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AGDT: A Mathematical Model of Hybrid Algorithm for Efficient Routing in MANETs Using Dynamic Thresholds

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Abstract:
Due to the high mobility of nodes in the dynamic topology of Mobile Ad Hoc Networks (MANETs), it is challenging to define the precise position of a node in the network for effective data delivery. The paperproposed a hybrid algorithm for routing in MANETs called Adaptive GPSR with Dynamic Thresholds (AGDT). AGDT is a novel approach that combines the GPSR routing protocol with a dynamic threshold-based approach to increase the enactment of the network. The algorithm employs distance and direction-based thresholds to determine when to switch between GPSR and a perimeter-based approach for routing. The paper discusses the implementation of the algorithm and provides a performance evaluation of its effectiveness in comparison to other present routing algorithms. The results show that AGDT outperforms other protocols in terms of packet delivery ratio, end-to-end delay, and throughput. The paper concludes by highlighting the potential applications and benefits of the AGDT algorithm in MANETs.

Keywords: MANET, GPSR, Dynamic Thresholds, Routing.

1 Introduction:

Mobile Ad Hoc Networks (MANETs) are self-configuring networks of mobile devices that connect with each other over wireless communication[1]. Devices or nodes that participate in a MANET are mobile and have the ability to joint or dispensationany time in network. They are highly dynamic and resilient due to the fact that they rely to forward data packs to their respective end points. MANETs are useful in circumstancesplaces where there is no pre-existing infrastructure for networks to connect or in situations where the existing structure is damaged or unavailable. The ability of MANETs to operate without a fixed infrastructure makes them ideal for use in a widespreadvariety of solicitations, such as military networks, disaster response, and emergency services. The dynamic nature of the network topology and the restricted resources of the nodes, such as battery power, computing capabilities, and memory, make routing in MANETs a difficult problem to solve. These factors combine to make routing in MANETs a complex challenge. There are various routing algorithms developed to address the unique challenges of MANETs, including proactive, reactive, and hybrid protocols. Yet, due to this dynamic behaviour, it presents a substantial difficulty due to the fact that the topology of the network can shift quickly and in an unpredictable manner [2].

Routing in MANETs involves finding a route from a sender to a receiver, while taking into description the nodes mobility and the dynamic nature of the network. The design of efficient routing algorithms is crucial to ensure reliable and efficient communication in MANETs.MANETs make use of many different kinds of routing algorithms, including proactive, reactive, and hybrid protocols [3].

Proactive routing protocols are responsible for keeping all of the routing information in a network's nodes up to date. Optimal Link State Routing and Destination-Sequenced Distance Vectorare two modelsof proactive routing techniques. These protocols continuously exchange control messages to update routing tables and maintain paths to all destinations. These protocols are suitable for networks with high mobility and low data traffic, but they may not be scalable for large networks due to the high overhead associated with maintaining routing tables. Proactive routing also named as Table-driven.

Reactive routing protocols, do not keep routing info for all of the nodes. In its place, reactive routing protocols only build routes when they are required. Ad-hoc On-demand Distance Vector and Dynamic Source Routing are categories of this types of routing. These protocols will flood the request from root in network to find a route on demand, and then they will save the found route in a cache so that it may be used again in the future. Because of the reduced effort required to maintain routing tables, reactive protocols are well suited for networks that have a relatively low level of user mobility but a high volume of data traffic. It is also called On-demand protocols.

Hybrid routing protocols are the combinations of proactive and reactive routing. Hybrid routing protocols use proactive protocols for stable routes and reactive routing protocols for dynamic routes. Zone Routing Protocol (ZRP) and Hybrid Routing Protocol (HRP) are the categories of hybrid routing protocols [4]. The network is separated into zones by these protocols, and proactive routing is utilised inside each zone, while reactive protocol is utilized to connect the zones.

Geographic routing protocols are another type of routing protocol that may be used to route data packets. These methods make use of location information in addition to proactive, reactive, and hybrid routing techniques. Greedy Perimeter Stateless Routing and Geographic Distance Routing are two examples of geographic routing protocols. Other geographic routing methods include the following: (GEDIR). These protocols make use of location information in order to choose the next hop. Due to the fact that they do not rely on information on the topology of the network, geographic routing are suitable for networks that have both high levels of mobility and low levels of connectivity [5].

In past few years, MANET routing algorithms that can adapt to network dynamics have gained popularity and optimise the use of limited resources. This interest has been spurred on by the increasing number of MANETs that are being deployed worldwide. These algorithms include energy-efficient routing protocols, intelligent routing, and machine learning-based routing, among other types of routing. These kinds of algorithms intend to increase the performance of MANETs in the ratio of packets delivered, the end-to-end delay, power consumptions and the lifetime of the connections. MANETs are networks of mobile devices that are capable of automatically configuring themselves and that interact with one other through wireless connections. There is no permanent infrastructure required for MANETs to function. When it comes to MANETs, finding a solution to the issue of routing is especially challenging because of the dynamic nature of the network. MANETs make use of a diverse range of routing algorithms, such as proactive, reactive, and hybrid protocols, in addition to geographic routing protocols that make use of location information. The features of the network, such as its scalability, mobility, and data traffic, are taken into consideration while selecting the appropriate routing algorithm. The development of effective routing algorithms is an absolutely necessary step in order to guarantee dependable and effective communication in MANETs.

2 Routing In MANETs:

Setting up and maintaining path in a MANET system can be difficult owing to the limited resources available and the rapid changes that occur in the network. In order to tackle this issue, MANET routing protocols are separated into two basic categories: location-aware (position-based) and location-unaware (topology-based).

While establishing and maintaining routes, location-aware routing protocols rely on the locationdata of network nodes as their primary source of data. This strategy is especially helpful in circumstances in which nodes move around often or in which the topology of the network is subject to rapid modification. On the other hand, location-unaware routing protocols set up routes based on the structure of the network rather than taking into account the actual locations of the nodes [6].

In a MANET context, the unique requirements and qualities of the network should serve as the primary considerations in selecting the appropriate routing protocol. It is possible to increase the efficacy and dependability of communication inside the network by picking the protocol that is best suited to the situation.

2.1 Greedy Perimeter Stateless Routing (GPSR):

Greedy Perimeter Stateless Routing is a well-known and popular choice for the routing protocol. The Geographic Packet Switching and Routing Protocol, abbreviated GPSR, is a geographic routing system that determines which nodes in a network should receive packets based on their locations. A greedy forwarding approach is used by the protocol to route packets towards the target. With this method, nodes pick the neighbour who is physically located nearby to the receiver as the followingnode in the chain. Geographical routing is a method that leverages location information in order to construct a direct path towards the target. Other names for this approach include geographical routing, Geographical, and position-based routing. This strategy decreases the likelihood of nodes being inactive due to a variety of causes and improves the efficiency of transmission from the server. It is especially helpful in wireless sensor networks because of the widespread data sharing that occurs between wireless nodes [7].

This approach for routing employs a topology with a single next-hop, because the routing itself selects the most efficient path between neighbouring nodes. The amount of data that is allowed to overflow from the routing table can be reduced by using a geographical routing technique towards forwarding nodes. The approach prevents nodes within the transmission range from forwarding data packets by imposing restrictions on them. Nodes that depart from the routing path are not considered part of this transmission range since it is determined by the source nodes or the nodes in between. Nodes in Geographical routing, sometimes called Position-Based routing because of its other name, are responsible for marking the positions of their near neighbours. This approach forwards the packet using the Greedy Perimeter method, which further lowers the amount of energy that is used by each node since it reduces the amount of data overflow that occurs inside a single hop [8].

However, GPSR has some limitations, such as the inability to handle void regions and the need for precise location information. To address these limitations, a modified version of GPSR called Greedy Perimeter Stateless Routing with Guaranteed Delivery (GPSR-GD) was proposed[9], which uses a perimeter-based approach to bypass void regions in the network.Another modification of GPSR is the Greedy Perimeter Stateless Routing with Energy Efficiency (GPSR-EE) protocol [10], which integrates energy-awareness into GPSR. GPSR-EE uses a combination of distance and energy as metrics to select the next hop, thus conserving the energy of nodes and extending the network lifespan

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

AODV is intended to construct and maintain effective pathways between mobile nodes in a network environment that is dynamic and decentralised. Because it is an on-demand routing, it only creates path when really required, instead of continuously maintaining them. This approach minimizes network traffic and conserves resources [11].

AODV uses distance vector algorithms to decide the best routefrom sender to receiver. It also employs a number called sequenceto dodge loops in routing and ensure the freshness of routing information. AODV is a widely used protocol due to its simplicity, scalability, and adaptability to network changes.

2.3 Distance Sequenced Distance Vector (DSDV)

The DSDV used the concepts of Bellman-Ford routing algorithm which is a proactive routing method. This approach ensures that the minimum path is used when travelling from one node to another. It does this by implementing a new feature that assigns sequence numbers to each routing table entry across the whole network. This eliminates the possibility of routing loops being created. The routing database is frequently updated across the network to ensure that the routing information is always accurate and consistent. Exchanges of tables take place at regular intervals to ensure that the image of the network that is presented is always accurate [12].

Notation. D_i^h is the distance of route from node 1 to node i of h steps or less.

Set initially $D_i^0 = \infty$ for i ≠ 1 and $D_1^h = 0$ for all h.

The Algorithm is then simply, for all I ≠ 1,

$$D_i^{h+1} = \min\,[D_j^h + w_{ji}] \qquad (1)$$

After h iterations the algorithm is terminated if

$$D_i^h = D_i^{h-1}\, for\ all\ i \qquad (2)$$

During routing information packet broadcasting, two different kinds of messages have been specified in order to cut down on the amount of information that must be conveyed. One message contains all of the routing information that is currently accessible; this message is referred to as the full dump. The other message, which is referred to as the incremental dump, includes just the data that has changed since the last complete dump. The difference between an incremental dump and a complete dump is that the latter requires more Network Protocol Data Units (NPDU), while the former simply needs one NPDU to communicate all of the information. A node compares an information packet from some other node to the entry's sequence number. The node updates the item with the new sequence number if it is more or less than the previous sequence number. Using the same sequence number requires metric input.

2.4 Optimized Link State Routing Protocol(OLSR)

The OLSR is a proactive routing system that was developed specifically for MANETs. It operates well in extremely dense and extensive networks that have a high mobility requirement for their nodes. Here are some key features and benefits of OLSR:

- Multipoint Relays (MPRs): OLSR reduces the number of broadcast messages by using a set of MPR nodes. These nodes forward broadcast messages to their neighbours, reducing the overhead on the network.
- Topology Control: OLSR maintains a compact and up-to-date network topology allows it to efficiently route traffic between nodes.
- Multiple Metrics Support: OLSR supports multiple metrics for instance hop count, bandwidth, and delay, allowing it to choose the best route based on various criteria.
- Quick Route Setup: OLSR establishes routes quickly by using pre-calculated tables of the next-hop nodes for each destination. This approach minimizes the time needed to discover new routes and reduces the network traffic.
- Scalability: OLSR is scalable and can support a large number of nodes without causing network congestion or degrading the performance.

OLSR is widely used in various applications such as military and emergency response operations, where reliable and efficient communication is critical. Its efficient use of network resources and ability to adapt to altering network environments make it a robust and effective routing protocol for MANETs [13].

2.5 Dynamic Source Routing (DSR)

DSR is a reactive source routing mechanism. The protocol requires each packet to carry the entire address of each hop from the point of origin to the destination. An on-demand method is utilised by the protocol in order to perform route discovery and maintenance. The ability of nodes to cache numerous routes simultaneously is one of the advantages of DSR. This paves the way for more expedient route finding in the future. If the cache contains a legitimate route, then there is no need for any additional route finding to take place. On the other hand, an RREQ packet will be transmitted to begin route discovery [14] in the event that a legitimate route cannot be located. A route record field is included in the RREQ packet together with the address of receiver, sender information and exclusiveID number, and both of those addresses. A RREP is sent back with the reversal of the path followed by the RREQ when it reaches to the receiver. This happens when the RREQ reaches one of these two points. Monitoring acknowledgments or passively overhearing packets that are being passed by neighbouring nodes are two methods that may be used to identify broken connections.In order to let the source node know that the link has failed, an RERR packet is sent out into the network. The source node then has the option of utilising another route that is already known to it or initiating route discovery once more in order to locate a new route. DSR, in contrast to other protocols, does not need nodes to exchange greeting messages. As a result, nodes are able to preserve power and save bandwidth.

3 Literature Review:

Kannammal and Sujith Roy [15] presents a survey of secure routing protocols for MANETs. The authors review 38 routing protocols and classify them based on their security mechanisms, such as authentication, confidentiality, and integrity. They also discuss the challenges of securing routing in MANETs, such as node mobility, limited resources, and lack of centralized authority. They present a complete analysis in secure routing protocols and identify the outstanding research topics that exist within this field.

El-Kabbany et al. [16] compares the value of several routing protocols for MANETs, including AODV, Destination-Sequenced Distance Vector, DSR, and Temporally Ordered Routing Algorithm (TORA), amongst others. These protocols are analysed by the authors using a variety of performance criteria, including throughput, end-to-end latency. The findings of this study indicate that AODV protocol beats the other protocols in the common of test configurations.

Rahim et al. [17] present a review of energy-efficient routing strategies for Wireless Ad Hoc Networks (WANETs). The authors conduct an analysis different routing protocols and place them into one of four groups according on the energy-saving measures they implement. In addition to this, they evaluate the values of various used methods in terms of energy consumption, the ratio of packet delivery, and the longevity of the network. This research offers some helpful insights regarding energy-efficient routing methods.

Hadi and Makki [18] proposed an improve MANET routing protocol to use a hybrid swarm optimisation model. They implemented optimisation using a MANET network as the ideal setting, and the suggested approach combines cat swarm optimisation (CSO) with particle swarm optimisation (PSO). MANT network, also known as mobile sensor network, and utilising the methodology of the research, it is possible to identify the improvement mechanism (s) that could be used to put an end to degraded routing concerns and enhance act. Authors In contrast to those obtained using PSO and CSO, and providing evidence that the proposed model yields superior outcomes.

Saraswat and Khan [19] presented a routing that combines the routing, queuing, and location techniques to advance the overall worth of service provided by the network. The suggested solution employs multipath routing with QoS measurement methodology that makes advantage of un-assigned slots, which improve network resilience. The QoS methodology that used un-assign slot was used by the QoS policy that used un-assign slot. The authors provide evidence that the proposed method of QoS measuring in conjunction with an improved routing protocol was intended to achieve greater reliability.

Biswas AK et al. [20] designed and implemented a secure hybrid routing protocol including proactive and reactive protocol methods. Within the context of this protocol, both the spanning tree and the MANET are built in a proactive manner. In addition, M-S-T, is utilised in the construction of networks for the transmission of data.

4 Proposed Method:

The results of this study present a novel routing method that is appropriate to employs distance and direction-based thresholds to determine when to switch between GPSR and a perimeter-based approach for routing. The proposed algorithm is called Adaptive GPSR with Dynamic Thresholds (AGDT). AGDT is a hybrid algorithm that combines GPSR with a dynamic threshold-based approach for routing in MANETs. The algorithm uses distance and direction-based thresholds to determine when to switch between GPSR and a perimeter-based approach.

The AGDT algorithm works as follows:

- Before a source will transmit a packet to a destination, it will first determine whether or not the destination is in its range. In that case, the packet is sent along with the GPSR signal in order to reach its destination as quickly as possible. When destination node is not in range for transmission, the source will send out a Route Request (RREQ) message to its surrounding nodes.
- When a node has been given an RREQ message, the node will determine whether or not it is the destination node. It will send a Route Respond (RREP) message to the node that initiated the request. In the event that this is not the case, it appends its ID to the RREQ message and sends to its neighbours.
- Every node that obtains the RREQ message calculates its distance and direction to the destination node. If the distance is less than a distance threshold and the direction is within a direction threshold, the node switches to GPSR and forwards the packet directly to the destination. If the distance is larger than the distance threshold or direction is outside to direction threshold, the node uses the perimeter-based approach.
- The perimeter-based approach uses the right-hand rule to traverse the perimeter of the polygon formed by the nodes in the network. The node sends the packet to the nearest perimeter neighbour. If the node reaches a dead end, it backtracks to the last intersection and continues along the perimeter until it grasps the destination node or seeks a nearby node to forward the message.
- When network status changes, both the distance and direction criteria are dynamically modified. If the network is not very dense, the distance threshold will be higher, while if it is very dense, the threshold will be lower. In order to take into consideration the mobility of the node, the direction threshold is modified according to the node's position and velocity. In the event that a node is unable to locate a path to the receiver using either the GPSR or the perimeter-based technique, it will send a Route Error (RERR) message back to the node that it originated from to let it know that the destination cannot be reached.

The information regarding the AGDT routing is shown in the following algorithm. The symbol RN indicate the receiving node, N represent the neighbours of RN, n represent the single node in N, SN indicate sender, DN is the destination node and dv is distance vector of nodes n to DN.

Proposed AGDT algorithm.

```
Send a Packet:
if DN ϵ RN
        use GPSR to forward packet directly to DN
else
         broadcast RREQ message to neighbours with SN ID and DN ID
         wait for RREP or RERR message
end if
upon receiving RREQ message:
if node ϵ DN
      send RREP message back to SN with route information
else
      add node ID to RREQ message
      forward RREQ message to neighbours (N)
endif
while forwarding RREQ message:
calculate dv and direction to DN
if distance < distance threshold and direction within direction threshold:
    use GPSR to forward packet directly to DN
else
    use perimeter-based approach to forward packet along perimeter of polygon
    adjust distance and direction thresholds based on network conditions
endif
if DN is unreachable:
    send RERR message back to SN
endif
```

The AGDT algorithm provides a more efficient routing solution for MANETs by using GPSR for short-range communication and the perimeter-based approach for longer ranges. The dynamic thresholds ensure that the algorithm is adaptive to the network situations, allowing for better performance and more effective use of resources in network.

5 Simulation Environment:

In order to demonstrate the efficacy of the proposed method, the comparison of the throughput performance was done for different number of MANET routing methods. These routing include AODV, DSDV, OLSR and DSR. The Network Simulator-3 (NS-3) running on the Ubuntu platform is the simulation tool that is being utilised. Metrics of performance such as Throughput, Packet Delay Ratio, and End-to-End Delay are utilised in the process of performance evaluation.

5.1 Performance Metrics:

Performance metrics are used to measure the efficiency and effectiveness of routing algorithms. Here are some used performance metrics for this research work:

- **Throughput**: It is a measurement of the total quantity of data that can be sent via the network in a certain length of time.The unit of throughput is bits per second (bps) [21, 22].

$$Throughput = \frac{Number\ of\ Packets\ send\ Productively}{Total\ Period} \quad (3)$$

- **Packet Delay Ratio**: It is the ratio of the number of packets that are transferred to the number of packets that are delivered within a certain amount of time. It is a measure of the efficiency of the routing algorithm [21].

$$Packet\ Delay\ Ratio = \frac{Number\ of\ Packets\ Received}{Number\ of\ Packets\ Sent} \times 100 \quad (4)$$

- **End to End Delay**: It is the amount of time that elapses between when a packet leaves its origin and when it arrives at its destination. It includes the time taken for packet transmission, propagation, and processing delays.

Different routing algorithms have different strengths and weaknesses, and their performance metrics can help network administrators to choose the most appropriate algorithm for their specific needs. Real-time applications need low end-to-end latency and jitter. On the other hand, if the network is used for bulk data transfer, throughput and packet delay ratio may be more important.

6 Results and Discussion

The effectiveness of the simulation is appraised in accordance with the performance indicators of throughput, packet delay ratio, and end-to-end delay.

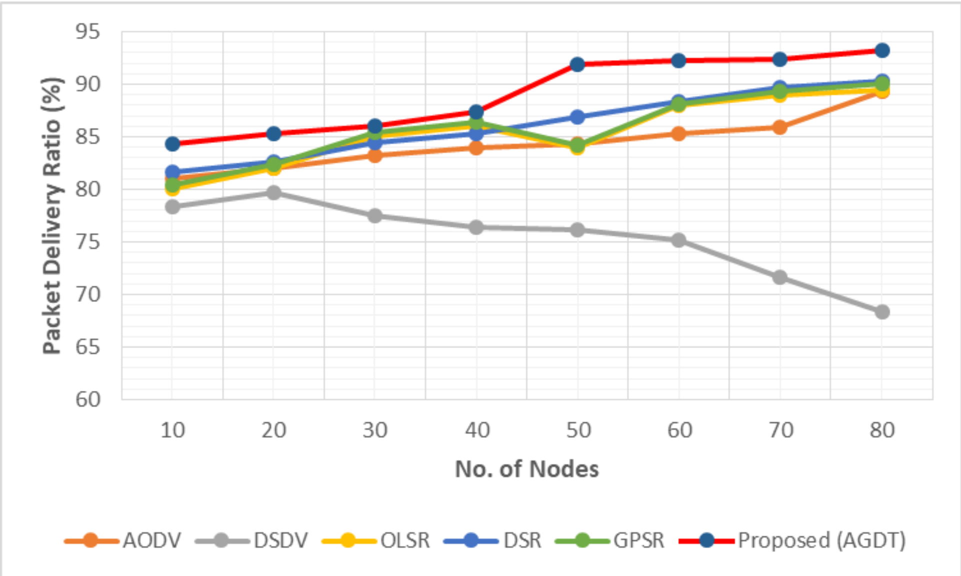

Figure 1: Packet Delivery Ratio comparison with different node density

The term "Packet Delivery Ratio" refers to the proportion of data that are effectivelysent to the receiver node in comparison to the total packets that were transmitted from the sender. The findings that are illustrated in Figure 1 reveal that the suggested algorithm AGDT accomplishes a higher Packet Delivery Ratio value than the methods AODV, DSDV, OLSR, DSR, and GPSR.

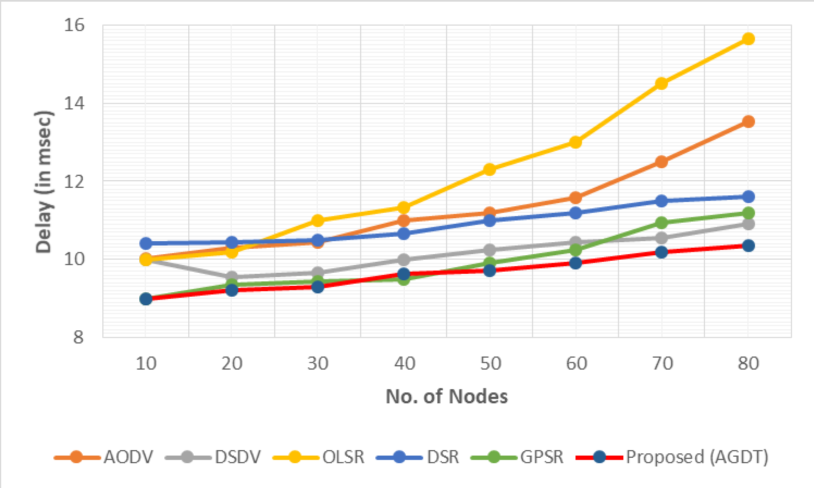

Figure 2: End-to-End Delay comparison with different node density

End-to-end delay is the average time a data packet takes to transit from a source node to its target. This delay begins when the packet leaves the source node and remains until the packet touches its final node. It is necessary for good performance to have a low average latency from beginning to end. The end-to-end latency of the suggested method is much shorter than that of any of the previous algorithms that have been utilised, as can be shown in Figure 2. The ability to send data packets straight to a one-hop neighbour or greedily avoids delays incurred by buffering data packets during route discovery and saves time on route rediscovery. Forwarding the data packet straight to a one-hop neighbour will remove these delays.If the destination is a neighbour on the same hop as the sender, then the availability of greedily forwarding the data packet reduces delays caused by buffering of data packets. If the destination is further away, then the delay is caused by buffering of data packets.

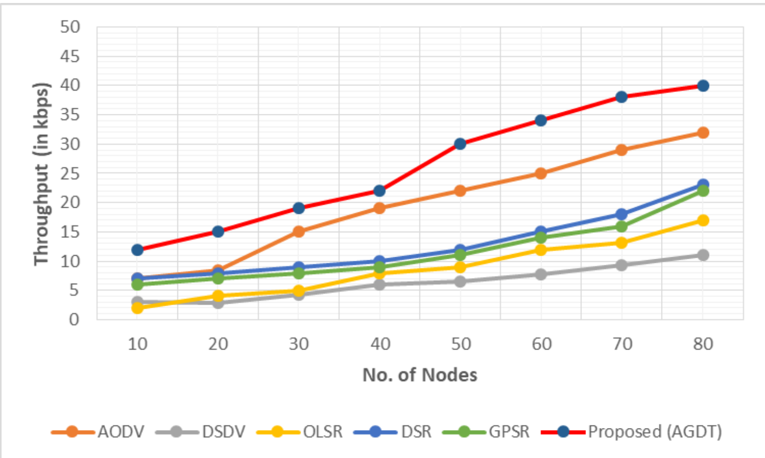

Figure 3: Throughput comparison with different node density

Throughput (kbps) is the quantity of data that can be transmitted in a particular time. The results of the comparison in figure 3 show that the AGDT performs well than other algorithms that have been used. It's possible that the lessened amount of traffic on the path is responsible for this effect. It has also been demonstrated that AGDT method performs better than other used algorithms due to the failure of greedy forwarding.

7 Conclusion

An ad-hoc network that operates short of the need for a base station to be established in a centralised location. The most major challenge presented by MANETs is the unexpected breakdown of connectivity. Because of this difficulty, we are obligated to re-establish the connection by sending RREQ and RREP packets. The efficiency of the network will suffer as a direct consequence of this. For the purpose of routing using GPSR in MANET, our flexible dynamic threshold-based hybrid method has been developed. The hybrid routing protocol that has been developed is better suited for usage in MANETs, which reside a very large amount of mobile nodes that change at a variety of speeds and regularly modify those speeds. These mobile nodes also frequently adjust the rates at which they travel.

This study also included the simulation of a variety of MANET routing protocols in NS3 and an analysis of how well they performed. The proposed method named as AGDT has been put into action, evaluated based on a variety of performance metrics, and compared to the results obtained by a number of different MANET routing protocols like AODV, DSDV, OLSR, and DSR. Throughput, packet delivery ratio, and end-to-end latency are some of the performance measures that are evaluated in this study.

When it comes to the implementation of wireless sensor networks, the routing protocol that is utilised is an essential component that must be deliberated about. In spite of this, in addition to the research that is currently being conducted on routing protocols, a number of other aspects of MANET, such as their power consumption and network security, should be taken into consideration for future works to increase the overall performance of routing algorithms.

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