Log Normal Shadowing

- Models attenuation from obstructions
- Random due to random # and type of obstructions
- Typically follows a log-normal distribution
  - dB value of power is normally distributed
  - $\mu=0$ (mean captured in path loss), $4<\sigma<12$ (empirical)
  - CLT used to explain this model
  - Decorrelates over decorrelation distance $X_c$

Combined Path Loss and Shadowing

- Linear Model: $\psi$ lognormal
  \[
  \frac{P_r}{P_t} = K \left( \frac{d_0}{d} \right)^\psi
  \]

- dB Model
  \[
  \frac{P_r}{P_t} (dB) = 10 \log K - 10 \gamma \log_{10} \left( \frac{d}{d_0} \right) - \psi_{\text{av}} \cdot \psi_{\text{av}} \sim N(\mu_\psi, \sigma_\psi^2)
  \]

  $\mu_\psi=0$ when average shadowing incorporated into K and $\gamma$, else $\mu_\psi>0$
Outage Probability

- Path loss only: circular “cells”; Path loss+shadowing: amoeba-shaped cells
- Outage probability: probability received power falls below given minimum:
  \[ P_{out} = P(P_r < P_{min}) \]
- For log-normal shadowing model
  \[ P_{out} = 1 - Q\left(\frac{P_{min} - (P_t + 10\log_{10}K - 10\gamma\log_{10}(d/d_0))}{\sigma_{\psi\nu}}\right) \]

Model Parameters from Empirical Measurements

- Fit model to data
- Path loss \((K,\gamma)\), \(d_0\) known:
  - “Best fit” line through dB data
  - \(K\) obtained from measurements at \(d_0\).
    - Or can solve for \((K,\gamma)\) simultaneously (least squares fit)
  - Exponent is MMSE estimate based on data
  - Captures mean due to shadowing
- Shadowing variance
  - Variance of data relative to path loss model (straight line) with MMSE estimate for \(\gamma\)

Statistical Multipath Model

- Random # of multipath components, each with
  - Random amplitude
  - Random phase
  - Random Doppler shift
  - Random delay
- Random components change with time
- Leads to time-varying channel impulse response

Main Points

- Random attenuation due to shadowing modeled as log-normal (empirical parameters)
- Shadowing decorrelates over decorrelation distance
- Combined path loss and shadowing leads to outage and non-circular coverage areas for WiFi/cellular
- Path loss and shadowing parameters obtained from empirical measurements through a least-squares fit
  - Matches environment in which measurements are taken.
  - Can do a 1D fit with \(K\) fixed or a 2D fit over \(K\) and \(\gamma\).
- Statistical multipath model leads to a time-varying channel impulse response