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Performance Analysis of Hybrid Protocols in MANETs

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Abstract

A Mobile Ad-hoc Network (MANET) is a self-starting dynamic network made up of mobile nodes where each and every participation node willingly transmits the packets destined to some remote node using wireless transmission. One of the key features of MANET is that it can be formed without any preexisting infrastructure. One of the types of routing protocols used in MANET is the hybrid protocol which combines the advantages of the proactive and the reactive protocols. In this paper, three Hybrid routing protocols in MANET were examined, namely: Adaptive Distance Vector routing protocol, Zone Routing Protocol (ZRP) and Sharp Hybrid Adaptive Routing Protocol (SHARP). Simulation was carried out on the aforementioned protocols using some parameters. After obtaining the results of the simulation tests, the three hybrid protocols were then compared with one another using the metrics of throughput, packet delivery ratio and average end-to-end delay. Based on the result of the performance comparison we were able to ascertain which protocol is better than the others in terms of the metric in question .

Keywords: MANET, ADV, ZRP, SHARP, Throughput, Packet Delivery Ratio, Average End-to-End Delay.

Introduction

A Mobile Ad-Hoc Network (MANET) is a temporary network set up for a particular purpose without the aid of any pre-existing infrastructure [1]. Simply put a mobile ad-hoc network is a type of network that comes together as needed, not necessarily with the support of any existing Internet infrastructure or any fixed stations [2]. MANET can also be defined as a decentralized network of autonomous mobile nodes that are able to communicate with each other over wireless links [3]. The nodes in MANET exchange packets using a radio channel. As a result of the fact that the nodes are not in direct reach of each other, they make use of intermediate nodes to forward packets. Hence, for a Mobile Ad-Hoc Network, threats exist to the network both from external nodes that are not authorized to participate in the network and from internal nodes that have the authorization credentials to participate in the mobile ad-hoc network.

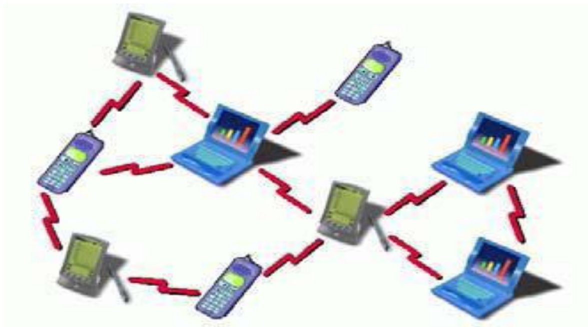

Fig. 1, mobile ad-hoc network

One of the distinguishing features of MANET is that each node must be able to act as a router in order to find the optimal route to forward a packet. Due to the fact that in MANET the nodes may be mobile, entering and leaving the network, the topology of the network continuously changes.

MANETs are faced with some limitations which include the fact that there is limited bandwidth available because of the wireless medium of communication used in the network, and another constraint is power consumption problem due to the fact that MANET is mainly applied to mobile devices such as laptops, mobile phones and personal digital assistants [4].

One of the vital areas of research in MANET is establishing and maintaining the ad-hoc network through the use of routing protocols. The limited resources in MANETs have made the designing of a reliable and efficient routing strategy a colossal problem. A good routing strategy is needed to efficiently make use of the limited resources available while at the same time being adaptable to the changing network conditions which include the network size, network partitioning and traffic density [5]. Routing protocols are used when a packet needs to be transmitted to a destination through a number of nodes. These protocols help to find a route for the delivery of packets to the right destination. Routing protocols can be classified into three namely: A) proactive or table-driven routing protocols B) reactive or on-demand routing protocols C) hybrid routing protocols.

In this paper, the emphasis is on the hybrid routing protocol which is a class of routing protocols that combine the merits of the proactive and reactive protocols. Three hybrid protocols were discussed and analyzed in this paper, they are Adaptive Distance Vector routing protocol, Zone Routing Protocol (ZRP), and Sharp Hybrid Adaptive Routing Protocol (SHARP). The performance of these three hybrid protocols were compared with one another and the analysis was done based on the metrics of throughput, packet delivery ratio, and average end-to-end delay and is presented with the simulation results obtained using the Network Simulator version 2.35.

Section 2 of this paper discusses the routing protocols in MANET, Section 3 focuses on the implementation of the hybrid protocols examined in this paper, Section 4 deals with the characteristics of the hybrid protocols examined in this research, Section 5 considers some types of performance metrics used in MANET, Section 6 deals with the simulation methodology and parameters for this research, Section 7 deals with the simulation results and performance comparison of the three hybrid protocols considered, Section 8 concludes with the comparison of the overall performance of the three hybrid protocols ADV, ZRP and SHARP based on the throughput, packet delivery ratio and average end-to-end delay metrics.

Routing Protocols in MANET

A routing protocol is needed whenever a packet needs to be transmitted to a destination via a number of nodes and numerous routing protocols have been proposed for such kind of Ad-hoc networks. These protocols find a route for delivery of packets to the correct destination. Basically, routing protocols can be broadly classified into three types as A) table-driven (or) proactive routing protocol, B) on-demand (or) reactive routing protocol C) hybrid routing protocol.

Table-Driven (or) Proactive routing protocols. Every node maintains the network topology information in the form of routing tables by periodically exchanging routing information. Routing information is generally flooded in the whole network whenever a node requires a path to the destination. It runs an appropriate path-finding algorithm on the topology information it maintains. Some of the existing table-driven (or) proactive protocols are DSDV, WRP, CGSR, OLSR, STAR, FSR, HSR, and GSR.

On-Demand (or) Reactive routing protocols. Protocols that fall under this category do not maintain the network topology information. They obtain the necessary path when it is required, by using a connection establishment process. Hence, these protocols do not exchange routing information periodically. Some of the existing routing protocols that belong to this category are DSR, AODV, TORA, ABR, SSA, FORP, and PLBR.

Hybrid routing protocols. Protocols belonging to this category combine the best features of the above two categories. Nodes within a certain distance from the node concerned or within a particular geographical region are said to be within the routing zone of the given node. For routing within this zone a table-driven approach is used. For nodes that are located beyond this zone an on-demand approach is used. Some of the protocols in this category are CEDAR, ZRP, and ZHLS. The next sub-section describes the implementation of the hybrid protocols examined in this paper.

Implementation of Hybrid Protocols

Adaptive Distance Vector Routing (ADV). This is a routing algorithm that exhibits some characteristics of the reactive protocols by varying the frequency and size of the routing updates in response to mobility conditions and network load [6]. The Adaptive Distance Vector Routing algorithm uses sequence numbers in order to avoid loops that are long-lived. Like other distance vector algorithms, the ADV uses routing updates to maintain routes. For ADV, the size and frequency of the routing updates is varied in response to node mobility and traffic in order to reduce the routing overhead. One of the ways of achieving this is by varying the number of active routes that are maintained. To achieve a reduction of the size of the routing updates, ADV maintains and advertises routes for active receivers only instead of the conventional approach where routes are maintained and advertised for all the nodes in the network. A node is regarded as an active receiver if it is the receiver of a currently active connection. If the destination of an entry in the routing table is an active receiver, such entry is tagged with a flag called the receiver flag. When a new connection begins, an init-connection control packet in the network is broadcasted by the source in order to advertise that its destination node is an active receiver. When the init-connection packet is received by the target destination node, it responds if it is not yet an active receiver and broadcasts a receiver-alert packet making use of its present sequence number. With a pair of these broadcasts, all the nodes will be aware of an active receiver and they then route to it briskly. Conversely, when a connection is to be closed, an end-connection control packet is broadcasted throughout the network thereby signifying that the connection has been terminated. A non-receiver alert control packet is broadcasted throughout the network by the destination node if it has no additional active connections. This signifies that the destination node in question has stopped to be an active receiver. The processes of connection initiation and termination are used once for each connection and they both help to vary the number of routes maintained on the network.

Zone Routing Protocol (ZRP). The zone routing protocol was invented by Zygmunt Haas of Cornell University. The zone routing protocol being a typical hybrid protocol combines the advantages of the proactive and reactive approaches by maintaining an up-to-date map of a zone centered on each node. Routes within the zone are readily available, but for routes that are not within the zone, the ZRP makes use of a route discovery process that benefits from the local routing information of the zone. On one hand, the ZRP limits the scope of the proactive procedure to the local neighborhood of the node. The local routing information is referred to often in the operation of the ZRP, thereby reducing the waste associated with the schemes that are completely proactive. On the other hand, though the network is global the search throughout the network is done by effectively querying selected nodes in the network as opposed to the conventional approach where all the network nodes are queried.

The ZRP identifies multiple routes to the destination that are loop-free and as a result performance and reliability is increased. For the ZRP, routing is flat and not hierarchical thereby reducing organizational overhead and also allows the discovery of the best routes possible and as well reduces network congestion. It is worthy of note that the most beautiful feature of the ZRP is that it adapts its behavior based on the configuration of the network and the behavior of the users.

Sharp Hybrid Adaptive Routing Protocol (SHARP). SHARP makes use of the vital trade-off that exists between the proactive and the reactive routing in order to find a good balance between proactively propagated route information and the route information that is left up on demand discovery [7]. In performing routing, SHARP makes use of both a proactive and reactive protocol.

Each SHARP node determines the network neighborhood referred to as the proactive zone where the routing information relating to it is disseminated proactively. SHARP makes use of a proactive routing algorithm that has two important features which are efficiency and analytical tractability. SHARP can also make use of any reactive routing algorithm whose costs can be analytically characterized. With traditional routing protocols, applications have no control over performance. Conversely, SHARP allows each application to pursue different quantitative metrics in order to guide the trade-off that exists between increased overhead for proactive information dissemination and reduced latency and loss rate. As a result, each SHARP node can independently pursue different application-specific performance guarantees.

Characteristics of the Hybrid Protocols

The three hybrid protocols examined in this study are ADV, ZRP and SHARP. Their characteristics are discussed in this section of the paper.

Adaptive Distance Vector routing protocol (ADV). ADV is a distance vector routing algorithm that exhibits some reactive (on-demand) characteristics in the sense that it varies the frequency and the size of the routing updates in response to the network load and the mobility conditions. In high mobility cases, ADV gives significantly high peak throughput and low packet delays. At moderate to high loads, ADV uses few routing and control overhead packets both at the IP and MAC layer level. The MAC layer level routing packets include all the IP layer routing packets and the MAC control exchange packets used for reliable transmission of unicast data and routing packets.

Zone Routing Protocol (ZRP). ZRP proactively maintains routes within the local region of the network [8]. The ZRP identifies multiple routes to the destination that are loop-free and as a result, performance and reliability is increased. ZRP makes use of flat structures as opposed to hierarchical ones because hierarchical schemes can lead to congestion localization. ZRP limits the scope of the proactive procedure to the local neighborhood of the node thereby leading to a massive reduction in cost. With ZRP, though the on-demand search for nodes outside the zone is global, it is done by querying only a subset of the nodes in the network. The changes that occur in the network topology of ZRP however have a local effect only. A key concept in ZRP is that of routing zones. A routing zone refers to the neighborhood which each node individually creates for itself. The zone is referred to as a collection of nodes whose minimum distance from the node considered is not greater than a value called the zone radius.

ZRP is somewhat scalable and the absence of hierarchies eliminates definitive points of congestion.

Sharp Hybrid Adaptive Routing Protocol (SHARP). SHARP makes use of the important trade-off that exists between proactive and reactive routing in order to find a good balance between route information propagated proactively and route information that is left up on demand discovery. SHARP uses both a proactive and a reactive protocol to perform routing.
SHARP has the following unique features or characteristics:

Adaptability: SHARP is applicable to a range of network characteristics. It adjusts its behavior automatically to achieve target goals in the face of network characteristics such as changes in traffic patterns and node mobility.

Flexibility: SHARP enables applications to optimize for different application-specific metrics at the routing layer.

Efficiency and practicality: SHARP achieves better performance than strategies that are pure and non-hybrid and SHARP does not invoke costly low-level primitives such as those for reliable broadcast and distributed agreement.

Performance Metrics

There are a number of qualitative and quantitative metrics that can be used to compare reactive routing protocols. Most of the existing routing protocols ensure the qualitative metrics. Therefore the following different quantitative metrics have been considered to make the comparative study of their routing protocols through simulation.

Routing overhead: This metric describes how many routing packets for route discovery and route maintenance need to be sent so as to propagate the data packets.

Average delay: This metric represents average end-to-end delay and indicates how long it takes for a packet to travel from the source to the application layer of the destination. It is measured in seconds.

Throughput: This metrics represents the total number of bits forwarded to higher layers per second. It is measured in bps. It can also be defined as the total amount of data a receiver actually receives from the sender to the amount of time it takes a receiver to obtain the last packet.

Media Access Delay: The time a node takes to access media for starting the packet transmission is called media access delay. The delay is recorded for each packet when it is sent to the physical layer for the first time.

Packet Delivery Ratio: This is the ratio between the amount of incoming data packets and actually received data packets.

Path Optimality: This metric can be defined as the difference between the path actually taken and the best possible path for a packet to reach its destination.

Simulation Methodology and Parameters

In order to carry out a performance comparison of the three hybrid protocols examined in this paper which are ADV, ZRP and SHARP, the Network simulator version 2.35 was employed. A simulation study was carried out to compare the performance of the aforementioned hybrid protocols based on the following metrics: i) throughput ii) packet delivery ratio iii) average end-to-end delay. The parameters used for the simulation include:

Table 1, Parameters for Simulation

PARAMETER	VALUE
Protocols	ADV, ZRP, SHARP
Packet size	512 bytes
Maximum speed	10m/s
Area	400x400
Number of nodes	50,75,100
Application	FTP
Simulation time in sec	20,40,60,80 & 100

Simulation Results and Performance Comparison

Throughput. Throughput refers to the ratio of the total amount of data that reaches a receiver from a sender to the amount of time it takes the receiver to get the last packet [9]. When the throughput values of each of the three hybrid protocols are compared, we find out that SHARP has the highest throughput. The throughput values of the ADV, ZRP and SHARP protocols for 50, 75 and 100 nodes at Pause times 20,40,60,80 and 100s are recorded in Table 1 and are plotted on the different scales in Figures 1, 2 and 3.

Based on the results of simulation, the throughput value of ZRP reduces initially but as time increases it begins to maintain its value. The throughput value of ADV increases initially but fails to maintain its value as the time increases, hence ZRP shows better performance than ADV in terms of throughput. SHARP maintained the highest values of throughput for a considerably long period of time during the simulation and thus SHARP shows better performance than ZRP and ADV in terms of throughput.

Table 2, Comparison of Throughput

Pause Time (sec)	Protocol								
	ADV			ZRP			SHARP		
	50N	75N	100N	50N	75N	100N	50N	75N	100N
20	260501	302658	253016	523602	425152	526821	602154	652142	452651
40	306125	295362	259632	315356	548621	458623	632057	458126	452368
60	235620	215836	302658	452369	458569	621235	589521	458236	516523
80	256326	198258	304589	458962	456822	512364	568236	541226	458951
100	215369	125895	213698	520368	541238	458621	425485	458513	584523

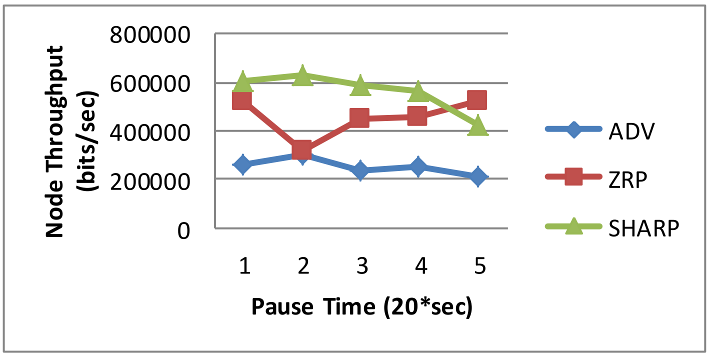

Fig. 2, Comparison of Node Throughput for 50 Nodes

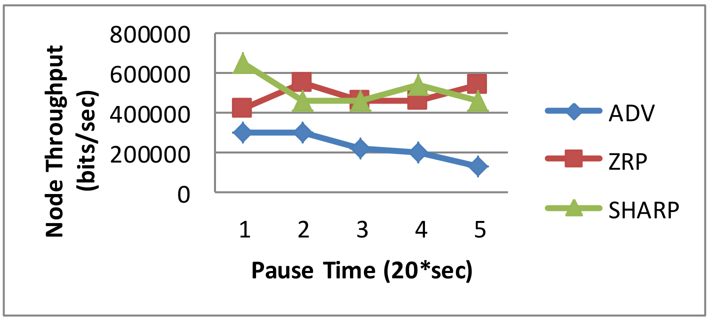

Fig. 3, Comparison of Node Throughput for 75 Nodes

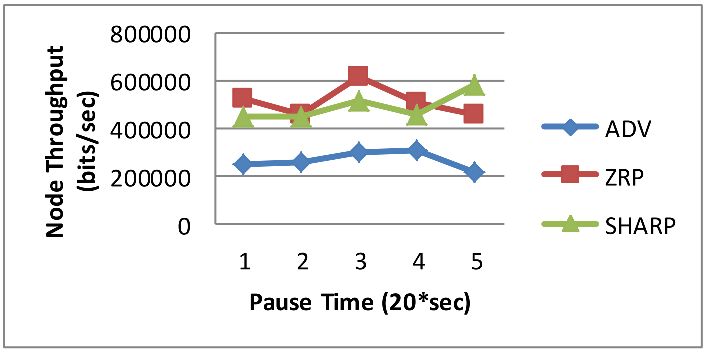

Fig. 4, Comparison of Node Throughput for 100 Nodes

Packet Delivery Ratio. Packet delivery ratio refers to the ratio that exists between the number of packets transmitted by a traffic source and the number of packets received by a traffic sink [9]. The packet delivery ratio measures both the correctness and efficiency of the routing protocols and as such a high packet delivery ratio is desired in any network. Table 2 shows the packet delivery ratio values of the three hybrid protocols examined for 50,75 and 100 nodes at Pause times 20,40,60,80 and 100. These PDR values are plotted on the different scales in Figures 4, 5 and 6. The Packet delivery ratio value of ADV is higher than the other protocols. ZRP has higher PDR values than SHARP hence, ZRP is more reliable than SHARP in terms of Packet delivery ratio. ADV is however the most reliable of the three protocols in terms of Packet delivery ratio.

Table 3, Packet Delivery Ratio

Pause Time (sec)	Protocol								
	ADV			ZRP			SHARP		
	50N	75N	100N	50N	75N	100N	50N	75N	100N
20	97.252	98.02	95	98.265	97.65	98.25	95.25	85.63	79.996
40	98.235	97	92.25	98.32	96.663	96	85.6	88.65	81.210
60	98.00	96.12	96.2	97.20	98.52	97	84.65	89.623	86.25
80	98.325	97.520	98.220	97.25	97.230	96.658	86.33	87.698	89.25
100	99.250	96.32	98.88	98.25	95.20	92.2	98.25	89.251	88.25

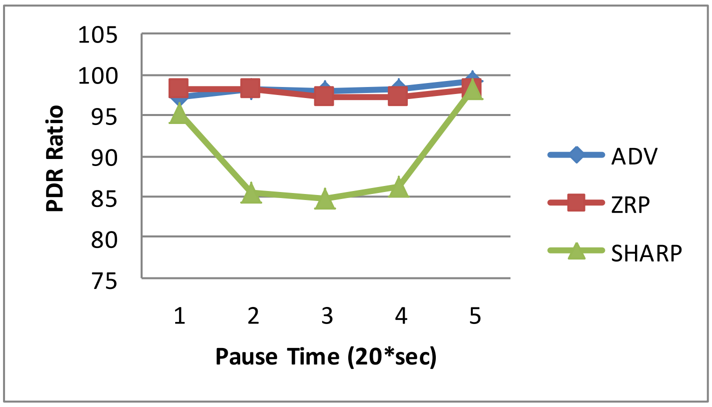

Fig. 5, Comparison of PDR for 50 Nodes

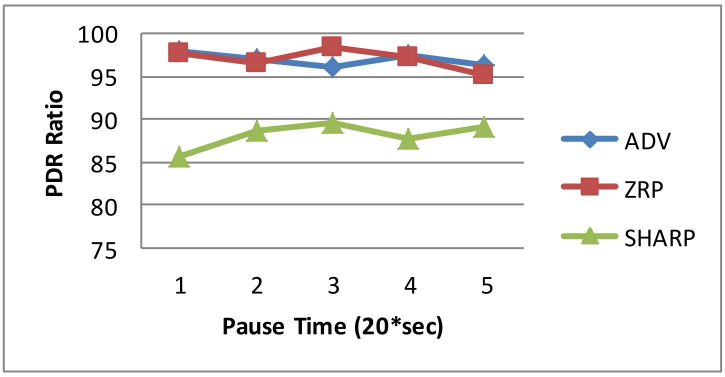

Fig. 6, Comparison of PDR for 75 Nodes

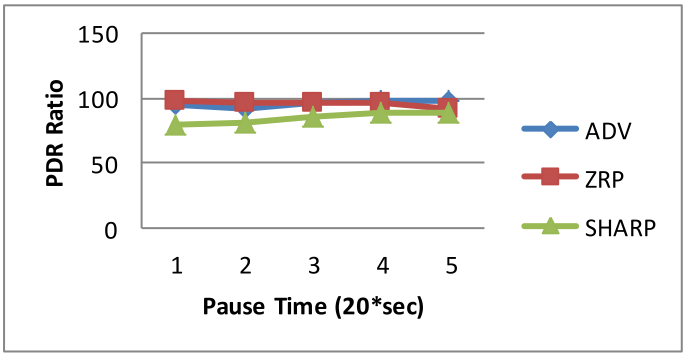

Fig. 7 Comparison of PDR for 100 Nodes

Average End-To-End Delay. The end-to-end delay of the packet is the average time which the packet takes to traverse the network [9]. It is measured in seconds and it includes all the delays in the network. The end-to-end delay is a measure of how well a routing protocol adapts to the different constraints in the network and thus represents the reliability of the routing protocol in question.

Table 3 shows the end-to-end delay values of the three hybrid protocols examined for 50,75 and 100 node values at pause times 20,40,60,80 and 100. These end-to-end values are plotted on the different scales in Figures 7, 8 and 9. ADV has the shortest end-to-end delay when compared to ZRP and SHARP. Hence, ADV will consume less time than the two other protocols. ZRP has a shorter end-to-end delay than SHARP hence, it has a better performance than SHARP in terms of end-to-end delay. ADV has the shortest end-to-end delay of the three protocols and hence, has a better performance and higher reliability than the other two protocols in terms of end-to-end delay.

Table 4, Average End-To-End Delay

Pause Time (sec)	Protocol								
	ADV			ZRP			SHARP		
	50N	75N	100N	50N	75N	100N	50N	75N	100N
20	0.25125	0.12564	0.10322	0.19562	0.23691	0.19535	0.29586	0.12501	0.12535
40	0.12586	0.23142	0.09152	0.19535	0.21365	0.19258	0.30021	0.15368	0.12567
60	0.32154	0.12536	0.09874	0.25125	0.12478	0.20125	0.31120	0.12562	0.13621

80	0.35142	0.12536	0.10325	0.21464	0.12364	0.20580	0.29852	0.12632	0.12547
100	0.36021	0.12535	0.12547	0.19821	0.12547	0.23640	0.30120	0.20321	0.19254

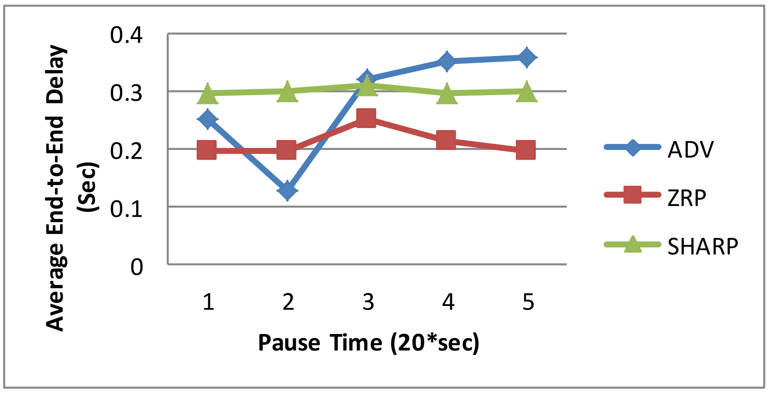

Fig. 8, Comparison of Average End-to-End Delay for 50 Nodes

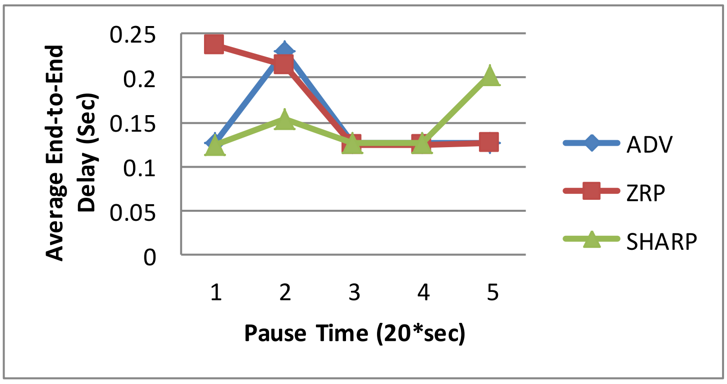

Fig. 9, Comparison of Average End-to-End Delay for 75 Nodes

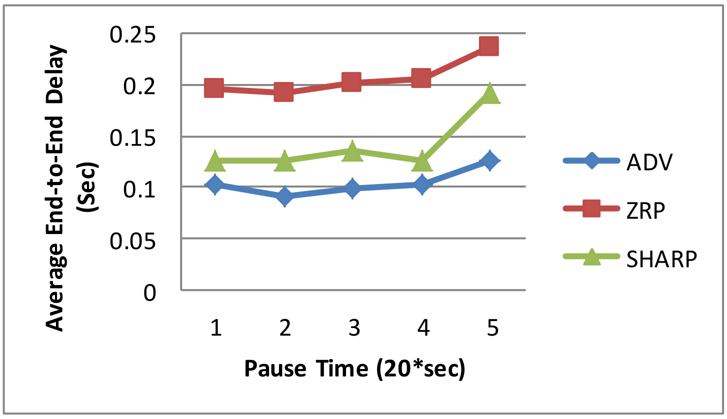

Fig. 10, Comparison of Average End-to-End Delay for 100 Nodes

Conclusion

In this paper, the performance of three hybrid protocols namely ADV, ZRP and SHARP were analyzed using the Network simulator version 2.35. We obtained results of simulation of throughput, packet delivery ratio and average end-to-end delay over the aforementioned hybrid protocols by varying the simulation time and the network size. ADV shows better performance than ZRP and SHARP in terms of packet delivery ratio and average end-to-end delay. SHARP shows better performance than ADV and ZRP in terms of throughput. Overall, ADV has higher reliability than ZRP and SHARP based on the metrics considered.

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