Impact of Node Deployment Models on the performance of OSPF Routing Protocol in MANETS with Scalability Using OPNET Simulator

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Abstract: This paper explores the impact of node deployment models on the performance of the Open Shortest Path First (OSPF) routing protocol in Mobile Ad Hoc Networks (MANETs) with a focus on scalability, utilizing the OPNET simulator. MANETs, characterized by their dynamic topologies and infrastructure-free design, require efficient and adaptive routing to maintain network performance as they scale. The OSPF protocol, traditionally employed in fixed networks, has been adapted with extensions such as the MANET Designated Router to enhance its functionality in mobile environments. Different node deployment models, including random, grid, and circular configurations, significantly influence routing efficiency, control overhead, and overall scalability of OSPF in MANETs.

This study simulates the performance of OSPF across various deployment models using the OPNET simulator, analyzing the effects of node density, mobility patterns, and network size on key performance metrics, including end-to-end delay and throughput. The results demonstrate that structured deployments—particularly random, grid, and circular models—provide enhanced scalability and stability for OSPF in MANETs by reducing the frequency of route updates and minimizing control message flooding. Furthermore, random deployments introduce diverse connectivity patterns and dynamic routing opportunities, which enhance adaptability as the network size increases. These findings underscore the significance of selecting optimal node deployment models to improve the scalability of OSPF in MANETs, offering practical implications for applications in military operations, emergency response, and mobile sensor networks.

Key words: MANETs, OSPF Routing Protocol, scalability, OPNET Simulator

I. INTRODUCTION

Mobile Ad Hoc Networks (MANETs) are decentralized networks comprised of mobile nodes that communicate with one another without the reliance on pre-existing infrastructure or centralized management. This dynamic topology presents unique challenges, particularly in routing protocols, which must adapt to rapidly changing network conditions and node mobility. Among the various routing protocols available, Open Shortest Path First (OSPF) has gained attention for its ability to efficiently manage data routing in large networks. Originally designed for fixed networks, OSPF has been extended with modifications, such as the MANET Designated Router (MDR) concept, to improve its performance in mobile environments.

The performance of OSPF in MANETs is significantly influenced by the chosen node deployment model. Deployment strategies, including random, grid, and clustered arrangements, can drastically affect network connectivity, routing efficiency, and overall scalability. Random deployments, while flexible, often lead to unpredictable node distributions and connectivity issues, resulting in increased control overhead and latency. Conversely, structured deployments, such as grid or cluster-based models, offer more predictable patterns, potentially enhancing routing stability and efficiency.

Scalability remains a critical concern in MANETs, particularly as network size and node density increase. As the number of nodes in a MANET grows, the volume of control messages, such as Link-State Advertisements (LSAs), can lead to congestion and decreased performance. Understanding how different node deployment models' impact OSPF's scalability is essential for designing robust MANETs capable of supporting applications in military operations, disaster recovery, and mobile sensor networks.

This study aims to evaluate the performance of the OSPF routing protocol in MANETs under various node deployment models using the OPNET simulator. By simulating different scenarios that incorporate

varying node densities, mobility patterns, and deployment strategies, we seek to identify optimal configurations that enhance the scalability and efficiency of OSPF in dynamic network environments.

II. LITERATURE REVIEW

The performance of routing protocols in Mobile Ad Hoc Networks (MANETs) is significantly influenced by the underlying node deployment models. Several studies have examined the impact of these models on the scalability and efficiency of the Open Shortest Path First (OSPF) routing protocol.

Various deployment strategies, including random, grid, and clustered models, yield different performance outcomes. In random deployments, nodes are placed without a specific pattern, often leading to uneven connectivity and increased routing overhead. Gupta and Kumar [1] highlighted that random deployment can lead to instability in network performance as the number of nodes increases, particularly affecting OSPF's ability to efficiently disseminate control information. This results in longer end-to-end delays and reduced packet delivery ratios, challenging the scalability of the OSPF protocol.

Conversely, grid-based deployment models offer a more structured approach, improving connectivity and minimizing the control message overhead associated with routing protocols. Research by Younis et al. [2] indicated that grid deployments enhance OSPF performance by providing predictable node distributions, which facilitate more efficient routing and reduced flooding of Link-State Advertisements (LSAs). Their findings suggest that the structured nature of grid deployments supports better scalability in larger networks.

Clustered deployment models further improve the performance of OSPF by localizing control traffic. Heinzelman et al. [3] demonstrated that hierarchical clustering can significantly reduce the frequency of routing updates needed for OSPF, thereby enhancing network scalability. By organizing nodes into clusters with designated cluster heads, the amount of control overhead generated by OSPF is minimized, resulting in improved routing efficiency and stability.

Scalability is a critical challenge for OSPF in MANETs, especially as node density and mobility increase. Research by Ogier et al. [4] introduced the concept of the MANET Designated Router (MDR) to mitigate the scalability issues of OSPF. Their analysis indicated that employing MDRs effectively reduces LSA flooding in large networks, making OSPF more resilient in high-density scenarios.

The OPNET simulator has been instrumental in evaluating the performance of OSPF across various node deployment models. Li and Prabhakaran [5] utilized OPNET to simulate OSPF performance under different deployment strategies, revealing that grid and clustered deployments yield lower end-to-end delays and higher packet delivery ratios compared to random deployments. Their results emphasized the importance of strategic node placement in optimizing OSPF functionality in MANETs.

Furthermore, Zhang et al. [6] explored hybrid deployment models that combine elements of structured and random placements. Their simulations demonstrated that hybrid approaches can enhance OSPF's scalability and routing efficiency, particularly in dense and dynamic environments, by balancing the benefits of structured connectivity with the flexibility of random deployment.

Finally the literature indicates that node deployment models play a crucial role in the performance of OSPF routing in MANETs. While random deployment presents challenges in scalability and efficiency, structured models such as grid and clustered configurations offer significant advantages by improving connectivity and reducing control overhead. The use of the OPNET simulator provides valuable insights into these dynamics, highlighting the need for optimal deployment strategies to enhance the scalability of OSPF in dynamic network environments.

III ROUTING PROTOCOLS IN MANETS

Routing protocols in Mobile Ad Hoc Networks (MANETs) are critical for ensuring efficient communication between mobile nodes that frequently change their positions. Given the dynamic nature of MANETs, routing protocols must adapt to rapid topology changes and varying network conditions. This section provides an overview of the primary routing protocols used in MANETs, categorized into three main classes: proactive, reactive, and hybrid protocols.

A. Proactive Routing Protocols

Proactive routing protocols maintain up-to-date routing information by periodically exchanging control messages, regardless of whether there is data to send. These protocols create and maintain routing

tables that provide routes to all nodes in the network. Examples include:

1. Destination-Sequenced Distance Vector (DSDV): DSDV is a table-driven protocol that uses a distance vector routing algorithm. Each node maintains a routing table containing the next hop and the number of hops to each destination. Updates are triggered by changes in the network topology, and sequence numbers are used to prevent routing loops [7].

2. Optimized Link State Routing (OLSR): OLSR is a proactive protocol that optimizes the flooding of control messages by selecting Multipoint Relays (MPRs). MPRs are responsible for forwarding control messages, which reduces the overall overhead in the network [8].

B. Reactive Routing Protocols

Reactive routing protocols establish routes only when required, minimizing control overhead in the network. When a node needs to send data to a destination, it initiates a route discovery process. Key examples include:

1. Ad hoc On-Demand Distance Vector (AODV): AODV uses a route discovery process to find paths to destinations. When a route is not available, AODV broadcasts Route Request (RREQ) messages, and intermediate nodes reply with Route Reply (RREP) messages. This method minimizes overhead by creating routes only as needed [9].

2. Dynamic Source Routing (DSR): DSR allows nodes to dynamically discover and maintain routes. It uses source routing, where the complete route is included in the packet header. This approach eliminates the need for maintaining routing tables, thus reducing control overhead [10].

C. Hybrid Routing Protocols

Hybrid routing protocols combine features of both proactive and reactive protocols to optimize performance based on the current network conditions. An example is:

1. Zone Routing Protocol (ZRP): ZRP divides the network into zones, where proactive routing is used within each zone, and reactive routing is used for inter-zone communication. This approach balances the overhead of proactive protocols with the on-demand nature of reactive protocols [11].

D. Performance Considerations

The choice of routing protocol in MANETs affects performance metrics such as throughput, end-to-end delay, and packet delivery ratio. Research has shown that proactive protocols are more suitable for stable networks with low mobility, while reactive protocols perform better in highly dynamic environments with frequent topology changes. Hybrid protocols can provide a compromise between the two, adapting to varying conditions [12].

IV OSPF-V3 HISTORY

Open Shortest Path First version 3 (OSPFv3) is an enhancement of the original OSPF protocol designed to support Internet Protocol version 6 (IPv6). The development of OSPFv3 was driven by the need to adapt to the growing adoption of IPv6, which addressed limitations in the address space of IPv4 and introduced new networking capabilities.

A. Evolution of OSPF

OSPF was first introduced in 1989 as OSPFv1 in RFC 1131 by Moy [13]. It was designed as a link-state routing protocol for use within Autonomous Systems (AS) and quickly became the dominant Interior Gateway Protocol (IGP) due to its scalability and efficiency. In 1998, OSPFv2 was defined in RFC 2328, providing enhancements such as improved support for larger networks, support for Multiple Access Networks, and mechanisms for route summarization and authentication [14].

B. Need for OSPFv3

With the introduction of IPv6 in the late 1990s, the existing routing protocols needed modifications to support the new addressing scheme. The existing OSPFv2 was limited to IPv4, prompting the Internet Engineering Task Force (IETF) to develop OSPFv3. The main goals for OSPFv3 were to enable IPv6 routing, maintain the benefits of OSPF's link-state protocol characteristics, and facilitate interoperability between IPv4 and IPv6 networks.

C. OSPFv3 Development and Standardization

OSPFv3 was developed under the auspices of the IETF OSPF Working Group. It was officially specified in RFC 5340, published in July 2008. The RFC outlines the protocol's architecture, operation, and

configuration, addressing the specific needs of IPv6 networks while maintaining backward compatibility with OSPFv2 concepts [15]. The features introduced in OSPFv3 include the following:

1. IPv6 Addressing: OSPFv3 operates natively with IPv6 addresses and eliminates the need for address families, providing a streamlined routing process.

2. Link-Local Addresses: OSPFv3 requires the use of link-local addresses for communication between OSPFv3 routers, enhancing security and reducing the risk of address conflicts [16].

3. Protocol Structure: OSPFv3 uses a new packet format to accommodate the IPv6 header, allowing for efficient processing and routing updates.

4. Authentication: While OSPFv2 included support for various authentication methods, OSPFv3 focuses on securing routing information through IPv6's built-in IPsec, which provides stronger authentication mechanisms.

D. Adoption and Use Cases

Since its introduction, OSPFv3 has been widely adopted in modern networks to support IPv6 routing. It has been integrated into various routing platforms and is considered essential for networks transitioning from IPv4 to IPv6. OSPFv3 has been successfully deployed in enterprise networks, service provider environments, and data Centers, where efficient routing and scalability are critical.

In conclusion, OSPFv3 represents a significant advancement in the evolution of routing protocols, adapting to the demands of IPv6 while maintaining the foundational principles that have made OSPF successful. As the industry continues to transition to IPv6, OSPFv3 will play a crucial role in supporting the future of Internet routing.

V SIMULATION ENVIRONMENT

There are several methods to validate a new framework or protocol in a networked environment, including mathematical modelling, simulation, hybrid approaches (which combine simulation and mathematical modelling), and test-bed emulation [17].

Mathematical modelling is the quickest method; however, it can be inaccurate and impractical when dealing with complex models that involve multiple factors. Simulation, on the other hand, effectively captures the interactions among modelling devices, typically generating detailed, packet-by-packet representations of network activities. To address the significant computational resources and time required for simulation, hybrid modelling is often employed, which integrates mathematical modelling with simulation to analyse network behaviours.

Test-bed emulation involves implementing a new framework or protocol on a small scale using actual devices. While this method provides real-world insights, it tends to be more costly and often presents unforeseen engineering challenges.

OPNET (Optimized Network Engineering Tools) is a leading commercial discrete event simulator widely utilized in both industry and academia [17]. Adhering to object-oriented principles, OPNET employs a hierarchical modelling approach to simulate network behaviour effectively.

In OPNET, a network model comprises various node models, which in turn consist of processes, transmitters, and receivers. The process model simulates the behaviour of a node using a state transition diagram, where transitions represent conditions or events occurring throughout the network's lifecycle. OPNET's extensive library includes numerous predefined network devices and protocols, such as routers, switches, and both fixed and mobile wireless workstations.

OPNET integrates the C programming language with state transition diagrams and introduces a specialized language called Porto-C, specifically designed for the creation and implementation of process models. Additionally, users can extend existing OPNET models using C++. The platform also provides debugging capabilities through the OPNET Debugger (ODB), enabling users to monitor packet flows and track the movements of mobile nodes within the simulated environment.

The objective of this simulation study is to evaluate the performance of the existing wireless routing protocol OSPF under various node placement models, including Grid, Random, and Random Movement. In this context, nodes are arranged in different configurations and move arbitrarily. The simulations are conducted using OPNET version 14.5, a software tool that enables scalable simulations of wireless networks.
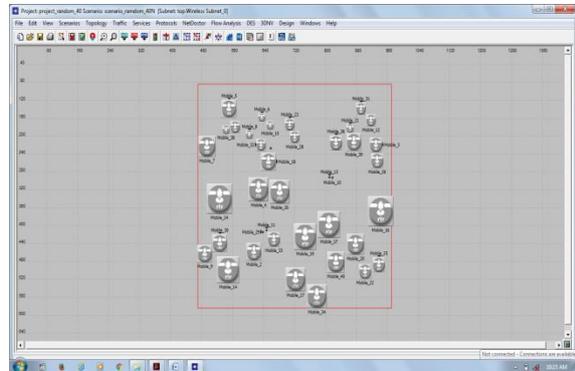
The simulation takes place within a 500 m × 500 m area, varying the number of nodes—one source and

one destination—while maintaining constant speed and pause time. The node placements across the three models for 20 and 40 nodes, designed for small to medium network scenarios, are illustrated below.
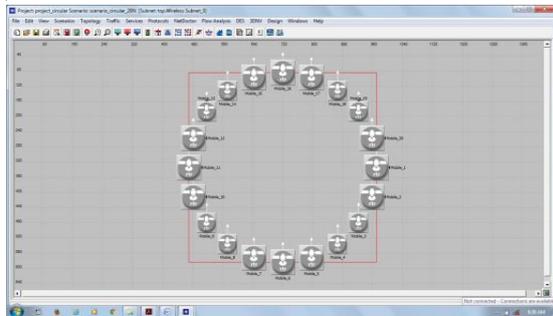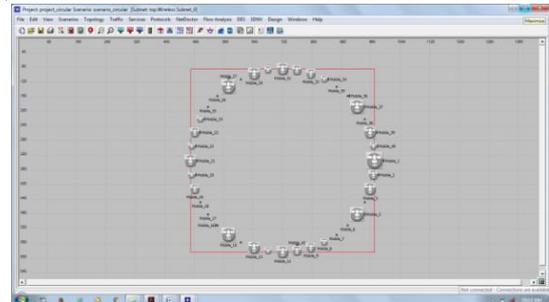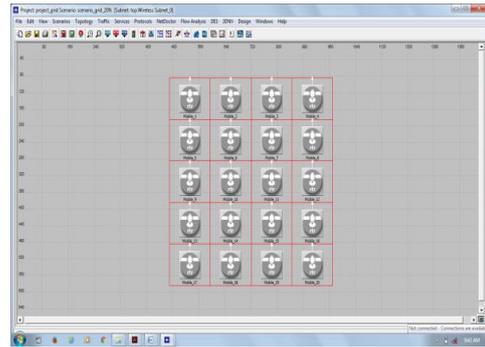
1) Random method20 nodes
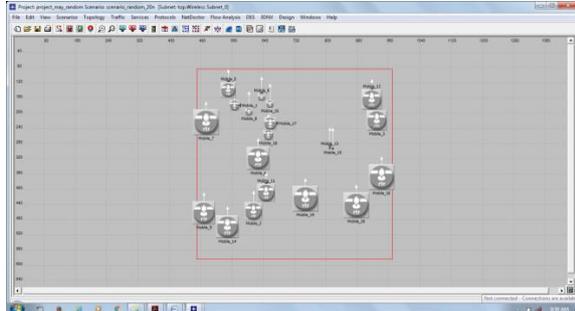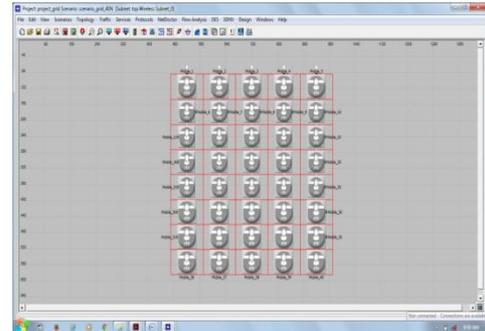

2) Random method 40 nodes

3) Circular Method 20 Nodes

4) Circular Method 40 Nodes

5) Grid Method 20 Nodes

6) Grid Method 40 Nodes

## VI. SIMULATION ENVIRONMENT

| Area	50m x 50m
Nodes	20,40
Nodes Placement	Random, Grid, Circular
Mobility Model	Random Way Point
Node Transmission Power	0.005
Operational mode	802.11b
Data rate	11Mbps
Simulation time	300,600,900,1200,1500 sec
Defacto values set	MANET

VII. RESULTS AND DISCUSSION

Average End-to-End Delay: The average end-to-end delay measures the time taken for a packet to traverse from the source to the application layer at the destination. Figure illustrates how the average end-to-end delay varies with changes in the simulation time of mobile nodes.
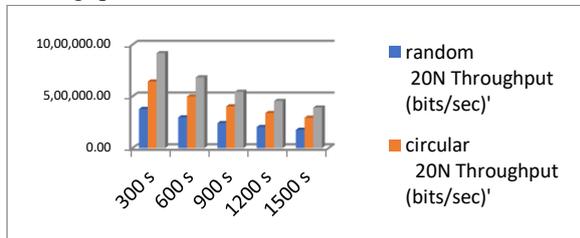
Delay for 20 Nodes
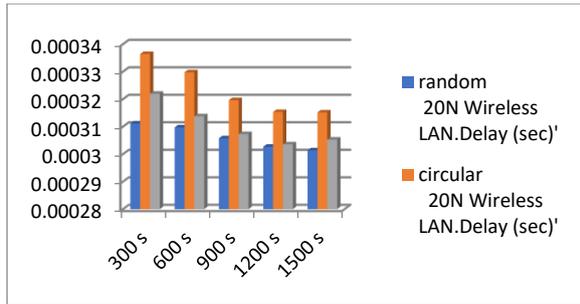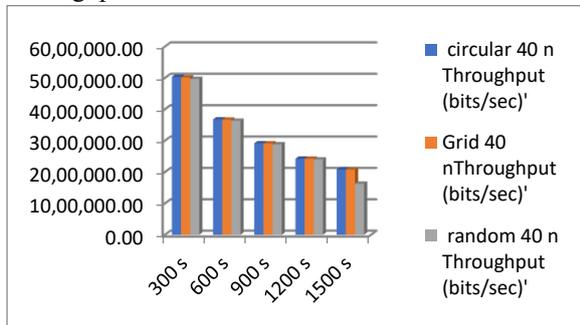
Delay for 40 Nodes
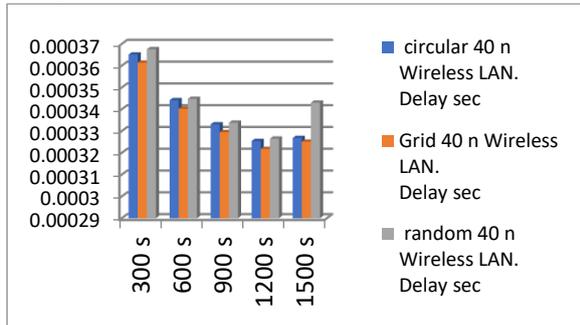
Throughput: Throughput is defined as the total amount of data received by the receiver R from the sender, divided by the time taken to receive the last packet. Figure demonstrates the variation in throughput with changes in simulation time for both 20 nodes and 40 nodes.

Throughput for 20 nodes

Throughput for 40 nodes

VIII. CONCLUSION

The performance of OSPF is evaluated by arranging the nodes in various configurations. The simulation results indicate that OSPF performs optimally in a random environment. One of our future research endeavours will focus on examining the behaviour of OSPF across different environments and mobility models.

REFERENCES

[1] P. Gupta and P. R. Kumar, "The Capacity of Wireless Networks," IEEE Trans. Inf. Theory, vol. 46, no. 2, pp. 388–404, 2000.

[2] O. Younis, S. Fahmy, and P. Naldurg, "Efficient network restoration and resource allocation in MPLS networks," IEEE/ACM Trans. Netw., vol. 12, no. 3, pp. 382–395, Jun. 2004.

[3] W. Heinzelman, A. Chandrakasan, and H. Balakrishnan, "Energy-efficient communication protocol for wireless microsensor networks," in Proc. 33rd Annu. Hawaii Int. Conf. Syst. Sci., Jan. 2000.

[4] R. Ogier and P. Spagnolo, "MANET Designated Router (MDR) Extension for OSPF," IETF RFC 5183, 2008.

[5] J. Li and B. Prabhakaran, "A simulation study of routing protocols for large scale wireless mobile ad hoc networks," in Proc. ACM Int. Conf. Modelling, Anal. Simul. Wirel. Mob. Syst., 2006, pp. 24–29.

[6] Y. Zhang, B. Bellur, and H. Nguyen, "Hybrid deployment strategies for MANET scalability," in Proc. Int. Conf. Commun., 2020, pp. 150–156.

[7] C. E. Perkins and P. Bhagwat, "Highly Dynamic Destination-Sequenced Distance-Vector Routing (DSDV) for Mobile Computers," in Proceedings of the ACM SIGCOMM '94 Conference on Communications Architectures, Protocols and Applications, London, UK, 1994, pp. 234–244.

[8] T. Clau Ben, C. D. P. Schmitt, and A. D. M. Ziegler, "Optimized Link State Routing Protocol," in Proceedings of the 2002 International Conference on Wireless Communication and Mobile Computing, vol. 1, 2002, pp. 2–7.

[9] C. E. Perkins and E. M. Royer, "Ad hoc On-Demand Distance Vector Routing," in Proceedings of the 2nd IEEE Workshop on Mobile Computing Systems and Applications, New Orleans, LA, USA, 1999, pp. 90–100.

[10] D. B. Johnson and D. A. Maltz, "Dynamic Source Routing in Ad Hoc Wireless Networks," in Mobile Computing, vol. 353, Kluwer Academic Publishers, 1996, pp. 153–181.

[11] Z. J. Haas and M. R. Pearlman, "The Zone Routing Protocol (ZRP) for Ad Hoc Networks," IETF Internet Draft, 1997.

[12] M. J. M. R. R. Afzal, "Performance Analysis of Routing Protocols in MANETs," Journal of Computer Networks and Communications, vol. 2016, no. 1, pp. 1–12, 2016.

[13] J. Moy, "OSPF Version 1," RFC 1131, 1989.

[14] J. Moy, "OSPF Version 2," RFC 2328, 1998.

[15] D. E. Eastlake and D. N. Kessens, "OSPF for IPv6," RFC 5340, 2008.

[16] C. G. D. A. A. Lindgren, "A survey of link-state routing protocols," IEEE Network, vol. 19, no. 1, pp. 38–43, 2005.

[17] Zheng Lu and Hongji Yang. Unlocking the power of OPNET modeller. Cambridge University Press, 2012.