IMPACT OF INTERSECTIONS ON THE PERFORMANCE OF POSITION-BASED ROUTING PROTOCOLS FOR VANETS: A CASE STUDY-SMART CITIES

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ABSTRACT

Purpose: The Vehicular Ad-Hoc Networks (VANET) is an emerging area for smart cities as observed in last few decades. However, some hurdles for VANET exist that need to be resolved before its full implementation in smart cities. The routing is one of the main factors for having effective communication between smart vehicles that urgently need to be addressed. One factor that affects communication between the vehicles is the intersection points that obstruct the communication.

Design/Methodology/Approach: The traditional routing schemes fail to address the intersection problems that occur during the two points of communication. Therefore, this article analyses the performance of existing position-based routing protocol for inter-vehicle ad hoc networks, considering the impact of a number of intersections. This simulation evaluates different position-based routing protocols such as Intersection-based Distance and Traffic-Aware Routing (IDTAR), Improved Greedy Traffic-Aware Routing Protocol (GyTAR), Anchor-Based Street and Traffic Aware Routing (A-STAR) and Geographic Source Routing *(*GSR), based on road topology and the number of intersections.

Findings: As a result, the protocol IDTAR has a lower end-to-end delay and high packet delivery ratio in terms of the number of intersections as a case study of smart cities. This concludes that IDTAR can be adaptive to smart cities communication, although some questions need to be considered in terms of its security, compatibility, reliability and robustness.

Practical implications: The role of VANET has been highlighted in smart cities due to its implications day-to-day life. The vehicles in VANET are equipped with wireless communication nodes to provide network connectivity. Such types of network operate without the legacy infrastructure, as well as legacy client/servers.

Originality/Value of paper: Additionally, the study contributes to smart cities by measuring the performance of position-based routing protocols for VANETs

Key Words: VANETs; Greedy Routing; Dijkstra algorithm; Glomosim; VANETMOBISIM; CBR; TWO-RAY; IEEE 802.11

INTRODUCTION

A Vehicular Ad-Hoc Network (VANET) is a type of mobile ad-hoc network where vehicles communicate wirelessly to provide safety and comfort (Al-Mayouf et al., 2016a). VANET has started getting more consideration due to the emergence of smart cities. The role of VANET has been highlighted in smart cities due to its implications for day-to-day life. The vehicles in VANET are equipped with wireless communication nodes to provide network connectivity. Such types of network operate without the legacy infrastructure as well as legacy client/servers. Each vehicle equipped with a communication device has an ad-hoc node that communicates with each other in its wireless network zone in smart cities. Such a wireless network helps the drivers to select an optimal path and to avoid accidents (Kosch et al., 2006).

In addition, the packet routing plays an important role in the VANET application success, which is also one of the important requirements in smart cities' communication. The frequent changing of the routing topology and high speed of vehicles demands a routing protocol that must cope with smart cities (Khekare and Sakhare, 2013). However, traditional routing protocol fails to do this with their current architecture setups (Al-Mayouf et al., 2016a).

Most of VANET's routing protocols use a greedy routing mechanism to forward data packets to its destination (Karp and Kung, 2000; Lochert et al., 2003; Seet et al., 2004; Jerbi et al., 2007). In a greedy VANET routing protocol, the forwarding node sends data packets to the node that is closest to its destination. It may be possible that the forwarding node may not find another node closer to the destination than itself; this is considered to be a local optimum or local maximum problem. This is because the forwarding vehicle cannot find the suitable vehicle in its radio range to the forwarding packet.

Therefore, this study is motivated by the problems highlighted above for VANETs in smart cities; these problems need to be given strong consideration in the near future. We have evaluated the existing VANET routing protocols in terms of smart cities and have concluded that not all such routing VANET protocols are completely adaptable to smart cities, due to their routing protocol architectures and mechanism. We did this by evaluating the protocols based on the end-to-end delay and packet radio delivery characteristics. This study is concerned with the simulation and performance analysis of position-based routing protocols, specifically:

- Geographic Source Routing (GSR) (Lochert et al., 2003);
- An anchor-based Street and Traffic-Aware Routing with Statically Rated map (A-STAR-SR) (Seet et al., 2004);
- Improved Greedy Traffic-Aware Routing Protocol (GyTAR) (Jerbi et al., 2007);
- Intersection-based Distance and Traffic-Aware Routing (IDTAR) (Abdelmuttlib, 2011).

RELATED STUDIES

Many studies (e.g., Li et al., 2000; Seet et al., 2004), compared the performance of topology-based routing protocols, namely Ad-hoc on Demand Distance Vector (AODV) (Perkins and Royer, 1999) and Dynamic Source Routing (DSR) (Johnson and Maltz, 1996), against position-based routing protocols. The results showed that position-based routing protocols perform better than topology-based routing protocols. Recently, enormous numbers of position-based routing protocols have been introduced; these are the most distinguished protocols considered in this study. This section gives an overview of these protocols; they are then discussed extensively in the next section.

GSR (Lochert et al., 2003) combines position-based routing with geographical information. A Dijkstra algorithm was used to calculate the shortest path on the graphical model of the city, where the intersection is modelled as vertex and streets as edges. The intersections set establishes the path to the destination. GSR (Lochert et al., 2003) follows a carry-and-forward strategy to counter the local maximum problem. For the experiments, a small part of the city of Berlin (6.25 km × 3.45 km) was modelled as a graph of streets with 28 vertices and 67 edges. The limitations of GSR are that it does not consider the vehicle density/connectivity between two intersections; therefore, the route might not be connected through. There is, therefore, a high possibility of a Local Maximum Problem occurrence.

An anchor-based Street and Traffic-Aware Routing with Statically Rated map (A-STAR-SR) (Seet et al., 2004) uses route information to select anchor paths considering the weight of a line of buses. A-STAR (Seet et al., 2004) introduced a new recovery strategy in which a new anchor path is calculated when the packet gets stuck in a local maximum problem; this area would be declared “Out-of-Service” temporarily and would not be used in the calculation of anchor paths. A grid map was used (2800 3 2400 m^2) for the number of roads segments and intersections not mentioned clearly. The limitation of that research is that simulation was carried out for just one network of roads.

Improved Greedy Traffic-Aware Routing Protocol (GyTAR) (Jerbi et al., 2007) uses both city maps and the vehicle’s density to select the intermediate intersections that data packets pass through to reach the desired destination. GyTAR (Jerbi et al., 2007) introduced an improved greedy forwarding strategy to route data packets between two consequent intersections where, in an improved greedy forwarding strategy, the direction and speed of the vehicle are considered; it also uses a carry and forward strategy in order to recover from the local maximum problem. The terrain area of the experiments was 2500 3 2000 m^2, consisting of 16 intersections and 26 two-way roads.

The limitations of the research (Jerbi et al., 2007) are:

1) The comparison conducted in the study used GyTAR (Jerbi et al., 2007), GSR (Lochert et al., 2003) and avoided A-STAR (Jerbi et al., 2007), the most recent Overlaid Position-based routing protocol at that time;
2) The simulation was carried out for just one network of roads.

Intersection-based Distance and Traffic-Aware Routing (IDTAR) (Abdelmuttlib, 2011) provides a reasonable performance by finding robust routes, consequently decreasing the occurrence of a local maximum problem and the cost of recovery strategy in the city environments. Similar to GyTAR, it is composed from two modules: first, a selection of suitable intersections to pass a packet through to the destination. Second, a greedy forwarding strategy between the two involved intersections, where the packet will be passed successively closer towards the destination along streets that have a high density of vehicles.

The details of all the aforementioned protocols with different properties are summarised in Table 1.

Simulation *setup and scenarios*

In this section, we have evaluated the existing VANET routing protocol in smart cities by having different scenarios. Each scenario is different based on the number of roads and intersections in smart cities. In addition, for each scenario, we increased

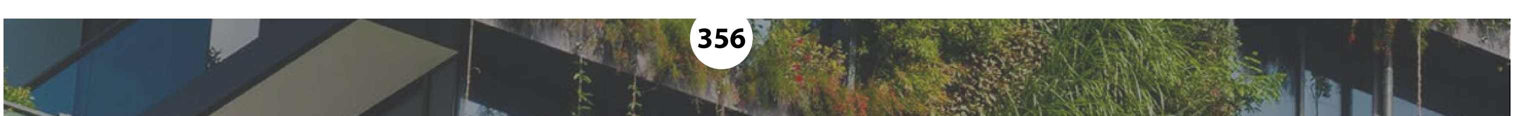


Table 1 Characteristics of Position-Based Routing Protocols for Vanets

Characteristics \ Protocol	GSR	A-STAR-SR	GYTAR	IDTAR
Forwarding method	Greedy forwarding	Greedy forwarding	Improved Greedy forwarding	Greedy forwarding
Recovery Strategy	Carry-and- forward	Recomputed an-chor-path	Carry-and-forward	Re-compute an-chor-path
Anchor-selection	Dijkstra algorithm with weight of hop count	Dijkstra algorithm with weight of road	Dynamically selects anchor based on traffic density and curve metric distance	Dynamically selects anchor based on traffic density and curve-metric distance
Digital map required	Yes	Yes	Yes	Yes

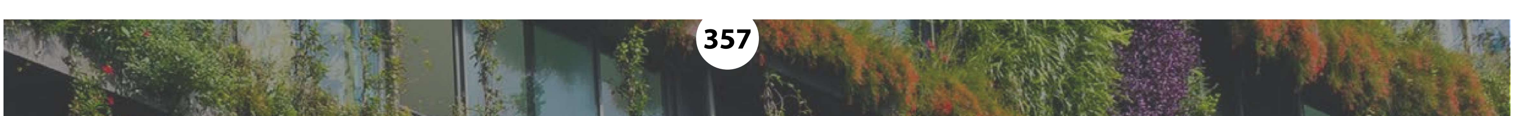
Source: Devised by authors

In this section, we have evaluated the existing VANET routing protocol in smart cities by having different scenarios. Each scenario is different based on the number of roads and intersections in smart cities. In addition, for each scenario, we increased the number of nodes (smart vehicles) from 100 to 300 with a break of 50 nodes. This gives us the best method of properly judging the protocol based on different infrastructure setups. The simulation was created by a simulation tool called Glomosim. This helps us to have a VANET infrastructure due to our customised requirements. The simulation specification is explained in Table 2.
Simulation *setup*

We considered different vehicle densities under which the performance of each protocol was evaluated. The speed of vehicles was limited to 60km/h.

Table 2 Summary of Parameters Settings in the Simulation

Parameter	Setting
Simulator name	Glomosim[1]
Mobility model	VANETMOBISIM[2]
Packet sending rate	4 packets/second
Traffic model	10 CBR connections
Data packet size	128 Bytes
Map size	2500 3 2000 m^2
Node number	100 to 300, in steps of 50
Simulation time	200 Seconds
MAC protocol	IEEE 802.11
Radio propagation model	TWO-RAY[3]



[1]Martin, 2001.
[2]Harri et al., 2006.
[3]Rappaport, 2001.

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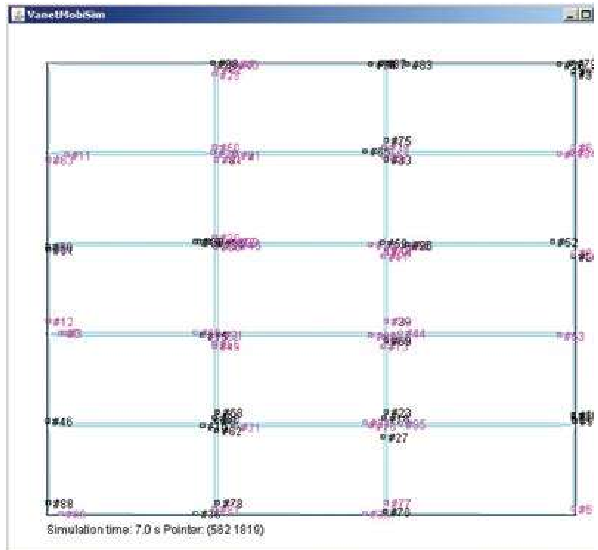

Figure 1 First City Scenario

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Simulation scenarios

The simulation scenarios were based on different city maps in which a number of roads and intersections were changed according to our requirements. Each of the scenarios is explained in the subsequent section below.

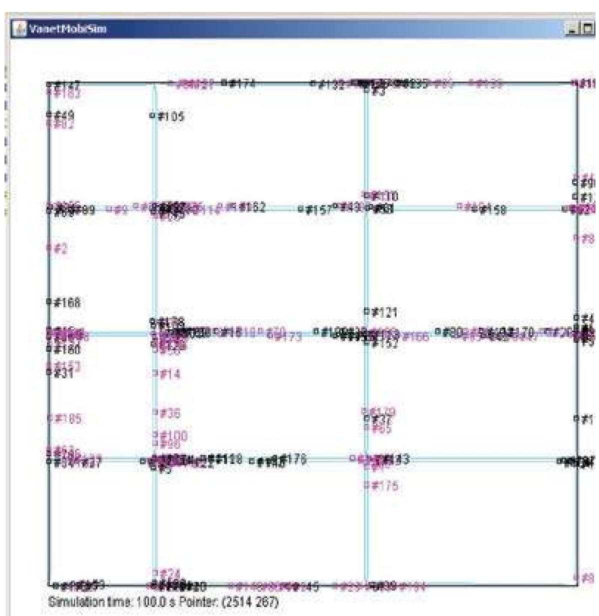

Figure 2 Second City Scenario

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First city scenario

In this scenario, and in order to model a city map similar to the geometric shapes of the smart cities, we designed a grid map in which 24 intersections were taken that are connected with 76 road segments; this is shown in Figure 1.

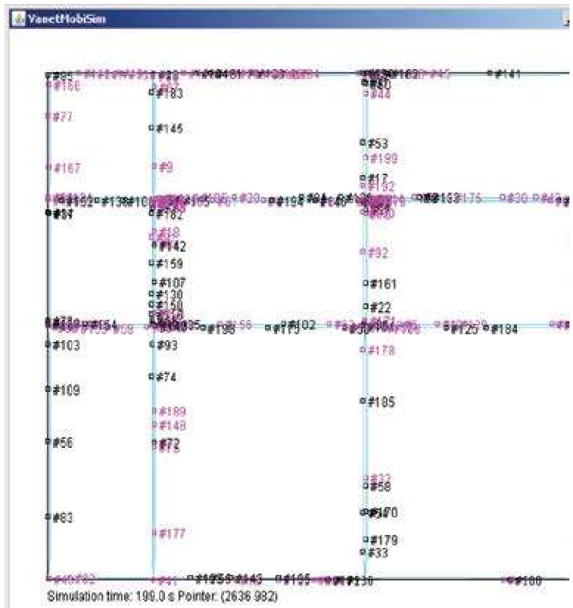

Figure 3 Third City Scenario

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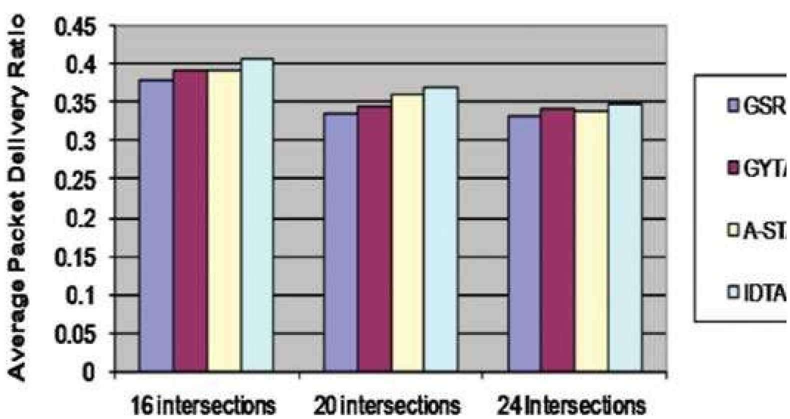

Figure 4 Impact of Intersections Number on Packet Delivery Ratio

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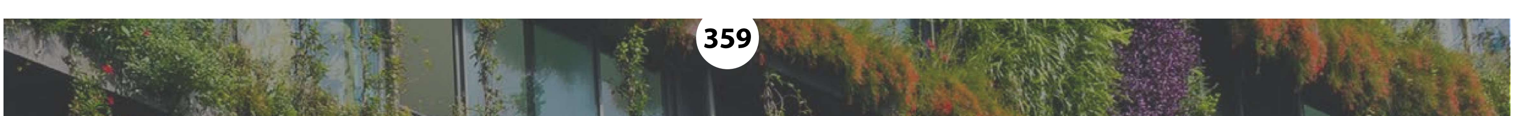
Second city scenario

In this scenario, to make a considerable difference as compared to the first scenario, we removed four intersections and 14 road segments from the smart cities. We then re-arranged the distances between the intersections accordingly. This then gives the smart city with 20 intersections and 62 road segments as depicted in Figure 2.



Third city scenario

In this scenario, we changed our smart city setup by reducing the number of intersections and road segments. We selected 16 intersections and 48 road segments, as illustrated in Figure 3.

RESULT AND DISCUSSION

In this section, we comprehensively explain the results obtained from our simulation environment. The results are based on our frequent experiments; each experiment was conducted more than 10 times. This gives us an average value for our final conclusions.

Figure 4 shows the packet delivery ratios of the four protocols in the different scenarios of smart cities. It comprises 16 intersections, 20 intersections, and 24 intersections, respectively. In all these scenarios the average packet delivery ratio was calculated from 10 runs. In the first scenario, IDTAR demonstrates the highest average packet delivery ratio, followed by GyTAR, A-STAR and at finally GSR. The same ranking appeared again in the second city scenario. In the third smart city scenario, IDTAR came at the top, followed by A-STAR, GyTAR, and last was GSR. The

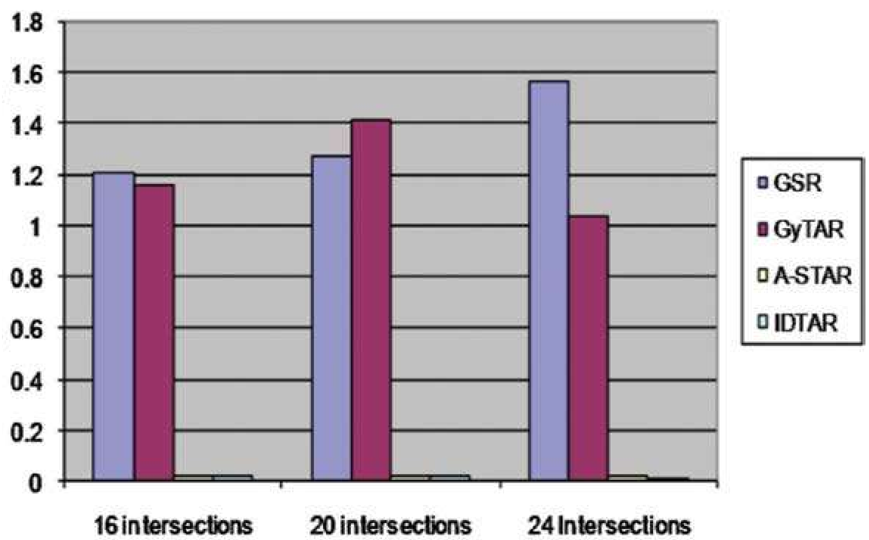


Figure 5 Impact of Intersections Number on End-to-end Delay

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results reveal that the increment of intersection slows down the performance of the four protocols.

Figure 5 shows an end-to-end delay of the four protocols in the different scenarios of smart cities, and comprises 16 intersections, 20 intersections, and 24 intersections respectively. In all these scenarios the end-to-end calculated is performed 10 times, and an average value is taken for our final value. In the first scenario, GSR demonstrated the highest end-to-end delay, followed by GyTAR, IDTAR, and the lowest end-to-end delay was achieved by A-STAR. In the second smart city scenario, GyTAR shows the highest end-to-end delay, followed by GSR, then at the lowest level IDTAR and A-STAR. In third smart city scenario, GSR achieved the maximum end-to-end delay, followed by GyTAR, then closely by IDTAR and A-STAR. In the evaluation of the impact of the number of intersections on the overall end-to-end delay of the four protocols, we observed that the increment in the number of intersections increases the end-to-end delay of GSR and A-STAR, and decreases the end-to-end delay of GyTAR and IDTAR.

CONCLUSIONS

After a great many evaluation experiments, we concluded that the IDTAR routing VANET protocol is best for all the selected routing protocols in terms of smart cities. The IDTAR provides less end-to-end delay and maximum packet delivery ratio. It is considered the best for adapting to the smart cities VANET routing communication, due to its re-computing anchor path and dynamic selection of anchor based on traffic density and curve-metric distance: these provide the maximum packet delivery ratio. These parameters also help IDTAR to be adopted by smart cities where smart vehicles communicate with each other in the VANET environment.

In future, we are going to implement our scenarios in real smart cities to evaluate and compare the existing VANET routing protocols with real facts and figures. In addition, we are going to propose our framework that will cope with all the issues related to the VANET routing protocol in smart cities.

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