Wireless Network for Unmanned Ground Vehicle

Prof Renuka Bhandari\textsuperscript{1}, Vijaya Khati\textsuperscript{2}, Sangita Yadav\textsuperscript{3}, Moni Kumari\textsuperscript{4}

\textsuperscript{1}rbhandari@aitpune.edu.in, \textsuperscript{2}vijaykhati_12622@aitpune.edu.in, \textsuperscript{3}sangitayadav_12609@aitpune.edu.in, \textsuperscript{4}monikumari_12504@aitpune.edu.in

\textsuperscript{1234}AIT, Pune, INDIA

Abstract: Controlling and monitoring of unmanned ground vehicles (UGV) based on wireless communications is an upcoming research area. The control and implementation of the UGVs make use of wireless network techniques to set up a long range, high speed, noise immune and reliable connection with the remote base station. This paper proposes to select the most optimum path loss model after evaluating many models using simulation software like MATLAB. Further the most suitable network topology and modulation scheme is chosen according to the scenario, amount of traffic and whether the communication is LOS or NLOS. The design of UGV includes sensors, network devices, micro controller, mechanical and electrical design. These types of vehicles can be used in multiple operations as search and rescue.

Keyword: modulation scheme, network topology, path loss model, remote base station, unmanned ground vehicles.

I. INTRODUCTION

Electromagnetic waves carry the information and data from transmitter antenna to receiver antenna in a wireless communication. During propagation through the medium, the signal attenuates. Path loss is defined as this reduction in the strength of the signal from transmitting antenna to receiving antenna. To determine path loss at the receiver the path loss models used are empirical, deterministic and stochastic. Factors that contribute in the path loss are atmospheric absorption, antenna misalignment loss, feeder loss, diffraction, multipath signal loss and polarization loss. Different path loss models are there for different types of environments such as urban, suburban, and rural. Most of the researchers are the modes for all types of environments \cite{8}. However, a few models are specified for rural environments. It is noticed that majority of path loss models consider only the essential parameters such as distance and carrier frequency at various terrains and topologies for wireless communication for unlicensed band whereas, the unimportant parameters are ignored.

II. PATH LOSS MODELS

To establish wireless communication for cellular systems, path loss models play an important role. Path loss models depict a set of algorithms and equations that help in propagation of radio signal and prediction in certain areas. During preliminary deployment of wireless network, to calculate the electromagnetic field strength, propagation path loss models are necessary. These Path loss models tell us about the degradation in strength of the signal as it propagates from transmitting antenna to the receiving antenna. This reduction in its strength is a function of distance between source and destination, the operating frequency, height of receiving antenna and other important factors like the type of terrain.

A. Free Space Path Loss Model

In telecommunication, the loss in strength of a signal as a result of line of sight path, not taking into consideration the reflection and diffraction owing to any obstacles in between is termed as free space path loss. It is estimated to be directly proportional to the square of distance between transmitting antenna and receiving antenna and also to the square of operating frequency. The mathematical equation for this model is given as:

$$PL = 20 \log 10 (d) + 20\log 10 (f) + 32.45$$

Where: $f$ is the frequency (in Mhz)
$ d$ is the distance from the transmitting antenna (in km).
B. Cost 231 Hata Model

This model is an extension of already existing urban hata model and covers an extended range of frequencies. The urban hata model is suitable for the frequency range 150 MHz to 1500 MHz to estimate the median path loss for a particular distance between source and destination up to 20 km and the transmitting antenna height being 30 - 200m and the receiving antenna height being 1-10m. However to estimate path loss for the frequency range 1500 MHz to 2000 MHz, the extension of Hata model that is cost 231 Hata model is incorporated. This model can estimate path loss in all the terrain profiles including urban, suburban and rural. Its important advantage is its simplicity and its suitability in higher frequency range, however it can not be used for the frequency range 2.5 GHz - 3.5 GHz. The mathematical equation for COST 231 Hata model can be given as:

\[ PL = 46.3 + 33.9 \log_{10}(f) + 13.82 \log_{10}(h_b) + \alpha_m (44.96 - 6.55 \log_{10}(h_r)) \log_{10}(d) + c_m \]

Where
- \( d \) is the distance between transmitting antenna and receiving antenna (in km)
- \( f \) is the operating frequency (in MHz)
- \( h_b \) is the transmitter antenna height (m)
- \( c_m \) has different values for different environments
  - 3db in urban area
  - 0 db in open rural and suburban areas
- \( \alpha_m \) is defined in urban areas as
  - \( \alpha_m = 3.20 (\log_{10}(11.75 h_r))^{24.79}, \text{for } f > 400 \text{MHz} \)
  - \( \alpha_m = 1.11 \log_{10}(f)^{0.7} h_r (1.5 \log_{10}(f)^{0.8}) \), suburban and rural areas
- \( h_r \) is the height of receiving antenna (in m)

C. Hata Okumura Extended Model

This model is ideal for urban areas without many tall buildings. It is the most popularly used radio propagation model. It served as a base to hata model. The frequency range offered is 150 MHz to 1920 MHz. The antenna height at mobile station is 1-3 m and the antenna height at base station is 30m – 100 m and the link distance being 10-100 km. The International Telecommunication Union extended this model further up to 3.5 GHz but any frequencies above that cannot be supported, and then a hypothetical method based on prerequisite knowledge of Okumura model is used. The mathematical expression for this model is given as:

\[ PL = A_{f_s} + A_{b_m} - G_b - G_r \]

Where
- \( A_{f_s} \) is the free space attenuation (dB)
- \( A_{b_m} \) is the basic median path loss (dB)
- \( G_b \) is the transmitter antenna height gain factor
- \( G_r \) is the receiver antenna height gain factor
These factors can be separately described and given by as:

- \( A_{f_s} = 92.4 + 20 \log_{10}(d) + 20 \log_{10}(f) \)
- \( A_{b_m} = 20.41 + 9.83 \log_{10}(d) + 7.894 \log_{10}(f) + 9.56 [\log_{10}(f)]^2 \)
- \( G_b = 10 \log_{10}(h_b /200)(13.958 + 5.8[\log_{10}(10)]^2 \)
- \( G_r \) for medium cities
  - \( G_r = 42.57 + 13.7 \log_{10}(f) + [\log_{10}(h_r) - 0.585] \)
  - For large cities
  - \( G_r = 0.759 h_r - 1.862 \)
Where \( d \) is the distance between transmitter and receiver antenna(km) 
\( f \) is the frequency(GHz)
h_r is the receiver antenna height (m)
h_b is the receiver antenna height (m)

D. COST 231 Walfish-Ikegami (W-I) Model

This radio propagation model is an amalgamation of two models - J. Walfisch and F Ikegami hence giving it its new name Cost Walfisch Ikegami. Since it was enhanced by the Cost 231 project it derived its name Cost 231 W I model. It is statistical model and not deterministic which considers the buildings in vertical plane between the source and destination. Many variables such as width of street, building height and height of transmitting and receiving antenna are considered and many terrain profiles such as urban, suburban and rural are considered. It gives highly accurate results because in terrains like urban areas the propagation in vertical plane is dominating but for the cases when wave guiding effects owing to multiple reflections exists, its accuracy takes a set back because of multiple diffractions in vertical plane.

The general parameters of the model are:
- Frequency f (800...2000 Mhz)
- Height of the transmitter h_TX (4...50 m)
- Height of the receiver h_RX (1...3 m)
- Distance d between transmitter and receiver (20...5000 m)

Parameters depending on the buildings:
- Mean value of building heights h_ROOF
- Mean value of widths of streets w
- Mean value of building separation b

This model determines mean separation between buildings, mean street width, and average height of buildings for a database, but practically, the buildings are not of equal heights. They are analysed individually for each receiver pixel based on the actual buildings in the vertical plane between Tx and Rx. The mathematical expression for this radio propagation model is

For LOS condition

PL_{LOS} = 42.6 + 26 \log_{10}(d) + 20 \log_{10}(f)

And for NLOS condition

PL_{NLOS} = L_{FSL} + L_{RTS} + L_{msd}

Where
- L_{FSL} is the free space path loss
- L_{RTS} is the roof top to street diffraction
- L_{msd} is the multi-screen diffraction loss

Roof top to street diffraction [4]:

L_{RTS} = \begin{cases} 
-16.9 - 10 \log_{10}(w) + 10 \log_{10}(f) + 20 \log_{10}(\delta h_m) + L_{ori}, & \text{if } h_{ROOF} > h_{m} \\
2.5 + 0.075(\varphi - 35), & \text{if } 0 \leq \varphi < 35 \\
4 - 0.114(\varphi - 55), & \text{if } 35 \leq \varphi < 55 \\
2.5 + 0.075(\varphi - 35), & \text{if } 55 \leq \varphi < 90 \\
\end{cases}

Note that
- \delta h_m = h_{ROOF} - h_{m}
- \delta h_{base} = h_{base} - h_{ROOF}

The Multi Screen Diffraction Loss is

L_{msd} = L_{bsh} + k_a \log_{10}(d) + k_d \log_{10}(f)

where
- L_{bsh} = -18 \log_{10}(1+\delta h_{base}) h_{base} > h_{ROOF}
- k_a = 54 - \delta h_{base}
- k_d = 18 (h_{base} > h_{ROOF})
- k_d = 18 - 15 (\delta h_{base}/h_{ROOF})(h_{base} \leq h_{ROOF})
III. METHODOLOGY

The scenario has a transmitter and receiver. The transmitter acts as source or base station and receiver acts as destination or the unmanned ground vehicle. A mix of star and mesh topology is incorporated between transmitter and receiver. The wireless communication between these two points is presumed as line of sight (LOS). Only COST-231 WI model accounts for non line of sight communication. The transmitter is fixed and the path loss is calculated with respect to receiver at various distances from the source. Urban, suburban and rural environments and in each environment the performance and signal strength is measured. 868 MHz is chosen as the fixed operating frequency. The distance between destination and source was fixed at 5km. 9dB of shadowing correction is incorporated of suburban and rural areas while 10dB of shadowing correction for urban areas. 60 m of building separation is kept in case of non line of sight wireless communication with 20m building height and 30 m width of street. Four path loss models namely, HATA Okumura, HATA model and COST-231 WI model were analysed.

IV. RESULTS AND DISCUSSIONS

All the path loss models were analysed using a matlab simulation. The estimated path loss values for Free Space model was presumed as the reference values for different analysed path loss models. The link distance between transmitter and receiver is taken to be 5km. Figure 1, 2 , 3 and 4 show the calculated path loss values for analysed models at 1.5 receiver antenna heights for urban environment. HATA model displayed the highest path loss value which was 156.1 dB with respect to reference model. COST 231 can be used for different environments as it does not take into account the additional factors except only one correction factor used for receiver antenna height. COST-231 WI showed the lowest path loss values which was 150.45 dB at 1.5 receiver height owing to the addition of extra parameters like $L_{msd}$, $L_{bsh}$, $k_a$, $k_d$ and $k_f$. 

![Figure 1: Path Loss estimated by Hata model](image-url)
Figure 2: Path Loss estimated by Cost 231 WI model

Figure 3: Path Loss estimated by Okumura model
V. CONCLUSION

The unmanned Ground Vehicles are useful in military, surveillance, riot control etc. Based on the results of our simulation, it is inferred that the models results were incompatible because of embodiment of different variables and different variables. Hence, this brings us to a conclusion that one specific path loss model is not ideal for all antenna heights for all terrains. However, Cost 231 WI model could be favoured owing to its suitability to our scenario. Cost 231 WI model is the best suited path loss model for our project and a combination of star and mesh topology would give best results for our scenario. The above choices may give best results for our case but different scenarios might need different choices of path loss models, network technology depending upon the amount of traffic, fading and shadowing and whether the communication is LOS or NLOS. In order to validate the productiveness of the proposal, various remote operating tests for the UGV were conducted. The UGVs are controlled from a remote base station which receives real time data and sensor information from the UGVs and in return sends movement and motion commands. In some developed systems, a graphical user interface reduces the workload on the operator and the operator can control multiple unmanned ground vehicles simultaneously. As a consequence, we expect a UGV capable of playing an inevitable role in the military operations in near future.

REFERENCES


