A Comparative Analysis of Mobile Ad Hoc Network Protocols

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Abstract— An ad-hoc network is a collection of wireless mobile nodes dynamically forming a temporary network without the use of any existing infrastructure or centralized administration. The communication in ad hoc networks can be direct or through multiple hops in between. Quality of Service (QoS) is concerned with providing a minimum guarantee to the services such as bandwidth, throughput, end to end delay, jitter delay, etc. There are an increasing number of real-time and multimedia applications requiring quality of service (QoS) guarantees. This paper simulates mobile ad hoc networks with three different protocols: AODV, DSR and DSDV. By varying certain parameters such as pause time and number of nodes, its effect on QoS provided by these protocols and their suitability to various applications requiring some minimum level of QoS will be determined. This paper intends to bring about a comparative analysis of these three methods vis-à-vis end to end delay, packet delivery fraction and throughput. This paper studies the performance of a routing protocol vis-à-vis pause time and varying network size. The number of nodes in MANET significantly affects the network performance and hence the QoS. The pause time of nodes, which defines the mobility pattern, is another important factor.

Key words: QoS, Ad Hoc Networks, MANET, Routing Protocols, Throughput, End to End Delay, Packet Delivery Fraction, Performance Evaluation

I. Introduction

Mobile Ad-hoc networks (MANETs) are self-organizing, infrastructure-less and multi-hop packet forwarding networks. There is no concept of fixed base station. So, each node in the network acts as a router to forward the packets to the next node. Ad-hoc networks are capable of handling of topology changes and malfunctions in nodes.

At places where no infrastructure such as internet is available, an Ad-hoc network could be used by a group of wireless mobile nodes. This can be the case in areas where network infrastructure may be undesirable due to reason such as crisis, cost and inconvenience. Examples of such situations include disaster recovery personnel or military troops in cases where normal infrastructure is either unavailable or destroyed. Other examples where ad hoc networks could be used include business associates wishing to share files in airport terminals, meetings, conferences, etc. or students needing to interact during a lecture. If each mobile host is wishing to communicate is equipped with wireless local area network interface, the group of mobile hosts may form an ad-hoc network.

Quality of Service (QoS) is the performance level of a service offered by the network to the user. The goal of QoS is to achieve a more deterministic network behaviour, so that information carried by the network can be better delivered and network resources can be better utilized. A service can be perceived by a set of measurable pre-specified service requirements such as minimum bandwidth, maximum delay, maximum delay variance (jitter) and maximum packet loss rate.

Ad-hoc wireless network routing protocols can be classified into three major categories based on routing information update mechanism. They are:

A. *Reactive or on-demand routing protocols*

Protocols that fall under this category do not maintain the network topology information. They obtain the necessary path when it is required, by using a connection establishment process. Hence these protocols do not exchange routine information periodically. The two main reactive protocols discussed in this thesis: Dynamic Source Routing (DSR) and Ad-hoc On-Demand Distance Vector Routing (AODV).

B. *Proactive or table-driven routing protocols*

In table driven routing protocols, every node maintains the network topology information in the form of routing tables by periodically exchanging routing information. Routing information is generally flooded in the whole network. Whenever a node requires a path to a destination, it runs an appropriate path finding algorithm on the topology information it maintains.

C. *Hybrid routing protocols*

Protocols belonging to this category combine the best features of the above two categories. Nodes within a certain distance from the node concerned or within a particular geographical region are said to be within the routing zone of the given node. For routing within this zone, a table-driven approach is used. For nodes that are located in this zone, are on-demand approach is used. Zone Routing Protocol (ZRP) is a famous hybrid routing protocol.

The key challenge in mobile ad hoc networks is to route the packets with low overheads even in dynamic conditions of node mobility, limited channel bandwidth and limited battery power of nodes. Overhead is defined as control messages, which consumes channel bandwidth as well as the battery power of nodes. The mobility of nodes changes the topology of network frequently. When a node becomes unavailable, alternate routes have to be searched. This increases the delay and also number of lost packets.

II. Related Study

When two nodes want to communicate to each other, two cases can occur: either they are neighbours, in which case they can communicate directly, or they are too distant, in which case messages must be routed. Routing is the problem of sending a packet from a source node to a destination one. Manickam et al. [11] compares three MANET Routing protocols: DSDV, AODV and DSR. It concludes that DSR is preferable for moderate traffic with moderate mobility while DSDV produces low end-to-end delay compared to other protocols, due to its proactive nature. Ehsan et al. [12] compares four different types of routing protocols: DSDV, DSR, AODV and TORA. While DSDV is a proactive protocol, others are reactive in nature. It concludes that DSR outperforms all other three. DSR generates less routing load then AODV. While AODV suffers from higher end to end delays, TORA has very high routing overhead and DSDV has a low packet delivery fraction at high mobility. Bouhorma et al. [13] compares two routing protocols: AODV and DSR and concludes that while DSR scales well in small networks with low node speeds, AODV performs better and exhibits higher packet delivery ratio even at higher mobility. Baraković et al. [14], compares performances of three routing protocols: DSDV DSR and AODV. It concludes that under low mobility scenarios, all three protocols show similar results, while under high load conditions or high mobility, AODV performs pretty well. DSDV depicts a low packet delivery fraction while DSR shows overall low performance of higher Normalized Routing Load and higher delay.

III. Simulation Environment and Performance Metrics

NS2 version 2.31 has been used as the simulator to model various ad hoc network protocols. Three protocols: DSDV, DSR and AODV have been simulated and compared in terms of QoS. Out of these, DSDV is a proactive routing protocol which maintains the connectivity information to other nodes by exchanging packets regularly, while the other two are reactive protocols which establish a path only when required.

A. *Fixed Parameters*

Parameter Name	Value
Environment Size	1000m X 1000m
Traffic type	Constant Bit Rate
Transmission Range	100 m
Packet size	512 bytes
Packet Rate	5 packet /s
Speed Range	0-20 m/s
Simulation Time	300 s

Fig. 1: Fixed parameters used for the simulation

A simulation area of 1000m X 1000m has been selected to provide ample area for random movement. The transmission range has been fixed at 100m. The traffic type is CBR at the rate of 5 packets/sec. Simulation time has been fixed to 300s and node movement speed is in the range of 0-20 m/s. The size of packets has been kept constant to 512 bytes.

B. *Variable Parameters*

1) Pausetime:

This is the duration of time, a node remains stationary when it arrives at a location, before moving forward. After this time, node will again move to another location. Pausetime defines the mobility pattern of the nodes. A pausetime of zero means highly dynamic nodes and higher pause-times reduce the mobility of nodes. In our simulation, we measure the performance of various protocols under different pause-times. The simulation is repeated with pause times of 0s, 5s, 15s, 50s and 150s. The pause time of 150s represents a fairly static network scenario. The effect of pause- time is reflected on the performance metrics for AODV, DSR and DSDV.

2) Number of nodes:

The number of nodes in an ad hoc network greatly affects the performance and hence the QoS delivered by a protocol. The more the number of nodes, more will be the number of packets to be sent and received. The behaviour of a protocol will vary as the number of nodes increases.

C. *Performance Metrics*

The metrics being used to evaluate the performance of routing protocols in this paper are: average end-to-end delay, Packet Delivery Fraction and throughput of the network.

1) Average end-to-end delay:

The end-to-end delay of a packet represents the time it takes to route a packet from source to the destination. This delay consists of propagation delay, queuing delay, and transmission delay introduced by network components. The average end-to-end delay is the average of end-to-end delay of all the packets which are successfully delivered. The end to end delay is important because today many applications need a small latency to deliver usable results. It shows the suitability of the protocol for these applications.

2) Packet delivery fraction:

The packet delivery ratio is defined as the ratio between the number of packets received by the destination to the number of packets sent by the source. It describes percentage of the packets which reach the destination. A high percentage is desirable and reflects the reliability of the network.

3) Throughput:

Throughput of a network is defined as the number of packets per unit time received by destination. A higher throughput reflects a higher efficiency of the network. However, a higher throughput may result in longer end to end delays.

IV. Simulation Results & Analysis

Comparative Analysis of Protocols with increasing pause time

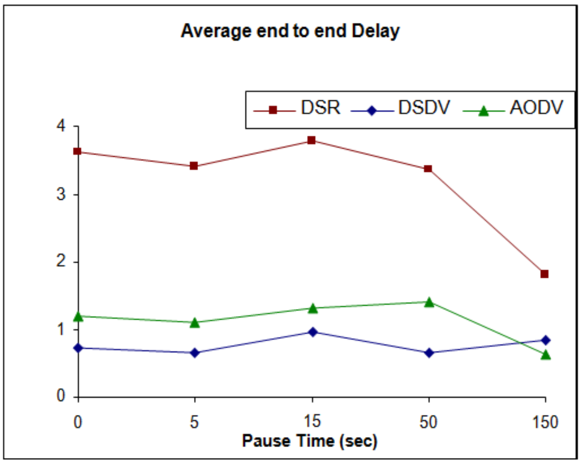

Fig. 2: Average end-to-end delay versus pause time

The comparison of end to end delay for the three protocols in Fig. 2 shows that that end to end delay is minimum for DSDV and highest for DSR. DSDV yields lowest end to end delay as it maintains least cost routing information in its tables. Therefore, the delay is minimum, while AODV and DSR find the path only when required. The paths found by DSR and ASODV may not be the shortest paths. For DSR, the delay is significantly higher than AODV. This can be attributed to the fact that the route discovery in AODV is refreshed after some time, hence fresh routes are always discovered after a timeout. While in DSR, the route discovered is continued for longer period. Also, the trend is that delay reduces gradually with higher pause time. This is quite natural because at lower mobility (higher pause time), frequent network topology changes do not occur, hence the shortest path does not change.

The comparison of Packet delivery fraction values for AODV, DSDV and DSR in Fig. 3 shows that the packet delivery fraction is highest for AODV and lowest for DSDV. AODV re-determines the shortest path after a timeout, hence recent paths are stored. Older paths are discarded, hence a higher packet delivery fraction.

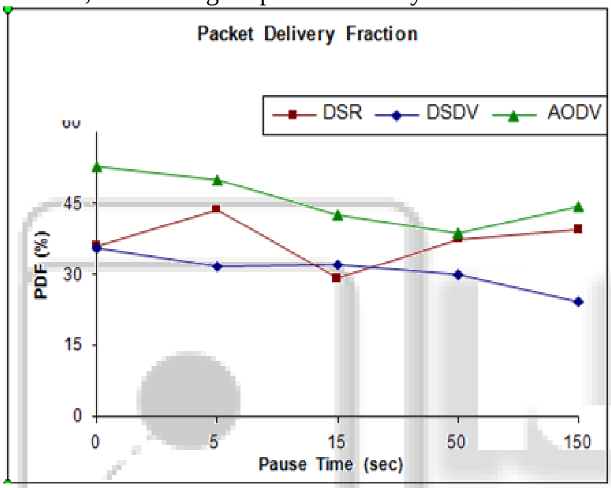

Fig. 3: Packet delivery fraction versus pause time

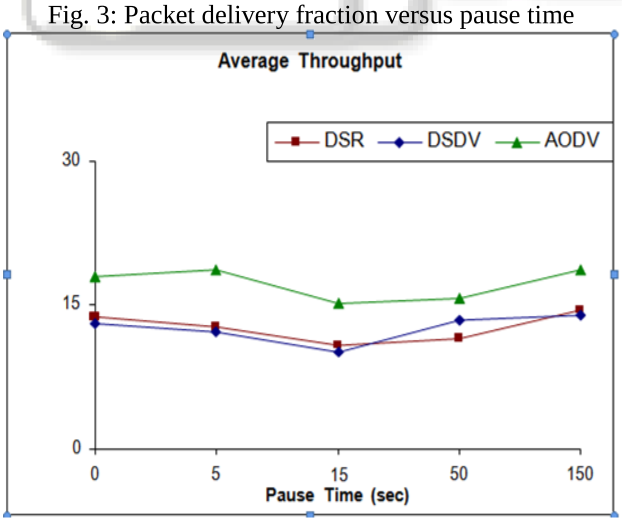

Fig. 4: Average throughput versus pause time

Throughput is defined as the number of packets delivered per unit time. A look at the throughput values in Fig. 4 shows that AODV has the highest throughput. The reason for high throughput can be attributed to high packet delivery ratio. A lower packet delivery fraction for DSR and DSDV is the reason for a low throughput in DSR and DSDV.

Comparative Analysis of Protocols with increasing Number of Nodes

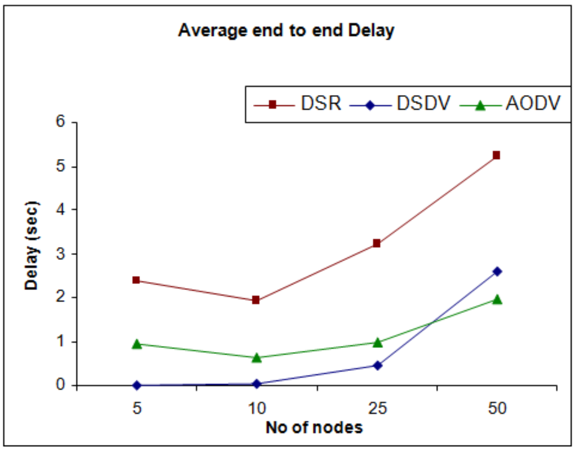

Fig. 5: Average end to end delay versus number of nodes

The end to end delay as a function of number of nodes in Fig. 5 clearly shows a sharp increase in delay with increase in nodes. With increase in number of nodes, there is a sharp increase in time required to find the path to destination. There are many possibilities of reaching the destination and determining the shortest path requires considerable time. DSDV yields the lowest delay values, which is due to proactive nature of routing protocol. Paths to all destinations are readily available in a table, which reduces delay costs.

The graph in Fig. 6 shows that packet delivery fraction decreases as the number of nodes increase. This is quite natural because as the number of nodes increase, the chances of two random nodes being out of range increase. Also, the time required to determine the path to destination increases significantly which means that more packets will be lost while discovering the routes. A higher buffer size can reduce somewhat, this increased packet loss. The comparison shows that AODV delivers the maximum fraction of packets while DSDV delivers the least. In AODV, the path changes are refreshed which gives better delivery fraction.

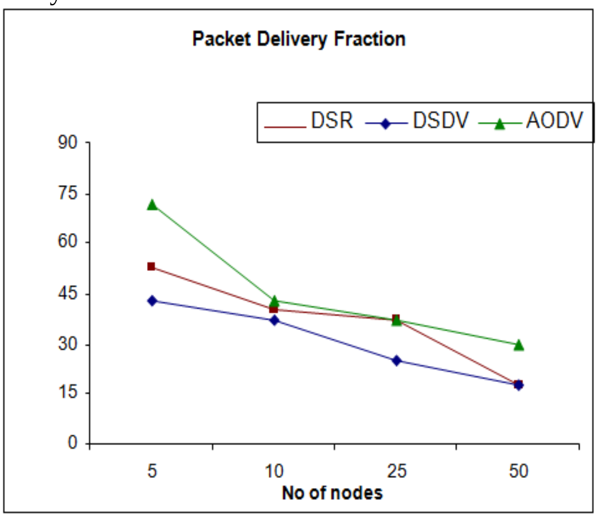

Fig. 6: Packet delivery fraction versus number of nodes

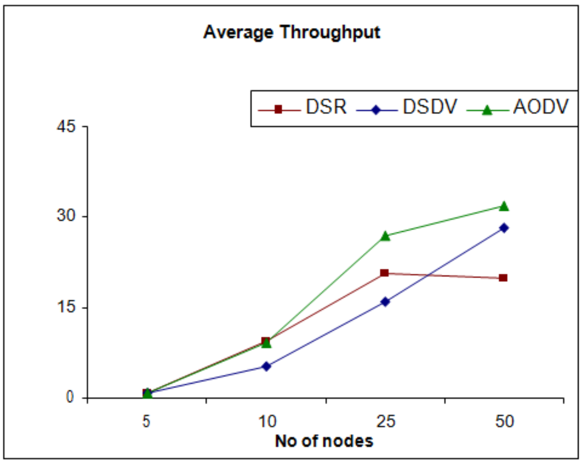

Fig 7: Average throughput versus number of nodes

The throughput of network in Fig. 7 shows that the throughput of the network increases with increased node numbers. When more nodes participate in a communication, more number of packets are transmitted and received. Thus, the average number of packets received increases. Best throughput is exhibited by AODV which is due to its higher packet delivery ratio. Due to the same reason, DSDV exhibits lowest throughput.

V. Conclusion

The general analysis of end to end delay for all the three protocols show that the delay increases with increasing number of nodes. When the number of nodes are less, the end to end delay is also significantly less. This is due to the fact that as the number of nodes increase, the possibility of multi-hop routing increases, which pushes the delay values. For lesser number of nodes, routing is limited to few hops only, hence lower values of end to end delay. For higher pause times, there is a reduction in end to end delay. This is because, the network becomes rather static and hence the location of nodes is already known which results in minimum route discovery time. Average end to end delay is least in DSDV, followed by AODV and finally DSR. This is because, DSDV is a proactive method and routinely exchanges routing tables between nodes to establish least cost paths to other destinations. It is not on-demand method like DSR and AODV. AODV builds only one path to each destination and is therefore faster than DSR for low load conditions. The data for packet delivery fraction shows that it falls as the number of nodes increase. This is because with more number of nodes, the chances of two random nodes being out of transmission range are high. This results in lower received packets and hence lower packet delivery fraction. The packet delivery fraction is highest for AODV, followed for DSR and finally DSDV. AODV gives the highest packet delivery, as the method is dynamic and maintains only a single path. The average throughput increases with increasing number of nodes. This behaviour is exhibited by all the three protocols. It is justified because the number of packets sent and received increases with increasing number of nodes, hence higher throughput. For application requiring very low delay, DSDV may be appropriate for moderate size of networks. However, when the size increases, the routing overhead is considerable in DSDV due to large number of control packets exchanged between nodes to keep the tables up-to-date. For larger network sizes, reactive protocols such as AODV or DSR may be better. AODV has moderately low delay values and considered overall efficient with high throughput and low packet delivery ratio.

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