Performance analysis of AODV, DSR & TORA Routing Protocols

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Abstract- **The field of Mobile Ad hoc Networks (MANETs) has gained an important part of the interest of researchers and become very popular in last few years. MANETs can operate without fixed infrastructure and can survive rapid changes in the network topology. They can be studied formally as graphs in which the set of edges varies in time. The main method for evaluating the performance of MANETs is simulation. This paper is subjected to the on-demand routing protocols with identical loads and environment conditions and evaluates their relative performance with respect to the two performance metrics: average End-to-End delay and packet delivery ratio. We investigated various simulation scenarios with varying pause times. From the detailed simulation results and analysis, a suitable routing protocol can be chosen for a specified network and goal.**

Index Terms- **MANET, AODV, DSR, TORA**

I. INTRODUCTION

The history of wireless networks started in the 1970s and the interest has been growing ever since. At present, this sharing of information is difficult, as the users need to perform administrative tasks and set up static, bi-directional links between the computers. This motivates the construction of temporary networks with no wires, no communication infrastructure and no administrative intervention required. Such interconnection between mobile computers is called an *Ad hoc Network*. Ad hoc networks are emerging as the next generation of networks and defined as a collection of mobile nodes forming a temporary (spontaneous) network without the aid of any centralized administration or standard support services. In Latin, *ad hoc* literally means "for this," further meaning "for this purpose only" and thus usually temporary [1]. An ad hoc network is usually thought of as a network with nodes that are relatively mobile compared to a wired network. Hence the topology of the network is much more dynamic and the changes are often unpredictable oppose to the Internet which is a wired network. This fact creates many challenging research issues, since the objectives of how routing should take place is often unclear because of the different resources like bandwidth, battery power and demands like latency.

MANETs have several salient characteristics: 1) Dynamic topologies 2) Bandwidth constrained, variable capacity links 3) Energy-constrained operation 4) Limited physical security. Therefore the routing protocols used in ordinary wired networks are not well suited for this kind of dynamic environment. Routing algorithms are often difficult to be formalized into mathematics they are instead tested using extensive simulation. Recently more attention has been paid to use specific network parameters when specifying routing metrics. Examples might include delay of the network, link capacity, link stability or identifying low mobility nodes. These schemes are generally based on previous work, which is then enhanced with the new metrics.

Paper Outline

The rest of the paper is organized as follows: Section II presents the definition of MANET and its topology. Section III presents the mobile ad hoc routing protocols categories. Section IV provides an overview and general comparison of the routing protocols used in the study. The simulation environment and performance metrics are described in Section V and then the results are presented in Section VI. Finally Section VII concludes the paper.

II. MOBILE AD HOC NETWORK

A MANET topology can also be defined as a dynamic (arbitrary) multi-hop graph $G = (N, L)$, where N is a finite set of mobile nodes (MNs) and L is a set of edges which represent wireless links. A link $(i, j) \in L$ exists if and only if the distance between two mobile nodes is less or equal than a fixed radius r as shown. This r represents the radio transmission range that depends on wireless channel characteristics including transmission power. Accordingly, the neighborhood of a node x is defined by the set of nodes that are inside a circle (assume that MNs are moving in a two-dimensional plane) with center at x and radius r, and it is denoted by:

$$N_r(x) = N_x = \{n_f \mid d(x, n_f\} \le r, x \ne n_f, \forall j \in N, j \le\mid N \mid\}$$

where x is an arbitrary node in graph G and d is a distance function [8].

A path (route) from node i to node j, denoted by R_{ij} is a sequence of nodes $R_{ij}=(i,n_1, n_2,\ldots,n_k, j)$ where (i,n_1), (n_k,j) and (n_y,n_{y+1}) for $1\le y \le k$-1 are links. A simple path from i to j is a sequence of nodes with no node being repeated more than once. Due to the mobility of the nodes, the set of paths (wireless links) between any pair of nodes and distances is changing over time. New links can be established and existing links can vanish.

III. ROUTING PROTOCOLS

Routing protocols for Mobile ad hoc networks can be broadly classified into two main categories:

- Proactive or table-driven routing protocols
- Reactive or on-demand routing protocols.

A. Table Driven Routing Protocols (Proactive)

In proactive or table-driven routing protocols, each node continuously maintains up-to-date routes to every other node in the network. Routing information is periodically transmitted throughout the network in order to maintain routing table consistency. Thus, if a route has already existed before traffic arrives, transmission occurs without delay. Otherwise, traffic packets should wait in queue until the node receives routing information corresponding to its destination. However, for highly dynamic network topology, the proactive schemes require a significant amount of resources to keep routing information up-to-date and reliable. Certain proactive routing protocols are Destination-Sequenced Distance Vector (DSDV), Wireless Routing Protocol (WRP), Global State Routing (GSR) and Cluster-head Gateway Switch Routing (CGSR).

B. On-Demand Routing Protocols (Reactive)

In contrast to proactive approach, in reactive or on demand protocols, a node initiates a route discovery throughout the network, only when it wants to send packets to its destination. For this purpose, a node initiates a *route discovery* process through the network. This process is completed once a route is determined or all possible permutations have been examined. Once a route has been established, it is maintained by a *route maintenance* process until either the destination becomes inaccessible along every path from the source or until the route is no longer desired. In reactive schemes, nodes maintain the routes to active destinations. A route search is needed for every unknown destination. Therefore, theoretically the communication overhead is reduced at expense of delay due to route research. Some reactive protocols are Cluster Based Routing Protocol (CBRP), Ad hoc On-Demand Distance Vector (AODV), Dynamic Source Routing (DSR), Temporally Ordered Routing Algorithm (TORA), Associativity-Based Routing (ABR), Signal Stability Routing (SSR) and Location Aided Routing (LAR).

IV. Overview of AODV, DSR and TORA

Every routing protocol has its own merits and demerits, none of them can be claimed as absolutely better than others. We have selected the three reactive routing protocols – AODV, DSR and TORA for evaluation [11,18].

A. Ad hoc On-demand Distance Vector Routing (AODV)

Ad-hoc On-demand distance vector (AODV) [4,16] is another variant of classical distance vector routing algorithm, a confluence of both DSDV [5] and DSR [6]. It shares DSR's on-demand characteristics hence discovers routes whenever it is needed via a similar route discovery process. However, AODV adopts traditional routing tables; one entry per destination which is in contrast to DSR that maintains multiple route cache entries for each destination. The initial design of AODV is undertaken after the experience with DSDV routing algorithm. Like DSDV, AODV provides loop free routes while repairing link breakages but unlike DSDV, it doesn't require global periodic routing advertisements. AODV also has other significant features. Whenever a route is available from source to destination, it does not add any overhead to the packets. However, route discovery process is only initiated when routes are not used and/or they expired and consequently discarded. This strategy reduces the effects of stale routes as well as the need for route maintenance for unused routes. Another distinguishing feature of AODV is the ability to provide unicast, multicast and broadcast communication. AODV uses a broadcast route discovery algorithm and then the unicast route reply massage.

B. Dynamic Source Routing (DSR)

The Dynamic Source Routing (DSR) [6] is one of the purest examples of an on-demand routing protocol that is based on the concept of source routing. It is designed specially for use in multihop ad hoc networks of mobile nodes. It allows the network to be completely self-organizing and self-configuring and does not need any existing network infrastructure or administration. DSR uses no periodic routing messages like AODV, thereby reduces network bandwidth overhead, conserves battery power and avoids large routing updates. Instead DSR needs support from the MAC layer to identify link failure. DSR is composed of the two mechanisms of Route Discovery and Route Maintenance, which work together to allow nodes to discover and maintain source routes to arbitrary destinations in the network. DSR has a unique advantage by virtue of source routing. As the route is part of the packet itself, routing loops, either short – lived or long – lived, cannot be formed as they can be immediately detected and eliminated. This property opens up the protocol to a variety of useful optimizations.

Neither AODV nor DSR guarantees shortest path. If the destination alone can respond to route requests and the source node is always the initiator of the route request, the initial route may the shortest.

C. Temporary Ordered Routing Algorithm (TORA)

The Temporally Ordered Routing Algorithm (TORA) is a highly adaptive, efficient and scalable distributed routing algorithm based on the concept of link reversal [3]. TORA is proposed for highly dynamic mobile, multi-hop wireless networks. It is a source-initiated on-demand routing protocol. It finds multiple routes from a source node to a destination node. The main feature of TORA is that the control messages are localized to a very small set of nodes near the occurrence of a topological change. To achieve this, the nodes maintain routing information about adjacent nodes. The protocol has three basic functions: *Route creation*, *Route maintenance* and *Route erasure*. TORA can suffer from unbounded worst-case convergence time for very stressful scenarios [15,17]. TORA has a unique feature of maintaining multiple routes to the destination so that topological changes do not require any reaction at all. The protocol reacts only when all routes to the destination are lost. In the event of network partitions the protocol is able to detect the partition and erase all invalid routes.

Table 1 lists some comparisons between the three routing protocols discussed above.

TABLE 1. COMPARISON OF THE THREE ROUTING PROTOCOLS

Parameters	AODV	DSR	TORA
Source Routing	No	Yes	No
Topology	Full	Full	Reduced
Broadcast	Full	Full	Local
Update information	Route error	Route error	Node's height
Update destination	Source	Source	Neighbors
Method	Unicast	Unicast	Broadcast
Storage Complexity	O(E)	O(E)	O(Dd*A)

Abbreviations:
Dd – Number of maximum desired destinations
E – Communication pairs
A – Average number of adjacent nodes

V. SIMULATION

The simulations were performed using Network Simulator 2 (Ns-2) [2], particularly popular in the ad hoc networking community. The traffic sources are CBR (continuous bit –rate). The source-destination pairs are spread randomly over the network.

The mobility model uses 'random waypoint model' in a rectangular filed of 500m x 500m with 50 nodes. During the simulation, each node starts its journey from a random spot to a random chosen destination. Once the destination is reached, the node takes a rest period of time in second and another random destination is chosen after that pause time. This process repeats throughout the simulation, causing continuous changes in the topology of the underlying network. Different network scenario for different number of nodes and pause times are generated. The model parameters that have been used in the following experiments are summarized in Table 2.

TABLE 2. SIMULATION PARAMETERS

Parameter	Value
Simulator	ns-2
Protocols studied	AODV, DSR and TORA
Simulation time	200 sec
Simulation area	500 x 500
Transmission range	250 m
Node movement model	Random waypoint
Bandwidth	2 MBit
Traffic type	CBR (UDP)
Data payload	Bytes/packet
Bandwidth	2 Mbps

Performance Indices

The following performance metrics are considered for evaluation:

Packet Delivery Fraction (PDF): The ratio of the data packets delivered to the destinations to those generated by the sources. Mathematically, it can be expressed as:

$$P = \frac{1}{c}\sum_{f=1}^{e}\frac{R_f}{N_f}$$

where P is the fraction of successfully delivered packets, C is the total number of flow or connections, f is the unique flow id serving as index, R_f is the count of packets received from flow f and N_f is the count of packets transmitted to f.

Average end-to-end delay: 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. It can be defined as:

$$D = \frac{1}{N}\sum_{i=1}^{s}(r_i - s_i)$$

where N is the number of successfully received packets, i is unique packet identifier, r_i is time at which a packet with unique id i is received, s_i is time at which a packet with unique id i is sent and D is measured in ms. It should be less for high performance.

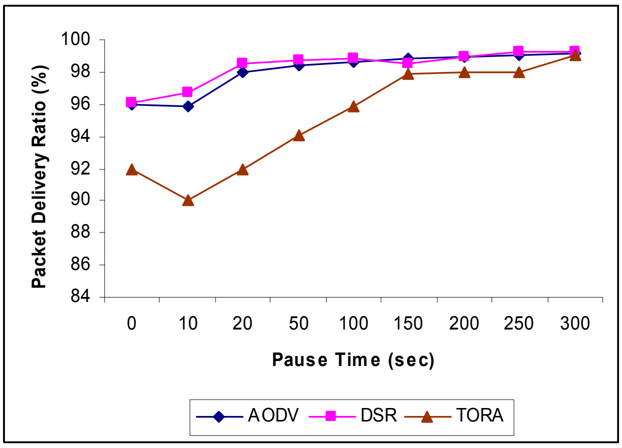
VI. SIMULATION RESULTS & OBSERVATIONS

The simulation results are shown in the following section in the form of line graphs. Graphs show comparison between the three protocols by varying different numbers of sources on the basis of the above-mentioned metrics as a function of pause time.

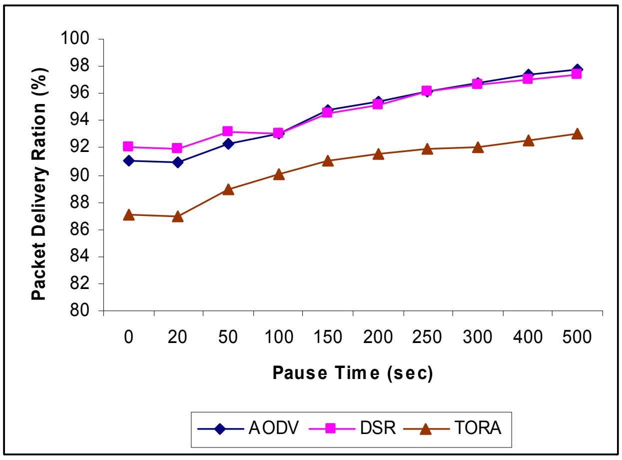
A. Packet Delivery Fraction (PDF) or Throughput

Figure 1 a-c, shows a comparison between the routing protocols on the basis of packet delivery fraction as a function of pause time and using different number of traffic sources. Throughput describes the loss rate as seen by the transport layer. It reflects the completeness and accuracy of the routing protocol. From these graphs it is clear that throughput decrease with increase in mobility. As the packet drop at such a high load traffic is much high.

TORA performs better at high mobility but in other cases it shows to have a lower throughput. AODV in our simulation experiment shows to have the best overall performance. On-demand protocols (DSR and AODV) drop a considerable number of packets during the route discovery phase, as route acquisition takes time proportional to the distance between the source and destination. The situation is similar with TORA. Packet drops are fewer with proactive protocols as alternate routing table entries can always be assigned in response to link failures. TORA can be quite sensitive to the loss of routing packets compared to the other protocols. Buffering of data packets while route discovery in progress, has a great potential of improving DSR, AODV and TORA performances. AODV has a slightly lower packet delivery performance than DSR because of higher drop rates. AODV uses route expiry, dropping some packets when a route expires and a new route must be found [13].



(a)



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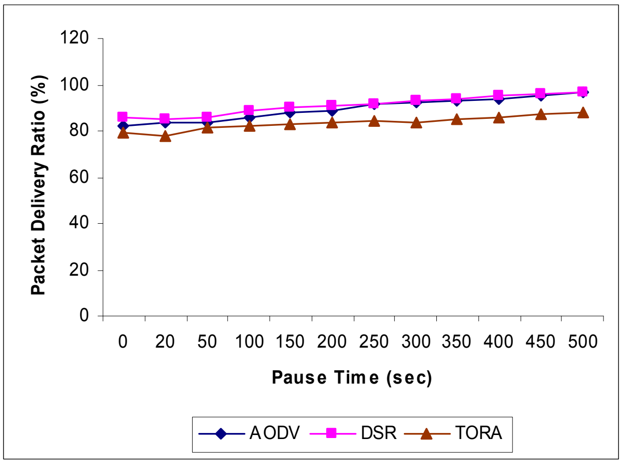
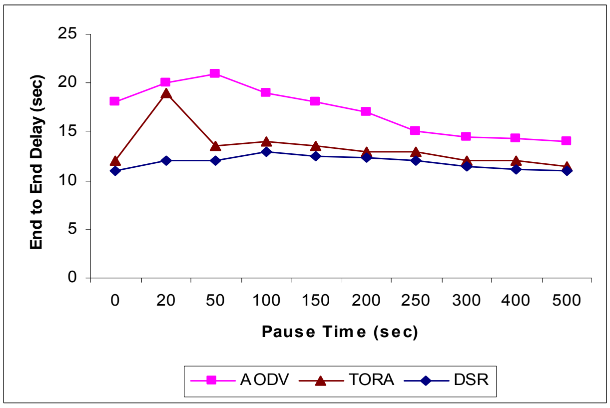
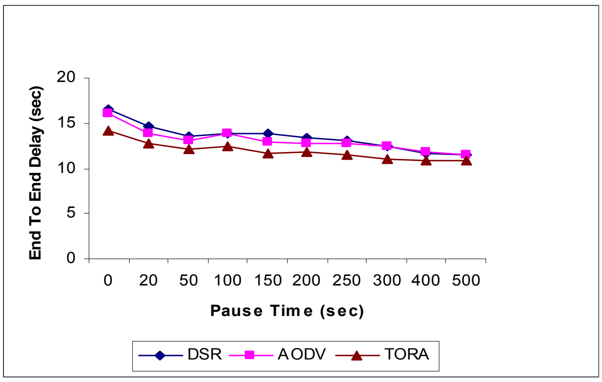


(c)

Figure 1. Packet delivery fraction vs. Pause time for 50-node model with (a) 10 sources, (b) 20 sources and (c) 50 sources.



(a)



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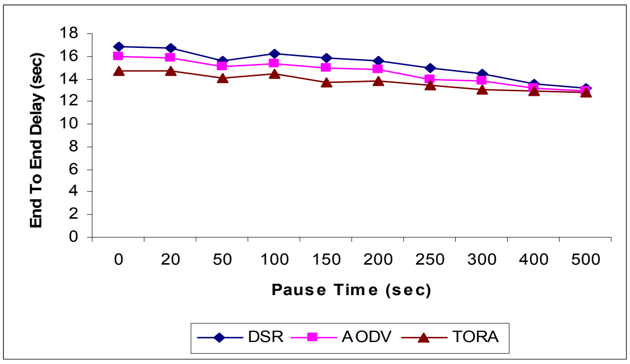

(c)

Figure 2. End to End Delay vs. Pause time for 50-node model with (a) 10 sources, (b) 20 sources and (c) 50 sources.

B. End to End Delay

Figure 2 a-c, shows the graphs for end-to-end delay Vs pause time. From these graphs we see that the average packet delay increase for increase in number of nodes waiting in the interface queue while routing protocols try to find valid route to the destination. Besides the actual delivery of data packets, the delay time is also affected by route discovery, which is the first step to begin a communication session. The source routing protocols have a longer delay because their route discovery takes more time as every intermediate node tries to extract information before forwarding the reply. The same thing happens when a data packet is forwarded hop by hop. Hence, while source routing makes route discovery more profitable, it slows down the transmission of packets.

AODV and DSR show poor delay characteristics as their routes are typically not the shortest. Even if the initial route discovery phase finds the shortest route (it typically will), the route may not remain the shortest over a period of time due to node mobility. However, AODV performs a little better delay-wise and can possibly do even better with some fine-tuning of this timeout period by making it a function of node mobility. TORA too has the worst delay characteristics because of the loss of distance information with progress. Also in TORA route construction may not occur quickly. This leads to potential lengthy delays while waiting for new routes to be determined. In DSR Route Discovery is fast, therefore shows a better delay performance than the other reactive protocols at low pause time (high mobility). But in case of congestion (high traffic) DSR control messages get loss thus eliminating its advantage of fast establishing new route. Under such situations DSR has a relatively high delay that AODV, but however the delay decreases with increase in pause time [11].

Without any periodic hello messages, DSR outperforms the other protocols in terms of overhead. In most cases, both the packet overhead and the byte overhead of DSR are less than a quarter of AODV's overhead. AODV has the largest routing load (in the 50-node cases, as many as 6.5 routing packets per data packet and 2 routing bytes per data byte) because the number of its route discoveries is the most, and the discovery is network-wide flooding. When there are more connections, more routing is needed, and so the proportion of hello messages in the total overhead becomes smaller. As the result, AODV gets closer to DSR. The excellent routing load performance of DSR is due to the optimizations possible by virtue of source routing. TORA's performance is not very competitive with the distance vector and on-demand protocols. We conjecture that it is due to the fact network partitions cause TORA to do substantial work to erase routes even when those routes are not in use [13]. However, TORA shows a better performance for large networks with low mobility rate.

Comparison Study

The goal of this performance evaluation is a comparison of a MANET between AODV, DSR and TORA routing protocols. AODV in our simulation experiment shows to have the overall best performance. It has an improvement of DSR and DSDV and has advantages of both of them. TORA performs better at high speed high mobility and has a high throughput as compared to AODV and DSR. It often serves as the underlying protocol for lightweight adaptive multicast algorithms. Whereas DSR suits for network in which mobiles move at moderate speed. It has a significant overhead as the packet size is large carrying full routing information.

Table 3 shows a numerical comparison of the three protocols, "1" for the best up to "4" for the worst [14].

TABLE 3. NUMERICAL COMPARISON OF THE THREE ROUTING PROTOCOLS

Metrics	AODV	DSR	TORA
Scalability	2	3	1
Delay	3	2	4
Routing overhead	2	1	3
Drop packet	1	2	3
Throughput	1	2	4
Dynamic adaptability	2	3	1
Energy conservation	2	1	3

VII. CONCLUSIONS

As a special type of network, Mobile Ad hoc Networks (MANETs) have received increasing research attention in recent years. There are many active research projects concerned with MANETs. Mobile ad hoc networks are wireless networks that use multi-hop routing instead of static networks infrastructure to provide network connectivity. MANETs have applications in rapidly deployed and dynamic military and civilian systems. The network topology in MANETs 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 MANETs routing protocols, comparing and improving existing MANETs routing protocols before any routing protocols are standardized using simulations.

This work is an attempt towards a comprehensive performance evaluation of three commonly used mobile ad hoc routing protocols (DSR, TORA and AODV). Over the past few years, new standards have been introduced to enhance the capabilities of ad hoc routing protocols. As a result, ad hoc networking has been receiving much attention from the wireless research community. In this paper, using the latest simulation environment NS 2, we evaluated the performance of three widely used ad hoc network routing protocols using packet-level simulation. The simulation characteristics used in this research, that is, packet delivery fraction and end-to-end delay are unique in nature, and are very important for detailed performance evaluation of any networking protocol.

We can summarize our final conclusion from our experimental results as follows:

- Increase in the density of nodes yields to an increase in the mean End-to-End delay.
- Increase in the pause time leads to a decrease in the mean End-to-End delay.
- Increase in the number of nodes will cause increase in the mean time for loop detection.

In short, AODV has the best all round performance. DSR is suitable for networks with moderate mobility rate. It has low overhead that makes it suitable for low bandwidth and low power network. Whereas TORA is suitable for operation in large mobile networks having dense population of nodes. The major benefit is its excellent support for multiple routes and multicasting.

FUTURE WORK

In the future, extensive complex simulations could be carried out using other existing performance metrics, in order to gain a more in-depth performance analysis of the ad hoc routing protocols. Other new protocols performance could be studied too.

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