# Project 1
# Probing Wireless Channels

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18-452/750 - Recitation

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## Overview

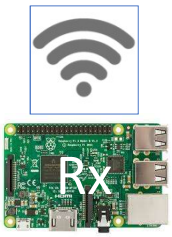
- Goals and experiments
- Experiment set up
- Analyzing the data

# Big Picture

- Objective: Experimentally observe SNR of a wireless channel
- Observe how it changes depending on the physical environment
- Experiments:
  - Line of sight channels
  - Non-line of sigh channels
  - Impact of distance and frequency band on throughput
- We are interested in signal strength, bit rate, and throughput
  - Use Wireshark tool to look at low level headers and signal strength
  - Use iPerf to measure throughput at the application level

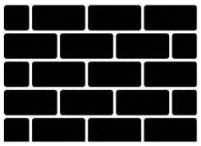


# How does the channel change?




Varies over time

Crowded space



Obstructions

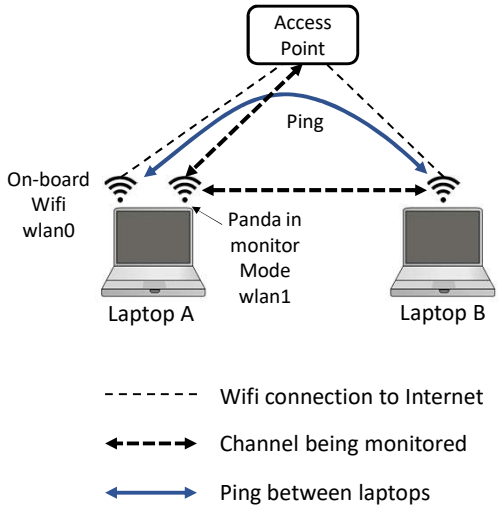
Mobility

# Tools

- The Panda wireless adaptor collects channel information
  - Must be passed up to the OS
- Wireshark is an open source tool that monitors network traffic and parses the network headers for standard protocols
  - Widely used; all layers of the stack
- iPerf is an application tool to measure throughput



# Simple Set up




- Two laptops connected to Wifi using the build-in Wifi interface
  - Exchange traffic using ping
- Panda adaptor set to listen on the same frequency band
- Wireshark captures headers and collects signal strength info
  - Only monitors the channel
- The channel being monitored is that between the Panda adapter and any transmitter in range

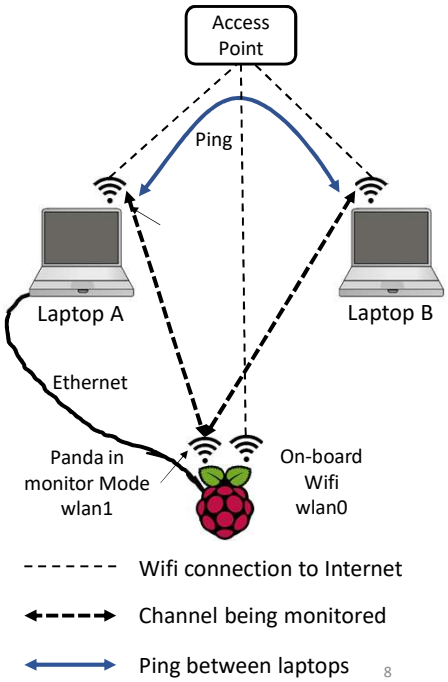
# Discussion

- The challenge is setting up Wireshark on your laptop
  - Set up depends on the OS and sometimes also on the hardware
  - This should work for some people but it some teams will have problems
  - Different set up with a Raspberry Pi as an alternative (next slide)
- Make sure that you understand what channel you are monitoring
  - Wireshark will show you traffic on many channel
  - You can use the IEEE MAC addresses to identify traffic on "your" channel
  - When changing the environment (obstacles, distance, …) you must be aware of where the two end points are
- Flood ping should only be used between laptops
  - Can be interpreted as an attack – don't attack servers!



# Set up with Raspberry Pi

- Raspberry Pi comes with the software you need to run the experiments
- Instructions for set up are in the handout
- Ethernet provides reliable way to ssh into Pi, although WiFi shold work
- Again: you need must be aware of what channel(s) you are monitoring
  - Note that the Pi needs power so you cannot move it



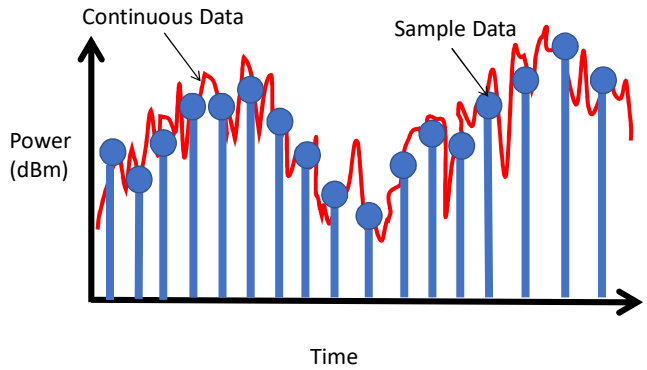
# Overview

- Goals and experiments
- Experiment set up
- Analyzing the data



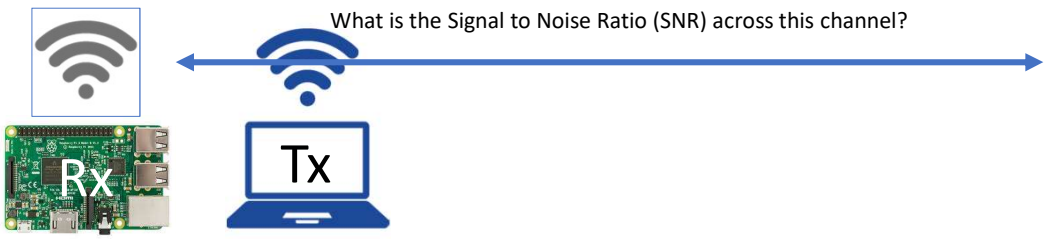
# Sampling of a continuous signal

- Channel WiFi signal is a continuous signal that you are sampling at discrete time intervals—this creates variations in the measurements



# Experimental Data Collection

- 2 Methods
  - Continuous Data Collection
    - Measure continuously while moving one device at a constant rate
  - Discrete Data Collection
    - Measure discrete points in the channel






# Continuous Data Collection

- Example Setup:
  - Planned path, movement rate
- Execution:
  - `sudo ping -f 192.168.1.1`
  - Walk path: moving one device (reference animation)

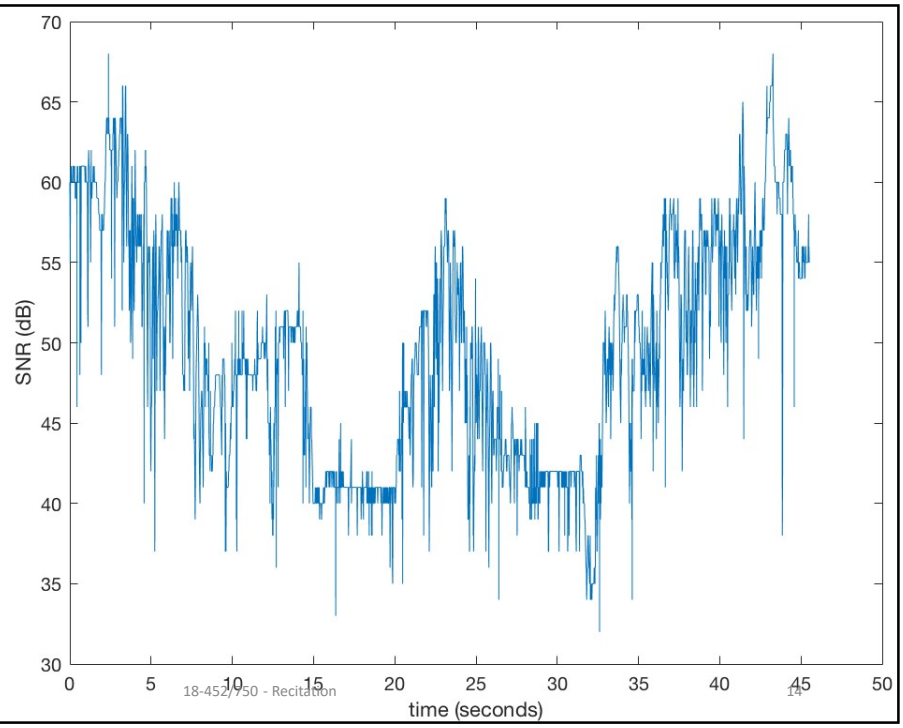
# Continuous Data Collection Example

- Setup:
  - Planned path:
    - Devices begin together, walk away from the device, go into adjacent room, close the door, pause, open the door, walk devices towards each other, …
  - Generate data: using ping flood
    - `sudo ping -f 192.168.1.1`
  - Data collected using Wireshark in monitor mode on Raspberry Pi (stationary)
- Intuition: SNR will decrease as distance increases, closing door will also decrease SNR, etc



# Raw Data Connected

- Can connect samples with a link
- Confusing what is the data and what is the connecting line
- Matlab is a great tool to plot and process data
  - Any tool should do; scripts for processing
  - Some Matlab scripts in only copy of the slides



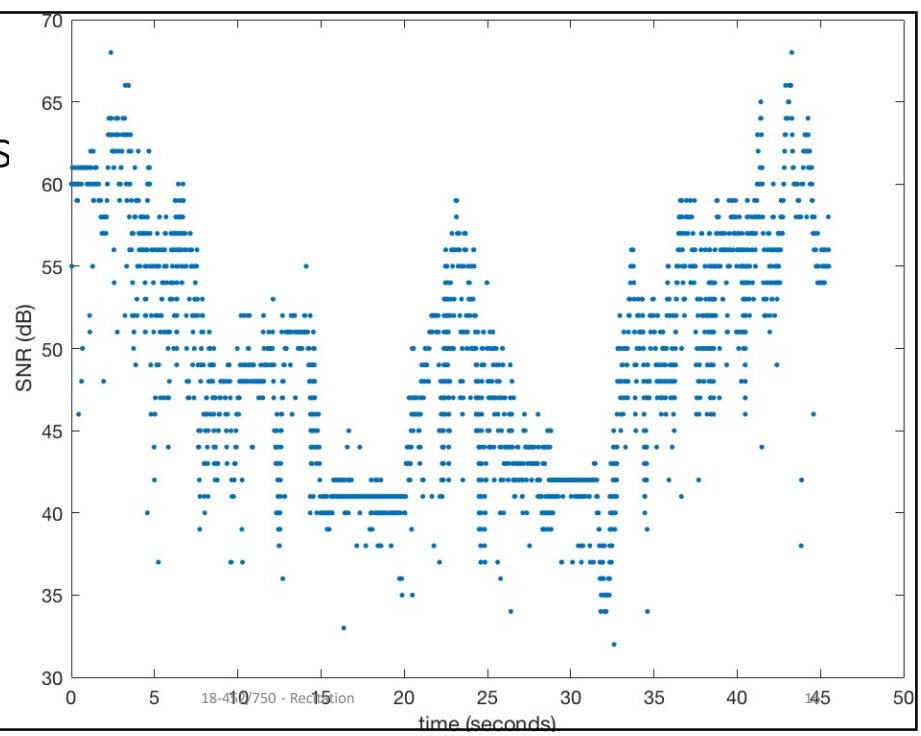
# Matlab Code – Raw Data - Connected

```
% Plot SNR for all data points --connected
figure(1)
plot(data(:,time),SNR)
ylabel('SNR (dB)')
xlabel('time (seconds)')
```



# Raw Data Discrete Pts

- All samples individual dots
- Significant variation due to sampling
- Outliers



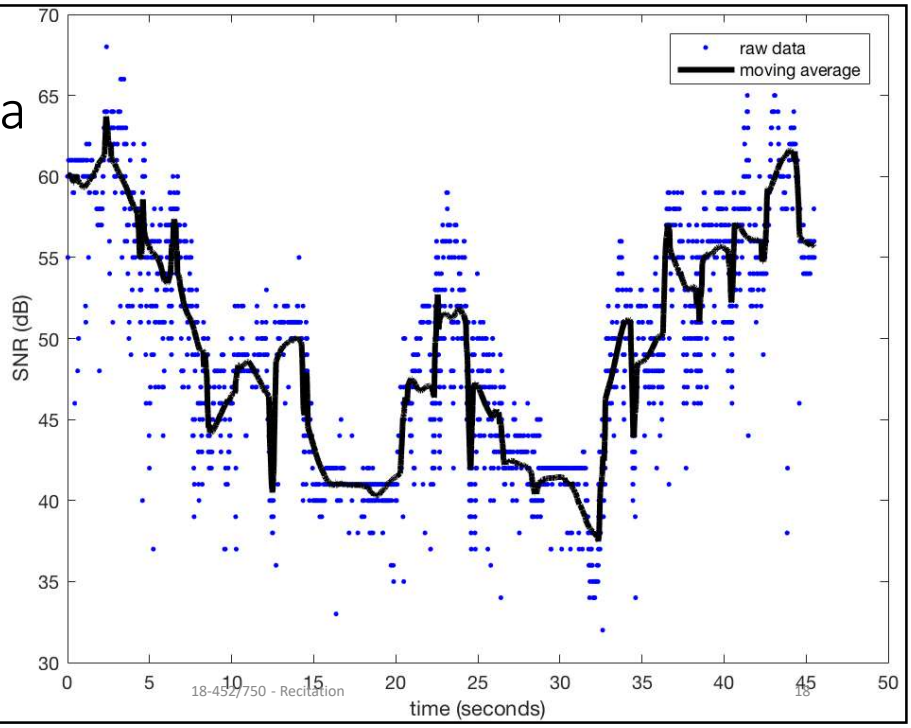
# Matlab Code – Raw Data – Discrete Points

```
% Plot SNR for all data points (discrete points)
figure(1)
plot(data(:,time),SNR,'.')
ylabel('SNR (dB)')
xlabel('time (seconds)')
```



# Filtered Data

- Moving window average of data
- Selection of the window selection impacts output
  - E.g., slow fading effect for longer windows
- Multiple functions



## Matlab Code – Moving Average

```
figure(2)
window = 117;
p=plot(data(:,time),SNR,'b.',...
       data(:,time),movmean(SNR,window,'omitnan'),'k-');
legend('raw data','moving average')
p(2).LineWidth = 3;
xlabel('time (seconds)')
ylabel('SNR (dB)')
```



## Matlab – Other moving average functions

- `movmean`
- `sgolayfilt`

# Discrete Data Collection

- Example Setup:
  - Planned measurement locations, planned data collection (e.g. number of packets, time)
- Execution:
  - Using ping (to send a specific number of ICMP packets):
    - Device 2: `sudo ping -f 192.168.1.1 -c 10000`
  - Using iperf3 (to send TCP packets for a specific amount of time):
    - Device 1: `iperf3 -s`
    - Device 2: `iperf3 -c 192.168.1.1 -t 30`
  - Repeat data generation operation at each measurement location

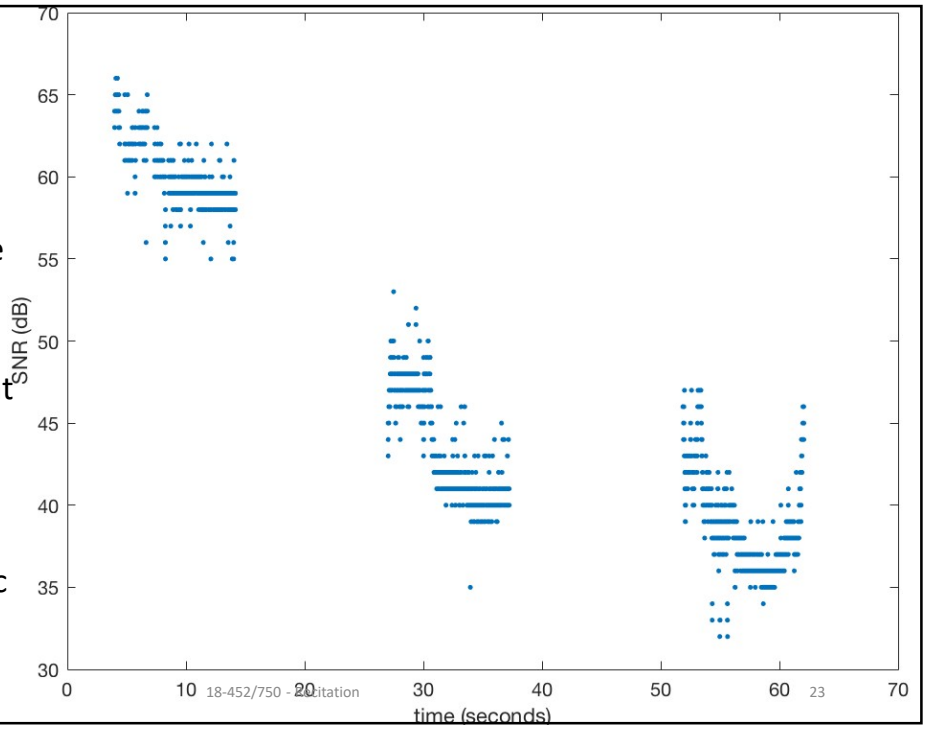


# Discrete Data Collection Example

- Setup:
  - Collection Points: Selected 3 locations from Continuous data collection experiment
    - Devices next to each other
    - Devices maximum separation point
    - Devices with door closed between them
  - Generate data: using iperf3 (https://iperf.fr/iperf-download.php)
    - `Raspberry Pi:  iperf3 -s`
    - `Laptop:  iperf3 -c 192.168.1.1 -t 10`
  - Data collected using Wireshark in monitor mode on Raspberry Pi (stationary), 10 seconds for each location
- Intuition: SNR will decrease as distance increases, closing door will also decrease SNR
  - Results should be similar to continuous data collection

# Raw Data

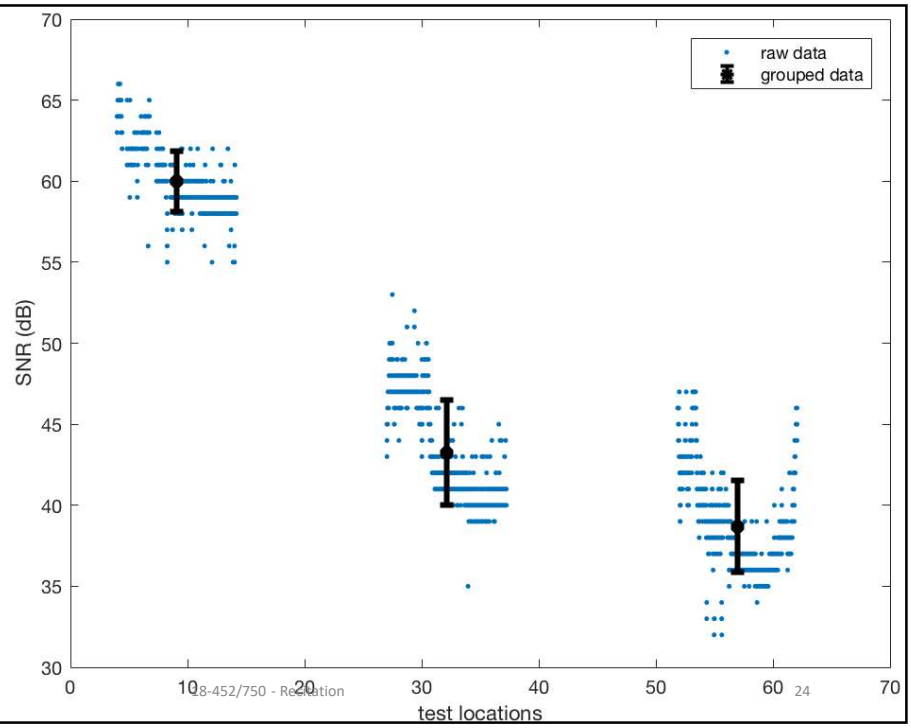
- 3 discrete test events in one file
- Location constant for each discrete iperf3 test
- Can be grouped into each specific test location






# Grouped Data

- Plot mean with error bars of standard deviation
- Allows to generalize what the sample data value is about a condition



# Matlab code – Data grouping

```
% Group data
% Test event times [3.9834 14.1687], [27.0304 37.2376], [51.8701 62.0550]
group1 = data;
group1(group1(:,time)>14.2,:)=[];
group1_SNR=group1(:,signal_strength)-group1(:,noise);
group1_SNR_avg = mean(group1_SNR);
group1_SNR_std = std(group1_SNR);

group2 = data;
group2(group2(:,time)<14.2,:)=[];
group2(group2(:,time)>51.5,:)=[];
group2_SNR=group2(:,signal_strength)-group2(:,noise);
group2_SNR_avg = mean(group2_SNR);
group2_SNR_std = std(group2_SNR);

group3 = data;
group3(group3(:,time)<51.5,:)=[];
group3_SNR=group3(:,signal_strength)-group3(:,noise);
group3_SNR_avg = mean(group3_SNR);
group3_SNR_std = std(group3_SNR);
```

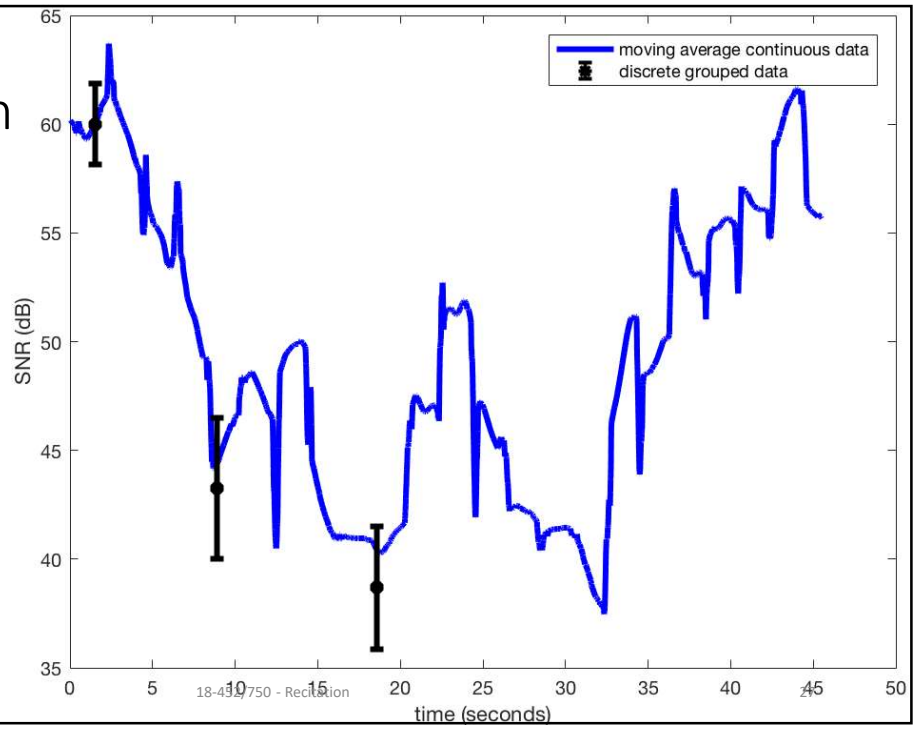


# Matlab code - Plotting

```
avgs = [group1_SNR_avg group2_SNR_avg group3_SNR_avg];
stds = [group1_SNR_std group2_SNR_std group3_SNR_std];
x=[(3.9834+14.1687)/2,(27.0304+37.2376)/2,(51.8701+62.0550)/2];
figure(1)
plot(data(:,time),SNR,'.')
Hold on
errorbar(x, avgs, stds,'k*','LineWidth', 3)
Hold off
ylabel('SNR (dB)')
xlabel('test locations')
legend('raw data','grouped data')
```

# Comparison

- Plot of both data collection events together to allow for easier analysis



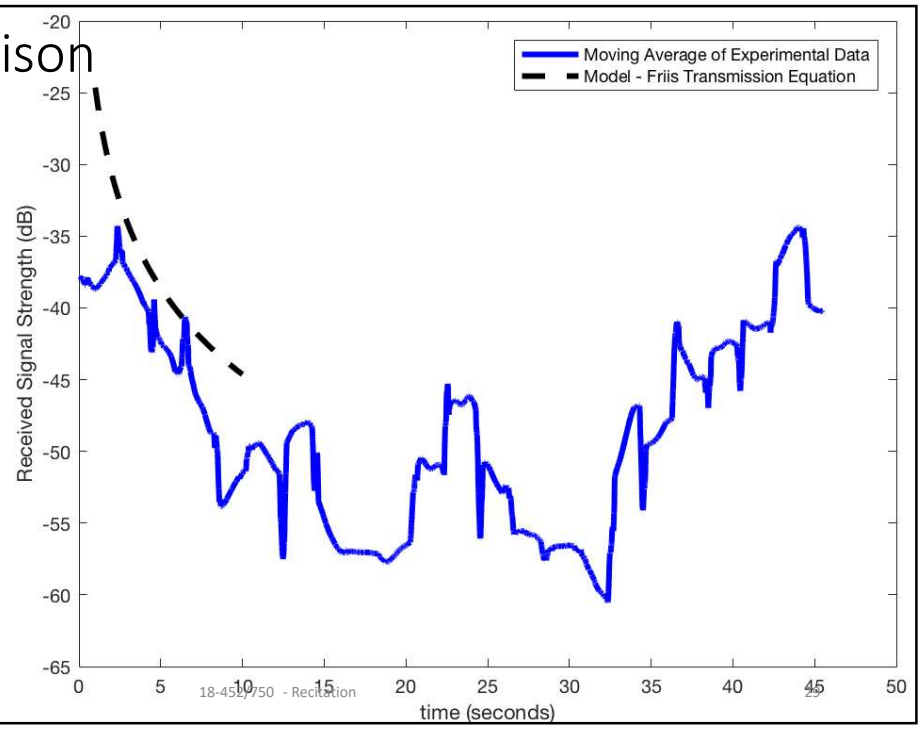



# Analysis Thoughts

- Be creative in how you analyze the data
  - Compare to simple channel models presented in class
  - Compare the results of different environments
- Can be beneficial to observe different characteristics of the data
  - Example: how to signal strength and bitrate compare
  - Bit rate versus throughput

# Model Comparison

- List Assumptions
  - Tx Power: 20 dBm
  - G: -10 dB
- Remember: all models are wrong, some are useful






# Components

- Can be beneficial to analyze data from different aspects