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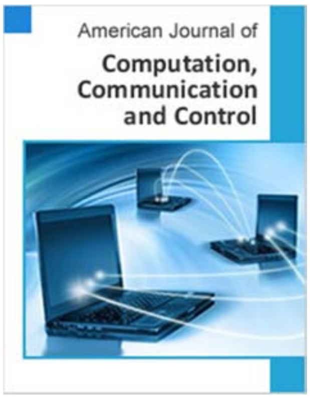

Examining Four Ad Hoc Routing Protocols for a Road Traffic Monitoring System

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Abstract
This paper studies and evaluates the performance of 4 Ad hoc routing protocols to carry the information of a road traffic monitoring system. The suggested information gathering and monitoring system is designed for vehicular ad-hoc networks (VANETs), that is implemented in a large. The suggested infrastructure consists of low cost wireless sensors covering certain areas and connected to “the monitoring and control center” through a master node. The operation of the suggested system is divided into four main phases: the first phase deals with the information gathering process in the vehicles and sensors level, the second phase deals with the information transmission from the sensors to the master node, the third phase (the subject of this paper), focuses on the information transportation between the master nodes until it reaches “the monitoring and control center” which monitors the road traffic of a large geographical area. Finally the fourth phase deals with the dissemination of the gathered information to the vehicles. The mechanisms of the information transportation in the third phase are proposed to be in an ad-hoc manner, so we study the performance of the disseminated master nodes along a city map using four ad-hoc protocols: Ad-hoc On Demand Distance Vector Routing Protocol “AODV”, Dynamic Source routing “DSR”, Optimized Link State Routing Protocol “OLSR” and the Temporally-Ordered Routing Algorithm Protocol “TORA”, then choosing the best one according to many metrics such as data delivery, latency and average throughput on the radio channel.

1. Introduction

The new developments in the Local Area Networks “LANs” have led to appearance of new types of networks such as Vehicular Ad-hoc Networks “VANETs”, VANETS is special type of Mobile Ad-hoc Networks “MANETs” [1]. These networks are distributed and self-organized networks [2], and it provide the base to develop new systems to enhance the drivers’ and passengers’ safety and convenience on roads during the travelling time, and formed as new fashion of intelligent transportation systems “ITSs”. This network constructed between the mobile vehicles equipped with transceiver devices, which integrated with the embedded microcomputers, sensor devices, positioning device such as GPS, digital maps and intelligent algorithms. All of these factors help to develop the new application for safety enhancement along the roads, help the drivers to get the information about the road status in the real time and allow the drivers to react to the that information in the right manner. The information that represents the current status of the road helps to facilitate the ride in the road networks, it also helps to find the new methods to solve the congestion problems, thereby reduce the time and fuel consumption [3]. In addition to safety concerns, others applications may be supported in the VANETs that do not represent safety, which requires the Quality of service "QoS". There are two scenarios of vehicles communications networks; the first is Vehicle-to-vehicle communication V2V and Vehicles-to-Roadside Unit (RSUs) which is referred to as (Vehicle-to-RSU V2R). RSUs connect with each other, as well as it can communicate with other networks such as the Internet [4, 5] As in Figure 1.

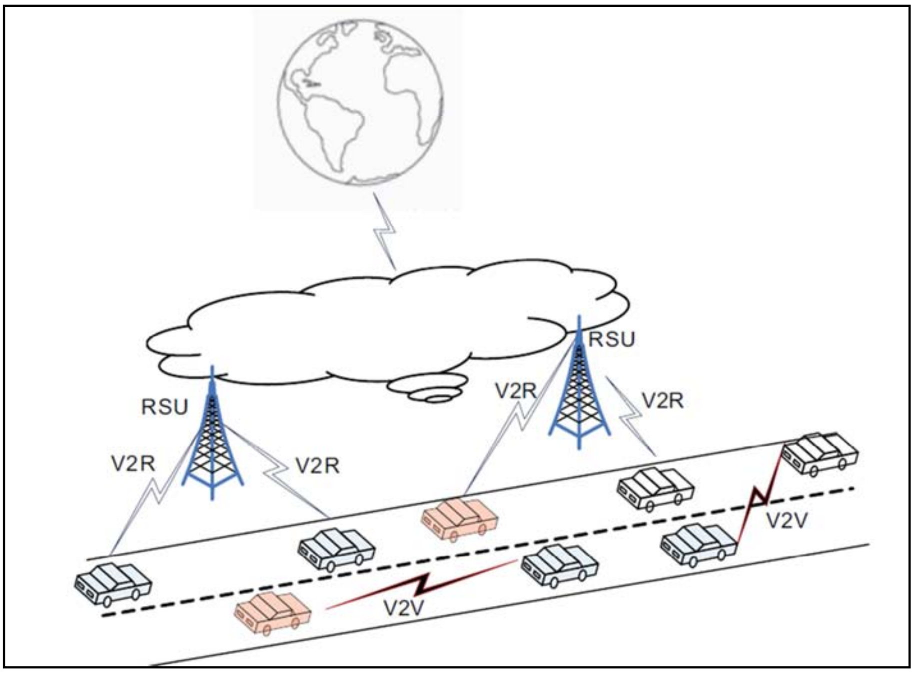


Figure 1. *Architecture of vehicular networks.*

The vehicular networks have been expected to apply new technologies in the wireless domain such as Dedicated Short Range communication "DSRC", which depend on the developed version of IEEE802.11 standards, suitable for vehicular environment. The DSRC is developed to use high data rates in the dynamic topology like VANETs that requires high date rate [6].

2. Literature Review

Here the new taxonomies of information gathering and dissemination, technologies and algorithms have been proposed to produce the robust real time information for navigation system. These issues take a lot of efforts of researches such as:

Y. Wu et.al. design in 2010 a novel vehicular driving navigation system based on VANET as presented in [7]. The hardware of the system is an ARM9 embedded device with GPS, 802.11 communication module and a Human Machine Interface (HMI). The HMI displays the driving states of the adjacent vehicles and the emergency road information to remind the driver of the safety driving. A power control mechanism is also applied in the system to increase the throughput of the system.

In the 2011 [8] Fallah, Y. P. et. al. analyze the effect of different choices of the rate and range and present models that quantify network performance in terms of its ability to disseminate tracking information. Following a throughput analysis of the hidden node effected VANET, they shows that the channel occupancy or busy ratio can be used as feedback measure the quantifies the success of the information dissemination, and consequently, the cooperative vehicle safety systems CVSSs, under different network conditions. These findings are used to design feedback control schemes for transmission range adaption, which are robust to variation of road and network traffic.

In the 2011 [9] Panichpapiboon, et al. classify and provide an in-depth review of protocols in an ad-hoc wireless communications and vehicular technology, it is foreseeable that, in the near future, traffic information will be collected and disseminated in real-time by mobile sensor instead of fixed sensors used in the current infrastructure-based traffic information systems. A distributed networks of vehicles such as vehicular ad-hoc networks (VANETs) can be easily turn into an infrastructure- less self-organizing traffic information system, where any vehicle can participate in the collecting and reporting useful traffic information such as travel time, flow rate and density. Disseminating traffic information relies on broadcasting protocols. Recently, there have been a significant number of broadcasting protocols for VANETs reported in the literature.

N. Alam el. at. In 2012 [10] discuss the position information that is a fundamental requirement for many vehicular applications such as navigation and other applications, and location-based services (LBSs). Relatives positioning effective for many applications, including collision avoidance and LBSs. Although Global Navigation Satellite Systems (GNSSs) can be used for absolute or relative positioning, the level of accuracy does not meet the requirements of many applications. Cooperative positioning (CP) techniques, fusing data from different sources, can be used to improve the performance of absolute or relative positioning in vehicular ad-hoc networks (VANETs).

3. AD-HOC Routing Protocols

Many routing protocols have been proposed for the mobile and fixed ad hoc networks, it have been classified as Proactive or Table Driven routing Protocol, Reactive or On Demand Routing Protocol.

Optimized Link State Routing Protocol OLSR is a proactive protocol, all nodes have route table for routing information to every node in the network. OLSR is an optimization version of a pure link state protocol. OLSR protocol uses Multipoint Relays (MPR) to reduce the possible overhead in the network [11, 12]. OLSR uses the control messages: Hello and Topology Control (TC). OLSR continuously maintains routes to all destinations in the network.

Ad hoc On Demand Distance Vector Routing Protocol AODV is reactive protocol. In AODV each node maintains a route table contains routing information but does not necessarily maintain routes to every node in the network entries in the route table are verified to ensure whether there is a current route to that destination node or not. This protocol uses control message RREQ and RREP [13-15].

Temporally-Ordered Routing Algorithm Protocol TORA is a hybrid, distributed, highly adaptive routing protocol which is also known as link reversal protocol. TORA reduces the control messages in the network by having the nodes to query for a path only when it needs to send a packet to a destination [16-18]. In TORA three steps are involved in establishing a network. The first is creating the routes from source to destination, maintaining the routes and erasing invalid routes. The control messages used in the TORA protocol is QUERY packet and the UPDATE packet.

Dynamic Source routing DSR is an On-demand reactive routing protocol. The DSR has two functions first is route discovery and the second is route maintenance [19, 20]. DSR allows mobile sources to dynamically discover paths towards any desired destination. Every data packet includes a complete list of nodes. There are no periodic topology update packets. When a source node that desires to send data to a particular destination, it first checks to verify if it has a route in its cache for that destination, if it hasn't then it will discover the route to the destination. This protocol uses Route Request message Route Reply messages.

4. Description of the Proposed System

In order to validate the suggested system, there are some scientific bases and hypotheses should be considered to build the proposed system. This system consists of several parts as follows:

1 Vehicles: some parts have to be embedded in the vehicles to run the navigation and monitoring system[21], as follow:
   a) A computer system to handle the gathered information and the protocols associated with it.
   b) Wireless transceiver module using 5GHz licensed band for IEEE 802.11a standard [22].
   c) Positioning system like GPS or GNSSs.
   d) A set of sensors to collect the vehicles and road status.
   e) Graphical Input/output system that represents the interaction interface between the user and the system.

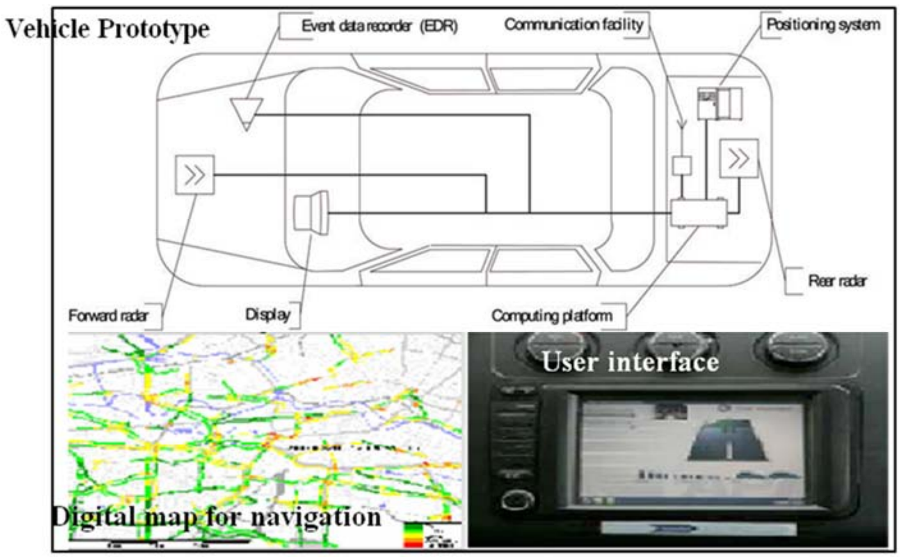


Figure 2. *A model of smart vehicles.*

2 Sensors: the sensors are seeded on the main roads to collect information from the vehicles passing these roads, as shown in the Figure 3. Then, these sensors prepare the summarized packets that represents the status of roads and send them to the central points. These sensors are supposed to be :

a) Low-cost in terms of installation and embedded in nature.
b) The coverage area of the sensor is 300 meters in every direction according to IEEE 802.11a standard.
c) The sensors use 5GHz licensed band IEEE 802.11a [9].

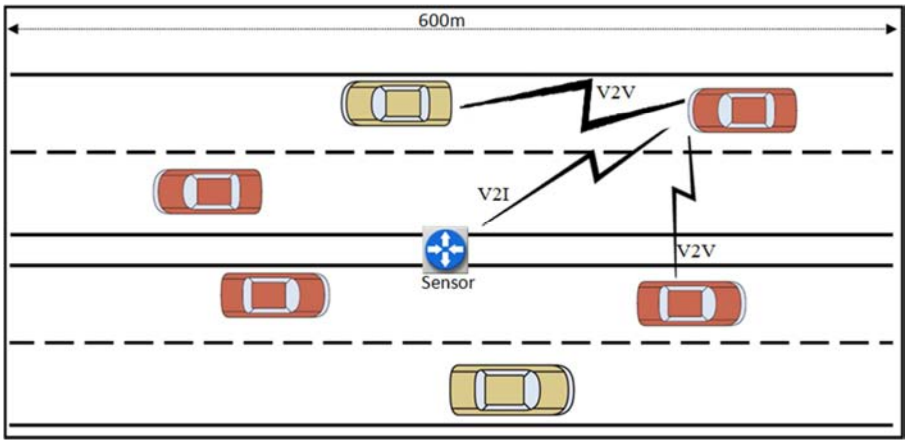


Figure 3. *The basic construction of the system, the local navigation system.*

3 Master Nodes: Each master node has at most eight sensors associated with it as shown in Figure 4. I receives the packets from these sensors, summarize them and then send a traffic status packet to the monitoring server.

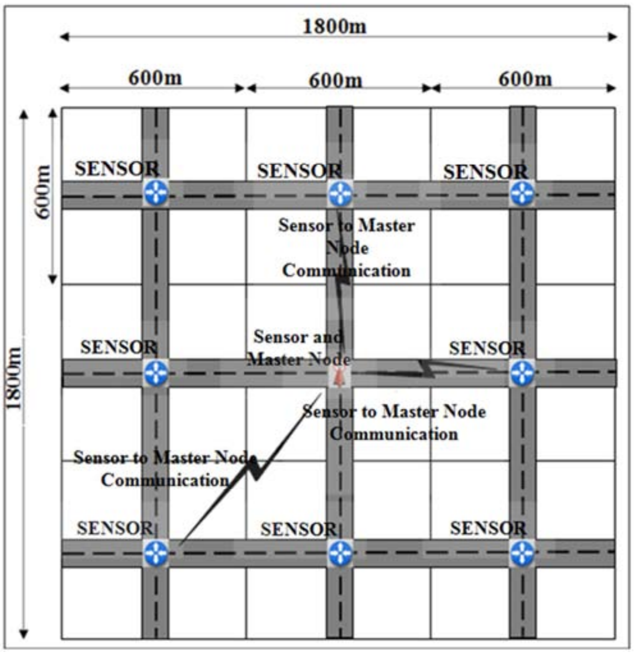


Figure 4. *The master node with its sensors。*

4 Monitoring and control center: The main action of this part is to collect the information from the master nodes, processing the data then creating the traffic map of the whole city.

5. Mechanism of the System Actions

Road navigation and the monitoring systems are divided into two main modes depending on the nature of the information that it received from the vehicles present on the road, these modes are: Local View Navigation System which is based primarily on real-time information from the vehicles periodic messages. The second is the global View Navigation System which depends mainly on the information collected in the VANET infrastructure. The strength and accuracy of the navigation and monitoring system depends on how quickly and precisely that information are assembled [23]. The mechanism for the collection and distribution of information in the system will go through four phases to run the navigation system, as follows:

The first phase: it is the local navigation system; it relies mainly on the vehicles Broadcast periodic messages (heartbeats or beacons). Vehicles massages go through the area of 600 m^2, at the same time this messages are received by the sensor located in that section of the road. The length of these messages ranges between 25Byte to several hundred [24], the size of message must be reduced as much as possible to avoid the congestion in the radio channel [24]. In our system, the message size was selected to be 100Byte. This message contains information such as vehicle ID, road ID, position using GPS or others, timestamp [25], velocity [23], Direction [25, 26] and acceleration.

The second phase: he sensor collects information then summaries each road section status and sends periodic messages to the master node every two seconds. VANETs have applied several methods for information gathering and dissemination because these networks have a lot of limitation factors such as capacity and communication environment during rush hour etc., which affect negatively on the used application, since each application has its own manner with data processing in terms of publishing, latency and other characteristics [3]. The method proposed in this paper is that the length of each section of the road is 600 meter, the sensor is in center of this area (in the ideal case) and receives vehicle information, extracts reports then sends messages to the master node. In this way, the information is assembled with the lowest possible cost, while avoiding flooding, retransmission and transmission by geographical location.

The third phase: The master nodes collect the messages then combine that information (which represent the traffic from nine sensors or less) and send them to the control server using ad-hoc network. This phase is the main subject of this paper.

The fourth phase: The messages sent by the master nodes are received by the management and monitoring server; processed and redistributed to vehicles in the roads networks (for large area (city, for example)).

Figure 5 shows the system phases.

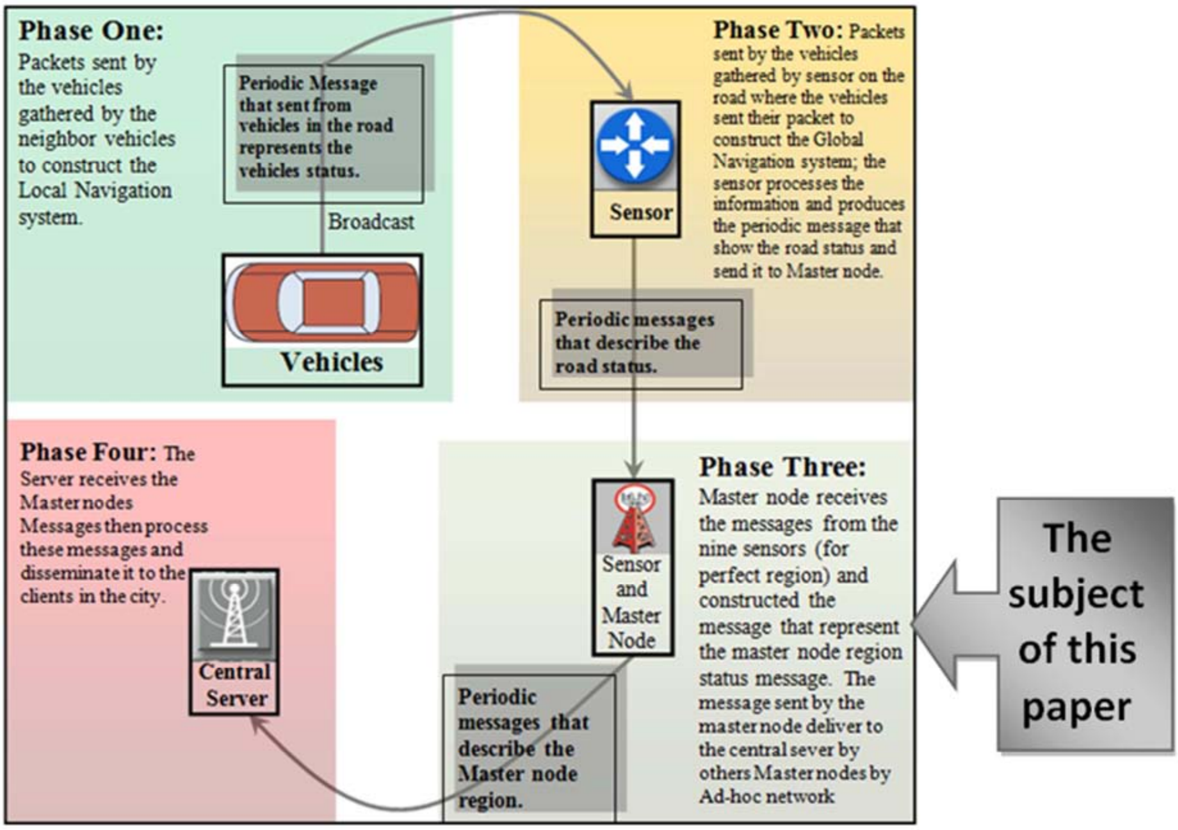


Figure 5. *System collection and distrusting phases.*

6. The Simulation Model

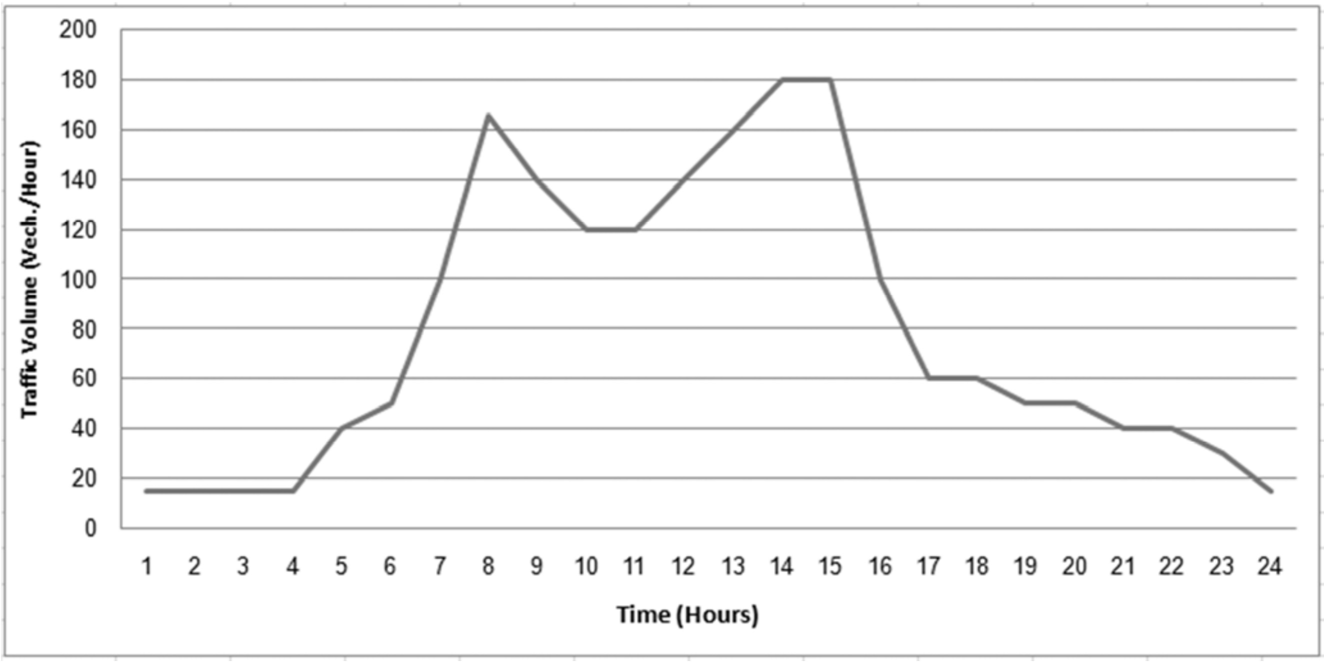
Our aim in this section is to simulate the ad-hoc network among the master nodes in the proposed system, to validate the results and to compare between different routing protocols. In our study, we used the map of Mosul city/Iraq while assuming seeding the master nodes as shown in Figure 6a. Mosul city is the second largest city in Iraq, it is vital city with population near 1.6 million, and has a lot of traffic problems. The map taken for the study is (16.5*16.5) Km, we seed the master nodes in the city in the vital roads of the city map.

The Traffic volume statistics are collected for a four lanes road (in Mosul city/Iraq) bypasses the Mosul University Campus, see Figure 6b. A simulation model is built using the (OPNET IT GURU academic edition) Network Simulation package. The goal of building this model is to generate a traffic patterns as close as possible to the real situations. The following assumptions are adopted when building the simulation model:

1 In order to simplify our simulation model, the master nodes are assumed to be identical and subjected to the same road traffic conditions shown earlier in Figure 6b with ideal communication circumstances. The hardware and software performance of these nodes were assumed to be that of RSUs as detailed in [28, 29].
2 The data traffic generated by the master nodes (resulting from their interaction with the vehicles and the other master nodes) are forwarded using a suitable routing protocol to a central server. It is assumed that the vehicles broadcast their 100 byte status packets each one second [3], while the master nodes generate their 1000 byte traffic reports 10 times per minute and forward them to the central server [3].

The initial settings of the simulation model are isted in Table 1 below.

(a)



(b)

Figure 6. *(a) The seeded master nodes on the city map (b) Road traffic statistics.*

Table 1. *The initial settings of the simulation model.*

Simulation Time (Minute)	60
No. of Master Nodes	50
Network Span Area	(16.5 Km x16.5 Km)
Distance between Master Nodes (Km)	1
Master node to Server Packet Length (Byte)	1000
Master node to Server Packets Rate (Packet/Minute)	10
Master Node Modeling Parameters	Packets Processing Rate (Packet/sec.) = 2000 Memory (Byte) = 2 M
WLAN settings	Data Rate (Mbps) : 18 for IEEE802.11a/g
Routing Protocol settings	Hello Interval(sec.) = 2 TC Interval(sec.) = 5 Neighbor Hold Time(sec.) = 6 Topology Hold Time(sec.) = 15 Duplicate Message Hold Time(sec.) = 30 Initial TTL = 3 TTL Threshold = 7 Buffer size (packet) = 200 Route expiry interval (sec.) = 1000
Street Geometry	2 way – 3 lanes each Vehicle Max. speed (Km/hour) = 100 Max. Flow (Vehicle/Lane) = 14
Vehicles movement modeling	Random way point
Summarization Technique	Self-Organizing Traffic Information System (SOTIS)

7. Results and Discussion

There are number of metrics to be compared among these protocols as follow:

a) Average Throughput (bps): the total number of bits per second forwarded to higher layers; it describes the loss rate as seen by the transport layer and reflects the completeness and accuracy of the routing protocol.
b) Average Packet End-to-End Delay (sec): It is the average time it takes an application on a source node to generate a packet until the packet is received by the application layer of the destination node. It includes delays that arise as a result of propagation and transmission buffering for the period of the route finding, queuing at the network interface and retransmission at the MAC layer.
c) Average Routing Overhead Traffic (bps): It is the amount of routing packets that is transmitted over the network. The routing overhead determines the scalability of the protocol in the network. It is expressed in bits per second or packet per second.
d) FTP Upload Response (sec): the time elapsed between the time of sending a file and the of server response.

The discussion of the results is presented below:

Average Wireless LAN Throughput: Figure 7 shows that the worst performance on the wireless channel is OLSR protocol then AODV, TORA, DSR respectively. OLSR has the proactive property that makes it periodically send the updated topology information throughout the entire network, this operation adds sometimes an extra load to the network, AODV uses the periodically information update to maintain the table already constructed for the information that it needed but not for all network nodes it just updated the neighbor nodes status, TORA shows a good performance near DSR but the failure of data delivery (the dropped packets) could cause the application failure. DSR is the best for our application because it uses the information already exist to reduce the management information and perform updating information as needed only.

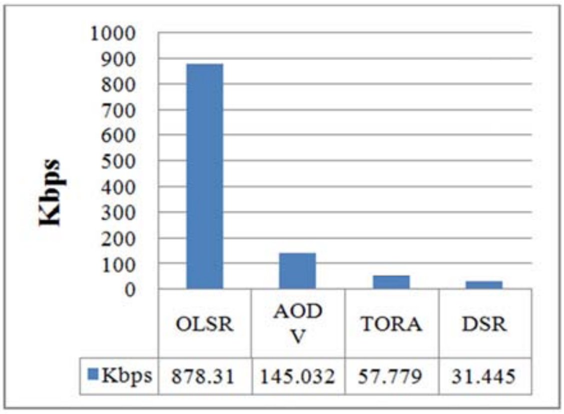


Figure 7. *WLAN throughput for the four ad-hoc protocol.*

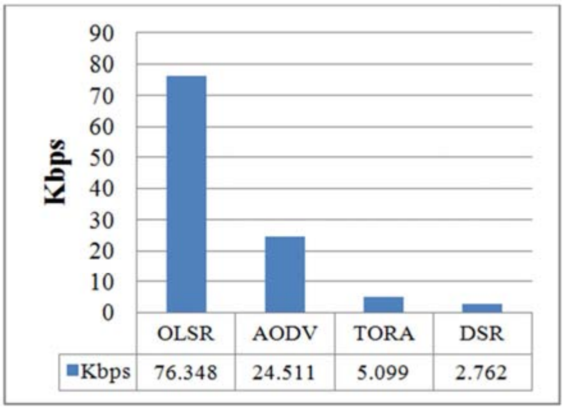


Figure 8. *Average Routing Overhead Traffic for the four the ad-hoc protocols*

Average Routing Overhead Traffic: Figure 8 shows the routing data volume in the wireless channel and explains the effect of the protocol characteristics according to its class: active, proactive or hybrid. Proactive protocols such as OLSR consume the wireless channel capacity just with routing information, while the reactive protocol such as DSR protocol doesn’t.

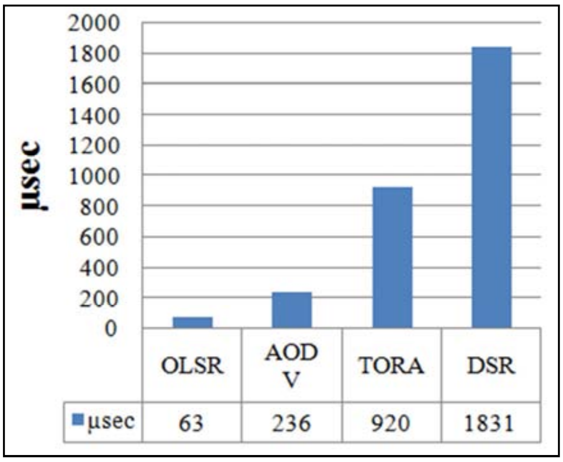


Figure 9. *Average wireless LAN media access delay for the four protocols.*

The Average wireless LAN media access Delay: Figure 9 shows that DSR has the worst performance followed by TORA, AODV and OLSR. OLSR works better than anyone of all other protocols, the reason is that the proactive protocol has its' updated information table about the whole nodes in the network by the periodic messages HELLO and TC (Topology Control), it serves the demand to access the wireless channel as fast as possible. The AODV has the routing tables for maintaining the routing information only for the neighbored nodes. TORA does not use the periodic update information to efficiently use the bandwidth and to reduce the communication overhead. In DSR when any node wants to access the medium to send its data to other nodes in the network; it doesn't have the information about the network topology and takes more time to access the wireless channel because it uses their algorithms for route request and reply.

FTP Upload response: Figure 10 shows that DSR is the best because it includes the complete sequence of the nodes to reach the destination (path for packet) in the packets' header, followed by AODV which have the next hop routing table, then TORA that continuously adapts and scales the routing mechanism to enhance the routing, Finally, OLSR which waits the up-to-dated routing table information sequences to forward the message to the destination.

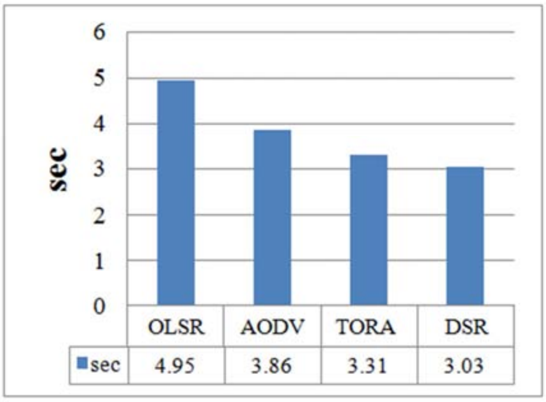


Figure 10. *FTP Upload response for the studied ad-hoc protocols.*

The FTP performance: Figure 11 shows that TORA protocol has the worst performance due to many factors such as the number of the nodes in the networks, while the DSR shows a good delivery ratio.

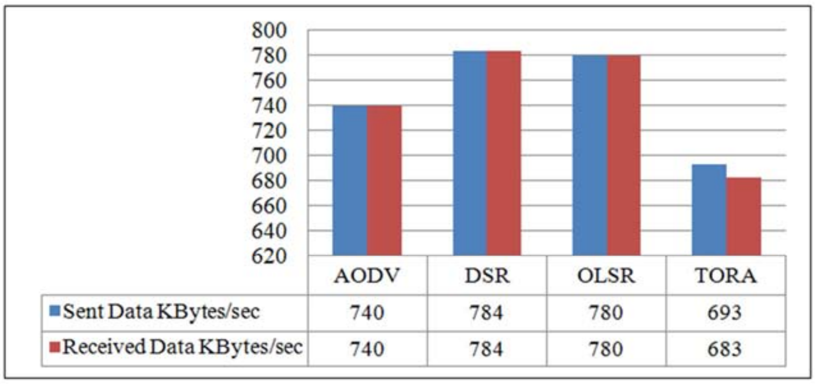


Figure 11. *Sent and received data in FTP protocol.*

8. Conclusion

In this paper, we examined the performance of different Ad hoc routing protocols to be used in a high resolution and real time information gathering and monitoring system. The intended system aims to maintain a realistic picture of the road traffic situation by distributing traffic sensors all around the city streets and receive their traffic reports in real time. In order to achieve these goals, the proper Ad hoc protocol must be chosen. Our simulation study shows that the best protocols suited for our purpose are OLSR and DSR due to their data delivery, lower latency values, the lower amount of the routing information transported in the wireless channel and, finally, the lowest load on the wireless channel.

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