The Optimal Path-based AODV Routing Protocol for Mobile Ad-hoc Networks

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Abstract*—Mobile Ad-Hoc Network (MANET) is an infrastructure less peer-to-peer or multi-hop wireless network of autonomous collection of portable devices such as smart phones, personal laptops, sensors, iPads, PDAs etc. Mobile devices that forms a temporary network to transfer messages among the nodes without any fixed network infrastructure or centralized administration. When a node joins or leaves the network, MANET is set up to automatically reconstruct its topology and routing table information for the transmission of data packets. High mobility of nodes causes frequent changes in the network topology, and this leads to link breakage and increases reinitiating of the route discovery process. Making it difficult and complicated to decide the optimum path from the source to the destination. This paper proposes a new TH-AODV routing protocol algorithm for optimal path selection in MANETs by joining the Ad-hoc On-Demand Distance Vector protocol with the factors of time and hop-count. In TH-AODV algorithm, if a communication link is broken, the best route for data delivery is determined by matching the path from the source to the destination or the path from the node at the damaged link to the destination. Moreover, we have compared the suggested TH-AODV algorithm with other three types of routing algorithm proactive, reactive, and hybrid routing protocols utilizing the network simulator NS-3. We investigated that the performance differences on simulated areas as "600 x 600 m^2, 800 x 800 m^2, and 1000 x 1000 m^2" for low and high mobile nodes between 10 to 60 nodes. The proposed algorithm has been evaluated based on the performance metrics: packet delivery ratio, average end-to-end delay, and throughput. The simulation results revealed that TH-AODV routing algorithm outperforms when the number of nodes and configuration area are increased.

Keywords—MANET, AODV, NS-3, Mobile Ad-hoc Networks, Routing Protocols

I. INTRODUCTION

Wireless communication is evolving and emergent research area that will allow user to electronically access the web objects and web related services regardless of where they sited. As seen in figures 1.1 and 1.2, there are two different types of wireless networks: infrastructure networks and infrastructure-less networks, often known as MANETS. A MANETS are established without the need for a formal configuration. Nodes connected to the network can be dynamically configured without adhering to any officially pre-defined top-down architecture as seen in traditional networks. The MANET is consist of mobile-nodes that move around a lot. Special routing methods are required to accommodate the changing topology [1]. Flat routing methods, such as the DSDV algorithm, may be sufficient for relatively small networks. Reactive routing techniques, like AODV, are required in bigger networks. MANET is one of the more inventive and demanding aspects of wireless network, and for the potential to become more prevalent in our daily lives. In comparison to conventional network communication options, MANET, which are composed of devices that self-organize into networks, offer a great degree of freedom at a lower price. [2].

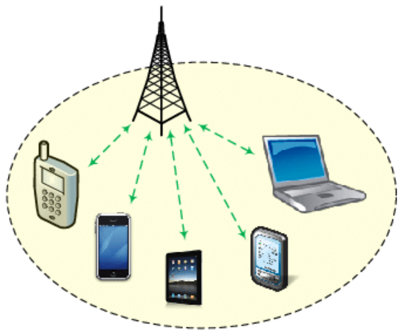

Fig. 1. Infrastructure (base station) network

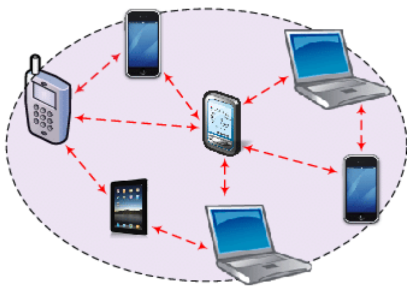

Fig. 2. Infrastructure-less (mobile) network

MANETS have recently been a prominent research area among academics due to its independence and flexibility. To provide effective communication, these networks need a new set of networking protocols due to their dynamic topology or nature and less infrastructure. MANETS may be set up fast and at a cheap cost, and they are simple to manage. There is little doubt that we will see increase in the number of nodes, with applicable routing algorithm being one of the most important challenges. When the data needs to be transferred to a node via many distinct nodes, a routing algorithm is required. There are many routing protocols for fixed networks: or the link-state method or distance vector algorithm. The fixe network algorithms were established for procedure in wired networks with fixed topology. They're also computationally demanding, which makes them tough to use on a budget. As a result of these issues, new routing algorithms are being developed that take into account the features of MANET. An ad-hoc manner routing protocol must be able to determine the optimum path among devices with dynamical links, decrease direction-finding overhead to permit suitable routing way, reduce period to join after topology variations, and take full advantage of bandwidth consumption. As a result, one of the primary study areas in MANETS is developing routing capability. Many researchers analyzed routing protocols and discovered that the AODV algorithm performs well in larger configuration areas with a huge number of devices. However, further research into the AODV routing algorithm is required to discover the optimum path when a communication link is broken [3].

II. Routing Protocols Classification

The lack of limited resources in MANETs have made it challenging to improve an operative and consistent routing protocols. To make the most of these less number of resources, and smart routing algorithms are needed that can adapt to altering network settings such as web objects size, circulation intensity, device mobility mode, battery power, network topology nature, and broken links. For MANET networks, various routing procedures have been proposed and deployed. These protocols must contend with the network's limited resources, which include power consumption, bandwidth, and mobility. There are various ways to categorize present routing protocols, but the majority of them are established on routing scheme and network configuration. Routing protocols can be grouped as chart driven, on-demand driven, or hybrid, depending on the routing technique [3], [4].

A. Table-driven Proactive Protocols

Proactive routing procedures are often identified as "table-driven protocols". By continuously assessing routes to all nodes, each node in this protocol keeps complete information about the network structure. As a result, they preserve reliable and latest routing facts. These protocol is referred to as proactive manner as they store routing facts earlier it is required. Each device in the setup keeps track of how to go to the rest of the network's nodes. In proactive routing, the route information is kept up to date [5].

When the network topology changes, it is updated in the routing tables. As a result of the increased overhead in the routing table, more bandwidth is consumed. The total of essential routing information tables and the techniques that alterations in network topology are the areas where they differ. DSDV, GSR, and FSR are some of the proactive protocols now in use.

1) DSDV proactive Protocol

The table-driven proactive DSDV protocol designed is based on the old-fashioned Bellman-Ford strategies. Every device in the system preserves a transmitting table, which embraces a list of all the possible link to the target node. The target node, the shortest way metric to the destination in reference to hop node count, the next-hop node address, and a arrangement number which is generated by the target node are all involved in each token in the table. The path with the most sequence numbers is the one to take. To avoid routing loops, order records are applied to identify the old routes link from new links. Routing information table updates are transferred all over the network at regular intervals to keep that the table has the most up-to-date information and is consistent. Time-based or event-based route adjustments are possible. Every device transfers routing data to its direct neighbors regularly. A device can additionally disseminate its altered routing table information as the previous update, rather than communicating the whole routing table [6].

B. On-demand Reactive Protocols

On-demand reactive routing is a dissimilar method from table-driven proactive approach. A routing path is discovered only when it is required in this manner. These are referred to as reactive since no routing information needs to be maintained at the devices if there isn't any interaction. A route finding set-up raises a path-determination method as necessary. After examining all of the route variants, the discovery phase ends either with a route found or with no route available. The key benefit of reactive approach is that it spares the wireless medium from routing overhead for routes that might never be utilized. Despite the fact that reactive strategy does not have a static overhead, they have experience considerable route detection delays. AODV, DSR, ABR, and SSBA are some of the existing reactive protocols [1].

1) AODV reactive protocol

As a reactive way protocol, AODV strategy has to preserve way of the active pathways direction-finding information. Each device maintains a next-hop transmitting table that contains end point information for which this one currently takes a route track. If a path entry in the directing database has not been used for a predetermined period, it will expire. Furthermore, AODV take on the DSDV destination arrangement number approach. If no route is available, an AODV source device begins a path finding operation to send packets to the endpoint. The source device broadcasts “route request RREQ packets” during the route discovery phase. An RREQ contains the source device and destination device addresses, the broadcast identification number, which serves as a unique identifier, the destination's past observed order number, and the source device's arrangement number. Order numbers guarantee loop-free and current paths.

Each node in AODV has a cache storage to preserve track of the “RREQs” it has acquired. The path back to each “RREQ” creator is likewise stored in the cache storage. When the destination node, or a device with a path to the destination, collects the “RREQ”, and it matches its present endpoint order records to the unique showed in the “RREQ”. Only if the endpoint order digit is the same to or larger than the one showed in “RREQ” is a “route reply RREP” packet made and delivered back to the source device in reply to “RREQ”. As a result, the direction-finding information is at all times up to date. Every middle device along the route changes its next-hop in the table records with reference to the destination device after getting the “RREP” packet. “RREP” packets that is dismissed or have a lesser endpoint order digit will be eliminated.

a) Route Finding Discovery process

In case there is no path from source node to destination, the source node sends a broadcast message including the source device's address, source device's sequence number, destination device's address, destination device's sequence number, and broadcast unique ID to its nearby nodes. During route discovery, there are two references, such as a forward reference and a backward reference, are used for the route finding discovery process. Forward reference checks the gateway nodes while data is being conveyed to a destination. The backward reference keeps track of the intermediate devices, and when the path request message eventually arrives at the last device, it unicasts the response message to the source across those nodes. The route request id, which is utilized to verify the latest link to the destination, is the main feature of AODV.

b) Route for AODV: Maintenance

Route error, hello, and time out messages are three different types of messages that are transmitted in the middle of the source device and the destination device. Since a node will propagate an error message to its upstream nodes only when it detects a broken link, the "route error message" assures that this communication is disseminated to whole nodes in the network. The forward and backward references are maintained against expiration by the hello message. When there is no activity in the middle of the source device and the destination device for a specified time period, a time out message ensures the termination of the link.

C. Hybrid (proactive+Reactive) Protocols

Hybrid manner protocols are designed to incorporate proactive way and reactive way strategies. The ZRP is a nice illustration of such a protocol. ZRP splits the topology into regions and attempts to apply various routing protocols inside and among the regions, considering the drawbacks and advantages of each procedure. ZRP is completely integrated, which means that any routing protocol can be used within and among zones. The hop radius is defined by the parameter r, which determines the size of the zones. Intra-region routing is performed using a proactive way protocol because proactive protocols preserve current scenario of the region's topology, resulting in no primary latency while connecting with device within the region. Inter-region routing is handled through a reactive way protocol.

1) ZRP Protocol

It was one of the initially developed protocols that provide the mixture of routing. In this technique, the area range is the best key variable. Each network node has a zone defined around it, with an area identical to the region's radius. Zone devices are divided into two types, periphery, and inner devices. Peripheral devices are devices whose least distance beginning to the midpoint device is accurately equivalent to the range of the region. The least distance between interior nodes and the zone radius is fewer than the region range. Within zones, routing is finished through proactive manner (intra region - IARP), while within zones, routing is finished through reactive manner (inter-region - IERP) [4].

D. Proposed TH-AODV Routing Protocol

When a source node in a MANET wants to transfer packets to a destination, it first checks for the destination node's routing facts in its routing info table. Data packs will be supplied from the source to the target via next-hop node condition the way occurs. The source initiate the request procedure by broadcasting RREQ packets if the routing table information is incorrect. To avoid duplication processing, every node transmits an RREQ with the sequenceID, the sourceID. The source enter the indication of an appropriate time to delay for the link reply after delivering the RREQ. The primary objective of sending an RREQ is to construct an opposite route thus the RREP target node can return to the source node and follow this path. The routing tables of intermediary nodes will be updated by RREQ transfer. If the present node to the target node or intermediate node, and there is a feasible path to the target node in the routing table, the RREP is returned. Otherwise, the RREQ is broadcast to the neighbors. While a node gets an RREP message, it transmits RREP message to the destination, then the target node forward an RREP message in the path routing table, ensuring that data packs are directed to the target node. To complete the path discovery, the hop is followed by another hop until the source node is reached. Generally in AODV routing algorithm works when a link breaks, the node flooding a RERR message to neighbor nodes, and then forwards the RERR message to the source. The same source again restart a route finding process to discover a path to the intended location.

The proposed a new TH-AODV protocol method for optimal path selection in MANETs by combining the Ad-hoc On-Demand Distance Vector (AODV) protocol with the factors of time and hop-count. In TH-AODV algorithm, if a communication link is broken, the best route for data delivery is determined by comparing the path from the source node to the destination node or the path from the node at the damaged link to the destination node.

III. Related Works

[7] presented an EFST-AODV routing strategy as an enhancement over AODV in terms of establishing a higher-quality route between source device and destination device. They changed the path call and path response levels in this manner. The cost metric of a route is estimated during the route request phase using factors such as remaining energy level, interval, and reserve. The typical remaining energy and typical delay of the whole track are determined in the route reply phase, and the data sending choice is made at the source device appropriately.

[8] introduced a new reactive way routing strategy, "Mobility Aware and Dual-Phase Ad-hoc On-demand Distance Vector with Adaptive Hello Messages", which was considered a key extension lead of the AODV routing strategy. This method focused on creating paths that take into account device quickness and ways of motion of source device, resulting in additional constant routes and fewer path breakages.

[9] introduced a novel "Density Aware Energy Efficient (DAEE)" routing strategy to decrease RREQ messages. Their suggested that the method aids us in identifying only those nodes that may act as packet forwarders or gateways, reducing the amount of duplicated RREQ. The higher the node density in a location, the more connected a node is to other nodes. When selecting a gateway, the relative density of neighboring nodes is taken into account. They compared their work to the old-style AODV method at various quickness and total number of nodes.

For mobile ad hoc networks, [10] presented a new greedy sending enhancement transmitting approach. The quality of the link was evaluated by considering the relative location between nodes and the path's maintenance cost during the data forwarding step, which also estimated the data transmission area. The next hop is determined by the node with the largest metric value, which is determined by the signal strength, the distance between the intermediate node and the destination, and the frequency of nearest neighbors.

Using NS-2 simulations, [4] compared the performance of the DSDV protocol, AODV protocol, and ZRP protocols for MANNETS. DSDV employs the proactive way table-driven direction-finding method, AODV employs the reactive on-demand way routing approach, and ZRP employs the proactive plus on-demand direction-finding strategy. The results of the simulations demonstrate that AODV and ZRP outperform than DSDV in high mobility simulations.

IV. Performance Metrics

To achieve the required Quality of Service, the routing algorithm directly influences the network, which is characterized by the performance metrics. The following metrics are taken into account in this work.

A. End-to-End Delay

The amount of time it takes for a communication to transfer from its origin to its final destination is known as the delay. EED is determined as follows:

$EED = PT + TT + QT + PD$ Where,

"PT - Propagation Time"
"TT - Transmission Time"
"QT - Queuing Time"
"PD - Processing Delay"

B. Throughput

Throughput of a node is the evaluation of in which way straightforwardly a node can actually transmit data via networks. The average level of efficiently transmitting data over a communication medium is called throughput.

$$\text{Throughput} = \frac{Total\ Received\ Bytes}{Elapsed\ Time}$$

C. Packet Delivery Ratio

The ratio of packets transmitted by the source node to message received by the destination is known as the packet delivery ratio [4].

$$PDR = \frac{Totat\ packets\ received(dest\_node)}{Totat\ packets\ sent(source\_node)}$$

V. Methodology

We evaluate three types of routing protocols with proposed a new TH-ADOV routing protocol which is time and hop-count based AODV routing protocol through a sequences of simulation experiments. The performance variances are assessed on 600 meter multiplication with 600 meter square, 800 meter multiplication with 800 meter square, and 1000 meter multiplication with 1000 meter square field simulation regions of the procedures for ten to sixty mobile nodes. We used three performance metrics to evaluate performance: throughput, packet transmission ratio, and average end-to-end delay are the metrics used for measuring performances. The methodology of this research work organized as follows, firstly, we installed NS-3 network simulator on Ubuntu OS, then routing protocols were configured, creating traffic network models and mobility network models, and lastly investigating these protocols by applying performance metrics in different simulation regions. This structure and test were finished our Ubuntu laptop with core i7 processor, RAM - 8GB. A range of routing protocols were configured in NS-3, such as DSDV, AODV, and ZRP. Mainly, we developed the Time and Hop-count based TH-ADOV routing protocol.

A. Generating Traffic Models

We employed "Continuous Bit Rate – CBR" bases of traffic to generate network traffic models for our investigation. The source node-destination node combines are distributed throughout the network. The data packet size used is 512 bytes. To alter the amount of load provided in the network, different source-destination combinations are used, and the packet transmission rate in each couple adjusts. An traffic simulation generator module can be used to establish TCP and CBR sample traffic connections among mobile nodes. The following code thus appears as follows:

"Ns cbrgen.tcl [-type cbr|tcp] [-nn nodes] [-seed seed] [-mc connections] [-rate rate]"

B. Generating Mobility Models

The network random waypoint models are used by the network mobility model in a rectangular area. 600 meter multiplication with 600 meter square, 800 meter multiplication with 800 meter square, and 1000 meter multiplication with 1000 meter square field simulations were used, with 10 to 60 nodes and 100 seconds of simulation time slot. Each packet starts its travel from an arbitrary position to a random destination with a randomly selected velocity. After a brief pause, a new arbitrary destination has been chosen until the destination has been extended. The pause interval, which moves the absolute speeds of the moveable device, is adjustable. Similar movement and traffic environments are employed all four protocols to ensure equal performance.

VI. Results & Discussion

In the similar simulation setting, an effort was prepared to match the three protocols with proposed protocol. The same measure models were utilized for the simulations models, the number of traffic scenario was fixed and the field configurations were used: 600 X 600m^2, 800 X 800m^2 and 1000 X 1000m^2 fields with 10 to 60 nodes and 100secs of simulation interval.

The performance of the simulation reveals several significant characteristics that are different among the routing protocols. Dynamic nature entails periodic transmission errors, and each routing scheme responds to link errors differently. The performance variations are a result of these protocols' differing fundamental functioning processes.

TABLE I. Simulation Parameters

Protocols	DSDV, AODV, ZRP and TH-ADOV
Simulation Region	600 X 600m^2, 800 X 800m^2 and 1000 X 1000m^2
Number of Nodes	10 to 60
Communication Range	100m
Mobility Type	Random Way Point
Traffic Type	CBR
Payload Size	512 bytes

A. Average Throughput Comparison

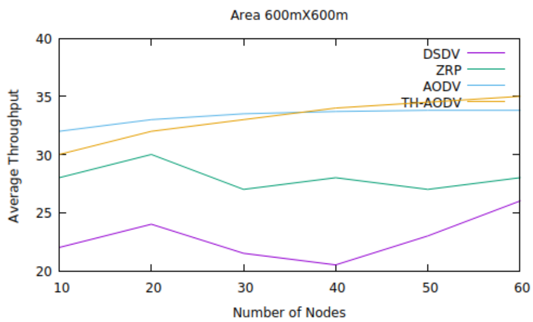

Fig. 3. Area 600*600m^2: - Throughput

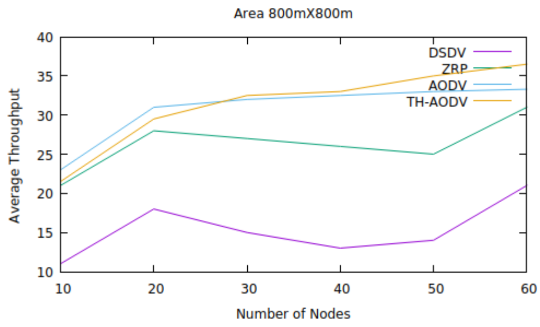

Fig. 4. Area 800*800m^2: - Throughput

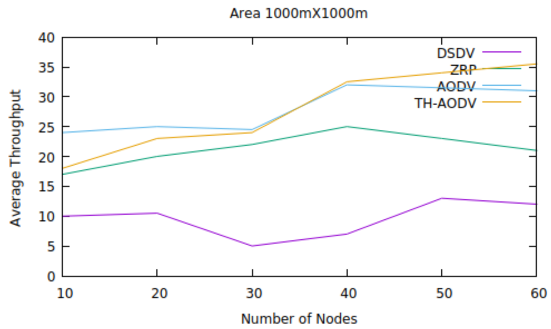

Fig. 5. Area 1000*1000m^2: - Throughput

Figure 3, 4, and 5 show the average throughput for different simulation areas. The average throughput of the DSDV, AODV, ZRP, and TH-AODV routing protocols is initially too high for AODV and too low for DSDV, as seen in the diagrams above. When the number of devices increases, the TH-AODV routing protocol's performance begins to outperform than AODV. The reason for this change is that in the TH-AODV protocol, which considers time and hop-count factors, finding the shortest path from the linked broken node to the destination node.

B. Average end-to-end delay Comparison

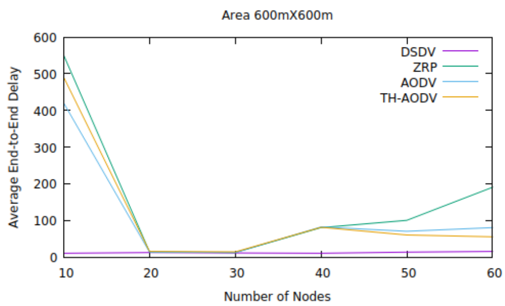

Fig. 6. Area 600*600m^2: - EED

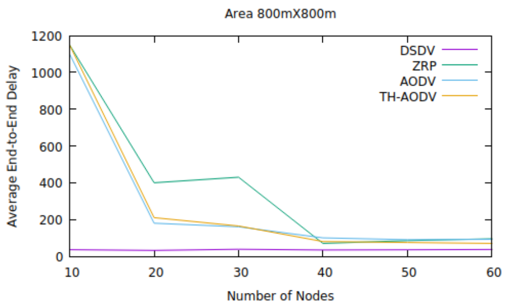

Fig. 7. Area 800*800m^2: - EED

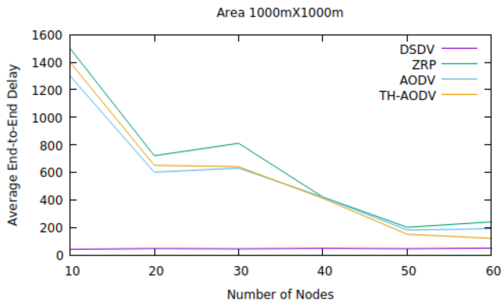

Fig. 8. Area 1000*1000m^2: - EED

Figure 6, 7 and 8 depict the average EDD for different simulation areas. The node range 10-20, the average EED delay was decreased in all four algorithms such as DSDV protocol, AODV protocol, ZRP protocol and proposed TH-AODV protocol. The average EED was upper in both AODV and TH-AODV as compared to both DSDV and ZRP when the node range 30-60. The node range beyond 50, the average EED was lower in proposed TH-AODV than AODV, ZRP, and DSDV.

C. Packet Delivery Ratio Comparison

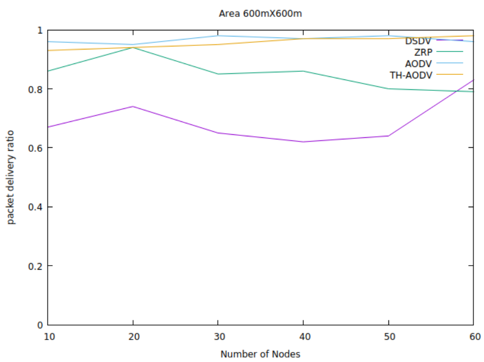

Fig. 9. Area 600*600m^2: - PDR

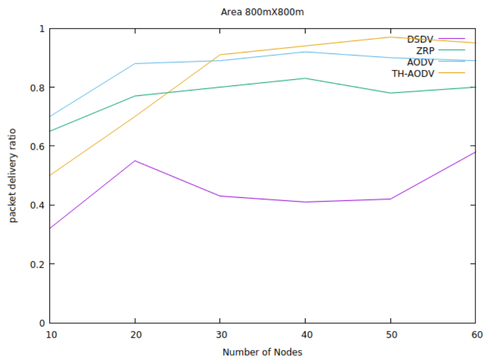

Fig. 10. Area 800*800m^2: - PDR

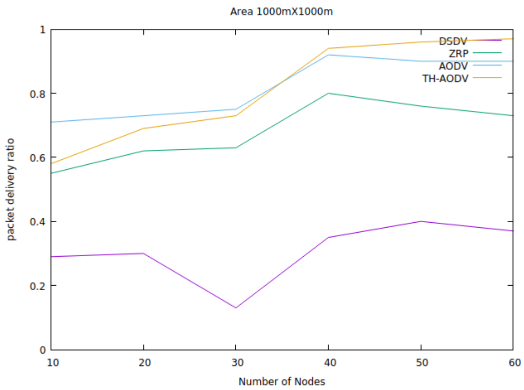

Fig. 11. Area 1000*1000m^2: - PDR

Figure 9, 10 and 11 show the packet delivery ratio for different simulation areas. The PDR for TH-AODV was higher, the algorithm DSDV was lower and the algorithm AODV and ZRP performed mainly fit to the MANET. Due to time and hop-count factors, the protocol TH-AODV is more efficient than further procedures in re-establishing the link when the link breaks during communication and retransmitting packets to the destination faster.

VII. Conclusions and Future Work

The performance for the DSDV, AODV, and ZRP protocols was compared to proposed routing methods for MANETS applying ns-3 network simulator. The algorithm DSDV employs a proactive way table-driven approach, routing AODV protocol employs a reactive on-demand approach, and ZRP employs a proactive plus on-demand routing approach. The high mobility scenario, both TH-AODV and AODV protocols outperform well than protocol DSDV. The same high mobility scenario, DSDV protocol causes frequent connection failures, and the overload of updating all nodes and routing table with fresh routing information is significantly higher than in protocol AODV and protocol ZRP, where paths are created only when they are needed.

TH-AODV employs on-demand route discovery in linked to a variety of routing mechanics. TH-AODV use routing information tables, one route per destination node, and destination node sequence numbers to minimize loops and assess path newness.

In summary, DSDV outperforms both AODV protocol and ZRP protocol when the number of nodes are decreased, whereas TH-AODV outperforms large numbers of nodes in high-mobility circumstances. As the information from the various sources show, as the total number of nodes increases, TH-AODV begins to outperform. Although TH-Routing protocol is high in terms of performance, security and power consuming needs to be investigate in the future.

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