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Performance Evaluation of Routing Protocols for multimedia transmission over Mobile Ad hoc Networks

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Abstract— **Mobile ad hoc networks (MANETs) are becoming more essential to wireless communications due to growing popularity of mobile devices. The integration of mobile ad hoc devices inside vehicles has led to another type of networks, called Vehicular Ad hoc Networks (VANETs) which are also becoming important. These networks require specialized routing protocols due to their ad hoc nature. The performance of these protocols has been tested for the case of general traffic but not in respect with to multimedia traffic and especially video transmission. In this paper we conduct a number of simulations in order to evaluate the performance of three of the most popular routing protocols for MANETs and VANETs, namely AODV, DSR and OLSR, for different number of simultaneous video transmissions. We use the packet delivery ratio, the end-to-end delay, the packet delay variation (jitter) and the routing overhead as evaluation metrics. The results indicate that the DSR protocol outperforms AODV and OLSR in terms of end-to-end delay and packet delay variation and seems to be the most efficient routing protocol when multimedia traffic and especially video traffic is considered.**

Keywords-MANET; AODV; DSR; OLSR; multimedia;

I. INTRODUCTION

Mobile ad hoc networks (MANETs) are becoming more essential to wireless communications due to growing popularity of mobile devices. Their ability to be self-configured and form a mobile mesh network using wireless links, makes them suitable for a number of cases that other type of networks cannot fulfill the necessary requirements. MANETs offer the freedom to use mobile devices and move independently of the location of base stations (and outside their coverage) with the help of other network devices. The lack of predefined infrastructure makes them suitable for emergence conditions like for example after physical disasters. Also, the widespread of mobile devices that are equipped with Wi-Fi interfaces opens new research areas that study the IEEE 802.11 performance over these networks.

The integration of mobile ad hoc devices inside vehicles has led to another type of networks, called Vehicular Ad hoc Networks (VANETs). In this type of network, the end points are mainly vehicles that communicate among each other and sometimes with static devices/stations. Up to now, the main use of VANETs, is to transmit road and traffic information, but they can also be used for any application that utilize wireless ad hoc connections. The topology of these networks can be considered as extremely dynamic due to the fact that the nodes are constantly moving. That means that a connection between two nodes may be interrupted several times during the transmission period. The reestablishment of a new connection requires the discovery of any available path from the source to destination node.

The routing protocols that have been developed for Mobile Ad hoc Networks are directly affecting data transmission, the performance of network applications and the end user

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experience. Each protocol has its own routing strategy that is used in order to discover a routing path between two ends. The performance varies, depending on network conditions like the density of nodes in a specific area, their speed and direction.

As the mobile and handheld devices are becoming even more popular, and the use of ad hoc networks is increasingly perceived as significant, there is substantial relative work by the research community, regarding the differences among the existing ad hoc routing protocols. In [1], a comparison of the performance of two prominent on-demand reactive routing protocols for MANET (DSR and AODV) is presented along with the traditional proactive DSDV protocol.

In [2], the effects of various mobility models on the performance of DSR and AODV are studied. The experimental results illustrate that the performance of routing protocols vary across different mobility models, node densities and length of data paths. Another performance evaluation of the three widely used MANET routing protocols (DSDV, AODV and DSR) with respect to group and entity mobility models is presented in [3]. Simulation results indicate that the relative ranking of routing protocols may vary depending on the implemented mobility model.

In this paper, we evaluate the performance of three popular routing protocols: two reactive (AODV, DSR) and one proactive (OLSR), when transmitting multimedia data in a multi-hop mobile network. Multimedia transmission over MANET is an emerging topic with many possible applications. The mobility scenario simulates the environment of a modern city, where the vehicles (mobile nodes) are connected to each other and communicate. The vehicles are almost always moving, maximizing the routing process complexity.

The paper is organized as follows: The next section presents the main ad hoc routing protocols that are used in the performance evaluation process. Section III presents the performance evaluation metrics. In section IV, we present the simulation results from various cases. Finally, we conclude the paper in section V and present the plans for future work.

II. Ad Hoc Routing Protocols

Routing protocols for ad hoc networks can be classified into three main categories. In Proactive routing protocols ([4], [5], [6]), every node in the network has one or more routes to any possible destination in its routing table at any given time. Reactive routing protocols ([7], [8], [9]) obtain a route to a destination on a demand fashion. When the upper transport layer has data to send, the protocol initiates a route discovery process, if such a route does not already exist, in order to find a path to the destination. In Hybrid routing protocols ([10], [11]), every node acts reactively in the region close to its proximity and proactively outside of that region, or zone. Hybrid protocols take advantage of both reactive and proactive protocols, but may require additional hardware, such as GPS devices, separated or integrated into the communication device.

A. OLSR

Optimized Link State Routing [6] is a proactive protocol that is based on the link state algorithm. OLSR has been modified and optimized to efficiently operate MANET routing. The main concept of the protocol is to adapt the changes of the network without creating control messages overhead due to the protocol flooding nature. Thus, the designers of OSLR decided to have only a subset of nodes, named Multipoint Relays (MPRs), in the network responsible for broadcasting control messages and generating link state information. A second optimization is that every MPR may choose to broadcast link state information only between itself and the nodes that have selected it as an MPR.

B. DSR

Dynamic Source Routing [7] is a reactive protocol that is based on two main mechanisms: route discovery and route maintenance. Both mechanisms are implemented in an ad hoc fashion and in the absence of any kind of periodic control messages. The main concept of the protocol is "source routing", in which nodes place in the header of a packet the route that the packet must follow from a source to a destination. Each node "caches" the routes to any destination that has recently used, or discovered by overhearing its neighbors' transmission. When there is no such route, a route discovery process is initiated. The protocol is designed for a MANET of up to two hundreds nodes with high mobility rates and is loop-free.

C. AODV

Ad Hoc On-Demand Distance Vector [8] is a reactive routing protocol that is based on the Bellman-Form algorithm. AODV uses originator and destination sequence numbers to avoid both "loops" and the "count to infinity" problems that may occur during the routing calculation process. AODV, as a reactive routing protocol, does not explicitly maintain a route for any possible destination in the network. However, its routing table maintains routing information for any route that has been recently used, so that a node is able to send data packets to any destination that exists in its routing table without flooding the network with new Route Request messages.

The above protocols are the most widespread protocols for MANETs. They have a lot of structural differences and produce different routing overhead, thus, their performance depends on the network topology.

III. Performance Evaluation Metrics

The most important issue when evaluating the performance of any protocol is related to the metrics that are used for the evaluation. In this work, we base our evaluation criteria on the IETF recommendations in RFC 2501 [12]. As suggested, routing protocols for MANETs should be evaluated on both qualitative and quantitative metrics. Qualitative metrics describe desirable protocols' attributes that make them efficient for use in the ad hoc wireless environment. Quantitative metrics include statistical data, which provide the tools to assess the performance of the routing protocols. The data should be correlated with the dynamics of the ad hoc wireless network. We will start our evaluation process by comparing the most well-known routing protocols by using qualitative metrics. Then, the selected protocols will be tested through simulations with the ns-2 [13] simulation software by using quantitative metrics in a changing wireless network.

A. Qualitative metrics

Qualitative metrics include i) loop Freedom, ii) Security, ii) demand-based operation if energy consumption is a major issue iii) proactive operation when latency is a major issue, iv) unidirectional link support and v) sleep mode. In fact, a routing protocol for MANETs should keep a balance between latency and routing overhead, energy consumption, and node participation in the routing process, and should employ security mechanisms. Table I summarizes the performance evaluation of proactive routing protocols.

TABLE I. COMPARISON OF PROACTIVE PROTOCOLS

Qualitative metrics	**OLSR**	**DSDV**	**CGSR**
Loop free	Yes	Yes	Yes
Security	No	No	No
Support for unidirectional links	Yes	No	No
Sleep mode	Yes	No	No
Multicasting	No	No	No
Routing scheme	Flat	Flat	Hierarchical
Nodes with special tasks	Yes	No	Yes
Routing metric	Shortest distance	Shortest distance	Shortest path

By summarizing the above results, we can see that OLSR is closer to the IETF MANET working-group design recommendations. Indeed, OLSR has been designed with high respect to RFC 2501. Perhaps the only visible disadvantage is the high routing overhead. However, it is mainly up to the network designer to decide what he really needs from a network. If the main concerns are timely and reliable data delivery then OLSR may well fit as the selected routing protocol. If the main concern is utilization of the biggest portion of the available bandwidth, leaving a small portion for control messages, then OLSR is not the proper choice.

On the other hand, the CGSR [5] clustering scheme is very reflective to disaster related structure and communications and could provide a good choice, with of course, a number of extensions and modifications. Finally, given the qualitative metrics and the attributes of the above protocols, we select OLSR for further evaluation in our simulations.

TABLE II. COMPARISON OF REACTIVE PROTOCOLS

Qualitative metrics	**AODV**	**DSR**	**TORA**
Loop free	Yes	Yes	Yes
Security	No	No	No
Support for unidirectional links	No	Yes	No
Sleep mode	No	No	No
Multicasting	Yes	No	No
Routing scheme	Flat	Flat	Flat
Nodes with special tasks	No	No	No
Routing metric	Shortest path	Shortest path	Shortest path

Table II summarizes the performance of reactive routing protocols. All the presented reactive protocols are loop-free.

Only DSR in its current state, without any modification, can support both bidirectional and unidirectional links. However, DSR will introduce high routing overhead as routing information is stored at the data packets' header. Thus, DSR will not scale well in large networks if the communicating nodes are located at opposite edges of the network. None of the three protocols supports the "sleep mode," another important factor for power preservation, especially in battery-powered mobile nodes. TORA [9] seems to be a more power-effective protocol, as it localizes most of its function in a small area and not in the entire network. However, the exchange of `HELO` messages by the underlying IMEP protocol will introduce power consumption. AODV will consume more power than DSR due to the exchange of periodic `HELO` messages. TORA does not necessarily find the shortest path between a source/destination pair, as data flows form nodes with higher height to nodes with lower height.

Given the qualitative metrics and the attributes of the three protocols, we suggest that AODV and DSR would be good candidates for the routing protocol in mobile ad hoc wireless networks. Therefore, we select both AODV and DSR for further evaluation in our simulations.

B. Quantitative metrics

In our evaluation, we use four quantitative metrics which indicate the efficiency of the tested protocols especially with focus on multimedia transmission. The selection is as follows:

1) Packet delivery ratio (PDR)

PDR is defined as the fraction of all the received data packets at the destinations over the number of data packets sent by the sources. This is an important metric in networks. If the application uses TCP as the layer 4 protocol, high packet loss at the intermediate nodes will result in retransmissions by the sources that will result in network congestion. If the application is using UDP, like multimedia applications, high packet loss can reduce the quality of end user experience.

2) Average end-to-end delay

End-to-end delay includes all possible delays in the network caused by route discovery latency, retransmission by the intermediate nodes, processing delay, queuing delay, and propagation delay. To average the end-to-end delay we add every delay for each successful data packet delivery and divide that sum by the number of successfully received data packets. This metric is important in delay sensitive applications such as video and voice transmission.

3) Packet delay variation

Packet delay variation (PDV), or jitter, is defined as the difference in end-to-end delay between selected packets in a single connection. Any lost packets are ignored from this metric. Like end-to-end delay, PDV is also important in the case of multimedia transmission and other delay sensitive applications.

4) Routing overhead

The routing overhead is defined as the number of all routing control packets sent by all nodes. This metric discloses how efficient the routing protocol is. Proactive protocols are expected to transmit higher number of control packets than reactive ones. The bigger the number of control packets is, the less efficient the protocol is.

IV. SIMULATION RESULTS

The objective of the simulations is to evaluate the performance of different routing protocols for Vehicular Ad hoc Networks. Simulations were carried out by taking into account realistic conditions and using the ns-2.34 network simulator. The mobility model that is studied is based on the Manhattan city model with uniform sized building blocks. Manhattan grid mobility model can be considered as an ideal model to represent the topology of a big city.

The simulation area is 500x500 meters in a 5x5 grid. Inside this area, there are 50 mobile nodes representing moving vehicles that are actually the transmitters and receivers of the information. The moving speed varies from 0 to 20m/sec, having a mean value of 15m/sec. For each connection, data traffic is generated at a constant bit rate, using packets of 512 bytes. The traffic is assumed to use Real-time Transport Protocol (RTP) [14] that is designed for audio and video delivery over IP networks. The following table summarizes the simulation parameters.

TABLE III. SIMULATION PARAMETERS

Routing Protocols	AODV, DSR, OLSR
Mobility model	Manhattan Grid Model
Simulation duration	900 seconds
Number of nodes	50
Simulation area	500 x 500m
Node speed	0 – 20 m/sec (random)
Antenna	OmniAntenna
MAC	802.11g
Traffic	CBR
Application	RTP
Data packet size	512 bytes
Rate	64 packets/sec

In the following set of simulations, we evaluate the performance when streaming with 256 kbps data rate. Fig. 1 shows the packet delivery ratio of AODV, DSR and OLSR protocols as a function of the number of connections.

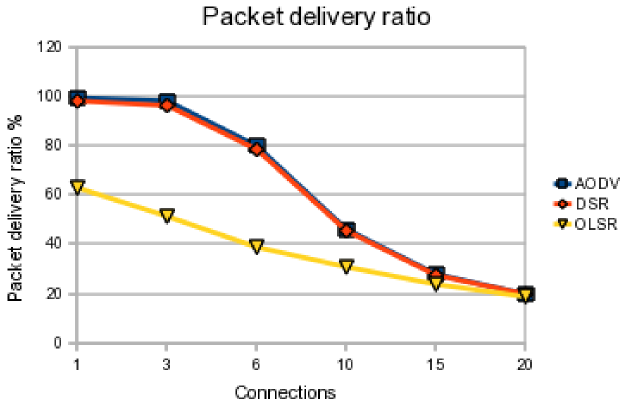

Figure 1. Delivery ratio over different maximum connections

We can observe that the packet delivery ratio decreases when increasing the transmission sessions. AODV and DSR present identical performance while OLSR has the lowest performance. In the case of multimedia transmission, the OLSR does not seem to be suitable, as the packed delivery ratio is very low even when having only one stream. However, the reactive protocols present an acceptable ratio for up to 6 connections.

In parallel, the end-to-end delay is investigated with different number of connections. This metric is very essential when transmitting multimedia data as it affects the quality of the streaming video. For real-time multimedia services, the accepted threshold of delay can be considered to be approximately 150 milliseconds. As it is obvious from Fig. 2, the delay depends on the number of simultaneous connections.

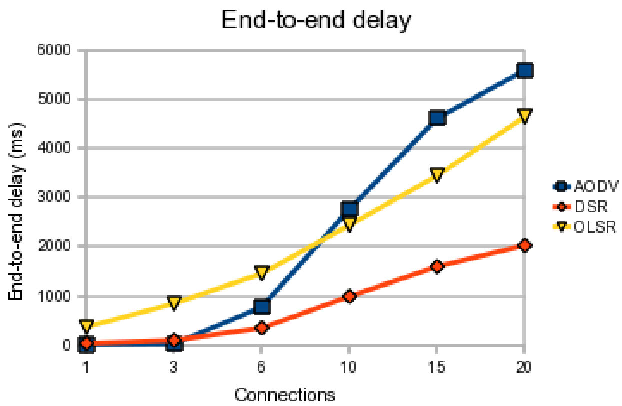

Figure 2. Average end to end delay (measured in milliseconds)

It is interesting to observe that the increment on the OLSR protocol is almost linear, while in AODV is exponential. This is an expected behavior of a reactive protocol because AODV needs to update the routing table when a new connection is established. OLSR periodically updates its routing table and therefore seems to be a more efficient solution for delay-sensitive applications, like multimedia streaming. On the other hand, we can observe that DSR is a much more efficient reactive routing protocol than AODV for multimedia data transmission. Even DSR seems to be more efficient than OLSR for delay-sensitive applications.

Packet delay variation, or delay jitter, is used to measure the variance of the packet delay. In this metric, it is possible to have both positive and negatives values depending on the variation of the end to end delay. However, the following figure shows the average packet delay variation in absolute values.

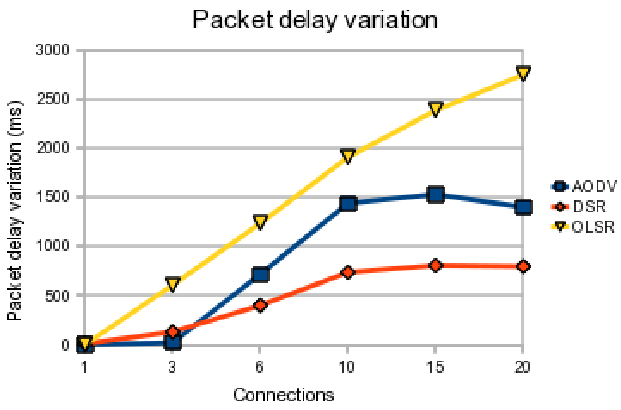

Figure 3. Packet delay variation (jitter)

The packet delay variation of the reactive routing protocols converges into an upper limit when increasing the connections above 10. In order to have high quality video and audio streaming it is important to have low packet delay variation. It is also interesting to observe that OLSR presents the lowest performance. One could expect that a proactive routing protocol like OLSR would reduce the packet delay variation at the destination node. However, our simulation results disclose that the existence of an up-to-date routing table cannot necessarily guarantee better performance in terms of delay. The main reason is that the periodic exchange of control packets occupies a noticeable portion of the available bandwidth and as a result, the transmission time for data packets increases. DSR and AODV leave more space for data packets and their performance seems to be independent from the number of connections in terms of packet delay variation. Once again DSR presents the best performance.

Fig. 4 depicts the routing overhead in terms of the number of routing packets that are transmitted. The comparison of the routing overhead that each protocol adds to the network shows that the proactive protocol OLSR has different behavior than the two reactive protocols. In OLSR, the number of routing packets depends only on the network size and not on the number of connections. We can also observe that DSR clearly outperforms AODV.

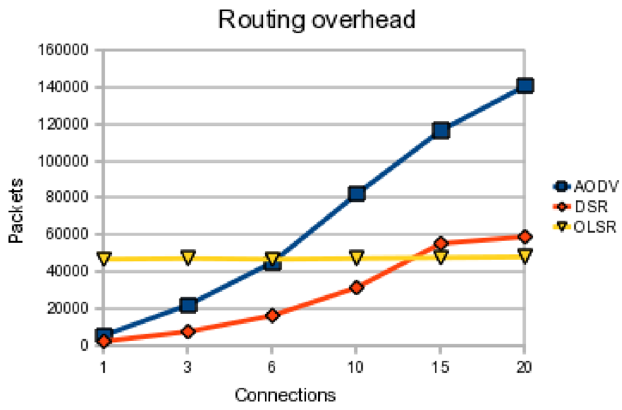

Figure 4. Routing overhead

As the above results indicate, DSR and AODV perform better than OLSR having in mind the transmission of multimedia data over MANETs. OLSR seems to be ineligible for multimedia data transmission. For this reason at the next set of simulations, the focus is put on areas with high packet delivery ratio and acceptable values for end-to-end delay. As it is shown in Fig. 1, OLSR has very low packet delivery ratio; thus, the next comparison is conducted only by using AODV and DSR, with a number between 3 and 6 connections. Therefore, we investigate the performance of AODV and DSR, when transmitting at different data rates.

Fig. 5 depicts the simulation results. We can observe that both reactive protocols AODV and DSR succeed similar performance.

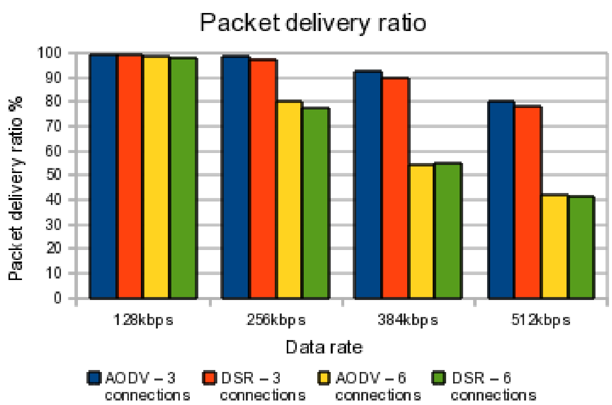

Figure 5. Delivery ratio over different data rates

Therefore we reach to the conclusion that the ratio is decreased when increasing the data rate or the number of connections. That means that either the number of simultaneous connections has to be limited, or the multimedia streaming has to be adapted (e.g. using lower rates) to the number of connections in order to succeed high packet delivery ratio.,.

Fig. 6 illustrates the average end-to-end delay when increasing the data rate. With higher transmission rates, the end-to-end delay increases. Although, this is somehow expected, the increase in the case of AODV is much higher than in DSR, and this is a strong indication that AODV is really unsuitable for interactive multimedia applications with high data rates.

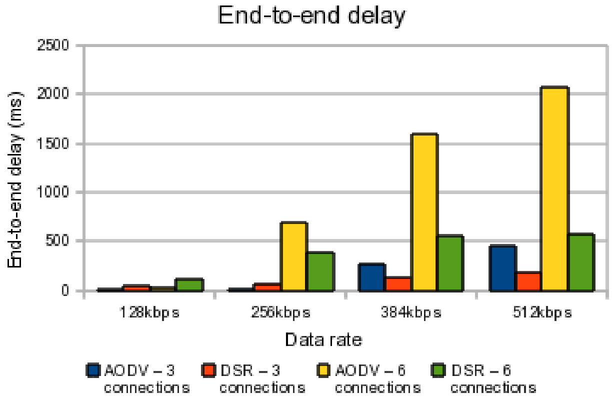

Figure 6. Average end to end delay over different data rates

The above results verify the observations during the previous set of experiments (Fig. 2), in which AODV presented the worse behavior in terms of end-to-end delay measurements. We also verify that although AODV and DSR are both reactive protocols they present completely different performance in terms of the end-to-end delay. This conclusion is confirmed also when varying the transmission rate, in which DSR clearly outperforms AODV when increasing the multimedia streaming quality.

V. Conclusions And Future Work

In this paper, we studied the performance of different routing protocols for multimedia data transmission over vehicular ad hoc networks. The focus was put on the performance evaluation metrics that were used in our simulations. The mobility model represented a city-like topology with fix-sized building blocks, with moving nodes at high speeds that challenged the performance of the routing protocols. Three popular routing protocols were selected for the evaluation: two reactive (AODV, DSR) and one proactive (OLSR).

OLSR presented the lowest performance in terms of packet delivery ratio and jitter delay. The proactive behavior of a routing protocol cannot necessarily guarantee low jitter delay values although proactive protocols have always in its routing tables a possible path to any destination. Therefore, OLSR cannot be a proper choice for delay-sensitive applications.

AODV presented a good performance but with rather high routing overhead. The packet delivery ratio measurements disclosed that AODV is a more efficient solution than DSR with, however, high routing overhead and very delay jitter values.

DSR outperformed both AODV and OLSR, in terms of end-to-end delay and packet delay variation and seemed to be the most efficient in the simulated environment. The low jitter delay and the adequate packet delivery ratio values suggested DSR as a serious proposal for multimedia data transmission in wireless ad hoc networks.

In our future work we intent to include media-centric metrics, in our evaluation process, in order to better investigate the performance of routing protocols for multimedia data transmission in wireless ad hoc networks. In addition, we plan to evaluate the performance of MANET routing protocols in conjunction with flow/congestion control mechanisms and Variable Bit Rate (VBR) multimedia traffic.

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