ERWPM-MANET: Evaluation of Radio Wave Propagation Models in Mobile Ad-hoc Network by using Distance Scenario

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Abstract: Mobile Ad-hoc Networks (MANETs) are a kind of networks comprised of nodes which are mobile from place to place in nature, hence the name is MANET. Being an ad-hoc network, it does not need a centralised control infrastructure. Along with the mobile nodes, these type of networks also deals with the radio propagation models in which the nodes communicate with one another using different propagation models. These propagation models have their own kind of communication scenarios in which direct Line of Sight (LoS), Non-Line of Sight (N-LoS), two ray ground reflection etc. By communicating with one another, these propagation models undergo issues like going away from each other in which the distance increases and it directly affects their efficiency. In this paper, two -ray ground and free-space radio waves propagation models have been taken into consideration to check the distance-based scenarios in different distance ranges. With the help of Ad-hoc On-demand Distance Vector (AODV) routing scheme the simulations have been performed in NS-2 by taking the performance evaluation metrics that are average throughput, average latency and average packet drop. The simulations revealed that distance has a direct impact on the performance of propagation models. It has been concluded that two ray ground gives the best performance in contrast with the free space propagation model. The main reason is that two ray ground uses the two-way ground reflection in which it communicates via LOS and N-LOS. The simulations results have revealed that the proposed radio wave propagation models have a huge impact with the distance-based scenario to evaluate the performance of AODV routing scheme.

Keywords: MANET, AODV, Two Ray Ground Model, Free Space Model, Distance Based Performance.

1. Introduction

The unfolding wide-scale growth of mobile-phone market is in the development of empowering practical real-world positioning environments for MANET (Mobile Ad-hoc Network) and its based applications and services. The quality of these applications and services will innately rest on the behaviour of the underlying MANET network; hence, these behaviours need to be well understood (Abdali & Muniyandi, 2017). MANET is an ad-hoc network that needs no physical entity like central entity (Al-Majeed, Samayeva & Karam, 2019). It is self-configuring and self-organized network. MANET becomes very common to use, it is very simple and ease of deployment, when there are many limitations to install wired network either for restrictively of wired infrastructure or for duration of the installation or for other details. It can be the key in these situations. For example, MANET can be used and compatible for precarious circumstances which include law-enforcement, military, along with disaster recovery and emergency rescue (Antony & Thomas, 2018).

A MANET is characterised by a set of mobile nodes connected using wireless networks. The easy use of MANET is flexible and network lead to the communication era for their extensive usage. The The sender and receiver nodes in this network are utilized with the location information for finding a suitable nodes. This procedure can be done via an efficient and robust routing scheme like AODV that uses the concept of flooding for finding the route initiation (Arora, Millman & Neville, 2011). Apart from this, some issues may exist in this network like mobility of node, having limited power of computation etc. These issues are to be solved properly because MANET possesses some breakage in routes (Caso et al., 2019).

MANETs is comprised of mobile nodes that move from one place to another and communicate without possessing any physical infrastructure or central entity. From recent decades, these ad-hoc networks are evolving with the passage of time and the demand is increasing day by day, which has paved much area of interest for research and technological innovation (Sun et al.,

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2018). With these advantages, the MANET has some issues which are encountered during the transmission of data. These issues arise at the physical layer, especially with the propagation model embedded within it Because of the mobility nature of MANET, less throughput and the data loss occurs due to the embedded propagation models that have limited range of signal propagation efficiency. By going between nodes can ultimately affect the propagation models due to which huge amount of data loss occurs. Each propagation model has a unique feature in regarding communication. From this, regarding the distance based impact, this paper focuses on checking the performance of two ray ground and free space propagation models by placing the distance based scenarios to check impact in each one of them.

The core contributions of the proposed work are as follow:

- To study the state-of-the-art solutions for the proposed work.
- To identify the problem and state the proposed approach in respect of methodology.
- To study the performance analysis of free space and two ray ground Reflection radio wave propagation models in MANET by using the distance based scenarios.
- To simulate and analyze the mentioned radio wave propagation models in MANET by taking into consideration the performance evaluation metrics (Average Packet Drop, Average Latency and Average Throughput).
- To simulate and compare the proposed radio propagation models in terms of the mentioned evaluation metrics by using the proposed distance based scenarios.

The rest of the paper is organised as: Section 2 explains and consists of related literature in which the related work has been shown from different articles. Section 3 explains the main procedure and methodology of this paper along with simulation setup. Section 4 is consisting of the experimental results along with evaluation of the results. And finally, Section 5 consists of conclusion.

2. Review of the related literature

Authors in (Aldhaibani, Rahman & Alwarafy, 2020) proposed a procedure to examine the millimetre frequency band in indoor environments stairwell. In this work, the two signals were considered to measure within the two stairwells. The mentioned approach has the ability to generate immediate response during emergency situations in which the siren is implemented for this activity. From different frequencies of millimetres, the directional siren antenna for the co-polarization as well as cross-polarization had been deployed with the range of 26, 28, 32 and 38 GHz. A wave signal of millimetre that is efficient in the environment of 5G wireless networks within the two diverse situations of the stairwell is analyzed. For the investigation and analysis, four types of radio wave path loss propagation models have been deployed. The floating intercept path loss and close in free space reference models have been adopted. The alpha beta gamma and frequency dependent path loss are applied for checking the multiple frequencies. The analysis concluded that the effectiveness of the multi-floor stairwell's signal strength is beneficial for the study of path loss. Similarly, standard deviations, path loss exponent values and additional metrics are yielded. Authors in (Liu et al., 2021) proposed a model named channel via a utilisation approach of Ray Tracing (RT) for the analysis to check how the propagation of wave can be affected by the realistic localisation systems. For the trial in this perspective, 3-D information from a scenario of a University campus has been used. With the various propagation approach and mechanism, the RT is used to check the stimulus of the channel impulse response (CIR)" or "the channel impulse response (CIR) of the radio wave from the position to the target nodes using 3 diverse bands of frequency that are scattering, diffraction and reflection, as well as their combining strategy. Therefore, the mentioned CIRs are used for the estimation of the target location. Their work has the potential within the three aspects that are (1) to provide a free approach of measurement that has the ability to properly check the impact of the localisation of the realistic environments and (2) to reveal how radio wave propagation and environment models are affected by the performance of localisation. Their suggested approach has the ability to be transferred and to analyse the additional approaches in sensor network's localisation.

Authors in (Hams et al., 2021) presented four radio wave propagation models based on LTE technology for the location within the Tripoli environments. These models were Ericson 9999, Okumura-Hata, Okumura and COST 231. Their results have revealed that the Okumura radio wave propagation model as the lowest RMSE value from this scenario it has revealed the real time applications Authors in (Shuhaimi et al., 2021) analysed the performance of diverse radio wave propagation models that are Nakagami, two ray ground reflection and free space for VANET on the method of RPM (Rounds Per Minute). They have observed the average end to end delay, throughput and packet loss within the vehicles to deploy diverse kinds of RPMs and then it has been contrasted to check which RPM is the best. In VANET, to obtain and analyse the impact and performance of RPM, numerous softwares are available. The most suitable is Java Open Street Map (JOSM). For the analysis of the VANET propagation models, the NS-2 simulation tool has been used in which Mobility Model Generator and Urban Mobility (SUMO) have been utilised with the perspective of the operating system of Linux Ubuntu v20.04 as a core operating system. For the proposed work, the authors have collected the data from a place named Jalan Besar Selayang Baru, Batu Caves Selangor. The location was selected in the range of 2 km, with the area size of 2 km by 2 km for the thoroughly info of the mentioned radio wave propagation models. The authors have concluded that VANET performs better than the RPM.

Authors in (Adebowale et al., 2021) presented a broad investigation along with a systematic literature review on the uses of the nature inspired computational algorithms within the radio wave propagation models to analyse. They have covered to check the Swarm Intelligence (SI), Fuzzy Inference System (FISs), Artificial Neural Networks (ANNs) along with additional computational algorithms. In this article, the authors have projected a survey which addressed future research directions, open research issues, different research areas and some other aspects that are illustrated and discussed. The core idea of this article was to serve and judge the impact of path loss prediction in radio propagation models and to see how much impact can be arise on these models. Authors in (Diago-Mosquera et al., 2020) addressed a broad survey of a model of propagation called the Indoor Narrowband Model, which has been there for 3 decades for the analysis and effectiveness in the field of research. This model has shown significant improvements and also have discussed some limitations too for the benchmark of classifications. At last, the Indoor Radio Wave Popagation model, with the open issues and future research directions, has been suggested in broad perspective.

Authors in (Zhang et al., 2021) performed the characteristics of the mmWave channel based on clustering analysis for the urban dense environments. In the initial stage, the radio wave propagation settings were conducted with the identified bands of 28 and 39 GHz in dense and central business residential areas. The sounder approach of cluster based designed model of channel supports a directional oriented scanning of the sounding that helps in the collection of relevant and sufficient data for the modelling of the statistical channel. Then, with the utilisation of the improved algorithm named Auto-Clustering, clusters of multipath as well as the source of scattering are addressed and identified. An efficient and suitable measurement for intra and inter-clustering is achieved and portrayed in the RMS angular spread, RMS delay spread, the RiceanK-factor, cluster member as well as their correlations. The contrast evaluations of the two metrics along with the two mmWave bands for both LoS and N-LoS links are illustrated additionally with exterior walls reflection and the diffraction signal over the height of the buildings with the rooftops. At last, their results have shown the base clustering analysis undergoes and carries the full advantage of the proposed model of mmWave with beanspace characteristics of channel, with some upcoming deployments and implementation to design and deploy the proposed wave model in a wireless network.

Authors in (Grimm, 2019) provided a broad and thoroughly survey regarding the models of channels in mobile communications that will be utilise in a new 5G system of radio. At first, a comprehensive discussion regarding the framework of the channel models which is comprised of the classical path loss versus the distance small scale and large scale models of fading as well as the MIMO mechanism's model was started The next step was to find the differences among the microwave and mmWave channel model were suggested and introduced, and the most popular two radio channel models were discussed in aspect of the mmWave channel model. A model named the 3RD Generation Partnership Project, that is adopted by the NYUSIM model and ITU, was implemented from many years in the measuring field of a zone in New York City. This beam includes the multipoint transmission of data with the leverage rate. The results have concluded that the performance metrics of channel models (hardware/signal processing requirements, coverage, efficiency of spectrum etc.) are exclusively and extensively sensitive.

Authors in (El Chall et al., 2019) proposed that a propagation model named EM along with the antenna that is fixed on-body metrics, has to be utilised for the development of the scalable models of path gain along with the optimised strategies of design. Taking into consideration the planer dissipative surface, a novel radio propagation model was argued on that has the ability to follow the Somerfield issue and problem. A procedure called Quasi-Static Ranges has been suggested to solve its adoptability and discussed its core and basic principles of the propagation of electromagnetic within deployed on-body LoS scenarios within the suggested frequencies between the ranges of 400 MHz and 60G Hz. Taking into consideration these results, an antenna was introduced in de-embedded perspective in their solution proposal that has the ability to average radiate the antenna far field and to model it. Additionally, the terminologies TE one and TM field components were discussed for the introduction of the two sources of equivalent dipole of electricity. Their procedure empowered the introduction of the on-body directions along with the effectiveness of the area of the antenna for the introduction of the properties of the radiation. Through, this scheme was at the beginning limited for the sigh propagation w.r.t LoS, a phantom was introduced named cylindrical dielectric phantom for the covering of the N-LoS connections and links. In this scenario, a method named De-Embedding Method was introduced to model the range of quasi-static range whereas the curved path of propagation was treated within the adoptable cylindrical model that has the ability to emphasize the TE/TM decomposition of the far field to the polar model. At last, their suggested theory was analysed and verified by the full human body along with the setups of measurements in the chamber of anechoic.

Authors in (Gulfam et al., 2019) investigated a novel approach named LoRaWAN; a radio channel in the introduced band of 868 MHz. The campaign extensively was utilised for the outdoor and indoor settings in rural as well as urban locations in Lebanon (Saint Joseph University of Beirut campus, Beirut city, Bekaa valley). From their results, the model named PL was embedded to deploy for the proposed approach of LoRAWAN communication as well as it was contrasted with the most widely used models of empirical. Furthermore, the coverage and performance of the LoRaWAN model that was implanting was analysed on some real environment’s measurement. The proposed work’s results have showed that the PL Model had an accurate and remarkable efficiency to be deployed in the location mentioned before in Lebanon as well as in other identical locations. The paving range of this proposed model lied between 8 km to 45 km and was generated in rural and urban environment accordingly. This activity showed the efficiency and accuracy of the long range IoT communication for this promising technology.

Authors in (Yaro & Sha'ameri, 2018) presented a brief overview and evaluation of Azimuthal Multipath Shape factor and Second Order Fading Statistics factor (S.O.F.S) for the indoor and outdoor mmWave channels of radio propagation. For the study of the channel’s characteristics of the radio propagation of the fading statistics, an analytical relationship of a plain regular statistic was introduced and discussed. In open literature the plain of the angle of arrival measurements yields are avail for 4 diverse indoor and outdoor environments with the scenario ranges of the frequencies of 28 and 38 GHz along with the 9 diverse radio propagation models with the ranges of 28-38 GHz. These were to be extracted with the utilisation of diverse interpretation approaches of the graphical data. The level-crossing rate, average fade duration, spatial auto covariance, spatial coherence distance, direction of maximum fading, angular constriction and standard deviation and angular spread are the considered aspects of the qualifier for the division of the energy in an angular area of domain with S.O.F.S respectively. The study focused only on an azimuth plane on the angular spread. The generated and attempted evaluation of the SOFS and angular spread has extreme benefits and significance in interleaving algorithms, error correction approach, channel estimation, antenna beams, equalization schemes and designing modulation schemes for the proposed mmWave radio propagation in indoor and outdoor environments.

Authors in (Harinda et al., 2019) considered that the attenuation of a signal is the key and core contributor to a procedure named TDOA, as well as the error's estimation and the impact of it on a propagation model of path loss on the accuracy of PE at system of MLAT was decided. Two propagation models were proposed. These models were the Free Space Path Loss (FSPL) and the Okumura-Hata Based on the actual system of the work, a receiver and a transmitter were used for evaluation in the civil aviation surveillance. Based on the square ground receiver stations GRS's configuration, the Monte Carlo's simulations and some irregular and randomly appointed aircrafts portion revealed that the proposed MLAT system has the highest PE error with the Okumura-Hata propagation model. The altitude error obtained as well as the horizontal coordinate for the consideration with the Okumura-Hata with the range of 2.5 km and 0.6 km is considered higher than the results of the FSPL model respectively.

Authors in (Hussain et al., 2020) proposed a novel approach to check the performance evaluation of the radio propagation model along with the impact of these models on OLSR routing protocol. Two dense and sparse scenarios were proposed and the impact made in different propagation models from the proposed scenarios was checked. The simulations using NS-2 were placed to check how much impact has arisen on the performance of the OLSR protocol, as well as two ray ground, shadowing and free space It has been tested under the dense and sparse environments of the placement of the nodes. From the simulations, the two ray ground has shown much better performance in contrast with the other propagation models in MANET.

Authors in (Mir & Filali, 2016) suggested a simulation based study by using the NS-3 simulation tool to check the LoRa-WAN (Long-Range Wide Area Network) on a range of 868MHz in the urban environment by the utilisation of the radio propagation models Walfish-Ikegami (COST-WI), COST-231 and COST-321-Hata and Okumura-Hata model, in this work the LoRa-WAN used the frequency range of 868 MHz for the communications in Europe. The values were contrasted in real-world scenarios and measurements of these were taken in the city of Glasgow for the analysis and accuracy of the empirical models for the utilisation of the coverage prediction and planning of LoRa-WAN networks. The predicted received signals accuracy was compared with it. From the evaluation and comparison of study basis of the propagation, models showed COST-WI and Okumura-Hata over estimated and under estimated (the same power) in the city of Glasgow's scenarios. Likewise, the Okumura Hata Model has shown high accuracy prediction while the other model, COST-WI, had the least accuracy. The small model's prediction or the mean absolute indicated error was expected. The study revealed the it may be used to given the insight into the accuracy and effectiveness of the propagation model of empirical for the analysis and estimation of the IoT's connectivity along with the LoRa-WAN's networks in a N-LoS's urban environments.

Authors in (Yildirim et al., 2021) proposed an approach which is based on AI and solution for acceleration with the improvement and diverse methods of the geometry-based approach. By taking into considerations, a ray tracing concept with the utilisation of radio propagation has been used by applying AI and machine learning as core methodology. Authors in (Isabona & Ojuh, 2021) suggested a novel approach for enhancing a large-scale radio wave propagation model for the network with the focus on path loss model by using the terminologies of Very High Frequency (VHF) and Ultra-High Frequency (UHF). For set-up was deployed for the multi-propagation arrangements for calculating the received signal's strength with seven transmitters of broadcasting with the distance coverage of 145.5 km in the environment of Nigeria. Impersonal style: "A distance-based path loss with the UHF and VHF bands was predicted. Authors in (Gerasimov et al., 2021) proposed a methodological based approach by using a propagation algorithm named Levenberg-Marquardt Algorithm (LMA) which has an accurate and fast optimal speed of convergence. A radio path loss propagation model was suggested by focusing on the signal strength at receiver side by deployed terms as LTE eNodeBs with the set-up of three diverse environments that are urban, rural and suburban. The numbers of eNodeBs were 32, 28 and 30 m with the 10 MHz bandwidth channel and operated each on 2.6 GHz range of frequency. Authors in (Hossain et al., 2021) have provided a conceptual framework regarding the Cognitive Radio (CR) terminology to be used in networks especially in VANETs in which it'll be deployed in cars but will be utilized by only licensed cars to sense the capabilities of the license spectrum. For the location of the vacant spectrums that are not in the usage of any licensing users.

Authors in (Dalveren et al., 2021) suggested an approach of radio propagation to be used in scaling and the measurement of it within the scenarios of the tunnels in which the path loss and obstacles may block the signal. Due to the reflection in internal environment of tunnels, the path loss as well as the fading causes the disruption of the signal and results become poor and inadequate. Authors in (Bhardwaj et al., 2021) proposed an approach to avoid the attenuation and blocking of the radio wave signal caused by the human body. An indoor short 28 GHz range was suggested. A model named Street Canyon Propagation has been taken into fully considerations. It has the ability of propagating a signal in four diverse ways for the to consider of human body (i.e. if a body block signals then it will use an alternative path to propagate and so on). For this scheme, a double knife-edge diffraction (DKED) propagation model was predicted. if the signal travels in multi path, then DKED is the model which will be used to overcome the attenuation of that signal.

Authors in (Zhang et al., 2021) proposed a system for radio propagation model to avoid the signal attenuation as well as the fading and interferences. For this purpose, under 120 scenarios of blockages have been tested. The methodology was an extension and improved version of the existing work in which the same terminology was adopted, but this time they have used a different and robust scheme. For this study configuration tests were taken at the complete number of channel of acquisitions 180000 with the 60 GHz of the state of the art. Authors in (Aldhaibani et al., 2020) deployed a scheme for the mmWave known as millimetre-wave a cellular system for propagation scenario. An analysis of the mmWave was conducted based on cluster approach by takin two typical urban-dense environments for the performance and deploy. With the two introduced bands of ranges 39 and 28 GHz within dense residential and central business district areas for the presentation and experiment. At last, the results have revealed that the cluster based approach for mmWava has the potential and takes into further implications for deploy and the design in a wireless network of mmWave.

3. The proposed methodology

This Section illustrates how the proposed research work has been carried out by using the proposed methodology for accomplish the main objectives of the research. This Section deals with the first objective in which the initial step is to design a simulation setup for the research. The main reason is to check and evaluate the performance impact of the two ray ground and free space radio wave propagation models based on the distance based scenarios. There are three steps in the simulation scenario which are pre simulation, execution and post execution. Will all these a TCL script is to be written which demonstrates the performance of the proposed metrics. Each activity in perspective of simulation will be recorded and the metrics have been recorded accordingly for the subsequent results. After simulation, each scenario will be portrayed in Microsoft excel for visual illustration in the form of graphical representation.

3.1. Scenario of simulation

For simulation, the tool used in this work is NS-2. This is a popular efficient tool used in the network environment to design and code complex problem and find a better solution for that. In simulation environment, there is a technique that is used for the analysis of the results is AWK and PERL scripts. These use the .tr files which are originated from the running script of TCL. Furthermore, the simulation work has been illustrated in the form of tables and graphs which are explained in Section 4. The simulation of this work is categorised into three subsections (Figure 1) that are pre-simulation, execution and post simulation phase and these are explained here.

a. Pre-Simulation Phase

The given name of this phase simply denotes the initial stage of the simulation for the proposed work. In this phase, the metrics are set according to the work before the starting of the actual work. This phase explains the scenarios and other related aspects. A TCL script is the one in which all these activities have to be mentioned and written in which each activity has to be explained regarding the work.

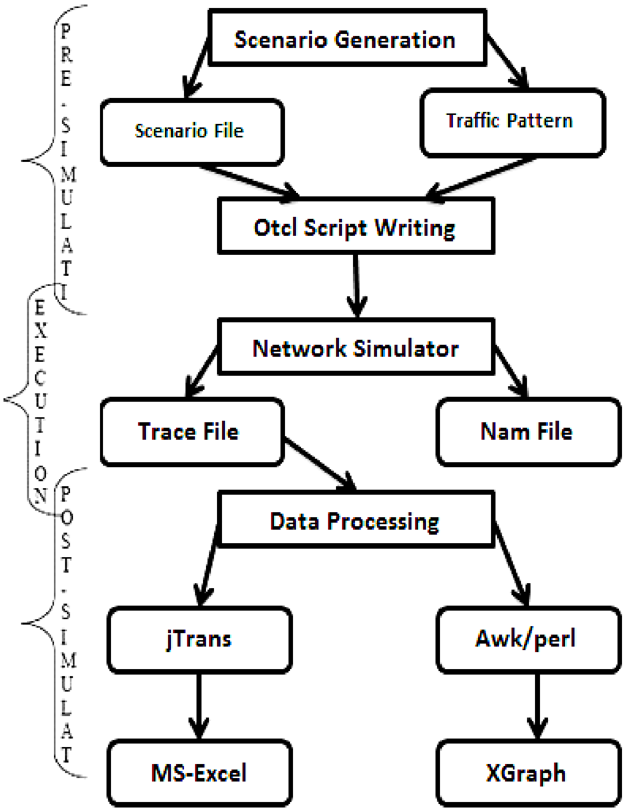

Figure 1. Phases of Simulations

b. Execution Phase

This phase explains the actual running environment in which the simulation takes place for the further process. The simulation script has been prepared from the previous phase's OTcl language for this. From the execution of the simulations the two scenarios have been generated; the animated and trace. These are actually files generated from the simulations. The file of trace is comprised of each activity that occurred during the simulations in which the packets are sent, dropped and received and also how much time the simulation had to generate these results. Whereas, the animation file has the ability to keep track of the network in aspect of visual and physical layout.

c. Post Simulation Phase

This is the last phase of simulations for the proposed work. The major and key purpose of this phase is to critically evaluate and analyse the results that have been generated and to acquire the desired information from the .tr generated file. In this regard, the AWK and PERL are the two common approaches and techniques for the analysis and evaluation of the generated results.

The simulations have been conducted for the proposed research work to evaluate the performance of two ray ground and free space radio wave propagation models via distance based scenario with the help of AODV routing protocol. The generation simulation metrics have been given the Table 1 in which each activity is illustrated from the simulation tool to the mainly used routing protocol, AODV, for the proposed work. These are the mandatory metrics for simulations which reveal how the simulations have been conducted and how the results have been generated. The information and descriptions of all the metrics are shown in the given Table for understanding the environment and simulation setup.

Table 1. Metrics for simulation

Metric	Value
Simulator	Network Simulator-2.34
Channel type	Wireless 802.11s
Pause Time	2 seconds
Node Mobility	1-10 m/sec
Mobility Model	Random Way Point
Packet Size	1000 Bytes
Agent	TCP
Minimum Distance	0-10 meters
Maximum Distance	40 meters
Number of Nodes	100
Simulation Area	500m X 500m
Simulation time	100 seconds
Proposed Propagation Models	Two Ray Ground Free Space
Evaluation Metrics	Average Throughput (kbps) Average Latency (milliseconds) Average Packet Drop (packets)
Routing Protocol	AODV

The distance based scenario in meters is shown in Figure 2 and Figure 3 in which the minimum distance is 10 meters and maximum distance is 40 meters for the proposed work.

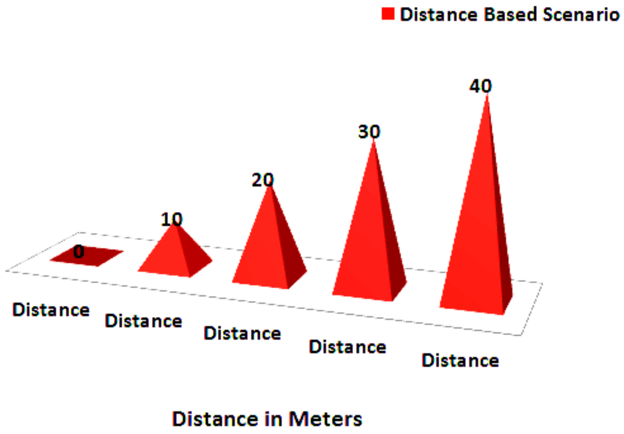

Figure 2. The proposed distance based illustration-1

Figure 3. The proposed distance based illustration-2

3.2. The proposed models of propagation

a. Two-Ray ground propagation model

This is a kind of radio wave propagation model in which the communication takes place by using the two signals approach (Figure 4). One for direct LoS, which is direct signal propagation, and the other is N-Los, which is the two way ground reflection approach (Popoola et al., 2019). This model can propagate signals in both directions as mentioned in LoS and N-LoS, for which it uses the ground as a communication medium. From sender to receiver, the energy of the signal transmitted and the energy of the signal received are not the same. This means that the energy of the received will be less that the energy of the transmitted signal, because during the propagation the signal travels and consumes energy. In this model, it calculates the energy of the signal at the receiver side and uses the capacitor filter technique to boost the energy of the signal (Khan et al., 2017). It has also some limitations in which it needs to propagate the signal but both the transmitter and receiver should be at the same height. This model is considered the best in contrast with the free space and other propagation models (Martinez et al., 2009).

The *P* (power) of the receiver by *d* (distance) is given;

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

The terms used in this formula are P_t, G_r, G_r, h_t, h_r and L,

Where, power of transmitted signal is p_t, the antenna gain of transmitter and receiver are noted as G_t and G_r. The terms for height are h_t and h_r and for arrangement failure, L (Eltahir, 2007).

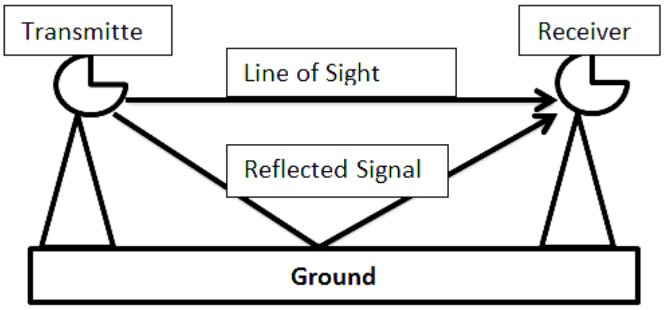

Figure 4. A Scenario of Two Ray Ground Propagation Model

b. Free space propagation model

This is a model in which the clear LoS takes place and in which both the transmitter *t* and receiver *r* are at the same height or at least both are visible to each other for direct signal propagation (Mir & Filali, 2016) (Figure 5). The reflection approach is not used when an obstacle comes between the transmitter and receiver so it only utilises the clear LoS approach. The power of transmitter and receiver's gain is reliable based on the distance between source and destination. As mentioned earlier, the power of the signal received decreases as the signal goes and paves long distance. That's why this model gives poor performance when the distance increases from source to destination, which is the main limitation of this model. For the signal strength and its calculation, H.T. Friis had proposed the Equation to calculate the signal gain at the d (distance) from the source to destination or transmitter *r* to receiver *r*, by using the mentioned formula 2 (Li et al., 2019), (Jacquet et al., 2001).

By using Equation 2, the antenna gain of this model can be calculated.

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

The terms, P_t, G_t, G_r, λ, d *and* L are used to denote the different aspects of calculation.

Whereas the power of transmitter is P_t, the antenna gain of transmitter is G_t, gain of receiver is G_r, d for distance and λ is the wavelength. Similarly, L denoted the loss of the level which is calculated by using the expression of $L\ (L \geq 1)$ and L=1, $G_t = G_r = 1$.

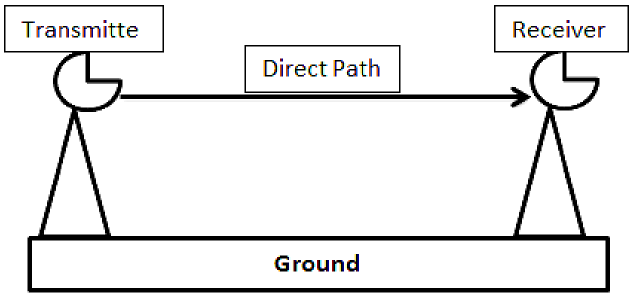

Figure 5. A Scenario of Free-Space Propagation Model

4. Performance analysis and evaluations

This Section provides the experimental results along with proper justification for the proposed method. Each scenario is discussed with tabular and graphical illustration. From the proposed approach in which two propagation models are mentioned for analysis and evaluation. Based on the performance evaluation metrics that are Average Throughput, Average Latency and Average Packet Drop, these evaluation parameters are explained in the given subsections

a. Average throughput

The term throughput denotes the sent and received data in packets or bits which are calculated in the formula 3, as given. In network, the average throughput is the overall amount of sent packets and received packets in the given simulation time interval (Figure 6). The number of frequency passing through a medium per seconds is the actual throughput in which it shows how many packets are sent and how many are delivered to destination in the mentioned amount of time interval (Jubair et al., 2018).

The average throughput of a network can be calculated by using the given Equation 3.

$$Average\ Throughput = \sum_{i=1}^{n} \frac{Received\ \ packets\ i \times packet\ size}{total\ simulation\ time} \qquad (3)$$

From the given equation the average throughput can be calculated. In this regard the mentioned values are the average throughput of two ray ground and free space propagation models. As shown in the given table and graphical illustration, two ray ground and free space have shown better performance in respect to average throughput. The distance based performance has been recorded in which four sequences are used for distance that are calculated in meters, in which the starting point is 0 and the last point or maximum value is 40 meters. At 0 or initial point both have values of 0, and when the simulation has started then at distance 10m the value of two ray ground is 90 whereas the value of free space is 89 at that point. Proceeding to the next level (i.e. increase in the distance from 10 to 20 m) the value of two ray ground is 91 and free space is 80. Similarly, at distance 40 m the value of two ray ground is 83 and free space is 78. These recorded values are the throughput in kbps in which the two ray grounds have shown better performance as compared to free space. The main reason is that the signal propagates and can pave long distance in two ray ground models which doesn’t need clear LOS. But free space purely focuses on the clear LOS, that’s why the signal can’t travel in large distance in this scenario, that’s why it has shown poor performance in contrast with the two ray ground.

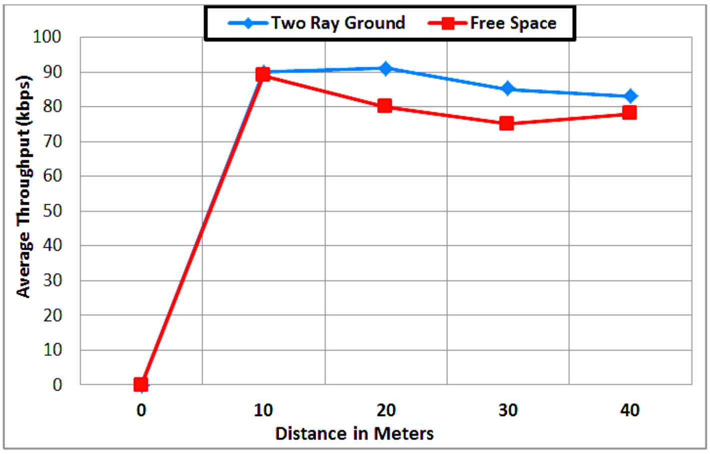

Figure 6. Average Throughput (kbps) of two ray ground and free space

b. Average latency

Delay is the time taken by a packet from source node to destination node or from sender to receiver. The latency can be calculated in seconds or milliseconds. The minimum latency denotes high performance and effectiveness. The average latency of a network (Figure 7) can be calculated by using the given Equation 4 (Hussain et al., 2020).

$$Average\ Latency = \sum_{i=1}^{n} \frac{received\ time\ i - sent\ time\ i}{Total\ data} \quad (4)$$

From the given equation 4, the average latency can be calculated. In this regard the mentioned values are the average latency of two ray ground and free space propagation models. As shown in the given table and graphical illustration, two ray ground and free space have shown better performance in respect to average latency. The distance based performance has been recorded in which four sequences are used for distance that are completely in meters in which starting point is 0 and the last point or maximum value is 40 meters. At initial point both have values in 0 but when the simulation has started then at distance 10m the value of two ray ground is 0.8 whereas the value of free space is 1 at that point. Forwarding to the next level i.e., increasing in the distance from 10 m to 20 m the value of two ray ground is 0.4 and free space is 0.9. Similarly, at distance 40 m the value of two ray ground is 0.5 and free space is 0.2. These recorded values are the latency in milliseconds in which the two ray ground have shown better performance as compared to free space. The main reason is that the signal propagates and can pave long distance in two ray ground models which doesn't need clear LOS. But free space purely focuses on the clear LOS. That is why the signal can't travel in large distance in this scenario and that is why it has shown poor performance in contrast with the two ray ground.

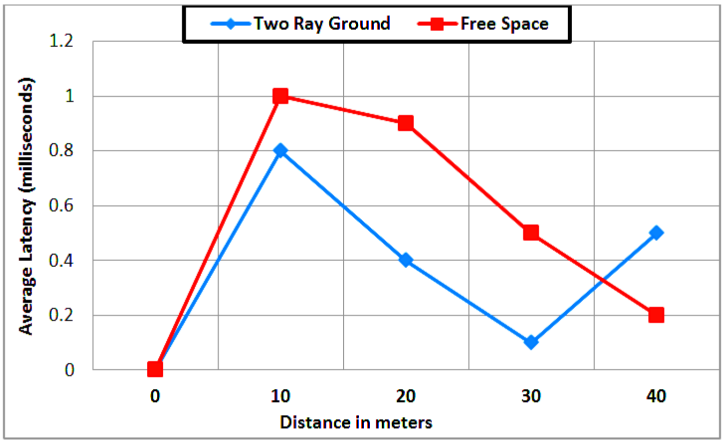

Figure 7. Average Latency of two ray ground and free space

c. Average packet drop

Packet drop is the quantity in which the sent packets and actually delivered packets of a network can be measured. This metric can be calculated in packets (Cavilla et al., 2004). The drop of packets is generally impacted during the time of transmission of data from source to destination, the collision of the signals or the congestion of the network or a receiver side. The packet drop can be calculated by the Equation 5 (Hussain et al., 2020).

$$Packet\ Drop = \sum_{i=1}^{n} \frac{Packet\_Dropped \times Packet\_Size}{Total\ Time} \tag{5}$$

From the given equation 5, the average packet drop values can be calculated. In this regard, the mentioned values are the average packet drop of two ray ground and free space propagation models. As shown in the given table and graphical illustration (Figure 8), the two ray ground and free space have shown better performance in respect to average packet drop. The distance based performance has been recorded using four sequences for distance that are completely in meters, in which the starting point is 0 and the last point or maximum value is 40 meters. At 0 or initial point both have values in 0 but when the simulation starts, then at distance 10 m the value of two ray ground is 207, whereas the value of free space is 387 at that point. Forwarding to the next level (i.e., increasing in the distance from 10 m to 20 m) the value of two ray ground is 352 and free space is 607. Similarly, at distance 40 m the value of two ray ground is 350 and free space is 200. These recorded values are the packet drop in which the maximum size of the packet is 1000 bytes in which the two ray ground has shown better performance as compared to free space but especially after the overall average value is better. The main reason is that the signal propagates and can pave long distance in two ray ground models that doesn't need clear LOS. But free space purely focuses on the clear LOS, that is why the signal can't travel in large distances in this scenario and that is why it has shown poor performance in contrast with the two ray ground. At the last point during simulation the free space has given the best performance in which it has dropped fewer amounts of packets but, by combining the results and taking into consideration the average level, the two ray ground models have achieved better results.

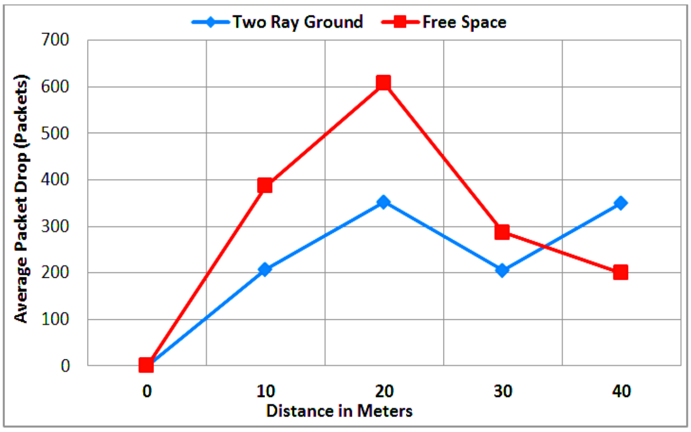

Figure 8. Average Packet Drop of two ray ground and free space

d. Compiled average results

The given Table 2 illustrates the compiled results of the proposed approach with respect to average packet drop, average latency and average throughput. The overall best performance has been shown by two ray ground propagation models in the proposed work. The key and major factor is the signal propagation by two approaches, one direct LoS and the other reflected signal using an obstacle in which the angle of incident and angle of reflection remain the same at the same height.

Table 2. Compiled Average Results

Model Name	Average Throughput	Average Latency	Average Packet Drop
Two-Ray Ground	87.25	0.45	278.5
Free-Space	80.5	0.65	370.25

The values of Table 2 are illustrated in the following Figures separately (Figure 9) in which the mentioned evaluation metrics are shown differently. By taking the average evaluation of the simulation, results of the two ray ground have shown outstanding performance as compared to the free space model. Free space model has also shown best result in other points. This evaluation concluded that two ray ground model can achieve better performance as compared to free space model. The main reason is that two ray ground signal can travel in both LOS and N-LOS, in which it uses the two way ground reflection mechanism to calculate the signal strength.

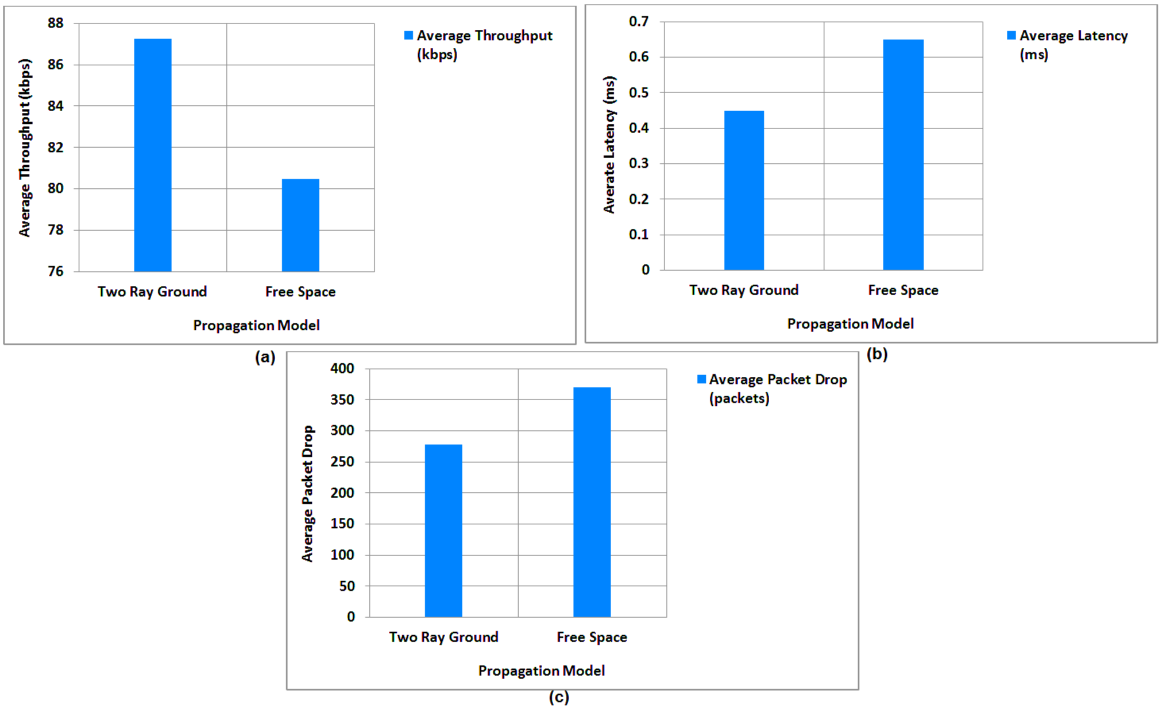

Figure 9. (a) Average Throughput, (b) Average Latency, and (c) Average Packet Drop

5. Conclusion

MANET is a network in which the nodes are mobile in nature and freely communicate with each other without having any centralised infrastructure. This is an ad-hoc network which is a temporary designed network in places where there are required specific and temporary tasks. The nodes of MANET are equipped with a tiny batter as well as a radio antenna to transmit and receive the signal (i.e., to propagate the signal in the network's range. Whenever the distance increases in this network it ultimately affects the performance of the propagation models within the nodes). In this paper, the performance evaluation of two radio wave propagation models have been proposed via distance based scenario. The simulations have been performed using NS-2 for the proposed research work. The results have concluded that distance has a strong impact on the performance of free space and two ray ground radio wave propagation models. The performance metrics that were takien into considerations are average latency, average packet drop and average throughput. With the help of AODV, MANET's existing routing protocol has been taken as a major protocol for the proposed work. It has been concluded that distance has a strong impact on the performance of two ray ground and free space in considered scenarios. By combining the results, two ray ground values of average throughput has been recorded 87.25 kbps whereas the free space average throughput value has been recorded 80.5 kbps. Similarly, the average latency of two ray ground has been recorded 0.45 ms whereas free space has been recorded 0.65ms and average packet drop (packets) of two ray ground has been recorded 278.5 packets, whereas free space's packet drop has been recorded 370.25 packets, respectively.

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