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Impact of Network Size on Routing Protocols Performance in Wireless Sensor Network: A Simulation

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Abstract: - Wireless sensor networks (WSNs) are a decentralized kind of network which is equipped with sensor nodes and is rapidly being utilized to intelligently monitor different environmental conditions at a minimal cost. Sensor nodes are often battery-powered and the essential issue to address is how to decrease node energy consumption so that the network lifetime may be prolonged to realistic lengths. Routing is one of the primary operations performed within the network which consumes a sufficient amount of energy. Therefore, it is very much essential to consider the finest routing protocol so that it consumes less energy. In this article, we look at several routing protocols used in WSNs, including AODV, DSDV, DSR, OSLR and M-GEAR. Furthermore, we studied the execution of selected protocols based on network factors such as network latency, packet delivery ratio, and network throughput against multiple network sizes. The simulation findings show that protocol performance varies depending on network size and that selecting the optimum protocol based on network parameters is also crucial.

Keywords: WSNs, Performance Comparison, Network Sizes, AODV, DSR, DSDV, OSLR, M-GEAR

I. INTRODUCTION

Wireless sensor networks (WSNs), which are decentralized networks of sensors with the capacity to perceive, process, and communicate, are rapidly being utilized in disciplines such as engineering, healthcare, automobiles, smart homes etc. Due to the rapid advancement of wireless communication particularly in the area of WSNs, it has become a leading area of ongoing research in computer science and engineering. In this type of network, a group of independent sensor nodes are deployed across an area that interact among themselves in order to share different services, resources, or computing time in a restricted location [1]. This network has an autonomous distributed management system which helps the nodes to easily enter and exit the networks. One of the primary study topics in WSN is the establishment and maintenance of a sensor network using routing [2]. Routing means the process of choosing a traffic path inside a network or across many networks to send and receive data. It involves transmission of data packets through intermediary nodes from their point of origin to their intended destination. Each protocol used for routing has a unique method for locating and maintaining the route. Every route protocol has a data structure that stores route data and it modifies the table as necessary for route maintenance. A routing algorithm does the comparison of performance of different routes using a value known as a routing metric. Metrics might include data such as bandwidth, latency, hop count, route cost, load, dependability, and transmission cost. The routing table has information only about the best potential routes. Link-state or topological databases however may also contain some additional data. WSNs are the most significant advancement in the world of telecommunications [3, 4].

Routing is essential in communication because it allows the efficient transmission of data from one node to another. A number of routing techniques have been developed in the context of Wireless Sensor Networks (WSNs). As outlined in [5] these techniques or protocols can be classified and thoroughly examined. These routing protocols use various strategies and metrics to determine the best path for data transmission between

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nodes. Some protocols assess available transmission capacity, while others rely on hop count checks. As discussed in [6] each approach has its own set of advantages and disadvantages.

The primary goals of this research are to simulate how network size affects the performance of routing protocols in Wireless Sensor Networks (WSNs). We want to see if there are any changes in the effectiveness of these protocols as the network grows or shrinks. By doing so, we hope to provide insights into which routing protocols are better suited for different network sizes, which will ultimately aid in optimizing the performance and efficiency of WSNs. Furthermore, we hope to identify potential challenges or limitations that may arise as network size varies, thereby contributing valuable knowledge to the field of WSN research and assisting in the development of more robust and adaptable routing protocols.

II. ROUTING PROTOCOLS

The basic characteristics of the selected protocols explored in this simulation-based study are described in brief in this section. Here AODV and DSR are from the Reactive category whereas DSDV and OLSR are from the Proactive category [7]. In proactive routing, every node maintains a path between two nodes at all times. Due to this, route development and route maintenance are done using a mix of periodic and event-triggered routing. On the other hand, in reactive or on demand protocol, routes are found only when they are needed [8].

2.1 AODV: This protocol is a mixture of on demand and distance vector routing i.e., it follows the hop-by-hop methodology to establish the path [9]. It only builds routes between nodes when source nodes request them. In AODV routing, the next-hop information for each data flow must be kept by nodes.

2.2 DSR: DSR allows nodes to find a route to any other node over several network hops automatically [10]. In DSR, it initiates a flooding-based route-finding procedure to find the best possible path between the nodes.

2.3 DSDV: It is a hop-by-hop vector routing system that necessitates regular broadcasting of routing modifications by every node [10, 11]. In DSDV, even if the routes are not required, each node operates as a router, maintaining a routing database and transferring periodic routing changes.

2.4 OSLR: The OLSR protocol is a proactive protocol which uses Multipoint Relays (MPR) concept for forwarding control traffic [12]. Nodes in the OLSR network communicate topological information with other nodes on a regular basis.

2.5 M-GEAR: The gateway-based multi-hop routing protocol examined in this work is an upgraded form of GEAR protocol [13]. In homogeneous wireless sensor networks, the M-GEAR protocol is primarily used to increase network longevity. In this situation, the proposed method intends to increase this protocol's throughput and increase the network lifetime for heterogeneous wireless sensor networks (HWSNs). The M-GEAR network is split into numerous fields, and the sensor nodes in the first field talk to the base station directly.

III. RELATED WORK

In [13], the authors published a study that compared AODV and DSDV routing performance assessments based on NS2 simulator node velocity. The results obtained from the simulation demonstrated that AODV outperformed DSDV from the viewpoint of output, latency, and PDR factor performance and on the other hand, DSDV outperforms AODV from the viewpoint of energy use. In [14], the necessary hop count for a multi-hop route was calculated by computing hop progress while taking node density into account. The findings led to an investigation into the scaling relations among node density, throughput, and delay in multi-hop wireless networks. In [15, 16], the authors present a thorough framework that takes the underlying network architecture and protocols into account in order to create a reliable connection. They carefully define and examine the connectivity requirements for two different network architectures, one is Adhoc network and the other is sensor network. In [17], an analytical methodology to investigate the hop count distribution in a multi-hop wireless network while accommodating arbitrary node density variations was described. They compute the path connection probability in a network by estimating the average progress of each hop. In [18], the authors investigated the load and density effect on the DSDV and AODV routing protocols using UDP/CBR and TCP/FTP traffic. They evaluated throughput, PDR, and end-to-end latency under various network conditions and discovered that AODV performed better in PDR and had the lowest end-to-end delay. They both perform poorly under high density and load. In [19], three routing protocols (DSR, DSDV and AODV) that are based on the Random Mobility Model are investigated from the viewpoint of how they work with the QoS, such as the Normalized Routing Load (NRL) and other metrics. DSDV, a proactive protocol, was also shown to exceed all other reactive protocols for end-to-end latency, while the reactive protocols exceeded those for other QoS measures. In [20], authors also examined video streaming routing protocols and discovered that enhanced Video streaming in MANET (EVSM) beat AODV and AOMDV to explain the improvement in performance by the EVDM routing technique (60:40 Multipath Routing Design). The performance assessment criteria used in the study are as follows: PDF/PDR overhead, delay, transmission and routing. The authors of [21-24] described the M-GEAR protocol, which uses a gateway node to lower the consumption of energy of a sensor network. This method led to better Cluster Head distribution across the WSN. Simulation calculations reveal that the M-GEAR protocol has longer lifetime, lower power consumption, and an innovative mechanism for effectively transporting data from various nodes to the base station as compared to its base protocol i.e. GEAR protocol.

IV. METHODOLOGY

It is common practice to use simulation to observe the functioning and outcome of a WSN before deploying it in a real-world environment. A variety of network simulators may be used to properly simulate the scenario as if it were being implemented in real time [25, 26]. In this work, simulation was done using NS2 simulator (version 2.35).

During the process of this simulation work, we partitioned the whole network into distinct network sizes with node count - 25, 50, 75 and 100 respectively. Different evaluation metrics such as average throughput, packet delivery ratio, and end-to-end delay were used to examine the impact of different network sizes in routing protocols - AODV, DSR, DSDV OSLR and M-GEAR performance. Figure 1 illustrates the various steps involved in the routing protocol performance evaluation process.

This simulation process comprises of the following steps:

Step 1: Allocate the node count to WSNs.
Step 2: Add protocols.
Step 3: Make the TCL file and run it.
Step 4: Extract specific data from the TCL file.
Step 5: Implement the performance matrices.
Step 6: Run the simulation.
Step 7: View and evaluate the outcomes.
Step 8: Exit

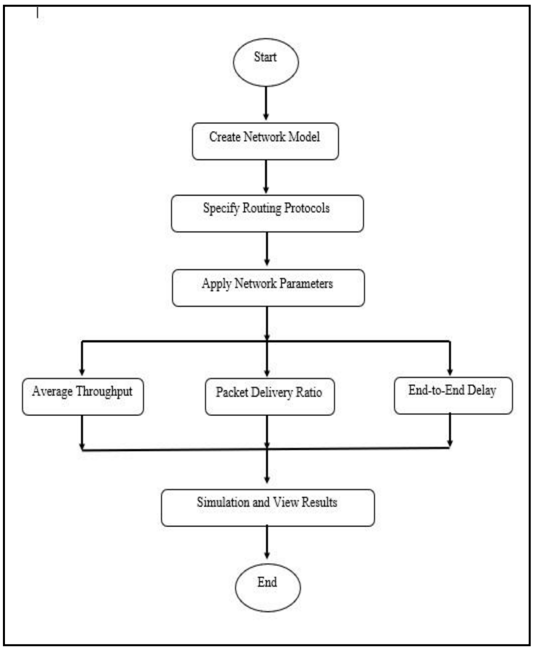

Figure 1: Steps in routing protocol performance evaluation

V. PERFORMANCE EVALUATION PARAMETERS

Evaluation of different routing protocols performance is done by considering the following parameters [27, 28]:

5.1 End to End Delay (EED): It refers to the time it takes for an entire communication to travel from its source to its destination. In case of end-to-end delay, lower the value means better in terms of performance. End-to-end delay can be calculated as:

EED= Receiving time – Sending time

5.2 Average Throughput: Average throughput is a network connection performance indicator that reflects how many messages successfully arrive at their destination. The term "throughput" represents the average rate of successful message delivery through a communication network. In case of network throughput, higher the value means better in terms of performance**.** It can be computed as:

Network Throughput = Received packet/ Total time.

5.3 Packet Delivery Ratio: It is determined by comparing the total number of packets sent from the source node to the total number of packets that were successfully delivered from the source node to the destination node. In case of PDR, higher the value means better in terms of performance**.** It can be computed as:

PDR= total no. of pkt. Arrived/total no. of pkt. sent from sources.

VI. SIMULATION AND RESULTS DISCUSSION

For this analysis, we have used different node count – 25, 50, 75 and 100 for each simulation. The results obtained after simulation are reported against the parameters mentioned in section 5.

Table 1: Simulation Parameters

Sl No	Parameters	Values
1	Type of the channel	Wireless
2	Routing Protocols	AODV, DSDV, DSR, OSLR, M-GEAR
3	Transport Protocols	TCP/UDP
4	Radio-propagation Model	Propagation/Two ray
5	Node count	25, 50, 75, 100

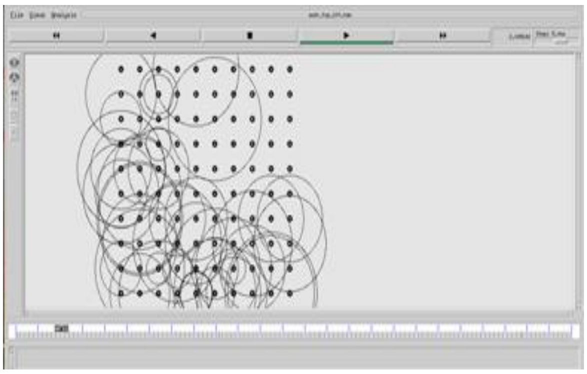

Figure 2: Deployment of Sensor Nodes

6.1 End to End Delay: The graphical representation of End-to-End delay is presented in Figure 3 and the values are given in Table.2. Here the black line indicates AODV, yellow line indicates DSDV, green line indicates DSR and red line indicates OLSR routing protocols.

Table 2: End to End Value vs Node Count

Protocols	End to End Delay Value			
	N=25	N=50	N=75	N=100
AODV	204.09	135	227.63	217.04
DSDV	237.60	354.43	458.67	524.23
DSR	221	181	796	238.58
OSLR	1214.55	1774.61	234.96	235.94
M-GEAR	24	24	26	30

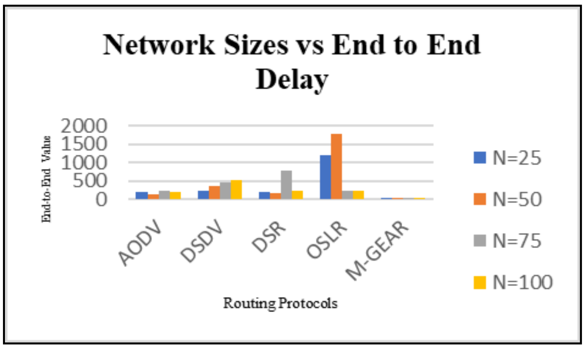

Figure 3: End to End Value vs Node Count

Observations:

i. AODV works well, and the delay ratio decreases as the node count increases.
ii. DSDV's performance gradually decreases as the node count grows.
iii. DSR improves its performance as the node count reaches the maximum size.
iv. In this case, OLSR performs badly because as the node count rises, the time delay increases, but it abruptly decreases after 50 nodes.
v. M-GEAR performance is better and also almost consistent throughout the simulation.
vi. Overall, M-GEAR outperforms in end-to-end delay matrices.

6.2 Network Throughput: The graphical representation of network throughput results is presented in Figure 4 and the values are given in Table 3. Here the black line indicates AODV, yellow line indicates DSDV, green line indicates DSR and red line indicates OSLR routing protocols in the given plot.

Table 3: Network Throughput values vs Node Count

Protocols	Network Throughput			
	N=25	N=50	N=75	N=100
AODV	767.88	766.66	780.77	522.24
DSDV	752.17	746.85	733.35	732.92
DSR	752.11	748.13	543.18	752.87
OSLR	532.81	706.21	0	0
M-GEAR	1313	2698	4605	6512

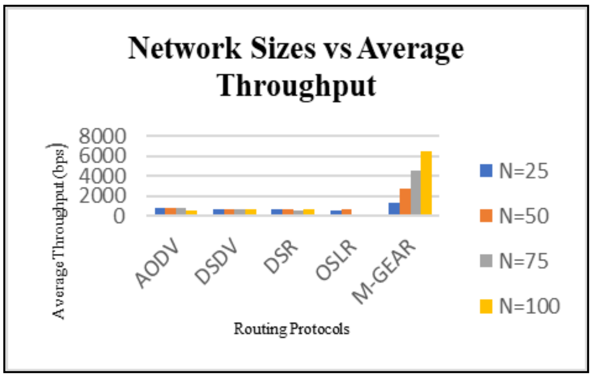

Figure 4: Network Throughput values vs Node Count

Observations:

i. AODV excels in network throughput matrices initially, but decreases its performance at the end.

ii. The performance of DSDV slightly decreases as the network size increases in the simulation.

iii. The performance of DSR also decreases as the network size increases. However it is able to improve its performance at the end.

iv. In this case, OLSR also performs badly, as it delivers lower average throughput as the node count grows, and it also returns negative values for a network with more than 50 nodes.

v. M-GEAR performance is increasing as the network size increases.

vi. Overall, M-GEAR outperforms in network throughput matrices.

6.3 Packet Delivery Ratio: The graphical result of PDR of the simulation is presented in Figure 5 and the values are given in Table 4. Here, the black line indicates AODV, yellow line indicates DSDV, green line indicates DSR and red line indicates OLSR routing protocols in the given plot.

Table 4: PDR values vs Node Count

Protocols	**Packet Delivery Ratio**			
	N=25	**N=50**	**N=75**	**N=100**
AODV	100	100	99.3	100
DSDV	85.86	74.74	61.22	55.75
DSR	97.40	97.53	74.45	97.95
OSLR	73.27	63.43	0	0
M-GEAR	68	69	69	71

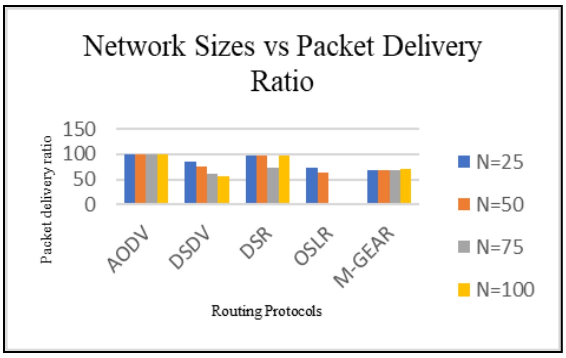

Figure 5: PDR values vs Node Count

Observations*:*

i. AODV performance is almost 100% throughout the simulation.
ii. DSDV performance degrades with increase in the node count.
iii. DSR performs effectively as the node count in a network rises.
iv. In this circumstance, OLSR also performs badly, as it delivers fewer packets as the node count grows, and it also returns negative values for nodes with more than 50 nodes.
v. M-GEAR performance is almost consistent but not as good as the others.
vi. AODV outperforms in Packet Delivery matrices.

During this simulation, it is observed that AODV performs well against PDR and M-GEAR performs well against network throughput and end-to-end delay. The results of the simulation study on the chosen protocols clearly show that no one protocol outperforms the others in all aspects. However, the M-GEAR protocol performance is much better as compared to the others in two out of the three selected parameters. Another observation from the simulation study is that, network size plays a significant role in the performance of a routing protocol. First off, as the number of sensor nodes rises, network management and coordination become more challenging. For larger networks to ensure effective communication between nodes, efficient routing protocols, resource allocation schemes, and data management techniques are crucial.

The network size also affects energy usage. Greater power consumption may be required by nodes in larger WSNs as a result of data transmission over longer distances. Additionally, as there are more nodes in the network, transmissions occur more frequently, which can quickly deplete the nodes' limited energy supplies. For larger WSNs to last longer, managing energy efficiently becomes very essential.

VII. CONCLUSION AND FUTURE WORKS

In this study, we examined five routing protocols performances against multiple network sizes. The chosen performance indicators were used to determine the efficiency and acceptability of the protocols in terms of network sizes. When assessing the performance of various routing protocols with respect to network size, it is vital to consider multiple performance metrics such as Network Delay, Packet Delivery Ratio, Network Throughput etc, select appropriate evaluation techniques, and consider the specific requirements and limitations of the wireless sensor network application. It is also observed that some protocols have the capabilities to adapt to the changes and subsequently adjust and improve their routing behavior. The unique opportunities and challenges faced by various network structures have an impact on the effectiveness of a protocol.

Based on the results of this study, there are a number of directions for future research. One important area of study could be to look into how different network topologies, other than just size, affect the performance of routing protocols in Wireless Sensor Networks (WSNs).

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR’S CONTRIBUTIONS

P. P. Bairagi designed and conducted the study, and wrote the initial draft of the manuscript. M. Dutta and K. S. Babulal provided expertise in statistical analysis, and critically revised the manuscript. G. Kataria, B. Sharma and V. Rathi offered technical support and expertise in the field. All authors have read and approved the final version of the manuscript.

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