Performance Comparison of Mobile Ad-hoc Network Routing Protocol

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Summary

Ad hoc networks are characterized by multi-hop wireless connectivity, frequently changing network topology and the need for efficient dynamic routing protocols plays an important role. We compare the performance of two prominent on-demand routing protocols for mobile ad hoc networks: Dynamic Source Routing (DSR), Ad Hoc On-demand distance Vector Routing (AODV). A detailed simulation model with MAC and physical layer models is used to study the interlayer interactions and their performance implications. We demonstrate that even though DSR and AODV share similar on-demand behavior, the differences in the protocol mechanisms can lead to significant performance differentials. In this paper we examine two on demand routing protocols AODV and DSR based on packet delivery ratio, normalized routing load, normalized MAC load, average end to end delay by varying the number of sources, speed and pause time.

Key words:

AODV, DSR, MANET, Random way point model.

1. Introduction

Mobile ad-hoc wireless networks hold the promise of the future, with the capability to establish networks at anytime, anywhere. These networks don't rely on extraneous hardware, which makes them an ideal candidate for rescue and emergency operations. These networks are built, operated, and maintained by their constituent wireless nodes. These nodes generally have a limited transmission range and, so, each node seeks the assistance of its neighboring nodes in forwarding packets. In order to establish routes between nodes which are further than a single hop, specially configured routing protocols are engaged. The unique feature of these protocols is their ability to trace routes in spite of a dynamic topology. These protocols can be categorized into two main types: reactive and proactive. The nodes in an ad hoc network generally have limited battery power and, so, reactive routing protocols endeavor to save power by discovering routes only when they are essentially required. In contrast, proactive routing protocols establish and maintain routes at all instants of time so as to avoid the latency that occurs during new route discoveries [1]

Mobility models define nodes' movement pattern in ad-hoc networks. Since, MANETs are currently not deployed on a large scale and due to the inherent randomness of mobility models, research in evaluating the performance of routing protocols on various mobility models are simulation based [2]. Therefore in most of the cases performance analysis is carried out using various popular simulators like NS-2. In this paper, the performance of MANET using AODV and DSR routing protocol is evaluated by comparing different mobility models like Random Waypoint mobility.

Some of the problems related to wireless communication are multipath propagation, path loss, interference, and limited frequency spectrum. Due to the radio frequency and the nature of the terrain are not same everywhere, it is hard to estimate the path loss during communication. During communication a number of signals in the atmosphere may interfere with each other resulting in the destruction of the original signal. Limited Frequency Spectrum is where, frequency bands are shared by many wireless technologies and not by one single wireless technology [3, 4].

Wireless networking is an emerging technology that allows users to access information and services electronically, regardless of their geographic position. Wireless networks can be classified in two types:

- Infrastructured networks.
- Infrastructureless (Ad hoc) networks [5]

An ad hoc networks or infrastructureless networks is a collection of mobile nodes which forms a temporary network without the aid of centralized administration or standard support devices regularly available in conventional networks. In this paper, it is assumed that the mobile hosts uses wireless RF transceivers as their network interface. Routing protocol plays an important role if two hosts wishes to exchange packets which may not be able to communicate directly. All nodes are mobile and can be connected dynamically in an arbitrary manner. All nodes of these networks behave as routers and take part in discovery and maintenance of routes to other nodes

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in the network. This situation becomes more complicated if more nodes are added within the network. An Ad-Hoc routing protocol must be able to decide the best path between the nodes, minimize the bandwidth overhead to enable proper routing, minimize the time required to converge after the topology changes. Ad hoc networks are very useful in emergency search-and-rescue operations, meetings or conventions in which persons wish to quickly share information, and data acquisition operations in inhospitable terrain.

2. Desirable properties of Ad-Hoc Routing protocols

The properties that are desirable in Ad-Hoc Routing protocols are

Distributed operation: The protocol should be distributed. It should not be dependent on a centralized controlling node. This is the case even for stationary networks. The difference is that the nodes in an ad-hoc network can enter or leave the network very easily and because of mobility the network can be partitioned.

Loop free: To improve the overall performance, the routing protocol should guarantee that the routes supplied are loop free. This avoids any waste of bandwidth or CPU consumption.

Demand based operation: To minimize the control overhead in the network and thus not waste the network resources the protocol should be reactive. This means that the protocol should react only when needed and that the protocol should not periodically broadcast control information.

Unidirectional link support: The radio environment can cause the formation of unidirectional links. Utilization of these links and not only the bi-directional links improves the routing protocol performance.

Security: The radio environment is especially vulnerable to impersonation attacks so to ensure the wanted behavior of the routing protocol we need some sort of security measures. Authentication and encryption is the way to go and problem here lies within distributing the keys among the nodes in the ad-hoc network.

Power conservation: The nodes in the ad-hoc network can be laptops and thin clients such as PDA's that are limited in battery power and therefore uses some standby mode to save the power. It is therefore very important that the routing protocol has support for these sleep modes.

Multiple routes: To reduce the number of reactions to topological changes and congestion multiple routes can be used. If one route becomes invalid, it is possible that another stored route could still be valid and thus saving the routing protocol from initiating another route discovery procedure.

Quality of Service Support: Some sort of Quality of service is necessary to incorporate into the routing protocol. This helps to find what these networks will be used for. It could be for instance real time traffic support.

It should be noted that none of the proposed protocols have all these properties, but it is necessary to remember that the protocols are still under development and are probably extended with more functionality.

3. Routing Protocol Classification

Routing protocols are classified into different categories depending on their properties.

- Centralized vs distributed
- Static vs adaptive
- Reactive vs proactive

In centralized algorithms, all route choices are made at central node, while in distributed algorithms, the computation of the routes is shared among the network nodes.

Another classification of routing protocols relates to whether they change routes in response to the traffic input patterns. In static algorithms, the route used by the source-destination pairs is fixed regardless of traffic conditions. It can only change in response to a node or link failure. This type of algorithm cannot achieve high throughput under a broad variety of traffic input patterns. Most major packet networks uses some form of adaptive routing where the routes used to route between source-destination pairs may change in response to congestion.

Proactive protocols continuously evaluate the routes within the network, so that when a packet needs to be forwarded the route is already known and can be immediately used. Reactive protocols invoke a route determination procedure on demand only.

Table Driven Protocols*:* Table driven protocols maintain consistent and up to date routing information about each node in the network [6]. These protocols require each node to store their routing information and when there is a change in network topology updation has to be made throughout the network. Some of the existing table driven protocols are

- Destination sequenced Distance vector routing (DSDV)
- Wireless routing protocol (WRP)

- Fish eye State Routing protocol (FSR)
- Optimised Link State Routing protocol (OLSR)
- Cluster Gateway switch routing protocol (CGSR)
- Topology Dissemination Based on Reverse path forwarding (TBRPF)

On-Demand routing protocols: In On-Demand routing protocols, the routes are created as and when required. When a source wants to send to a destination, it invokes the route discovery mechanisms to find the path to the destination. Once a Route has been established, it is maintained until either the destination becomes inaccessible (along every path from the source), or until the route is no longer used, or expired [7].

The different types of On Demand driven protocols are:
- Ad hoc On Demand Distance Vector (AODV)
- Dynamic Source routing protocol (DSR)
- Temporally ordered routing algorithm (TORA)
- Associativity Based routing (ABR)

In recent years, a variety of new routing protocols targeted specifically at this environment have been developed. We will provide routing performance estimates that were gathered through simulation, by investigating a common reactive routing protocol DSR [8] and AODV.

4. Comparison of Table-Driven and On-Demand Routing Protocols

The table-driven ad hoc routing approach is similar to the connectionless approach of forwarding packets, with no regard to when and how frequently such routes are desired. It relies on an underlying routing table update mechanism that involves the constant propagation of routing information. This is not the case, however, for on-demand routing protocols. When a node using an on-demand protocol desires a route to a new destination, it will have to wait until such a route can be discovered. On the other hand, because routing information is constantly propagated and maintained in table-driven routing protocols, a route to every other node in the ad hoc network is always available, regardless of whether or not it is needed. This feature, although useful for datagram traffic, incurs substantial signaling traffic and power consumption. Since both bandwidth and battery power are scarce resources in mobile computers, this becomes a serious limitation [9].

Dynamic Source Routing (DSR): The key distinguishing feature of DSR [10, 11] is the use of source routing. Dynamic Source Routing (DSR) [12] is a reactive protocol i.e. it doesn't use periodic advertisements. It computes the routes when necessary and then maintains them. Source routing is a routing technique in which the sender of a packet determines the complete sequence of nodes through which the packet has to pass, the sender explicitly lists this route in the packet's header, identifying each forwarding "hop" by the address of the next node to which to transmit the packet on its way to the destination host.

Ad Hoc On-Demand Distance Vector Routing (AODV): Ad hoc On-demand Distance Vector (AODV) [13] is essentially a combination of both DSR and DSDV. It borrows the basic on-demand mechanism of Route Discovery and Route Maintenance from DSR, plus the use of hop-by-hop routing, sequence numbers, and periodic beacons from DSDV. It uses destination sequence numbers to ensure loop freedom at all times and by avoiding the Bellman-Ford "count-to-infinity" problem offers quick convergence when the ad hoc network topology changes

In this research paper we attempted to present an overview of two main categories of mobile ad-hoc routing protocols and performance comparison of both the protocols based on Random way point model and the simulation of two routing protocols focussing on their differences in their dynamic behaviours that can lead to performance differences.

Random way point mobility model: The random way point mobility model is simple and is widely used to evaluate the performance of MANETs. The random way point mobility model contains pause time between changes in direction and/or speed. Once a Mobile Node begins to move, it stays in one location for a specified pause time. After the specified pause time is elapsed, the MN randomly selects the next destination in the simulation area and chooses a speed uniformly distributed between the minimum speed and maximum speed and travels with a speed v whose value is uniformly chosen in the interval (0, V_{max}). V_{max} is some parameter that can be set to reflect the degree of mobility. Then, the MN continues its journey toward the newly selected destination at the chosen speed. As soon as the MN arrives at the destination, it stays again for the indicated pause time before repeating the process [14].

5. Simulation Model

A detailed simulation model based on *ns-2*[15] is used in the evaluation. The Distributed Coordination Function (DCF) of IEEE 802.11[16] for wireless LANs is used as the MAC layer protocol. An unslotted carrier sense multiple access (CSMA) technique with collision avoidance (CSMA/CA) is used to transmit the data packets. The radio model uses characteristics similar to a commercial radio interface, Lucent's WaveLAN. WaveLAN [17, 18] is modeled as a shared-media radio with a nominal bit rate of 2 Mb/s and a nominal radio range of 250 m [19, 20].

The protocols maintain a *send buffer* of 64 packets. It contains all data packets waiting for a route, such as packets for which route discovery has started, but no reply has arrived yet. To prevent buffering of packets indefinitely, packets are dropped if they wait in the send buffer for more than 30 s. All packets (both data and routing) sent by the routing layer are queued at the *interface queue* until the MAC layer can transmit them. The interface queue has a maximum size of 50 packets and is maintained as a priority queue with two priori-ties each served in FIFO order. Routing packets get higher priority than data packets. The mobile devices features, as well as the traffic pattern characteristics can be consulted in [21].

Traffic and Mobility models: In this paper we are using traffic and mobility model based on Continuous bit rate (CBR) traffic sources are used. The source-destination pairs are spread randomly over the network. Only 512-byte data packets are used. The number of source-destination pairs and the packet sending rate in each pair is varied to change the offered load in the network.

The mobility model uses the *random waypoint* model [22] in a rectangular field. The field configurations used is: 500 m x 500 m field with 50 nodes . Here, each packet starts its journey from a random location to a random destination with a randomly chosen speed (uniformly distributed between 0–20 m/s). Once the destination is reached, another random destination is targeted after a pause. The pause time, which affects the relative speeds of the mobiles, is also varied. Simulations are run for 100 simulated seconds. Identical mobility and traffic scenarios are used across protocols to gather fair results. Mobility models have significant impact on simulation results [23].

6. Performance Metrics

The following four important performance metrics are considered for evaluation of these two on demand routing protocols:

Packet delivery fraction: The ratio of the data packets delivered to the destinations to those generated by the CBR sources.

Average end-to-end delay of data packets: This includes all possible delays caused by buffering during route discovery latency, queuing at the interface queue, retransmission delays at the MAC, and propagation and transfer times.

Normalized routing load: The number of routing packets transmitted per data packet delivered at the destination. Each hop-wise transmission of a routing packet is counted as one transmission

Normalized MAC load: The number of routing, Address resolution protocol (ARP), and control (e.g., RTS, CTS, ACK) packets transmitted by the MAC layer for each delivered data packet. Essentially, it considers both routing overhead and the MAC control overhead. Like normalized routing load, this metric also accounts for transmission at every hop.

The first two metrics are the most important for best effort traffic. The routing load metric evaluates the efficiency of the routing protocol. Finally the MAC load is a measure of effective utilization of the wireless medium by data traffic.

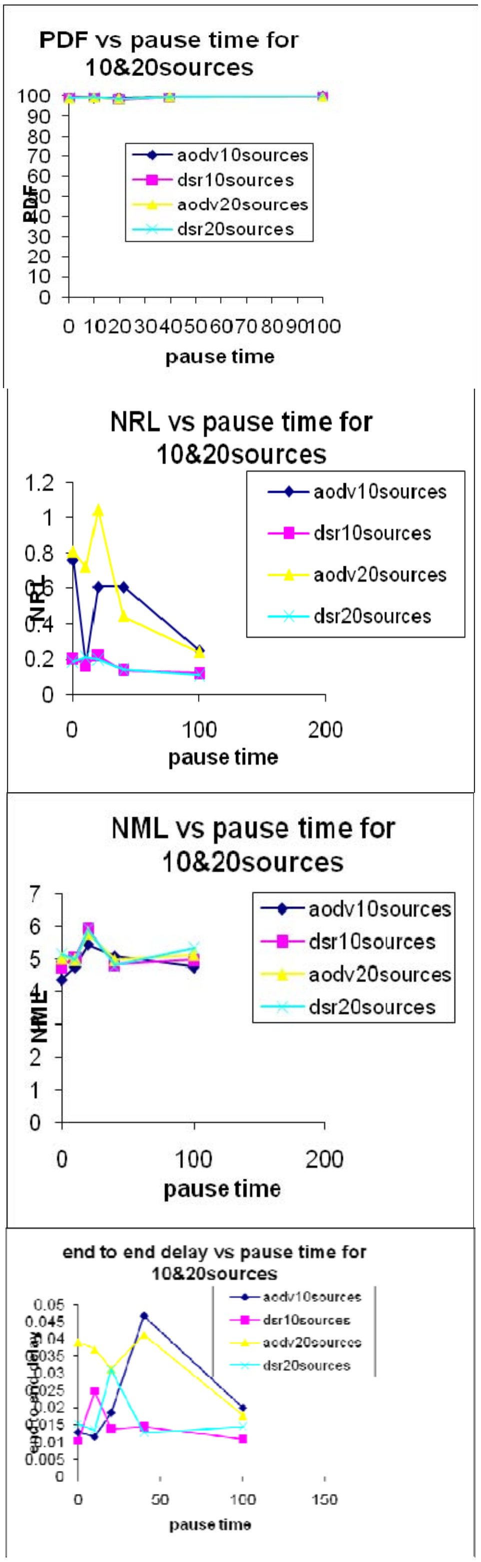
7. Results and Discussions

The simulation parameters which have been considered for doing the performance comparison of two on-demand routing protocols is given below in Table-1.

Protocols	**AODV, DSR**
Simulation time	100 seconds
#of nodes	50
Map size	500mx500m
Max speed	20m/s
Mobility model	Random way point
Traffic Type	Constant bit rate (CBR)
Packet Size	512 bytes
Connection rate	4pkts/sec
Pause time	0,10,20,40,100
#of connections	10,20,30,40

Table -1 Simulation parameters

This simulation analysis is made from the graph 1 for 10 sources. First we analyze the first parameter Packet delivery ratio with respect varied pause times. The graph shows that the packet delivery ratio for the two on-demand routing protocol is similar.



Graph 1: These graphs are drawn considering 10 sources and 20 sources

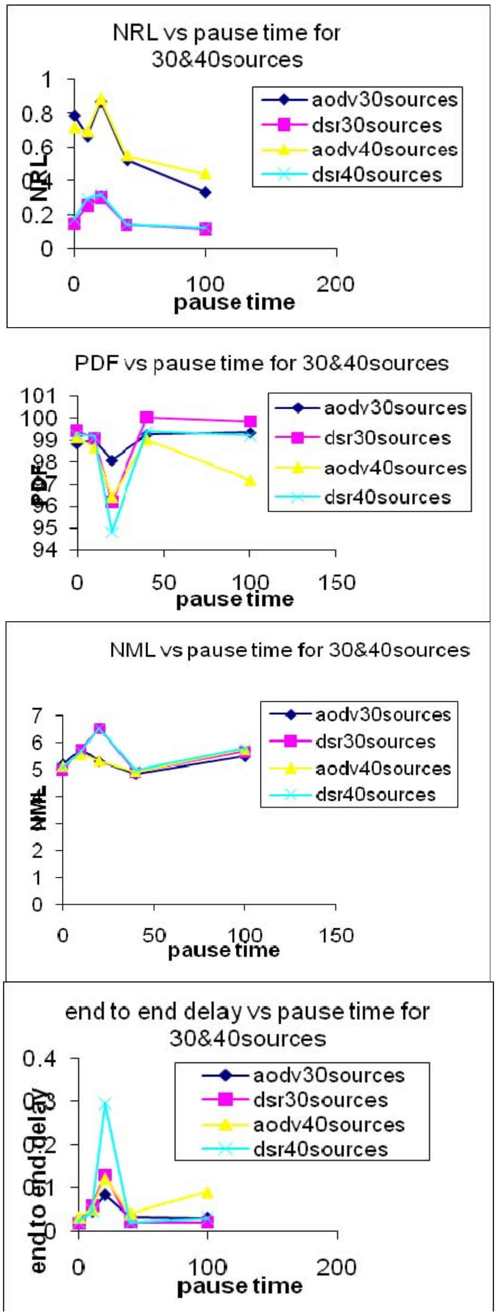
The second parameter Normalized routing load with varied pause times is analyzed and it is found that for DSR it is less when compared to AODV and we see that it is fairly stable even with increase number of sources. A relatively stable normalizes routing load is a desirable property for scalability of the protocols. We find that major contribution to AODV routing overhead is from route requests, while route replies constitute a large fraction of DSR routing overhead. By virtue of aggressive caching, DSR is more likely to find the route in the cache and hence the route discovery process occurs less frequently than AODV and hence the routing overhead for DSR is less when compared to AODV.

The third parameter Normalized MAC load is analyzed with respect to different pause times and it is found that for AODV it is less when compared to DSR for lower pause times. This is because RERRs are handled different in each protocol. RERR are unicast in DSR, and therefore contribute to additional MAC overhead like RREPs. In AODV, RERRs are broadcast like RREQs and hence are less expensive. Consequently when the MAC overhead is factored DSR is found to generate higher overall network load than AODV in all scenarios despite having less routing overhead. With respect to fourth parameter when analyzed the delay AODV and DSR have identical delays for 10 sources.

The simulation analysis for the graph 1 for 20 sources shows that the packet delivery ratio with respect to varied pause times for both the protocols looks similar. The Normalized routing load for DSR is found to be less when compared to AODV because of DSR aggressive caching technique. The Normalized MAC load for AODV is slightly lesser when compared to DSR. The end to end delays for both the protocols looks identical.

The simulation analysis for the graph 2 for 30 sources shows that the packet delivery ratio with respect to varied pause times for both the protocols looks similar. The Normalized routing load with respect to varied pause times for DSR is found to be very less when compared to AODV because of DSR aggressive caching technique.

The Normalized MAC load for AODV is slightly lesser when compared to DSR. With respect to end to end delays in the case of 30 sources AODV has less delay than DSR for lower pause times. But for higher pause times DSR has less delay when compared to AODV. The simulation analysis for the graph 2 for 40 sources shows that the packet delivery ratio with respect to varied pause times for both the protocols looks similar. The Normalized routing load with respect to varied pause times for DSR is found to be very less when compared to AODV because of DSR aggressive caching technique. The Normalized MAC load for AODV is slightly lesser when compared to DSR. With respect to end to end delays in the case of 40 sources AODV has less delay than DSR for lower pause times. But for higher pause times DSR has less delay when compared to AODV.



Graph-2 These graphs are drawn considering 30 and 40 sources

8. Observation and Conclusion

The simulation results bring out some important characteristic of differences between the two on demand routing protocols. The presence of high mobility implies frequent link failures and each routing protocol reacts differently during link failures. The different basic working mechanism of these protocols leads to the differences in their performances.

For DSR and AODV, packet delivery ratio is independent of offered traffic load, with both protocols delivering between 85% and 100% of the packets in all cases. In contrast, the lazy approach used by the on-demand protocols, AODV and DSR to build the routing information as and when they are created make them more adaptive and result in better performance (high packet delivery fraction and lower average end-to-end packet delays).

Next the simulation results compare the performances of AODV and DSR lead us to the following conclusions.

Effect of Mobility: In the presence of high mobility, link failures can happen very frequently. Link failures trigger new route discoveries in AODV since it has at most one route per destination in its routing table. Thus, the frequency of route discoveries in AODV is directly proportional to the number of route breaks. The reaction of DSR to link failures in comparison is mild and causes route discovery less often. The reason is the abundance of cached routes at each node. Thus, the route discovery is delayed in DSR until all cached routes fail. But with high mobility, the chance of the caches being stale is quite high in DSR.

Eventually when a route discovery is initiated, the large number of replies received in response is associated with high MAC overhead and cause increased interference to data traffic. Hence, the cache staleness and high MAC overhead together result in significant degradation in performance for DSR in high mobility scenarios. In lower mobility scenarios, DSR often performs better than AODV, because the chances of find the route in one of the caches is much higher. However, due to the constrained simulation environment (lesser simulation time and lesser mobility models), the better performance of DSR over AODV couldn't be observed.

Routing Load Effect: DSR almost always has a lower routing load than AODV. This can be attributed to the caching strategy used by DSR. By virtue of aggressive caching, DSR is more likely to find a route in the cache, and hence resorts to route discovery less frequently than AODV.

In this paper we have compared the performance of AODV and DSR routing protocols for ad hoc networks using ns-2 simulations. Unfortunately, TORA simulations couldn't be successfully carried out. AODV and DSR use the reactive On-demand routing strategy. Both AODV and DSR perform better under high mobility simulations. High mobility results in frequent link failures and the overhead involved in updating all the nodes with the new routing information as in DSDV is much more than that involved AODV and DSR, where the routes are created as and when required.

DSR and AODV both use on-demand route discovery, but with different routing mechanics. In particular, DSR uses source routing and route caches, and does not depend on any periodic or timer-based activities. DSR exploits caching aggressively and maintains multiple routes per destination. AODV, on the other hand, uses routing tables, one route per destination, and destination sequence numbers, a mechanism to prevent loops and to determine freshness of routes. The general observation from the simulation is that for application-oriented metrics such as packet delivery fraction and delay. AODV, outperforms DSR in more "stressful" situations (i.e., smaller number of nodes and lower load and/or mobility), with widening performance gaps with increasing stress (e.g., more load, higher mobility). DSR, however, consistently generates less routing load than AODV. The poor performances of DSR are mainly attributed to aggressive use of caching, and lack of any mechanism to expire stale routes or determine the freshness of routes when multiple choices are available. Aggressive caching, however, seems to help DSR at low loads and also keeps its routing load down. If there could be any mechanisms to expire routes and or determine the freshness of routes in the route cache could benefit DSR performance significantly. It is found that for lower loads DSR is more effective while AODV is more effective for higher loads.

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