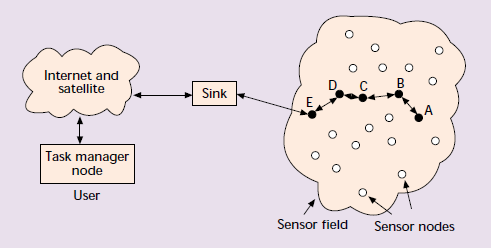
**MEASUREMENT-BASED CHANNEL MODELING FOR 2.6 GHZ INDOOR RADIO PROPAGATION IN WIRELESS SENSOR NETWORK**

The radio propagation in indoor environment is introduced in this paper. Modelling the channel as a linear time-varying filter at each location using three-dimensional space are implemented in indoor channel propagation. The spatial and temporal variations of the channel, large scale path losses, mean excess delay and RMS delay spread are explored in the propagation methods. The signal transmitted from the base reaches the portable radio receivers through one or more main waves. The main waves consist of a line-of-sight (LOS) ray in the indoor propagation channel. The several rays are scattered or reflected by the main structures such as floors, ceilings and outer walls, etc. The noise and co-channel interference are the unwanted random effects after received signal. The multipath fading degrades the performance of communication systems operating inside buildings. The modelling of the arrival-time sequence has not received adequate attention in propagation channel. The temporal and spatial correlations among the path variables have not been fully addressed. A simplified mathematical analysis based on standard assumption was used in the mobile channel. The receiver configuration, including RAKE signal was based on standard and reasonable assumptions. A realistic simulation using an elaborate channel simulator was used in mobile channel [70].

The Wireless Sensor Networks (WSN) are one of the growing technologies, which draw a huge attraction because of its wide range of applications in the field of healthcare, habitat monitoring, traffic surveillance, military applications, home automation, industrial automation, etc. The RSSI based Indoor Localization with interference avoidance for wireless sensor networks using anchor node is implemented in this work. The range free and range based are localization techniques used in Wireless sensor networks. The location of sensor node is estimated based on the network connectivity in range free techniques. The range free techniques include approximation point-in-triangulation test (APIT), centroid, amorphous localization and DV-hop. The range based techniques are more accurate in comparison to range free techniques. The range based localization techniques includes Time of Arrival (TOA), Angle of Arrival (AOA), Time Difference of Arrival (TDOA) and Received Signal Strength Indicator (RSSI) in the indoor propagation channel. The log-distance path loss model and convenient calibration techniques are used to minimize localization error in frequency channel. The localization accuracy can be improved by using a number of sectors with a reduced beam width [71].

In WSN, a large number of sensor nodes are distributed as tags, routers and gateways perform certain functions like data collection, data transmission and data storage respectively.   
A large number of wireless nodes communicating in the same frequency range results in signal crossovers. The use of less number of routers reduces the system reliability due to failure of a single router. The optimum number of nodes needs to be chosen in the network to overcome the effects of interference. The optimum number of nodes reduces the number of Radio-frequency communicating devices. The Cultural Algorithm (CA) based optimization techniques are employed to reduce interference and energy loss in the network. The hardware model has been implemented from an AC source and DC source in propagation channel. The CA is an evolutionary algorithm used for solving numerical function optimization problems in sensor networks [72].

The recent advances in wireless communications and electronics have allowed the development of low-power, low-cost and multifunctional sensor nodes. The sensor networks can be used in enormous applications such as in military, health and home. The sensor nodes are usually distributed in a sensor field. The scattered sensor nodes have the abilities to gather data and route data back to the sink. The design of the sensor networks is described in Fig.3.1 The various factors, including fault tolerance, production costs, operating environment, scalability, operating environment, hardware constraints, sensor network topology and power consumption are used in sensor networks [73].



**Fig.3.1** Scattering of sensor nodes in sensor field.

The WSNs are networks of distributed autonomous devices, which can sense or monitor the physical environment. The computational intelligence (CI) has been used in recent years to address various challenges in data aggregation and other parameters such as fusion, energy aware routing, security, optimal deployment, localization and task scheduling, etc. The CI provides adaptive mechanisms, which exhibits intelligent behavior in complex and dynamic environments. The CI brings about autonomous behavior, flexibility and robustness against topology changes, scenario changes and communication failures. The nodes in the most of the WSNs have limited energy. A topology of sensor nodes and a limited number of powerful base stations are basic scenario in sensor networks. In order to ensure sustained long-term sensing operation, the communication tasks need to be exercised frugally. The data is distributed throughout the nodes in the networks. The sensor nodes need to be placed accurately at predetermined locations. The location awareness in all deployed sensors is done using node localization. The location information is used to detect and record events using geometric-aware routing. The time-of-arrival of signals from multiple based stations are detected using localization methods in WSNs [74].

**3.1 Analysis of Fading channels**

The fading statistics of the propagation channels among sensor nodes are essential to determine the possible outage, data rate, and latency of the sensor networks. The main objective of the sensor network is to sense and gather the information from the surrounding environment and transmit the collected information to a nearby sink either directly or through the intermediate nodes. However, these networks face diverse channel conditions among the nodes. The network essentially gathers information related to the surrounding environment. The sensor ranging from security surveillance, inventory management to telemedicine sensors for advanced health care services. The capacity, latency and energy consumption are essentially influenced by the statistics of the propagation channels between the sensor nodes. The measurement frequency of fading statistics is 2.6 GHz. The 2.45 GHz ISM band yield similar propagation characteristics. The large-scale variations of Rx power, show that the path-loss exponent are close to the propagation channel. The large-scale fading is very similar to the three antenna height. The regression parameters for a cubic fit to our measured K-factors are implemented in this paper. The spatial selectivity of the channel is used to characterize the auto-covariance of the envelope. The communication between nodes in a cluster cannot occur with complete reliability. In order to arrive at realistic evaluations of the diversity/multiplexing trade-off in an ad-hoc network. The rate of decay is parameterized by the path-loss exponent [75].

The distributed sparse random projections in wireless compressive sensing over fading channels are implemented in this paper. To reduce the communication burden for wireless compressive sensing (WCS), the sparse random matrices are introduced. The communication channels between sensor nodes and the fusion centre undergo fading effects. The probability of sensor transmissions at each node is based on the channel fading statistics to minimize the number of measurements collected at the fusion centre. The wireless compressive sensing (WCS) poses the necessity to measure the channel between the sensor nodes. Therefore, the performance of the sensor networks such as, capacity, reliability, energy consumption and latency is influenced by the statistics in the propagation channel. Hence, the fading statistics between the sensor nodes is essential to achieve a certain outage probability and for the optimum placement of sensor nodes. The channel undergoes independent and non-identical fading for designing the probabilities of transmission at each node [76].

The wireless body network (WBAN) is a specific type of wearable system, where a number of radio devices from a self-contained network on the human body. The local environment plays an important role in the performance of radio and communications systems. The influence of user state and environment of fading characteristics at 2.45 GHz in wireless body area networks is investigated in this paper. The signal fading consists of a number of strategically placed body-worn receivers, which is operating at 2.45 GHz in a wireless body area network. The user state and local environment play an important role in the determination of on-body propagation characteristic. The time-varying on-body EM filed pattern becomes interrupted at a much faster rate due to the user’s movement. At each location on the user’s body is experienced with an instantaneous field strength. The measurement environment, experimental procedure and on-body measurement system is analyzed in this paper. The random scattered component generated by the body is further enhanced by the environmental multipath. The reflection, diffraction, scattering and absorption are depending upon the user state and transmission path length. Due to the user’s movement, the time-varying on-body EM field pattern becomes interrupted at a much faster rate. The Diffraction, reflection, scattering and absorption become responsible for varying degree depending on the user state and transmission path length. The average straight line velocity for each of the mobile sessions was estimated by using 1.0 ms-1 distance. The path loss distribution was well described by the lognormal distribution in wireless body area networks [77].

The spatial diversity gains inherent in multiuser wireless systems by using Cooperative communications have been proposed in this paper. The advantage of cooperation can be further exploited by optimal allocation of the energy and bandwidth resources. The sensor and wireless mesh networks have an increasing demand for low and small cost devices, which are densely deployed over a wide area in emerging wireless applications. To maximize the system performance under the respective resource constraints, many research efforts have been implemented. The users share and coordinate their resource to enhance the transmission quality in the spatial diversity. The number of nodes in the networks increases exponentially with the complexity of the optimal power allocation in the networks. Hence, the complexity of the optimal schemes increases exponentially with the number of nodes in the networks. The spatial sampling employs the selective relaying (SR) techniques in the cooperative communication [78].

The organization of nodes in wireless sensor networks (WSNs) arises as one of the biggest challenges in distributing a large number of embedded systems to fulfil a specific application. Nowadays, the characterization of the propagation channel has gained interest in the indoor environment. In the wireless indoor environment, complexity is due to the interaction of the signals transmitted through the channel with the environment. In addition, the reflections from large structures such as walls and ceilings, diffraction of the waves around objects, and signal scattering contributes to complexity. As a consequence of these complex interactions, there is a presence of multipath signals (presence of many signal components) at the receiving end. The Doppler shift is an another challenging property of wireless channels that causes due to the motion of the receiver, the transmitter, and any moving objects in the channel. The accurate Radio Frequency (RF) propagation simulation plays an important role for the pre-deployment phase and for the performance evaluation in WSNs. The 3D radio propagation simulation method for indoor ZigBee has been presented in this paper. The ray tracing method performs more robustly and accurately than other propagation methods [79].

The bit error rates (BERs) with Rayleigh fading for differential phase shift keying (DPSK) and quadrature amplitude modulation (QAM) are established corresponding to realize the effect of Rayleigh fading. Moreover, indoor applications suffer from path-loss, reflection, diffraction and scattering than the outdoor applications [80].

A Directional transmission and reception using multiple-i/p-o/p (MIMO) technologies allows spatial multiplexing in a wireless network. The multipath propagations in radio channels usually result in the angular spread of the signal power. The random movement of the nodes results in the angular power spectral density (APSD) of the indoor channels. The packet-level channel model can be suitably incorporated into analytical frameworks and fast simulations of upper-layer network protocols [81].

The measurement campaign within 3.1-8.5 GHz using a new UWB systems with spatial in-body Channel Characterization is proposed in this work. The new path loss models are obtained from two methods such as, in-body to in-body (IB2IB) and in-body to on-body (IB2OB) scenarios are considered. The effects of the heterogeneity of the human tissues is checked using UWB channel characterization [82].

The multiple transmitters and receivers can be used to provide high link capacity. The effect of intra-element spacing on the channel capacity is studied and measured in this paper. The narrowband model for the obstructed-line-of-sight (OLOS) and indoor MIMO channel is completely based on this covariance structure in this work. In future wireless local-area networks, the terminal and access points are being considered at both the terminal and access points. Hence, it is necessary to model the channel accurately to handle the path loss effects and power attenuation in the network [83].

A measurement-based spatio-temporal statistical channel model for short-range millimeter-wave links at 60 and 70 GHz is presented in this work. The novel propagation channel model for large indoor open halls are analysed. The angular-delay domain representations of the specular and diffuse paths present in the statistical channel model. The channel propagation characteristics for WSNs are measured in indoor residence and office environments to address the existing problems of channel propagation model [84].

The indoor radio frequency signal propagation at 2.4GHz ISM band (Industrial, Medical and scientific) supported by using propagation models. The electromagnetic wave propagation in the space can theoretically obtain the solution of Maxwell’s equation. However, extensive measurement in channel modelling is important for the design and performance evaluation of the wireless communication systems [85].

A new empirical model for indoor propagation prediction is presented in this paper. The empirical models for indoor propagation prediction are used to improve accuracy over conventional empirical models. Normally, experimentation is done to characterize the channel. The Statistical model and propagation study is used to determine the radio channel characterization, when the specific knowledge of the signal propagation and their channel characteristics are unknown [86].

The fading characteristics of channel propagation are tested and fitted with a third-order polynomial log-distance path-loss model. The most suitable parameters are used to estimate the position of the target node. The implemented algorithm improves the average localization accuracy of about 75%. The most suitable parameters are used to estimate the position of the target node in locating phase [87].

The penetration losses measurement for regular building at 2.6 GHz Long Term Evolution (LTE) cellular communication is presented in this work. The aim of the work is to estimate the performance of radio channel penetration at 2.6 GHz in the indoor office building environment. The penetration of radio channel at 2.6 GHz is used in the interior of the building [88].

The Goodness-of-fit test apply to the data sets obtained from the indoor environment. The Rice/Rayleigh description of fading was applied to the indoor environments. The specific goodness-of-fit tests are applied to the data. There is no limitation imposed on the number and the parameters of the signals. It was found that this test provided accurate approximations under all situations, when the signal and the interferers were distributed. The range of applicability for three accurate approximations was tabulated in this paper. The improved analysis of local narrow-band path-loss data at Digital enhanced cordless telecommunications (DECT) is carried out by applying specific goodness-of-fit tests [89].

The validity of the conventional Gaussian approximation depends on the time-bandwidth product. The performance of TR signaling in conjunction with a simple AcR in dense multipath Ultra-band channels is proposed in this paper. The multipath fading seriously degrades the performance of communication systems inside buildings and it is the results of signal interference among several delayed replicas of a transmitted signal [90].

The UWB communications based on fading margin in ultra wideband communications over Multipath Channels is designed in this paper. The fading margin and the transmitter-receiver separation distance for both the line of sight and no line of sight scenarios are analysed with indoor multipath channels [91].

The multipath components of any transmitter-receiver pair in the indoor power-line environment is presented in this paper. The result of signal interference among several delayed replicas of a transmitted signal using multipath fading is analysed. The varying channel behaviour of different load impedances can be explained [92].

**3.2 Channel modelling**

The propagation involves the transmissions of signals by the transmitter which propagates through a medium and finally received through the receiver. The signals are attenuated due to diffraction, reflection and scattering as a result of some obstacles or interferences. The feature of the wireless transmission channel does not fully meet the properties of the transmission media as this channel is highly sensitive to interferences produced by the obstacles, communication distance and noise, etc. All these effects are because of the change in the position of the transceiver and the fluctuation in the environmental conditions. The transmitted signal generally reaches the receiver through different paths and may experience propagation mechanisms such as transmission, scattering, reflection and diffraction along the paths. The diffraction occurs when there is no line of sight for a signal between the transmitter antenna and the receiver antenna. The signal acquires non-zero strength as a result of this diffraction. The scattering of waves is due to the presence of rough surfaces and small objects in the transmission channel area. The signal level at the receiver antenna is different from the prediction made by the models that take into account the path-loss, diffraction and reflection because of the signal scattering. The degree of the impact depends on the wavelength of the signal and the surrounding circumstances. Another major influence of the wireless channel on the receiver signal is the attenuation of the receiver signal with respect to the transmitted signal. The receiver power is influenced by a product of the three factors; path-loss, large-scale fading and small-scale fading.

## **Path loss**

The Path loss represents the attenuation of the received signal as the function of the distance between the TX and the Rx. It is the major component in the analysis and design of the link budget of a telecommunication system. Conventionally, path loss tends to increase with distance. Alternatively, path loss can be expressed as an average path power gain,, that has a power law decay in the distance,

****  (3.1)

Where  is the Transmitter-Receiver distance, at the reference distance (usually assumed 1 m) and n is called the propagation exponent, where r is the radius.

## **Large-scale fading**

The large-scale fading is the result of signal attenuation due to signal propagation over large distances and diffraction around large objects in the propagation path. The Large-scale fading is defined as random variations of locally averaged receiver power. The fading is observed when Interacting Objects (IOs) such as, buildings or terrain, block the line-of-Sight (LOS) or other dominant multipath components.

## **Small-scale fading**

The small scale fading is due to the presence of reflectors and scatters because multiple copies of the transmitted signal arrive at the receiver with different attenuations and time-delay of arrival. The copies are often termed as Multi-Path Components (MPCs). The small-scale fading refers to random fluctuation of the receiving signal caused by an interference pattern of these MPCs. The pattern may change in space due to the motion of the receiver or in time due to the motion of the transmitter or scattered. The Time variant Channel impulse response is written as

 (3.2)

Where, r= and δ (·) is the delta Dirac function, l is the number of MPCs. β is Propagation constant.

**3.3 Measurement set up**

The need for the transmission of voice and data within network place is increasing in Indoor Radio communication. The interference environment and the fading effects are the two different aspects of indoor radio. Indoor channel is divided into three classes that includes cordless telephone systems, in building cellular system and local area networks. The variation of the environment is much greater for smaller range of transmission. The distance between the transmitter and the receiver is very small in the indoor channel propagation. The propagation within the building is influenced by specific parameters such as layout of building, construction material and building type. In addition, there is a noticeable growth in the use of hand-portable equipment like transceivers. Hence, telephone companies show great interest towards the indoor propagation and provide indoor wireless communication to the customers.

The statistical data provide the basis to model the indoor propagation channel. These statistical data are used to form an accurate channel modelling which is analysed by using the simulation model. The simulator provides the experimental results in a well-defined fashion and it’s a platform to execute the performance of the network. The WSN is simulated using the Network Simulator tool. The development of the WSN in the simulator involves the following steps and the steps are represented in the flowchart. Fig. 3.2 represents the flowchart for the indoor scenario creation.

Antenna Nodal deployment

Localization of the antenna nodes

Measurement Range

Fading analysis

Performance parameters are characterized using the simulation graph

Mention the antenna height

**Fig 3.2** Flow chart for Indoor scenario creation in Network Simulator

***Step 1: Nodal deployment:***

The sensor nodes are the end elements. For better compilation and analysis, each node is provided with multiple types of sensor and they are assumed to have multiple capabilities. These nodes provide the real time coverage and they store detected events and finally transmit them in bulk. Therefore, proper nodal deployment is necessary and it is the first step involved in the characterization. There are some localized nodes and a master node that is connected to the computer and un-localized nodes to be located in nodal deployment. The localized nodes are responsible for receiving and sending the data packets. The master node receives the information sent by the fixed nodes, and then transmits them to the computer for building the model parameter table and locating the target node. In this paper, 18 nodes are located and clustered. The clustering involves grouping nodes into clusters and electing a cluster head i.e. the data transmission occurs from members of a cluster base station through another cluster heads. Thus, the collection of cluster heads in the network form a connected dominating set.

***Step 2: Localization of the antenna nodes:***

The localization enables us to determine the location of sensor nodes in the wireless sensor networks through communication between the localized node and the un-localized node for determining their geometrical placement or position. The location of nodes is determined through the distance and angle between nodes. To measure the position of the nodes the Channel Sounders are used. The channel sounders are placed outside the area. The measurement is carried out and the antennas are fixed at the wall to avoid free movement that causes fading.

***Step 3: Measurement Range****:*

The center frequency range is taken as 2.6 GHz having a signal bandwidth of 200 MHz. It comprises of 321 subcarriers. The time delay between two successive signal transmissions is 1.6 μs. The propagation channel is measured at the regular spatial intervals of. To enhance the SNR through coherent averaging, a set of ten shots are recorded at each spatial positions.

***Step 4: Mention the antenna height:***

The measurement is carried out for different combinations of Rx and nominal TX antenna heights. Four different combinations of Rx and nominal TX antenna heights are used. The Rx combinations (positions) include rx1, rx6 and rx10 whereas the TX combinations used are tx1, tx5, tx6 and tx10 respectively. Among these combinations, tx1 corresponds to rx1, tx2 is equal to rx2 and so on. Tx5 is placed 5mts above tx1 on the left side of the wall whereas tx10 is placed 5mts above TX 6 are fixed on the right side of the wall at a height of 20 and 25 cms respectively. TX’s are fixed at a place where in the corresponding RX move towards them from the starting point. Consider that TX is placed on tx1 then the measurement run initiated from rx1 implies same-wall measurement and the measurement run from rx6 implies opposite wall measurements.

Therefore, same-wall measurement refers to the measurement run where the start position is referred as opposite wall measurements. The antenna rotates to 90 degrees in the vertical-plane perpendicular to the wall to obtain uniform elevation pattern. The equal antenna height is employed for analysis. The equal antenna heights are employed for analysis. That is if both the TX and Rx antenna are placed at a distance of 20 cm above the floor, then the configuration is termed as TX20RX20. Similarly, TX60RX60 and TX100RX100 configuration are used. For each of the above configurations, 200 measurement run is obtained with two Rx start positions and two TX heights. Among the 200 measurement runs, 100 same and opposite-walls are present. The set of measurement runs with the uniform pattern for the fading analysis.

***Step 5: Fading analysis:***

The Fading analysis is done using Ricean distribution. The Ricean model is the best method to analyses the distribution of the small scale fading amplitude since it is valid for different antenna heights in the same and opposite wall scenarios. In addition, Ricean distribution is often used to model the propagation path consisting of one strong direct LOS component and many random weaker components. The Ricean K-factor is used to measure small-scale variations during the computation and at the end of the computation. The Rice factor is a log normally distributes random variable with distance –dependent parameters. In addition, theoretical studies of the communicating sensor nodes pose certain assumptions on the propagation channels between the nodes. It is evident from the study that the rice factor increases as the distance between the tx and rx decreases, and eventually reach very high value for small separations.  is deﬁned as the power ratio between the deterministic and diffuse components of the channel. can be estimated for all the measurement runs. The logarithmic samples are distributed log normally N (μdB, σdB). The variation of  for the varying measurement run can be explained by a mixture model, which is given by

 (3.3)

Where, N is the log normal distribution.

- mean of the logarithmic rice factor

– Standard deviation

α – mixture weight

The Log normal distribution, mean of the logarithmic rice factor, standard deviation and mixture weight are the parameters of tx-rx separation. These parameters depend on the distance between the tx and the midpoint of the small scale amplitude that is the link distance. Value can be obtained from (3.1) for all measurement runs. It is well known that there is an increment in the rice factor when the distance between tx-rx decreases. Moreover, the co-variance of the  value is investigated for all the measurement run. Analysis reveals that for all antenna heights the  covariance value is around 0.5.

***Step 6: Performance parameters are characterized using the simulation graph:***

The analysis of performance parameters done through the simulation. Simulation is carried out using the simulation network tool. It analyse the performance factors such as SNR, co-variance, cumulative probability for varying antenna heights. The auto co-variance of the envelope is commonly used to characterize the spatial selectivity of the channel. The Signal-to-Noise Ratio (SNR) is the measure of the desired signal to the level of background noise and it is measured at the output side of the receiver.

**Implementation steps:**

It is possible to model the radio channel with the required parameters. The proposed method to model the channel is greatly helpful to investigate SNR and analyse the interference of signals in the indoor environment. The steps for channel modelling is given below.

***Nodal deployment:***

The nodes are deployed in the small scale area, which are separated from each other. The uniform random distribution is obtained for the nodes from the measurement run values and it is represented as m. If the mixture weight is greater than m, then calculate the *KRice* value otherwise *KRice  =0.* , is used as the metric to determine the small-scale envelope distribution.

Therefore, can be estimated for all the measurement runs. In Ricean distribution, the logarithmic samples are distributed log normally .The variation of  for the varying measurement run can be explained by a mixture model, which is given by equation (3.3). The values of parameters in the above expression can be obtained from table 3.1 and 3.2

respectively.

**Table 3.1** represents K factor mixture model – same wall

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Antenna |  | | | |  |  | |
| Tx20Rx20 | 0.79 | -6.41 | 12.06 | -1.58 | 3.75 | -0.13 | 1.25 |
| Tx60Rx60 | -1.72 | 18.62 | -67.55 | 81.64 | 4.47 | -0.11 | 1.12 |
| Tx100Rx100 | -1.40 | 15.13 | -54.8 | 66.72 | 4.14 | -0.02 | 0.85 |

**Table 3.2** represents K factor mixture model – opposite wall

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Antenna |  | | | |  |  | |
| Tx20Rx20 | 1.23 | -9.52 | 20.64 | -8.17 | 3.84 | -0.05 | 1.05 |
| Tx60Rx60 | -0.84 | 5.80 | -14.6 | 14.68 | 3.61 | -0.06 | 1.04 |
| Tx100Rx100 | -0.43 | 3.57 | -10.09 | 10.66 | 4.80 | -0.04 | 0.98 |

***SSSF sequence generation:*** Theuniform distribution is generated that holds all the sequences. The small scale samples are obtained from those sequences.

***SLSF sequence generation:***From the obtained sequences that is from the distribution, large scale samples are generated and it is represented as co-related lognormal random variable and is given by,

 (3.4)

***Calculation of S:***The small scale fading and large scale fading obtained from the previous step is integrated to form a third variable called as S. S as the combination of SSF and LSF are expressed as,

 (3.5)

***Calculation of performance parameters:***

***Total path gain:***Total path gain is obtained through multiplying the distance dependent path gain with the S sequence. Therefore, the total path gain is expressed as

 (3.6)

***Co-variance:***  is deﬁned as the power ratio between the deterministic and diffuse components of the channel. Co-variance can be calculated from the below formula,

** (3.7)

Where,  is the total path Gain.

The node sends 1000 packets and therefore the total path gain is divided by 1000.

***Cumulative Probability:***Cumulative probability is defined as the probability that the instantaneous error probability exceeds a specific value or equivalently that the probability that the output of SNR falls below a specific threshold. Cumulative probability is obtained by multiplying the co-variance with two. It is given below,

 (3.8)

***Signal-to-Noise Ratio (SNR):***SNR is the measure of the desired signal when compared to the noise signal.

** (3.9)

Improvement in SNR is achieved to extra 10 Db through coherent averaging of complex channel gains.

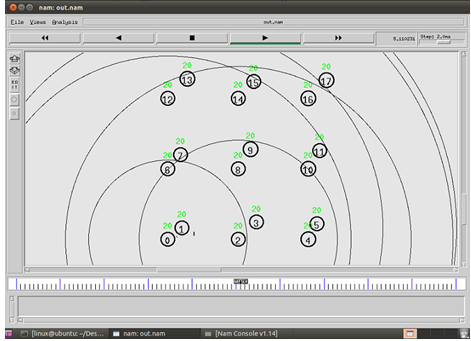
***Throughput:***Throughput is the maximum rate of production or the maximum rate at which the signal is processed.

 (3.10)

Where, is the total path Gain.

**3.4 Results and analysis**

The Network consoles window executes NAM visualization window, which helps in visualizing node placement and packet transmission and queue type. This window visualizes the distribution of nodes in the network. The packet transmission in NAM window is visualized as shown in Fig 3.3. The simulation is carried out in the network simulator that predicts the performance of the network accurately.



**Fig 3.3**. Network console window

The parameters used in the simulation are distance dependent and the antenna used for the collection of data are of equal height. The graphical representation of the obtained statistical data is done using the GNU plot in NS2. The performance parameters used in the comparison include the cumulative probability, average covariance, average SNR, and the throughput.

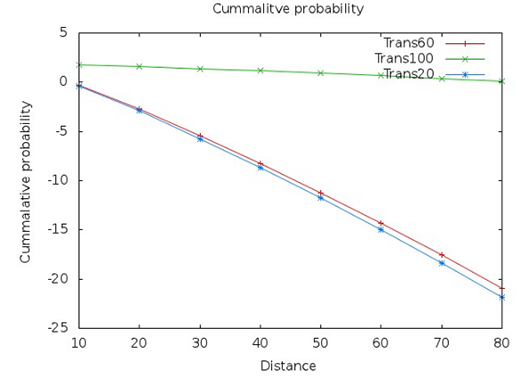
***Cumulative Probability:***

The cumulative distribution value for the three antenna height combinations is shown in table 3. The distance and the cumulative probability of each antenna height are compared initially. When the distance between the nodes is 10, the cumulative probability is -0.42. The distance between the nodes is 20, the cumulative probability is -2.85 and when the nodal distance is 60, the cumulative probability is -14.93. From this it is understood that in TX20RX20, the distance between the nodes increases, then the cumulative probability decreases and the negativity decreases. The antenna height 60 (TX60RX60), the distance between the nodes and the cumulative probabilities are compared. The cumulative probability is 1.61, when the distance is 20. The nodal distance is 30, 40, 50 then the cumulative probability is 1, 37, 1.15, and 0.91 respectively. When the nodal distance increases the value of cumulative probability is decreasing. The cumulative probability takes a positive value when compared to the other antenna heights.

**Table 3.3** shows Cumulative probability values for different antenna height configuration

|  |  |  |  |
| --- | --- | --- | --- |
| Distance between nodes | TX20RX20 | TX60RX60 | TX100RX100 |
| 10 | -0.42 | -0.32 | 1.79 |
| 20 | -2.85 | -2.67 | 1.61 |
| 30 | -5.77 | -5.47 | 1.37 |
| 40 | -8.66 | -8.27 | 1.15 |
| 50 | -11.75 | -11.22 | 0.91 |
| 60 | -14.93 | -14.29 | 0.66 |
| 70 | -18.34 | -17.57 | 0.39 |
| 80 | -21.80 | -20.90 | 0.12 |

The cumulative probability for the three antenna heights is obtained and the comparison is made in terms of antenna heights and cumulative probability. Refer table 3. The cumulative probability for the antenna heights 20, 60 and 100 are -0.42, -0.32 and 1.79 respectively, when the nodal distance is 10. The cumulative probability for the three antenna combinations are -5.77, -5.47 and 1.37 respectively, when the nodal distance is 30. When the nodal distance is 40, the cumulative probability for three antenna combinations include -8.66, -8.27 and 1.15 respectively. For the nodal distance 50, the cumulative probability for the antenna combinations tx20rx20, tx60rx60 and tx100rx100 are -11.75, -11.22 and 0.91 respectively. Similarly, for the distances 60, 70 and 80 the cumulative probability obtained is increasing. Hence, it is well understood from the above discussion that the cumulative probability increases with antenna heights. The value corresponding to tx20rx20 and tx60rx60 are negative, whereas tx100rx100 takes the positive value of cumulative probability that is tx100rx100 is better compared to other antenna heights. The negativity reduces with the increasing antenna heights. Hence, the cumulative probability decreases as distance increases and as the antenna height increases the cumulative probability also increases.



**Fig.3.4** Cumulative probability curve

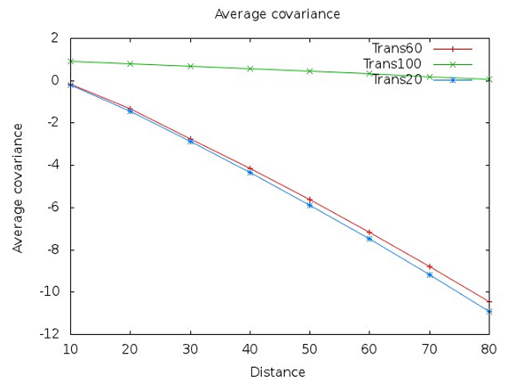
The results tabulated above are represented in the GNU plot shown in Fig 3.4. The graph clearly shows the variation of cumulative probability with distance and it also provides a clear view of the cumulative probability for the antenna heights. The cumulative probabilities corresponding to the distance is plotted. The value of cumulative probability tends to decrease with increasing values of distance. The distance increases when the negativity increases. The cumulative probability for the antenna height tx60rx60 is analysed for various distances. It is found that the value of cumulative probability decreases as the distance between the nodes increases. The antennas tx20rx60 is better compared to tx20rx20. The cumulative probability with respect to distance is analysed for the antenna height tx100rx100. It is less negative when compared to the other two antenna heights. It is less negative when compared to the other two antenna heights. The performance of antenna tx100rx100 is truly better when compared with the antennas tx20rx20 and tx60rx60. That is the value of cumulative probability takes positive values when antenna height increases. This rise can be clearly viewed in the graph, which is shown in Fig 3.4.

***Average Covariance:***

The comparison of the distance between the nodes for varying antenna height is done. Initially, the height of the antenna is taken as 20(TX20RX20). The average covariance is found to be -0.21, when the distance between the nodes is 10. The average covariance is found to be -0.21 whereas for the nodal distance 20, the average covariance is -1.42. Similarly, for the distances 30, 40, 50, 60, 70 and 80, the average covariance obtained is found to be -2.88, -2.88, -4.34, -5.87, -7.46, -9.17 and -10.45 respectively. The average covariance decreases gradually with the increase in the nodal distance. The distance of the nodes and the average covariance is compared when the height of the antenna is taken as 60 (TX60RX60). The average covariance is -0.61 when the distance of the nodes is 10. The cumulative probability obtained is -1.33 for the nodal distance 20. And for the nodal distances 30, 40, 50 the average covariance is found to be 2.73, -4.13 and -5.61 respectively. The average covariance values decrease when the distance between the nodes increases. The average covariance is 0.89 and the covariance is 0.80. The average covariance value is 0.57, 0.4 and 0.33 respectively, for the antenna heights 40, 50, 60. The average covariance value decreases gradually when nodal distance increase. The comparison of the average covariance with the antenna height is necessary and it is evident. The average covariance increase gradually with the antenna height. For the nodal distance 10, the average covariance for antenna heights 20, 60 and 100 are -0.21, -0.16 and 0.89 respectively. Similarly, for the nodal distance 20, the average covariance for the three antenna combinations are -1.42, -1.33 and 0.80 respectively. When the nodal distance is 30, the average covariance for the antenna heights tx20rx20, tx60rx60 and tx100rx100 are -2.88, -2.73 and 0.68 respectively. The average covariance for the three antenna heights when the distance between the nodes is 40 are -4.34, -4.13 and 0.57 respectively. Similarly, the average covariance for the nodal distances 50, 60, 70 and 80 are noted and it is found that the average covariance increases from the negative value to positive value. From this, it is concluded that when the antenna height increases the average covariance also increases. The comparison of distance with the antenna height proves that as the distance increases the average covariance decreases and becomes more negative. However, the comparison among the antenna heights proves that the average covariance value increases and takes the positive value. Table 4 shows the covariance values for the varying distance of nodes and for the three antenna combination.

**Table 3.4** Average covariance values for different antenna height configuration.

|  |  |  |  |
| --- | --- | --- | --- |
| Distance between nodes | TX20RX20 | TX60RX60 | TX100RX100 |
| 10 | -0.21 | -0.16 | 0.89 |
| 20 | -1.42 | -1.33 | 0.80 |
| 30 | -2.88 | -2.73 | 0.68 |
| 40 | -4.34 | -4.13 | 0.57 |
| 50 | -5.87 | -5.61 | 0.45 |
| 60 | -7.46 | -7.14 | 0.33 |
| 70 | -9.17 | -8.78 | 0.19 |
| 80 | -10.45 | -10.45 | 0.06 |



**Fig.3.5.**Average covariance GNU Plot

The clear view of the variation of average covariance with respect to distance is plotted in the GNU plot. Fig 3.5 shows the value of covariance for different nodal distance and the antenna heights. The value of covariance for different nodal distance and the antenna heights is shown in Fig. 3.5 . The value of the covariance is compared to the distance. In tx20rx20 is found that the value of the covariance decrease from 0.87 to 0.06. The value of average covariance decreases, when the distance between the nodes increases. Now the comparison between the three antenna heights in terms of average covariance is done. From this comparison, it is evident that the value of covariance increases as the antenna height increases. For increasing antenna height, average covariance value increases. But the value is negative in tx20rx20 and tx60rx60 antenna height, whereas for tx100rx100 average covariance value is positive. However, the average covariance decreases as the distance between the nodes increases and increases when antenna height increases. Thus, the average covariance value is better for the antenna tx100rx100 when compared to the other antennas tx20rx20 and tx60rx60.

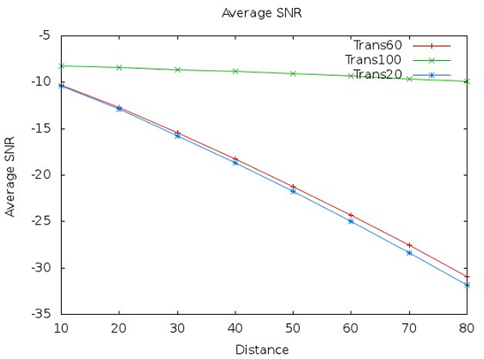
***Average SNR:***

The values of the average SNR and the distance between the nodes is shown in Table 5. The distance between the individual antennas are compared with the average covariance for various heights of antennas. The value of average SNR for different nodal distance is obtained from the nodal height 10. The average SNR obtained is -10.42 and it is -12.85 for the nodal distance 20.

For the antenna height 60 (tx60rx60), the average SNR for varying nodal distance is compared. When the nodal distance is 10, the average SNR obtained is -10.32 and for the nodal distance 20, it is -12.67. The average SNR obtained is -18.27, -24.29 and -30.90 for the nodal distances 40, 60, 80. This makes it clear that as the distance between the nodes increases the average SNR value also increases. Comparison of nodal distance and the average SNR is done for the antenna height 100 (tx100rx100). For the nodal distance 10, the average SNR value obtained is -8.20. The average SNR value is -8.38 for the nodal distance 20. Similarly, the average SNR value for the nodal distances 40, 50, 60 and 80 are -8.84, -9.08, -9.33 and -9.87 respectively. Thus, average SNR increases with increasing nodal distance. The comparison of the average SNR for the antenna heights 20 (TX20RX20), 60 (tx20rx20), 60 (tx60rx60) and 100(tx100rx100) is done. The values of average SNR for the antenna heights 10, 60 and 100 are -10.42, -10.32 and -8.20 respectively for the nodal distance 10. The average SNR values for these heights tx20rx20, tx60rx60 and tx100rx100 are -15.77, -15.47 and -8.62 respectively. The average SNR value is -18.68, -18.27 and -8.84 for the antenna heights tx20rx20, tx60rx60 and tx100rx100 when the nodal distance 40. When the nodal distance is 50, the average SNR values are -21.75, -21.22 and -9.08 respectively. Similarly, the average SNR values for the varying distance for the antenna heights tx20rx20, tx60rx60 and tx100rx100 for the distances 60, 70 and 80 are tabulated. From the above values, it is clearly evident that as the antenna height increases the value of SNR increases and reaches the less negative value. Moreover, from the above table it can be concluded that the distance between the nodes increases, then the average SNR value decreases gradually. Average SNR for the varying heights are tabulated in the table 3.5

**Table 3.5** the average SNR values for different antenna heights.

|  |  |  |  |
| --- | --- | --- | --- |
| Distance between nodes | TX20RX20 | TX60RX60 | TX100RX100 |
| 10 | -10.42 | -10.32 | -8.20 |
| 20 | -12.85 | -12.67 | -8.38 |
| 30 | -15.77 | -15.47 | -8.62 |
| 40 | -18.68 | -18.27 | -8.84 |
| 50 | -21.75 | -21.22 | -9.08 |
| 60 | -24.93 | -24.29 | -9.33 |
| 70 | -28.34 | -27.57 | -9.60 |
| 80 | -31.80 | -30.90 | -9.87 |

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**Fig 3.6** Shows Average SNR GNU Plot

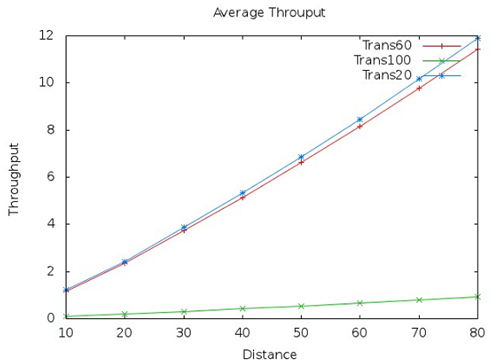
The tabulated values are represented in the GNU plot as shown in Fig 3.6 The obtained values of SNR for the respective antenna heights can be analysed for varying distance. The graph represents the distance between the nodes and the average SNR ratio of the individual antenna heights. It proves that SNR decreases and takes a very negative value. When the antenna height is tx60rx60 is decreasing from -10.32 to -30.90, it proves that the average SNR value decrease. When the distance between the nodes increases, the average SNR decreases and takes a very negative value. On comparing the average SNR value of all the three antennas it is evident that the average SNR value increases when the height of antenna increases. It is found that the average Signal to Noise Ratio decreases as the distance between nodes increases, whereas when the antenna height increases, the SNR value increases that is less negative. Antenna tx100rx100 proves to be better when compared to the other antenna heights.

*Throughput:* The values of throughput for different nodal distance is shown in table 6. The comparison of the nodal distance and the throughput values for various antenna heights is compared and analysed. For antenna height 20 (tx20rx20), the value of throughput obtained is 1.21 when the distance between the node is 10. When the nodal distance is 20, the throughput value obtained is 2.42. Thus, for the antenna heights 40, 50, 60 and 80 the throughput value obtained is 5.34, 6.87, 8.46 and 11.90 respectively. This proves that when the nodal distance increases the throughput value also increases. For antenna height 60 (tx60rx60), the value of throughput for different nodal distance is analysed. When the nodal distance is 10, the throughput value is 1.16 and it is 2.33 for the nodal distance of 20. Similarly, for nodal distances 50, 60 and 80 the value of throughput obtained is 6.61, 8.14 and 11.45 respectively. Hence, it is very clear that when the nodal distance increases, the value of throughput also increases. Likewise, for antenna height 100 (tx100rx100), the value of throughput is 0.10 when the distance between the nodes is 10. Throughput value is 0.19 when the distance between the nodes is 20. When the nodal distance is 30, 40, 60 and 80, the throughput values are 0.31, 0.42, 0.66 and 0.93 respectively. This gives a clear idea that the throughput value increases when the distance between the nodes increases.

The throughput values for the antenna heights 20, 60 and 100 are compared. When the distance between the nodes is 10, the throughput values for the antenna heights tx20rx20, tx60rx60 and tx100rx100 are 1.21, 1.16 and 0.10 respectively. Similarly, when the nodal distance is 20, the throughput values for the antenna height tx20rx20, tx60rx60 and tx100rx100 are 2.42, 2.33 and 0.19 respectively. When the nodal distance is 30, the throughput values for the antennas tx20rx20, tx60rx60 and tx100rx100 are 3.88, 3.73 and 0.31 respectively. The value of throughput for the antenna combinations tx20rx20, tx60rx60 and tx100rx100 are 5.34, 5.13 and 0.42 when the distance between the nodes is 40. Similarly, on comparing the values of throughput for the distances 60, 70 and 80, it is found that the throughput value decreases with increasing antenna heights. Table 6 shows the value of throughput for varying antenna heights. Initially the distance between the nodes and the throughput of individual antenna values are compared and it is found that the throughput increases when the distance between the nodes increases and then the throughput values for different antenna heights are compared. It is found that as the antenna height increases the value of throughput decreases.

**Table 3.6** shows throughput values for different antenna height configuration.

|  |  |  |  |
| --- | --- | --- | --- |
| Distance between nodes | TX20RX20 | TX60RX60 | TX100RX100 |
| 10 | 1.21 | 1.16 | 0.10 |
| 20 | 2.42 | 2.33 | 0.19 |
| 30 | 3.88 | 3.73 | 0.31 |
| 40 | 5.34 | 5.13 | 0.42 |
| 50 | 6.87 | 6.61 | 0.54 |
| 60 | 8.46 | 8.14 | 0.66 |
| 70 | 10.17 | 9.78 | 0.80 |
| 80 | 11.90 | 11.45 | 0.93 |



**Fig 3.7** shows the throughput GNU Plot

The tabulated values are plotted in the GNU plot as shown in Fig 3.7 The nodal distance and the throughput values of the individual antennas are compared. For antenna height tx20rx20, as the distance between the nodes increases the value of throughput also increases gradually. For the antenna height tx60rx60, the throughput value increases when the distance between the nodes increases. The value of throughput increases with an increase in the nodal distance. The comparison of throughput values for the different antenna heights. At the same time the throughput value of tx100rx100 also proves that it is low, when compared to the other antenna heights tx20rx20 and tx60rx60.

For tx20rx20 and tx60rx60 antenna height throughput is good compared to maximum antenna height tx100rx100. Thus, it is concluded that the distance between the nodes increase the throughput value with decrease in the antenna heights.

**3.5 Summary**

The characterization of the wireless propagation channel has been using the Ricean distribution. The proper nodal deployment in the indoor scenario has been done for three antenna heights Tx20Rx20, Tx60Rx60 and Tx100Rx100. The measurement has been analyzed and it contributes the small scale amplitude distribution. Ricean distribution remains the best fit to model the channel with the required performance criteria. The distance dependent Ricean variable mixture model has been presented. The value is found to be around 0.5, when the covariance of the channel has been investigated. The SNR is improved in this method to another 10dB. The proposed model is relevant to SNR investigations and interference analysis. The same wall measurement and opposite wall measurement have been analyzed in this proposed method. The simulation results presents that all nodes within the spatial extend experience the channel statistics.