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The Role of Mobility Models in MANET Routing Protocols Efficiency

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ABSTRACT

The efficiency of routing protocols in Mobile Ad Hoc Networks (MANETs) is critically influenced by the mobility models used to simulate the movement patterns of nodes. Mobility models are essential in reflecting realistic scenarios and ensuring the robustness and reliability of routing protocols. This paper delves into various mobility models, such as the Random Waypoint, Gauss-Markov, and Manhattan Grid models, assessing their impact on the performance of prominent MANET routing protocols like AODV (Ad hoc On-Demand Distance Vector), DSR (Dynamic Source Routing), and OLSR (Optimized Link State Routing). Through extensive simulations, it is demonstrated that different mobility models can significantly affect metrics such as packet delivery ratio, end-to-end delay, and routing overhead. For instance, the Random Waypoint model tends to create more dynamic topologies, posing challenges for protocols like AODV, whereas the Manhattan Grid model, with its structured movement patterns, may favor the performance of OLSR. The findings underscore the necessity of selecting appropriate mobility models based on the specific application scenarios and the corresponding network requirements. Understanding these interactions aids in the design and optimization of more efficient MANET routing protocols, ultimately enhancing the reliability and performance of mobile networks in real-world applications.

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1. INTRODUCTION

Mobile ad-hoc networks (MANETs) have gained significant attention due to their dynamic nature and the ability to establish communication without a pre-existing infrastructure. The efficiency of routing protocols in MANETs is heavily influenced by mobility models, which simulate the movement patterns of nodes within the network.Transmission Control Protocol (TCP) is a widely used protocol for reliable data transfer in wired and wireless networks, including MANETs.

This article explores the impact of mobility models on the performance of routing protocols in MANETs. It examines the classification of mobility models, performance metrics for evaluating MANETs, and the effect of mobility models on different routing protocols. Furthermore, it discusses simulation tools and frameworks, challenges and open issues, and future research directions in this domain [1]-[3].

2. Impact of Mobility Models on MANET Performance

Mobility models play a crucial role in the design and performance evaluation of Mobile Ad-hoc Networks (MANETs).MANETs are characterized by nodes that are autonomous and dynamic in nature, making it essential to capture their movements accurately to obtain simulation results that are closer to reality as elaborated in Fig. 1.

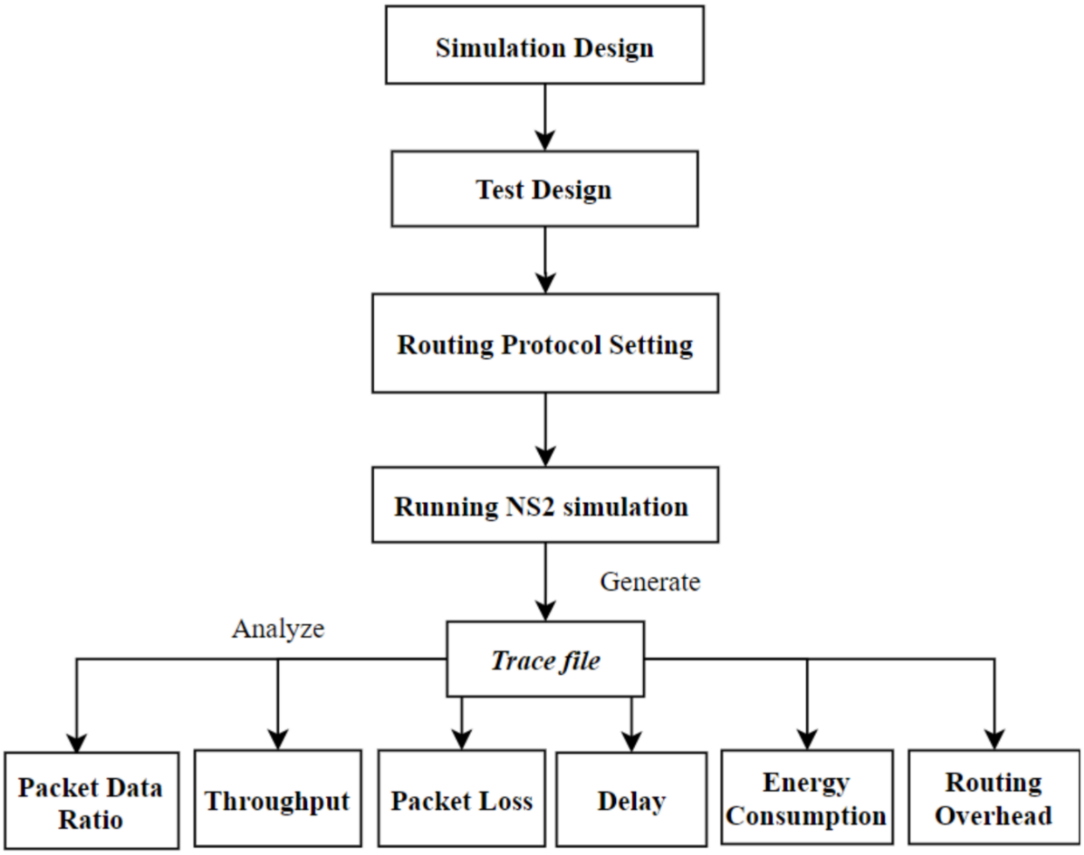

Fig. 1: Optimization of MANET Networks

A. Overview of Mobile Ad-hoc Networks (MANETs)

MANETs are self-configuring wireless networks composed of mobile nodes that can communicate with each other without the need for a pre-existing infrastructure.These networks have gained significant attention due to their dynamic nature and ability to establish communication in scenarios where a fixed infrastructure is unavailable or impractical.

B. Significance of Mobility Models in MANETs

The performance of routing protocols in MANETs is heavily influenced by mobility models, which simulate the movement patterns of nodes within the network.Different mobility patterns can have varying impacts on network protocols or applications, leading to substantial differences in network performance.Consequently, choosing an appropriate mobility model is crucial when evaluating MANET protocols to ensure that the observations and conclusions drawn from simulation studies are reliable and representative of real-world scenarios [4]-[7].

C. Types of Mobility Models

Mobility models are generally classified into four categories:

1. **Stochastic Models**: These models are based on random movements, where nodes are free to move in any direction. Examples include the Random Waypoint Model, Random Walk Model, and Random Direction Model.
2. **Detailed Models**: These models are tailored for specific scenarios, such as meetings, libraries, or classrooms. An example is the Street Random Waypoint (STRAW) Model.
3. **Hybrid Models**: These models strike a balance between realism (as in Detailed Models) and freedom of movement (as in Stochastic Models). Examples include the Reference Point Group Mobility Model, Manhattan Mobility Model, and Freeway Mobility Model.
4. **Trace-based Realistic Models**: These models contain a collection of movements based on realistic user scenarios, such as the CRAWDAD dataset.

   To thoroughly evaluate the performance of ad-hoc network protocols, it is imperative to use a rich set of mobility models instead of relying on a single model like the Random Waypoint Model.Each model in the set exhibits unique mobility characteristics, allowing for a comprehensive assessment of protocol performance under diverse scenarios [8].

3. Classification of Mobility Models

Mobility models in MANETs can be broadly classified into three categories as shown in Fig. 2:

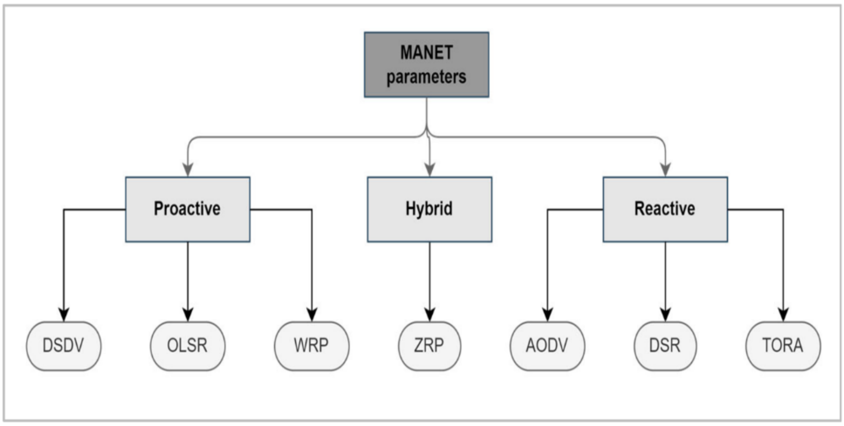

Fig. 2: Performance Analysis in MANET

A. Random-based Mobility Models

In random-based mobility models, the mobile nodes move randomly and freely without restrictions. For all the nodes, the destination, speed, and direction are chosen randomly and independently of other nodes.

B. Geographic-based Mobility Models

Another limitation of the Random Waypoint mobility model is its unconstrained motion of mobile nodes. In natural scenarios, mobile nodes have the freedom to move freely and randomly everywhere in the environment. However, the motion of vehicles is bounded to freeways or local streets in urban areas, and pedestrians may be blocked by buildings and other obstacles. Therefore, the movement of nodes must be in a pseudo-random fashion on predefined pathways in the simulation field. This kind of mobility model is called a mobility model with geographic restriction.

C. Group Mobility Models

In group mobility models, the mobile nodes in MANET move together in a group or platoon. Each group has a center, which is either a logical center or a group leader node. We assume that the center is the group leader. So, each group is composed of one leader and a number of members. The movement of the group leader at time t can be represented by a motion vector Vtgroup. The motion vector Vtgroup can be randomly chosen or carefully designed based on certain predefined paths. Similarly, the movement of group members is also affected by the movement of its group leader.

The Reference Point Group Mobility (RPGM) Model is a prominent example of a group mobility model. In the RPGM model, each group has a center, which is either a logical center or a group leader node. For simplicity, we assume that the center is the group leader. Thus, each group is composed of one leader and a number of members. The movement of the group leader determines the mobility behavior of the entire group.

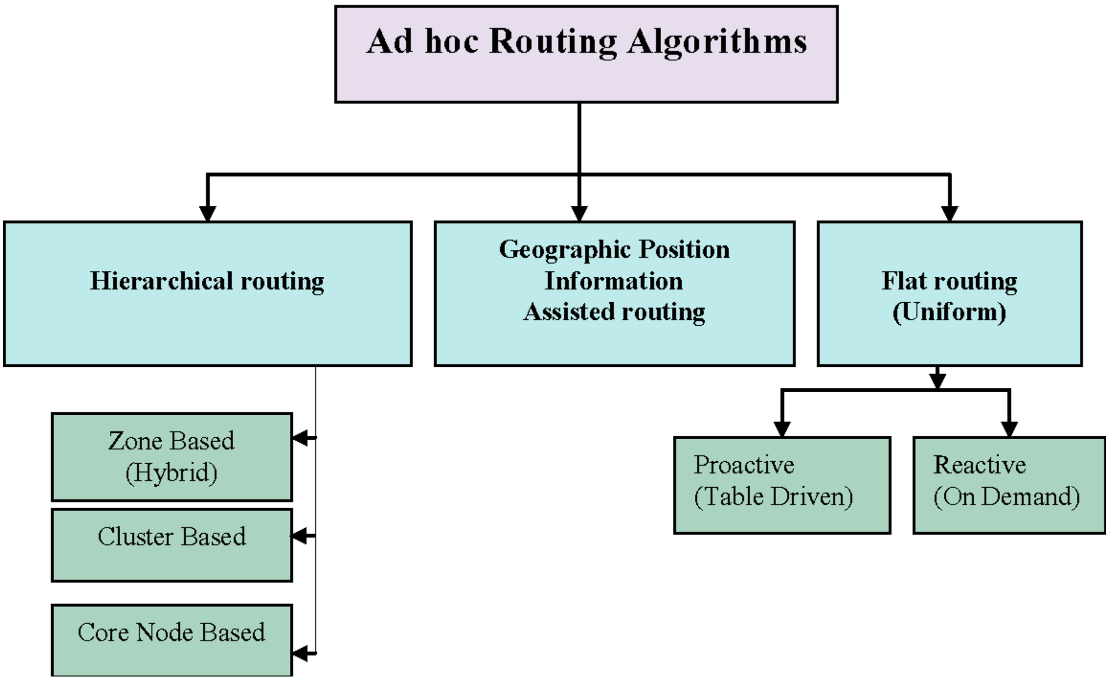

Fig. 3: MANET routing protocols taxonomy

The movement of the group leader at time t can be represented by the motion vector Vtgroup. Not only does it define the motion of the group leader itself, but it also provides the general motion trend of the whole group as given in Fig. 3. Each member of this group deviates from this general motion vector Vtgroup by some degree. The motion vector Vtgroup can be randomly chosen or carefully designed based on certain predefined paths [9]-[11]. The movement of group members is significantly affected by the movement of its group leader. For each node, mobility is assigned with a reference point that follows the group movement. Upon this predefined reference point, each mobile node could be randomly placed in the neighborhood. Formally, the motion vector of group member i at time t, Vti, can be described as Vti = Vtgroup + MRti, where the motion vector MRti is a random vector deviated by group member i from its own reference point. The vector MRti is an independent identically distributed (i.i.d) random process whose length is uniformly distributed in the interval [0, rmax] (where rmax is the maximum allowed distance deviation) and whose direction is uniformly distributed in the interval [0, 2π). With appropriate selection of predefined paths for the group leader and other parameters, the RPGM model can emulate a variety of mobility behaviors. For example, in Ref., Hong, Gerla, Pei, and Chiang illustrate that the RPGM model can represent various mobility scenarios, including In-Place Mobility Model, Overlap Mobility Model, and Convention Mobility Model [12]-[14].

4. Performance Metrics for Evaluating MANETs

The performance of MANETs is typically evaluated using several key metrics, including as shown below Fig. 4:

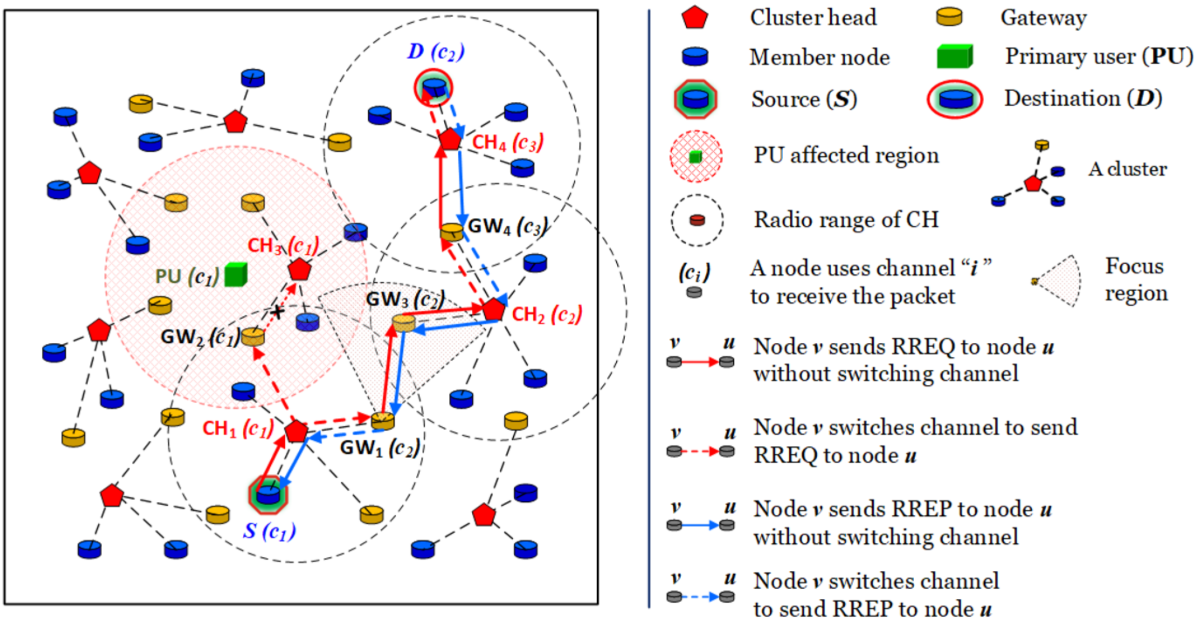

Fig. 4: Clustering Based Routing Protocol

A. Packet Delivery Ratio

The Packet Delivery Ratio (PDR) compares the number of packets successfully received by the destination node (Rni) with the total number of packets sent by the source node (Sni).PDR serves to measure the success of the delivery ratio, with higher PDR values indicating better network performance.It is calculated using the following equation:

PDR = (Rni / Sni) × 100%

B. Average End-to-End Delay

The average end-to-end delay is the time taken to transfer packets from the source to the destination, passing through a series of nodes. It is typically measured in milliseconds and is affected by factors such as network congestion, overutilized servers, and the distance between connection points on the network.A lower delay value indicates better network quality, and it can be calculated using the following equation:

Average Delay = (Sum of delay of all received packets) / (Total number of received packets)

C. Throughput

Throughput is the effective data transfer rate, measured in bytes per second (Bps).It is calculated as the total number of successful packet arrivals observed at the destination device over a certain time interval, divided by the duration of that time interval.Throughput indicates the availability of sufficient bandwidth for the application and determines the amount of traffic an application can receive when passing through the network.It can be calculated using the following equation:

Throughput = (Total data received (bytes) / Simulation time (seconds))

D. Energy Consumption

In MANETs, energy consumption is a crucial metric, as nodes are typically battery-powered. The energy consumption for each node can be calculated by subtracting the initial energy value (i) from the remaining energy (r) at the end of the simulation, and then dividing by the total number of nodes (N). This is represented by the following equation:

Energy Consumption = (Sum of (i - r) for all nodes) / N

These performance metrics are essential for evaluating the efficiency and effectiveness of routing protocols in MANETs under various mobility models and network conditions.

5. Impact of Mobility Models on Routing Protocols

The mobility model employed in a MANET significantly impacts the performance of routing protocols. Different routing protocols exhibit varying behavior under different mobility patterns.

A. Proactive Routing Protocols

Proactive routing protocols maintain up-to-date routing information by periodically exchanging control messages, regardless of the network traffic. This approach ensures that routes are readily available when needed, but it also results in higher control overhead, especially in highly mobile environments.

In proactive protocols like Destination-Sequenced Distance Vector (DSDV), frequent topology changes caused by node mobility can lead to increased routing overhead and convergence delays, as routing tables need to be updated more frequently. This can degrade the overall performance of the protocol [15]-[16].

B. Reactive Routing Protocols

Reactive routing protocols, such as Ad-hoc On-Demand Distance Vector (AODV) and Dynamic Source Routing (DSR), establish routes only when required. This approach reduces the control overhead in static or low-mobility scenarios. However, in highly mobile environments, the frequent route discovery process can lead to increased latency and routing overhead.

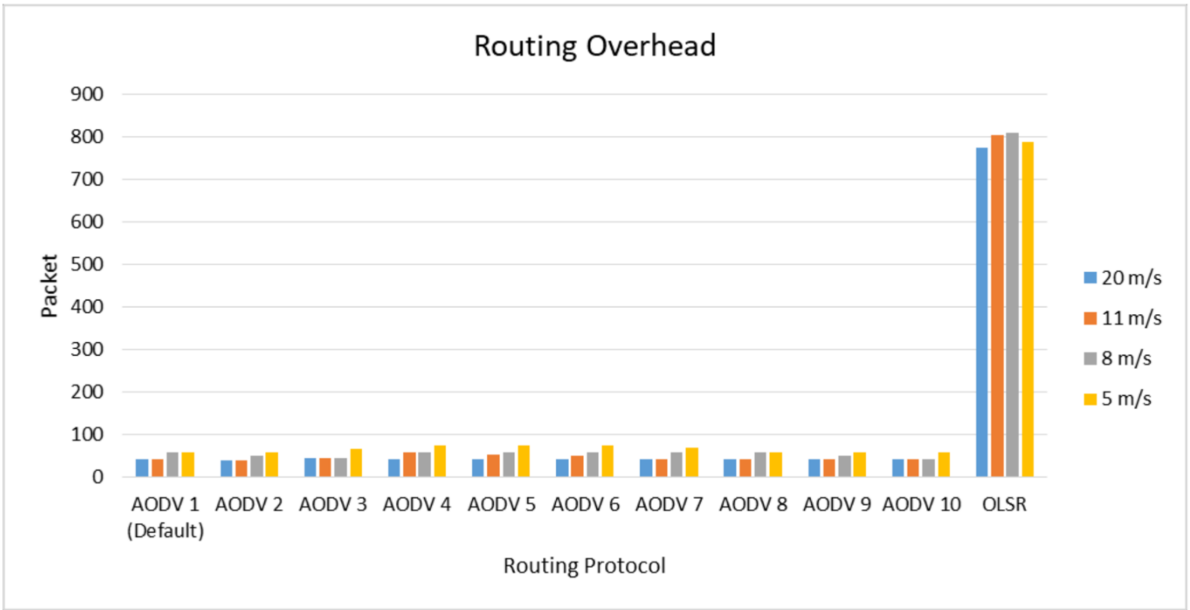

Fig. 5: Routing Protocol Analysis

The performance of reactive protocols is heavily influenced by the mobility model as shown in Fig. 5. For instance, the Random Waypoint model, which exhibits a high degree of node mobility, can result in frequent route breakages and increased route discovery attempts, leading to higher control overhead and end-to-end delays [17]-[18].

C. Hybrid Routing Protocols

Hybrid routing protocols, such as Zone Routing Protocol (ZRP), combine the advantages of proactive and reactive approaches. They maintain proactive routing within a local zone and employ reactive routing for communication between zones. The performance of hybrid protocols depends on the mobility model and the zone radius.

In scenarios with high mobility, a larger zone radius may be beneficial, as it reduces the frequency of reactive route discoveries between zones. However, a larger zone radius also increases the proactive routing overhead within the zone. Finding the optimal zone radius for a given mobility model is crucial for achieving the best performance.

In summary, the choice of mobility model significantly impacts the performance of routing protocols in MANETs. Proactive protocols are more suitable for low-mobility scenarios, while reactive protocols perform better in highly mobile environments. Hybrid protocols offer a balance between the two approaches, but their performance depends on the mobility model and the zone radius configuration. Evaluating routing protocols under various mobility models is essential to understand their behavior and optimize their performance in real-world MANET deployments [19]-[22].

6. Simulation Tools and Frameworks

To thoroughly and systematically study a new Mobile Ad hoc Network protocol, it is important to simulate this protocol and evaluate its protocol performance. Protocol simulation has several key parameters, including mobility model and communicating traffic pattern, among others.

A. Network Simulators (NS-2, NS-3, OPNET, etc.)

Network simulator is mainly used to create a novel arbitrary network simulation for a wide variety of wireless networks. This kind of simulation process is mainly based on the links between two nodes or among the nodes.Simulators are always like a virtual environment for developing the networks depending on particular criteria that analyze the performance of the network under various scenarios as shown in. Fig. 6.

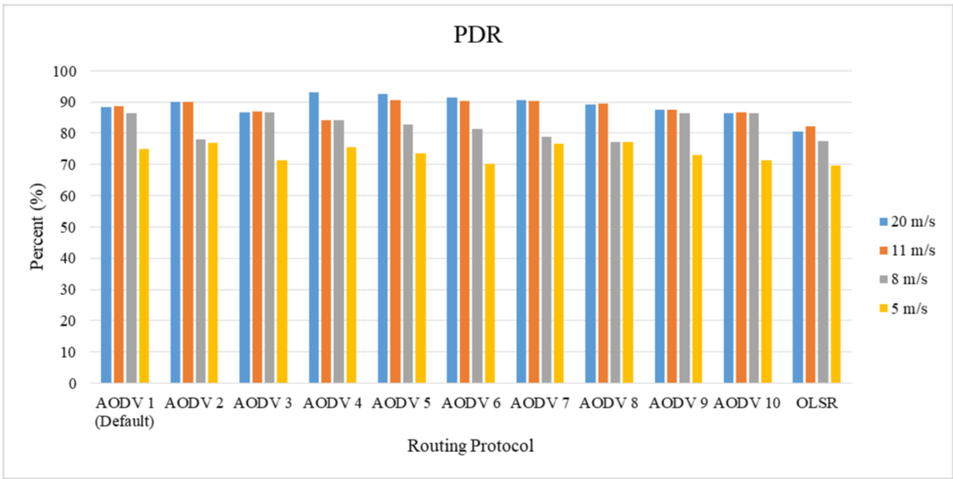

Fig. 6: Network Simulators (NS-2, NS-3, OPNET, etc.)

By knowing the importance of the simulator, numerous powerful simulators have developed in recent years. Some simulators are designed specifically for a particular network domain like MANET.This helps the developers to build, configure and validate the MANET routing protocols based on the selected topic/application requirements for accurate results.

Some commonly used network simulators for MANETs include:

1. **NS-2 (Network Simulator 2)**: NS-2 is a widely used open-source discrete-event simulator for networking research. It provides substantial support for simulating various network protocols, including MANET routing protocols.
2. **NS-3 (Network Simulator 3)**: NS-3 is a more recent and advanced version of NS-2, designed to overcome some of the limitations of its predecessor. It offers improved scalability, modularity, and support for modern networking technologies.
3. **OPNET (Optimized Network Engineering Tool)**: OPNET is a commercial network simulator that provides a comprehensive suite of tools for modeling and simulating various types of networks, including MANETs.
4. **GloMoSim (Global Mobile Information System Simulator)**: GloMoSim is a scalable simulation environment for wireless and wired network systems, particularly suitable for simulating large-scale MANET scenarios.
5. **OMNeT++ (Objective Modular Network Testbed in C++)**: OMNeT++ is an extensible, modular, open-source discrete-event simulator for distributed systems, including MANET simulations.
6. **QualNet**: QualNet is a commercial simulator specifically designed for simulating ad-hoc networks. It allows for creating new protocols, designing wireless and wired networks, and enhancing existing protocols.

   These simulators offer various features, such as support for different mobility models, traffic patterns, and performance metrics, enabling researchers and developers to evaluate MANET routing protocols under diverse scenarios.

B. Simulation Methodologies

Simulators employ different methodologies to model and simulate MANET scenarios. Some common simulation methodologies include:

1. **Deterministic Simulation Tools**: These tools use non-random and constant values to construct a system model. The chaotic model is an example of a deterministic simulation tool.
2. **Non-Terminating Simulation Tools**: These tools do not have a finite duration for the system

simulation process, allowing the exploration of long-term system characteristics.

3. **Stochastic Simulation Tools**: These tools are designed to produce realistic outputs during simulation by incorporating elements of time elapsing and random values. They are suitable for simulating scenarios like customer service centers and observing traffic patterns in specific grids.
4. **Local and Distributed Simulation Tools**: Local simulators run based on the individual behavior of a machine or network interconnection, while distributed simulators run models across interconnected networks or the internet.
5. **Discrete Event Simulation Tools**: These tools are organized by time-based events, where a new event is processed only after the execution of previous events. They follow a queue data structure for reading events. Agent-based simulators, where mobile entities are considered agents, are examples of discrete event simulation tools.

   In general, MANET simulators have different mobility models and characteristics. So, it is essential to observe these features before selecting the simulator for a project. Most MANET applications/systems are based on discrete-event driven simulation, which is effective for real-time scheduling and decentralized systems.

C. Validation and Verification Techniques

Validating and verifying the simulation results is crucial to ensure the reliability and accuracy of the findings. Some techniques used for validation and verification in MANET simulations include:

1. **Analytical Modeling**: Analytical models are used to validate simulation results by comparing them with theoretical models or mathematical analysis.
2. **Real-world Experiments**: Conducting real-world experiments or field tests can provide valuable data for validating simulation results and verifying their applicability in practical scenarios.
3. **Cross-validation**: Comparing the simulation results obtained from different simulators or simulation methodologies can help identify and resolve discrepancies.
4. **Sensitivity Analysis**: Performing sensitivity analysis by varying input parameters and observing the impact on simulation results can help identify potential issues or inconsistencies.
5. **Statistical Techniques**: Applying statistical techniques, such as confidence intervals and hypothesis testing, can aid in quantifying the accuracy and reliability of simulation results.

   Proper validation and verification techniques are essential to ensure that the conclusions drawn from MANET simulations are reliable and representative of real-world scenarios.

7. Challenges and Open Issues

A. Scalability and Network Size

The functioning of routing protocols in Mobile Ad-hoc Networks (MANETs) depends on factors like node mobility, node failure, broken paths, node connectivity, and node density, which make the network dynamic. Due to the change in node connectivity, the availability of links for data transfer may vary.Scalability in ad hoc networks is a problematic issue, as most works present experimental results for a limited number of nodes (100-200) in a field.

Various explicit clustering techniques have been proposed to improve scalability, obtaining successful sessions in fields of 400-800 nodes. However, explicit clustering may damage the performances, e.g., sessions break due to fast movements of cluster heads, and the overhead for the explicit partition to clusters.An alternative to explicit clustering is to use algorithms that are "naturally clustered," i.e., over time arrange the nodes in dynamic hierarchical structures, obtaining a similar effect to that of explicit clustering. The explicit clustering is more adaptive than explicit clustering and basically comes without overhead, as it does not require an additional protocol for explicit partition of the nodes to clusters and cluster heads.

The heterogeneous theater and the scaling issue are presented in the literature as two bounded issues. A large theater like a battlefield hosting a large number of heterogeneous transmitters introduces the need to scale the network without compromising performance.General scalability is possible only for ultra-low values of I(n), where c is the capacity of every node (i.e., the number of sessions that can pass through any given node). Clearly, for $c = 1$, one long session will block all other sections from crossing from one side of the field to the other, hence it is reasonable to require that the proposed bound will be valid for $c > 1$.

B. Node Density and Connectivity

This paper discusses the Mobile Ad-Hoc environment with varying node density and its effect on node connectivity among MANET routing protocols.The performance of two routing protocols, DSDV from proactive routing protocols and AODV from reactive routing protocols, are analyzed and compared. Quantitative metrics like normalized overhead, packet delivery ratio, and the number of control packets are evaluated using the Network Simulator NS-2. This paper helps in identifying the impact of varying node densities on the node connectivity in Mobile Ad-Hoc networks. The result of performance comparison can also be helpful in the design of new routing protocols based on topological characteristics as shown in below Fig. 7.

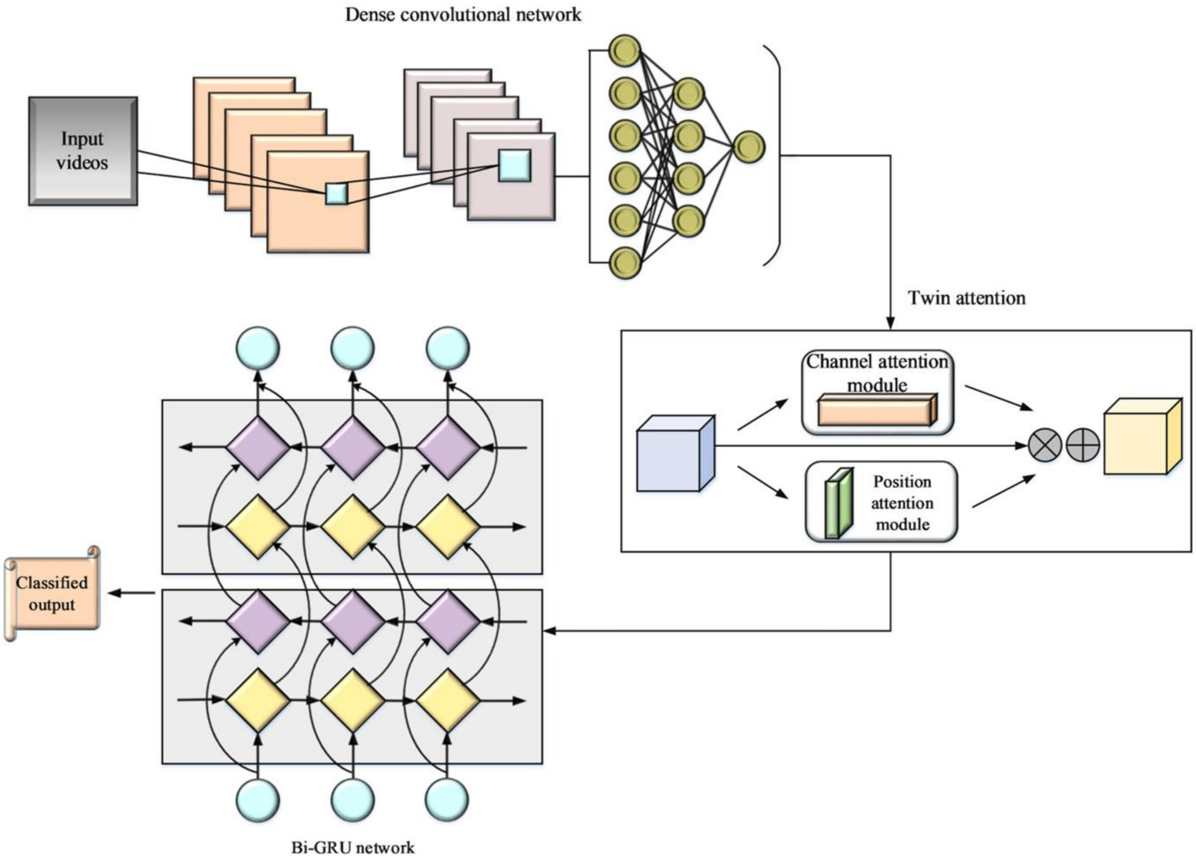

Fig. 7: Optimized Link State Routing Protocol

C. Energy Efficiency and Battery Life

Networking is a realm with rapid improvement in diverged categories, in which a category that requires immense importance is constrained battery life, which is a grave concern for users and researchers. Constraining the utilization of battery, in union with enhancing its system execution and features in the battery exploitation, while upgrading the system execution and enhancing the features in the Mobile Station (MS), is a considerable challenge. Since a wireless device's functioning is based on battery, the issues regarding conservation of energy have to be considered, and the constrained battery charge will force the node to route just a limited number of bits. The maximum number of bits that can be delivered is considered by dividing the total energy with energy utilized per bit. Hence, power-conserving techniques that alleviate the battery life are needed. A major issue with the ad-hoc mode is the constrained battery and restricted data transmission bandwidth.

Thereupon, the considerate part of the ad-hoc systems has the algorithm-centric implementation along with deduction for energy depleted per bit during transmission based on transmission strategies to deduce overhead control and alleviate the performance of bandwidth consumption. The energy model presented by the Qualnet simulator gives the measure of energy absorbed by the nodes in different modes: a) Transmit mode: The device dispatches the data to the destination or intermittent node; b) Receive mode: The node retrieves the data from the source node or intermittent node; c) Idle mode: There is no active session for the node when present in an idle state, but the node tends to continuously hear the signals within its range from its neighboring nodes, in the event that neighboring nodes have data for the intended node, so as to establish a connection; d) Sleep mode: Sleep mode enables the station to rest itself down for a while. However, in sleep mode, the MS stays associated with the base station. In this way, in Sleep mode, the BS holds all the data that is associated with the node in the sleep mode, as it does amid connected mode.

8. Future Research Directions

A. Intelligent Mobility Models

In line with the observation that mobile nodes in MANETs tend to coordinate their movement, the Reference Point Group Mobility (RPGM) Model has been proposed.This model is designed to emulate scenarios where nodes move together in a group or platoon, such as soldiers in a military operation or rescue crews during disaster relief efforts. In the RPGM model, each group has a center, which is either a logical center or a group leader node. For simplicity, it is assumed that the center is the group leader. Thus, each group comprises one leader and several members. The movement of the group leader determines the mobility behavior of the entire group.

With appropriate selection of predefined paths for the group leader and other parameters, the RPGM model can emulate various mobility behaviors. For example, Hong, Gerla, Pei, and Chiang have illustrated that the RPGM model can represent different mobility scenarios, including In-Place Mobility Model, Overlap Mobility Model, and Convention Mobility Model. Furthermore, the Mobility Vector framework, an extension of the RPGM model, has been proposed by Hong, Kwon, Gerla, et al.This framework suggests that many realistic mobility scenarios could be modeled and generated by properly choosing checkpoints along the preferred motion path of the group leader. If these checkpoints can accurately reflect the motion behavior in realistic scenarios, the Mobility Vector model provides a general and flexible framework for describing and modeling mobility patterns.

B. Cross-Layer Optimization

Mobility models with temporal and spatial dependencies, as well as models with geographic restrictions, introduce new challenges that must be studied carefully before widespread commercial deployment of MANETs can be expected.These challenges include dynamic topologies, routing, device discovery, bandwidth-constrained variable capacity links, power-constrained operation, security and reliability, Quality of Service (QoS), inter-networking, multicast, IP-layer mobile routing, and the diffusion hole problem.

Cross-layer optimization techniques, which involve the joint design and optimization of protocols across multiple layers of the network stack, can be explored to address these challenges. By considering the interdependencies between different layers and leveraging cross-layer information exchange, cross-layer optimization can lead to improved performance, energy efficiency, and adaptability to dynamic network conditions.

C. Integration with Emerging Technologies (5G, IoT, etc.)

As emerging technologies such as 5G and the Internet of Things (IoT) continue to evolve, their integration with MANETs presents promising research opportunities.The combination of these technologies can enable a wide range of applications and services, such as real-time monitoring, remote healthcare, smart cities, and industrial automation.Fog computing infrastructures have emerged to enhance response time and bandwidth usage, overcoming the limitations of cloud computing architectures for real-time services and device mobility.Fog nodes, distributed as fog computing entities, can provide effective ways to overcome many limitations of existing computing architectures that rely solely on cloud computing and end-user devices.

The fog-cloud paradigm combines the ability to execute smaller, localized applications at the edge and supports different IoT application requirements by converting collected data into near real-time processes.This paradigm can be leveraged to address the challenges of MANETs, such as limited bandwidth, energy constraints, and mobility-induced disruptions.Research efforts can focus on developing efficient protocols and algorithms for integrating MANETs with fog computing and 5G networks, enabling seamless communication, data processing, and resource allocation across these heterogeneous environments.Additionally, issues related to reliability, security, and privacy in these integrated systems need to be addressed to ensure robust and secure operation.

9. CONCLUSION

Mobility models play a pivotal role in evaluating the performance of routing protocols in Mobile Ad-hoc Networks (MANETs). The choice of mobility model significantly impacts the behavior and efficiency of different routing protocols under various network conditions. Proactive protocols tend to perform better in low-mobility scenarios, while reactive protocols are more suitable for highly mobile environments. Hybrid protocols offer a balance between the two approaches, but their performance depends on the mobility model and the zone radius configuration.As research in MANETs progresses, the development of intelligent mobility models, cross-layer optimization techniques, and the integration with emerging technologies like 5G and the Internet of Things (IoT) present promising avenues for further exploration. These advancements hold the potential to enhance the performance, energy efficiency, and adaptability of MANETs, enabling seamless communication and data processing across heterogeneous environments while addressing the challenges of limited bandwidth, energy constraints, and mobility-induced disruptions.

REFERENCES

[1] Kumar, M. V. S. (2012). Performance analysis of various mobility models on MANET routing protocols. International Journal of Computer Science Issues, 9(2), 132-139.

[2] Li, Y., Cai, Z., & Feng, J. (2015). Comparative analysis of MANET routing protocols on mobility and congestion control. KSII Transactions on Internet and Information Systems, 9(3), 1133-1151.

[3] Maihöfer, C., & Dressler, F. (2007). The flow-aware ad hoc routing protocol (FAR). In Proceedings of the IEEE Symposium on Computers and Communications (ISCC'07) (pp. 581-588). IEEE.

[4] Rani, B.M.S., et al., "Road Identification Through Efficient Edge Segmentation Based on Morphological Operations," Traitement du Signal, 38(5), 2021.

[5] Babu, D. Vijendra, et al. "Digital code modulation-based MIMO system for underwater localization and navigation using MAP algorithm." Soft Computing (2023): 1-9.

[6] Milbrandt, J. B., Johnson, D. B., & Kravets, R. H. (2000). An ad hoc network in a moving vehicle. IEEE Wireless Communications, 7(5), 14-22.

[7] Ng, C. T., &Tham, C. K. (2005). A comprehensive survey of mobile ad hoc network routing protocols. IEEE Communications Surveys & Tutorials, 7(3), 6-42.

[8] The Network Simulator - ns-2. (n.d.). Retrieved from https://www.isi.edu/nsnam/ns/
[9] Selvam, L., et al. "Collaborative autonomous system based wireless security in signal processing using deep learning techniques." Optik 272 (2023): 170313.
[10] Perkins, C. E., & Royer, E. M. (1999). Ad-hoc on-demand distance vector routing. In Proceedings of the 2nd IEEE Workshop on Mobile Computing Systems and Applications (pp. 90-100). IEEE.
[11] Bettstetter, C. (2001). Mobility modeling in wireless networks: Categorization, smooth movement, and border effects. ACM SIGMOBILE Mobile Computing and Communications Review, 5(3), 55-66.
[12] Johnson, D. B., Maltz, D. A., & Broch, J. (2001). DSR: The dynamic source routing protocol for multi-hop wireless ad hoc networks. In Ad hoc networking (pp. 139-172). Addison-Wesley Longman Publishing Co., Inc.
[13] Vijay, V. and Srinivasulu, A., “A novel square wave generator using second-generation differential current conveyor,” Arabian Journal for Science and Engineering, 42(12), 2017, pp.4983-4990.
[14] Nizam, Taaha, et al. "Novel all-pass section for high-performance signal processing using CMOS DCCII." TENCON 2021-2021 IEEE Region 10 Conference (TENCON). IEEE, 2021.
[15] Karedla, R., &Pompili, D. (2005). A survey of network simulations in wireless ad hoc networks. Wireless Communications and Mobile Computing, 5(7), 847-868.
[16] Royer, E. M., &Toh, C. K. (1999). A review of current routing protocols for ad hoc mobile wireless networks. IEEE Personal Communications, 6(2), 46-55.
[17] Turgut, D., &Özgüner, F. (2006). On-demand multipath distance vector routing in ad hoc networks. IEEE Transactions on Computers, 55(10), 1246-1259.
[18] Tanenbaum, A. S., & Wetherall, D. J. (2011). Computer Networks (5th ed.). Pearson.
[19] Rani, B. M. S., et al. "Disease prediction based retinal segmentation using bi-directional ConvLSTMU-Net." Journal of Ambient Intelligence and Humanized Computing (2021): 1-10.
[20] Wang, X., Jiang, Y., & Guan, Z. (2013). On-demand multipath distance vector routing in mobile ad hoc networks. International Journal of Computer Science Issues, 10(3), 283-287.
[21] Wei, Y., Ji, H., & Shu, Y. (2016). Performance analysis of ad hoc network routing protocols based on different mobility models. Ad Hoc Networks, 41, 16-30.Pittala, C.S., et al., “1-Bit FinFET carry cells for low voltage high-speed digital signal processing applications,” Silicon, 15(2), 2023, pp.713-724.
[22] Spyropoulos, T., Psounis, K., & Raghavendra, C. S. (2005). Spray and wait: An efficient routing scheme for intermittently connected mobile networks. In Proceedings of the 2005 ACM SIGCOMM Workshop on Delay-Tolerant Networking (pp. 252-259). ACM.