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Performance Evaluation of AODV, LEACH & TORA Protocols through Simulation

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Abstract*— A Mobile Ad-Hoc Network (MANET)[1][2][3][4][5][6][7][8] is a collection of wireless mobile nodes forming a temporary network without using any centralized access point or administration. MANET protocols have to face high challenges due to dynamically changing topologies, low transmission power and asymmetric links of network. MANET is a spontaneous network. It is useful when dealing with wireless devices in which some of the devices are part of network only for duration of a communication session. An attempt has been made to compare the performance of three protocols AODV, LEACH, TORA. AODV stands for ad-hoc on demand distance vector. It's aim is to reduce the number of broadcast messages sent throughout the network by discovering routes on demand instead of keeping complete up to date route information. TORA which based on the concept of link reversal. this is adaptive, scalable routing algorithm. The Concept of TORA is that control messages are localized to a small set of nodes nearby a topological change. TORA finds multiple routes from source to destination in a highly dynamic mobile networking environment. LEACH (low energy adaptive clustering hierarchy). LEACH is clustering based routing protocol which minimizes global energy usage by distributing load to all other nodes at different point in time. It will outperform static clustering algorithm & it require nodes to be volunteer & high energy cluster head that choose to be CH at a given time & not ideal for large geographical areas. Comparison is made on the basis of packet delivery fraction, average end-to-end delay, packet loss and the simulator used is NS2 [11]. In this paper we have taken all the scenarios for simulation and then analyzed the results. AODV shows the best performance with its ability to maintain connection by periodic exchange of information required for TCP network and also best in case of packet delivery fraction and TORA performs well when number of node increases for packet delivery fraction. As we analyzed by NS2, LEACH performs well for average end to end delay and packet loss. TORA does not perform well for packet loss and average end to end delay.

***Keywords*— MANETS, IETF, AODV, LEACH, TORA**

I. INTRODUCTION

MOBILE AD-HOC NETWORKS [3][8]

MANET is an infrastructure less collection of mobile nodes that can arbitrarily change their geographical locations such as these networks have dynamic topologies which are composed of bandwidth constrainted wireless links. MANET is the quick remedy for any disaster situation. MANET is a collection of mobile network nodes with the capability of transmitting & receiving information wirelessly. Since 1980s, mobile cellular networks have been in use and the use of wireless networks is increasing tremendously. Three types of mobile wireless networks exist: infrastructure-networks, ad-hoc networks and hybrid networks. An infrastructure-network consists of a group of mobile nodes with some bridges. These bridges called base-stations connect the wireless network to the wired network. Communication takes place between two or more nodes by first searching for the nearest base-station and information flow takes place between the two nodes with the base-station as a bridge between them. In ad-hoc networks, there are no centralized base-stations, fixed routers and central administration. All nodes move randomly and are capable of discovering and maintaining the routes between them. Each node acts as a router and communicates to other for a short interval of time like: emergency searches, quickly sharable information like meetings etc. A hybrid-network makes use of both the networks: infrastructure and ad-hoc networks.

A. *Characteristics Of MANETs*

- *Dynamic topology:* Topology of network changes rapidly and randomly consisting of both bi-directional and unidirectional links [3][9].

Fig.1: A Mobile Ad-Hoc Network

- *Bandwidth-constrained, variable capacity links:* The capacity of wireless-networks is significantly lesser than the hardwired systems. Considering the multiple access, fading, noise, and interference conditions, etc. [3][9] the throughput of wireless networks is often much less than a radio's maximum transmission rate.
- *Energy-constrained operation:* All MANET nodes rely on exhaustible means for their energy like battery, so energy-conservation is taken into care [3][8][9].
- *Limited physical security:* Wireless systems are less secure than the hardwired ones. The possibility of eavesdropping, spoofing and denial-of-service attacks should be considered. Decentralized nature of network control in MANETs [6] provides additional robustness against the single points of failure of more centralized approaches to reduce threats in wireless networks [3][8][9].

B. Applications of MANET

Cooperative and mobile data exchange in case of industrial and commercial applications. MANETs combined with satellite-based information delivery, provides an extremely flexible method for establishing communications for fire/safety/rescue operations [3][8]. MANET can also be used by students to participate in an interactive lecture using laptop computers.MANET can also be used in disaster relief operations after a hurricane or earthquake and mine site operation.

C. Description Of Mobile Ad-Hoc Network Routing Protocol

Routing in MANETs

Mobile Ad-hoc networks are self-organizing and self-configuring multi-hop wireless networks, where the structure of the network changes dynamically [3][8]. Nodes in the network cooperate in multi-hop forwarding and utilize the same random access wireless channel. A node forwards and receives packets to and from other nodes, and hence acts both as client or a server. Since the nodes are mobile, a dynamic routing protocol is needed. Since the routing in ad-hoc networks has become a challenging issue, the Internet Engineering Task Force (IETF), MANET [6] working group is working continuously to ensure standardization of routing protocols.

Classification of Routng Protocol

The routing protocols can be divided as flat-routing, hierarchical routing and geographic position assisted routing depending on the network structure [2][8].

Flat Routing Protocols:

These protocols are further subdivided into Reactive routing-protocol (on-demand), Proactive routing protocol (table-driven) and Hybrid-protocols [3][8]. Proactive routing is mostly based on LS (link-state) while on-demand routing is based on DV (distance-vector).

Proactive (Table-Driven) Routing Protocols [2][8]:

In this routing protocol, each node is allocated more than one table containing the latest information about the routes in the network with respective costs of the routes between two nodes. Since, there are many table-driven routing protocols; routing information-updation, the number of tables related to each protocol differs them in one or other way. The protocols work good only when the network is small, as the increased number of nodes will cause more overhead of updation of information inside a table related to each node with more bandwidth consumption. An example of this protocol is Destination Sequenced Distance Vector (DSDV) [6].

Reactive (On-Demand) Protocols [2][8]:

As the name suggests, there is no procedure of maintaining and updating tables according to latest route topology. Whenever a communication is desired, route discovery by flooding the route request packets throughout the network is done leading to connection establishment and further sending and receiving of packets within the network. Examples of On-demand routing protocol are Dynamic Source Routing (DSR), Ad-hoc On-demand Distance Vector Routing (AODV) [6].

Hybrid Routing Protocols [2][8]:

The different types of delays and overheads suffered by reactive and proactive protocols are recovered in a hybrid network. Whenever the network is small, proactive routing is used and reactive routing is used for larger networks making it a hybrid network. The protocol is suitable for highly versatile networks, characterized by a large range of node mobility and large network diameters. An example of it is ZRP (Zone Routing Protocol) [3].

Hierarchical Routing Protocols [2][8]:

A Hierarchical-network is used when the size of network inside a MANET[8] increases tremendously. Some examples of the protocol are Hierarchical State Routing (HSR), Zone Routing Protocol (ZRP), Cluster-head Gateway Switch Routing Protocol (CGSR), Land-Mark Ad-Hoc Routing Protocol (LANMAR)[3][8][9][7].

Geographical Routing Protocols [2][8]:

Two approaches to geographic mobile ad- hoc networks are i.e. Actual geographic coordinates (as obtained through GPS – the Global Positioning System) and Reference points in some fixed coordinate system. For the effective location-based routing, the routing updates must be done faster in compare of the network mobility rate as the node positions changes quickly in the network. Some of its examples are: Geo-Cast (Geographic Addressing and Routing), DREAM (Distance Routing Effect Algorithm for Mobility), GPSR (Greedy Perimeter Stateless Routing).

Description of routing protocols : AODV, LEACH and TORA

Ad-hoc On Demand Distance Vector Routing [1][7]

It is a purely On-Demand route acquisition system. It is better than DSDV network as the size of network may increase depending on the number of nodes. It uses traditional routing tables, one entry per destination. This is in contrast to DSR, which can maintain multiple route cache entries for each destination. Without source routing, AODV relies on routing table entries to propagate an RREP back to the source and subsequently to route data packets to the destination. AODV uses sequence number maintained at each destination to determine freshness of routing information and to prevent routing loops. All routing packets carry these sequence number.

LEACH (Low energy adaptive clustering hierarchy)
LEACH is based on a hierarchical clustering structure model and energy efficient cluster-based routing protocols for sensor networks. In this routing protocol, nodes self-organize themselves into several local clusters, each of which has one node serving as the cluster-head. In order to prolong the overall lifetime of the sensor networks, LEACH changes cluster heads periodically. LEACH has two main steps: the set-up phase and the steady-state phase. In the set-up phase, there are two parts, the cluster-head electing part and the cluster constructing part. After the cluster-heads have been decided on, sensor nodes (which are chosen as cluster-heads) broadcast an advertisement message that includes their node ID as the cluster-head ID to inform non-cluster sensor nodes that the chosen sensor nodes are new cluster-heads in the sensor networks. They use the carrier-sense multiple access (CSMA) medium access control (MAC) protocol to transmit this information. The non-cluster sensor nodes that receive it choose the most suitable cluster-head according to the signal strength of the advertisement message, and send a join request message to register on the chosen cluster-head. After receiving the join message, the cluster-heads make a time division multiple-access (TDMA) schedule for data exchange with non-cluster sensor nodes. Then, the cluster head informs the sensor nodes of its own cluster and the sensor nodes then start sending their data to the base station via their cluster-head during the steady-state phase. the balance of energy consumption between all nodes in this manner does not ensure that the sensing coverage is preserved sufficiently

TORA (Temporally ordered routing algorithm)
This is based on a link reversal algorithm. It is designed to discover routes on demand, provide multiple routes to a destination, establish route quickly & minimize communication overhead by localizing algorithm reaction to topological changes when possible. Concept of TORA is that control messages are localized to a small set of nodes nearby a topological change & nodes maintain routing information about their immediate one hop neighbours. Three basic functions of TORA are: route creation, route maintenance, route erasure. Nodes uses height matric to establish a direct cyclic graph rooted at the destination during the route creation & route maintenance phase. The link can be either upstream or downtream based on the relative height matric of the adjacent nodes.

D. ***Sub Categories of MANET***
VANET (Vehicular adhoc network) : Vehicular adhoc network is a form of MANET. It provides wireless communication among vehicles and vehicle to road side equipments. The communication between vehicles is used for safety and for entertainments as well. The performance of communication depends on how better the routing takes place in the network. Routing of data depends on routing protocol being used in network. It allows an automobile to become both a wireless node and a router.it can communicate with each other , with roadside infrastructure nodes(which may, in turn connect to the internet), as well as with pedestrians equipped with wireless devices such as a smart phones or PDAs. Because of the pervasiveness of roads and highways, VANET deployment can cover very large areas. It enables a wide range of applications. Basic applications are aimed at improving road safety (collision warnings, weather and road hazard alerts, road closure and detour information) as well as providing driver convenience(notification of real time traffic information, parking availability, location based services).
WSN (Wireless sensor network) : the original motivation for WSN research stemmed from the vision of smart dust in late 1990s. WSN consists of a large number of small, cheap and resource constrained sensors as well as a few base stations or sinks. In most WSN setting sensor collect data from environment and forward it hop by hop to the sink. A sink is a powerful entity that may serve as a gateway to another network, a data processing or storage center, or an access point for human interface. WSN deployment can be adhoc; for example, sensor might be air dropped over a designated area without exact prepositioning. Because of their allegedly eaily deployment, WSNs have appeal for a wide range of applications in military, environmental, disaster relief and homeland security domains.
WMN (Wireless mesh network): WSN is a mesh network created through the connection of wireless access points installed at each network user's locale. Each network user is also a provider, forwarding data to the next node. The networking infrastructure is decentralized and simplified because each node need only transmit as far as the next node. WMN could allow people living in remote areas and small business operating in rural neighborhoods to connect their networks together for affordable internet connection. Wi-fi card in your laptop might become an access point in addition to its normal role as network client. In full mesh topology every node communicates with every other node not just back and forth to a central router. In partial mesh network node communicate with all nearby nodes but not distant node. All communication is between the point and access point servers. The client server relationship is the basis for this technology.

In section I we will describe the introduction of MANET, different characteristics of MANET, routing in MANET. What different protocols we use in MANET and description of all protocols and why we use AODV, LEACH, TORA for comparison. Then we will describe the sub category of MANET like VANET, WSN, WMN.
In section II we will describe related work in which different comparisons of different protocols are done. In section III we will describe the experimental evaluation of 3 protocols (AODV, LEACH, and TORA).

II. RELATED WORK

There are many comparisons like performance comparison of AODV, DSR, DSDV, and TORA according to effect of speed, no. of packets transmitted, no. of packets lost, bytes, bitrate, packet delay. By that comparison they showed that DSR, TORA shows the better performances as compared to AODV, DSDV. Using NS2 they presented simulation.[4].
In [5] there is comparison of different protocols in MANETs and WSNs. In MANET there are AODV, DSDV, and TORA protocol. In which AODV performance is

better in MANET but TORA is very poor and unreliable. Whereas in WSN, protocols taken AODV, DSDV, TORA, LEACH. Performance of AODV, LEACH is better but AODV is less reliable than LEACH because the result of AODV is fluctuated but that of LEACH is not. AODV performs better in both MANETs and WSNs.
In [6] new version of LEACH is created called VLEACH. We concluded that no. of messages created by VLEACH is less than the message created by original LEACH. If messages created by VLEACH are less that mean the network energy remaining using VLEACH is more than the remaining network energy using original LEACH. Therefore version of LEACH performs much better.
In [7][8] there are comparison of DSR, ZRP, LAR1, AODV, in which ZRP fails to deliver a greater percentage of the originated data packets. When network size grows AODV performs better therefore DSR, ZRP completely fail in performance in large network. DSR shows extreme high delays. LAR1 is better in term of delivery ratio and routing overhead but LAR1 aditionally uses geographical information.
In[9] there is comparison of AODV, DSDV routing protocols in MANETs using NS2. Delay in AODV is high but later low but in case of DSDV it is very low at starting and increased gradually specially for UDP packets. DSDV gives better jitter performance due to low node mobility and free channel. But packet arrival time and jitter will be high in AODV due to high node mobility and availability of free channel. Therefore performance of AODV is better than DSDV routing protocol for real time application.

III. EXPERIMENTAL EVALUATIONS OF THREE PROTOCOLS

AODV: It is the base protocol. It tries to minimize required no. of broadcast. It is the improved version of DSDV.
It creates routes on a on demand basis as opposed to maintain a complete list of routes for each destination. It has path discovery process, maintaining routes. It leads to frequent system wide broadcasts. Its size is strongly limited.
AODV provides both a route table for unicast routes and a multicast route table for multicast routes. It combine unicast, multicast, and multicast communications but it uses symmetric links between neighboring nodes.

LEACH: A node in network is no longer useful when its battery dies so we use LEACH. It space out the lifespan of the nodes allowing it to do the only minimum work it needs to transmit data. It has 2 phases: setup phase, where cluster head are chosen and steady phase, in which CH is maintained when data is transmitted between nodes. Goal of LEACH is to increase the life of network. It is clustering based routing protocol minimizes global energy usage by distributing load to all nodes at different point in time.

TORA: This is adaptive and scalable routing algorithm based on the concept of link reversal. It finds multiple routes from source to destination in a highly dynamic mobile networking environment. The concept of TORA is that control messages are localized to a small set of nodes nearby a topological change. Node maintain routing information about their immediate one hop neighbors. It's basic function is route creation, route maintenance and route erasure.
Performance evaluation of AODV, LEACH, TORA is not evaluated till now, so we are showing experimental setup of these three protocols, by which we get different different results using NS2

A. Experimental Setup using NS2 and evaluating protocol parameters

NS2 is a discrete event network simulator and is a variant of the REAL network simulator. Initially intended for wired networks, the Monarch Group at CMU have extended NS2 to support wireless networking such as MANET and wireless LANs as well. Most MANET routing protocols are available for NS2 as well as 802.11 MAC layer implementation.
In scenario 1 following parameters have been used such as number of nodes, simulation time, routing protocols, simulation model, MAC type, Link layer type, packet size, interface type, pause time, node speed, queue length, traffic type.

B. Simulation Experiment and Result

A simulation experiment was performed by using NS2[ ] simulator to study the performance of three protocols mentioned above-AODV, LEACH, TORA. Simulation experiment was performed on a computer with dual core 1.7GHz processor and 2GB RAM. Simulation experiment was performed twice by taking 20, 40, 60, 80 in first scenario and 50, 100, 150,200, 300 in second scenario to study the performance of three protocols in MANET. Simulation time will be 50 sec for first scenario nad 100 sec for second scenario, pause time will be 00 sec and 10 sec for first and second scenario, node speed will be 20m/s and 10 m/s for first and second scenario. Our parameter that were taken for simulation are also shown in table

TABLE1:

Various parameters used while varying number of connections

PARAMETER	VALUE
Number of nodes	20, 40, 60, 80, 100 50, 100, 150, 200, 300
Simulation time	50 sec, 100 sec
Routing protocol	AODV, LEACH, TORA
Simulation model	Two Ray Ground
MAC Type	802.11
Link Layer Type	LL
Interface Type	Queue
Traffic Type	CBR
Packet Size	512 MB
Queue Length	50
Pause Time	00 sec, 10 sec
Node speed	20 m/s, 10 m/s

C. Experimenting AODV, LEACH, TORA Protocols

The performance of the network was evaluated by using three matrics (i) packet delivery fraction (PDF) (ii)average end-to-end delay (iii)packet loss

Packet delivery fraction(PDF): it is a ratio of data packet delivered to the destination to those generated by the constant bit rate (CBR) sources.

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

Packet loss: a packet is dropped in two cases : the buffer is full when packet needs to be buffered and the time that the packet has been buffered exceeds the limit.

Simulation is performed by taking different node values. Number of packet delivery is increased in starting 94.18 then remain constant not decrease much in AODV but in TORA packet delivery fraction is not good for starting nodes but as we increase number of nodes packet delivery fraction will increase from 78.02 to 89.22. NS2 simulator generated a AODV.tcl, LEACH.tcl, TORA.tcl file which contains all the statistics regarding number of packet send, average end-to-end delay(in seconds) and packet loss.

D. Using packet delivery fraction (PDF)

Packet delivery fraction is calculated by extracting data from AODV.tcl file, LEACH.tcl file, TORA.tcl file and three curves one for AODV, one for LEACH, one for TORA are plotted by taking %age of nodes on X-axis and %age of PDF on Y-axis as shown in figure for 20, 40, 60, 80, 100 nodes and 50, 100, 150, 200, 300 nodes respectively from figure2 (a),(b). it is quite clear that PDF for AODV is better but when we increase number of nodes then PDF in TORA will increase and in LEACH PDF performance is not good.

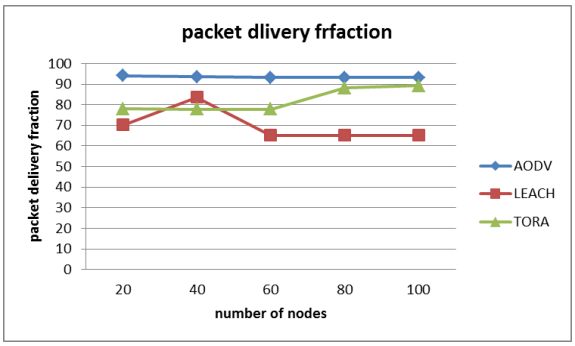

Fig.2(a) packet delivery fraction for AODV, LEACH, TORA Scenario 1

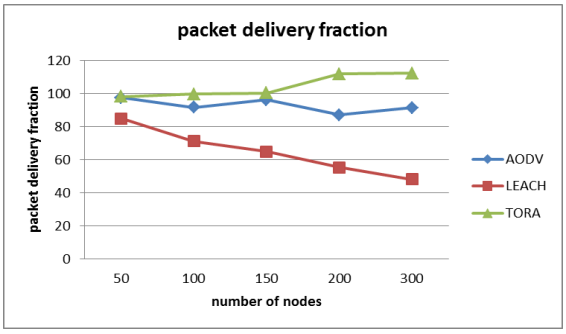

Fig.2(b) packet delivery fraction for AODV, LEACH, TORA, Scenario 2

E. average end-to-end delay

Average end-to-end delay is calculating by extracting data from AODV.tcl , LEACH.tcl, TORA.tcl file and three curves one for AODV, one for LEACH, one for TORA are plotted by taking %age of number of nodes on X-axis and average end-to-end delay on Y-axis as shown in figure3(a),(b) for 20, 40, 60, 80, 100 nodes and 50, 100, 150, 200, 300 nodes respectively. From figure, it is quite clear that the average end-to-end delay has increased in case of AODV, due to overhead increased. But it is less in LEACHand it has been calculated that average end-to-end delay will increase in TORA as number of nodes increases.

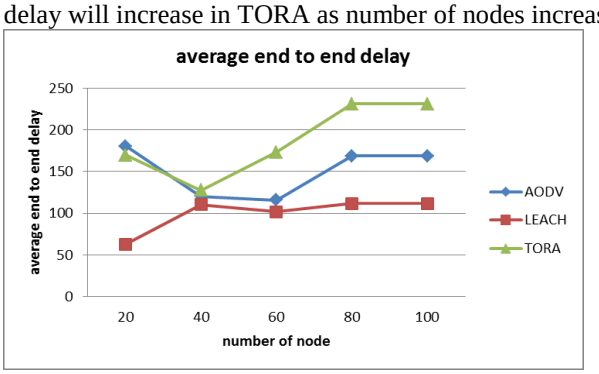

Fig.3(a) average end to end delay for AODV, LEACH, TORA Scenario 1

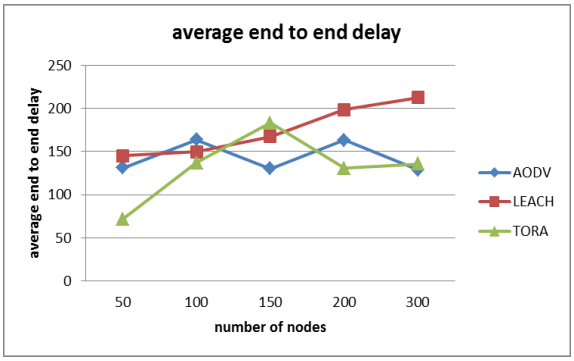

Fig.3(b) Average end to end delay for AODV, LEACH, TORA Scenario 2

F. packet loss

Packet loss is calculated by extracting data from AODV.tcl, LEACH.tcl, TORA.tcl files and three curves, one for AODV, one for LEACH, one for TORA are plotted by taking 5age of number of nodes on X-axis and packet loss on Y-axis as shown in figure for 20, 40, 60, 80, 100 nodes and 50, 100, 150, 200, 300 nodes respectively. From figure4(a),(b) it is quite clear that the packet loss has increased in case of AODV with some value. In LEACH packet loss is less as compared to AODV, TORA. In TORA packet loss will increase due to delay.

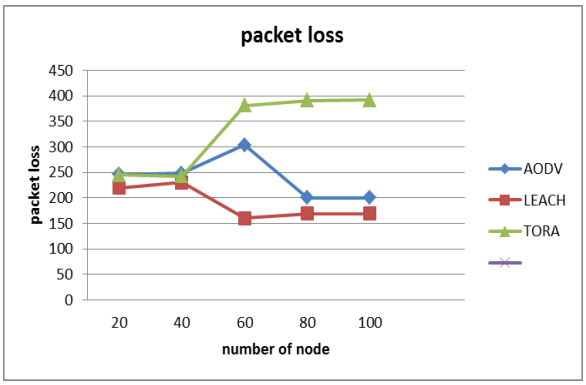

Fig.4(a) Packet loss for AODV LEACH, TORA Scenario 1

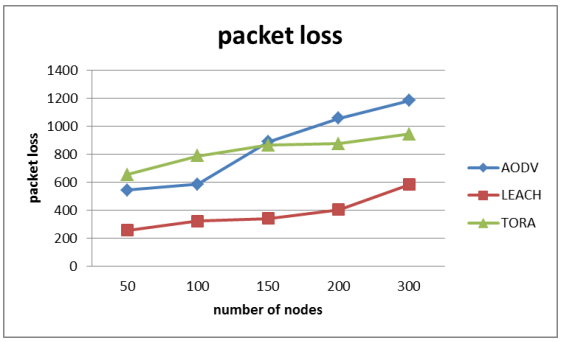

Fig.4(b) Packet loss for AODV, LEACH, TORA Scenario 2

IV Conclusion

In this paper we have evaluated three protocols- AODV, LEACH, TORA. These protocols have been tested on NS2 simulator by using three metrics- packet delivery fraction, average end-to-end delay, packet loss.

The packet delivery fraction (PDF) metric has shown that AODV and TORA gives better performance but LEACH is not better for PDF. Hereas in TORA, initial value will be less for PDF but as we increases number of nodes PDF will increase.

The average end-to-end delay metric has shown that average delay has increased in case of AODV, TORA, but in case of LEACH, it will be less as compared to AODV, TORA.

The packet losss metric has shown that number of packet losss in AODV, TORA will be more due to overhead, but in case of LEACH packet loss will be less.

We can say that LEACH protocol has become better for average end-to-end delay and packet loss.

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