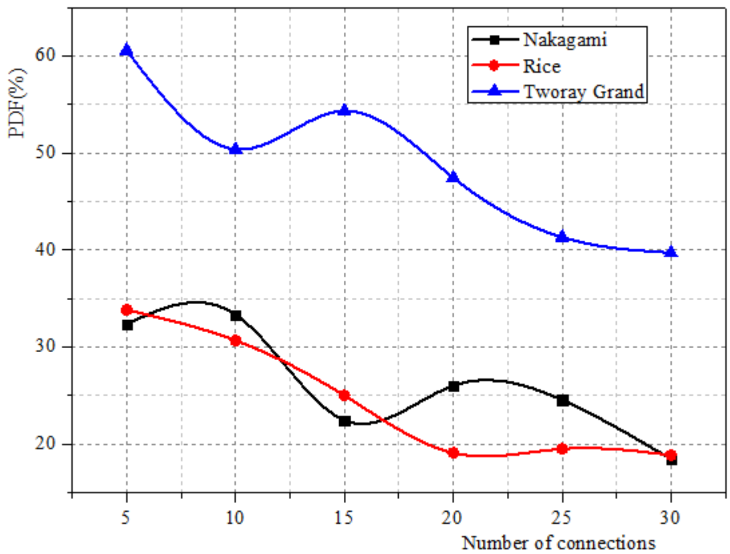

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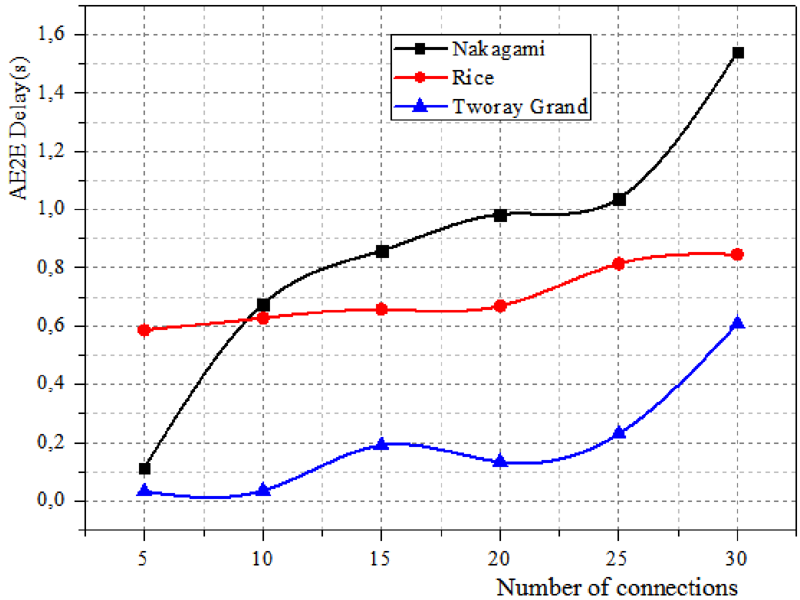
Fig. 2: (a) AODV-PDF versus number of connections; (b) OLSR- PDF versus number of connections

Average End-to-End Delay

As for the average delay from end to end, the three models offer the same behavior. In Figure 3, an increase in the end-to-end delay can be seen when the number of connections increases. AODV protocol has a delay significantly higher than OLSR. Because when a new connection is established, an AODV reactive protocol must update the routing table. AODV is used for spontaneous connections; its weak point is its latency. In fact, the discovery of roads induces an important latency time. The OLSR protocol has a higher routing control message rate than AODV.

Throughput

A high received packet ratio implies a higher data rate. As expected, the Two-Ray Grand model offers the best data rate values, the Rice and Nakagami models offer lower throughput. The flow rate decreases with the number of connections. The OLSR protocol has a slightly higher bit rate than AODV.



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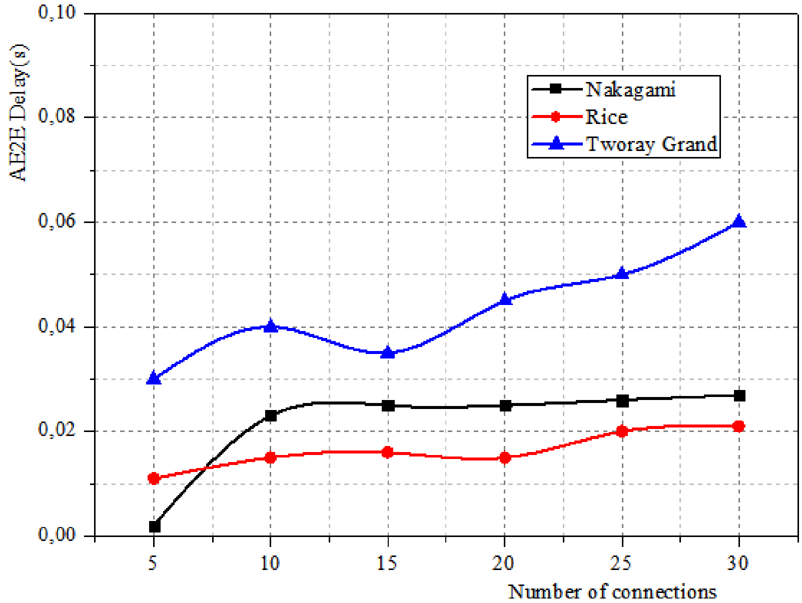

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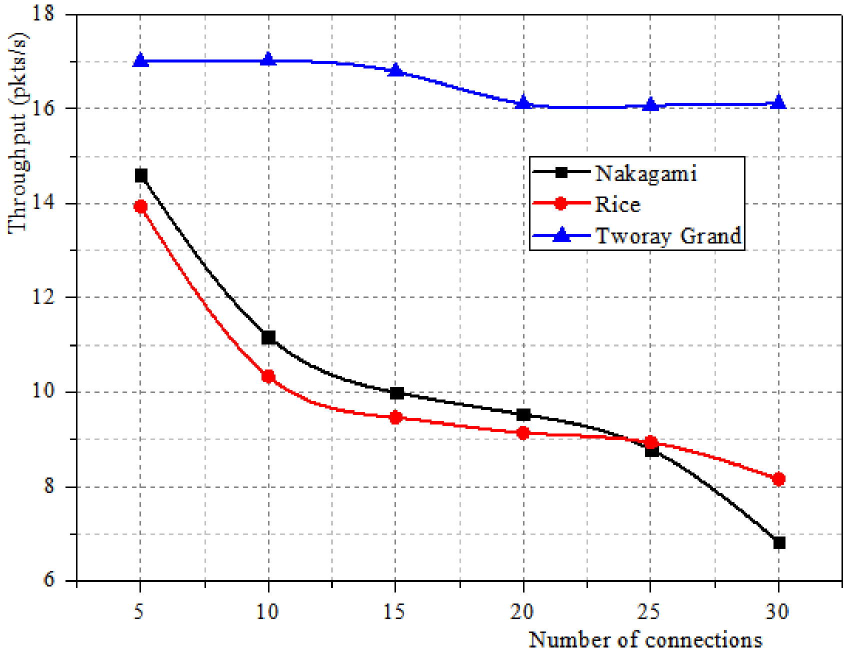
Fig. 3: (a) AODV-AE2E Delay versus number of connections; (b) OLSR-AE2E Delay versus number of connections



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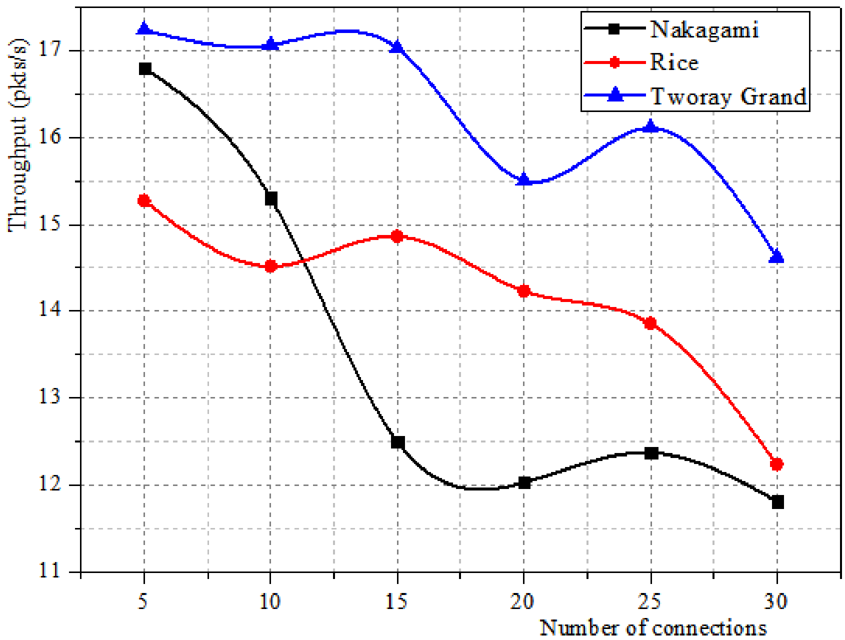

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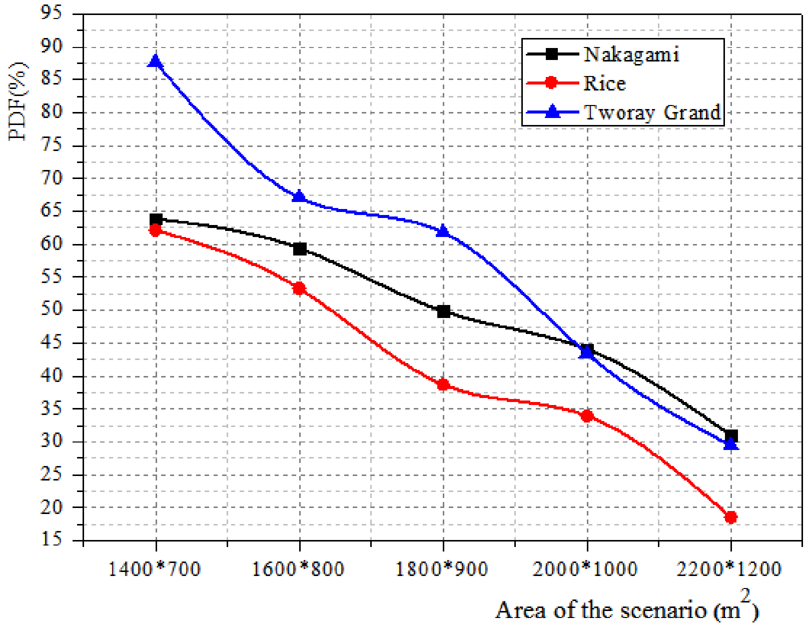
Fig. 4: (a) AODV-Throughput versus number of connections; (b) OLSR-Throughput versus number of connections

Scenario 2: Varying the Scenario Size

In Figures 5-7, are shown respectively the results corresponding to the PDF, AE2E Delay and Throughput.

Packet Delivery Fraction

When there are increases in the size of the scenario, the density nodes decreases. The total number of packets received decreases. By increasing the size of the simulated scenario increases the block size, this prevents direct communication through the blocks and then limits the spread and increases the radio losses of data packets which resulted to a decrease of useful throughput and increase the number of nodes blind.



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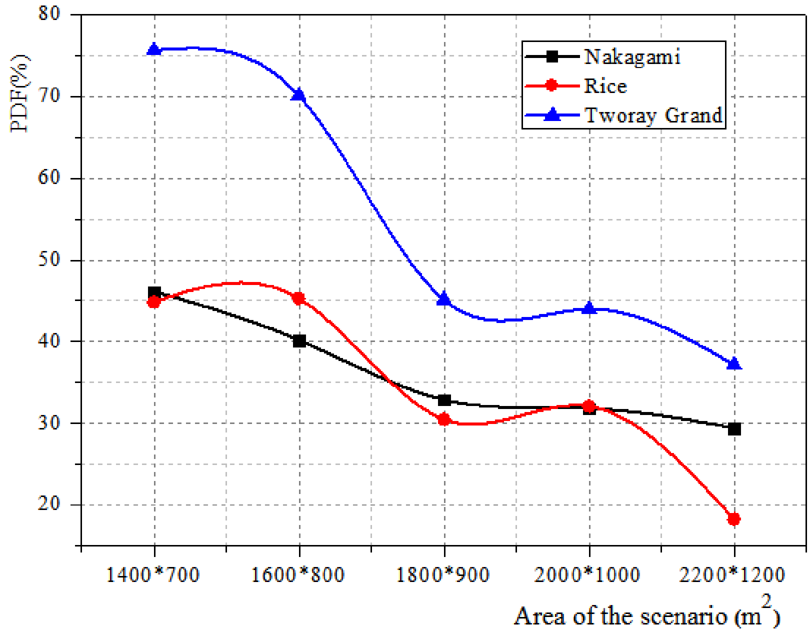


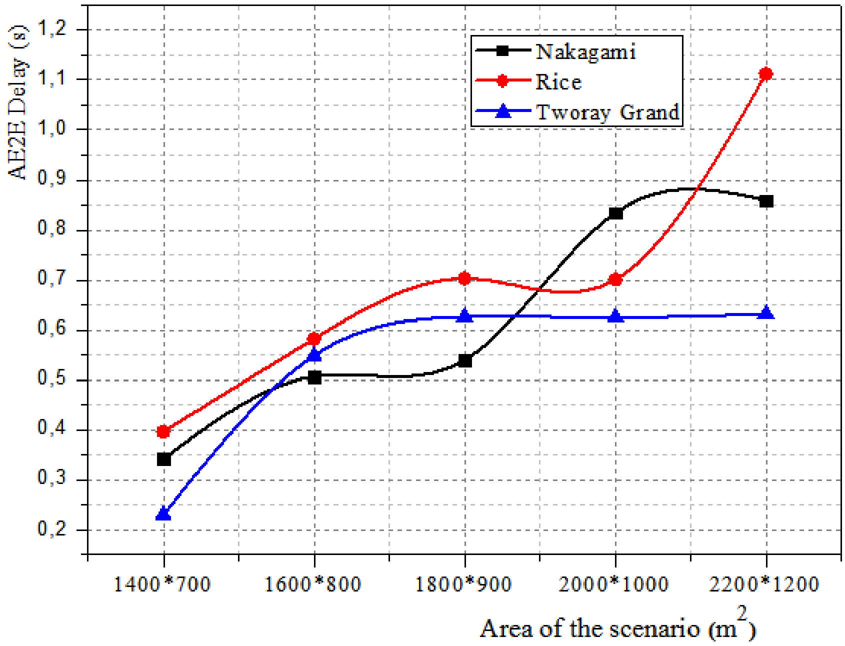
(b)

Fig. 5: (a) AODV- PDF versus size of the area; (b) OLSR- PDF versus size of the area

By increasing the size of the simulated scenario increases the block size, this prevents direct communication through the blocks and then limits the spread and increases the radio losses of data packets which resulted to a decrease of useful throughput and increase the number of nodes blind. The Smart City Architecture (The block size in the topology) plays an important role in the performance of VANET. With large buildings, vehicles spend more time crossing intersections; thus, the nodes are mobile more often. This high mobility weakens connectivity in the network and lowers the delivery rate.

Average End-to-End Delay

Figure 6; illustrate the average end-to-end delay, as building sizes increase, the system needs more time to inform vehicles. As can be seen from the figure, the rate of blind nodes depends strongly on this factor.



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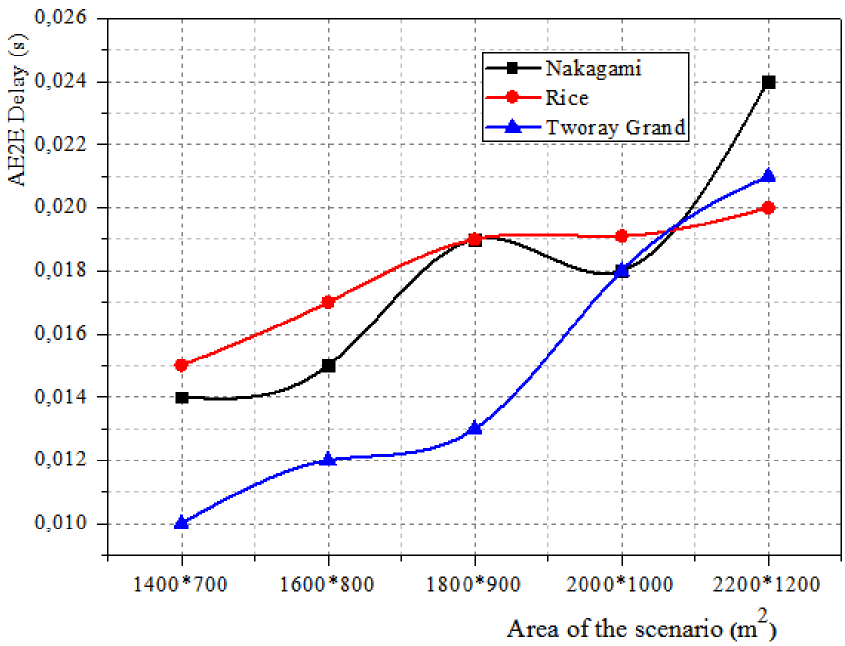

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Fig. 6: (a) AODV-AE2E Delay versus size of the area; (b) OLSR-AE2E Delay versus size of the area

As the size of the area increases, the number of blind nodes also increases and the number of packets received per node decreases.

Throughput

Figure 7; illustrate the variation of throughput as a function of the scenario size. As expected, The Two-Ray Grand model offers the best throughput compared to the Rice and Nakagami models. The rate of blind vehicles depends on the size of the buildings. AODV has a slightly lower flow rate than OLSR.

Scenario 3

In Figure 8-10; are shown respectively the results corresponding to the PDF, AE2E Delay and throughput.

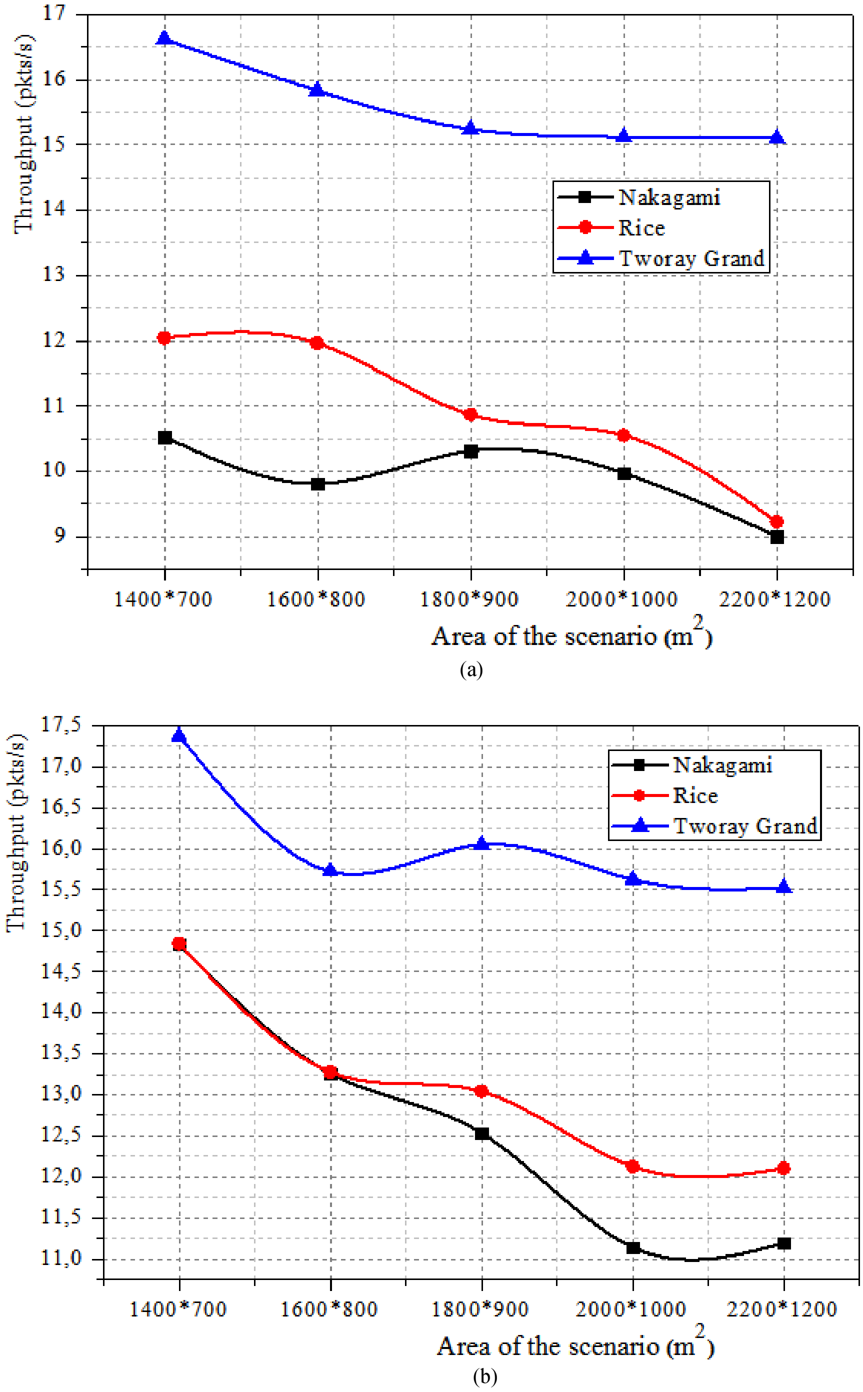
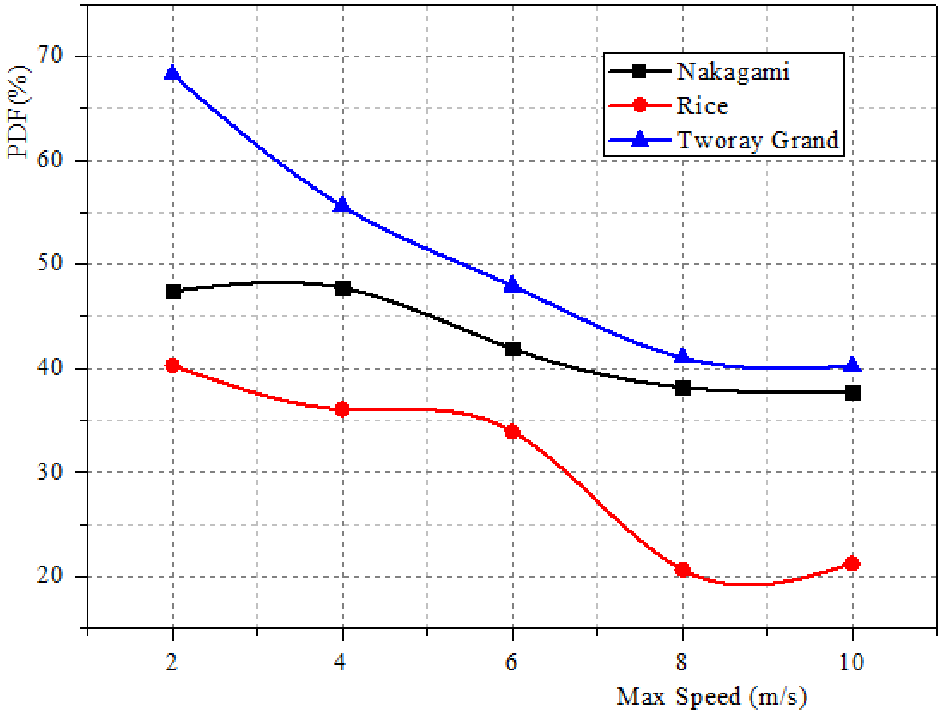


Fig. 7: (a) AODV-Throughput versus size of the area; (b) OLSR-Throughput versus size of the area

Packet Delivery Fraction

Fig. 8 shows that the delivery fraction packets decrease as a function of the increase in speed. Therefore, the links are weaker with speed.

From point of view Throughput, we note that the two-ray ground is more efficient than Nakagami and Rice due to the low signal intensity caused by the obstacles which causes the loss of packets on the weak links and causes the interruption of links and hence the urgent need to create a new route. The Rice and Nakagami models are most appropriate for simulating urban scenarios. The OLSR protocol shows the poor delivery rate of data packets because it uses bad routes to send the data packets.



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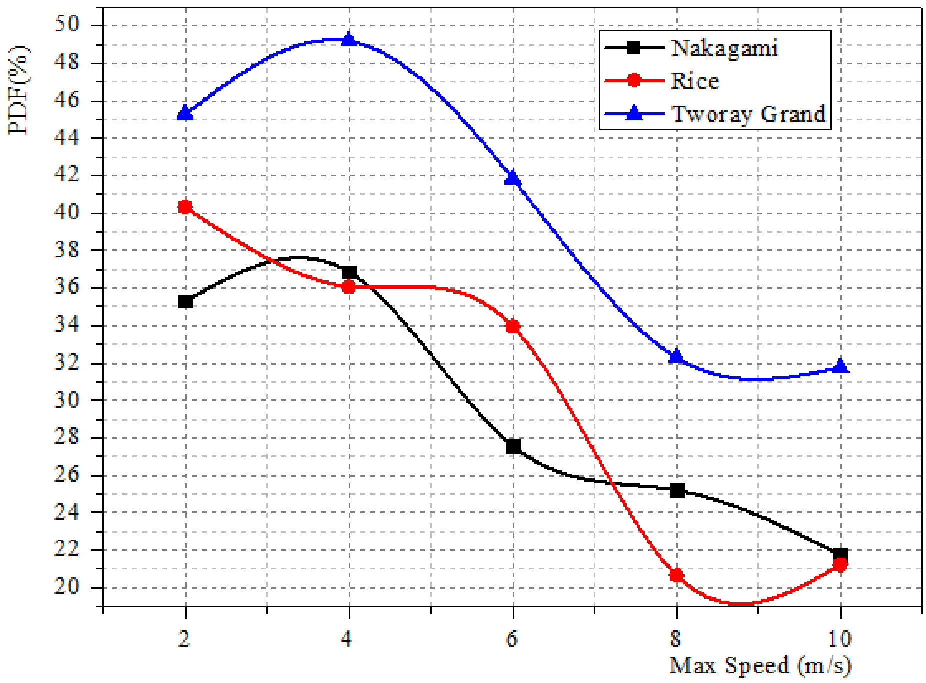

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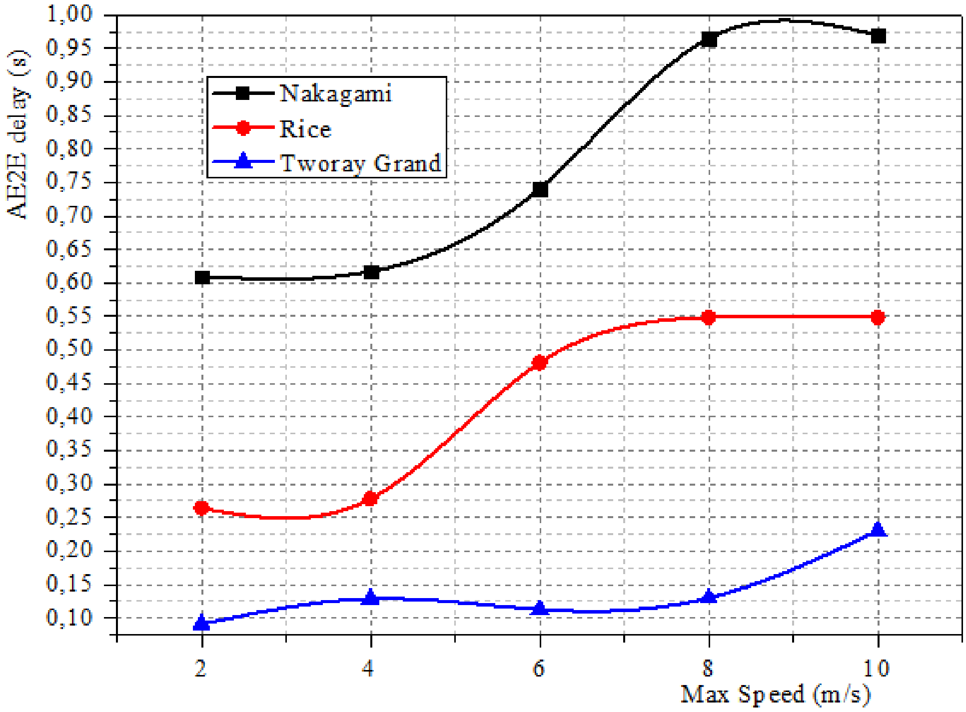
Fig. 8: (a) AODV- PDF versus Speed; (b) OLSR- PDF versus Speed

Average End-to-End Delay

It is also found that the mobility of the nodes has an influence on each metric; in other words, it mainly influences the end-to-end delay. The OLSR protocol has an end-to-end delay considerably less than that of the AODV, therefore, once the link is broken the packets are deleted. In addition, data packets suffer additional delays due to frequent retransmissions and their suppression.



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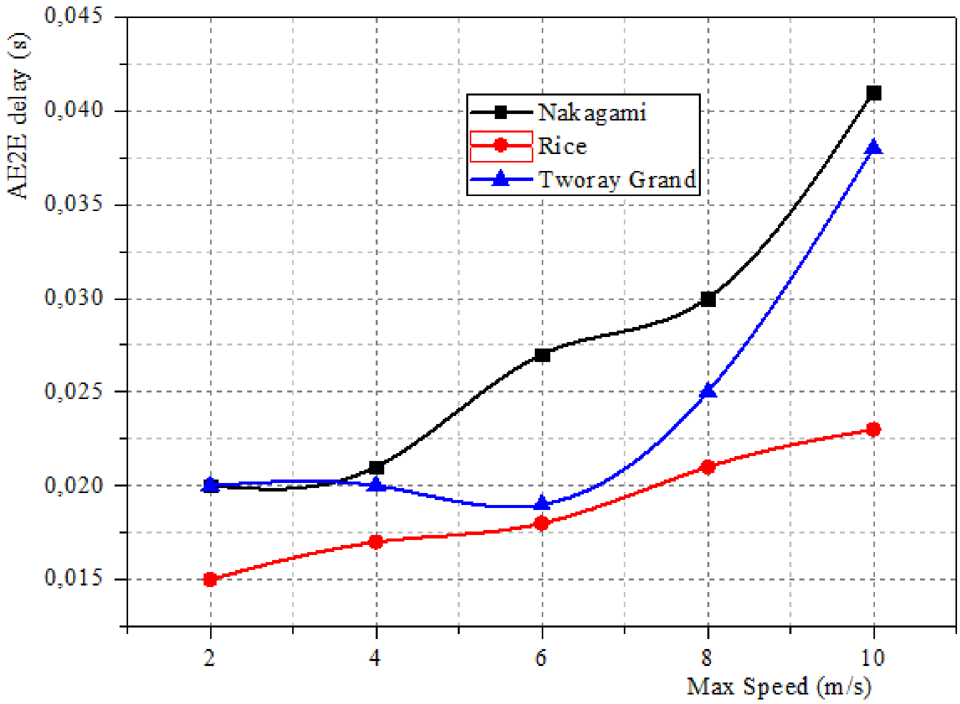

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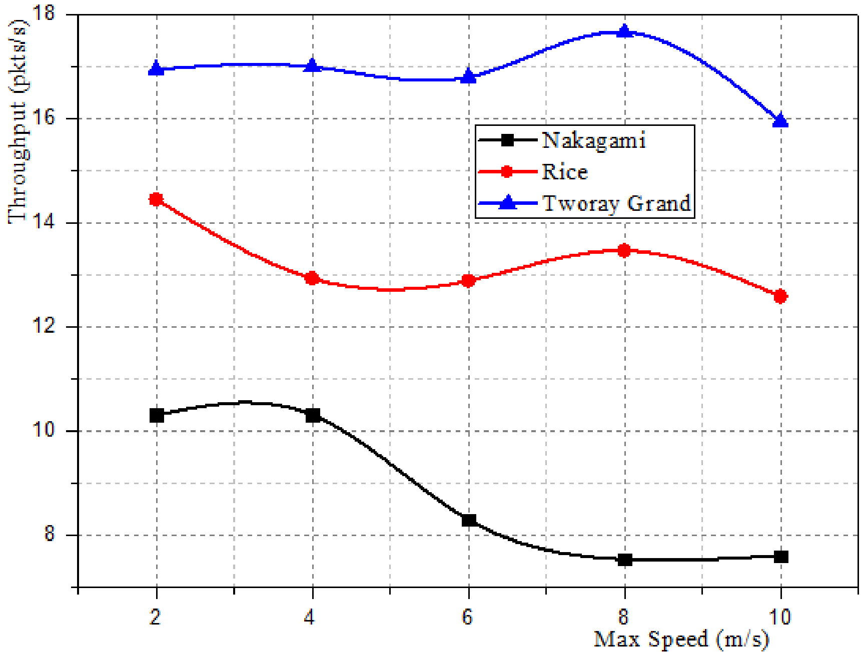
Fig. 9: (a) AODV-AE2E Delay versus Speed; (b) OLSR-AE2E Delay versus Speed

Throughput

In Figure 10, we see that, when the speed increases the throughput decreases slightly because it must find the best way and the channel will be less used for data transfer which reduces throughput. We note that the Two-Ray Grand model is more efficient than the Rice and Nakagami models.



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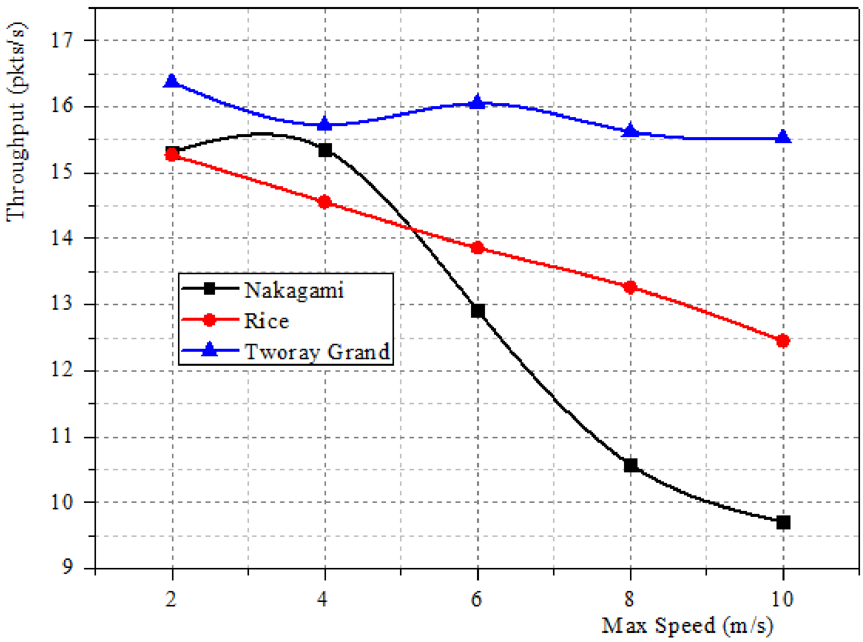

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Fig. 10: (a) AODV-Throughput versus speed; (b) OLSR-Throughput versus speed

Conclusion and Perspectives

In this paper, we first began by studying the influence of radio propagation models on the performance of VANETs, we find that propagation models have a considerable impact on the performance of routing protocols. The performances of the latter are degraded in the case of the Ricean and Nakagami fading models, this being due to the great variation in the intensity of the received signal. In our study, we compared the performance of two routing protocols (AODV and OLSR) for three propagation models (rice with two rays, rice and nakagami). We studied these protocols under different parameters such as traffic density, Smart City architecture (scenario area size) and vehicle mobility. We found that for most of the parameters we used in this paper, OLSR performed better than AODV. Indeed, OLSR has lower routing overhead costs and a short end-to-end delay. For the PDR, OLSR may be challenged by AODV. We also illustrated in this article that average speed was not a valid parameter for evaluating routing protocols in VANET. As a result, these protocols should instead be evaluated against new measures, such as acceleration/deceleration, or street length instead of simple average mobility.

We can also say that, the propagation delay is lower when Traffic density increases. When the area increases, the system needs more time to inform the rest of the vehicles and the percentage of blind nodes also increases and the total number of packets received per node decreases. When the area is very small or the traffic density increase, the percentage of blind nodes is also very small. In future studies, we will include geographic routing protocols in the same way we would take into account new measures, such as acceleration/deceleration, or street length instead of simple average mobility.

Acknowledgment

The authors would like to acknowledge the members of the research team for their efforts and their time and supporting this study.

Author's Contributions

Abdallah Rhattoy: Designed the research plan and organized the study and participated in all experiments, coordinated the data-analysis and programing, simulation of the problem, contributed to the writing of the manuscript, and review and correction of remarks.

Mohamed Lahmer: Coordinated the data-analysis and contribute in drafting and review the article critically.

Idriss Chana: Coordinated the data-analysis and contribute in drafting the article.

Ethics

The participants are informed that their comments will contribute to a research project and all other authors have read and approved the manuscript and no ethical problem.

References

BonnMotion, 2017. BonnMotion: A mobility scenario generation and analysis tool.

Carvalho, M.M. and J.J. Garcia-Luna-Aceves, 2004. Modeling single-hop wireless networks under Rician fading channels. Proceedings of the IEEE Wireless Communications and Networking Conference, Mar. 21-25, IEEE Xplore Press, Atlanta, GA, USA., pp: 219-224. DOI: 10.1109/WCNC.2004.1311546

Dearlove, C. and T. Clausen, 2009. The optimized link state routing protocol version 2. IETF Draft RFC draft-ietf-manet-olsrv2-10.

Delgrossi, L., 2014. The future of the automobile vehicle safety communications. S. University.

Geetha, J. and G. Gopinath, 2008. Performance comparison of two on-demand routing protocols for ad-hoc networks based on random way point mobility model. Am. J. Applied Sci., 5: 659-664. DOI: 10.3844/ajassp.2008.659.664

Khatri, P. and M. Rajput, 2010. Performance study of ad-hoc reactive routing protocols. J. Comput. Sci., 6: 1159-1163. DOI: 10.3844/jcssp.2010.1159.1163

Pranav, K. and L. Kapang, 2011. Comparative study of radio propagation and mobility models in vehicular adhoc network. IJCA J., 16: 37-42. DOI: 10.5120/2031-2600

Rhattoy, A. and A. Zatni, 2012. The impact of radio propagation models on ad hoc networks performances. J. Comput. Sci., 8: 752-760. DOI: 10.3844/jcssp.2012.752.760

Rhattoy, A. and M. Lahmer, 2008. Simulation de la couche physique dans les réseaux mobiles. Errachidia, Maroc.

Schmitz, A. and M. Wenig, 2006. The effect of the radio wave propagation model in mobile ad hoc networks. Proceedings of the 9th ACM International Symposium on Modeling Analysis and Simulation of Wireless and Mobile Systems, Oct. 02-06, ACM, USA, pp: 61-67. DOI: 10.1145/1164717.1164730

Shaheen, A., A. Gaamel and A. Bahaj, 2016. Comparison and analysis study between AODV and DSR routing protocols in VANET with IEEE 802.11b. J. Ubiquitous Syst. Pervasive Netw., 7: 7-12. DOI: 10.5383/JUSPN.07.01.002

Sugandhi, P. and C. Nayak, 2016. A review of performance evaluation and enhancement of proactive and reactive routing protocols of MANET. Int. J. Rapid Res. Eng. Technol. Appl. Sci., 2: 1-6.

Vinothini, S.V. and J.J. Raybin Jose, 2015. A review on routing protocols in VANET. Int. J. Adv. Res. Comput. Commun. Eng., 4: 438-443.