An Investigation of the Characteristics and Performance of Hybrid Routing Protocol in (MANET)

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Abstract

Mobile ad hoc network (MANET) is a set of nodes, which communicates using wireless medium and forming an arbitrary and dynamic network. Data is transmitted by forwarding the data from one node to another. To achieve this, each MANET node must act as both a host and a routing node. Routing in MANET poses a challenge because of the frequent changes in network topology in addition to the limited resources available for each node. Many different routing protocols have developed for MANET but in general, they can be categorized into three categories, which are proactive, reactive, and hybrid routing protocols. Hybrid routing protocols are interesting because they combine the characteristics of both proactive and reactive routing protocols. In this paper, we study the characteristics of a hybrid routing protocol (ZRP) and then compare its performance with a proactive (FSRL) and reactive (AODV) routing protocols.

Keywords: *MANET, hybrid routing protocol, ZRP.*

1. Introduction

MANET is a collection of wireless mobile nodes dynamically forming a temporary network without the use of any existing network infrastructure such as fixed routers and routing backbones. MANET consists of many mobile nodes that communicate with each other. Routing between two nodes requires data to be forwarded from one node to another [3]. As such, a MANET node not only behaves as a host, but also behaves as a routing node. A MANET node can be arbitrarily located and is free to move randomly at any given time, thus allowing the network topology and interconnection between nodes to change rapidly. Wireless networks use electromagnetic waves to transmit and receive data instead of using physical cables [11]. A centric challenge in MANET is to design routing protocols that can accommodate this behavior. The optimal routing strategy based on the underlying network topology, rate of change, traffic pattern, and varies dynamically. Many routing protocols have been proposed and widely evaluated for their efficiency in routing packets. In addition, there are two types of wireless network [20, 14]. The first type is called an infrastructure network. In infrastructure network, there exists a device called a base station and all mobile devices within the area will communicate with the base station. The base station, in turn, is connected to the wired network.

Figure 1, shows an example of an infrastructure network. The second type of wireless network is called the ad hoc network. In ad hoc network, all devices communicate with each other, without the use of a base station. Since there is no base station, an ad hoc network normally has no connectivity to the wired network. Communications is performed between the wireless devices within the range of wireless transmission [2].

Fig. 1: an infrastructure wireless network

However, a node can be arbitrarily located and are free to move randomly at any given time, thus allowing network topology and interconnections between nodes to change rapidly. Routing protocol is an essential component of a MANET, which enables data to be transferred correctly from one MANET node to another [28].

2. Routing Protocols

Many routing protocols have proposed for MANET. Although most of them are shortest path routing protocols, there are also routing protocols that perform routing based on other characteristics such as power, bandwidth, security and reliability [6]. Routing is the process of finding a best path from a source to some arbitrary destination on the network. The broadcasting [23, 24, 29] is inevitable and a common operation in MANET. It comprises of diffusing a message from a source node to all the nodes in the wireless network. Broadcast can be accustomed to diffuse information to the whole network. It is also utilized for route discovery protocols in MANET.

Routing in MANET involves two activities. The first is to determine an optimal routing path from the source node to the destination node. The second activity is to transfer the information groups (called packets) through the network [25]. Routing protocols in MANET can generally be categorized into three strategies namely (a) table driven routing protocols (Proactive), (b) on-demand routing protocols (Reactive) and (c) Hybrid routing protocol [12, 26]. Figure 2 shows the classification of routing protocols in Mobile Ad Hoc Network together with example of protocols that goes under each category [27].
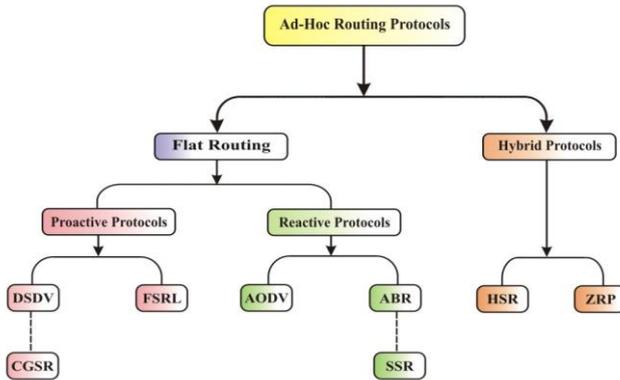

Fig. 2: shows the classification of routing protocols

Proactive routing protocol is characterized by the need to maintain an up-to-date routing table. With an up-to-date routing table, packets can immediately be forwarded once there is a routing request. However, the overhead required to maintain an up-to-date routing table may be high especially in a large MANET or a MANET with constantly changing topology. Reactive routing protocol takes a different approach where the path to be taken is computed only when there is a routing request. With this approach, there is no overhead required to maintain an up-to-date routing table. However, there will be some delays before data packets can start to be transmitted. Based on these characteristics, it can be theorized that proactive routing protocols is suitable when the MANET is small, slowly moving and has frequent data transmission. On the other hand, reactive routing protocol is suitable when the MANET large, fast moving and has infrequent data transmission. Hybrid routing protocols try to combine the characteristics of both proactive and reactive routing protocols. This means that the routing protocol will behave like a proactive routing protocol in one scenario and behave like a reactive routing protocol in another scenario.

For the purpose of this paper, we have chosen one protocol from each category. For the proactive, the FSRL protocol, for the reactive category, the AODV protocol and for the hybrid category, chosen the ZRP protocol. The details of these three protocols categories are explained below.

2.1. Fisheye State Routing Link (FSRL)

FSRL is a proactive table-driven routing protocol. It is a simple, efficient link state routing protocol with reduced overhead to maintain network topology information [12]. Link state routing protocols updates concurrent with the nodes within a smaller scope are propagated with higher frequency [2] FSRL protocol is designed to provide quick and efficient path establishment in MANET with population of tens to thousands of mobile nodes. It can provide contact between mobile nodes with minimum control overhead and minimal path acquirement delay [12].

However, when a packet, reaches its destination, it gets increasingly accurate routing instructions as it come in sectors with a higher refresh rate. FSRL introduces the concept of multilevel fisheye scope to decrease routing update by reducing the routing packet sizes and update message frequency [22]. FSRL is a specif-

ic enforcement of LANMAR routing [16]. The Landmark Ad hoc Routing (LANMAR) routing protocols packets contains two kinds of messages: Fisheye State Routing Link (FSRL) message and LMU (LANAMR) update message. FSRL comprise of the fisheye scope topology table of a node.

Figure3, interprets the function of fisheye scope in the wireless network and the packages with different shadow of grey define the fisheye scope [2]. When a source sends packets to the destination inside its neighboring scope (i.e., the source and the destination belong to the same subnet), desired routing information can be found from the source's routing table.
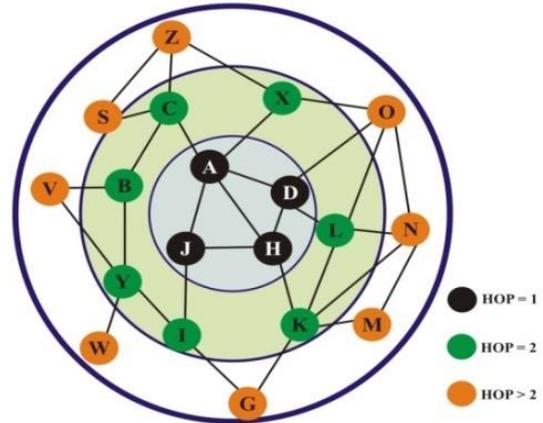

Fig. 3: Scopes of FSRL [12]

FSRL message reduces the traffic overhead created by nodes exchange, the link state information of all the nodes in the fisheye scope is exchanged more frequently with node bordering than nodes far way from center. The link state information of a node contains not only its links to its neighbors, but to all the second hop neighbors as well. If on average, a node in the wireless network has N neighbors, the links state declared in the FSRL by a single node would be N*N (N neighbors, each neighbor also has N neighbors). As the fisheye scope of LANMAR is set to be two, there are leastwise N*N nodes in a fisheye scope in a mobile ad-hoc wireless network. The FSRL exchanged by the nodes within the fisheye scope would be N*N*N for a control time interval.

2.2. Ad hoc On-Demand Distance Vector (AODV)

The AODV routing protocols is an improvement of DSDV algorithm due to the number of required broadcast by making routes on a demand basis, in contrast to maintaining a perfect list of routes as in the DSDV algorithm. [13]. When a node wants to send data packets from source to destination node, it checks its routing table to determine whether it has a route [12].

When a new node wants to send a packet to a destination, the node broadcasts a (RREQ) to discover a route to the destination shown in Figure 4. It broadcasts a route request (RREQ) message to its node neighbors. For each node that receives the broadcasts composite an inverse route towards the originator of (RREQ), when the intended destination receives the (RREQ), it response by sending a Route Reply (RREP). It is very important to notice that the only changeable information in (RREQ) and in (RREP) is the hop count (which is being monotonically augmented at each the hop). The (RREP) is unicast back to the originator of (RREQ).

AODV is a loop free protocol; AODV algorithm gives an easy way to get alteration in the link situation. Route discovery Process (RDP); though AODV can unicast and broadcast communication, the RDP begins whenever a source node wants to transmit data to another node and no routing information is available in routing table for this node.
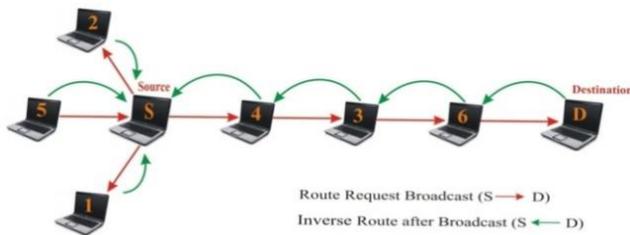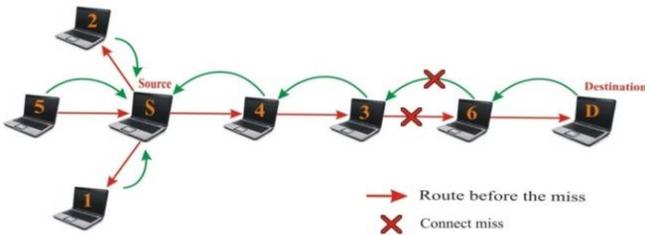
Fig. 4: Route Request Broadcast

Fig. 5: Route Reply Broadcast

The main outline of the RDP processes are the source node begin a RDP by multicasting Route-Request (RREQ) packets, any node in network with a current route form source to destination can unicast a Route-Reply (RREP) packet back to the source node, each node maintains route information in route table, and the information obtained during RREQ and RREP message is kept with other routing information in the route table.

Figure 4 shows the AODV finds routes whenever it is required by RDP using traditional routing tables; there is one entry per destination. AODV utilizes a broadcast route discovery algorithm and then the unicast RREP massage for discover the route; the following sections interpret these mechanisms in more detail [5]. A route performed between source and destination is maintained while needed by the source. When node link break in an active route is discovered, the broken link is inactive which that routing error and an RERR message is sent node to other nodes. These nodes in reverse reproduce the RERR to their precursor nodes, and so on until the source node is arrived as shown in the Figure 5.The affected source node may then select to either stop sending data or reinitiate route discovery for that destination by sending out a new RREQ message.

The main advantages of AODV routing protocol are broadcast find packets only when necessary, discriminate between local connectivity management (neighborhood detection) and general topology maintenance [21]. AODV avoids making temporary loop problem, for limitation of AODV requirement on broadcast between a nodes can detect each other broadcast, and the message can be misused for insider attacks contain route disruption, node separation and route invasion [17].

2.3. Zone Routing Protocol (ZRP)

The ZRP is a hybrid routing protocol that divides the network into zones [2, 12]. ZRP is the first hybrid routing protocol, which combines both reactive and proactive routing protocols component, taking advantage of pro-active detection within a node's local neighborhood, and applying a reactive protocol for contact between these neighborhoods. These local neighborhoods are called "zones" for each node indeed within multiple overlapping zones, and each zone may be of a different size [18, 10].

The network is divided into overlapping, changeable-size zones. ZRP comprises of several components, which only together provide the full routing utility to ZRP. Each component works individually of the other node and they may utilize different technique in order to increase efficiency in their particular area. ZRP routing protocols comprises of three parts routing components [10]:

- *Intrazone Routing Protocol (IARP)*: IARP [8] is the first proactive component of the ZRP protocol. This protocol is used by a node to transmission with the interior nodes of its

zone and is specified by the zones radius (the number of hops from the node to its exterior nodes). Because it depends on the change in topology, local neighborhood of a node may change rapidly. A node always needs to update the routing information in order to determine nodes. The IARP provide for local route optimization during the elimination of redundant routes and the abstracting of routes if a route with fewer hops has been detected, as well as bypassing link-failures during multiple (local) hops

- *Interzone Routing Protocol (IERP)*: IERP [9] is the global reactive component of the ZRP, its implementation to takes advantage of the known local topology of each node's zone surrounding R-hop neighborhood, and using a reactive approach empowers communication with a node in other zone. The IERP protocol is dependent upon the local connectivity maintained by the IARP. In addition to change the way route detects is handled: Instead of invasion a route request to all nodes, it should instead utilize the Bordercast Resolution Protocol (BRP) to only initiate route requests with peripheral nodes.

- *Bordercast Resolution Protocol (BRP)*: BRP [4] is supply border-casting packet routing delivery service. The BRP utilize a map of an extended routing zone, by condition the local proactive IARP, to construct Bordercast (multicast) trees along which query packets are directed. (Within the context of the hybrid ZRP, the BRP used to guide the route requests of the global reactive IERP. The BRP uses special query control mechanisms to steer route requests away from areas of the network that have already been covered by the query.

However, a route to a destination within the local zone can be established from the proactively cached routing table of the source by IARP, therefore, if the source and destination is in the same zone, the packet can be delivered immediately. Most of the existing proactive routing algorithms can be used as the IARP for ZRP. For routes beyond the local zone, route discovery happens reactively. The source node sends a route requests to its border nodes, containing its own address, the destination address and a unique sequence number. Border nodes are nodes which are exactly the maximum number of hops to the defined local zone away from the source [19].

The border nodes check their local zone for the destination. If the requested node is not a member of this local zone, the node adds its own address to the route request packet and forwards the packet to its border nodes. If the destination is a member of the local zone of the node, it sends a route reply on the reverse path back to the source. The source node uses the path saved in the route reply packet to send data packets to the destination.
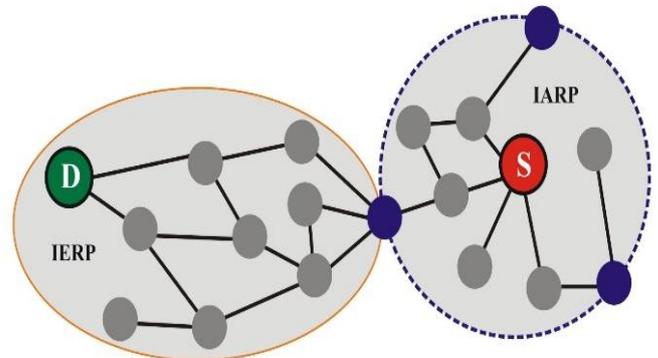

Fig. 6: ZRP having Zone radius =2-Hop

Consider the wireless network in Figure6, the node S (source) has a packet to send to node D (destination). ZRP having zone radius is r=2-hop. The node uses the routing table provided by IARP to check whether the destination is during its zone. Since it is not

found, a route request is issued utilizing IERP. The request is broadcast to the peripheral nodes (blue in the picture). Each of these nodes searches their routing table for the destination.

3. Materials and Method

The QualNet 4.5.1 simulator is used for the analysis. We use CBR (Constant Bit Rate) application, IEEE 802.11b MAC and physical channel based on statistical propagation model due to the inter-arrival time between consecutive packets is constant and a packet is sent over each connection in every interval seconds. A random distributed CBR traffic model is used which allows every node in the network to be a potential traffic source and destination [7]. Random traffic connections of CBR can be setup between nodes using a traffic-scenario generator script CBR traffic has been widely used in previous performance studies of routing protocols [1, 15]. In CBR application represent its use all the traffic types. The performance of the routing protocols is evaluated using three different performance metrics which are throughput, end-to-end delay and jitter. The definition of the performance metrics are given below:

A. *Throughput*: Refers to the average rate of successful data packets received at the destination. Throughput is the number of packet delivering at the sink node per unit time and is usually expressed in bytes or bits per sec (byte/sec or bit/sec).

B. *End-to-End Delay (E-2-E)*: Refers to the average E-2-E delay of data packets. It's the time between the attainment of a packet in the queue to the departure of the packet from the queue in (CBR) server is considered in milliseconds (ms). The value is averaged over the number of packets. This metric describes the packet delivery time: the lower the E-2-E delay the better the routing protocol performance. E-2-E delay can be represented mathematically.

C. *Jitter*: Refers to the variation in the time between packets arrival, caused by network congestion, timing drift, or route changes. It signifies the packets from the source reach the destination with different delays. A packet's delay varies with its position in the queues of the routers along the path between source and destination and this position can vary unpredictably.

The simulation parameters used for this simulation is summarized in Table 1.

Simulation parameters	
Parameter	Value
Transmission power	15dB
AP range radius (m)	500
Bandwidth	1M
Number of nodes	25, 50, 75, and 100
Terrain-dimensions (m)	1500, 1500
AP- AP distance (m)	200, 500m
Frequency band (GHz)	2.4
Simulation time	50sec
Traffic type	CBR
MAC type	IEEE 802.11b
Antenna type	Omni-Antenna

4. Results

4.1 Throughput

It is clearly observe that the ZRP protocol shows the highest gain in throughput throughout the simulation compared to AODV and FSRL. When the number of deployed nodes is 25 for example, the ZRP attains a throughput level of 10000 mbps while the AODV achieves 8000 Mbps and the FSRL at about 3000 Mbps. This means that the ZRP protocol outperforms the AODV and FSRL protocols by 25% and 233% respectively. This is due to the fact that the ZRP protocols has the ability to search the route quickly

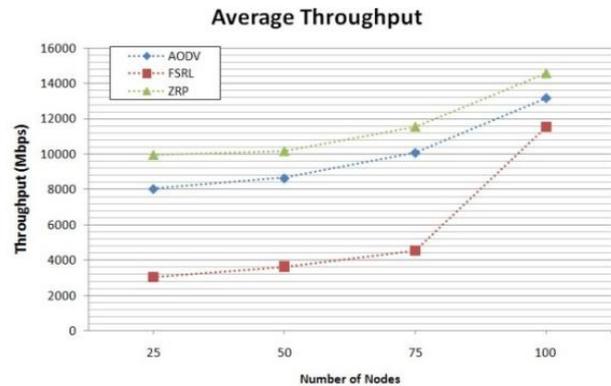as it avoids expiring good route by updating route lifetime appropriately.

Fig 7: The Achieved Throughput

Figure 8, illustrates the total average network throughput of the three routing protocols considered in this paper. As in Figure 7, it is noted that the ZRP protocol, which achieves 11.6 Mbps, outperforms the other two routing protocols (AODV, FSRL) in terms of the overall average throughput, followed by the AODV (10Mbps). Again, the FSRL protocol has the poorest average throughput performance of 5.6 Mbps. The reason for the vast difference in performances of the different protocols is the same as the explanation provided in Figure 7.
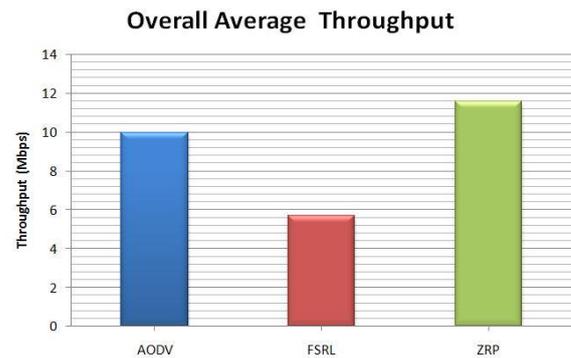

Fig. 8: The Overall Average of Throughput

4.2 Average End-to-End (E2E) delay

Figure 9, illustrates the average E-2-E delay of the three simulated routing protocols. The ZRP has the highest E-2-E delay throughout the simulation followed by AODV and FSRL. Again, the FSRL maintains the lowest E-2-E delay throughout the simulation. When the number of deployed nodes is 25 ZRP has an E-2-E delay of 1s while AODV has 0.5s and the FSRL has about 0.2s. This means that the FSRL outperforms the E-2-E delay of ZRP and AODV protocols by 80% and 60% respectively. This improvement becomes even more pronounced as the number of deployed nodes in the network increases.

Figure10, shows the result of the overall average E-2-E delay of each of the routing protocols. As in Figure9, it is noted that the FSRL, which achieves the total average E-2-E delay of 1.4s overall E-2-E delay, outperforms the other two routing protocols (AODV, ZRP) in terms of the overall average overall E-2-E delay, followed by the AODV (2s) and ZRP (4s).
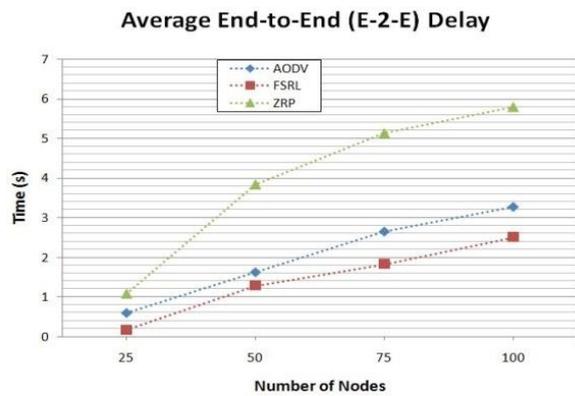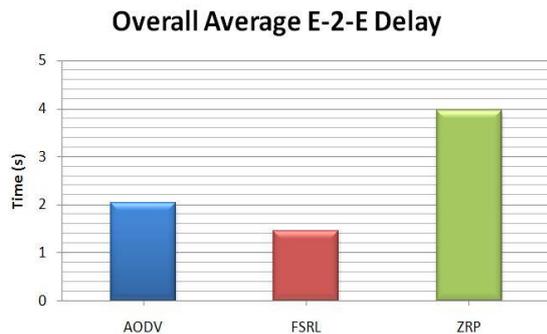
Fig. 9: The Average End-to-End Delay

Fig. 10: The Total Average of E-to-E Delay Time

4.3 Jitter

It is clearly observed that the FSRL protocol shows the best jitter performance throughout the simulation compared to AODV and ZRP. When the number of deployed nodes is 25 for example, the FSRL attains a jitter level of only 0.02s while the AODV achieves 0.04s and the ZRP at about 0.11s. This means that the FSRL protocol outperforms that of AODV and ZRP protocols by 50% and 82% respectively.

Although the jitter of each of protocols increases with the number of deployed nodes, the FSRL protocol maintain the best performance through the simulation, followed by the AODV. The ZRP shows the worst jitter performance for the whole duration of the simulation. A similar result is obtained in Fig12.
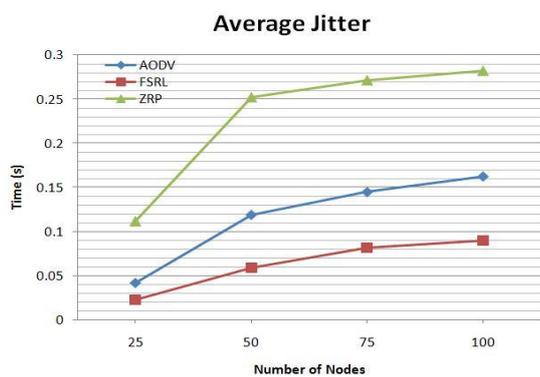

Fig. 11: Average Jitter

Figure 12, shows the overall average packet latency (jitter) of each of the routing protocols (How is this calculated?). Here, it is can be noted that the FSRL protocol shows the most favorable results of 0.06s, followed by AODV with 0.12s. The worst jitter performance is registered by the ZRP with 0.23s.
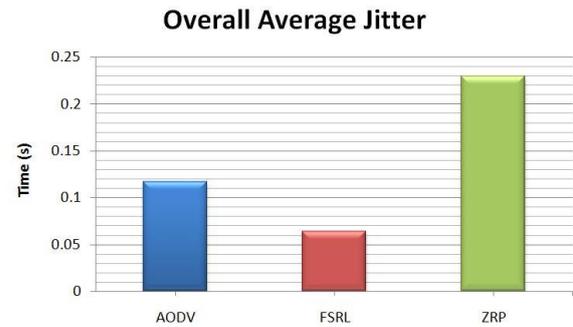

Fig. 12: The overall Average Jitter

5. Discussion

From the simulation results, it can be concluded that the ZRP protocol achieves the best throughput followed by the AODV in all cases of the simulation. This is due to the fact that the ZRP has the ability to search the route quickly as it avoids existing blocked route and continually updating route appropriately. Also ZRP requires sending more routing packets due to its proactive scheme, namely the frequent hello packets to update the routing table within the local zone, than the AODV and FSRL. Though AODV uses on-demand routing scheme, it always has higher average throughput than FSRL, due to aggressive caching. The FSRL shows the worst throughput among the three protocols. Due to FSRL protocol will most often find a route in its cache and therefore rarely initiate a route discovery process unlike AODV.

From the figures the average E-2-E delay, the ZRP has the highest E-2-E delay among the three protocols because the node utilizes the routing table provided by IARP to check whether the destination is within its zone. Since it is not found, a route request is issued utilizing IERP. Also a node checks the local zone for destination, if destination is a member of the local zone of the node; it sends a route reply on the reverse path back to the source. The source node uses the path saved in the route reply packet to send data packets to destination. The FSRL protocol shows the lowest E-2-E delay throughout the simulation, followed by the ZRP and AODV. FSRL demonstrate less delay than the other two protocols due to its proactive nature. A similar result is found for jitter performance, where the ZRP has average jitter between AODV and FSRL because there is more chance for jitter as the source node initiates the route mechanism by broadcasting a route request packet to its neighbours. The FSRL maintains the best performance through the simulation, followed by the AODV. The ZRP shows the worst jitter performance for the whole duration of the simulation.

6. Conclusion

From the simulation results, it can be concluded that it is observed that ZRP achieves the best throughput followed by the AODV in all cases of the simulation. The FSRL shows the worst throughput among the three protocols. On the other hand, the FSRL shows the lowest E-2-E delay throughout the simulation, followed by the AODV. The ZRP has the highest E-2-E delay among the three routing protocols. A similar result is found for jitter performance, where FSRL shows the lowest jitter followed by AODV for the whole duration of the simulation. The ZRP has the worst jitter performance as well.

In conclusion, while the ZRP shows the best throughput performance, the FSRL has the best E-2-E delay and jitter performances among the three. In either case, the AODV shows the second best performance for all the studied performance metrics. The overall performance of ZRP in terms of network load is best as compared to FSRL and AODV.

Acknowledgement

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