Analysis and Simulations of Routing Protocols with Different Load Conditions of MANETs

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Abstract- In this paper, we have compared important characteristics of MANET proactive routing protocol (DSDV), reactive protocols (AODV, DSR and TORA) and hybrid protocol (ZRP). Extensive simulations are being carried out with different load conditions of MANETs. The offered network loads in the performance plots are characterized by three parameters i.e. packet size, number of connections i.e. source destination pair and packet arrival rate.
Keywords- MANET, AODV, DSR, DSDV, TORA and ZRP.

I. INTRODUCTION

A Mobile Ad-Hoc Network (MANET) is an autonomous collection of distributed mobile users. Every host in a MANET works as a source and a sink, and also relays packets for other hosts and is thus a router as well. This type of network can be used in fire, safety, rescue, disaster recovery operations, conference and campus settings, car networks, personal area networking, etc. MANETs have similar characteristics to other wireless communication networks, which are mainly attributed to the wireless channel's properties. A wireless channel is error-prone, which means that link bandwidth and packet delay are unpredictable due to multi-path fading, interference, and shadowing. Besides this common characteristic, MANETs have their own features: They are autonomous and infrastructure less; they utilize multi-hop routing; they support a dynamic topology; the nodes are energy constrained; the bandwidth is limited; and they are self creating, self-organizing and self-administering [1].

This paper is organized as follows. In Section II we give a brief description of the five candidates routing protocol considered for our study. Section III presents the details of simulation setup. Section IV presents the performance metrics used in our study. Simulation results followed by discussion are described in Section V. Finally, conclusions are presented in Section VI.

II. ROUTING PROTOCOLS FOR MANETs

Routing protocols for MANETs can be classified according to the routing strategy followed to find a path to the destination [2]. We have considered for our study the following proactive, reactive and hybrid routing protocols.

A. Destination Sequenced Distance Vector (DSDV) Routing Protocol

DSDV [3] is a proactive routing scheme and is the expansion of traditional distance vector routing protocol. In this routing protocol, routing messages are exchanged among mobile nodes that are within range of one another. Routing updates may be triggered or routine. A packet for which the route to its destination is not known is cached while routing queries are sent out. The packets are cached until route-replies are received from the destination.

B. Dynamic Source Routing (DSR) Routing Protocol

DSR [4] protocol is a reactive routing protocol, which means that nodes request routing information only when needed. DSR is based on source routing concept, where the sender constructs a source route in the packet's header. This source route lists all the addresses of the immediate nodes responsible for forwarding the packet to the destination. When a sender wants to communicate with another node (destination), it checks its route cache to see if there is any routing information related to that destination. If route cache contains no such information, then the sender will initiate a route discovery process by broadcasting a route request. If the route discovery is successful, the initiating host receives a route reply packet listing a sequence of network hops through which it may reach the target.

DSR also utilizes a route maintenance scheme. This scheme, however, uses the data link layer acknowledgements to learn of any lost links. If any lost link was detected, a route error control packet is sent to the originating node. Consequently, the node will remove that hop in error from the host's route cache, and all routes that contain this hop must be truncated at that point.

C. *Ad-hoc On-demand Distance Vector (AODV) Routing Protocol*

AODV [5] is a combination of both DSR and DSDV protocols. It has the basic route-discovery and route-maintenance of DSR protocol. AODV routing protocol uses broadcast discovery mechanism. To ensure that routing information is up-to-date, a sequence number is used. The path discovery is established whenever a source node wishes to communicate with another provided that it has no routing information of the destination in its routing table. Route discovery is initiated by broadcasting a route request control message that propagates in the forward path. If a neighbor knows the route to the destination, it replies with a control message route reply that propagates through the known path. Otherwise the neighbor will re-broadcast the route request message [6].

AODV maintains paths by using control messages called *Hello* messages, used to detect that neighbors are still in range of connectivity. If for any reason a link was lost (e.g. nodes moved away from range of connectivity) the node immediately engages a *route maintenance* scheme by initiating route request control messages. The node might learn of a lost link from its neighbors through route error control messages "*RERR*". *Hello* messages are sent on an interval of 1 second, while nodes can tolerate a loss of 2 *Hello* messages before declaring a lost link.

D. *Temporally Ordered Routing Algorithm (TORA)*

TORA [7] is a distributed routing protocol based on link reversal algorithm. At every node a separate copy of route request packet is sent for every destination. When a node needs a route to a given destination it broadcasts a query message containing the address of the destination for which it requires a route. This packet travels through the network until it reaches the destination or an intermediate node that has a route to the destination node. This recipient node then broadcasts an update packet listing its height with respect to the destination.

E. *Zone Routing Protocol (ZRP)*

ZRP [8] is a hybrid of a reactive and a proactive protocol. Since the advantage of either of the approaches depends on the characteristics of the network like the degree of mobility, it could be beneficial to combine them. It divides the network into several routing zones and specifies two totally detached protocols that operate inside and between the routing zones. The IntrA-zone Routing Protocol (IARP) operates inside the routing zone and learns the minimum distance and routes to all the nodes within the zone. The protocol is not defined and can include any number of proactive protocols, such as distance vector or link-state routing. The second protocol, the IntEr-zone Routing Protocol (IERP) is reactive and is used for finding routes between different routing zones.

The protocol then broadcasts (i.e. broadcast) a Route REQuest (RREQ) to all border nodes within the routing zone, which in turn forwards the request if the destination node is not found within their routing zone. This procedure is repeated until the requested node is found and a route reply is sent back to the source indicating the route. IERP uses a Broadcast Resolution Protocol (BRP) that is included in ZRP. The comparisons among these protocols are summarizing in the table I.

TABLE I COMPARISON OF TABLE-DRIVEN, ON-DEMAND AND HYBRID ROUTING PROTOCOLS

Parameter	**Table-driven Routing Protocols**	**On-demand Routing Protocols**	**Hybrid protocol**
Route availability	Always available irrespective of need	Computed when needed	Computed when needed
Routing philosophy	Flat	Flat	Hybrid, distance vector and link state
Periodic route updates	Always required	Not required	Only for IARP
Handling mobility	Updates occur at regular intervals	Use localized route discovery	IARP notifies IERP when change in routing zone
Control traffic generated	Usually higher than On-Demand	Increases with mobility of active routes	High when IARP interact with IERP as needed
Delay	Small as routes are predetermined	High as routes are computed when needed	Small as it used IARP
Scalability	Usually up to hundred nodes	Usually higher than Table-driven	Higher

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III SIMULATIONS DETAILS

Extensive simulations have been carried out using NS-2 simulator. NS-2 supports two languages, system programming language C++ for detail implementation and scripting language TCL for configuration and experimenting with different parameters quickly. NS-2 has all the essential features like abstraction, visualization, emulation, traffic and scenario generation. NS-2 architecture is shown in figure 1. Normally for large topologies, the node movement and traffic connection patterns are defined in separate files. These files define a topology of 670m x 670m with 10 to 150 nodes moving with a speed of up to 20 m/s with the pause time varying in discrete interval up to 900 sec. Each node is assigned a starting position, speed and a direction to move to the destination.

A traffic generator named *cbrgen* is developed to simulate constant bit rate (CBR) sources in NS-2. Each CBR packet size is 512 bytes and generates 1- 4 packets/sec. We have chosen two-ray ground reflection model. MAC layer uses IEEE 802.11 DCF (distributed coordination function). A mobility generator named *setdest* is developed to simulate node movement. For fairness, identical mobility and traffic scenarios are used across protocols. Important simulation parameters are summarized in Table II.

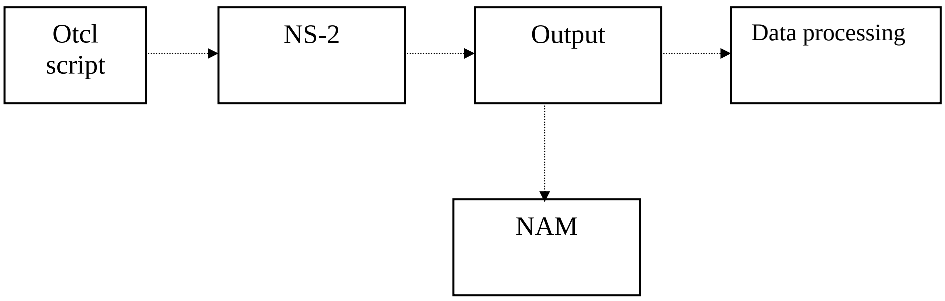

Figure 1: NS2 Architecture

TABLE II. SUMMARY OF SIMULATION PARAMETERS

Parameter	**Value**
Ad hoc routing protocol	DSDV, AODV, DSR, TORA and ZRP
MAC type	IEEE 802.11 DCF
Energy model	Node attribute: initial energy, tx Power= 0.6 mW and , rxPower = 0.3mW
Antenna type	Omni directional
Simulation time	900 seconds
Terrain dimension	670m x 670m
Transmission range	250 m
Node speed	0 – 20 m/s in steps of 5 m/s
Traffic type	CBR (UDP)
Data payload	512 bytes/packet
Packet rate	1- 4 packets/sec
Node pause time	0 - 900 s in steps of 100s
Bandwidth	2 Mbps
Traffic sources	10 to 50 in steps of 10
Propagation model	Two-ray ground reflection
Mobility model	Random waypoint
Interface queue type	Drop Tail/Priority Queue
Interface queue length	50 packets

A. Process of Simulation

Following steps are performed to carry out simulation process for the routing protocols.

Step 1 - Scenarios are generated using the setdest utility mentioned above which uses random waypoint mobility model. Here in this simulation scenarios are generated varying the pause time and maximum speed. Example to generate scenario is given as:

setdest -v1 -n 50 – p100 - m 10 -t 900 -x 670 -y 670

Where -v : version 1 or 2 , -n: number of nodes , -p : pause time , -m : maximum speed , -x and - y : area of simulation, -t : simulation time

Step 2 - Traffic pattern is generated using the cbrgen.tcl file given in the indep utilities. In this simulation only one traffic pattern is generated using the following method:

ns cbrgen.tcl - type cbr -nn 50 - seed 1 - mc 40 – rate 0.5

Where - type: type of traffic cbr or tcp, - nn: number of nodes, - seed: seed value, -mc: maximum connection sources, -rate: rate of sending packets.

Step 3 - After generating traffic patterns and scenarios a *tcl script* is written for generation of trace files. These generated traffic patterns and scenarios are fed in to the tcl script and then executed. On the execution of *tcl script* trace files are generated.

Step 4 – When trace files are generated then it is needed to analyze these files using the *awk script.* This simulation is performed to evaluate the performance based on the traffic load.

Step 5 – After analysis of trace files the obtained results are stored in a text file then presented by the graphs using Xgraph utility.

IV. PERFORMANCE METRICS

The following performance metrics are considered to analyze the performance of routing protocols.

Routing Protocol Overhead: The routing protocol overhead describes how many control packets (or in terms of bytes) for route discovery and route maintenance need to be sent in order to propagate the CBR packets. It includes the number of route requests transmitted, number of replies transmitted, number of route errors transmitted and number of route errors resent.

$$\frac{\sum_{i=1}^{s} \text{sum of routing packets transmitted by each source and destination}}{s} \qquad (1)$$

where i, indicates number of trace file
s, indicates the total number of trace files.

Throughput: Throughput is defined as the total number of packets (or in terms of bits) received successfully by the destination per unit time. We have normalized the throughput between 0 and 1 by dividing the total number of bits received successfully per unit time (e.g. $CBR_{recvtotalbits}$) to the total number of bits sent per unit time (e.g. $CBR_{senttotalbits}$).

$$\text{Throughput} = \frac{CBR_{recvtotalbits}}{CBR_{senttotalbits}} \qquad (2)$$

Average End-to-End Delay: The average time it takes a data packet to reach the destination. This includes all possible delays caused by buffering during route discovery latency, queuing at the interface queue, retransmission delays at the MAC, and propagation delay.

$$\frac{\sum_{i=1}^{s} \text{sum of average end-to-end delay for each destination}}{s} \qquad (3)$$

where i, indicates number of trace file
s, indicates the total number of trace files.

V. RESULTS AND DISCUSSION

We have simulated the following four different scenarios.

A. Network Load

The network load is characterized by three parameters i.e. packet size, number of connections and packet arrival rate. Figure 2 shows the throughput for pause time 0, number of nodes 50, node speed 5.m/s and increasing offered network load. Traffic sources are continuous bit rate (CBR) for a major part of the simulation though we have analyzed the effect of caching on TCP traffic as well. The source-destination pairs are spread randomly over the network. Only 512-byte data packets are used. The number of source-destination pairs and the packet sending rate in each pair is varied to change the offered load in the network. The throughput is normalized between 0 and 1 with respect to offered network load.

DSR's throughput starts saturating only at an offered load of around 68%. This is due to the aggressive use of caching and lack of any mechanism to expire stale routes. AODV's throughput however, increases further along before finally starting to saturate around 75% of the offered load. DSDV has low routing overhead and low packet delivery ratio. so the throughput decreases almost as much as AODV. TORA has low throughput because it has a high routing overhead and low packet delivery ratio as the offered load increases. ZRP maintains low overhead and high PDR so its throughput is higher among all the other protocols.

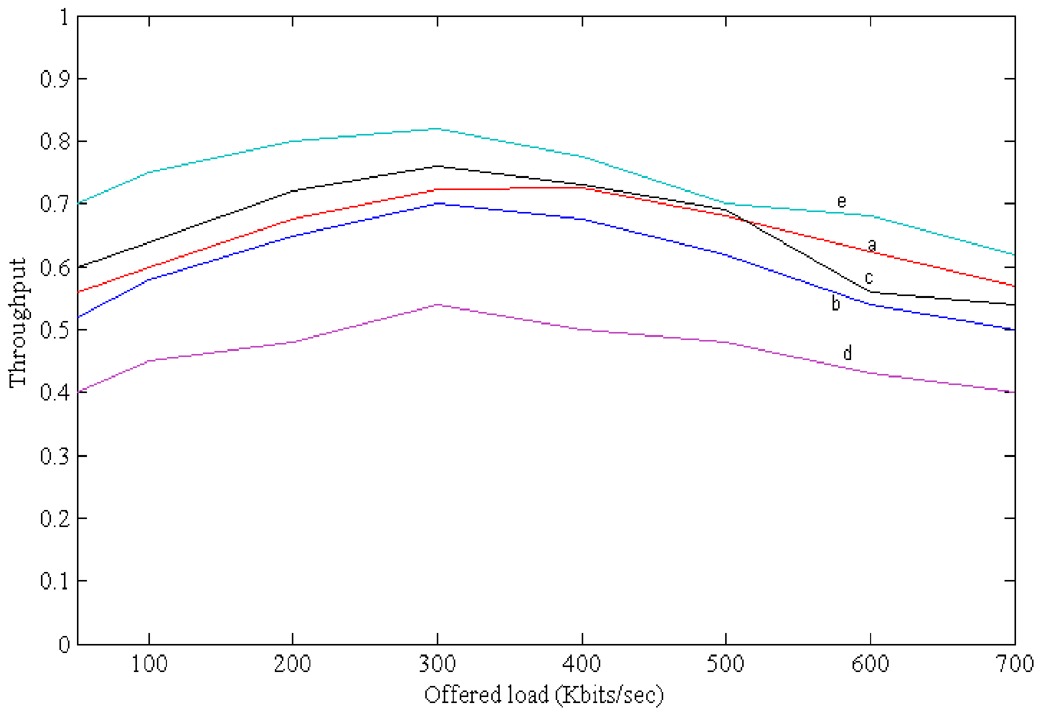

Figure 2 Throughput vs. offered load
(a) AODV (b) DSR (c) DSDV (d) TORA (e) ZRP

B. Throughput vs. Number of Nodes

Figure 3 shows the effect of increasing number of nodes on the throughput of the routing protocols. When the number of nodes in the network is moderate, the topology is dense and the connectivity is high. Hence, with larger number of nodes, all protocols perform well even during small pause time i.e. higher mobility. When nodes start dropping packets due to heavy load the throughput decreases to 60% for DSDV at 150 nodes. As the number of nodes increases more routing decisions are made and the number of routing packets exchanged increases.

Throughput of on-demand routing protocols also decreases as the number of node increases. The path length is greater because the numbers of nodes are increased. Routes are prone to disconnections due to node mobility when the path length is longer. Because any link failure along the path results in the inability of the source to reach the destination and longer routes have a greater probability of route disconnection. The low throughput when using DSR can be explained by the aggressive route caching built into this protocol. AODV shows even better results up 150 nodes and its throughput drops to 85%. ZRP is well scaled because the zone area is small. As the number of nodes increases it exhibit the more properties of reactive protocols.

C. Routing Overhead vs. Number of Nodes

Figure 4 shows the routing overhead as a function of the number of nodes. DSDV protocol has almost constant overhead when the number of nodes is low. As the number of nodes increases the DSDV suffers from heavy overhead due to dense topology. Increasing the number of nodes results in exponential increase in routing overhead. DSR always has a lower routing overhead than AODV. Due to aggressive caching DSR will most often find a route in its cache and therefore rarely initiate a route discovery process unlike AODV. DSR's routing overhead is dominated by route replies (unicast packets), while AODV's routing load is dominated by route requests (broadcast packets).

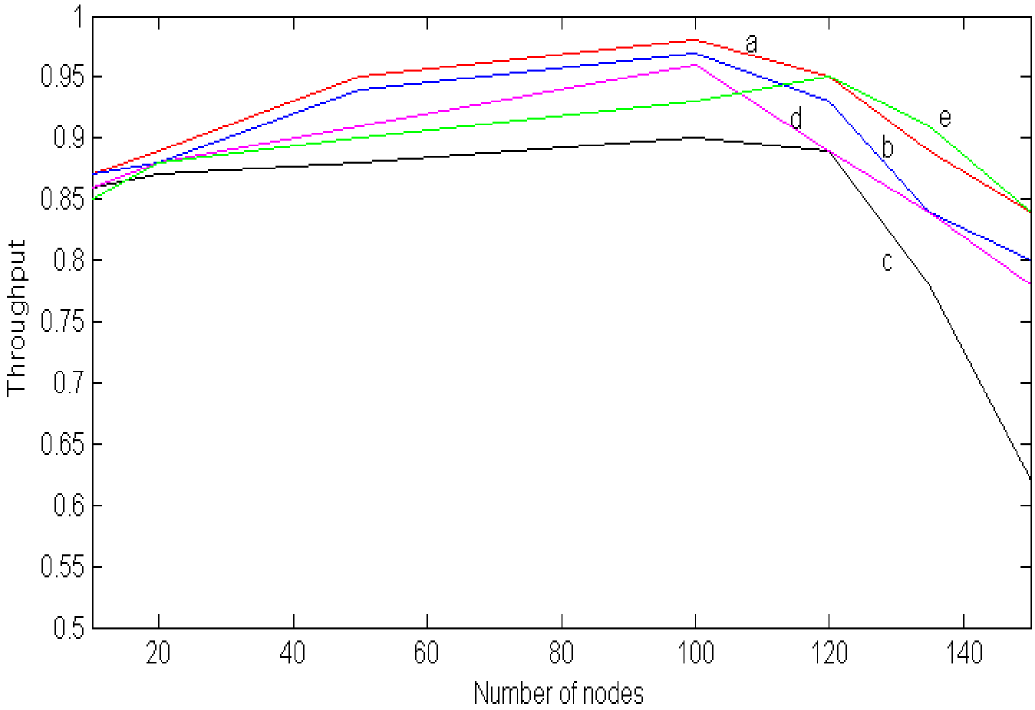

Figure 3 Throughput vs. number of nodes
(a) AODV (b) DSR (c) DSDV (d) TORA (e) ZRP

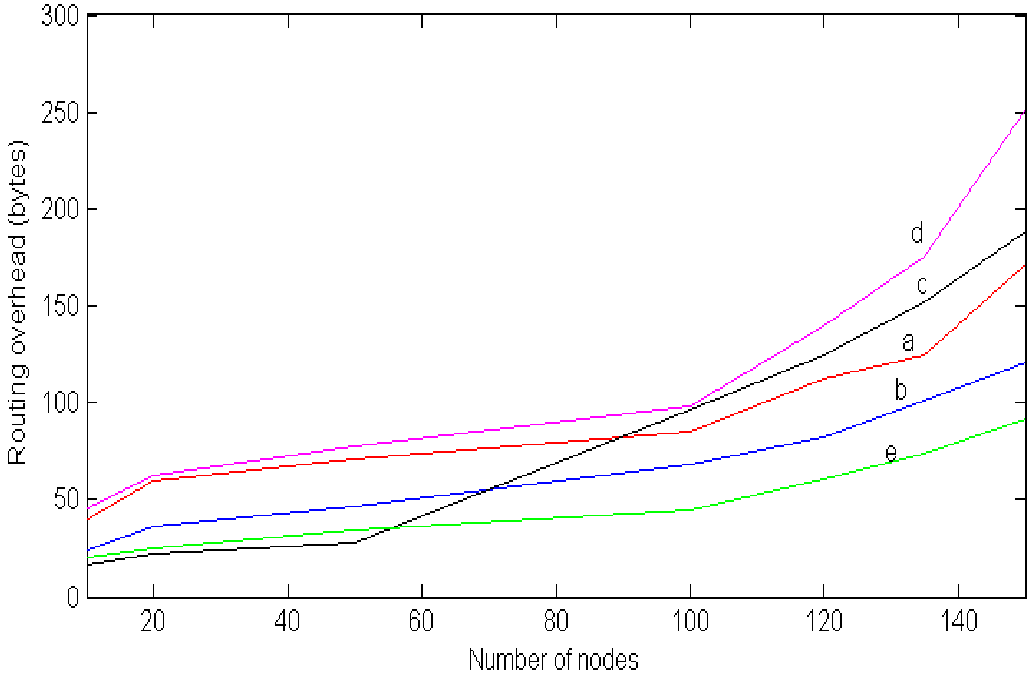

Figure 4 Routing overhead vs. number of nodes
(a) AODV (b) DSR (c) DSDV (d) TORA (e) ZRP

Therefore, DSR performs very well when looking at the routing overhead. The key idea of ZRP is to utilize the features of both proactive and reactive routing. Proactive routing inside a limited zone of radius 2, limit the overhead. Reactive routing reduces the amount of control traffic by discovering the path on-demand for estimations outside the routing zone. Therefore ZRP has low routing overhead among the all protocols.

D Average End-to-End Delay vs. Number of Nodes

Figure 5 shows the average end-to-end delay as a function of number of the nodes. DSR, DSDV, ZRP and TORA are less scalable as the number of nodes increases. The average end-to-end delay also increases. This is due to longer path lengths and higher probability of packet drop DSR often uses stale routes due to the large route cache which leads to frequent packet retransmission and extremely high delay times. AODV is well scale in terms of delay. AODV routing protocol uses broadcast discovery mechanism. The path discovery is initiated by broadcasting a route request control message *RREQ* that propagates in the forward path. If a neighbor knows the route to the destination, it replies with a route reply control message *RREP* that propagates through the reserve path.

DSDV performance severely affected because of more periodic updates among the neighboring nodes. This is why it has a higher delay. Therefore the average end-to-end delay increases as the number of nodes increases because of high density. The ZRP has low delay as compared to DSDV. This is due to the regular updates of the routing table within the zone and the routing optimization by the bordercast resolution protocol. The delay for ZRP is high when compared against AODV, DSR and TORA. This is due to increased in overlapping area as the number of nodes increased.

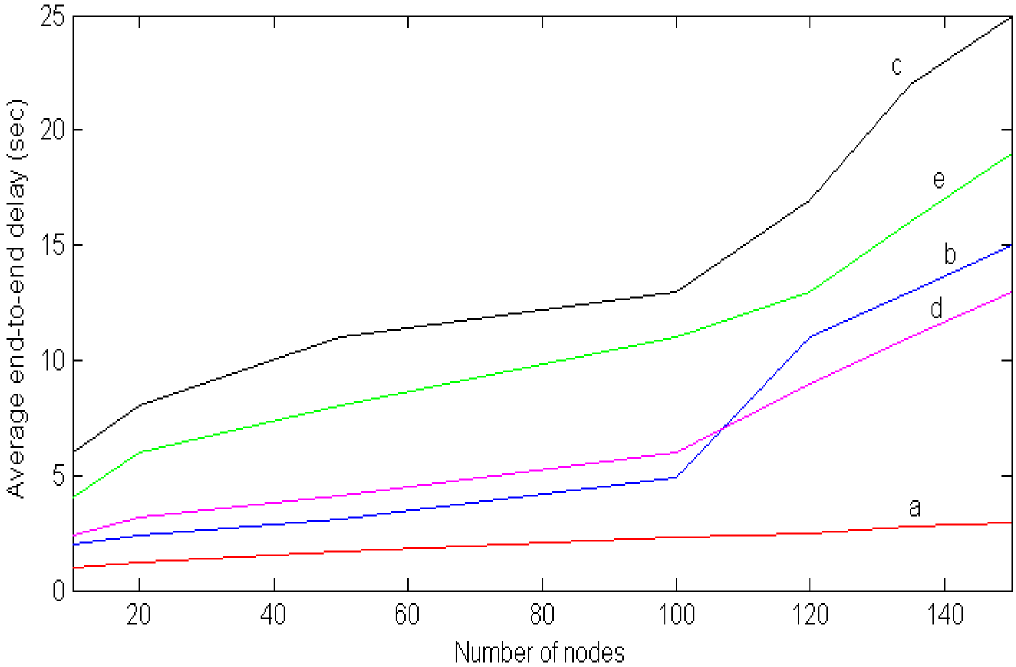

Figure 5 Average end-to-end delay vs. number of nodes
(a) AODV (b) DSR (c) DSDV (d) TORA (e) ZRP

VI. CONCLUSION

This paper is an effort to re-examine the various MANET routing protocols for different load conditions for MANETs. The DSDV is intrinsically not suitable for any mobile network because it involves periodic exchange of information. DSR protocol exhibits good throughput and low average end-to-end delay. AODV protocol is most suitable for the scalability point of view. TORA's performance is relatively poor when throughput and packet delivery ratio are considered as metrics. The ZRP's behavior can be adaptive based on the configuration of the network and the behavior of the users. ZRP can be applied to both small and large networks with high or low load quite well. To the best of our review this is first one to compare network load on all these five candidate protocols all together.

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