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A Comparative Performance Analysis of AODV, DSR and TORA Routing Protocols in MANETs

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Abstract— A mobile ad hoc network is a collection of autonomous mobile nodes that communicate with each other over wireless links. It is seen that mobile ad hoc networks will be an integral part of next generation networks because of its flexibility, infrastructure less nature, ease of maintenance, auto configuration, self administration capabilities, and costs effectiveness. 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. In this paper, an attempt has been made to compare three well know protocols AODV, DSR and TORA by using two performance metrics packet delivery fraction and end to end delay by varying the number of nodes and pause time with identical environment conditions. The comparison has been done by using simulation tool NS2 which is the main simulator, NAM (Network Animator) and excel graph which is used for preparing the graphs from the trace files.

Index Terms— MANET, AODV, DSR, TORA

I. INTRODUCTION

The adaptability of wireless systems is limited by the presence of a fixed supporting coordinate. This motivates the construction of temporary networks with no wires, no communication infrastructure and no administrative intervention required. Mobile ad hoc networks (MANETs) are rapidly evolving as an important area of mobile mobility. MANETs are infrastructure less and wireless in which there are severalrouters which are free to move arbitrarily and can manage themselves in same manners. A number of protocols have been developed for accomplish this task. 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 challenges in mobile ad hoc networks such as routing of packets with frequently mobile nodes movement, there are resource issues like power and storage and there are also wireless communication issues.

As mobile ad hoc network consists of wireless hosts that may move often. Movement of hosts results in a change in routes.

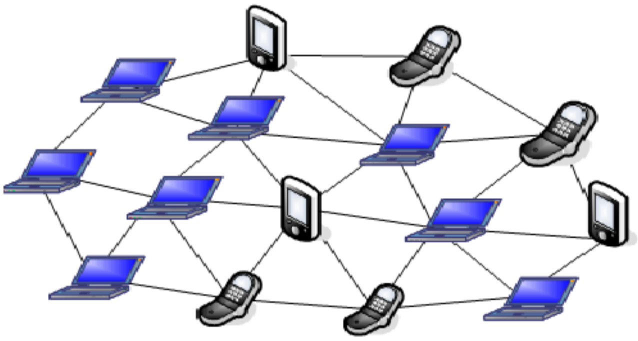

Fig 1: Mobile Ad Hoc Networks-MANETs.

The key challenges faced at different layers of MANET are shown in Fig. 2. It represents layered structure and approach to ad hoc networks.

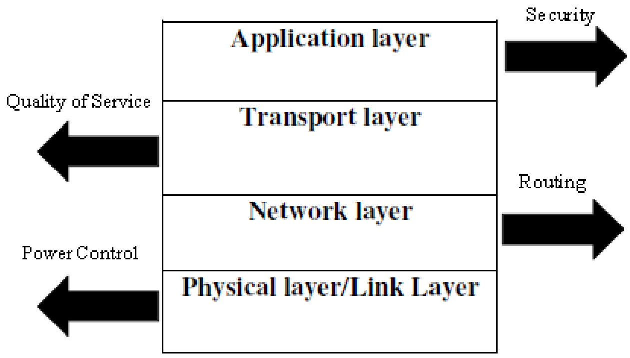

Fig.2: MANET Challenges

II. MOBILE AD HOC NETWORKS ROUTING PROTOCOLS

Routing protocol in MANET can be classified into several ways depending upon their network structure, communication model, routing strategy, and state information and so on but most of these are done depending on routing strategy and network structure. Based on the routing strategy the routing protocols can be classified into two parts:

- Table driven
- Source initiated (on demand), while depending on the network structure these are classified as flat routing, hierarchical routing and geographic position assisted routing.

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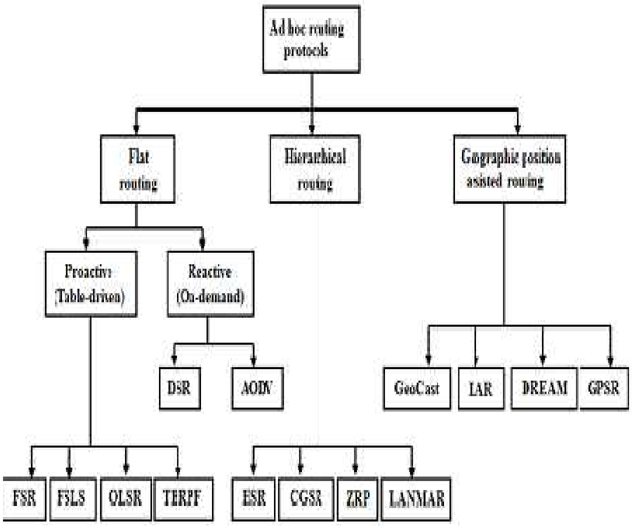

Fig.3: Routing Protocols in Mobile Ad-hoc Networks [2].

A. Flat Routing Protocols

Flat routing [2] protocols are divided mainly into two classes; the first one is proactive routing (table driven) protocols and other is reactive (on-demand) routing protocols. One thing is general for both protocol classes is that every node participating in routing play an equal role.

1) Table Driven Routing Protocols (Proactive)

Proactive MANET protocols are table-driven and will actively determine the layout of the network. Through a regular exchange of network topology packets between the nodes of the network, a complete picture of the network is maintained at every single node. There is hence minimal delay in determining the route to be taken. Some Proactive MANET Protocols include: DSDV, DBF, GSR, WRP, ZRP, FSR.

2) On-Demand Routing Protocols (Reactive)

On-demand routing is a popular routing category for wireless ad hoc routing. It is a relatively new routing philosophy that provides a scalable solution to relatively large network topologies. The design follows the idea that each node tries to reduce routing overhead by only sending routing packets when communication is requested. Common for most on-demand routing protocols are the route discovery phase where packets are flooded into the network in search of an optimal path to the destination node in the network. Some Reactive MANET Protocols include: DSR, AODV and TORA.

B. Hybrid Routing Protocols

Since proactive and reactive protocols each work best in oppositely different scenarios, hybrid method uses both. It is used to find a balance between both protocols. Proactive operations are restricted to small domain, whereas, reactive protocols are used for locating nodes outside those domains [4]. Some hybrid protocols are Zone Routing Protocol (ZRP), Wireless Ad hoc Routing Protocol (WARP).

C. Hierarchical Routing Protocols

As the size of the wireless network increases, the flat routing protocols may produce too much overhead for the MANET. In this case a hierarchical solution may be preferable [4]. Some hierarchical protocols are Hierarchical State Routing (HSR), Zone Routing Protocol (ZRP), Cluster head Gateway Switch Routing Protocol (CGSR).

D. Geographical Routing Protocols

There are two approaches to geographic mobile ad hoc networks:

- Actual geographic coordinates (as obtained through GPS - the Global Positioning System).
- Reference points in some fixed coordinate system.

An advantage of geographic routing protocols [4] is that they prevent network-wide searches for destinations. If the recent geographical coordinates are known then control and data packets can be sent in the general direction of the destination. Some geographical protocols are GeoCast (Geographic Addressing and Routing), DREAM (Distance Routing Effect Algorithm for Mobility), GPSR (Greedy Perimeter Stateless Routing).

III. 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)

The Ad hoc On-Demand Distance Vector (AODV) [8] algorithm enables dynamic, self-starting, multihop routing between participating mobile nodes wishing to establish and maintain an ad hoc network. AODV allows mobile nodes to obtain routes quickly for new destinations, and does not require nodes to maintain routes to destinations that are not in active communication. AODV allows mobile nodes to respond to link breakages and changes in network topology in a timely manner. The operation of AODV is loop-free, and by avoiding the Bellman-Ford "counting to infinity" problem offers quick convergence when the adhoc network topology changes (typically, when a node moves in the network). When links break, AODV causes the affected set of nodes to be notified so that they are able to invalidate the routes using the lost link. Route Requests (RREQs), Route Replies (RREPs) and Route Errors (RERRs) are message types defined by AODV [8,10].

B. Dynamic Source Routing (DSR)

The Dynamic Source Routing protocol (DSR) is an on demand routing protocol. DSR is a simple and efficient routing protocol designed specifically for use in multi-hop wireless ad hoc networks of mobile nodes. Using DSR, the network is completely selforganizing and self-configuring, requiring no existing network infrastructure or administration. The DSR protocol is composed of two main mechanisms that work together to allow the discovery and maintenance of source routes in the ad hoc network :

- Route Discovery is the mechanism by which a node S wishing to send a packet to a destination node D obtains a source route to D. Route Discovery is used only when S attempts to send a packet to D and does not already know a route to D.
- Route Maintenance is the mechanism by which node S is able to detect, while using a source route to D, if the network topology has changed such that it can no longer use its route to D because a link along the route no longer works.

When Route Maintenance indicates a source route is broken, S can attempt to use any other route it happens to know to D, or it can invoke Route Discovery again to find a new route for subsequent packets to D. Route Maintenance for this route is used only when S is actually sending packets to D.
In DSR Route Discovery and Route Maintenance each operate entirely" on demand".

C. Temporary Ordered Routing Algorithm (TORA)

The Temporally-Ordered Routing Algorithm (TORA) [26, 27] is an adaptive routing protocol for multi-hop networks that possesses the following attributes:

- Distributed execution
- Multipath routing
- The protocol can simultaneously support both source initiated, on-demand routing for some destinations and destination-initiated, proactive routing for other destinations.
- Minimization of communication overhead via localization of algorithmic reaction to topological changes.

TORA is distributed, in that routers need only maintain information about adjacent routers (i.e., one-hop knowledge). Like a distance-vector routing approach, TORA maintains state on a per-destination basis. However; TORA does not continuously execute a shortest-path computation and thus the metric used to establish the routing structure does not represent a distance. The destination-oriented nature of the routing structure in TORA supports a mix of reactive and proactive routing on a per-destination basis. During reactive operation, sources initiate the establishment of routes to a given destination on-demand. This mode of operation may be advantageous in dynamic networks with relatively sparse traffic patterns, since it may not be necessary (or desirable) to maintain routes between every source/destination pair at all times. At the same time, selected destinations can initiate proactive operation, resembling traditional table-driven routing approaches. This allows routes to be proactively maintained to destinations for which routing is consistently or frequently required. TORA is designed to minimize the communication overhead associated with adapting to network topological changes. The scope of TORA's control messaging is typically localized to a very small set of nodes near a topological change.

IV. SIMULATION

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

NS-2 is suitable for designing new protocols, comparing different protocols and traffic evaluations. It is an object oriented simulation written in C++, with an OTcl interpreter as a frontend. For all the simulations, the simulation time was fixed at 200 sec, the maximum speed of the nodes was set to 20m/s and the simulating nodes are varied. The model parameters that have been used are summarized in Table 1.

TABLE1: SIMULATION PARAMETER

Parameter	Value
Simulator	Ns-2.28
Radio propagation model	TwoRayGround
Environment size	1000x1000
Traffic type	CBR
Maximum Speed of nodes	20m/s
Queue length	250
Antenna type	Omnidirectional

The steps of simulation are shown in the below Figure.4.

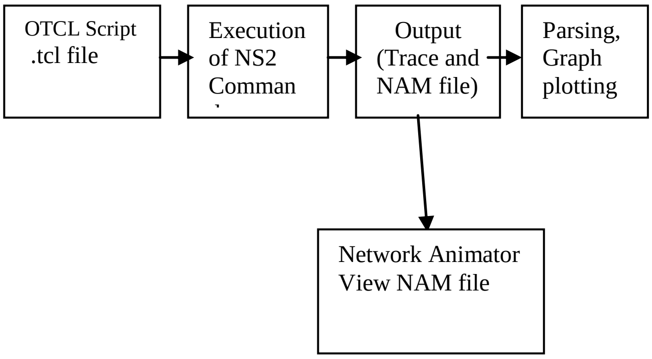

Figure 4: Simulation Process

A. *Performance indices*

The following performance metrics are considered for evaluation:

1) Packet delivery fraction (Throughput)

There is two representations of throughput; one is the amount of data transferred over the period of time expressed in kilobits per second (Kbps). The other is the packet delivery percentage obtained from a ratio of the number of data packets sent and the number of data packets received.

2) Avg. End-to-End Delay

This includes all possible delays caused by buffering during route discovery latency, queuing at the interface queue, retransmission on delays at MAC, and propagation and transfer times.

V. RESULT

As already outlined we have taken three On-demand (Reactive) routing protocols, namely Ad hoc On-Demand Distance Vector Routing (AODV) and Dynamic Source Routing (DSR) and Temporary Ordered Routing Algorithm (TORA). The comparison has been done by using simulation tool NS2 which is the main simulator, NAM (Network Animator) and excel graph which is used for preparing the graphs from the trace files.

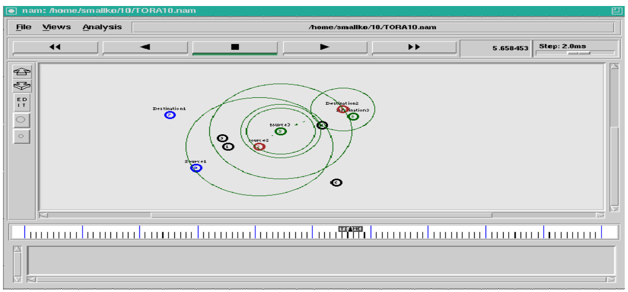

Figure 5: Route discovery and Packet Transmission in TORA

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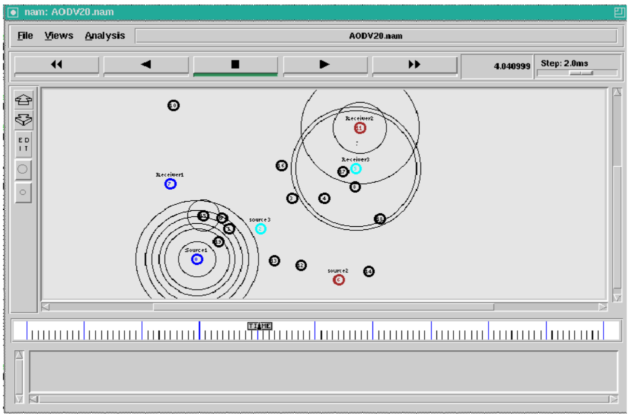

Figure 6: Route discovery and Packet Transmission in AODV

The above Figure 5 shows the packet transmission from the source node to the destination node using TORA protocol with 20 nodes. In case of wireless protocols, the nodes are not stationary and they are continuously moving. Each node has its own specific radio range, which is indicated by the circles in the Fig.5 and 6.Here all the nodes are mobile nodes and the selection of route is made by the current active node. Each and every node knows the status (Active or Dead) of the next node and communicates accordingly. The above Figure 6 shows the packet transmission from the source node to the destination node using TORA protocol. Similarly the packet transmission is made in DSR protocol with 5, 10 and 20 nodes and so on respectively.

The simulation is conducted in two different scenarios. In the first scenario, the comparison of the three routing protocols is compared in various numbers of nodes. The number of nodes is set to 5, 10, 15, 20, 25, 30, 35 and 40 nodes.

In the second scenario, the routing protocols are evaluated in different pause time while the number of nodes and the node speed are fixed. The node speed is set to 20m/s and the number of nodes is set to 20 nodes. The pause time are set to 0, 20, 50, 100, 150, 200, 250, 300, 400 and 500 second.

A. Various Numbers of Nodes

In this scenario, all the three routing protocol are evaluated based on the two performance metric which are Packet Delivery Fraction and End-to-End Delay.

1) Packet Delivery Fraction

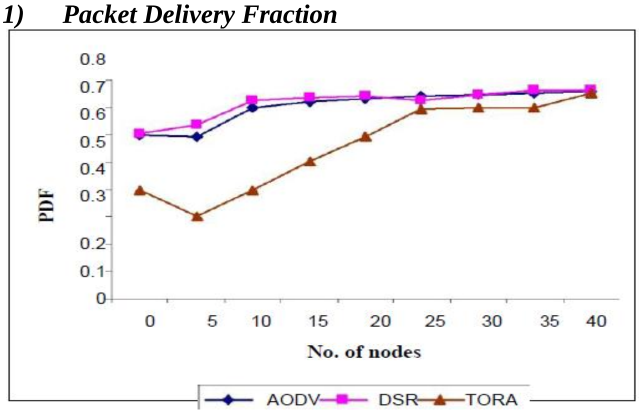

Figure 7: Packet Delivery Fraction in Scenario 1

Based on the Figure 7, it is shown than AODV perform better when the number of nodes increases because nodes become more stationary will lead to more stable path from source to destination. 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.

2) End-to-End Delay

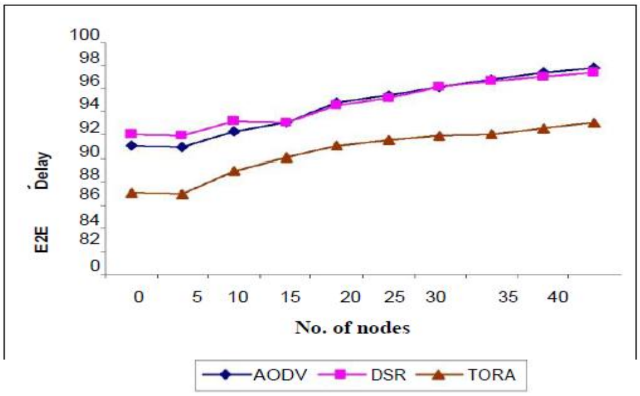

Figure 8: End To End Delay in Scenario 1

TORA didn't produce so much delay even the number of nodes increased. It is better the other two protocols. The performance of AODV is slight better than DSR especially when the number of nodes between 10 and 20 and at the last. It shows that, the DSR protocol improved the AODV but slightly lower than AODV when the nodes is higher.

B. Various Pause Time

In this scenario, all the three routing protocol are evaluated based on the two performance metric which are Packet Delivery Fraction and End-to-End Delay.

1) Packet Delivery Fraction

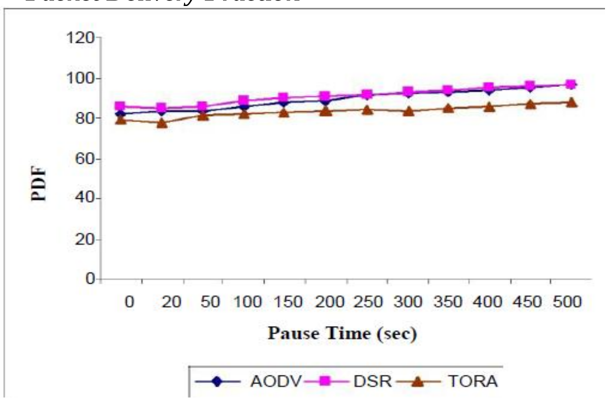

Figure 9: Packet Delivery Fraction in Scenario 2

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.

2) End-to-End Delay

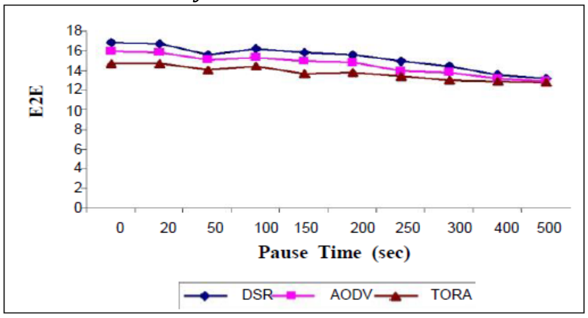

Figure 10: End To End Delay in Scenario 2

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. AODV performs a little better delay-wise and can possibly. 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 DSR eliminating its advantage of fast establishing of new route. Under such situations DSR has a relatively high delay that AODV. However, TORA shows a better performance for large networks with low mobility rate.

VI. CONCLUSION

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. The simulation characteristics used are packet delivery fraction and end-to-end delay.

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

The goal of this performance analysis is a comparison of AODV, DSR and TORA routing protocols in MANET. 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. Whereas DSR suits for network in which mobiles move at moderate speed.

FUTURE WORK

In this work other network parameters such as simulation time, traffic type-CBR, etc. are kept constant. Whereas the number of nodes and pause time is varied. It would be interesting to observe the behavior of these three protocols by varying other network parameters and by using other performance metrics.

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