W2

Computer Networks

Wireless Channel Modeling

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Path Loss

- ❑ Free space path loss:

$$P_L(d) = \frac{P_t}{P_r} = \frac{1}{G_t G_r}\left(\frac{4\pi d}{\lambda}\right)^2 = \frac{1}{G_t G_r}\left(\frac{4\pi f d}{c}\right)^2 \qquad \therefore P_L(d) \propto d^2$$

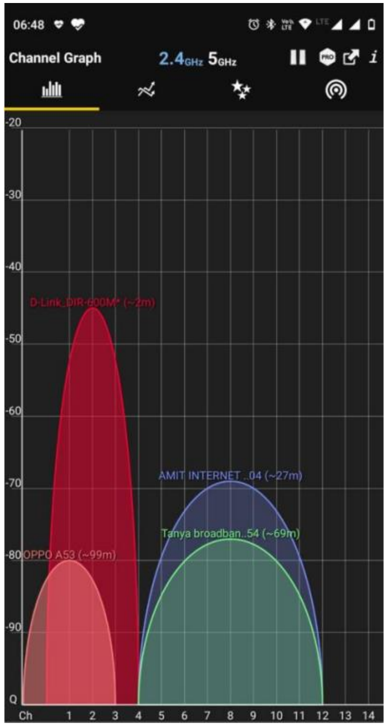
- ❑ Signal goes through
  - ❑ Reflections
  - ❑ Scattering
  - ❑ Diffractions
  - ❑ Attenuation due to obstructions

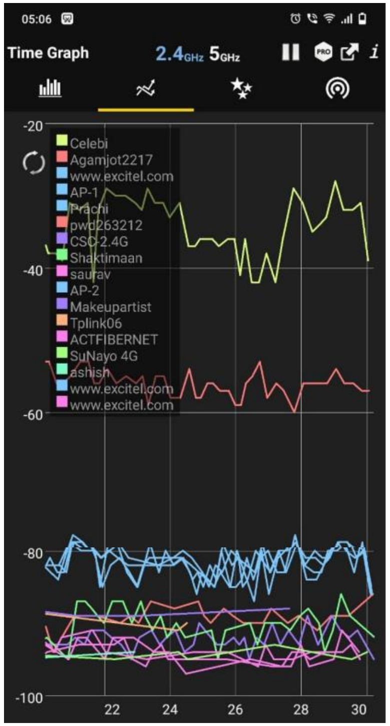
- ❑ In general: $P_L(d) \propto d^n \quad 2 \le n \le 8$

$\boxed{n \rightarrow \text{Path loss exponent}}$

Path Loss

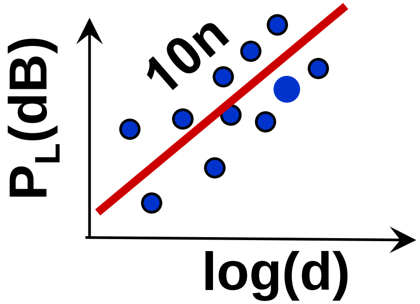
- Data from Wifi Analyzer: https://play.google.com/store/apps/details?id=com.farproc.wifi.analyzer&hl=en_IN&gl=US





Combined Path Loss and Shadowing

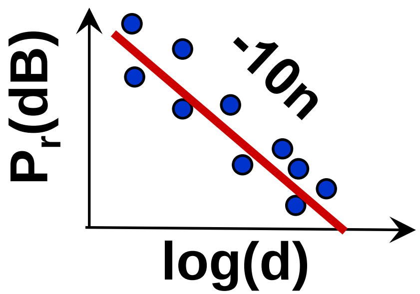
$$P_L(d) \propto d^n \qquad \therefore \frac{P_L(d)}{P_L(d_0)} = \frac{d^n}{d_0^n}$$



$$[P_L(d)]dB = [P_L(d_0)]dB + 10n\log_{10}(\frac{d}{d_0})$$

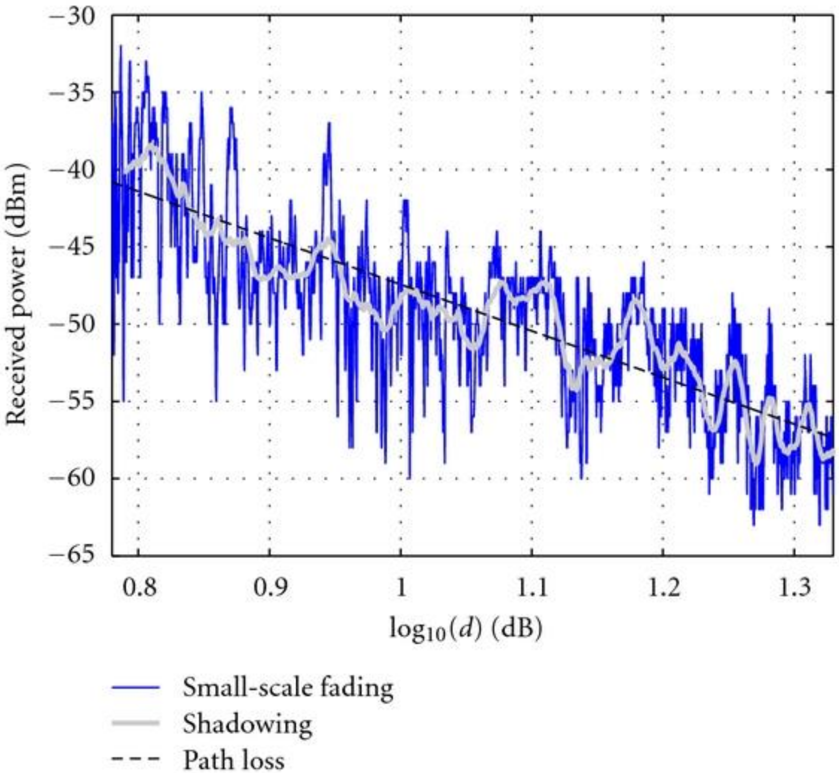
$$[P_L(d)]dB = [P_L(d_0)]dB + 10n\log_{10}\left(\frac{d}{d_0}\right) + \chi; \qquad \chi = \mathbb{N}(0, \sigma^2)$$

$$P_r(d)[dBm] = P_t(d)[dBm] - P_L(d)[dB]$$
$$= P_t(d)[dBm] - [P_L(d_0)]dB - 10n\log_{10}\left(\frac{d}{d_0}\right) + \chi$$

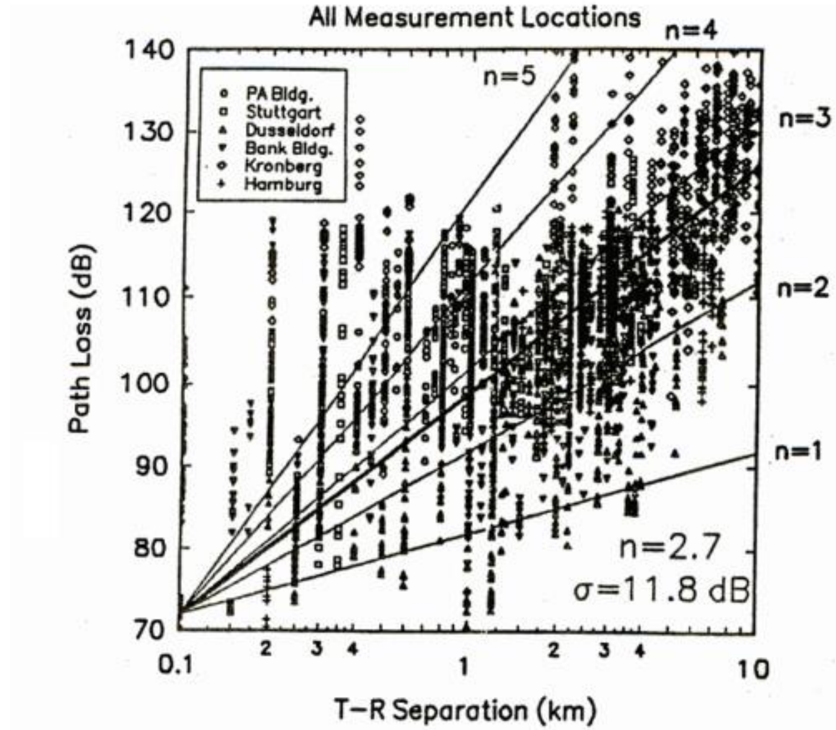


Log Normal Shadowing Model

Some Real Data



Src: https://www.hindawi.com/journals/jr/2011/340372/fig6/



Scatter plot of measured data and corresponding MMSE path loss model cities in Germany. For this data, $n = 2.7$ and $\sigma = 11.8$ dB

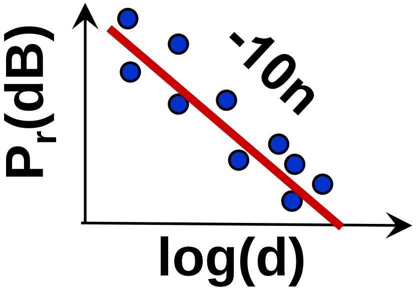
Src: Wireless Communications by Theodore S. Rappaport

How to Measure n?

$$P_r(d)[dBm] = P_t(d)[dBm] - [P_L(d_0)]dB - 10n\log_{10}\left(\frac{d}{d_0}\right) + \chi$$

$$= P_r(d_0)[dBm] - 10n\log_{10}\left(\frac{d}{d_0}\right) + \chi$$

- Measuring n:
  - Draw the “Best fit” line through dB data
  - Find the slope → divide by 10



- Shadowing variance:
  - Variance of data relative to the best fit straight line

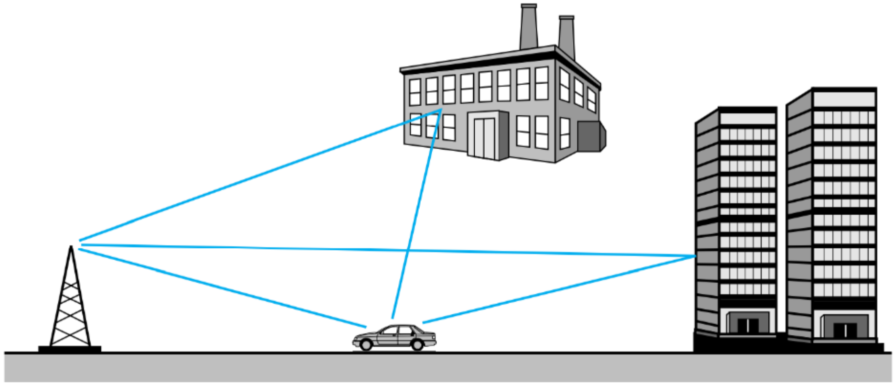
Typical Values for Path loss exponent

Environment	Path Loss Exponent (n)
Free space	2
Urban area cellular radio	2.7 to 3.5
Shadowed urban cellular radio	3 to 5
Inside a building - line-of-sight	1.6 to 1.8
Obstructed in building	4 to 6
Obstructed in factory	2 to 3

Src: https://www.gaussianwaves.com/2013/09/log-distance-path-loss-or-log-normal-shadowing-model/

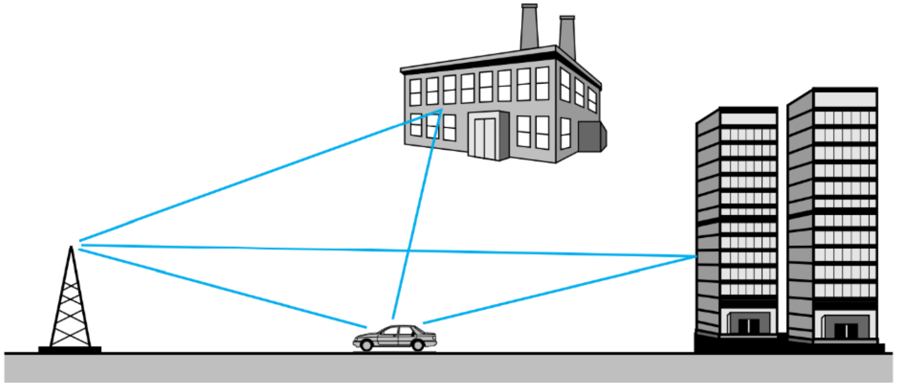
Multipath Propagation

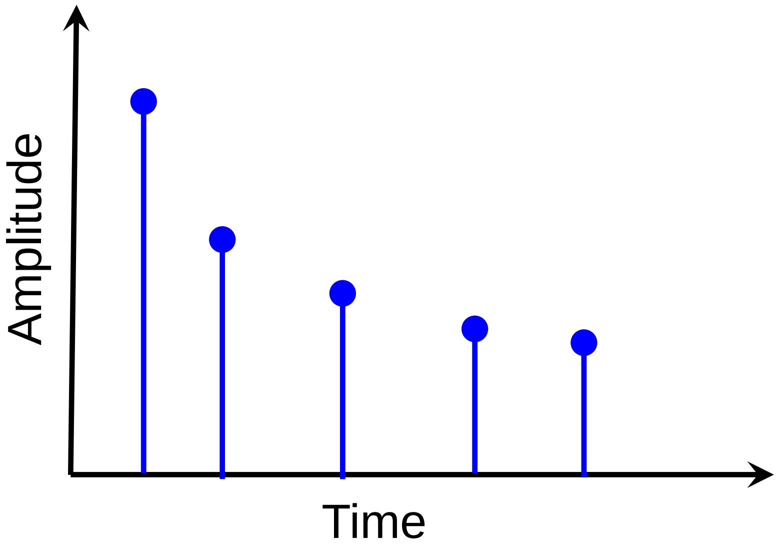
Multipath Propagation



- Multiple signal components reach at the receiver
- Each component experiences different levels of attenuation and delay
  - Leads to time-varying channel impulse response

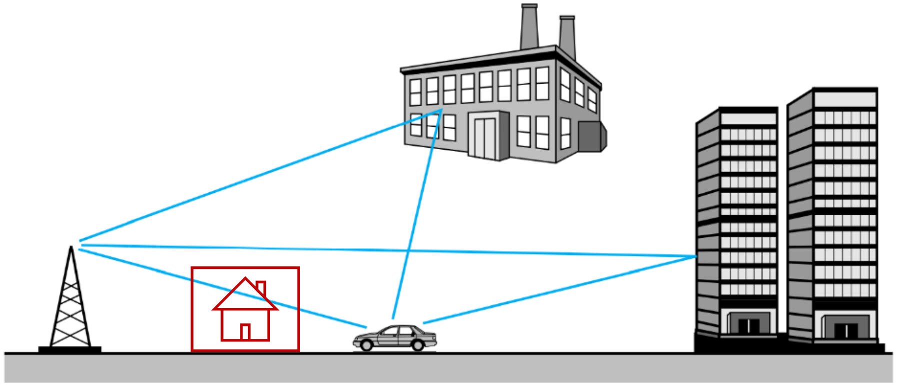
Multipath Propagation

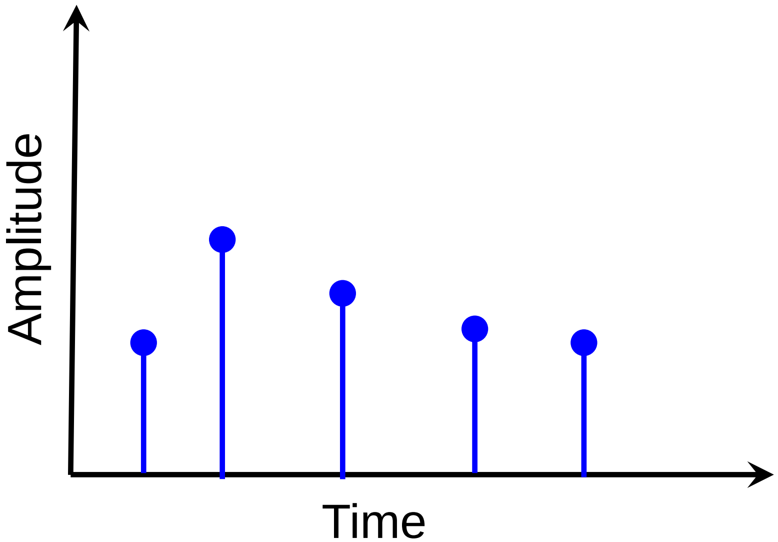




Channel Impulse Response

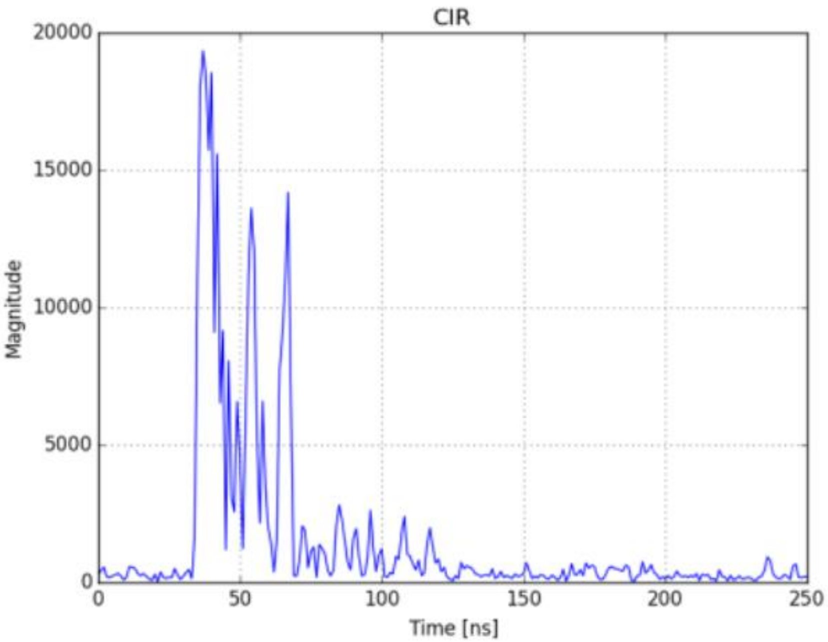
Multipath Propagation

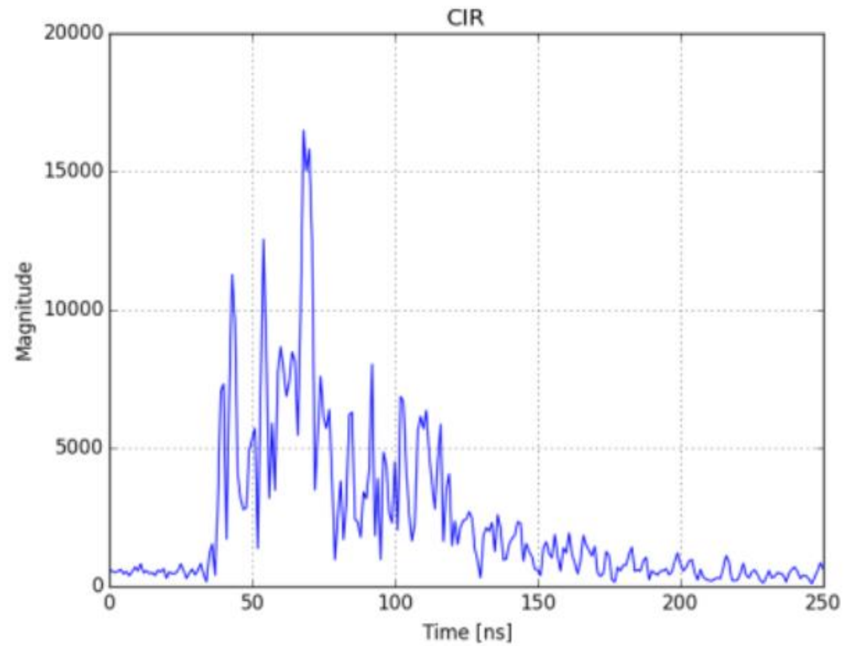




Channel Impulse Response

Multipath Propagation





Src: Bregar, Klemen & Hrovat, Andrej & Mohorcic, Mihael. (2016). NLOS Channel Detection with Multilayer Perceptron in Low-Rate Personal Area Networks for Indoor Localization Accuracy Improvement.

Summary

❑Wireless channel modeling:

- Free space path loss
- Log normal shadowing model
- Path loss exponent
- Multipath propagation