Performance Evaluation of Six Wireless Ad Hoc Network Routing Protocols *

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Abstract

Mobile wireless ad hoc networks are important for its applications in military actions and emergency rescue operations. These networks also have a high potential in commercial usage and daily life activities. One major issue for these networks is its performance. Although different attempts have been made for various routing protocols, the performance of the protocols are still relatively low compare with wired networks due to the limited bandwidth and the high control overhead. In this paper, the performance of six different routing protocols including those that are recently proposed are compared by a simulation model. Performance parameters, such as throughput and packet delivery ratio, are collected and analyzed as the mobility changes in a big range. In addition, file transfer and remote login applications will also be studied for each protocol.

1. Introduction

Mobile wireless ad hoc network consists of a number of mobile nodes, which are interconnected with each other using electromagnetic waves, such as radio waves. These networks have been used in military actions and emergency rescue operations in which no existing network infrastructure or central administration is available. As the restriction on the radio communication is lessen and the popularity of portable computer devices increases, the commercial value of these networks gains much attention. For example, business personnel can communicate or share information with each other whenever and wherever they want with mobile computing devices. Although these networks are very useful in many areas, its implementation is still in a developing stage. One major issue is about its performance, which is still relatively low compared to wired networks due to the limited bandwidth and the high control overhead.

In recent years, some new routing schemes were proposed, for example, the Dynamic Source Routing (DSR)[5], the Ad hoc On-demand Distance Vector Routing (AODV)[9], and the Location Aid Routing (LAR)[6]. Other existing routing protocols include Distributed Bellman-Ford (DBF) [2], Distance Sequence Distance Vector (DSDV) [10], Wireless Routing Protocol (WRP) [7], and Fisheye State Routing (FSR) [4]. In this paper, we are interested in the performance of six routing protocols, DBF, WRP, DSR, AODV, LAR and FSR, as the mobility change in a big range. To compare their performance, a simulation model that contains 100 nodes was developed. For each protocol, constant bit rate (cbr) traffic is used. We also study the application of file transfer (ftp) and remote login (telnet) functionality. In addition, a finer scale of mobility is used when the mobility is high for detailed investigation on the overall performance of the protocols.

2. Routing Protocols

In this section, we will introduce the wireless ad-hoc network routing protocols that will be studied by our model.

Distributed Bellman-Ford (DBF) [2,7]: a traditional table-driven routing protocol based on pure distance vector algorithm. Each node acts as a router and periodically informs its neighbors about its distance to all other nodes. Nodes that receive this information update their own routing tables. Nodes then pass the up-dated tables to their neighboring nodes. This updating process repeats a few times. Then, the routing table in each node becomes consistent with the tables in other nodes. The best routes with minimum cost (the shortest path) for each destination can then be computed in each node.

Wireless Routing Protocol (WRP) [7]: It is also a distance vector based protocol but with some enhancements. First, if there is no change in link, a simple periodic HELLO packet is exchanged between neighbors. Otherwise, only necessary information that reflects the updates is sent. Therefore, the control overhead can greatly be reduced. Second, when a node receives an updated message, it sends acknowledge message back. This increases the reliability of transmission. Third, a predecessor (second-to-last hop) node ID is used to calculate the entire path. Therefore, the number of temporary routing loops is reduced so that a faster convergence can be obtained.

Dynamic Source Routing (DSR) [5]: an on-demand and an enhanced version of source routing scheme. Route
discovery is initiated when necessary. Periodic update or triggered update is not required. It does not have the looping problem that happens in DBF. A whole routing path is specified in the header of the data packet being sent. Intermediate nodes do not need to keep routing information, but each node maintains a route cache to store the routing information it learns from the by-pass packets. More than one route for a destination can be stored in the route cache. The basic mechanisms in DSR are route discovery and route maintenance.

Ad-hoc On-demand Distance Vector Routing (AODV) [9]: basically a combination of DSR and Distance Sequence Distance Vector routing (DSDV) [10]. It consists of route discovery process that is used in DSR. It also employs the hop-by-hop routing, the sequence number (time stamp) and periodic hello message that is used in DSDV. It is a loop-free routing protocol. No global periodic routing update is required. It uses table-driven routing framework. A periodic Hello message is sent to node’s neighbor in order to maintain the route. As a result, the initial latency of route discovery can be reduced.

Location Aid Routing (LAR) [6]: an on-demand protocol that is similar to DSR, but uses the location information provided by the Global Positioning System (GPS) [8] to help in route discovery process. Location information is used to reduce the size of route searching area (Request Zone). Therefore, the overhead of route discovery can be greatly reduced. LAR has two schemes. In our simulation, scheme 1 (LAR1) is used. In this scheme, source node defines a circular area (Destination Zone) around the destination node. Request Zone is a smallest rectangular area that includes the Destination Zone and the source. Only nodes inside the Request Zone propagate the route request packet.

Fisheye State Routing (FSR) [4]: a link state based protocol. It maintains a topologic map of the network at each node. It is characterized in three ways. First, link state packets are not flooded. Only neighboring nodes exchange the link state information. Therefore, routing overhead can greatly be reduced. Second, link state exchange is time triggered, not event-triggered. Therefore, the overhead is steadier. Third, neighboring nodes of a node are grouped into different scope-levels, which are like the coloring of a fisheye. Scope-level is defined by the number of hop counts required for the source node to reach the destination node.

3. The Simulation Model and Environment

Our model consists of 100 nodes and 20 of them are sources. 16 of them generate constant bit rate (cbr) traffic while two sources generate file transfer (ftp) traffic and two sources generate remote login (telnet) traffic. Nodes are uniformly placed in a terrain size of 1000 square meters. Velocities of the nodes are randomly chosen from a range of 1 to 20 m/sec. Each node pauses a period (pause time) before its next movement. The lower the pause time, the higher the mobility and vice versa. In order to have a detailed study for high mobility, a finer scale of pause times is used for this mobility. The pause times that we used are 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 120, 140, 160, 180, 200, 250, 300, 350, 400, 450, 500, 600, 700, 800, 850, and 900 in seconds. The medium access control protocol is IEEE 802.11. Radio bandwidth is 2 Mbps. We run the simulation with the environment GloMoSim 2.02 [1] for a length of 900 seconds. Each data is the average of multiple output numbers. The metrics for the evaluation include the throughput (bps), that is, the number of bit transferred per second, and the packet delivery ratio, that is, the ratio of the number of the packets received in the destination node to the number of packets sent by the source node.

4. Simulation Results

4.1 Throughput

Figure 1, 2, and 3 shows the throughput for constant bit rate (cbr), file transfer (ftp), and remote login (telnet) respectively.

For cbr traffic, FSR seems has a high and consistent throughput. (see figure 1.) However, the throughput value represents the throughput of sending nodes only. Statistics of the receiving nodes cannot be collected until the mobility is really low. It may be due to the scope-level operations of FSR. Nodes in higher scope-level exchange routing information less frequently. Thus the route for the distant nodes may not be accurate. Although the route becomes accurate when the packets are approaching their destinations, the route processing may not be fast enough to react to the route changes. Distant nodes may not be able to receive the packets in time. When the pause time reaches 600 seconds, the destination nodes start to receive small number of packets, which gives a very small average value of throughput. Taking this factor into consideration, the relative throughput of the protocols based on our result is summarized in Table 1. Ranking 1 is the best and 6 is the worst. ‘Fast’ and ‘slow’ represent high and low mobility respectively.

Table 1: Table of relative throughput of the protocols

<table>
<thead>
<tr>
<th>Rank</th>
<th>Fast</th>
<th>slow</th>
<th>fast</th>
<th>slow</th>
<th>fast</th>
<th>slow</th>
<th>telnet</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>LAR1</td>
<td>LAR1</td>
<td>DSR</td>
<td>DSR</td>
<td>DSR</td>
<td>DSR</td>
<td>Slow</td>
</tr>
<tr>
<td>2</td>
<td>AODV</td>
<td>DSR</td>
<td>DBF</td>
<td>DBF</td>
<td>DSR</td>
<td>LAR1</td>
<td>AODV</td>
</tr>
<tr>
<td>3</td>
<td>DSR</td>
<td>WRP</td>
<td>LAR1</td>
<td>LAR1</td>
<td>DBF</td>
<td>DSR</td>
<td>DBF</td>
</tr>
<tr>
<td>4</td>
<td>WRP</td>
<td>AODV</td>
<td>AODV</td>
<td>WRP</td>
<td>DBF</td>
<td>WRP</td>
<td>FSR</td>
</tr>
<tr>
<td>5</td>
<td>DBF</td>
<td>AODV</td>
<td>WRP</td>
<td>AODV</td>
<td>DBF</td>
<td>FSR</td>
<td>FSR</td>
</tr>
<tr>
<td>6</td>
<td>FSR</td>
<td>FSR</td>
<td>FSR</td>
<td>FSR</td>
<td>FSR</td>
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</tr>
</tbody>
</table>
At high mobility, the throughput of AODV is slightly better than that of DSR because it has a lower initial route discovery latency. AODV is also better than WRP because it does not have the temporary looping problems. At low mobility, DSR is as good as LAR1 and is better than WRP and AODV. It is because the network topology is more stable, thus the number of route discovery decreases. Since DSR does not require any periodic hello message for route maintenance, it has a lower routing overhead than WRP and AODV. WRP is better than AODV because it has a more accurate route than that of AODV. DBF has a lower throughput and slower convergence in both high and low mobility. The reason may be due to its looping problem and the latency in waiting for route updates. FSR is the worst as we described previously.

For file transfer (ftp) traffic, the result is different from that of cbr. (see figure 2.) It may be due to the nature of these traffics. For the cbr traffic, packets are sent consecutively every small time interval. On the other hand, the packets in the ftp traffic are sent in batch. The number of sources also affects the throughput because more sources generates more traffics. In our simulation, there are only 2 ftp sources, but 16 cbr sources. Therefore cbr creates much more traffic than ftp. Because of these factors, the route discovery process in ftp traffic becomes relatively less significant than that of in cbr. In this case, DSR almost dominates the other protocols on both high and low mobility. DBF is at the second place while LAR1 is at the third place only. The reason may be due to the greatly reduction in the demand of route information processing or route discovery. Then, the throughput has a higher dependence on the accuracy of the route. As DSR uses route cache for route maintenance, most route information may still be valid and route discovery is less frequent. At low mobility, LAR1 still have to process the location information while DSR does not require that. This information may also have error which further affects the accuracy of the route. Therefore DSR also has a higher throughput than LAR1. DBF is the second best because it is based on periodic update, thus it has a more accurate routing information. AODV may require route discovery process because of its inaccurate routes. Then, its routing overhead increases. WRP is better than AODV at low mobility because it has more accurate routes. FSR is the worst because scope level mechanism reduces the accuracy of distant routes.

Finally, for the remote login (telnet) traffic, the results obtained are quite even as the fluctuations of throughputs for all the protocols are within a small region, that is, around 5 to 23 bps. (see figure 3.) Although DSR outperforms the other protocol, the overall difference between them is quite small because telnet session involves much less data transmission. Its time constraint is also less restrictive than that of cbr.

For constant bit rate traffic, at high mobility, the throughput of all the protocols fluctuates greatly except LAR1. The using of location information provided by GPS in LAR1 may reduce the size of the route discovery process. Thus it is less affected by the uneven nature of the topologic change. LAR1 dominates the other protocols both in high and medium mobility. The reason may also be due to the use of the location information, which helps to reduce the size of the route discovery area. Thus the routing overhead decreases and the throughput converge at high value. The topologic change has less effect on the this protocol.
4.2 Packet Delivery Ratio

In this section, we study the packet delivery ratio for each protocol. Figure 4 shows that the packet delivery ratio for cbr traffic follows a similar pattern to the throughput for cbr traffic. Table 2 shows the relative packet delivery ratios of the protocols.

Table 2: Relative packet delivery ratio of the protocols

<table>
<thead>
<tr>
<th>Rank</th>
<th>Fast</th>
<th>Med</th>
<th>slow</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>LAR1</td>
<td>LAR</td>
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</tr>
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</tr>
<tr>
<td>6</td>
<td>FSR</td>
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</tr>
</tbody>
</table>

In both high and low mobility, LAR1 has the highest and consistent packet delivery ratio. The explanation in the previous section about throughput for cbr can also be applied in this case. DSR also has a consistent high ratio around 99%. The initial route discovery latency of DSR may have little effect on its packet delivery. Packets may be preserved during transmission because DSR can route its packets through other routes when the original route is broken. At high mobility, the ratio of WRP is slightly less than that of the on-demand protocols. It may be due to the temporary loops and triggered updates, both of which increase the chances of collision and congestion, thus the packets are dropped. At medium and low mobility, the ratio of WRP is also constantly higher than that of AODV. DBF has a low packet delivery ratio and slow convergence. For FSR, node does not receive any packets until the mobility is low (beyond 700 seconds). The curve for FSR is not placed in the graph for simplicity. The above results follow a similar pattern to those results when compared to the graph in the previous section for cbr, thus the previous explanation may also be applied in this situation.

As the On-demand protocols, especially DSR, outperform the other protocols, it will be the focus of our investigation in future. For quality of service (QoS) provision, multicasting routing scheme should be the next focus. Finally, wireless ad hoc network cannot stand on its own, an efficient way to connect these networks to the existing network infrastructure should also be studied.

4. Conclusions and future works

Our results show that on-demand protocols (LAR, DSR and AODV) outperform the other protocols. Routing overhead in these protocols is greatly reduced because periodic updates and event-triggered updates that occurred in traditional routing protocol (DBF) are partially or fully eliminated. In particular, LAR1 almost dominates the others protocols in both throughput and packet delivery ratio for cbr traffic. However, a Global Positioning System is required. At low mobility, DSR gets the highest throughput in all three traffics: cbr, ftp, and telnet. AODV is slightly inferior to DSR because of its periodic hello message overhead. For ftp traffic, the route accuracy plays a more important role in throughput.

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Reference