Impact of Freeway Mobility Pattern on Routing Performance of Mobile Ad Hoc Networks

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Abstract

In all applications which are based on Mobile Ad-Hoc Networks, node mobility has a significant impact on the performance of routing protocols; consequently affect the usefulness of these applications. This paper presents an investigation and analysis of the performance of different routing protocols (AODV, DSR and OLSR) under freeway mobility pattern in motorway surveillance system based on Ad hoc camera network as a case study. The evaluation and analysis were performed for several different performance metrics and under varying network conditions. It has been shown from the results that under various mobility speeds and different traffic loads, AODV outperforms DSR and OLSR protocols, with respect to network throughput and protocol overhead. The conclusions of this study are important to provide a qualitative assessment of the applicability of these protocols to real-world motorway surveillance systems, and also as a basis for developing new ways to improve routing performance under different freeway mobility pattern conditions.

Keywords: *Freeway Mobility, Motorway Surveillance System, Overhead, Routing Protocol*

1. Introduction

A Mobile Ad-Hoc Network (MANET) is an autonomous wireless networking system consisting of independent nodes that move and dynamically change network connectivity [1]. Each node can communicate with other nodes that are within or outside its radio range. In MANET, the nodes are free to move randomly, thus the network's wireless topology may change rapidly and unpredictably. Mobile Ad hoc wireless networks eliminate the constraints of infrastructure and enable devices to create and join networks anytime, anywhere—for virtually any application since an Ad hoc wireless network is self-organizing, self-configuring and adaptive [2]. This means that a formed network can be de-formed on-the-fly without the need for any system administration. Any node in an Ad hoc network can function as source, destination, or intermediate node between any source and the destination.

MANET can be used in many real-world applications such as, military, disaster relief, delay-tolerant networking and vehicular communication[3-4]. Each of these applications can involve in different scenarios with different mobility patterns and the network traffic rates dependent on the environment and the nature of the interactions among the participants.

The node mobility of MANET causes the network topology to change with time, and MANET performances must be dynamically readjusted to such changes. Therefore, the networking and application protocol performances of mobile ad hoc networks are greatly influenced by the frequency of network topology changes. On the other hand, the performances of mobile ad hoc networks can vary significantly with different mobility models. Moreover, by varying different parameters of a given mobility model, the MANET performances are effected by a great extent [1].

The routing in mobile ad hoc networks is very challenging due to the frequent updates for changes in topologies, and active routes may be disconnected as mobile nodes move from one place to another. Routing schemes in mobile ad hoc networks must include mechanisms that cope with difficulties incurred by node mobility and topology changes along with lower consumption of energy, communications bandwidth, and computing resources. The traditional link-state and distance vector algorithms that are used for routing in non-MANET networks are not suitable for MANETs because of large routes updates traffic. The excessive overhead traffic caused route updates may lead to consumption of the significant part of the available resources including the channel bandwidth, especially in a large MANET. The increasing channel contention and retransmission may consume

considerable energy and may require each active mobile node to frequently recharge their power supply[1].

The mobility of nodes is the key attribute of MANET, and the performance of MANET needs to be studied in presence of mobility. The node mobility can cause unpredictable topology changes and expiration of the information used by traditional routing protocols in establishing a route[5]. Another consequence of mobility is the increased rate of link failure and the activation of broken links which increases both the congestion due to traffic backlogs and the volume of control traffic required to maintain the routes. Hence, mobility is a very important factor affecting the network performance.

The objectives of this paper are to investigate and analyze the impact of freeway mobility pattern on the performance of three types of routing protocols: Ad Hoc on Demand Distance Vector routing protocol (AODV), Dynamic Source Routing protocol (DSR), and Optimized Link State Routing protocol (OLSR), as they are used on Motorway wireless Ad hoc camera network scenario for different performance metrics and under different mobility conditions.

The mobility model with geographic restriction, same as the constrained topology-based model, where the movements of the mobile nodes are constrained by streets, freeways, or obstacles, and the freeway mobility pattern is an examples of this mobility models.

The main contribution of this paper is performance of a study and analysis of the impact of freeway mobility pattern on the performance of two on-demand routing protocols (AODV and DSR) and one table driven routing protocol (OLSR), as they are used on Motorway wireless Ad hoc camera network .

The remainder of this paper is organized as follows: Section 2 presents the related work of other authors. Section 3 describes the mobility models analysis and freeway mobility model characteristics. Section 4 describes different types of MANET routing protocols. Section 5 describes the simulation setup and network modeling. Section 6 presents the results and discussion. Finally, Section 7concludes the paper.

2. Related Work

Many studies have been undertaken to analyze and evaluate the effects of node mobility on the performance of routing protocols for different types of networks and under various mobility patterns. This section surveys the most pertinent studies presented in recent years.

The authors in [6] investigated the impact of swarming behavior of mobile nodes on the performance of MANET routing protocols. They characterized the effects of coordinated movements of mobile nodes by using a Markov chain, through which a quantized collaboration degree is defined. Based on the swarm mobility model, they analyzed the probabilistic properties of hop count as a complement to those analytical studies on packet delay performance. With a medium access control model, they derived an upper and a lower bound of routing overhead for MANET proactive routing protocols.

In [7], the performance of two MANET routing protocols (AODV and DSR) are inspected and examined based on variation of node density and mobility using mobility models such as Random Way Point (RWP) and Random Way Point with Attractions (RWP-ATTR). The authors showed that the performance is determined on the basis of packet delivery ratio, normalized routing load, throughput and average end-to-end delay with varying node density and mobility. They found that the DSR with higher node density shows an extreme degradation in performance and the non-uniform node distribution that occurred for RWP has significant impact on performance results for both protocols.

The authors in [8] studied the impact of mobility models in performance of multicast routing protocols in MANET. In this work, three widely used mobility models such as Random Way Point, Reference Point Group and Manhattan mobility models and three popular multicast routing protocols such as On-Demand Multicast Routing Protocol, Multicast Ad hoc On-demand Distance Vector Routing protocol and Adaptive Demand driven Multicast Routing protocol are chosen and implemented in NS2. They showed the relative strengths, weakness and applicability of multicast protocols to these mobility models. They found that the connectivity of the mobile nodes, route setup and repair time are the major factors that affect routing protocol performance.

In [9], the authors studied the impacts of mobility on routing protocol performance of MANETs with simulation. They used 802.11 as the wireless MAC protocol and AODV as the routing protocol. In their work, the results showed that the mobility of MANET is not always harmful to the routing protocol performance. The authors found that in the square scene, the impacts of mobility are slighter

than that in the rectangle scene. Specially, when the network load is heavy, the mobility even increases the throughput and the packet delivery ratio in the square scene. On the other hand, they found that the impacts of mobility are weakened by the increase of the network loads. Based on their works, they found that the increase of mobility only cause fast increase of overhead, which includes the sum of the control packets and the control overhead, under light network loads. However, when the network load is heavy, the increase of the mobility and the data packet sending rate don't lead to a clear increase of the overhead.

3. Mobility Models Analysis

The mobility metrics aim to capture the characteristics of different mobility patterns and can be used to analyze the impact of mobility models on the performance of communications protocols used over mobile ad hoc networks. Many mobility models can be used in mobile ad hoc networks, and each mobility model has its own mobility patterns that will impact the protocol performances. For example, there are many individual, group, flocking, and other mobility models. Again, each mobility model will also behave differently when there are obstructions.

Various mobility models were proposed to represent node mobility and to evaluate the performance of wireless networks. Based on specific mobility characteristics, the classification of mobility models is made primarily into four categories [1], these are:

➢ Random models: in this model the nodes move randomly and can be classified further based on the statistical properties of randomness. The random waypoint, random direction, and random walk mobility model fall into this category.

➢ Models with temporal dependency: The movement patterns of the mobility models with temporal dependency are likely to be influenced by their movement histories. The Gauss–Markov and smooth random mobility models are the examples of this mobility model category.

➢ Models with spatial dependency: in this model, the mobile nodes tend to travel in a correlated manner. These mobility models are termed as mobility models with spatial dependency, and mobility models like reference point group mobility model and other spatially correlated mobility models belong to this category.

➢ Models with geographical restrictions: In this model the node mobility is restricted with geographic restriction, same as the constrained topology-based model, where the movements of the mobile nodes are constrained by streets, freeways, and/or obstacles, and pathway or freeway and obstacle mobility models are two examples of this category.

As shown in Figure 1, the overall performance of any routing protocol depends on the duration of interconnections between any two nodes transferring data as well on the duration of interconnections between nodes of a data path containing n-nodes.

Figure 1. Block Diagram of the Dependency between Mobility Model and Routing Performance

An increase in the node speed will increase the probability of link breakage which reduces the duration of the path, as shown with the Equation (1).

$$Lp = \rho * \frac{Ns\,h}{R} \qquad (1)$$

Where (Lp) is the probability of link breakage, (ρ) is proportionality constant, (Ns) is the node speed, (h) is number of hops on path and (R) is the transmission range.

An increase in the probability of link breakage will reduce the duration of the path, as shown with the Equation (2).

$$PD = \frac{1}{Lp} \qquad\qquad (2)$$

From (1) and (2)

$$PD = \frac{R}{\rho Vs\,h} \qquad\qquad (3)$$

Equation 3 demonstrates that the path duration is inversely proportional to node speed (Ns). This can be interpreted to mean that the probability of link breakage increases as vehicle speed increases.

The mobility of the nodes affects the number of average connected paths, which in turn affect the performance of the routing algorithm. Under different mobility model, different types of routing protocols give different network performances. These differences arise due to the different functional mechanisms of these protocols to deal with the link breakage occurs due to node mobility, and also to the reaction of these protocol to the different mobility environments.

3.1. Routing Performance Influencing Factors

The key influencing mobility factors for routing performance in different settings of MANETs are[10]:

1. Node Velocity: The velocity of the mobile nodes within a MANET is not fixed. As there is no speed limitation of the wireless nodes, high speed of nodes might affect the performance of many protocols. A protocol is considered well for MANET if it can perform well both in relatively static and in fully dynamic network state; though it is true that routing in a highly mobile MANET is a tough task.

2. Mobility Direction: The direction of a node's mobility is not known in advance. It is a very common incident that a node travels to a direction where the number of neighbor nodes is less or there is no neighbor node. This is called *drifting away of a node from a MANET*. A hard-state approach or a soft-state approach could be used to handle such incidents.

3. Group or individual mobility: MANETs are often categorized as Pure MANET and Military MANET. In a pure MANET, it is not obvious that the nodes should move in groups, but in case of military MANET, group mobility is the main concern. A military MANET can maintain a well defined chain of commands, which is absent in case of a pure MANET. So the routing strategies could vary depending upon this factor[11].

4. Frequency of changing of mobility model: Routing strategy could also vary depending on the mobility model of the MANET. The topology of an ad hoc network could definitely change over time. But, the key factor here is the change of overall mobility model in a fast or relatively slow fashion. If the nodes change their relative positions too frequently, the maintenance cost of the overall network gets higher. For example, a MANET formed with vehicles on the motorways is highly dynamic, while an ad hoc network formed with some laptops and palmtops carried by the participants in a conference is relatively less dynamic.

In this paper the effects freeway mobility pattern on routing performance will be investigated at different network conditions.

3.2. Freeway Mobility Model (FWM)

This model emulates the motion behavior of mobile nodes on a freeway. This mobility model belongs to geographical restrictions category. It can be used in exchanging traffic status or tracking a vehicle on a freeway. In FWM model, nodes are only allowed to travel on the pathways. The freeway mobility pattern restricts each mobile node to its lane. On the other hand the velocity of a node is temporally dependent on its previous velocity and if two nodes on the same freeway lane are within the safety distance (SD), the velocity of the following node cannot exceed the velocity of the preceding node. Due to the aforesaid relationships, the Freeway mobility pattern is expected to have high spatial dependence and high temporal dependence. It also imposes strict geographic restrictions on the node movement by not allowing a node to change its lane.

4. Routing Protocol in Mobile Ad Hoc Networks

There are different criteria for classifying routing protocols for wireless Ad Hoc networks. Routing protocols are classified into two major types based on how and when routes are discovered: proactive or table driven, and reactive or on-demand.

In the proactive routing protocols, each node keeps its routing table updated with the route to each node in the network -- whether it needs it or not -- by sending control messages periodically between the hosts which update their routing tables. In proactive routing, each node has one or more routing tables that contain the latest information on the routes to any node in the network. The proactive routing protocols are based on either link-state or distance vector principles to maintain routes to every node in the network [12]. An example of proactive routing protocol is the Optimized Link State Routing Protocol (OLSR).

On the other hand, reactive routing is also known as an on-demand routing protocol since the nodes search routes to needed nodes only. Reactive protocols do not maintain routing information or routing activity at the network nodes if there is no communication. If a node needs to send a packet to another node, then the reactive protocol starts the route discovery operation in an on-demand manner, and when the route is established, the source node starts to send its packets via the established route to the destination. Examples of reactive routing protocols are the DSR and AODV. The next sub-section describes the basic features of these protocols. For a more detailed description, the reader is referred to the respective RFCs.

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

The Ad Hoc On-Demand Distance Vector Protocol (AODV) is an IP routing protocol that allows users to find and maintain routes to other users in the network. AODV is "on-demand" or "reactive" since the routes are established only when needed. The routing decisions are made using distance vectors, i.e. distances measured in hops to all available routers [13]. Each node maintains a routing table which contains routes to destinations. AODV can deal with any kind of mobility rate and a variety of data traffic. The two main mechanisms used by the AODV protocol to establish and maintain the connection between any pair of nodes are as follows:

- ➤ Route Discovery mechanism: in this phase, if a sender needs a route to a destination, it broadcasts a ROUTE REQUEST (RREQ) message. The sender then waits for NET TRAVERSAL TIME (NETT) for a ROUTE REPLY (RREP). If a RREP is not received within this time, the sender will rebroadcast another RREQ up to RREQ TRIES times. With each additional attempt, the waiting time (NETT) is doubled. Once the source node receives the RREP, the route has been established and the source starts to send data packets to the destination.

- ➤ Route Maintenance mechanism: in this phase, as mentioned in [13], the role of route maintenance is to provide feedback to the sender in case a link breakage occurs, to allow the route to be modified or re-discovered. A route can stop working simply because one of the mobile nodes has moved. If a source node moves, then it must rediscover a new route. If an intermediate node moves, it must inform all its neighbors that may need this hop. This new message is forwarded to all the other hops and the old route is deleted. The source node must then re-discover a new route or else the node upstream of that break may choose to repair the link locally if the destination was no farther than MAX_REPAIR_TTL hops.

4.2. Dynamic Source Routing Protocol (DSR)

Dynamic Source Routing (DSR) is a reactive, on-demand routing protocol for wireless Ad Hoc networks and is based on a method known as source routing, that is, the sender knows the complete hop-by-hop route to the destination. Nodes in a DSR broadcast route request on on-demand bases if the node does not have the required route in its routing table. Nodes in DSR 'learn' and cache multiple routes to each destination (either as a response to a request, forwarding, or overhearing) to be used in case of route loss. In addition, this also helps in reducing routing overheads. The on-demand feature of DSR reduces the bandwidth use, especially in cases where the mobility is low. The DSR uses two main

mechanisms which work together to enable nodes to discover routes to destinations, and to maintain the routes to prevent any loss [14], these are:

> *Route discovery* is the mechanism by which a node S wishing to send a packet to a destination node D obtains a source route to D. Route discovery is used only when S attempts to send a packet to D and does not already know a route to D [14].

> *Route maintenance* is the mechanism by which node S is able to detect, while using a source route to D, if the network topology has changed such that it can no longer use its route to D because a link along the route no longer works. When route maintenance indicates a source route is broken, S can attempt to use any other route it happens to know to D, or can invoke route discovery again to find a new route. Route maintenance is used only when S is actually sending packets to D.

4.3. Optimize Link State Routing Protocol (OLSR)

OLSR is an optimization of link-state routing [15]. OLSR is developed for mobile ad hoc networks. It operates as a table-driven, proactive protocol, that is, it exchanges topology information with other nodes of the network regularly. Each node selects a set of its neighbor nodes as "multipoint relays" (MPR). In OLSR, only nodes, selected as such MPRs are responsible for forwarding control traffic, intended for diffusion into the entire network. MPRs provide an efficient mechanism for flooding control traffic by reducing the number of transmissions required. Nodes, selected as MPRs, also have a special responsibility when declaring link state information in the network. Indeed, the only requirement for OLSR to provide shortest path routes to all destinations is that MPR nodes declare link state information for their MPR selectors. Additional available link state information may be utilized, for example for redundancy.

Nodes which have been selected as multipoint relays by some neighbor node(s) announce this information periodically in their control messages. Thereby, a node announces to the network that it has reachability to the nodes which have selected it as an MPR. In route calculation, the MPRs are used to form the route from a given node to any destination in the network. Furthermore, the protocol uses the MPRs to facilitate efficient flooding of control messages in the network. A node selects MPRs from among its one-hop neighbors with "symmetrical" (i.e., bidirectional) linkages. Therefore, selecting the route through MPRs automatically avoids the problems associated with data packet transfer over unidirectional links (such as the problem of not getting link-layer acknowledgments for data packets at each hop, for link layers employing this technique for unicast traffic).

5. Motorway Model Setup

Motorway Surveillance System (MSS) is one of the most important applications of wireless networks [16]. Most MSSs which are based on an infrastructure wireless network restrict the mobile users (vehicles) from effectively accessing the surveillance system network to get its data (images) [17]. Therefore, infrastructureless wireless networks (MANET) are more effective in constructing the surveillance system in order to give the mobile users (vehicles) the ability to effectively access the surveillance system camera network. Many parameters affect the performance of the MSS camera network, and the most important parameter is the performance of the routing protocol. Routing is a core problem in MSS network for sending data from one node to another. Therefore, it plays a very important role that affects the network's performance of the MSS. The network of the MSS scenario is modeled with the following model specifications to evaluate and analyze the impact of freeway mobility pattern on routing performance of MSS, these specification are:

1. The simulation scenario is a 5 km straight motorway section with two lanes heading in one direction.
2. 40 camera nodes are distributed along both sides of the motorway in a double line topology with 250 meter separations between each two cameras.
3. All the cameras of the second line are moved ahead by 125 meters than the cameras of the first line as shown in Figure 2.
4. Six vehicles are distributed on the lanes of the motorway and move in a freeway mobility pattern. The distance between each two vehicles is 50m.

5. The vehicles' speeds are distributed between 36 km/h as the minimum speed and 150 km/h as the maximum speed.
6. The size of data packet is 512 Bytes.
7. The value of packet rate is selected to be 20 packets / second.
8. All the cameras use UDP traffic sources with CBR traffic pattern.
9. All experiments tested for 500-seconds simulation time.
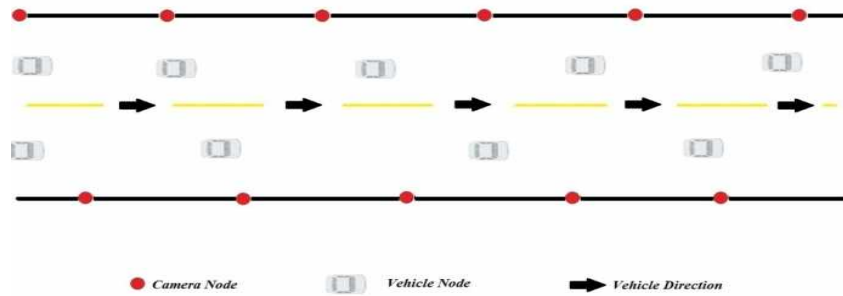10. The driver of the vehicle selects the desired camera to be ahead which means that the vehicle always moves toward the source node (desired camera).

Figure 2. Motorway Surveillance System Scenario

OMNeT++ Ver. 4.1 [18] was used to simulate the motorway models. Simulations with an extensive set of parameters were performed to evaluate and analyze the routing performance in a MSS under freeway mobility pattern for different vehicle speeds. The metrics selected to evaluate the performance AODV, DSR, OLSR routing protocols under different mobility environments are: Throughput, Packet Loss, Protocol overhead, and Average packet transmission time delay.

6. Results and Discussion

Two types of experiments were carried out to evaluate and analyze the impact of freeway mobility pattern on the performance of two reactive routing protocols (AODV and DSR) and one proactive routing protocol (OLSR) by varying node speed and under light and heavy network loads.

6.1. Throughput Evaluation

Figure 3 shows the network throughput (in Kbps) versus the vehicle speed using a light network load. There are three plots, each corresponding to a different routing protocol. For each protocol, the throughput of the network starts to decrease with an increase in the vehicle speed. Figure 3 demonstrates that the throughput's decrease percentage is slight at about 3% when using the AODV routing protocol, and less than the throughput's percentage decrease when using other protocols (DSR, by about 28.2% and OLSR, by about 11.77%). This is because the AODV reacts relatively quickly to the topological changes due to node mobility in the network and updates only the hosts that may be affected by the change. Moreover, Figure 3 shows that the performance of OLSR is better than DSR and less efficient than AODV.

Figure 4 shows the network throughput (in Kbps) versus the vehicle speed when using a heavy network load. This figure demonstrates that the performance of AODV outperforms the performance of the other two protocols (DSR and OLSR). While increasing vehicle speed, DSR exhibits the highest drop in throughput. This is due to packets being dropped along outdated routes. Figure 4 shows a big drop in DSR throughput at a higher number of sources. This is an effect of the higher network load caused by the source routes carried in all data packets, therefore, at higher mobility and when using a heavy network load, AODV and OLSR are more robust than DSR.
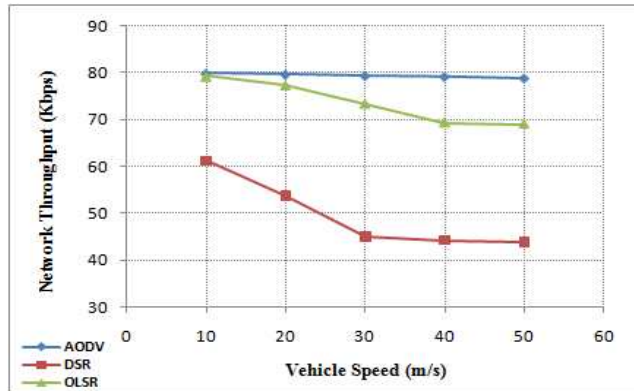
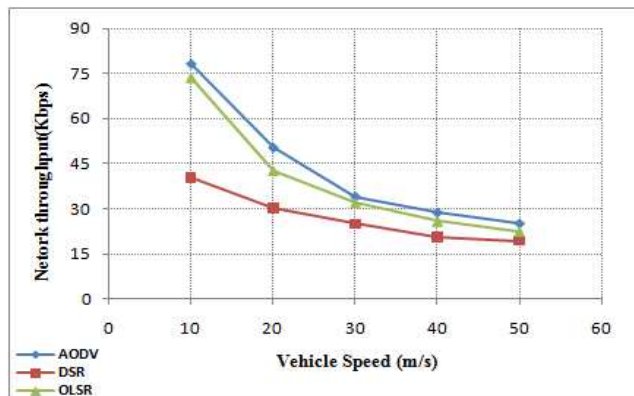**Figure 3.** Network Throughput vs. Vehicle Speed Using Light Network Load

Figure 4. Network Throughput vs. Vehicle Speed Using Heavy Network Load

6.2. Number of Packets Lost

Another important quality in communication is the packet loss performance of a network. It is influenced by many factors like routing protocol performance, interference, and channel conditions. Figure 5 shows number of lost packets versus vehicle speed when using a light network load. There are three plots, each corresponding to a different routing protocol. Figure 5 shows that the number of lost packets increases for all three routing protocols with an increase in the vehicle speed, because increasing vehicle speed will increase the probability of link breakage which leads to lost packets. The number of lost packets when using DSR is larger than number of lost packets when using other protocols (AODV and OLSR). This is because the DSR cannot react quickly to recover the broken link due to node mobility, especially when there is no route in its cache to the unreachable destination. Also, DSR can only rediscover new routes to the unreachable destination by the source node (source routing) rather than the upstream node of the broken link performing a local repair. This leads to an increase in the number of lost packets. Moreover, Figure 5 also shows that the AODV outperforms OLSR, as well as DSR. The OLSR reacts well to the link breakage because OLSR continuously maintains routes to all destinations in the network and when link break happens, it can find new route to the destination faster than DSR.

However, Figure 6 demonstrates that the number of lost packets increases with increasing vehicle speed when using a heavy network load for all three routing protocols. Increasing the network load means an increase in the amount of data pushed into the network; at higher loads, the network drops a rather large number of packets due to buffer overflow in some congested nodes. This congestion is caused by an increase in MAC layer packet collisions, giving less capacity to drain queues, combined with a higher aggregated packet rate in some forwarding nodes. Figure 6, shows that the number of dropped packets when using DSR is more than the number of dropped packets while using AODV or

OLSR, because the source routes carried in all data packets. Thus, DSR faces a higher packet loss than AODV and OLSR when the amount of traffic load is increased.
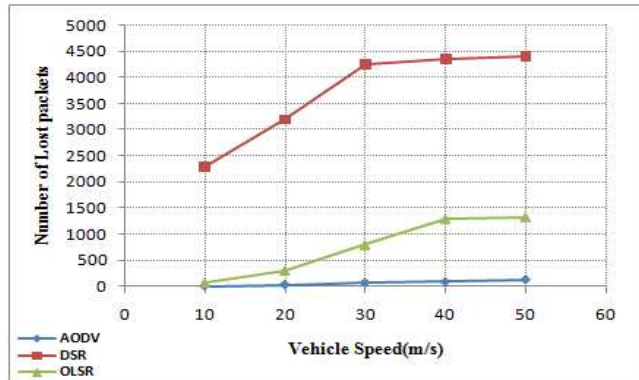

Figure 5. Number of Lost Packets vs. Vehicle Speed Using Light Network Load
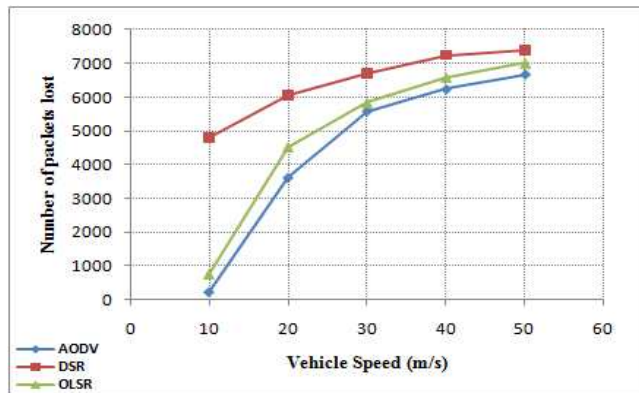

Figure 6. Number of Lost Packets vs. Vehicle Speed Using Heavy Network Load

6.3. Protocol Overhead

Protocol overhead represents total number of bytes generated by a routing protocol for routing operations within a network. Increased protocol overhead will negatively affect the network performance by consuming bandwidth. Figure 7 shows protocol overhead versus vehicle speed when using a light network load. Figure 7 demonstrates that the OLSR has the highest overhead. Because OLSR is a table-driven protocol, and the proactivity nature of OLSR makes it exchange topology information with other nodes of the network regularly and periodically, this increases the overhead. In contrast, the overhead of DSR is demonstrably lower than the overhead of AODV due to the way routes are detected in DSR; also the route acquisition procedure in DSR allows more routes to be detected and cached with the same RREQ than in AODV (which obtains a single route per RREQ), and this reduces the protocol overhead in DSR.

Figure 8 shows the protocol overhead versus vehicle speed when using a heavy network load. It demonstrates that the AODV overhead is lower than the overhead of OLSR and DSR. With an increase in the network load, the OLSR overhead still remains higher than DSR and AODV, likely due to the proactive nature of OLSR. The overhead of DSR is higher than the overhead of AODV, likely because DSR is based on source routing algorithms and every data packet must hold the entire route from the source to the destination in its header which increases the DSR overhead.

Taken together, Figure 7 and Figure 8 demonstrate that the overhead of the three protocols decreases with increases in vehicle speed in both cases (light and heavy network load). This is likely because at low speeds, routes are relatively long lived. More traffic is carried over the same paths during longer times, so a longer route will form and incur higher overhead.
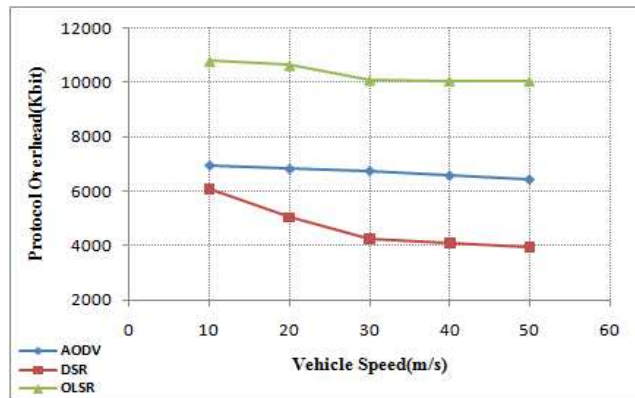
Figure 7. Protocol Overhead vs. Vehicle Speed Using Light Network Load
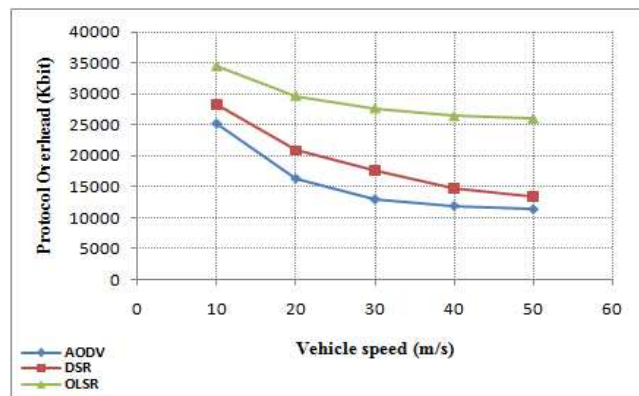

Figure 8. Protocol Overhead vs. Vehicle Speed Using Heavy Network Load

6.4. Packet Transmission Time Delay

The average packet transmission time delay increases with an increase in vehicle speed for all three protocols, as shown in Figure 9. However, at using light traffic load, OLSR has a lower delay than DSR and AODV for all vehicle speed values. OLSR consistently presents the lowest delay, regardless of the amount of data traffic. This may be explained by the fact that OLSR, as a proactive protocol, has faster processing at intermediate nodes. When a packet arrives at a node, it can immediately be forwarded or dropped. In reactive protocols, if there is no route to a destination, packets to that destination will be stored in a buffer while a route discovery procedure is conducted which takes some time. Moreover, OLSR continuously maintains routes to all destinations in the network. When link break occurs, it can quickly find a new route to the destination since the routing table has routes for all available hosts in the network. In contrast, DSR has a lower delay than AODV for all speed values due to the way routes are detected in DSR. The route acquisition procedure in DSR allows more routes to be detected and cached than in AODV, which obtains a single route per RREQ. With DSR, packets wait less time during route acquisition than with AODV.

Figure 10 shows that the average packet transmission time delays versus vehicle speed for all three routing protocols. All protocols exhibit higher delays when using a heavy network load than when using light network load. This is because the delay time is affected by the amount of data pushed into the network (offered load). The buffers become full much more quickly when using a heavy network load, so the packets have to stay in the buffers for a longer period of time before they are sent. Figure 10 also demonstrates that the packet transmission time delay of DSR is the lowest when compared to AODV and OLSR delays. This is because with a higher mobility and heavier traffic load, links are more frequently broken. Since routes are available in the cache of DSR, the route discovery procedure requires less time than the other protocols. The AODV discovers routes whenever a change in the

topology is detected. In OLSR, routes are known well in advance; hence the average packet transmission delay is less than AODV.
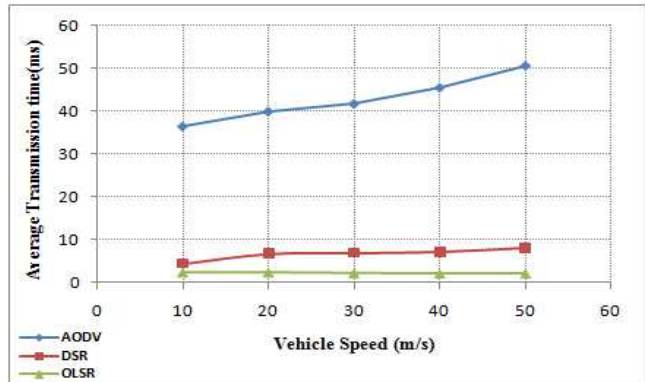

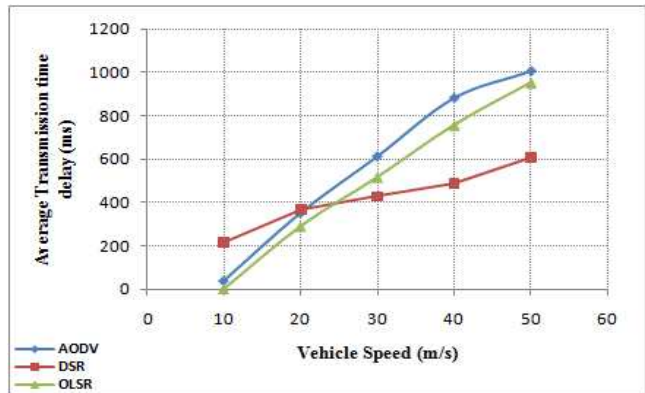**Figure 9.** Average Transmission Time Delay vs. Vehicle Speed Using Light Network Load

Figure 10. Average Transmission Time Delay vs. Vehicle Speed Using Heavy Network Load

7. Conclusion

In this paper, the impact of freeway mobility pattern on the performance of routing protocol in MSS scenario is studied and analyzed. The results showed that mobility pattern influences the network connectivity graph which in turn influences the performance of routing protocols. On the other hand, different mobility parameters setting have different impact on the performance evaluation of protocols. Therefore, choosing an appropriate mobility parameters setting is very important for protocol evaluation.

It can be concluded from the observed results that the DSR exhibits the highest drop in throughput with increasing of the node speed. However, the performance of AODV outperforms the performance of the other two protocols (DSR and OLSR) under different mobility speeds. The differences in the protocols performance arise due to the different mechanisms of these protocols to deal with the link breakage which happen due to node mobility. Based on the observed results, Table 1 shows an evaluation of different routing protocols under freeway mobility pattern.

The observed results showed that the freeway mobility of MANET is not always harmful to the routing protocol performance, which is mainly relied on the shape of the network scene. According to the experiments performed in this paper on motorway scenario with different network conditions, the results indicate that the protocol overhead decline with an increase in a node speed, especially if the source node lay ahead the destination node.

Table 1. Routing protocol evaluation under FWM pattern

Parameters	AODV	DSR	OLSR
Network Throughput	High	Low	Medium
Protocol Overhead	Low	Medium	High
End-to–End Delay	High	Low	Medium
Packet Transmission Ratio (PTR)	High	Low	Medium
Protocol reaction to increased offered load	Good	Poor	Acceptable
Protocol reaction to increases node speed	Good	Poor	Acceptable

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