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Original Article

An Adaptive Hybrid Routing Protocol for Efficient Data Transfer and Delay Control in Mobile Ad Hoc Network

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Abstract *- Research is gaining significant attention over the potential of wireless ad hoc networks in different domains of life. As a new gadget connects to an available network, the network grows. If the size of the network grows, the likelihood of node congestion grows as well, with an increase in packet delivery delay. This then gives rise to the complexity and unpredictability of network load. Therefore, the call for efficient routing protocols has become imperative as days go by in an ad hoc network. Available ad hoc networks can be MANETs (Mobile Ad hoc NETworks), WMNs (Wireless Mesh Networks), WSNs (Wireless Sensor Networks) or VANETs (Vehicular Ad Hoc NETworks). This research advocates a hybrid protocol that integrates AODV and OLSR. AODV was used for initiating the route selection and routing to the destination, but in the event of route congestion or link failure, the OLSR uses "multipoint relays" (MPR) to complete the packet routing to the target node. The performance of the novel "Responsive Hybrid Routing Protocol" (RHR) was tested on NS3 with several simulations for nodes between 20 to 200 and results compared to other individual protocols like AODV and OLSR. The test was conducted against network metrics like the ratio of the number of packets delivered, the ratio of end-to-end delay, the jitter delay and the ratio of packet throughput. This novel hybrid protocol RHR outperformed OLSR and AODV in the percentage of end-to-end and jitter delays. This research showed that RHR has the potential to mitigate delay and improve the transfer of packets in MANETs.*

Keywords **-** *Ad hoc, Delay, Hybrid, Performance, Protocol, Simulation.*

1. Introduction

As wireless devices and gadgets grow more and more prevalent, wired networks have become inefficient and have ushered in a new age of networking known as Ad Hoc networks. Ad Hoc Network is composed of two or more wireless gadgets, terminals, or connecting points that communicate with each other without the assistance of an administrator or central server. In addition, it is self-sufficient, configurable and linked by mobile wireless networks that act as routers at any point in data transmission [1].

They have a dynamic topology, low-bandwidth connections, a lack of resources in the nodes, and additional route choices (every node is a router). Its use can be advantageous in military situations (tanks, soldiers, and planes), meeting rooms, emergency and rescue operations, personal area networking such as Wireless home networking, Bluetooth, Special applications, and industry controls [2].

As wireless networking technology advances and the number of portable computing devices increases, wireless and mobile ad hoc networks will become valuable and perform an increasingly important part to both civilians and the military, where wireless access to the network backbone is either insufficient or unavailable. Mobile Ad hoc networks are made up of stations (nodes) that interact wirelessly without needing a permanent network infrastructure [3-4].

When the size of an ad hoc network grows above a certain threshold, any single routing system may become ineffective. As a result, the condition for utilization, the total connected nodes on the network, and the occupancy of a node's buffers all play a role in deciding which routing protocol to use [5].

Mobile Ad hoc networks provide a significant barrier to infrastructural maintenance. So, for example, the mobility of nodes affects the network architecture and results in frequent route breaks and service interruptions; the radio spectrum is restricted and prone to error, resulting in a data rate significantly lower than that of a wired network. Another difficulty for MANET is managing power on the nodes, which is limited by battery life and data delivery delays, especially when there is congestion on a channel [6].

Small and sophisticated network systems have always relied on routing as the basis for communication. Routing protocols are frequently unable to provide essential stability within a complex communication infrastructure when plagued with problems such as the mobility of nodes, dynamic communication difficulties, and node movement on devices with resource constraints [7]. The Problems that routing protocols in MANETs are confronted with, which the researcher hopes to find answers to, are:

- Frequent path breakage
- Delay in data delivery
- High packet loss

This research aims to produce a hybrid routing protocol comprising the combination of the strength of AODV (a reactive protocol) with that of OLSR (a proactive protocol). Some related works were explored, and the following were discovered.

2. Literature Review

There is no need to establish any infrastructure in a MANET to allow nodes to connect with one another. MANETs have special properties that make congestion control more difficult. The typical TCP congestion control technique is incapable of dealing with the unique peculiarities of a shareable wireless multi-hop network. The shared nature of the wireless network and the frequent changes in network topology poses substantial challenges [8]. This is why hybrid protocols play an important role in solving this challenge.

Major challenges observed by [9] are Spectrum allocation, Medium access control, routing protocols Self-configuration, Energy efficiency, Security & Privacy QoS, and Mobility management. These were highlighted as issues in wireless ad hoc networks.

The constantly changing characteristics of network topology cause some network links to be established while others are dropped. The routing techniques developed for wired networks cannot be employed in a professional setting for wireless networks. Here are a few innovative routing techniques for wireless ad hoc grids that are fit for the energetically changing ad hoc wireless scenario. [10] examined the QoS metrics of throughput, minimum, maximum, and average delay, as well as packet delivery ratio, for the two on-demand routing protocols AODV and DSR. Moving forward, let us take a look at hybrid protocols.

The researcher in [32] opined that the term "hybrid protocol" refers to protocols created by combining reactive and proactive routing protocols. In general, [12] affirmed the Distance Vector was used by the routing protocol to discover the shortest path and information about routes is sent as an update request to the rest of the neighbour nodes if the network topology changes.

In their study, [13] designed a Zone-based Hierarchical Link State Routing Protocol (ZHLS) from LSR (Local) and LSR (Global). The hierarchical routing structure is what ZHLS uses. Non-overlapping zones are used to segment this network protocol. Only the connected node inside its non-overlapping zone and the network's zone connectivity are known to each node. Global zone levels and Local nodes are used for link-state routing.

Also, [14] proffered the hybrid protocols named Distributed spanning tree (DST). It was a combination of HTF + DST. It uses a hierarchical routing structure. They suggested a distributed technique that adjusts to topology while using spanning trees in regions with stable topology. In regions where the topology is very dynamic, an intelligent flooding-like approach is used. The hold-and-forward method or the shuttling technique is used when routing packets in s.

According to [33], ZRP referred to as Zone Routing Protocols, is a hybrid protocol that combines IARP and IERP. It uses a flat routing structure. Every network node in the Zone Routing protocol employs the hybrid routing mechanism, which involves proactively preserving routing knowledge about its local surroundings, known as the routing zone, and reactively establishing routes to target areas outside the routing zone.

Besides, ZRP and DSV were combined to form HOPNET, which uses the hierarchical routing structure of soldier ants moving from one area to another. The HOPNET algorithm comprises a native proactively sourced path inside a node's neighbourhood and a reactive broadcast across neighbourhoods [16].

From different studies [17-18], the Independent Zone Routing Protocol (IZRP) was proposed. It was a modification to the Zone Routing Protocol that permits distributed configuration and responding to changes as regards the increase of node size of the network and zone on a per-node basis. As a hybrid routing protocol, the Zone Routing Protocol (ZRP) enables every network node to proactively store routing data about its routing zone while reactively acquiring routes to locations beyond the routing zone.

Furthermore, [34] in their work recommended a hybrid bio-inspired protocol called HACOR. It uses some characteristics from proactive and reactive protocols (ACO + Swarm intelligence). Data is sent to the destination using multiple paths because HACOR is established and relies on multipath during operation. It is also adaptable because it adjusts to the varying movement of nodes and network situations as it utilizes the ant agent structure.

Recently, [20] made an Improved Hybrid Routing Protocol with AODV + DTN. It uses a flat routing structure.

This protocol uses simulated foundation nodes that are carefully chosen due to their ability to deliver to the target node if a successful routing path cannot be established in the MANET.

An improved quality of service (QoS) routing for MANETs that converts problems of packet routing into a problem of resource scheduling in a hybrid network. Various routing algorithms were employed at various stages to achieve this [21].

Examples of other hybrid protocols, as highlighted by [12, 22], are Sharp Hybrid Adaptive Routing Protocol (SHARP) and Zone-based Hierarchical Link State Routing Protocol (ZHLS).

3. Materials and Methods

In this work, prototyping methodology was used. A prototype was constructed, tested, and revised using the iterative technique as needed until a satisfactory result was reached, from which the full system was developed [23]. An important part of the model approach was to build up an abstract model of the real system. This enables the researchers to have a deeper understanding of the system and run experiments that would be difficult or impossible to do in the real system because of cost or accessibility. It was common to combine this model technique with experimentation [24].

3.1. Approach

This study took an analytical and exploratory approach, combining research methodologies like qualitative and quantitative methods. Design, model simulation, data gathering, and visualization were part of the study process.

The research was conducted using the following procedures.

The First thing to do was to download Network Simulator 3 (NS3) was installed and connected. The second step was the selection of the reactive and proactive routing protocols Models, which are AODV and OLSR. These protocols were examined to understand their working and how it can be hybrid. Thirdly, the hybrid files were written; for the simulation of these protocols, a scenario file was written in C++, followed by system configuration and setup based on various parameters.

3.2. Proposed Hybrid Protocol (RHR)

The methodology that was adopted was prototype modelling. AODV protocol [25,35] was used for initiating the route selection and routing to the destination, but in the event of route congestion and failed links, the OLSR protocol [27] uses "multipoint relays" (MPR) to complete the packet routing to the destination node.

The Responsive Ad Hoc Hybrid (RHR) Protocol is another hybrid protocol for MANETs that coalesces the reactive and proactive routing approaches. When building a routing table, information is extracted from the packets with the headers RREQ and RREP to create the routing table. For instance, it changes to a proactive routing protocol mechanism in case of loss of a network link. MPR is used to acquire the path to the destination from OLSR. As the network changes, OLSR refreshes its database. To see whether there is a path to the destination, a node first checks its routing database. As long as the packet has a destination entry, it will be sent to the next node on its way to the destination.

The proposed hybrid routing protocol, named Responsive Ad Hoc Hybrid (RHR) Protocol routes by, utilizing the advantages of proactive and reactive routing. The routing table is built by extracting the necessary information from the RREQ and RREP packets. In the event that a link fails, it switches to the proactive routing protocol. It uses the OLSR's MPR to find out how to get to the destination. OLSR constantly discovers the network and updates its table. A node checks its routing record to see if there is a path to the destination when it wants to transfer a packet. If a destination entry exists, packets are sent to the following node on the path to the destination. As a result of congestion and delays, or if a route is no longer available, the proactive system selects a new route. The protocols are more sensitive and can readily adapt to the mobile network's changing topology. Below is the highlight of its phases.

3.3. Reactive Phase

AODV protocol comes into action during the reactive phase. Routing requests (RREQ) are normally sent from the source to the target node, while route responses (RREP) are sent in reverse from the destination back to the sender. From then, the sending node transmits data through the RREP message's reverse path to the destination node, which receives it. Route Error (RERR) notifications are sent when a link is broken or inaccessible. New nodes are discovered via RREQ and RREP messages based on the AODV's route discovery.

If a node's stability is regularly poor. It has a sideline label. When determining the total attempt made to get to the target node, the total attempts are considered. Nodes marked as unhealthy nodes achieve a maximum limit of attempts to reach the destination. Data delay control on the network is made easier using this method. The data delay algorithm is shown below;

- RREPs with destination sequence numbers less than or equal to the Max value are regarded to be sent by a "good" node, and vice versa.
- As soon as the RREP's destination sequence number exceeds the Max value, the RREP is tagged as Unhealthy,

and the transmitting node becomes an unhealthy node.

- So, the RREQ and RREP routing packets are used to propagate information about misbehaving nodes to other nodes in the network.

3.4. Proactive Phase

The Hello messages are intended to find out about local connections and neighbours. As a result of the Hello message broadcasting, the link is detected as well as the neighbours, are detected, and the MPR is selected. To maintain the network's topology, nodes communicate with each other via messages called Topology Control Messages.

By employing neighbour information and topology information, which are updated regularly, each node may calculate the paths to all known destinations. The shortest path algorithm is employed to determine these paths, and most hops are used as a result of this technique. The routing table is usually kept up to date whenever details about the neighboring network or the network topology change.

During the switch from the reactive to proactive phase, the protocol uses the topology discovery mechanism to update its routing table. It can initiate the failed route from the reactive phase. The constant topology discovery keeps the OLSR routing table updated. This helps to route packet data to the destination node when the reactive protocol (AODV) is unable to do that. This reduced delay in sending packet data as there is an immediate switch to proactive protocol when the reactive cannot get the job done.

3.5. Materials Used

In the past, network testbeds were used to evaluate network models. It was extremely problematic, but network simulators arrived on the scene and changed the game. Any defects in the test bed have no effect on the simulators. Simulators can be said to be easier to use and monitor because they allow the entire network to be managed in one place. Experiments can also be duplicated because they are specified as scenario files.

The simulated size of the network is only constrained by way of the capacity of the computer used for the simulation. Simulators make use of a repertoire of techniques to optimize their accuracy, scalability, speed and usability [28-29].

3.6. Simulation Scenario and Parameters

In a simulation environment, different parameters exist for describing the typical performance of MANET protocols; the settings were changed in a variety of ways. This simulation is dependent on the following factors, which are listed in the table below.

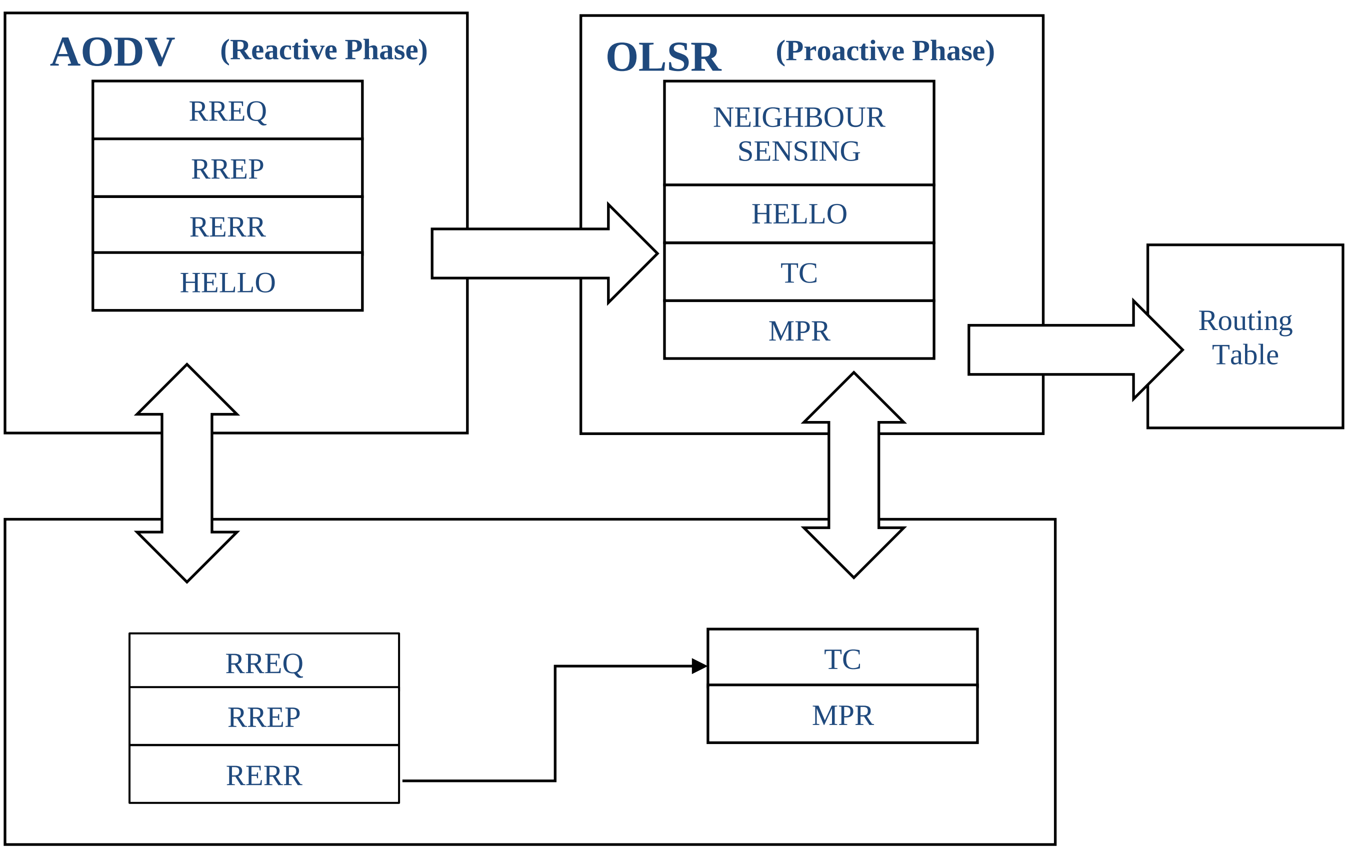

Fig. 1 Component diagram of the proposed hybrid protocol

Table 1. Simulation settings

S. NO	SETTINGS	VALUE
1	O S	Linux OS
2	Network Simulation tool	N S 3
3	Protocols	OLSR, AODV, RHR (Hybrid)
4	Simulation Nodes	20, 50, 100, 150, 200
5	Simulated Time for nodes	200 s
6	Size of Map	300×1500 meters
7	Speed of Nodes	20 m/s
8	Mobility Model	Random Way Point
9	Type of Traffic	Constant bitrate (CBR)
10	Size of Packet	512 bytes
11	Node Pause Time	0 s
12	Mac	Adhoc Wifi MAC
13	Bandwidth of links	2Mbit
14	Allocator Position:	Random Rectangular Position Allocator
15	Mac Standard	802.11
16	Physical mode	DsssRate11Mbps
17	Propagation Model:	Constant Speed Propagation Delay
18	Propagation Loss Model	Friis
19	No of Sinks	10

Table 2. Simulation Result for total sent packets of 20, 50, 100, 150, and 200 nodes

Protocols / No. of Nodes	AODV	OLSR	Hybrid (RHR)
20 Nodes	958	341	1103
50 Nodes	2624	353	3853
100 Nodes	4548	714	7795
150 Nodes	8532	727	13326
200 Nodes	19457	772	19020

In terms of performance output, different protocols will be compared. Finally, the results and related analyses will be displayed using a visualization graph [30-31].

4. Results and Discussion

The data were gotten from the simulation of the protocols for 20, 50, 100, 150 and 200 nodes. The simulation was carried out as shown in Table 2 above. Discussion shall be made below based on the number of nodes simulated. We shall be looking at how the number of nodes affects how well various MANET protocols perform when they are investigated.

4.1. Discussion for 20 Nodes

The figure 2 showed that OLSR lost more packets than Hybrid (RHR) and AODV. AODV lost fewer packets. Furthermore, the new Hybrid protocols (RHR) have the highest number of packets sent (1103) from Table 2. AODV followed behind with a value of 958, and OLSR sent the least total packets of 341. Out of the total sent packets, the hybrid has the highest received, followed by AODV, and OLSR received the least packets. This result showed that OLSR has the highest total packet loss and was followed by AODV and then followed by the hybrid RHR. In this light, RHR has a better packet transfer than OLSR and AODV.

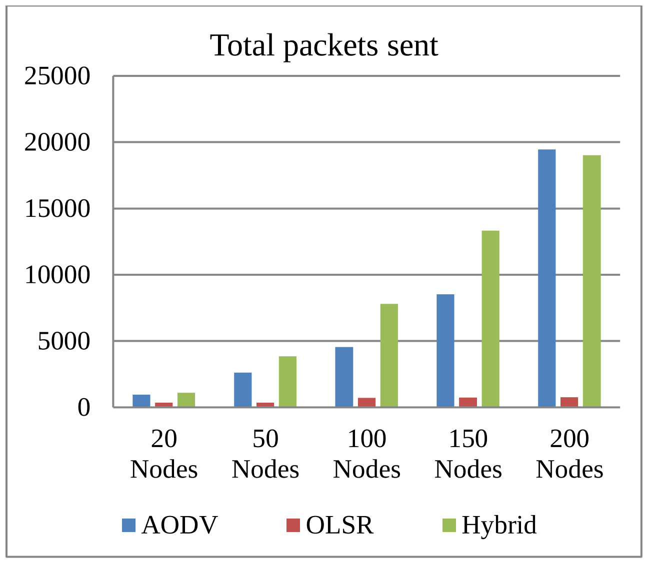

Fig. 2 Chart for total packets sent for 20, 50, 100, 150 and 200 nodes

4.2. Discussion for 50 Nodes

The chart above showed that the new Hybrid (RHR) lost fewer packets than OLSR and AODV. OLSR lost the most packets. Furthermore, in packet delivery, the new hybrid performed better for 50 nodes than AODV and OLSR.

The new Hybrid protocols (RHR) have the highest number of packets sent (3553) from Table 2. AODV followed behind with a value of 2624, and OLSR sent the least total packets of 353. Out of the total sent packets, the hybrid has the highest received, followed by AODV, and OLSR received the least packets. This resulted that the new hybrid having the best delivery ratio, followed by AODV and then OLSR. In this light, RHR has a better packet transfer than OLSR and AODV.

Table 3. Throughput data for network sizes 20, 50, 100, 150, and 200 nodes

Protocols /Nodes	20	50	100	150	200
AODV	11.3782	31.3477	12.8241	13.0469	7.65861
OLSR	1.8084	0.871654	1.50603	0.883071	0.810549
Hybrid	29.242	22.8114	9.32391	9.21641	8.79644

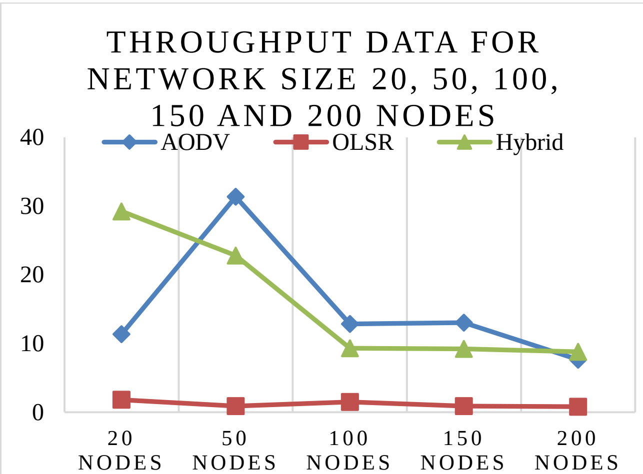

Fig. 3 Network throughput chart

4.3. Discussion for 100 Nodes

The new Hybrid protocols (RHR) have the highest number of packets sent (7795) from Table 2. AODV followed behind with a value of 4548, and OLSR sent the least total packets of 714. Out of the total sent packets, the hybrid has the highest received packets, followed by AODV and OLSR. Furthermore, in packet delivery, the new hybrid performed slightly better than AODV for 100 nodes, and OLSR performed poorly in packet delivery in this category. In this light, RHR has a better packet transfer than OLSR and AODV.

4.4. Discussion for 150 Nodes

From Table 2, the new Hybrid protocols (RHR) have the highest number of packets sent (13326). AODV followed behind with a value of 8532, and OLSR sent the least total packets of 727. Out of the total sent packets, the hybrid has the highest number of received packets, followed by AODV, and OLSR receives the least packets. This resulted that the new Hybrid protocol (RHR) having the best packet delivery ratio, followed by AODV and then OLSR.

4.5. Discussion for 200 Nodes

From Table 2 (200 nodes), the AODV protocols have the highest number of packets sent (19457). The new hybrid followed behind with a value of 19020, and OLSR sent the least total packets of 772. Out of the total sent packets, Hybrid (RHR) has the highest number of received packets, followed by AODV and OLSR received the least packets. This resulted in the AODV protocol having the highest total packet loss while the new hybrid followed OLSR.

Table 4. End-to-end delay data for network sizes of 20, 50, 100, 150, and 200 nodes

Protocols /Nodes	20	50	100	150	200
AODV	9.69298	21.4647	50.1019	11.9321	30.2728
OLSR	0.288301	0.118705	3.07469	2.17495	4.33002
Hybrid	0.428433	0.262357	1.06323	2.1313	3.55244

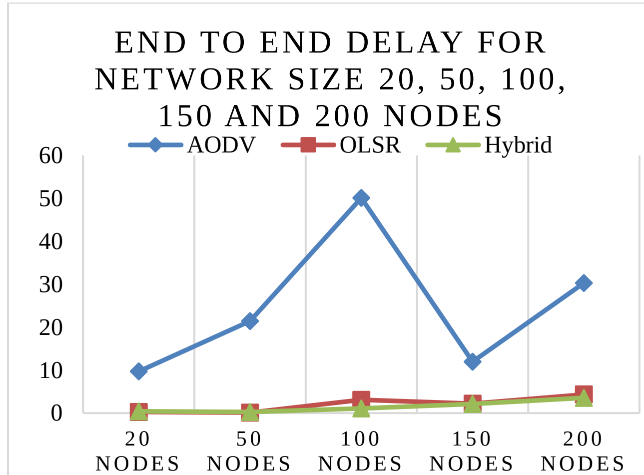

Fig. 4 End-to-end delay chart

Table 5. Jitter delay data for network sizes of 20, 50, 100, 150, and 200 nodes

Protocols / Nodes	20	50	100	150	200
AODV	60.5647	70.1164	234.614	547.863	1420.09
OLSR	2.26782	7.01784	49.4914	30.2224	43.3002
Hybrid	2.19979	1.52903	5.08029	9.24784	14.8703

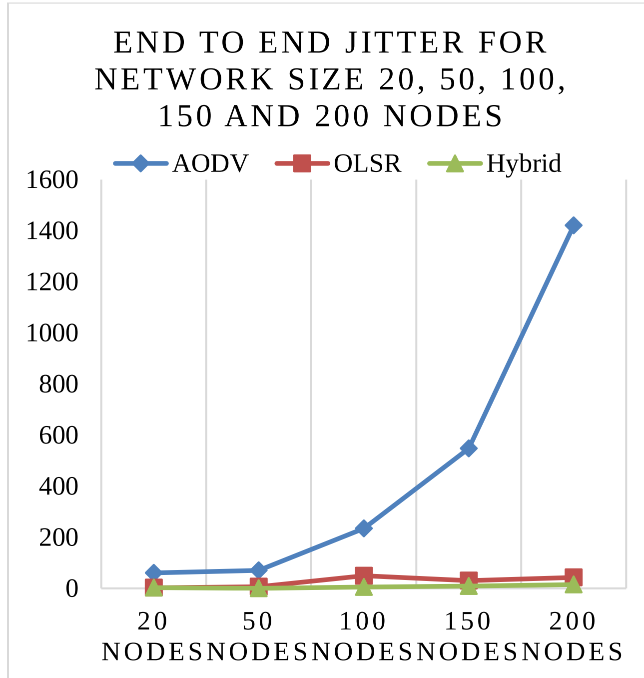

Fig. 5 Jitter delay chart

4.6. Throughput

The figure 3 shows that the new Hybrid protocols have an improved throughput for simulations of 20 and 200 nodes. For 50, 100, and 150 nodes, AODV has better throughput. This, after careful examination, is connected to the fact that the novel hybrid protocol sends a higher number of packets for nodes 50, 100, and 150 than AODV. This affected the throughput ratio and thus gave a better result.

4.7. End to End Delay

The chart from Figure 4 clearly showed that the new hybrid was better in end-to-end delay than the rest protocols (AODV and OLSR). The amount of delay from the hybrid routing protocol is the smallest among the rest. Producing a routing protocol that uses a minimal delay to route packet data is one of the objectives of this research. From the statistics above, it was achieved. OLSR has the second-best end-to-end delay, while AODV didn't perform well.

4.8. Jitter Delay

The variety of delays that packets traveling across a network connection experience before they reach their destination is known as Jitter delay. For end-to-end jitter delay, the new hybrid protocol (RHR) has the best jitter delay. Figure 5 clearly shows that the new hybrid protocol has a jitter lesser than the constituent protocols AODV and OLSR. OLSR followed as second best, while AODV has the worst jitter delay among the protocols compared.

5. Conclusion

This research identified the areas of strength of AODV and OLSR and combined them to produce a hybrid protocol (RHR), knowing that OLSR is a delay-intolerant protocol. The new hybrid protocols have shown from a series of simulations that it reduces delay and increases throughput compared to other hybrid protocols like ZRP and DST. The hybrid's data delivery was better than OLSR and AODV. RHR sends a higher number of packets during the simulation, and thus is the reason for its performance better than the state-of-the-art protocols (AODV, OLSR). As mobile ad hoc network usage grows around the world, researchers are encouraged to find better ways of routing that will remove the current bottlenecks routing protocols have. With more and more research on ad hoc networks, breakthroughs have become inevitable for MANET.

Some questions that keep begging for answers include how node mobility affects packet delivery in MANETs. Can the proposed hybrid algorithm RHR be applied to VANETs to ascertain suitability? These are areas of future research.

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