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Research Article

Performance Analysis of AODV, OLSR and GPSR MANET Routing Protocols with Respect to Network Size and Density

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Abstract: The aim of this study is to compare the performance of Optimized Link State Routing (OLSR), Ad hoc On-demand Distance Vector (AODV) and Greedy Perimeter Stateless Routing (GPSR) routing protocols with respect to network size and density. Each of these protocols represents the three categories of MANET routing protocols which are proactive, reactive and geographical routing protocol, respectively. The evaluation was done through simulation and the performance was measured in terms of throughput, average End-to-End (E2E) delay, Packet Delivery Fraction (PDF) and Normalized Routing Load (NRL). The results of the simulations show that the GPSR protocol is superior to OLSR and AODV in most cases. The results also show that throughput, end-to-end delay and packet delivery fraction are largely affected by the network size, while normalized routing load is largely affected by the number of nodes in the network.

Keywords: AODV, GPSR, MANET, OLSR, routing protocols, simulation

INTRODUCTION

Mobile Ad hoc Network (MANET) is a type of network that does not require a fixed infrastructure (Conti and Giordano, 2014). Instead, it consists of a group of nodes that can transmit and receive data amongst themselves. An important characteristic of MANET nodes is that they can move randomly but can still communicate with one another at any time. Another important characteristic of MANETs is that routes between two hosts might compose of hops through another host in the network. Given a condition where a sender node is beyond the transmission range when data transmission is initiated, communication can still occur if there are hosts between the sending and receiving nodes that are willing to forward data packets to the receiver node (Elgohary *et al*., 2014). This is known as multi-hopping, a distinctive characteristic of MANET. Routing protocols for MANETs are designed to provide a route between nodes. MANET routing protocols is categorized into 3 main groups: proactive, reactive and geographical routing. Proactive routing protocols or table-driven routing protocols have an up-to-date topological map that enables latest routes to be maintained. Therefore, when a node needs to transfer data to other node, destination of the path is readily known and can be immediately used. In reactive routing protocols, the topological map is not updated and thus routes through the network are not maintained. An additional procedure, called a "route discovery procedure," needs to be carried out before data packets can be transmitted. This can be accomplished by sending a query to the network (Komai *et al*., 2014). Protocol for reactive route is also known as on-demand routing protocol. The geographical routing protocol is suited to sensor networks that use location information to search for an efficient direction from the node's source to the destination. Protocol geographical route scales much better in ad hoc network mainly for two reasons. There is no need of having the latest routing table and global network topologies' view and its changes. Protocol geographical route scales is useful for large multi-hop wireless network topologies because the physical information of the nodes is tracked via using GPS or other types of positioning services. Since the nodes are moving randomly throughout the network and the position of the nodes alters continuously (Shi *et al*., 2011). According to Son *et al*. (2004), this protocol works by having each node forward a packet to the neighboring node nearest to the destination (Son *et al*., 2004). This is known as the greedy mechanism. The objective of this study is to investigate the effect of network size and density on the performance of MANET routing protocols using simulation.

LITERATURE REVIEW

Ad hoc On-demand Distance Vector (AODV) routing protocol: The AODV routing protocol is a reactive routing protocol. A reactive routing hunts for routes when data needs to be sent by a node. Hence, routes are formed when needed. The AODV routing protocol consists of four control packets: hello messages, Route Replies (RREPs), Route Error

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messages (RERRs) and Route Requests (RREQs). These control packets are used in two protocol mechanisms, route maintenance and route discovery. All nodes in the AODV protocol maintain a routing table to store information regarding active routes from source to destination. The information stored consists of number of hops, next hop, destination sequence number, active neighbours for a route and the destination of a route table entry and its time of expiry. Route entry timeouts are updated when used. To prevent looping in distance vector routing, a sequence number is sent with RREQs and RREPs, both of which are kept in the routing table. When a node receives multiple replies, the reply with the higher sequence number is used. The AODV mechanism specifies that when two routes possess similar sequence number, the shorter route is used (Fehnker *et al*., 2012).

Optimized Link State Routing (OLSR): OLSR is a proactive routing protocol and therefore keeps latest routes to other nodes in the network. It is important to sustain current routing information; proactive routing protocols need to send control messages periodically which will generate a large amount of routing overhead. However, OLSR is designed to minimize this overhead (Singla and Panag, 2013). Therefore, when needed, data can be sent without delay. OLSR routing protocol consists of three general elements: a mechanism for the effective flooding of control traffic, one for neighbor sensing and a mechanism to determine how to choose and publish adequate topological information in the network in order to provide the best routes (Ahlgren *et al*., 2012).

In this protocol, the information regarding network topology changes periodically through link state messages. A hop-by-hop mechanism is utilized to forward packets (Saputro *et al*., 2012). A Multipoint Relay (MPR) strategy is used to minimize the quantity of rebroadcasting nodes and the control message size during every route update (Ahn and Lee, 2014). Nodes can periodically exchange topological information. MPR creates a unique route from the given source to the destination. These nodes sense each other and, in situation involving symmetrical links, will consider every node a neighbor.

Furthermore, link sensing and MPR selection can be carried out through hello messages. All information related to the node that sends the hello message and its neighbouring nodes is in the message. Each node has the ability to obtain routing information to reach two hops from a hello message. It can also determine a subset of one hop symmetric neighbour nodes as its MPR set. This MPR set is acknowledged in its next broadcasting of a hello message. In the first phase, neighbour nodes are detected by use the hello messages. The exchange of the hello messages in OLSR permits the selection of the MPR nodes. The routing path to the known destination of each node is updated and recalculated when the updated information is received (Guo and Wang, 2014). The TC message broadcasts topological information throughout the network, but these messages is only forwarded through MPR nodes. With MPR, nodes are able to exchange topological information in a periodical manner without having to generate a large amount of traffic.

Greedy Perimeter Stateless Routing (GPSR): GPSR is a geographical routing protocol. Such protocols utilize position-based routing, where a node must know where its immediate neighbour is located (Seok and Saxena, 2013). GPSR routing protocols use periodic beaconing to maintain updated geographical location information of neighbouring nodes within their transmission range (Jaiswal and Khilar, 2011). Greedy forwarding decisions are made by GPSR with the information of the router's instant neighbors in the network topology. When a packet reaches where greedy forwarding is not possible, the packet is forwarded around the perimeter of the region, keeping status information of local topology. GPSR scales best than the shortest path and ad hoc routing protocols as the number of network destinations nodes grows (Alsaqour *et al*., 2012).

Related works: A large number of research papers published in recent years have simulated and equated to the MANET routing protocols' performance. In this section, we discuss a series of past studies that compared various MANET routing protocols performances.

The authors in Issariyakul and Hossain (2011) have compared the performance of three routing protocols: Destination Sequenced Distanced Vector (DSDV) routing, AODV and Dynamic Source Routing (DSR) (Vanthana and Prakash, 2014). The simulator tool NS-2 was used to link the three routing protocols performances. The parameters used by them were pause time, number of connections and packet size, whereas the performance metrics used were packet loss, average end-to-end delay and throughput. The simulation results showed that AODV is the most suitable protocol for Transmission Control Protocol (TCP) and real-time traffic, since AODV outperformed both the DSR and DSDV protocols for all simulation parameters.

Another study performed by Niraj and Arora (2012) compared AODV, DSR and DSDV performances using NS-2. The performance parameters used for evaluating the protocols were pause time, quantity of nodes and packet size and the performance metrics used were throughput, normalized routing load, packet delivery fraction and average end-to-end delay. The results of the simulation showed that DSR is superior to DSDV and AODV based on the throughput and packet delivery fraction. The regular end-to-end delay and the normalized routing load for AODV were found to be better than those for DSR and DSDV for varying numbers of nodes. Furthermore, Niraj and Arora (2012) reported that the routing overhead in AODV was better than that of DSDV and DSR with varying values of pause time.

Authors in Singla and Panag (2013) have compared the performance of AODV, OLSR, DSR and the Zone Routing Protocol (ZRP) used the simulator tool OPNET. The parameter used in the simulation was pause time and the metrics used were throughput, retransmission attempts, network load and media access delay. The results of the simulation showed that ZRP outperformed the other routing protocols in term of throughput, retransmission attempts and network load, whereas OLSR was superior to all other protocols in term of media access delay.

METHODOLOGY

Performance metrics: In MANET simulations, the number of performance metrics are commonly use to evaluate how the routing protocols' perform (Beigh and Peer, 2012). In this study, we used the following four performance metrics.

Packet Delivery Fraction (PDF) is data packets' fraction that effectively arrives at its destinations nodes. The packet delivery ratio indicates the efficiency of a protocol in transferring packets from source to destination. A higher value means that packet delivery is more successful (Anastasi *et al*., 2003):

$$PDF = \frac{\sum_{m=1}^{n} recvs}{\sum_{m=1}^{n} sends} \times 100$$

Throughput is the amount of data effectively sent to the destination within a specified time. It is normally measured in bytes per second. Throughput can be affected by several factors, including bandwidth, power, network topology and reliability of communication (Bai and Helmy, 2004):

$$Throughput = \frac{\sum_{m=1}^{n} recv}{PkTduratio\ n}$$

Average End-to-End delay (E2E) indicates packet transmission's interruption in from the main node to the destination. The total interruption is an accumulation of several small delays in the network. This comprises possible delays due to a buffer in route discovery latency, delays in lining up at the interface, Media Access Control (MAC) retransmission delays and transfer time and propagation delays. The average E2E delay of a received packet can be calculated by obtaining the time variance between the transmission and response of the packet at a Constant Bit Rate (CBR) and dividing the time difference by the total number of CBR transmissions. Lower end-end delays indicate better performance (Sinha and Sen, 2012):

$$E2E = \sum_{m=1}^{n} \frac{(CBR\ Recv\ Time - CBR\ Sent\ Time)}{\sum_{m=1}^{n} recvnum}$$

Normalized Routing Load (NRL) is the total of routing packets passedper data packet delivered to the destination node. This metric is used to measure the overhead generated by the routing protocol during its routing operation A low-value overhead means a lower number of control packets is created by the protocol, which leaves additional network resources available to transmit real data packets (Yussof *et al*., 2009):

$$NRL = \frac{\sum_{m=1}^{n} RPgen}{\sum_{m=1}^{n} recvs}$$

SIMULATION RESULTS

We simulated the AODV, GPSR and OLSR routing protocols using Network Simulator NS2 (version 2.33). The simulation was executed for two scenarios and the difference between them was in terms of the simulation parameter evaluated. In the first scenario, the simulation parameter that is varied was the number of nodes while the other parameters were kept constant. Increasing the quantity of nodes escalates the density of the network. The details of the simulation parameters for scenario 1 are listed in Table 1. The simulation parameter varied in the second scenario was network size. By increasing network size, the area in which nodes can travel becomes larger. The details of the simulation parameters for scenario 2 are listed in Table 2. For each scenario, we measured the performance of AODV, GPSR and OLSR using four performance metrics: average end-to-end delay, packet delivery fraction, throughput and normalized routing load.

Scenario 1: The impact of number of nodes: This scenario was simulated multiple times, where a different number of nodes were used in each simulation. The number of nodes used for each simulation is listed in Table 1. The simulation was run 10 times, each with a different seed, for every variation in the number of nodes. The results presented here were obtained by calculating the average of the simulation results.

Table 1: Simulation parameters for scenario 1

Number of nodes	30, 50, 70, 90, 110, 130, 150 nodes
Simulation time	900 sec
Map size	1250×1250 m
Max speed	20 m/sec
Mobility model	Random waypoint
Traffic type	Constant Bit Rate (CBR)
Packet size	512 bytes
Connection rate (nominal radio range)	4 pkts/sec
Pause time	20 sec
Number of connections	5
Bandwidth of links	2 Mbit
MAC layer type	IEEE 8051
Seed	5, 20, 44, 50, 64, 71, 80, 89, 91, 110

Table 2: Simulation parameters for scenario 2

Number of nodes	50 nodes
Simulation time	900 sec
Map size	500×500, 750×750, 1000×1000, 1250×1250, 1500×1500, 1750×1750
Max speed	20 m/sec
Mobility model	Random waypoint
Traffic type	Constant Bit Rate (CBR)
Packet size	512 bytes
Connection rate (nominal radio range)	4 pkts/sec
Pause time	20 sec
Number of connections	5
Bandwidth of links	2 Mbit
MAC layer type	IEEE 802.11
Seed	5, 20, 44, 50, 64, 71, 80, 89, 91, 110

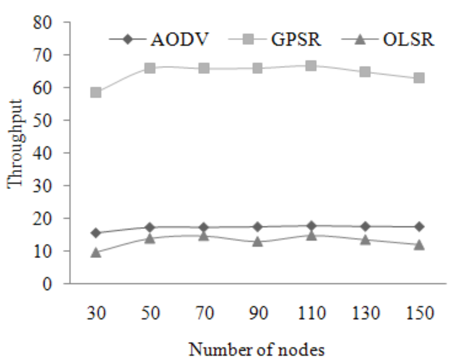

Fig. 1: Throughput for varying numbers of nodes for the three protocols

We simulated this network for each routing protocol and the results are shown in Fig. 1 to 4. Figure 1 shows the impact of the number of nodes on the throughput for each routing protocol. In general, the thought for all three protocols remain relatively similar regardless of the number of nodes in the network. However, GPSR has much higher throughput than that of AODV and OLSR. This is mainly due to the behavior of the GPSR protocol where packets are simply sent to the neighbor that is the nearest to the final node. No routing packets to search for a path need to be generated. This low overhead causes more bandwidth to

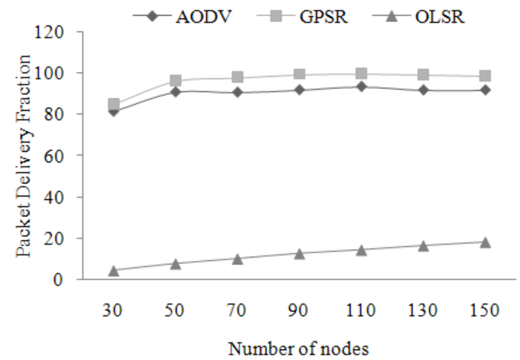

Fig. 2: Packet delivery fractions for varying numbers of nodes for the three protocols

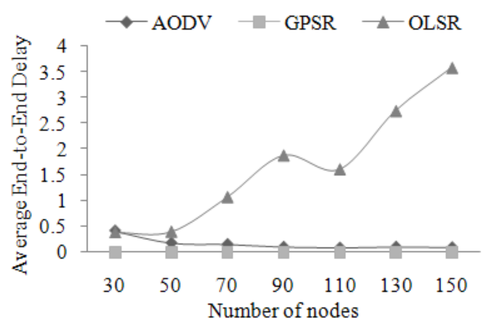

Fig. 3: The average end-to-end delay for varying numbers of nodes for the three protocols

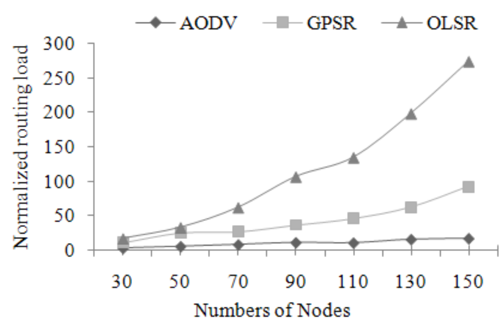

Fig. 4: Normalized routing load for varying numbers of nodes for the three protocols

be available for data transfer and this contributes to the higher throughput.

The throughput for the AODV routing protocol was higher than that for OLSR because AODV has a lower routing overhead than OLSR since it searches for paths on-demand and does not need to sustain the latest routing table. The lower overhead allows more bandwidth to be used for the data packets. OLSR recorded the worst throughput because it consumes a significant amount of network bandwidth because of the frequent need to send update messages.

Figure 2 shows the effect of the number of nodes on the packet delivery fraction for each protocol route. As the quantity of nodes grows, the packet delivery fraction

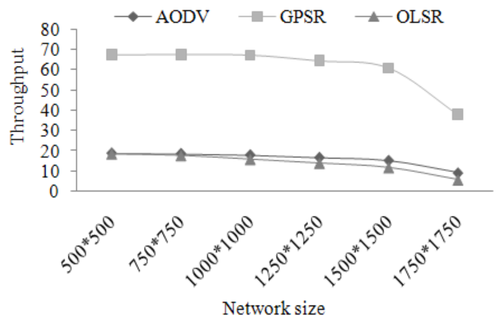

Fig. 5: Throughput results for networks of different sizes for the three protocols

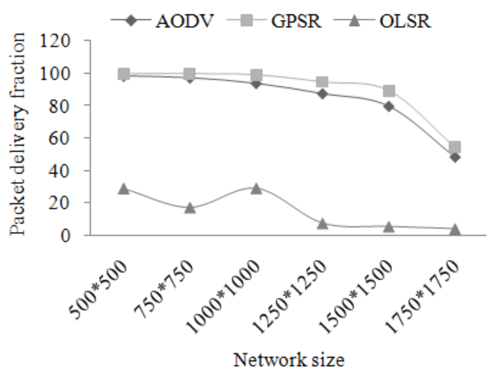

Fig. 6: Packet delivery fraction results for different network sizes for the three protocols

tends to slightly increase. The packet delivery fraction for the GPSR routing protocol was higher than that of the AODV and OLSR protocols. As the network becomes denser (i.e., the network contains more nodes), GPSR attains a packet delivery fraction higher than that of traditional protocols, such as AODV and OLSR. The performances of AODV are just a little but lower than that of GPSR. The OLSR routing protocol has the lowest value for packet delivery fraction. This is because in OLSR, nodes need send frequent updates, which can reduce the amount of network resources available to send data. This may cause some data packets to be dropped, thus lowering the packet delivery fraction.

Figure 3 shows how the number of nodes on average affects end-to-end delay as the number of nodes grows. The average E2E delay for the OLSR routing protocol grows with the escalating number of nodes. Increasing the quantity of nodes causes a change in the network topology, which in turn causes more update messages to be sent. These update messages can congest the network, causing a high delay for data packets. AODV performs relatively well with respect to E2E delay, where the performance is only slightly less than that of GPSR. The GPSR routing protocol delivered the best performance in terms of average E2E delay because the nodes only need to use location information to forward the packet to another node that is closer to the destination. Doing this requires very short amount of time.

Figure 4 shows the effect of the quantity of nodes on the normalized load route. As the quantity of nodes grows, we see a slight growth in AODV normalized routing load. This is due to the low demand for bandwidth needed to maintain the route between the source node and the destination node. The normalized routing load increases for GPSR with increasing number of nodes because there are more beacons that need to be processed in order to update the information regarding the geographic locations of the neighbouring nodes. With larger numbers of nodes, the normalized routing load for OLSR escalates tremendously because the nodes need to process more update messages.

Scenario 2: Impact of network size: This scenario is simulated multiple times and a different network size is used each time. The network size used for each simulation is listed in Table 2. For each network size, the simulation was run 10 times, each with a different seed. The results presented here were obtained by calculating the average of the simulation results.

The results of the simulation in terms of throughput for AODV, GPSR and OLSR in scenario 2 are shown in Fig. 5. It shows that throughput results for all three routing protocols decrease as network size increases. This is because when network size increases, nodes have greater freedom to move, which leads to changes in network topology. This makes it more difficult to find a routing track to the endpoint, regardless of the protocol. Some destination nodes may not even be reachable. The reason why GPSR performs better than AODV and OLSR is the same as the one described in scenario1 above.

Figure 6 shows GPSR, AODV and OLSR protocol route packet delivery fraction decrease as the network topology increases. This is because as the network gets larger, the nodes are capable of moving further from each other. As a result, links between nodes may break more easily as the nodes are mobile. Some nodes could become inaccessible, which reduces packet delivery fraction. Of the three routing protocols, GPSR provided the highest packet delivery fraction and OLSR provided the lowest.

Figure 7 shows the result of the average E2E delay for AODV, GPSR and OLSR. Obviously, the E2E delay gets higher as the network gets larger, especially starting from network size 1250×1250 m. However, the GPSR protocol is the least affected by the network size, providing a much lower E2E delay compared to AODV and GPSR, especially at the largest network size of 1750×1750 m. This could be attributed to the low overhead of GPSR, which causes the network to be less congested as compared to AODV and OLSR.

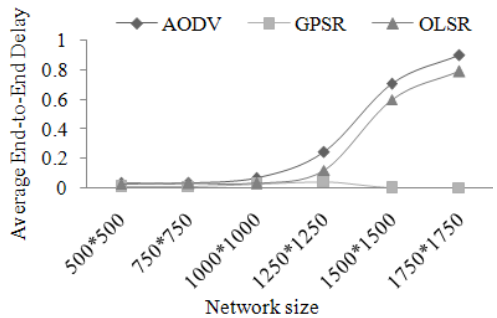

Fig. 7: Results for average end-to-end delay for networks of different sizes for the three protocols

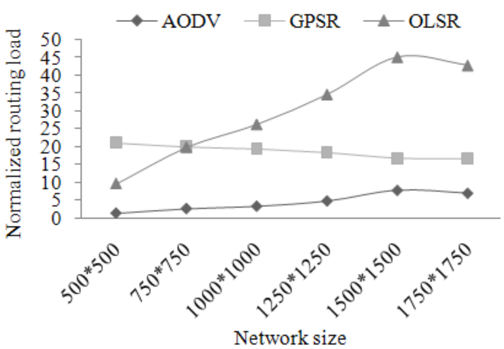

Fig. 8: Results for normalized routing load for varying network sizes for the three protocols

Figure 8 shows the results for the normalized routing load for the GPSR, AODV and OLSR protocol routes are based on the size of the network. The normalized routing load for OLSR increases as the network topology becomes bigger. This is as the network topology gets larger, the nodes tend to move more and therefore more update messages need to be generated by OLSR to preserve up-to-date routing information. For AODV, the normalized load route slightly grows as the network size intensifies because more RREP and RREQ messages need to be generated to search for nodes that have moved further away from the source. GPSR on the other hand is not very much affected by the network size. In fact, the normalized routing load tend to slightly decrease as the network size gets larger. This is because in GPSR no routing messages need to be sent to far away nodes. The routing mechanism relies on the location of neighboring nodes and this mechanism works pretty much the same way regardless of the network size or the nodes' location.

CONCLUSION

In this study, performances of OLSR, AODV routing and GPSR protocolsis each compared to proactive, reactive and geographical routing protocol, respectively. We used simulations to assess the how the route protocols perform with regards to the network size and density. The network performance was measured based on the throughput, average End-to-End (E2E) delay, Packet Delivery Fraction (PDF) and Normalized Routing Load (NRL). The results of the simulations show that GPSR is superior to OLSR and AODV in most cases. This is mainly attributed to GPSR's routing mechanism where information used by greedy decisions are forwarded using the router's nearest neighbors in the network topology. This mechanism has low overhead and this contributes to its good performance. The simulation results also shows that the rise in the nodes' number affects the normalized routing load, while the increase in network size has a large effect on throughput, end-to-end delay and packet delivery fraction.

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