International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878, Volume-1, Issue-3, August 2012

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

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Abstract: ***Mobile ad hoc network (MANET) is an autonomous system of mobile nodes connected by wireless links. Each node operates as an end system and also as a router to forward packets. The nodes are free to move about and organize themselves into a network. These nodes change position frequently. 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 work an attempt has been made to compare the performance of three on-demand routing protocols for MANETs:- Ad hoc On Demand Distance Vector (AODV), Dynamic Source Routing (DSR) protocols, and Temporally Ordered Routing Algorithm (TORA) with respect to the three performance metrics: average End-to-End delay, throughput and packet delivery ratio. The performance differentials are analyzed using varying number of nodes. These simulations are carried out using the ns-2 network simulator. The results presented in this work illustrate the importance in carefully evaluating and implementing routing protocols in an adhoc environment.***

***Index Terms**: AODV, DSR, MANETs, Route Reply, Route Request, Throughput. TORA.*

I. INTRODUCTION

Wireless cellular systems have been in use since 1980s. These systems work with the support of a centralized supporting structure such as an access point. 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. Ad-hoc is a latin word, which means "for this or for this only." Mobile Ad-Hoc Network (MANET) is a kind of wireless ad-hoc network and it is a self-configuring network of mobile routers (and associated hosts) connected by wireless links – the union of which forms an arbitrary topology. The routers, the participating nodes act as router, are free to move randomly and manage themselves arbitrarily & thus, the network's wireless topology may change rapidly and unpredictably. Such a network may operate in a standalone fashion, or may be connected to the larger Internet. 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.

MANETs have several salient characteristics:

1) Dynamic network topologies, 2) Bandwidth constrained, variable capacity links, 3) Energy-constrained operation, 4) Nodes can perform the roles of both hosts and routers, 5) Frequent routing updates. 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. Routing algorithms are often difficult to be formalized into mathematics they are instead tested using extensive simulation. Therefore in most of the cases performance analysis is carried out using various popular simulators like NS-2 on behalf of different performance matrices and by using some specific network parameters.

Revised Manuscript Received on 30 August 2012.

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II. ROUTING PROTOCOLS IN MANET

Classification of routing protocols in MANET's can be done in many ways, but most of these are done depending on routing strategy and network structure [4]. According to the routing strategy the routing protocols can be categorized as Table-driven and source initiated, while depending on the network structure these are classified as flat routing, hierarchical routing and geographic position assisted routing.

A. Flat Routing Protocols

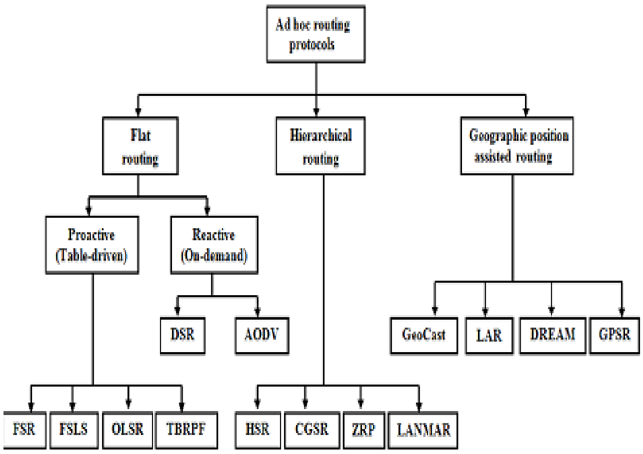

Figure1: Routing Protocols in Mobile Ad-hoc Networks [2].

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.

A.1. Table Driven Routing Protocols (Proactive)

These protocols are also called as proactive protocols since they maintain the routing information even before it is needed [2]. Each and every node in the network maintains routing information to every other node in the network. Routes information is generally kept in the routing tables and is periodically updated as the network topology changes.

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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. The proactive protocols are not suitable for larger networks, as they need to maintain node entries for each and every node in the routing table of every node. This causes more overhead in the routing table leading to consumption of more bandwidth. Certain proactive routing protocols are Destination Sequenced Distance Vector (DSDV), Global State Routing (GSR), Wireless Routing Protocol (WRP), and Optimized Link State Routing (OLSR) etc.

A.2. On-Demand Routing Protocols (Reactive)

These protocols are also called reactive protocols since they don't maintain routing information or routing activity at the network nodes if there is no communication. If a node wants to send a packet to another node then this protocol searches for the route in an on-demand manner and establishes the connection in order to transmit and receive the packet. Whenever a node needs a route to a given target, it initiates a route discovery process on the fly, for discovering out a pathway [4]. Once a route has been established, it is maintained by a route maintenance process.

This kind of protocols is usually based on flooding the network with Route Request (RREQ) and Route reply (RERP) messages .By the help of Route request message the route is discovered from source to target node; and as the target node gets a RREQ message it send RERP message for the confirmation that the route has been established. This kind of protocol is usually very effective on single-rate networks. It usually minimizes the number of hops of the selected path. However, on multi-rate networks, the number of hops is not as important as the throughput that can be obtained on a given path [7].

Some reactive protocols are Ad hoc On-Demand Distance Vector (AODV), Dynamic Source Routing (DSR), Temporally Ordered Routing Algorithm (TORA), Signal Stability Routing (SSR) and Location Aided Routing (LAR).

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:

1. Actual geographic coordinates (as obtained through GPS - the Global Positioning System).
2. 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 some merits and demerits, none of them can be claimed as absolutely better than others. For this paper work we have selected the three reactive routing protocols - AODV, DSR and TORA for evaluation.

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

Ad-hoc On-demand distance vector (AODV) [8] is essentially a combination of both DSR and DSDV. AODV defines three types of control messages for route establishment and maintenance: 1) RREQ, 2) RREP, 3) RERR. AODV is capable of both unicast and multicast routing [8].

When a source node desires a route to a destination for which it does not already have a route, it broadcasts a route request (RREQ) packet across the network. Nodes receiving this packet update their information for the source node and set up backwards pointers to the source node in the route tables. In addition to the source node's IP address, current sequence number, and broadcast ID, the RREQ also contains the most recent sequence number for the destination of which the source node is aware[10]. A node getting the RREQ may send a route reply (RREP) if it is either the destination or if it has a route to the destination with corresponding sequence number greater than or equal to that contained in the RREQ. If this is the case, it unicasts a RREP back to the source. Otherwise, it rebroadcasts the RREQ. Nodes keep track of the RREQ's source IP address and broadcast ID. If they receive a RREQ which they have already processed, they discard the RREQ and do not forward it. As the RREP propagates back to the source, nodes set up forward pointers to the destination. Once the source node receives the RREP, it may begin to forward data packets to the destination. If a link break occurs while the route is active, the node upstream of the break propagates a route error (RERR) message to the source node to inform it of the now unreachable destinations. After receiving the RERR, if the source node still desires the route, it can reinitiate route discovery. Multicast routes are set up in a similar manner. The sequence numbers are used by AODV to ensure the freshness of routes. It is loop-free, self-starting, and scales to large numbers of mobile nodes [8] [10].

B. Dynamic Source Routing (DSR)

Dynamic source routing protocol (DSR) is an on-demand, source routing protocol, whereby all the routing information is maintained (continually updated) at mobile nodes. DSR allows the network to be completely self-organizing and self-configuring, without the need for any existing network infrastructure or administration.

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The protocol is composed of the two main mechanisms of "Route Discovery" and "Route Maintenance", which work together to allow nodes to discover and maintain routes to arbitrary destinations in the ad hoc network. An optimum path for a communication between a source node and target node is determined by Route Discovery process. Route Maintenance ensures that the communication path remains optimum and loop-free according the change in network conditions, even if this requires altering the route during a transmission. The fundamental approach of this protocol during the route creation phase is to launch a route by flooding RouteRequest packets in the network. The destination node, on getting a RouteRequest packet, responds by transferring a RouteReply packet back to the source, which carries the route traversed by the RouteRequest packet received. DSR uses no periodic routing messages like AODV, thereby reduces network bandwidth overhead, conserves battery power and avoids large routing updates.

C. Temporary Ordered Routing Algorithm (TORA)

The Temporally Ordered Routing Algorithm (TORA) is a source-initiated on-demand routing protocol and it is a highly adaptive, proficient and scalable distributed routing algorithm based on the concept of link reversal. TORA is proposed for highly dynamic mobile, multihop wireless networks. It searches multiple routes from a source node to a destination node. The principal 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 retain routing information about adjacent nodes. The protocol has three basic functions: Route creation, Route maintenance and Route erasure. TORA uses three kinds of messages to process these functions:

1. The QRY message for creating a route.
2. The UDP message for both creating and maintaining routes.
3. The CLR message for erasing a route.

The route creation algorithm starts with the height (propagation ordering parameter in the quintuple) of destination set to 0 and all other height of node set to NULL. The source broadcasts a QRY packet with the destination node's id in it. A node with a non-NULL height responds with a UPD packet that has its height in it. A node receiving a UPD packet sets its height to one more than that of the node that generated the UPD [12]. A node with higher height is considered upstream and a node with lower height downstream. In this way a directed acyclic graph is constructed from source to the destination.

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.

For all the simulations, the simulation time was fixed at 200 sec, the maximum speed of the nodes was set to 15m/s and the simulating nodes are varied as 10 and 20 nodes respectively. The model parameters that have been used are summarized in Table 1.

Table I: **Simulation Parameter**

Parameter	**Value**
Simulator	Ns-2.28
Radio propagation model	TwoRayGround
Environment size	800x800
Traffic type	CBR
Maximum Speed of nodes	15m/s
Number of nodes	10 and 20
Queue length	250
Simulation time	200sec
Antenna type	Omnidirectional

Performance Indices

The following performance metrics are considered for evaluation:

Packet delivery ratio: The ratio between the number of packets originated by the CBR sources and the number of packets received by the CBR sink at the final destination. It describes the loss rate seen by the protocol.

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.

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). We have used following simulations to study and analyze our result .They are NS2 network simulator, NAM editor to show the animated schema of the three protocols AODV, DSR and TORA, their performances and their routing paths. Furthermore we have used X-graph to graphically represent the throughput, packet delivery ratio and avg. end-to-end delay for all the protocols and hence comparing them.

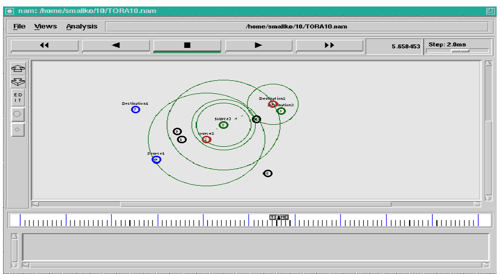

Figure 2: Route discovery and Packet Transmission in TORA

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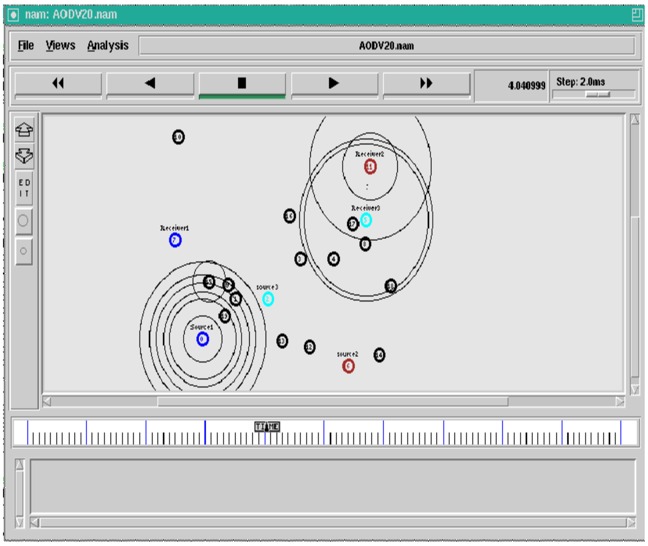
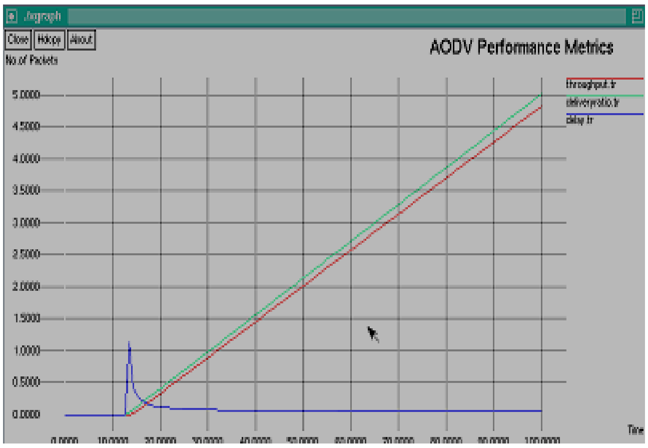


Figure 3: Route discovery and Packet Transmission in AODV

The above Figure 2 shows the packet transmission from the source node to the destination node using TORA protocol. 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 3 shows the packet transmission from the source node to the destination node using TORA protocol. Similarly the packet transmission is made in DSR protocol.



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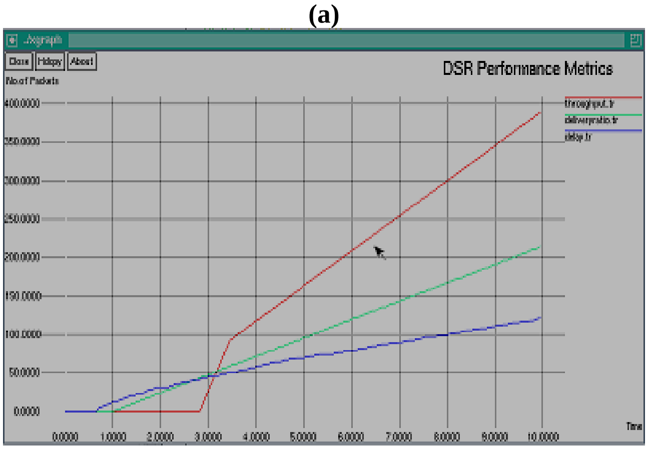

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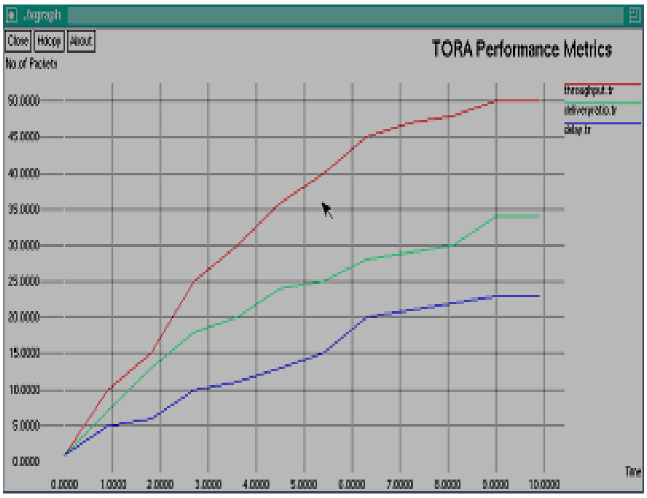
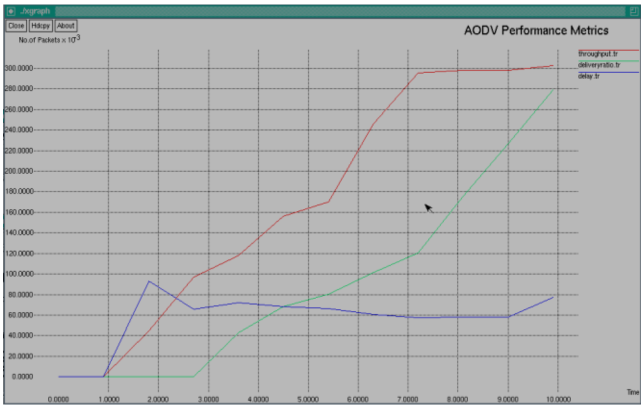


(c)

Figure 4: Graphical representation of performance metrics using 10 nodes (a) AODV (b) DSR (c) TORA

Figure 4 & Figure 5 shows the X graph of AODV, DSR and TORA routing protocols respectively. By studying the above graphs we see that as the simulation start all the performance metrics initially zero, because initially there is no CBR connection and nodes taking their right place.



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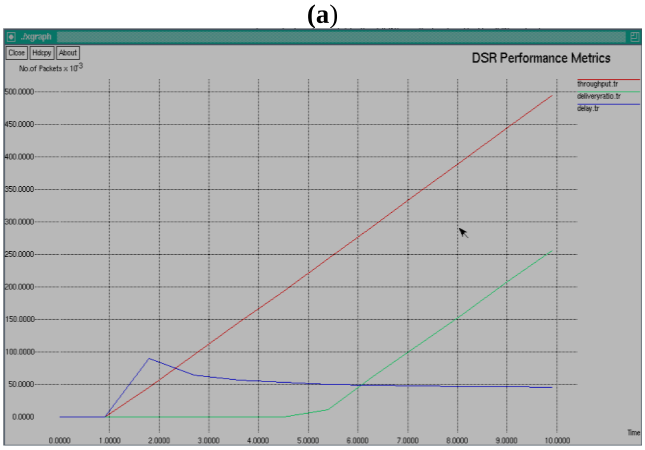

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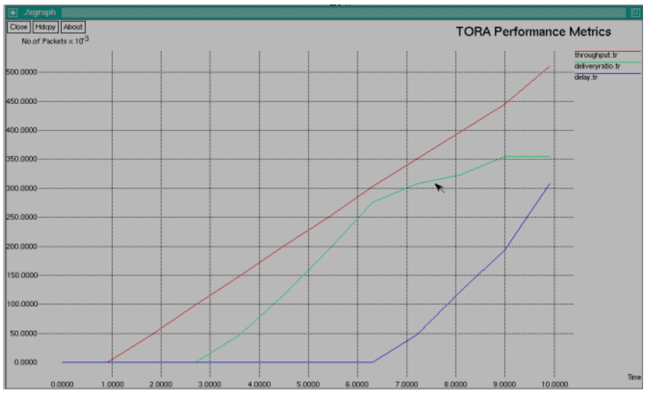

(c)

Figure 5: Graphical representation of performance metrics using 20 nodes (a) AODV (b) DSR (c) TORA

Two different simulation scenarios are generated and the simulating nodes are varied as 10 and 20. Other network parameters are kept constant during the simulation. The simulation characteristics used in this research, that is, throughput, packet delivery ratio and end-to-end delay are unique in nature, and are very important for detailed performance evaluation of any networking protocol.

It is observed that the packet delivery ratio is very high in case of AODV initially but it decreases substantially if the simulating nodes increases. In case of DSR simulation the packet delivery ratio is high in first scenario but it decreases initially in second if the simulating node increases. TORA packet delivery ratio is also increased if the number of nodes increased.

Throughput reflects the completeness and accuracy of the routing protocol. TORA has a high throughput as compared to AODV and DSR.

From the X 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. AODV and DSR show poor delay characteristics as their routes are typically not the shortest. 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. In DSR Route Discovery is fast, therefore shows a better delay performance than the other reactive protocols.

VI. CONCLUSION

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 network 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.

We have compared three On-demand routing protocols, namely, Ad hoc On-Demand Distance Vector Routing (AODV), Dynamic Source Routing (DSR) and Temporally ordered routing algorithm(TORA).The simulation of these protocol has been carried out using Network Simulator (NS-2.28).

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

AODV in our simulation experiment shows to have the overall best performance because it provides almost identical results in both scenario. It has an improvement of DSR and DSDV and has advantages of both of them. TORA performs better when mobile nodes increased and has a high throughput as compared to AODV and DSR. 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. Increase in the number of nodes will cause increase in the mean time for loop detection.

FUTURE WORK

In this work other network parameters such as simulation time, traffic type-CBR, etc. are kept constant. Whereas the number of nodes 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.

ACKNOWLEDGMENT

We would also to thank all the staff members of Computer Science & Engineering Department of Meerut Institute of Engineering and Technology for providing us all the facilities required for the completion of this work.

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