PERFORMANCE COMPARISON AND ANALYSIS OF MOBILE AD HOC ROUTING PROTOCOLS

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ABSTRACT

A mobile ad hoc network (MANET) is a wireless network that uses multi-hop peer-to-peer routing instead of static network infrastructure to provide network connectivity. MANETs have applications in rapidly deployed and dynamic military and civilian systems. The network topology in a MANET usually changes with time. Therefore, there are new challenges for routing protocols in MANETs since traditional routing protocols may not be suitable for MANETs. Researchers are designing new MANET routing protocols and comparing and improving existing MANET routing protocols before any routing protocols are standardized using simulations. However, the simulation results from different research groups are not consistent with each other. This is because of a lack of consistency in MANET routing protocol models and application environments, including networking and user traffic profiles. Therefore, the simulation scenarios are not equitable for all protocols and conclusions cannot be generalized. Furthermore, it is difficult for one to choose a proper routing protocol for a given MANET application. According to the aforementioned issues, this paper focuses on MANET routing protocols. Specifically, my contribution includes the characterization of different routing protocols and compare and analyze the performance of different routing protocols.

KEYWORDS

MANET

1. INTRODUCTION

Movements of nodes in a mobile ad hoc network cause the nodes to move in and out of range from one another. As the result, there is a continuous making and breaking of links in the network, making the network connectivity (topology) to vary dynamically with time. Since the network relies on multi-hop transmissions for communication, this imposes major challenges for the network layer to determine the multi-hop route over which data packets can be transmitted between a given pair of source and destination nodes. Because of this time-varying nature of the topology of mobile ad hoc networks, traditional routing techniques, such as the shortest-path and link-state protocols that are used in fixed networks, cannot be directly applied to ad hoc networks. A fundamental quality of routing protocols for ad hoc networks is that they must dynamically adapt to variations of the network topology. This is implemented by devising techniques for efficiently tracking changes in the network topology and rediscovering new routes when older ones are broken. Since an ad hoc network is infrastructure less, these operations are to be performed in a distributed fashion with the collective cooperation of all nodes in the network.

Because of its many challenges, routing has been a primary focus of researchers in mobile ad hoc networks. The MANET working group in the IETF has been working on the issue of standardizing an IP based routing standard for mobile ad hoc networks. Consequently, a large number of dynamic routing protocols applicable to mobile ad hoc networks have been developed. Based on when routing activities are initiated, routing protocols for mobile ad hoc networks may be broadly classified into three basic categories: (a) proactive or table-driven protocols, (b) reactive or on-demand routing protocols, and (c) hybrid routing protocols.

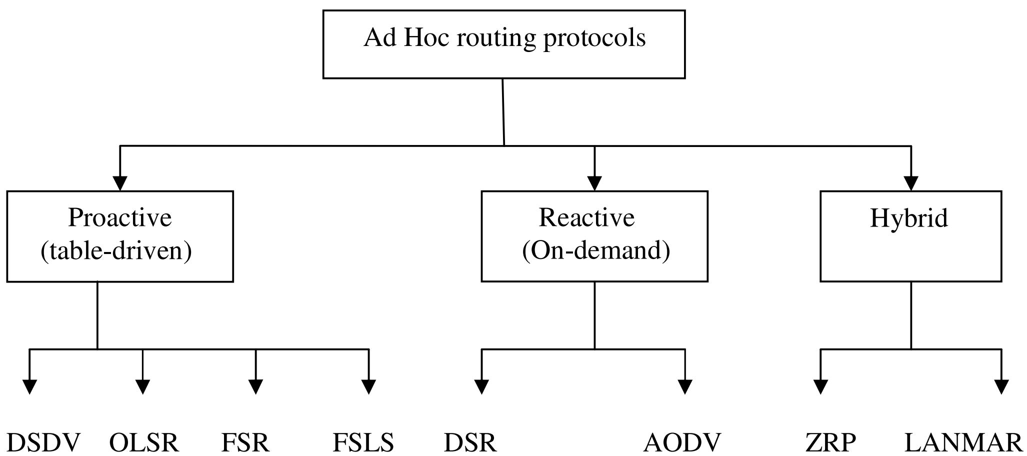

Figure 1. Classification and examples of ad hoc routing protocols.

Traditional distance-vector and link-state routing protocols [1] are proactive in that they maintain routes to all nodes, including nodes to which no packets are sent. For that reason they require a periodic control message, which leads to scarce resources such as power and link bandwidth being used more frequently for control traffic as mobility increases. One example of a proactive routing protocol is Optimized Link State Routing Protocol (OLSR) [2]. OLSR, which has managed to reduce the utilization of bandwidth significantly. Reactive routing protocols, on the other hand, operate only when there is a need of communication between two nodes. This approach allows the nodes to focus either on routes that are being used or on routes that are in process of being set up. Examples of reactive routing protocols are Ad hoc On-Demand Distance Vector (AODV) [3], and Dynamic Source Routing (DSR) [4].

Both proactive and reactive routing has specific advantages and disadvantages that make them suitable for certain types of scenarios. Proactive routing protocols have their routing tables updated at all times, thus the delay before sending a packet is minimal. However, routing tables that are always updated require periodic control messages that are flooded through the whole network- an operation that consumes a lot of time, bandwidth and energy. On the other hand, reactive routing protocols determine routes between nodes only when they are explicitly needed to route packets. However, whenever there is a need for sending a packet, the mobile node must first find the route if the route is not already known. This route discovery process may result in considerable delay. Combining the proactive and reactive approaches results in a hybrid routing protocol.

A hybrid approach minimizes the disadvantages, but also the advantages of the two combined approaches. The Zone Routing Protocol (ZRP) [5] is such a hybrid reactive /proactive routing protocol. Each mobile node proactively maintains routes within a local region (referred to as the routing zone). Mobile nodes residing outside the zone can be reached with reactive routing.

2. SIMULATION SET UP

This section describes the scenario, the movement model and the communication model used in this study. Moreover, it presents the parameters used in the simulations.

2.1. Scenario

The studied scenario consists of 15 mobile nodes, 2 gateways, 2 routers and 2 hosts. The topology is a rectangular area with 800 m length and 500 m width. A rectangular area was chosen in order to force the use of longer routes between nodes than would occur in a square area with equal node density. The two gateways are placed on each side of the area; their x,y-coordinates in meters are (100,250) and (700,250). All simulations are run for 900 seconds of simulated time.

Five of the 15 mobile nodes are constant bit rate traffic sources. They are distributed randomly within the mobile ad hoc network. The time when the five traffic sources start sending data packets is chosen uniformly distributed within the first ten seconds of the simulation. After this times the sources continue sending data until one second before the end of the simulation. The destination of each of the sources is one of the two hosts, chosen randomly.

A screenshot of the simulation scenario is shown in Figure 1. The five mobile nodes that are marked with a ring are the sources. The two hexagonal nodes are the gateways and the four square nodes are the two hosts and the two routers.

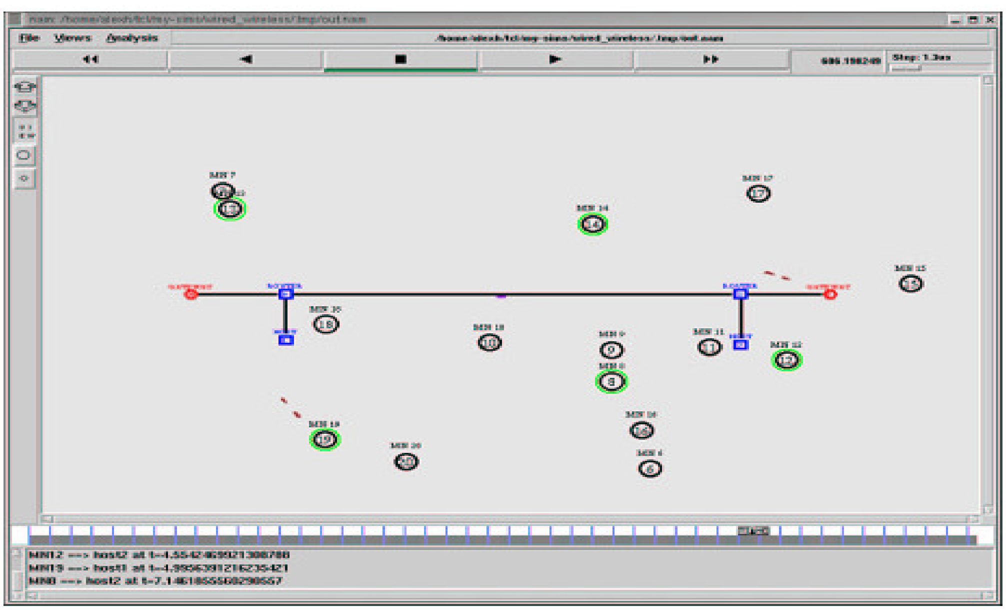

Figure 1. Screenshot of the simulation scenario.

2.3. Movement Model

The mobile nodes move according to the "random waypoint" model [6]. Each mobile node begins the simulation by remaining stationary for *pause time* seconds. It then selects a random destination in the defined topology area and moves to that destination at a random speed. The random speed is distributed uniformly between zero (zero not included) and some *maximum speed*. Upon reaching the destination, the mobile node pauses again for *pause time* seconds, selects another destination, and proceeds there as previously described. This movement pattern is repeated for the duration of the simulation.

2.4. Communication Model

In the scenario used in this study, five mobile nodes communicate with one of two fixed nodes (hosts) located on the internet through a gateway. As the goal of the simulations was to compare the different approaches for gateway discovery, the traffic source was chosen to be a constant bit rate (CBR) source. Each source mobile node generates packets every 0.2 seconds in this paper. Since each packet contain 512 bytes of data, the amount of generated data is 5*512*8 bit/s = 20 kbit/s, for each source. The traffic connection pattern is generated by CMU's traffic generator (*cbrgen.tcl)*. The main parameters in *cbrgen.tcl* are "connections" (number of sources) and "rate" (packet rate); see Table 1.

2.5. Parameters

The parameters that are common for all simulations are given in table 1 and the parameters that are specific for some simulations are shown in table 2.

Table 1: General parameters used in all simulations.

Parameter	**Value**
Transmission range	250 m
Simulation time	900 s
Topology size	800 m X 500 m
Number of mobile nodes	15
Number of sources	5
Number of gateways	2
Traffic type	Constant bit rate
Packet rate	5 packets/s
Packet size	512 bytes
Pause time	5 s
Maximum speed	10 m/s

The transmission range is the maximum possible distance between two communicating mobile nodes. If the distance between two mobile nodes is larger than 250 m they cannot communicate with each other directly.

Table 2: Specific parameters used in some simulations.

Parameter	**Value**
ADVERTISEMENT_INTERVAL	Varied from 2-60 seconds
ADVERTISEMENT_ZONE	3 hops

ADVERTISEMENT_INTERVAL is used when proactive and hybrid discovery methods are used. ADVERTISEMENT_ZONE is used for hybrid gateway discovery method and defines the range within which proactive gateway discovery is used.

3. PERFORMANCE METRICS

The second goal of this paper was to "implement and compare different approaches for gateway discovery". Comparing the different methods is done by simulating them and examining their behavior. In the simulations in the following section, the effects of different gateway advertisement intervals are evaluated. In comparing the gateway discovery approaches, the evaluation has been done according to the following two metrics:

_ *The packet delivery ratio is defined as the number of received data packets divided by the number of generated data packets.*

_ *The end-to-end delay is defined as the time a data packet is received by the destination minus the time the data packet is generated by the source.*

4. RESULTS AND DISCUSSIONS

In this section the effect of varying gateway advertisement intervals is evaluated. Since gateway advertisements are not sent in the reactive gateway discovery approach, the results for this approach are constant and independent of the advertisement interval. Each data point is an average value of 10 runs with the same communication model, but different randomly generated movement patterns.

4.1. Packet Delivery Ratio

Table 3 shows the packet delivery ratio of three gateway discovery methods of are proactive, reactive and hybrid:

Table 3. The value of packet delivery ratio

Interval(s)	2	10	20	30	40	50	60
Proactive	99.84	99.8379	99.842	99.82	99.815	99.795	99.825
Reactive	99.81	99.81	99.81	99.81	99.81	99.81	99.81
Hybrid	99.85	99.835	99.815	99.825	99.82	99.8275	99.835

The values of the Table 3 are from the analysis of the *out.tr* file of the simulation environment.

Figure 3 shows the packet delivery ratio with advertisement intervals between 2 and 60 seconds. As the figure shows, the packet delivery ratio is very high (above 99.8 %) for all three gateway discovery approaches. The figure also shows that the difference between the three approaches is very small. However, the proactive and hybrid approaches have some larger packet delivery ratio than the reactive approach, especially with short advertisement intervals. The reason is that the short advertisement intervals result in more gateway information (RREP_I and GWADV packets).

A mobile node that receive a RREP_I or a GWADV message, update its route entry for the gateway. Therefore, it is more likely for the mobile nodes to have fresher and shorter routes to a gateway and thereby minimizing the risk for link breaks. Link breaks can result in lost data packets since the source continues to send data packets until it receives a RERR message from the mobile node that has a broken link. The longer the route is (in number of hops), the longer times it can take before the source receive a RERR and hence, more data packets can be lost. When the advertisement interval increases, a mobile node receives less gateway information and consequently it does not update the route to the gateway as often as for short advertisement intervals. Therefore, the positive effect of periodic gateway information is decreased as the advertisement interval increases.

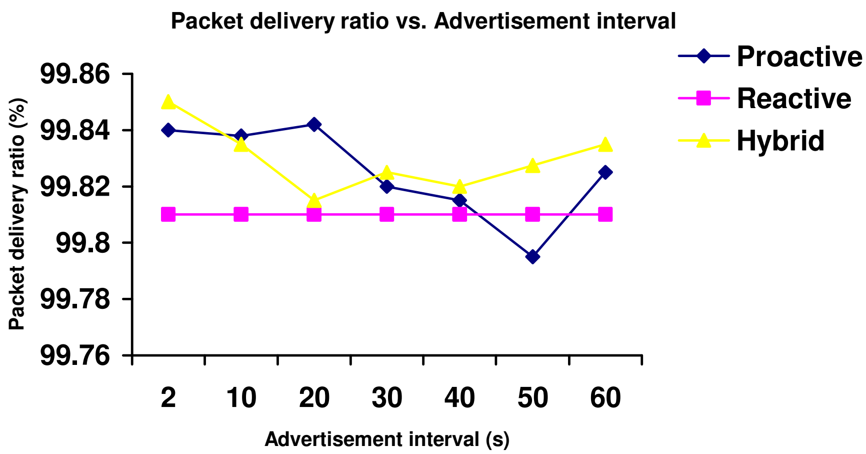

Figure 3. Combine Packet delivery ratio

4.2 Average End-to-end Delay

Table 4 show the average end to end delay of the three gateway discovery methods that are:

Table 4. The value of average end to end delay

Interval(s)	2	10	20	30	40	50	60
Proactive	19.235	19.435	19.512	19.615	19.665	19.725	19.7521
Reactive	20.5	20.5	20.5	20.5	20.5	20.5	20.5
Hybrid	19.465	19.256	19.3	19.3524	19.3649	19.3755	19.2689

Figure 5 shows the average end-to-end delay with advertisement intervals between 2 and 60 seconds. As the figure shows, the average end-to-end delay is less for the proactive and hybrid approaches than for the reactive approach. The reason is that the periodic gateway information sent by the gateways allows the mobile nodes to update their route entries for the gateways more often, resulting in fresher and shorter routes. With the reactive approach a mobile node continues to use a route to a gateway until it is broken. In some cases this route can be pretty long (in number of hops) and even if the mobile node is much closer to another gateway it does not use this gateway, but continues to send the data packets along the long route to the gateway further away until the route is broken. Therefore, the end-to-end delay increases for these data packets, resulting in increased average end-to-end delay for all data packets. The figure also shows that the average end-to-end delay is decreased slightly for short advertisement intervals when the advertisement interval is increased. At the first thought this might seem unexpected. However, it can be explained by the fact that very short advertisement intervals result in a lot of control traffic which lead to higher processing times for data packets at each node. Moreover, since the AODV messages are prioritized over data packets, these have to wait in the routing queue until the AODV messages are sent, resulting in higher end-to-end delay.

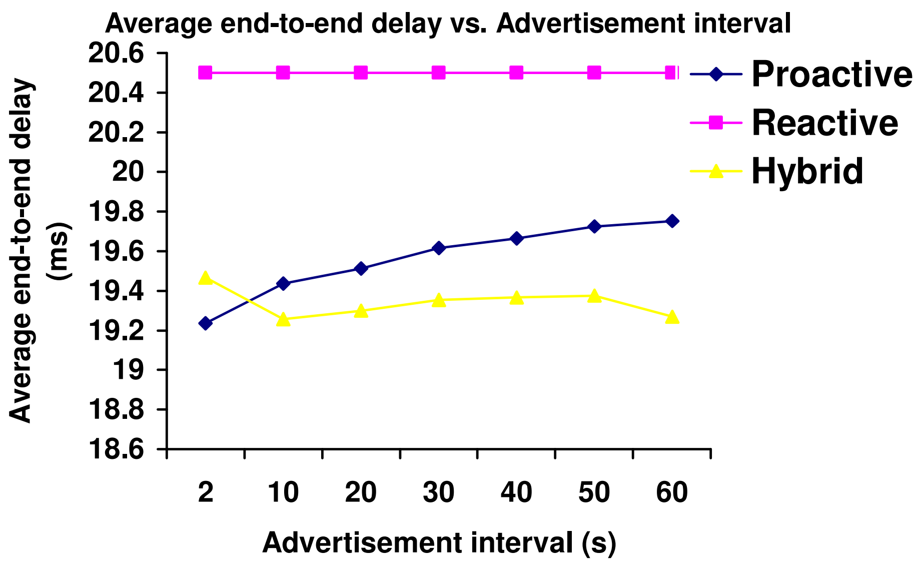

Figure 5. Combine Average End to End Delay

5. CONCLUSION

In this research, three methods for detection of these gateways have been presented, implemented and compared. The three methods for gateway detection are referred to as reactive, proactive and hybrid gateway discovery. The comparison between these methods provides us useful information. In this paper, the individual description of the three different gateway methods (that reactive, proactive and hybrid) of packet delivery ratio and average end-to-end delay. Next it analyze the comparison of the gateway methods.

Regarding the packet delivery ratio, the result is largely the same, regardless of which gateway discovery method is used. As for the average end-to-end delay, the proactive and hybrid methods perform slightly better than the reactive method.

The results presented are valid for the specific scenario used in this work. Therefore, one cannot tell which of the gateway discovery methods the best one for every possible scenario is. There are many factors that can be changed and their impact should be investigated. Unfortunately the scope of this paper made it impossible to deal with more than a part of these interesting issues.

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