Performance Evaluation of Hybrid Routing Protocols for Multimedia Transmission in Vehicular Ad Hoc Networks

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Abstract
Mobile ad hoc networks are becoming very popular in wireless communications due to the latest advances in technology. This has allowed millions of people to communicate with each other over wireless networks using mobile devices. Moreover, the latest models of many vehicles are equipped with communication devices which allow them to form a new type of ad hoc wireless networks, called Vehicular ad hoc Networks (VANETs). The main goal of VANETs is to increase the road safety and to reduce the human casualties by communicating critical data between vehicles thereby facilitating time-critical actions, as well as, entertaining the passengers. In this paper, we study the performance of many hybrid routing protocols in vehicular ad hoc networks to communicate multimedia traffic.

Keywords: VANETs, Multimedia, routing, Ad hoc Networks.

INTRODUCTION
A mobile ad hoc network (MANET) includes wireless devices which are capable to communicate with each other without the presence of any fixed infrastructure. The main characteristic of such networks is their ability to be self-configurable and to heal network disconnections, due to their freedom of mobility, independent of the location of base stations. Such characteristics make MANETs suitable for deployment in areas with emergency conditions such as natural disasters and war zones.

The integration of wireless communication devices inside vehicles has led to a new type of wireless networks, called vehicular ad hoc networks (VANETs). The end points in such network are vehicles that communicate through other vehicles in between to transmit road and traffic information. The main goal of such networks is to make roads safer, and to reduce the number of road accidents. VANETs can also be used for entertainment purposes in the vehicles, especially with young travellers in long distance trips.

The topology of VANETs is extremely dynamic due to the continuous movement of vehicles within the network, and due to the speeds they are moving at. This means that the connection between any two nodes may be interrupted several times during the transmission period. Therefore, routing protocols are required to adapt to the nature of VANETs and to maintain the required connections between communicating parties with minimal disruptions.

Many routing protocols have been proposed for VANETs environment [1], where their main goal is to provide an optimal path between communicating nodes with minimal overhead. The routing protocols are directly affecting data transmission, performance of the network application and the end user experience [2]. Each protocol is designed to find a different routing path between the communicating nodes. The performance of these protocols will vary depending on a number of network conditions such as nodes density, speed, and movement direction.

Routing protocols can be classified in many ways according to a number of aspects. One type of classification is based on characteristics of routing protocols and classifies existing routing protocols into five different groups: topology-based, position-based, geocast-based, broadcast-based, and cluster-based [3-5]. Other papers classify VANETs routing protocols according to the network structure, into three classes: hierarchical routing, flat routing, and position-based routing. Moreover, they can also be categorized into two classes according to the routing strategies, proactive and reactive [6].

The use of multimedia over VANETs is an emerging topic with many possible applications, such as entertainment of the passengers within the vehicle, broadcasted advertisements by roadside commercial companies, and more importantly, safety tips and warnings with regard to the road conditions. Therefore, in this paper we will conduct a simulation study to evaluate the performance of three hybrid routing protocols, in a multi-hop vehicular ad hoc network, to communicate multimedia traffic.

The paper is organized as follows: the next section presents the routing protocols that will be studied in this paper. In section III, we present the performance evaluation metrics that will be used in this paper, and the details of the simulation scenarios. Section IV highlights the results and analysis of our study. Finally, we conclude the paper in section V.

ROUTING PROTOCOLS
Routing protocols for VANETs can be generally classified into three main categories: proactive, reactive, and hybrid. In proactive routing protocols, each node will have a routing table with at least one valid route to every other destination in
the network at any given time [7-9]. On the other hand, reactive routing protocols need to discover a route to the required destination in an on-demand fashion, which means that they are only required to discover the path when there is data to be transmitted between the nodes [10-12]. Hybrid routing protocols take advantage of both reactive and proactive protocols, in addition to other available features such as GPS in order to find the optimal path [13-16]. In this paper, we will focus on the last category, namely, hybrid routing protocols. The selected hybrid routing protocols are briefly described next:

A. HYBRID LOCATION-BASED AD HOC ROUTING PROTOCOL (HLAR)

HLAR [13] is a hybrid position routing protocol designed to efficiently use all the available location information and to minimize the routing control overhead. This protocol is planned to switch to the on-demand routing when sufficient location information is unavailable or limited, it also deals with the problem of no closest neighbor to the destination (void regions), and so it is almost a scalable protocol. HLAR works as a reactive protocol in the route discovery process, however if there is no route to the destination node, the source node adds information about its location and the location of the destination in the route request packet then it searches for a closer node near the destination. If the node finds a neighbor which is closer to the destination, then it forwards the request packet to it. But if no closer neighbor node is found, it floods the route request packet to all its neighbors. The source node repeats these steps until it reaches the desired destination.

B. ZONE ROUTING PROTOCOL (ZRP)

ZRP [14] is the first protocol developed as a hybrid routing protocol, it allows a network node to divide the network into zones according to many factors; like: power of transmission, signal strength, speed and many other factors. ZRP uses independent protocols inside and outside the zone; it may use any existing proactive and reactive routing protocols. Inside the zone, the source node uses a proactive cached routing table to initiate a route to destination. This allows transmitting packets directly without delay. For outside zone, the ZRP reactively discover a route by transmitting a route request packet to the border nodes of its routing zone; the packet includes a unique sequence number, the source address and the destination address. When the border node receives a route request packet, it looks for the destination within its inside zone. If the destination is found, it sends a route reply on reverse path to the source node; if it doesn't find the destination in its local zone, the border node adds its address to the route request packet and forwards it to its own border nodes. After the source received a reply, it stores the path included in the route reply packet to use it for data transmission to the destination.

C. ZONE-BASED HIERARCHICAL LINK STATE (ZHLS)

ZHLS [15] protocol divides the network into non-overlapping zones; every network node has its own ID and a zone ID, which is measured by a GPS. There are two levels for structural topology: zone level topology and node level topology. In ZHLS there are no position administrators or cluster-heads to manage the data communication. This means that there is no traffic bottleneck. Besides that, the ZHLS reduces the transmission overheads when compared to the reactive protocols. ZHLS broadcast scheme shows lower overhead compared to the flooding scheme in pure reactive protocols. Also in ZHLS, the routes are more flexible to the dynamic topology because it required only the zone ID and the node ID of the destination node for routing. This means that there is no need to search for the location if the destination node does not move to another zone.

PERFORMANCE EVALUATION METRICS

One of the most important factors when evaluating the performance of routing protocols is to choose proper metrics to achieve a realistic evaluation. Therefore, in this work, we evaluate the performance of the chosen routing protocols based on qualitative and quantitative metrics as suggested by [2]. Qualitative metrics represent the protocol’s characteristics that make it suitable for use in the wireless ad hoc environment, such as being loop free, secure, and having a sleep mode. On the other hand, quantitative metrics represent a group of statistical measures used to assess the performance of the routing protocols, such as the packet delivery ratio, average end-to-end delay, delay introduced due to jitter, and the routing overhead. We will first start by comparing the selected routing protocols according to their qualitative metrics. Subsequently, we will test the selected protocols through realistic simulations using quantitative metrics under different network scenarios.

Table I summarizes the comparison between the selected routing protocols according to the chosen qualitative metrics.

<table>
<thead>
<tr>
<th>Qualitative Metrics</th>
<th>HLAR</th>
<th>ZRP</th>
<th>ZHLS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loop Free</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Security</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Uni-directionality</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Sleep mode</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Multicasting</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Routing Scheme</td>
<td>Flat</td>
<td>Flat</td>
<td>hierarchical</td>
</tr>
<tr>
<td>Routing Metric</td>
<td>Shortest path /Best quality</td>
<td>Shortest path</td>
<td>Shortest path</td>
</tr>
</tbody>
</table>

For the quantitative metrics, we will test the selected protocols under the scenario of multimedia transmission between the communicating parties under the following quality metrics. The packet delivery ratio (PDR) which is defined as the ratio between the total number of received packets at all destinations to the total number of transmitted packets sent by all sources. The end-to-end delay which accumulates all the possible delays from the time a packet is created at the source node till it successfully reaches its destination node. The
average of the end-to-end delay of all the successfully delivered packets will be called the average end-to-end delay. Delay jitter is the difference in end-to-end delay between all received packets in a single source-destination connection. The last metric is the routing overhead, which accumulates the number of all the required routing control packets sent by all nodes to initiate, and maintain the required connections. In our opinion, this is the most important metric when evaluating the performance of the various routing protocols, due to the fact that other metrics will be severely affected by the amount of routing overhead generated by the routing protocol.

The simulations for the selected hybrid protocols were carried using the ns2 simulator to evaluate their performance under different scenarios. The mobility model, which we adopt in this study, is 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 1km$^2$ with a 10by10 grid and a total of 100 mobile vehicles inside. All vehicles are assumed to have the same transmission range $R = 150$–250 meters, and their speeds are randomly distributed following a uniform distribution, with an average speed of 60 km/h. For clarity, we summarize all the simulation parameters in Table II.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of vehicles</td>
<td>100</td>
</tr>
<tr>
<td>Transmission range</td>
<td>150-250 meters</td>
</tr>
<tr>
<td>Data rate</td>
<td>256 kbps</td>
</tr>
<tr>
<td>MAC layer</td>
<td>802.11g</td>
</tr>
<tr>
<td>Average velocity</td>
<td>60 km/h</td>
</tr>
<tr>
<td>Simulation Area</td>
<td>1km$^2$</td>
</tr>
<tr>
<td>Mobility Model</td>
<td>Manhattan Model</td>
</tr>
<tr>
<td>Simulation Duration</td>
<td>900 seconds</td>
</tr>
</tbody>
</table>

SIMULATION RESULTS

Figure 1 shows the packet delivery ratio of the 3 hybrid routing protocols as a function of the number of connections for a data rate of 256 kbps. We can generally observe that the packet delivery ratio decreases for all the protocols as we increase the number of connections. The figure also shows that ZHLS and ZRP have a worsened performance compared to HLAR, and that ZHLS slightly outperforms ZRP.

Figure 1. Packet Delivery Ratio for different connections

Similarly, Figure 2 shows the end-to-end delay in milliseconds as a function of the number of connections. Again, the figure shows that HLAR has a much reduced delay compared to ZHLS and ZRP. This metric is very critical when transmitting multimedia data as it affects the overall quality of the streaming data.

Figure 2. End-to-End Delay (ms)

The delay jitter, or packet delay variation in other words is shown in figure 3 as a function of the number of connections in the network. The figure shows that ZRP has the lowest performance, while HLAR has the lowest variation in the end-to-end delay. It is well known that to have high quality multimedia streaming it is important to have low packet delay variations.
Finally, the routing overhead in terms of the number of routing overhead packets which have been transmitted in the network is shown in figure 4. The comparison of the amount of routing overhead that each protocol is adding to the network shows that HLAR has a much reduced routing overhead compared to the other two routing protocols. The figure also shows that ZHLS has slightly lower overhead compared to ZRP.

The results shown in figures 1-3, can be explained depending on the result shown in figure 4. As we mentioned earlier, the amount of the routing overhead generated by any routing protocol will affect its performance in the network. Figure 4 shows that ZRP has the highest routing overhead, therefore, we expect it to have the lowest PDR and the highest end-to-end delay, and delay jitter. This is due to the fact that ZRP is using proactive routing inside the zones to set up and maintain the required routing tables, in addition, to the routing overhead required to manage the required zones.

Even though that the zones in ZHLS don’t overlap as in ZRP, the nodes in each zone are required to broadcast link request and reply messages to discover their connections, as well as, exchange their routing tables with all the nodes within their zone to enable them to calculate their node level topology of that zone. This procedure needs to be performed periodically to detect and update any change in the node’s physical links. Also, gateway nodes in each zone need to broadcast the zone routing table throughout the network to allow all nodes to have a zone level topology of the network, the zone is updated only when any virtual link is broken or created. Due to the mobile nature of VANETs, this overhead to set up and maintain the intrazone and interzone clustering will grow up tremendously and affect the performance of the protocol.

In contrast, HLAR does not use any proactive components, nor does it need to set up or maintain any zones, or exchange any routing tables compared to ZRP and ZHLS. This will minimize the amount of routing overhead produced by HLAR, which in turn improves its overall performance.

In conclusion, we can say that the performance of the tested routing protocols is decreasing when we increase the number of connections or the data rate. Therefore, to guarantee a certain level of service when transmitting multimedia data we need either to limit the number of simultaneous connections in the network, or to reduce the data rate of current connections to accommodate new connections.

CONCLUSIONS AND FUTURE WORK
In this paper, we have studied the performance of 3 different hybrid routing protocols for multimedia transmission in vehicular ad hoc networks. The focus was to quantitatively evaluate the performance of the selected routing protocols, using a various performance metrics, under realistic mobility models and various simulation parameters in a city like topology, with moving nodes at speeds that will require the routing protocols work hardly to maintain the required connections.

In our future work, we intend to add more hybrid routing protocols to the study, and to add more mobility models, simulation scenarios, use congestion control mechanisms, and variable traffic rates.

REFERENCES


