ECE 60022

Monitoring characteristics of Wireless Channel at Purdue University

Rittwik Sood

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1 Introduction

Unlike wired networks, wireless channels are susceptible to various impairments that can degrade signal quality and impact network performance. Key characteristics of the wireless channel include signal strength, signal-to-noise ratio (SNR), fading, multipath propagation, and channel capacity. These characteristics fluctuate dynamically due to factors like distance from the access point, obstacles in the propagation path, and interference from other devices or networks [3].

Significance of Monitoring Wireless Channel Characteristics. Effective monitoring of wireless channel characteristics is vital for several reasons:

- **Performance Optimization:** By continuously monitoring the wireless channel, network administrators can identify and mitigate issues affecting signal quality and reliability. This optimization leads to improved network performance and user experience.
- **Fault Detection and Diagnosis:** Monitoring helps in detecting faults such as signal interference, packet loss, or coverage gaps, allowing prompt troubleshooting and resolution before they escalate into major issues.
- **Capacity Planning:** Understanding channel utilization and capacity constraints enables network planners to allocate resources efficiently, ensuring adequate bandwidth for all connected devices and minimizing congestion [2].
- **Security:** Monitoring can reveal unauthorized access attempts, rogue devices, or anomalous behavior on the network, enhancing security posture and enabling timely countermeasures.

This report is divided into various sections. Section 2 includes the concepts and mathematical formulas of the concerned research. Section 3 will cover the methodology used in this research project. Section 4 discusses results and draws comparison with various results. Section 5 talks about the conclusions drawn from this project.

2 Theory

In order to optimise the performance and increase the efficiency of a wireless network, it is important to monitor the physical layer characteristics of a wireless channel. This experimental monitoring can provide valuable information about network activity, usage patterns, and the behavior of wireless links. By collecting empirical measurements, researchers can analyze factors such as channel utilization, communication time, power distribution, and the effects of noise on wireless data transmission. Understanding these characteristics can help optimize the performance of the network, improve channel utilization, reduce communication time, and enhance power efficiency. Additionally, experimental monitoring allows for the evaluation of different wireless communication systems and the analysis of their power consumption and efficiency. Overall, experimentally monitoring the physical layer characteristics of a wireless channel in a wireless local area network is crucial for optimizing network performance, understanding usage patterns, and improving power efficiency.
SNR is a crucial metric used to quantify the quality of a signal relative to the noise present in the said wireless communication channel. SNR is the ratio of the strength of the desired signal (i.e., the transmitted data) to the level of interference or noise in the wireless channel. Mathematically, SNR is expressed in decibels (dB) as the ratio of signal power to noise power.

$$\mathrm{SNR}_{\mathrm{dB}} = 10\log_{10}\left(\frac{P_{\mathrm{signal}}}{P_{\mathrm{noise}}}\right) \tag{1}$$

SNR reduces as we increase the distance between transmitter and receiver respectively and the received power (P_r) and the transmitted power (P_t) follows the Frii's equation 2.

$$P_r^{[\mathsf{dB}]} = P_t^{[\mathsf{dB}]} + G_t^{[\mathsf{dBi}]} + G_r^{[\mathsf{dBi}]} + 20\log_{10}\left(\frac{\lambda}{4\pi d}\right), \tag{2}$$

where λ is the wavelength of the signal and d is the distance between transmitter and receiver respectively. In Friis formula, which follows free space path loss model

$$\frac{P_r}{P_t} = G_t G_r \left(\frac{\lambda}{4\pi d}\right)^2 \tag{3}$$

Received power falls off proportional to the distance squared. [1] In reality, the received power falls off in a complex manner whose approxiamte model can be made and a real number (γ) can be associated which best fits the model.

$$SNR \propto \left(\frac{d_0}{d}\right)^{\gamma} \tag{4}$$

SNR strength can be derived out in Line of Sight(LOS) Communication scenario and non-LOS (NLOS) scenario. In this article from now on, LOS and NLOS terms will be used for referring to above cases. The data has been collected in continuous bursts and discrete bursts of packets which helps in establishing a relationship between SNR strength vs distance and Data rate vs distance.

3 Methodology

3.1 Code Environment Variables

We use the `tshark` command line tool provided by `wireshark-cli` to capture packets. The `-I` flag sets the interface to monitor mode. The `-T` flag translates the data to `json` format. The `-V` flag causes the packet information to be printed in `stdout`. We redirect the information from `stdout` to the file `test.json` for post processing.

Below is the code variables we have used to extract out relevant parameters from the collected data to plot them and draw comparisons from them.

```
sudo tshark -V -I -T json > sample.json
```

wlan_radio.signal_dbm is the Received power in dbm of the transmitted signal and *wlan_radio.data_rate* is the data rate of the signal.

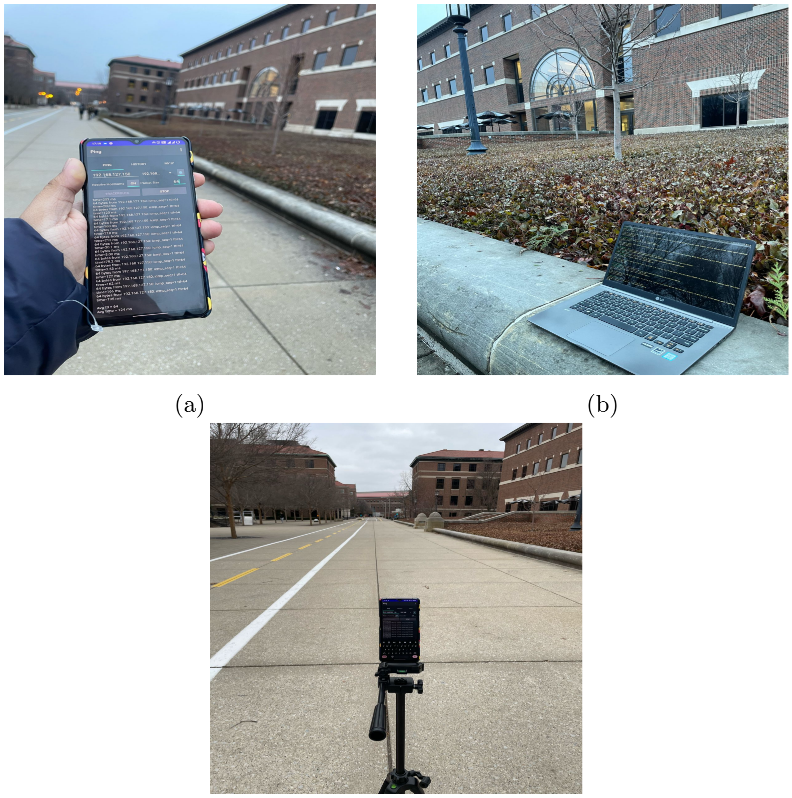
```
# extract data
jq --raw-output'.[] | select(."_source"."layers"."wlan_radio"
| type == "object") | select(."_source"."layers"."wlan_radio".
"wlan_radio.signal_dbm" != null) |'
# filter fields
"."_source"."layers"."frame"."frame.number")(."_source"."layers"."wlan_radio"."wlan_radio.signal_dbm")
(."_source"."layers"."wlan_radio"."wlan_radio.data_rate")" file_name.json
```

4 Results

4.1 Line of Sight Communication

Environment Description

The transmitter is always in the line of sight of the receiver. Figure 1 shows the experimental setup for line of sight measurements. The experiment was conducted infront of the MSEE building to use the open space for dominant LOS signal. 3000 samples were taken for each experiment.



(a) (b)

(c)

Figure 1: Experimental setup for line of sight measurements.

4.1.1 Discrete Measurement

We consider discrete distances from the transmitter and measure the signal power and data rate at the receiver. The distances of **0m**, **5m**, **10m**, **15m** and **20m** were taken into account and their Rx power values in db and the data rate were plotted. Figure 2 and 3 shows the graphs for discussed test cases. We also plot relationship between their mean values to indicate how Rx Power and data rate's average is falling off with increase in distance. Figure 4 plots the Rx Power in dbm vs logarithmic distance.

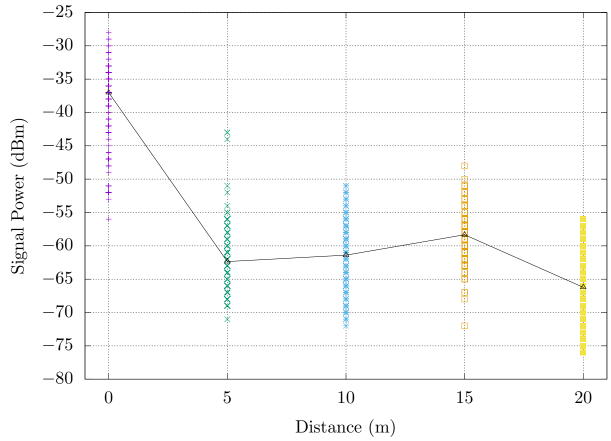


Figure 2: Rx power(dbm) vs distance in Discrete test measurements along with mapping their mean values

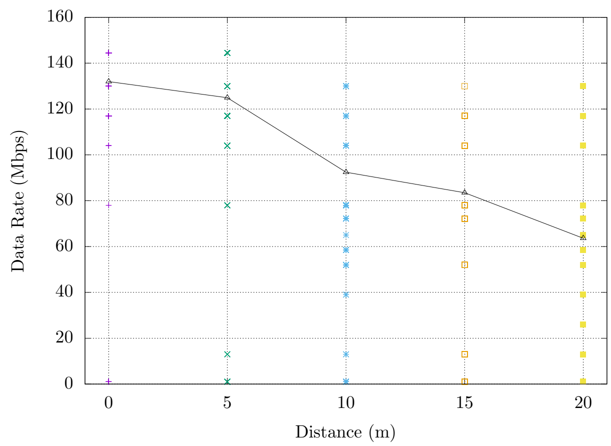


Figure 3: Data Rate (Mbps) vs distance in Discrete test measurements along with mapping their mean values

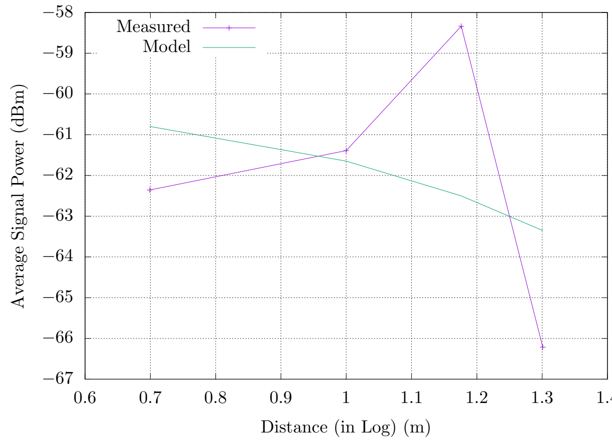


Figure 4: Measured vs Model plot of Rx power against logarithmic dist.

Figure 4 also plots Received power of measured experiment with modelled parameters found via best fit method. This plot helps us to find out the relevant parameters of the new observed model. According to eq (4), SNR is inversely proportional to distance powered gamma. Therefore, SNR can be represented as

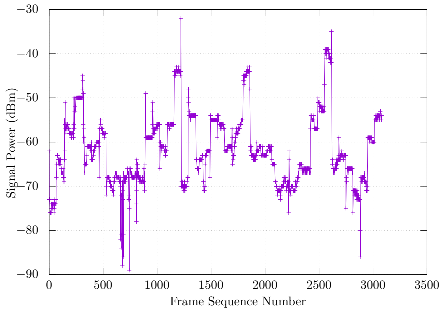
$$SNR = K.(\frac{d_0}{d})^{\gamma} \tag{5}$$

The empirical experiments should give us values of (K,γ). Plotting Figure 4 gives us values of

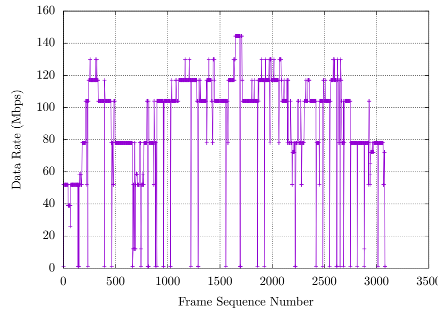
$$\boxed{(K, \gamma) = (-59.94422553, 0.17041546)}$$

4.1.2 Continuous Measurement

In this experiment, the receiver is moved continuously while the transmitter is kept at a fixed position until 3000 samples are collected. Figure 5a and 5b represents results for continuous measurements.



(a) Rx Power for 3000 frames



(b) Data Rate vs 3000 frames

Figure 5: Continuous Measurement for LOS case

4.2 Non-line of Sight Experiment

Environment Description The non-line of sight measurements are taken by placing the transmitter in a corner of the BHEE corridor. The receiver is placed at discrete distances to capture packets. Figure 6 shows the experimental setup.

(a)

(b)

(c)

Figure 6: Experimental setup for non-line of sight measurements.

4.2.1 Discrete Measurements

We consider discrete distances from the transmitter and measure the signal power and data rate at the receiver. The distances of **0m**, **5m**, **10m**, **15m** and **20m** were taken into account and their Rx power values in db and the data rate were plotted. Figure 7 and Fig 8 represents discrete measurements for NLOS Communication and its mean value relationship has been found out.

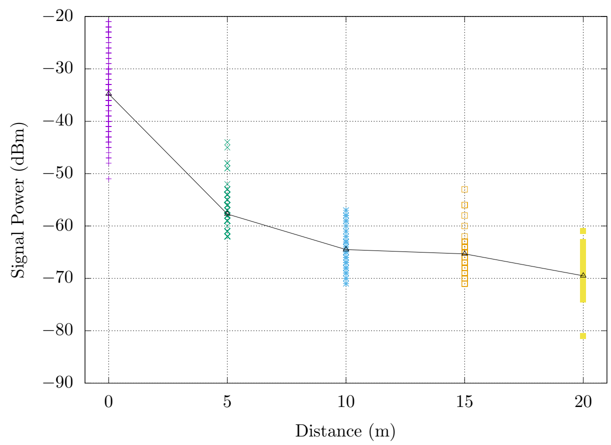


Figure 7: Rx Power vs distance for NLOS measurements

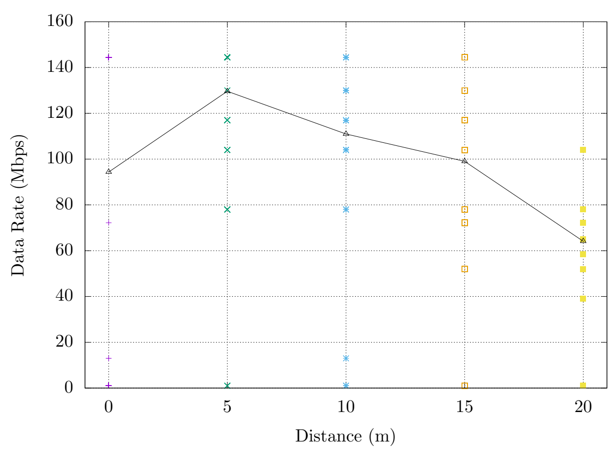


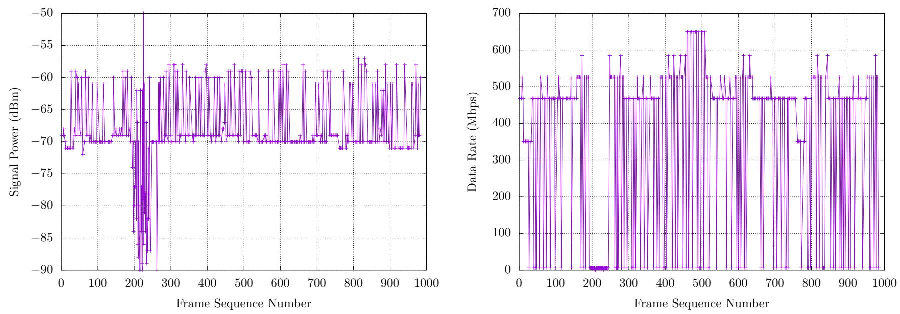
Figure 8: Data Rate vs distance for NLOS measurements

4.2.2 Continuous Measurements

In this experiment, the receiver is moved continuously while the transmitter is kept at a fixed position until 3000 samples are collected.

4.3 Blockage

We formulate an experiment to understand the impact of blockage on the wireless link. For this experiment, the transmitter and receiver are kept in different rooms. The wall between the rooms works as a blockage.



(a)

(b)

Figure 9: Signal Power and Data Rate with blockage in between

5 Conclusion

This section concludes the findings of all the experiments and provides an indication to Post Experiment analysis. Following experiments were conducted with following conclusions:

1. **LOS Communication, discrete distances**: *Rx power (in dbm) and Data Rate(Mbps) were plotted for 3000 frames at a distance of 0m, 5m, 10m, 15m ,20m. For each distance an average value for 3000 frames was collected and a relationship is established between various distances for both Rx Power and Data rate.*

2. **LOS Communication, continuous distances**: *Rx power (in dbm) and Data Rate(Mbps) were plotted for 3000 frames by moving the receiver across different places in a radius of 30m.*

   By various graphs, a comparisons between LOS and NLOS communication has also been drawn. Figure 10 and Figure 11 shows the above mentioned comparisons.

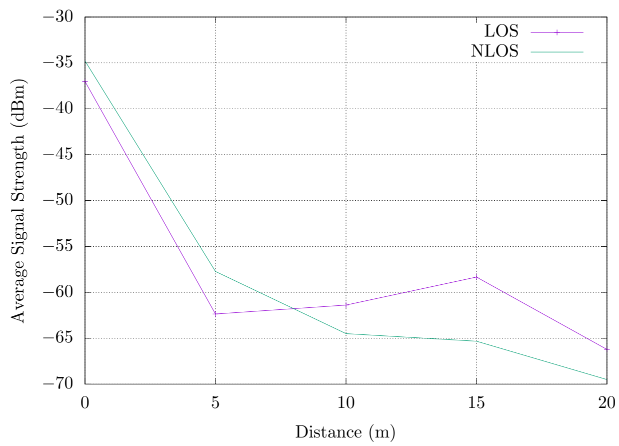


Figure 10: Rx Power at various distances for LOS vs NLOS Communication

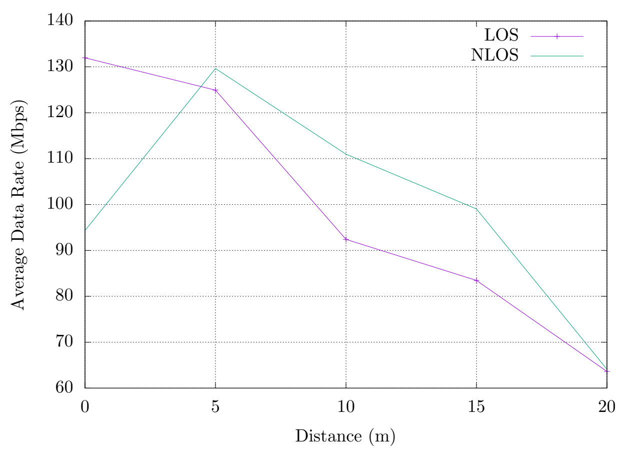


Figure 11: Data Rate at various distances for LOS vs NLOS Communication

3. **LOS Communication, making our own model**: *Rx power (in dbm) and Data Rate(Mbps) were plotted and* (K, γ) *was found out to best fit the model.*

   By experiment we found out the avg. signal strength varies inversely to the approximately 0.17^{th} power of distance. We conclude that there might be some power feedback mechanism from Rx to Tx which might increase the Tx power as we increase the distance. As the simple LOS model follows d^{-2} model, our Tx has to boost power for each discrete value as it is 0.17 instead of 2. That mechanism of power boost can not be found out in this article as a different protocol might have been used which is agnostic to

Rx statistics.

4. **NLOS Communication, discrete distances**: *Rx power (in dbm) and Data Rate(Mbps) were plotted for 3000 frames at a distance of 0m, 5m, 10m, 15m ,20m. For each distance an average value for 3000 frames was collected and a relationship is established between various distances for both Rx Power and Data rate.*

5. **NLOS Communication, continuous distances**: *Rx power (in dbm) and Data Rate(Mbps) were plotted for 3000 frames.*

6. **NLOS Communication with Blockage**: *Rx power (in dbm) and Data Rate(Mbps) were plotted for 3000 frames. The signal power is observed to be lower than the NLOS case even when the distance between the transmitter and the receiver is below 5 meters.*

List of figures drawn from the results of various experiments have been tabulated below.

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References

[1] Andrea Goldsmith. *Wireless communications.* Cambridge university press, 2005.

[2] Ajay R Mishra. *Advanced cellular network planning and optimisation: 2G/2.5 G/3G... evolution to 4G.* John Wiley & Sons, 2007.

[3] Ibraheem Shayea et al. “Key challenges, drivers and solutions for mobility management in 5G networks: A survey”. In: *IEEE access* 8 (2020), pp. 172534–172552.