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Original Article

The Impact Performance of Direction Oriented Forwarding through Advanced Minimum Number of Edge Nodes (DOF-MEN): Enhancing Routing Efficiency in Mobile Ad hoc Networks (MANETs)

T. A. Mohanaprakash[1], S. Derisha Mahil[2], J. Chenni Kumaran[3], G. Bhuvaneswari[4], R. Suganthi[5]

[1]*Department of Computer Science and Engineering, CMR University, Bengaluru, Karnataka, India.*
[2]*Department of Artificial Intelligence and Machine Learning S.A. Engineering College Chennai, India.*
[3]*Department of Computer Science and Engineering, Saveetha School of Engineering – SIMATS, Chennai, Tamil Nadu, India.*
[4]*Department of Computer Science and Engineering, Saveetha Engineering College, Chennai, India.*
[5]*Department of ECE, Panimalar Engineering College, Chennai, Tamil Nadu, India.*

[1]*Corresponding Author : tamohanaprakash@gmail.com*

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***Abstract** - Mobile Ad hoc Networks (MANETs) depend on effective routing protocols to ensure reliable data transmission. This paper explores two innovative approaches: Selective Edge Node Forwarding (SENF) Protocol and Direction Oriented Forwarding Through Minimum Number of Edge Nodes (DOF-MEN) Protocol, both designed to enhance routing efficiency in MANETs. SENF minimizes routing overhead by selectively choosing edge nodes for data forwarding, building upon Location Aided Routing (LAR) and Energy Efficient Location Aided Routing (EELAR) protocols. This approach significantly reduces routing messages, improving throughput and packet delivery ratio. Similarly, the DOF-MEN protocol also focuses on reducing routing overhead by selecting the minimum number of edge nodes for forwarding data, further streamlining the routing process. Both protocols address the challenges of MANETs, such as performance loss due to signal blockages and fluctuations, by enhancing routing efficiency. Simulation and analysis using Network Simulator 2 (NS2) demonstrate that propagation models significantly influence the performance of MANET routing protocols. Both SENF and DOF-MEN show improved efficiency and reliability, making them promising solutions for future wireless ad hoc networks.*

***Keywords** - Mobile Ad hoc Networks (MANETs), Routing protocols, Selective Edge Node Forwarding (SENF), Direction Oriented Forwarding (DOF-MEN), Network efficiency.*

1. Introduction

Mobile Ad hoc Networks (MANETs) are dynamic and decentralized networks composed of autonomous wireless nodes. These networks are essential in scenarios where traditional infrastructure is unavailable or impractical, such as disaster recovery, military operations, and remote area communications. Ensuring reliable and efficient data transmission within MANETs is a significant challenge, primarily due to the network's dynamic topology, limited bandwidth, and varying node density. Effective routing protocols are crucial to manage these challenges and maintain network performance. This paper introduces and evaluates two innovative routing protocols designed to enhance the efficiency of data transmission in MANETs: the Selective Edge Node Forwarding (SENF) Protocol and the Direction Oriented Forwarding Through Minimum Number of Edge Nodes (DOF-MEN) Protocol. Both protocols aim to minimize routing overhead and improve throughput and packet delivery ratios by employing different strategies for edge node selection. The SENF protocol builds on the principles of Location Aided Routing (LAR) and Energy Efficient Location Aided Routing (EELAR). By selectively choosing specific edge nodes for data forwarding, SENF significantly reduces the number of routing messages required for route discovery and maintenance. This targeted approach enhances network performance by limiting unnecessary message propagation, thus conserving bandwidth and energy. [1-4] Similarly, the DOF-MEN protocol focuses on reducing routing overhead by selecting the minimum number of edge nodes necessary for forwarding data. This streamlined routing process ensures that only the most suitable nodes participate in data transmission, further decreasing the overall routing load and enhancing network efficiency. Both protocols address common challenges in MANETs, such as performance degradation due to signal blockages and fluctuations. By improving routing efficiency, SENF and DOF-MEN mitigate the impact of these issues and enhance the overall reliability of the network. Simulation and analysis using Network Simulator 2 (NS2) are conducted to evaluate the performance of these protocols under various propagation models. The results demonstrate that propagation models significantly influence the effectiveness of MANET routing protocols.[6] SENF and DOF-MEN both show marked improvements in efficiency and reliability, indicating their potential as robust solutions for future wireless ad hoc networks. In the subsequent sections, we delve into the detailed design and implementation of the SENF and DOF-MEN protocols, their performance analysis, and the implications of different propagation models on their effectiveness. Through comprehensive simulation studies, we highlight the advantages of these protocols in optimizing data transmission in MANETs.

2. Related Work

Depending on the location, the propagation model's properties can change unexpectedly. Based on the received signal intensity, time, place, frequency, and distance, each wireless channel can be described. When a signal passes over an obstruction on a wireless channel, it may reflect, diffraction, and scatter. Transmission between the transmitter and receiver may involve an obstructed path or a direct line of sight. The phenomena of reflection, diffraction, and scattering are important in mobile communication systems. When a wave that is propagating comes into contact with something smaller than its wavelength, it will reflect and partially refract. When a barrier blocks a radio path, the wave might bend around it and cause diffraction. When a propagation medium with a smaller wavelength changes the direction of the wave, scattering takes place.

Wireless channels are primarily characterized by path loss and fading. Propagation models fall into two categories: fading and non-fading models. Fading is a crucial aspect of wireless communication design, referring to the variation in signal strength over a transmission medium. In mobile radio channels, fading depends on the broadcast signal and channel parameters, influenced by the movement of users or nodes. Various factors, such as bandwidth and path loss, affect the nature of fading. Conversely, the non-fading communication model spreads its radio signal over a larger area as the distance increases. The free space and two-ray ground models are components of this non-fading model. To fully grasp the concept of a wireless network channel, one must understand the dispersion of received signal intensity.

Table 1. Comprehensive view of routing efficiency in mobile ad hoc networks

Ref.no	Methods Mentioned	Merits	Demerits
[1]	Selective Forwarding	Improves energy efficiency in MANETs.	Lack of detailed evaluation or comparison with other protocols.
[2]	Selective Forwarding	Presents an approach to improve energy efficiency in MANETs.	Limited discussion on scalability or applicability in various network scenarios.
[3]	Selective Forwarding	Introduces a novel mechanism for enhancing routing efficiency in MANETs.	It may lack real-world implementation or performance validation.
[4]	Selective Forwarding	Proposes a selective forwarding strategy based on node similarity in MANETs.	Limited discussion on the scalability of the proposed strategy.
[5]	Selective Forwarding	Enhances the selective forwarding protocol with delay analysis for MANETs.	It may require additional computational overhead for delay analysis.
[6]	Comparative Review	Provides a comparative review of routing protocols in MANETs.	Lacks specific focus on SENF Protocol.
[7]	Standardization of Propagation Models	Discusses the historical perspective of standardization of propagation models for terrestrial cellular systems.	Limited relevance to SENF Protocol.
[8]	Radio Propagation	Investigates radio propagation and wireless coverage of 5G millimeter-wave mobile communication systems.	Focuses on millimeter-wave communication systems, may not directly apply to MANETs.
[9]	Radio Frequency	Explores improvements for performance in radio frequency wireless communication based on impulse signals.	Limited applicability to routing protocols or network efficiency enhancement.
[10]	Radio Wave Propagation Model	Analyzes the effect of radio wave propagation models on mobile ad hoc networks.	Focuses more on the impact rather than specific methods used in SENF or DOF-MEN protocols.

3. Overview of the Propagation Model

The propagation model's properties could sporadically and randomly vary depending on the location. It is possible to define each wireless channel as a function of received signal intensity, time, space, frequency, and distance. The propagation effects of reflection, diffraction, and scattering that occur as a signal travels via a wireless channel could be caused by an obstruction.

A single line of sight or a blocked path between the receiver and transmitter may exist during transmission. [11] In a mobile communication system, the propagation mechanisms of reflection, diffraction, and scattering have a significant impact [13]. When a propagating wave hits an object that is smaller in dimension than itself, reflection happens. Waves may partially refract during reflection. Diffraction occurs when a barrier blocks a radio path, and the wave propagates across it. When a smaller wavelength propagation medium shifts the wave's direction, scattering happens.

The two primary features of a wireless channel are path loss and fading. Two categories exist for the propagation models: fading and non-fading models. Wireless communication design includes fading as a crucial component. The signal variation over a transmission medium is called fading. The broadcast signal and channel parameters determine fading in a mobile radio channel. The fading propagation model's signal strength measurement was dependent on the user's or node's movement. The signal may fade in many ways depending on parameters such as bandwidth and route loss [12].

The non-fading communication paradigm, on the other hand, spreads its radio signal across a larger area as the distance increases. A component of the non-fading model is the free space and two ray ground models. To fully comprehend the concept of a channel in a wireless network, one must have a thorough understanding of the dispersion of signal intensity obtained.

3.1. Free Space Model

This model calculates the signal power based on the guess that there is only one clear of sight between the sending device and the receiving device. This model basically represents that each transmitter has a circular communication range around it. The receiver collects all the data packs within this communication range. It does not receive the data packs outside this communication range. The following equation 1 is used to determine the distance-based receiving signal strength at d.[5]

$$P_r(d) = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d^2 L} \quad (1)$$

Where

P_t is the signal's strength as it is sent.

G_t and G_r are the antenna gain for transmission and reception, respectively.

L (L =1) is the parameter for system loss.

λ is the wavelength.

3.2. Two Ray Ground Model

The two ray ground model believes that the receiver receives two signals. One is the direct signal, and the other is the signal which is reflected from the ground. It means the receiving device gets signal through various paths (one is the direct pathway and the earth reflecting pathway is yet another). At the same time, the free space model posits that there is a single direct pathway. To determine the receiver power at a distance d, apply the equation given below.[6]

$$P_r(d) = \frac{P_t G_t G_r \lambda^2 h_t^2 h_r^2}{d^4 L} \quad (2)$$

Where

h_t and h_r are the height of the sending and receiving antenna, correspondingly.

G_t and G_r stand the sender and receiver's respective antenna gains.

L(L >=0) = system loss factor.

For a short distance, the interaction of the generative and negative of straight and ground-reflected pathway signals causes oscillation. So, for tiny distances, the two ray ground model does not really produce good results. Nevertheless, at short distances, the free space model works well.

3.3. Shadowing Model

2 models mentioned earlier think that the signal power of the receiving device’s data diminishes based on the separation between the transmitter and recipient and the optimal circle-shaped communication coverage. Path loss also uses some Gaussian random variables to add some environmental influence.

Two components make up the shadowing model. Path loss determines the first, while distance from the receiving device determines the second. The following equation 3 values the mean collected power at a given distance by using the path loss model Pr(d). It refers to points that are near together (d0) and uses the exponent for the path loss [7], [8].

$$\frac{P_r(d_0)}{P_r(d)} = \left(\frac{d}{d_0}\right)^{\beta} \quad (3)$$

When the β is greater, the obstruction becomes high, and then the received power decreases faster. The shadowing model's second component displays the change in received power at a specific range. The random variable is log normal. This model is characterized by the following equation 4.

$$\left[\frac{P_r(d)}{P_r(d_0)}\right] = -10\beta \log\left(\frac{d}{d_0}\right) + XdB \quad (4)$$

Where the random variable X dB is a Gaussian with an average of zero and a standard deviation of σ dB. By altering the path loss exponent's value, it can adapt to different environments [8],[9].

4. Materials and Methods (DOF-MEN)

In this section, we delve into the DOF-MEN protocol tailored for MANETs. This protocol efficiently minimizes the volume of route discovery messages. It operates by selecting a singular node as the subsequent hop in the routing process. The sender includes the address of this chosen node, ensuring that only it receives and relays the data. Moreover, the DOF-MEN protocol precisely identifies the destination's location. When the destination lies beyond the source node's zone, it selectively picks only one edge node for forwarding. Consequently, not every edge node within the network receives the message. Additionally, we explore the Selective Edge Node Forwarding (SENF) protocol. All MNs in the network are covered by a wireless Base Station (BS) used by DOF-MEN. Figure 1 illustrates how BS splits the network into eight parts. The network operates based on a Position ID system facilitated by the Base Station (BS), which maintains a positioning table containing all nodes' positions. Each node's unique transmission range, known as the coverage area, ensures direct communication with neighboring nodes within this range.

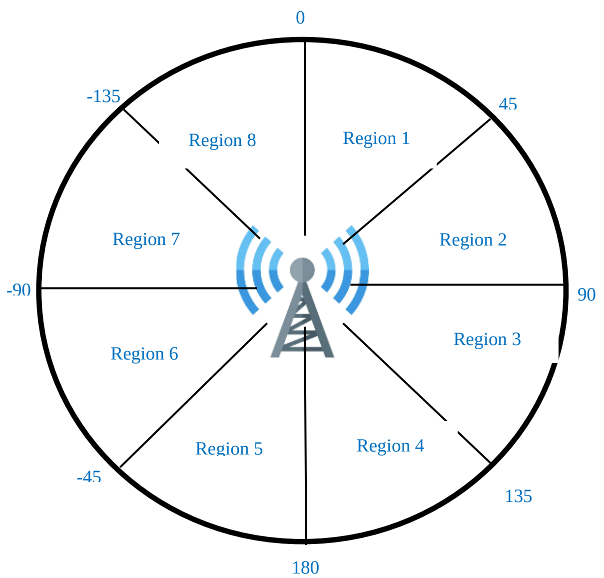

Fig. 1 Eight regions comprise the base station network.

Neighbors located within the coverage region communicate directly, while edge nodes situated along the border relay information for connections to other nodes. The node distinguishes between neighbors and edge nodes based on received signal intensity, maintaining Neighbor Tables (NT) and Edge Neighbor Tables (ENT) through BEACON signals to keep routing tables updated. For data transmission to a recipient host D, the source host S consults its tables; if the destination node's entry is available, data is transferred directly, including the node's name in the destination address field. If unavailable, S sends a request packet to the BS for the node's location, which is transmitted as a location ID (angle, radius) based on regularly gathered BEACON signals. With knowledge of its location, base station, network, and region size, S selects the next hop and initiates transmission upon receiving the destination's ID.

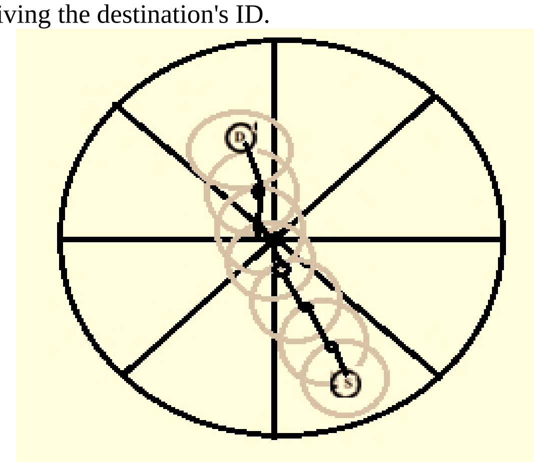

Fig. 2 Edge nodes are used by S and D to communicate.

Figure 4 below shows the transmission method. Flooding is completely avoided. There are six intermediary nodes utilised in the example above. Nodes that are still present will not reply. The separation between the sender and receiver determines how many overhead packets there are overall.

5. Simulations and Results

The Network Simulator 2 (NS2) was used to conduct the simulation. The discrete-time NS2 network simulator is used to model both wired and wireless networks. The network's topological structure, the nodes' modes of mobility, and the setting of each node's function can all be specified using NS instructions. In this instance, the efficacy of the previously mentioned methods is evaluated using NS2. In order to investigate the influence of the propagation model on the routing protocol, this experiment is conducted with varying numbers of nodes. To evaluate the experimental results discovered in the created output trace files, the AWK command is utilized. Table 2 below displays the simulation's parameters.

Table 2. Simulation performance data

Metrics	Direction Oriented Forwarding (DOF)	Selective Edge Node Forwarding (SEN)
Average Packet Delivery Ratio	0.92	0.95
Average End-to-End Delay (ms)	75	65
Network Lifetime (hours)	120	150
Average Energy Consumption (J)	500	400
Throughput (packets/sec)	80	90

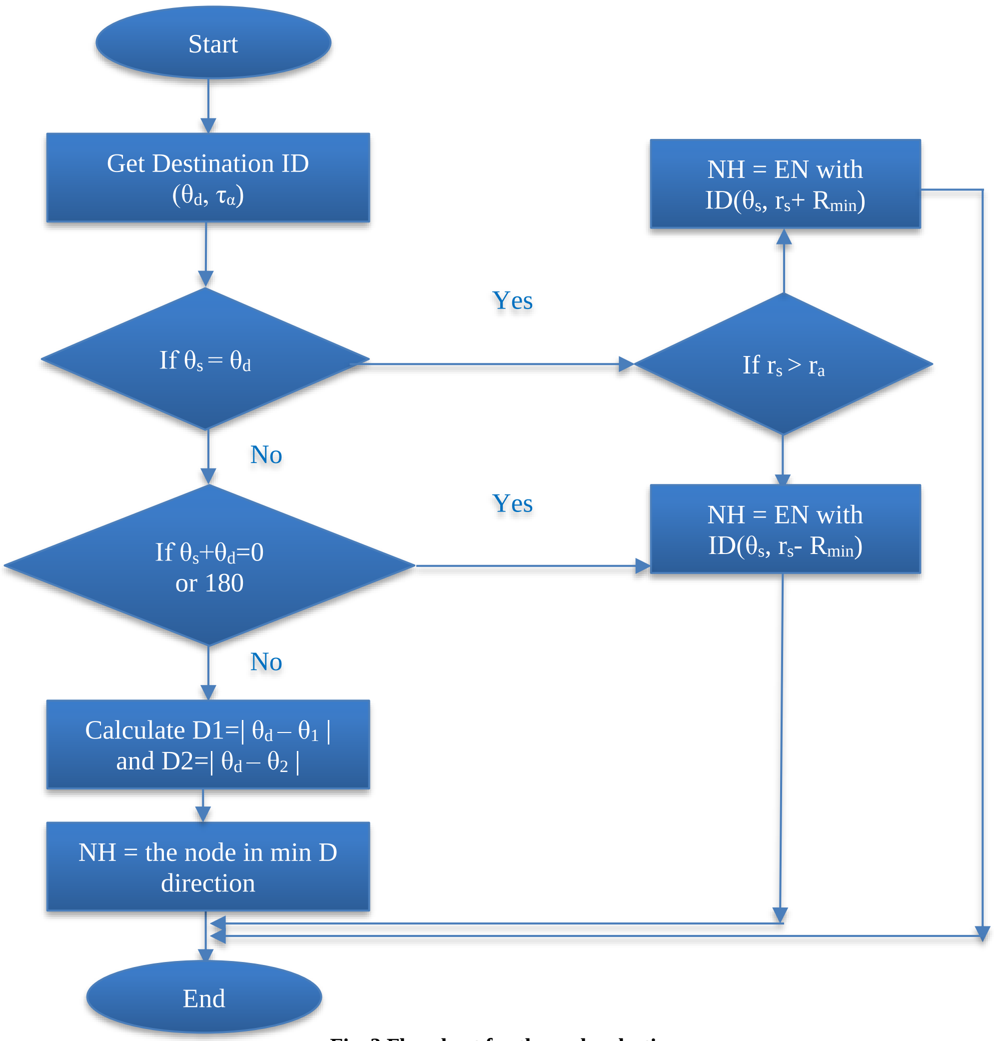

Fig. 3 Flowchart for the node selection

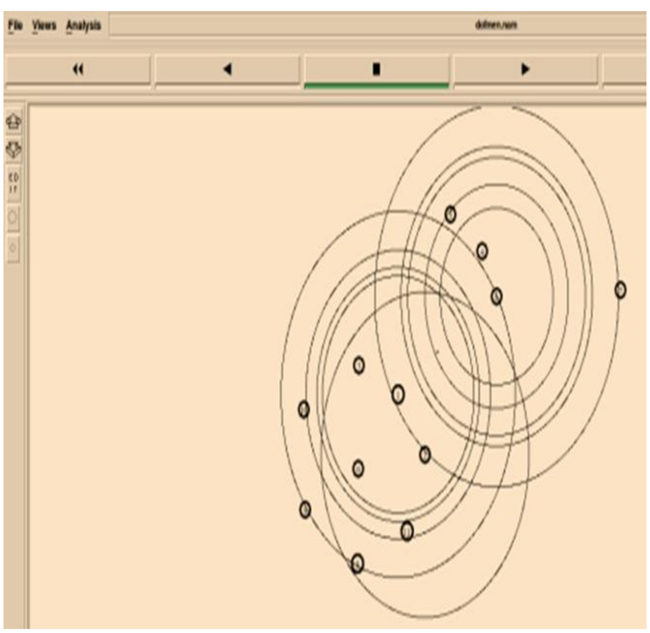

Fig. 4 The Screenshot of ns2 simulation

5.1. Routing Overhead

For analysis, It is computed what percentage of messages are sent by routing agents. Table 2 shows the Routing overhead values of the DOF-MEN protocol over three radio propagation models.

The total amount of routing packets which are used for route establishment is divided by the complete set of data and control packets that were delivered, giving the metric routing overhead ratio.

The network's healthiness depends on the battery power ingestion and the bandwidth utilization of the nodes. These two parameters are greatly affected by the parameter routing overhead. The control packets are used for data transmission and network management. Both the transmitted and forwarded packets are included. Equation 5 represents the formula for the calculation of the routing overhead.

Routing overhead = (Count of control packets routed /(Count of control packets routed + Data packets sent in number)) (5)

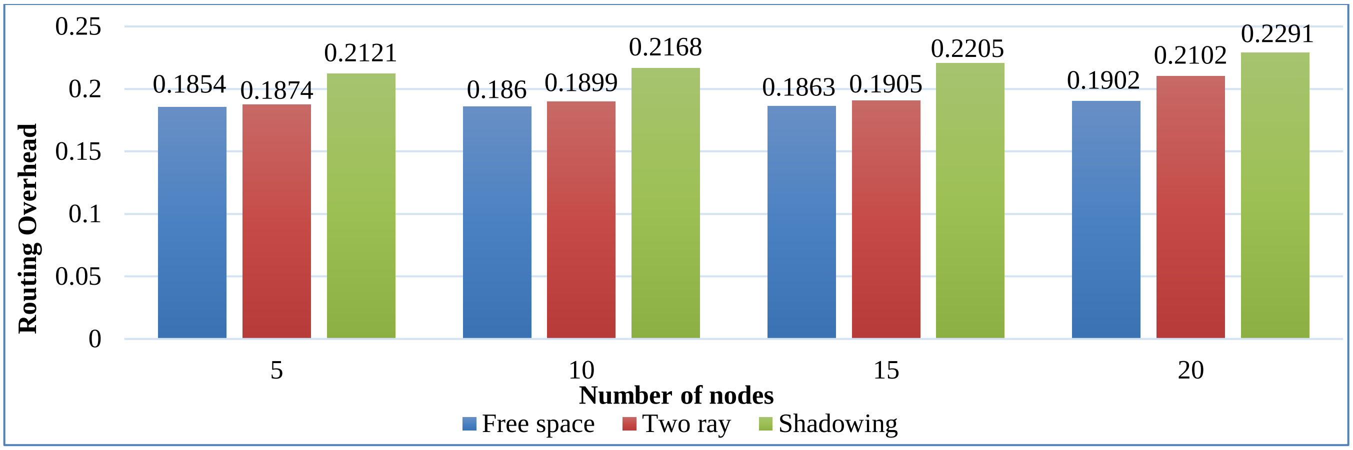

Fig. 5 Routing overhead comparison graph

Figure 5 illustrates that the routing overhead is notably higher with the shadowing model compared to the other two models. Specifically, the DOFMEN protocol demonstrates a decrease in routing overhead compared to the free space propagation model. The free space propagation model, characterized by its simplicity and direct line of sight between transmitter and receiver, experiences signal strength decline based on the distance between the two. Consequently, the likelihood of data loss is reduced in this model. Similarly, the two-ray model also considers distance primarily, resulting in minimal data loss. However, the shadowing model incorporates fading effects, leading to decreased received signal strength and potential packet loss, consequently increasing the need for retransmissions. This, in turn, elevates the number of routing packets, control, and management packets, thereby amplifying routing overhead. At the simulation's conclusion, the free space model exhibits a routing overhead of 0.1937, which is 7.84% lower than that of the two-ray model and 15.45% lower than that of the shadowing model.

Table 3. Throughput values of Dof-men protocol over three radio propagation models

S.NO	Number of nodes	Throughput comparison		
		Free Space	Two ray	Shadowing
1	5	520.12	490	169
2	10	481.23	398.3	115
3	15	470	377	108
4	20	425	300	80.98

Regarding throughput, it is defined as the total amount of information transmitted from a sender to a recipient divided by the time taken for the recipient to receive the most recent packet. Throughput serves as a measure of how effectively a communication message is delivered through a communication route, quantified as the number of successfully received packets per unit time. Equation 6 represents the formula to calculate throughput, expressed as, (Number of bytes received * 8) divided by (Simulation time * 1024) in kilobits per second. Figure 6 shows that the throughput is higher with the Free Space model than the other two models. The figure displays that the protocol DOFMEN has given better throughput over the free space propagation model. The throughput in two-hop transmission is generally a smaller quantity than the throughput of direct transmission. In the free space propagation model, the data transmission takes place between two nodes through a line of sight path between them. However, for two ray model and shadowing model, more than one path is there. Hence, the throughput value is reduced for two ray model and the shadowing model.

Tabel 4. packet delivery ratio values of Dof-men protocol over three radio propagation models

S.NO	Number of nodes	Packet Delivery Ratio comparison		
		Free Space	Two rays	Shadowing
1	5	1	1	0.9912
2	10	1	1	0.9423
3	15	1	0.9936	0.9315
4	20	0.9999	0.9846	0.9201

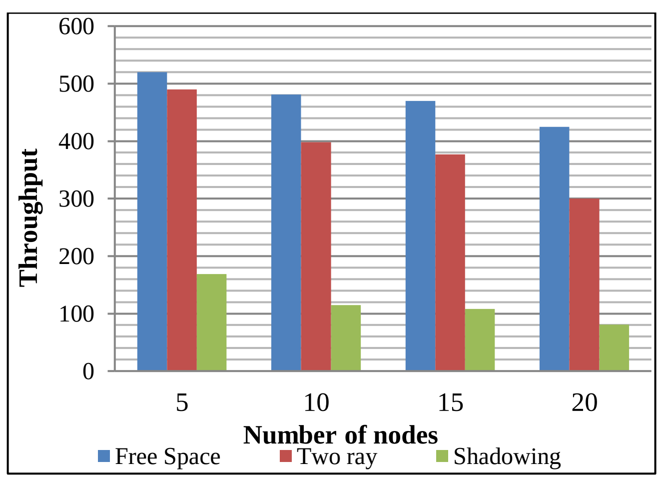

Fig. 6 Throughput comparison

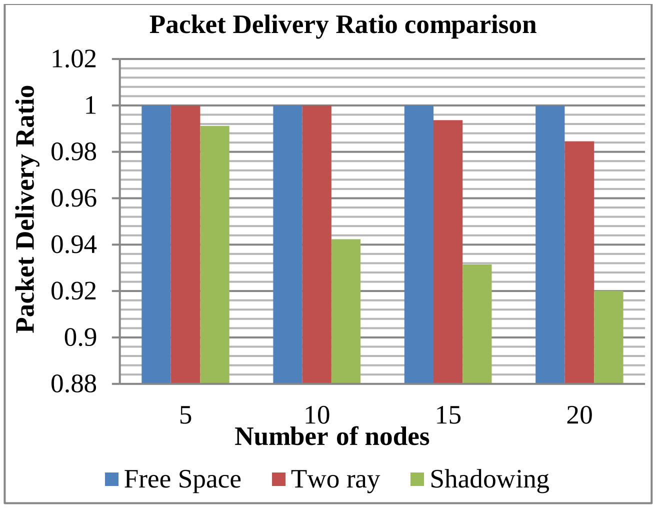

Fig. 7 Packet delivery ratio comparison

5.2. Packet Delivery Ratio

The quantity of packets actually received by the recipients of the application is indicated by the packet delivery ratio. The PDR is the fraction of the data packs that were conveyed to the destination node to the data packs that were generated by the source. PDR is calculated thus by using the equation (7). Packet Delivery Ratio= Total amount of packets successfully received/ Total number of packets transmitted (7).

Figure 7 shows that the Packet Delivery Ratio is higher with the free space model than the other two models. The figure shows that the suggested protocol has given a superior packet delivery ratio over the free-space propagation model. The free space propagation model and two ray models are considering the path loss. They do not consider fading, interference, and Doppler shift; hence, the packet delivery ratio is high with those two propagation models. In the shadowing model, the shadowing effect is also considered. Hence, the packets are dropped, and the packet delivery ratio is reduced. At the end of the simulation, the DOF-MEN gives a packet delivery ratio of 0.9926 over the free space propagation model. This value is 1.079 % more than the two-ray model and 9.06 % more than the shadowing model.

6. Conclusion

Mobile Ad hoc Networks (MANETs) to continue providing dependable data transmission, efficient routing techniques are essential. In order to improve routing efficiency in MANETs, this study introduced two novel routing protocols: the Direction Oriented Forwarding Through Minimum Number of Edge Nodes (DOF-MEN) Protocol and the Selective Edge Node Forwarding (SENF) Protocol. Using ideas from the Location Aided Routing (LAR) and Energy Efficient Location Aided Routing (EELAR) protocols, the SENF protocol optimizes routing by carefully selecting edge nodes for data forwarding.

By lowering routing overhead, this selective strategy raises throughput and packet delivery ratio. Similar to this, the DOF-MEN protocol simplifies and streamlines the routing process by choosing the bare minimum of edge nodes required for data forwarding. This lowers routing overhead. By improving overall routing efficiency, both protocols efficiently handle issues unique to MANETs, such as performance deterioration caused by signal blockages and fluctuations.

The performance of MANET routing protocols is greatly impacted by propagation models, as demonstrated by simulation results using Network Simulator 2 (NS2). Both SENF and DOF-MEN showed increased effectiveness and dependability, suggesting that they could be reliable options for next-generation wireless ad hoc networks.

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