VANET routing protocol for V2V implementation: A suitable solution for developing countries

Ahmed Yasser1*, M. Zorkany2 and Neamat Abdel Kader1

Abstract: During the last decade Intelligent Transportation System (ITS) research and development, including its implementation in a real life going through the optimization in order to have the best and accurate results is growing exponentially. Now ITS topics are standing on a solid ground. Many European countries and USA started to implement and use them. In the developing countries the infrastructure is not established well with a lot of challenges (ex. Infrastructure cost, ...). In this paper, Vehicle-to-Vehicle (V2V) implementation will be used as a standalone for ITS architecture in the developing countries without Road site units (RSU) infrastructure to overcome the current challenges. To do that, a full simulation for different Vehicular Ad-Hoc Network (VANET) routing protocols will be done using Opnet simulator to select the best protocol for V2V Implementation. Then the best V2V routing protocol based on the paper’s Key Performance Indicators and point of view will be used to compare between two different architectures, one with V2V + RSU implementation and the other one with proposed V2V only implementation. The results demonstrate that the proposed ITS architecture based on V2V only without RSU is capable of implementing ITS in developing countries.

Subjects: Packaging; Intelligent & Automated Transport System Technology; Intelligent Systems

Keywords: vehicle to vehicle (V2V); intelligent transportation systems (ITS); routing protocols

ABOUT THE AUTHORS
Ahmed Yasser is a MSc student, He had BSc degree in Electronic and Communication engineering 2006. His research focuses on Intelligent Transportation System (ITS), Vehicular Ad-Hoc Network (VANET) and Vehicle To Vehicle (V2V).

Dr M. Zorkany is an Assistant Professor in National telecommunication Institute, He had PhD degree in Electronic and Communication engineering 2012. His research focuses on signal and multimedia processing, communication, Intelligent Transportation System (ITS) and Internet of Things (IoT).

Dr Neamat Abdel Kader is a Professor in Faculty of Engineering Cairo University, She had PhD degree in Electronic and Communication engineering. Her research focuses on image processing, communication, Intelligent Transportation System (ITS) and Internet of Things (IoT), also she supervised a lot of researches for more than 20 years.

PUBLIC INTEREST STATEMENT
Implementing Vehicle to Vehicle (V2V) communication in our transportation system will enhance our daily lives, decrease the loss of lives and properties, enhance the investment opportunities in the developing countries, so this research question “is it doable to have a V2V implementation in the developing countries?” and based on the answer of this question, the research proposes the best V2V routing protocol to fit in these countries.

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1. Introduction

Intelligent Transportation System (ITS) is a diverse and expanding subject, with some of its constituent parts converging or overlapping. For example, transport and travel information might be viewed under a Smart Cities agenda, and similarly connected cars are an articulation of Machine-to-Machine (M2M) Communications and the Internet of Things (IoT), Vehicular Ad-Hoc Network (VANET) networks is usually developed as a part of ITS. ITS are developing applications which, without embodying intelligence as such, target to provide innovative services relating to different modes of transport and traffic management and enable different users to be better informed and make safer, more coordinated, and ‘smarter’ use of transport networks.

MANET is the short form of Mobile AdHoc Network. In ad-hoc networks all the nodes are mobile in nature and hence they can be interfaced dynamically in arbitrary fashion. VANET is the short form of Vehicular Adhoc Network, it is subclass of network of MANET type. The routing protocols of MANET are not feasible to be used in the VANET network.

VANET is one of the main types of mobile ad hoc networks (MANETs). From the high level perspective, they are the same. However, some characteristics are specific for the VANETs that make them not similar to the MANETs. Compared with the other classes of mobile ad hoc networks, VANETs have unique characteristics. The main characteristics of the VANETs are as follows: heterogeneous communication range, mobility of the vehicles, geographically constrained topology, time varying vehicle density, frequently disconnected network, dynamic topology, and the vehicles being the components that build the network (Najafzadeh, Ithnin, & Abd Razak, 2014).

The VANET routing protocols need to be designed considering factors such as the security, mobility and scalability of vehicular communication (Patel, Faisal, Batavia, Makhija, & Mani, 2016).

The goal of VANET architecture is to allow the connection between vehicles or between vehicles and fixed road side units leading to the following three possibilities (Da Cunha, Boukerche, Villas, Viana, & Loureiro, 2015).

• Vehicle-to-Vehicle (V2V) ad hoc network: allows the direct vehicular communication without relying on a fixed infrastructure support and can be mainly employed for security, safety and dissemination applications.

• Vehicle-to-Infrastructure (V2I) network: allows a vehicle to communicate with the roadside unit mainly for information and data gathering apps.

• Hybrid architecture: combines both V2I communications and V2V. In this scenario, a vehicle can communicate with the roadside infrastructure either in a multi-hop or single hop fashion, depending on the distance, i.e. if it can or not access directly the roadside unit. It enables long distance connection to the Internet or to vehicles that are far away.

V2V communication is the wireless transmission of data between motor vehicles (Rouse, 2014).

The main goal of V2V communication is to avoid accidents by allowing vehicles in transit to send speed and position data to one another over an ad hoc mesh network. Depending upon how the technology is implemented, the vehicle’s driver may receive a warning in a simple way should there
be a risk of an accident or the vehicle itself may take preemptive actions such as braking to slow down (Rouse, 2014).

V2V is important in the developing countries because of the bad infrastructure, low internet & networks capacity, large areas of uninhabited places and spread of theft of public properties led to not installing Road site units (RSU) on the high way roads.

In order to evaluate the V2V network or any other VANET network, some Key Performance Indicators (KPIs) are essential like (Delay, No. of Hops, Retransmission Attempts, Traffic Received, Throughput), it is not necessary that the network should have the best results in all KPIs, first they must be realistic, and provide acceptable results in all KPIs, and during the decision taking part all the KPIs must be prioritized based on the required solution (Coutinho, Wille, & Del Monego, 2015).

In this paper, a simulation using the Opnet modulator for the most popular VANET routing protocols will be done to obtain the best KPIs from its perspective and choose the best one based on the KPIs, then the implementation of the proposed routing protocol using RSU and without RSU will be done in order to find the best implementation for V2V without RSU which need to be used in the roads or the countries who do not have RSU implementation.

This paper is organized as follows. Related work is summarized in Section 2. A brief review of VANET routing protocols are presented in Section 3. The proposed V2V implementation is presented in Section 4. Simulation results and discussions are given in Section 5 and finally the conclusion and the references are included.

2. Related work
Vehicular Ad hoc Networks (VANETs) are group of vehicles with wireless communication enabled. Broadcasting is the task of sending a message from a source node to all other nodes in the network, which is repeatedly referred to as data dissemination. RSU is considered as wireless LAN access point and can provide communications with infrastructure. Also it can have higher range of communication up to 1,000 m (Balappgol & Deshmukh, 2015).

The current ITS architecture is based on (Vegni & Little, 2010):

- Vehicle to Vehicle (V2V)
- Vehicle to Roadside (V2R)
- Vehicle to Infrastructure (V2I)

Figure 1 describes the high level structure of ITS solution based on V2V assisted V2I.
There is a common factor in the wireless communication that it enables a large mobility and safety applications collection beside its assistance for V2V safety applications when mapped with RSU infrastructure, so V2V acts as the ITS program gateway because of being fully integrated (NHTSA, 2014).

3. Vanet routing protocols

High dynamic topology characteristics turn out the efficient VANET routing protocols design to be more hard. The VANET routing protocol can be classified into two categories such as Topology based routing protocols and Position based routing protocols, the most popular sub categories under them is Dynamic Source Routing (DSR), UMB, OLSR, TORA, GRP and Ad Hoc On Demand Distance Vector (AODV) (Paul, Ibrahim, Bikas, & Naser, 2011).

(1) Topology based routing protocols use links information to transmit the packets of data between nodes through the VANET. There are two sub categories under this mechanism, the proactive approach which depends on routing techniques related to table driven methodology and the reactive approach which depends on routing techniques related to on demand methodology (Paul et al., 2011).

(a) Proactive routing protocols are commonly depending on algorithms related to shortest route. They save all the data related to the connected nodes in predefined tables which are the main mechanism in these routing protocols. Also, there data are engaged with the partner nodes. Each routing table is updated by its node when the network topology is changed by any event.

Advantages

• Real time applications low latency.
• It is not required to have a path discovery.

Disadvantages

• A huge part of the available bandwidth occupied by unused routes.

(b) Reactive routing protocols are commonly depending on algorithms related to on demand actions. When two nodes want to communicate, they initiate the path discovery and one of its main benefits is the network traffic reduction (Kaur, Singh, & Sharma, 2016).

Advantages

• Flooding is required when it is requested, so it doesn’t require proactive overflow in the network.
• It controls the bandwidth as it is Beaconless.

Disadvantages

• Nodes communication disturbance occurred because of the network exaggerated flooding.
• High latency in path searching.

(2) Geographic based routing protocols are depending on algorithms related to the positioning mechanism using location based applications (For example GPS). Such applications are providing such data for path selection. Also these protocols are not servicing any tables related to routing data or any information related to the join status with the nearby nodes (Kaur et al., 2016).
Figure 2 describes the full chart of the VANET Routing Protocols based on their methodology and mechanism.

3.1. AODV
Ad Hoc On Demand Distance Vector routing protocol is depending on a mechanism related to on-demand approach which initiates a path when a VANET node transmits packets of data to another node. The Destination Sequence Number is used by this protocol which is a unique feature not available in similar sub category routing protocols. It can be used in singular and multimode routing (Perkins, Belding-Royer, & Das, 2003).

Like all reactive protocols, the philosophy in AODV, the information is only transmitted between nodes in an on-demand mode. When a node wants to transmit traffic to the host node without a predefined route, it will create a (RREQ) route request message to be flooded to the other nodes in a limited way (Hafslund, 2003).

AODV uses the below types of control messages for route servicing:

1. RREQ—When a node is seeking a path to a node, then it transmits the route request message.
2. RREP—A route reply message is transmitted in a single mode back to the source of a RREQ if the receiver is the node using the required address or it has a functional path to the required address.
3. RERR—In functional paths nodes observe upcoming hops link’s status. For reporting technique activation, a “precursor list” is retained by each node, which including its neighbors IP address probably to exercise it as a next hop among each destination node. When the broken link in an active route is detected, other nodes are warned by this message type for the link loss.

Advantages

• AODV can be used in large VANET networks.
• Any failure in the VANET links is handled in a prompt way by the AODV.
• The route redundancy and excessive memory requirements are minimized.
• Distance Sequence Number is providing recent route to the destination node.
Disadvantages

- It expends extra bandwidth, because of proactive beaoning. High control overhead is occurring when many route reply packets for a single path.
- Compared to other approaches, high processing time is required for the connection initiation and the first attempt to set the path.
- Route inconsistency may occur when old entries are included in intermediate nodes.

Figure 3 illustrates the routing mechanism of the AODV protocol.

### 3.2. DSR

The DSR protocol utilizes source routing and maintains functional paths. It consists of route detection and route servicing (Johnson & Maltz, 1996).

A node requires four essential structures of data that are considered to be conceptual, to be able to engage in the DSR: a Retransmission Buffer, a Send Buffer, a Route Cache and a Route Request Table (Josh Broch & Maltz, 1998).

1. **Route Request Table**: The route request table is partitioned by the target home address of the route discovery. The Route Request Table is considered of records collection about Route Request packets that were recently forwarded or originated by this node (Josh Broch & Maltz, 1998).

2. **Route Cache**: In the VANET network every node is servicing its own tables which save the route cache. Route Cache is responsible for storing all requested information related to routing by a new participant node in a VANET network using a DSR routing protocol (Josh Broch & Maltz, 1998).

3. **Retransmission Buffer**: The Retransmission Buffer of a node is packets queue sent by this node that is expecting for the arrival of an acknowledgment from the next hop in the source path (Josh Broch & Maltz, 1998).

4. **Send Buffer**: Every packet after being registered in the buffer should be deleted from the send buffer and get rid of it in SEND\_BUFFER\_TIMEOUT seconds, also is associated with the time it is registered into the buffer (Josh Broch & Maltz, 1998).

![AODV routing protocol](image)

**AODV uses three control messages to obtain and maintain routes:**

- **Route Request (RREQ)**
- **Route Reply (RREP)**
- **Route Error (RERR)**

  If a node is unable to forward packet, it generates a RERR message. When the originator node receives the RERR, it initiates a new route discovery for the given route.
Advantages

• No proactive updates are desired in DSR.
• Compared to other approaches, extra overload is occurring on the VANET as it searches for the paths in a reactive approach.
• Beacon less.

Disadvantages

• Cracked links can't be reformed locally.
• The performance is declining in highly dynamic VANET.
• The VANET is overflowed by superfluous load.
• In high traffic VANET network which is an expected pattern, Byte overhead is occurring by the path data in the header.

3.3. OLSR

It means optimized link state routing which means a routing protocol using the proactive mode. In this, whenever any change in the topology occur, MPR (multipoint relay) are responsible to generate and forward the topology information to selected nodes (Jacquet et al., 2003).

It is a proactive protocol based on the table-driven methodology. From its name, the link-state scheme is used by this protocol in an enhanced way to circulate topology information. OLSR is using this mechanism also, but in order to maintain bandwidth the message overflow in OLSR is enhanced as the protocol works in wireless multi-hop scenarios (Jacquet et al., 2003) (Figure 4).

Figure 4. MPR technique.
AS OLSR protocol based on tables, OLSR operation fundamentally consists of servicing and updating information in a set of tables. These tables are including data which is based on received control traffic, and control traffic is produced based on information returned from these tables. The tables are managing the route calculation itself as well (Jacquet et al., 2003).

OLSR uses the below essential control messages types:

1. Topology Control messages (TC).
2. HELLO control messages (HELLO).
3. Multiple Interface Declaration messages (MID).

Advantages

- In broadcast scenario, reduce the number of retransmission of packets.

Disadvantages

- In OLSR, large amount of bandwidth and CPU power is required to compute the optimal path.

3.4. GRP

GRP routing is used into two approaches. In greedy forwarding, the data is sent to the closest neighbor of the destination node using the three VANET routing mechanisms. In order to select the neighbor node, so these routing mechanisms will be used. The second approach is face-2 or perimeter routing which implies planner graph traversal concept (Perkins et al., 2003).

In order use the Greedy forwarding approach, the sender node determines the receiver node's estimated location. The message is transmitted to the receiver node's closest neighbor.

The positioning scheme is responsible for collecting the message for example GPS. The intermediate node receives the data to a neighbor two-faced through the receiver node's way (Mauve, Widmer, & Hartenstein, 2001). This process is persistent until the the receiver node receives the data. In the VANET network each node is servicing its own table where the address of the each node is registered (Sharma, Kaur, & Singh, 2012). The different routing mechanisms in the greedy forwarding are known as in terms of development, space and direction towards the receiver node (Maghsoudliou, Stilaire, & Kunz, 2011). From the different strategies, a node can choose to determines the packet should be transmitted to which neighbor node. The greedy forwarding main obstacle is to choose which neighbor node is the most accurate node to send the data to it. The different routing mechanisms are used for the neighbor node selection.

The three different routing mechanisms in Greedy forwarding approach are Nearest with Forwarded Progress (NFP), Most Forwarded within R (MFR) and Compass Routing.

Another approach which is defined as the Perimeter approach or Face-2 method in order to avert the limitations of the greedy forwarding approach. In this routing technique type, if the forward path cannot be determined by any node in the network, so the node with the least backward progress will receive the packet (Khakkar & Singh, 2012). One of the main drawbacks of this approach that the looping packets problem is existing, which doesn't exist in forward packet towards the destination with positive progress. The Perimeter approach is based on the planner graph traversal, so any node doesn't require to save any extra or unimportant information. By default it progresses to the greedy forwarding mode when the packet becomes more closer to the destination where the packet step inside the improvement mode (Menon & Prathap, 2013).
Advantages

- Route discovery and management is not required.
- Scalability.
- Suitable for high node mobility pattern.

Disadvantages

- It requires position determining services.
- GPS device doesn't work in tunnel because satellite signal is absent there.

4. PROPOSED V2V implementation

The paper is targeting to get the benefits of the current ITS architecture without using the RSU elements because of the infrastructure problems in the developing countries.

The proposed ITS architecture is implemented for delivering real time communication between vehicles directly without using road site unit based rebroadcast messages between vehicles.

The proposed ITS use V2V communications using DSRC units in each vehicle which depend on WiFi communication. Also the system can communicate with servers and traffic centres using ready-made GSM/GPRS which its infrastructure already exist in most developing countries.

While the current ITS architecture is based on V2V, V2I and V2R. The proposed ITS architecture is based on V2V as shown in Figure 5(b).
The proposed V2V communication depend on the wireless technology that supports V2V safety applications (DSRC-5.9 GHz) and also enable a broader set of safety and mobility applications. and these communications will combined with GSM/GPRS infrastructure.

The Connected Vehicle Core System Architecture describes the overall anticipated system, including V2I and V2V capabilities.

The proposed ITS architecture is based on two phases as the following:

Phase 1: select the most probable VANET routing protocol in ITS architecture.
Phase 2: compare between the current and proposed ITS architecture using this VANET routing protocol.

So in phase 1, the comparison will be done between most four different routing protocols in the V2V setup based on two different scenarios (Low and High Traffic), then choose the best VANET routing protocol based on the KPIs, and in phase 2, the comparison will be done between the current ITS architecture using this routing protocol, and the proposed architecture using the same routing protocol including some optimizations in the proposed routing protocol to offer a competitive KPIs with the current production ITS implementation.

To validate reality of proposed V2V implementation in two phases, two scenarios represent light and heavy traffic were used as the following:

In the first phase, two scenarios were used (1st one with 20 vehicles and the 2nd one with 40 vehicles) with four different routing protocols (AODV, DSR, GRP, OLSR) as discussed in Section 3 (VANET routing protocol), the comparison is based on 6 KPIs as the following.

• VANET Delay, VANET Throughput, VANET Retransmission Attempts, VANET Dropped Data, VANET Load and VANET Traffic Received.

In the second phase, the selected VANET routing protocol “AODV” will be used to compare between the V2V implementation without RSU and the actual V2V implementation in US and Europe using two scenarios (1st one with 20 vehicles and the 2nd one with 40 vehicles), the comparison is based on six KPIs as the following.

• VANET Delay, VANET Throughput, VANET Retransmission Attempts, VANET Load, AODV Number of Hops Per Route and AODV Route Discovery Time.

The main criteria for choosing the proposed ITS architecture is to meet the real life implementation challenges, and to be compared with the other current implemented solutions, so the measurements for these solutions were taken, and applied them on the proposed ITS architecture, in order to say clearly what is the paper position between the other solutions, so the below measurements were used as the following.

4.1. Safety
It is one of the main criteria as the VANET implementation does not accept any kind of failure, as this may impacts our lives directly, so it is not expected that there will be a problem in the routing protocol.

4.2. Efficiency
It was required to be sure that the data is exchanged between the vehicles in different Hops with the least data dropped rate, and implying good use of resources.
4.3. **Reliability**

This criteria was depending on choosing the routing protocol with the lowest number of errors, also failure to deliver the real-time data will adversely affect the performance of the V2V network.

4.4. **Performance**

The proposed routing protocol was requested to provide for example the lowest acceptable delay, retransmission attempts, route discovery time, and load.

4.5. **Consistency**

In these criteria, the main finding is to ensure that the V2V routing is processing all the time with 100 percent of its functionality and how to predict the average response time, delay and accuracy of data, in order to validate that the V2V network is working fine or need some maintenance.

4.6. **Standardization**

The comparison in this section was based on choosing the most standard routing protocol with the lowest adjustment in its default settings and on the other side to provide on the other side the best performance, this will be preferred on the real life implementations because less adjustments will lead to more simplicity.

5. **Simulation environment**

In this simulation a comparison will be done between four different VANET routing protocols for the V2V implementation in two different scenarios (Low Traffic and High Traffic) using some essential KPIS like (Delay, Dropped Data, Retransmission attempts) in order to find one routing protocol with acceptable results then this protocol will be used to compare between two implementations, one without RSU “V2V” and the other one with RSU “V2V + V2I”, after this final comparison, the simulation will declare if the V2V implementation without RSU using the proposed VANET routing protocol is ready for real life implementations or not for low and high traffic, and what is the required optimization to let its KPIS comes out with acceptable results compared with the V2V + V2I implementation (Figure 6).

![Figure 6. Simulation model](image)
In this paper the OPNET modulator will be used as the simulator, OPNET is based on a mechanism called discrete event system which means that the application behavior can simulate by modeling the events in the system in the order of the scenarios the user has set up. Hierarchical structure is used to regulate the networks. The programming tools are also required to perform the tasks of defining the state transition machine, defining network model and the process module. As other network simulators, OPNET also provides programming tools for users to define the packet format of the protocol (Pan & Jain, 2008).

For choosing the VANET routing protocol phase, nodes are randomly deployed in 9,000 × 1,000 m area. Simulations are carried out using the network simulator Opnet 14. Each node is equipped with a transceiver. Different nodes communicate via radio signals having a transmission range of 500 m. Channel bandwidth taken is 2 Mbps. Nodes are allowed to move randomly with different speed. Simulation Parameters used in the simulation shown in Table 1.

5.1. V2V routing protocol selection phase

5.1.1. VANET delay

First scenario

In the low traffic scenario, at the beginning of the simulation it was found that the AODV routing protocol has the highest delay because there was no acknowledgement applied on the vehicles yet, OLSR has the lowest delay, and after a while the AODV became the lowest delay as shown in Figure 7(a).

Second scenario

In the high traffic scenario, the output related to delay was nearly similar to the low traffic scenario, except more delay spikes in the DSR and less in the AODV as shown in Figure 7(b).

| Table 1. Simulation parameters |
|--------------------------------|
| Parameter                     | Value                  |
| Total simulation time         | 10 min                 |
| Simulation area               | 9,000 × 1,000 m        |
| Total number of vehicles      | First scenario = 20 vehicles |
|                               | Second scenario = 40 vehicles |
| Vehicles mobility             | 10, 15, 20, 25, 30, 35 km/h |
| Mobility model                | Random waypoint model   |
| Number of lanes               | 2                      |
| IEEE 802.11 p data rate       | 1 Mbps                 |
| Channel bandwidth             | 2 Mbps                 |
| Packet size                   | 512 bytes              |
| Transmission range per hop    | 500 m                  |
| Node processing delay         | 0.26 s                 |
5.1.2. VANET throughput

First scenario

In the low traffic scenario, it was found that the OLSR routing protocol has the highest throughput which means it is the best in units processing for a given time, AODV and GRP there results were in the middle range and DSR has the lowest throughput as shown in Figure 8(a).

Second scenario

In the high traffic scenario, the output related to throughput was nearly similar to the low traffic scenario, except some improvements in the GRP throughput but it didn’t change the main ranking as shown in Figure 8(b).
5.1.3. VANET retransmission attempts

First scenario

In the low traffic scenario, it was found that the GRP routing protocol has the highest Retransmission which is a major drawback in the routing protocol, OLSR was the lowest Retransmission, but in general the four routing protocols are nearly similar at the end of the simulation time as shown in Figure 9(a).

Second scenario

In the high traffic scenario, the output was different from the low scenario, the results are away from each other, AODV retransmission attempts are improving in the high traffic, on the other side GRP retransmission attempts are increasing in a parallel mode with any increase in the number of vehicles as shown in Figure 9(b).
5.1.4. VANET dropped data

First scenario

In the low traffic scenario, it was found that the GRP routing protocol has the highest Dropped Data, OLSR has the lowest Retransmission, but in general the OLSR, AODV, and DSR routing protocols are nearly similar at the end of the simulation time as shown in Figure 10(a).

Second scenario

In the high traffic scenario, the output related to dropped data was nearly similar to the low traffic scenario, except a very high dropped data rate in the DSR which is a drawback for the reactive routing protocols as shown in Figure 10(b).
5.1.5. VANET load

First scenario

In the low traffic scenario, it was found that the GRP routing protocol has the highest Load, AODV and DSR have the lowest Load because they are acting in a reactive mode which is depending on the requests sent first, regarding the OLSR its load was high because of the proactive searching for the best routing paths which consumes a lot of the network resources to sustain its performance, this reflects the reliability of the VANET network as shown in Figure 11(a).

Second scenario

In the high traffic scenario, the output related to the VANET load was more stable (Less spikes), but still AODV output was the best result, this scenario is more practical example, as most of the roads are including high traffic daily as shown in Figure 11(b).
5.1.6. VANET traffic received

First scenario

In the low traffic scenario, it was found that the DSR routing protocol has the highest Traffic Received, OLSR has the lowest Traffic Received because of its main advantage as it is a proactive routing protocol so it is managing the routes periodically without waiting for a broadcast to be sent then to discover the best routing path, regarding AODV the traffic was increasing due to the search of the undiscovered routes as shown in Figure 12(a).

Second scenario

In the high traffic scenario, it was found that the DSR routing protocol has the highest Traffic Received, GRP has the lowest Traffic Received with more stable behavior in this scenario, also AODV was improving in traffic with any increase in the number of vehicles, on the other side OLSR was providing worse results compared with the first scenario as shown in Figure 12(b).
From these KPIs in both scenarios, the OLSR and AODV are the best VANET Routing Protocols based on the simulation output, but from the real implementation perspective it is recommended to use the AODV because of its overall delay and load which is ideal for the real life implementation, although it is high in the retransmission attempts for low traffic but that was required in order to have accurate acknowledgement messages between vehicles in different Hops.

5.2. Comparison between proposed V2V and current ITS

5.2.1. VANET delay

First scenario

In the low traffic scenario, it was found that the AODV routing protocol with RSU implementation has higher delay than AODV routing protocol without RSU implementation, because there is a mandatory connection between vehicles and the RSUs, but in the other implementation without RSU, the connection will be between vehicles only as shown in Figure 13(a).
Second scenario

In the high traffic scenario, it was found that the AODV routing protocol with RSU implementation enhanced its results and became similar to AODV without RSU implementation results, because of the large number of vehicles which will decrease the delay between nodes as shown in Figure 13(b).

5.2.2. VANET throughput

First scenario

In the low traffic scenario, it was found that the AODV routing protocol with RSU implementation has higher throughput than AODV routing protocol without RSU implementation because of the RSUs which secure the highest processing in the network as shown in Figure 14(a).

Second scenario

In the high traffic scenario, it was found that the AODV routing protocol without RSU implementation improved it’s throughput due to the increase of the number of vehicles, so it was managed to send a high throughput as if there were implemented RSU as shown in Figure 14(b).
5.2.3. VANET retransmission attempts

First scenario

In the low traffic scenario, it was found that the AODV routing protocol with RSU implementation has lower retransmission attempts than AODV routing protocol without RSU implementation, because the failed communications is very low due to the accuracy of the using RSU access points as shown in Figure 15(a).

Second scenario

In the high traffic scenario, it was found that the AODV routing protocol with RSU implementation retransmission attempts results became similar to AODV routing protocol without RSU implementation results, the accuracy was impacted because of the high number of vehicles which led to more dynamic VANET network as shown in Figure 15(b).
5.2.4. VANET load

First scenario

In the low traffic scenario, it was found that the AODV routing protocol with RSU implementation has higher load than AODV routing protocol without RSU implementation, because the communication goes through vehicles and RSUs, so this implies a high load on the network as shown in Figure 16(a).

Second scenario

In the high traffic scenario, it was found that the AODV routing protocol with RSU implementation results became similar to AODV routing protocol without RSU implementation results, but still the AODV routing protocol without RSU implementation is lower in the load with more stable results in both cases as shown in Figure 16(b).
5.2.5. AODV number of hops per route

First scenario

In the low traffic scenario, it was found that the AODV routing protocol with RSU implementation has higher No. of Hops per Route than the AODV routing protocol without RSU implementation, as the IP forwarding without RSU depends on the shortest path and the speed of the vehicles in the Hop as shown in Figure 17(a).

Second scenario

In the high traffic scenario, the output related to the number of Hops per route data was nearly similar to the low traffic scenario, but still the results related to AODV routing protocol without RSU implementation is better than the AODV routing protocol with RSU implementation as shown in Figure 17(b).
5.2.6. AODV route discovery time

First scenario

In the low traffic scenario, it was found that the AODV routing protocol with RSU implementation has higher Route Discovery Time than the AODV routing protocol without RSU implementation, as the route must be calculated using the fixed nodes “RSU” as shown in Figure 18(a).

Second scenario

In the high traffic scenario, it was found that the AODV routing protocol with RSU implementation results are similar to Route Discovery Time than the AODV routing protocol without RSU implementation results, due to the high number of vehicles, so the route discovery time will be similar as if there are RSUs implemented as fixed nodes as shown in Figure 18(b).
From the above KPIs, AODV without RSU implementation results is better in most of the KPIs as the communication is applied exclusively between Vehicles only, and in the remaining KPIs in the second scenario which is related to high traffic, AODV without RSU implementation results enhanced it’s results, which means that the simulation can put the developing countries on the right track to implement, optimize and develop the V2V model in order to build a full integrated ITS solution.

6. Conclusion

V2V communication real life implementation till now requires RSUs in order to have accurate results and full safety for the society, but in the developing countries most of them don’t have well established infrastructure and on the other side, the accidents and loss of lives are increasing exponentially year by year, also the developing countries require to increase their investments, and this depends on providing full automated ITS including V2V communication in order have daily traffic flow without bottlenecks.

The proposed ITS solution was based on finding the most acceptable routing protocol in all KPIs from the paper’s perspective, then compare it with V2V + RSU implementation in order to check if the results are acceptable with the current real life V2V + V2I implementations in Europe and USA.

The AODV was chosen because its advantages are more than its disadvantages, many trials were done to have these results, the default settings were adjusted for the AODV routing protocol, starting from using the most acceptable range from Vehicle to Vehicle, decrease the delay in the intra-communication delay of the vehicle using the embedded solutions during the implementation, then took the actual numbers and apply it in the simulation, increase the transmission power within the
standard limits, finally AODV provided good results in the delay, load, retransmission attempts, but in other KPIs, other Routing protocols have better results because the AODV requires periodic bea-
coning and frequently updating the shortest route path which will lead to more accurate results on
the long term simulation.

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Author details
Ahmed Yasser1
E-mail: ahmedyasser.crm@gmail.com
ORCID ID: http://orcid.org/0000-0001-9771-6141
M. Zorkany2
E-mails: m_zorkany@yahoo.com, m_zorkany@nti.sci.eg
Neamat Abdel Kader1
E-mail: nemat2000@hotmail.com
1  Faculty of Engineering, Cairo University, Cairo, Egypt.
2  Department of Electronics and IOT, National Telecommunications Institute, Cairo, Egypt.

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