1/19/12

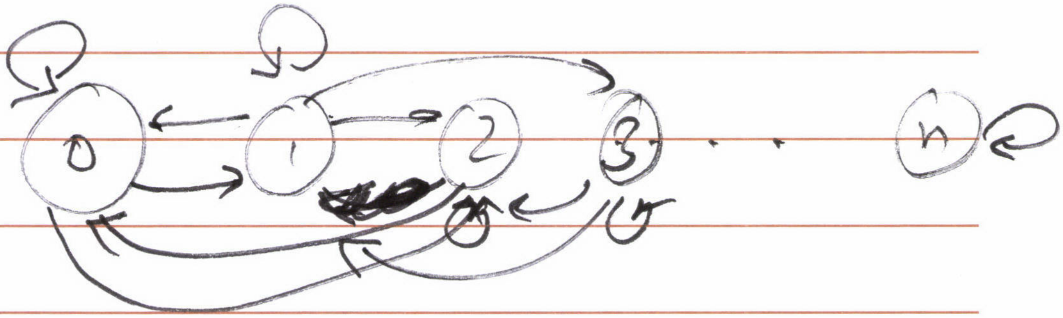
EE597 Lecture 4

Radio Propagation in Wireless Channels

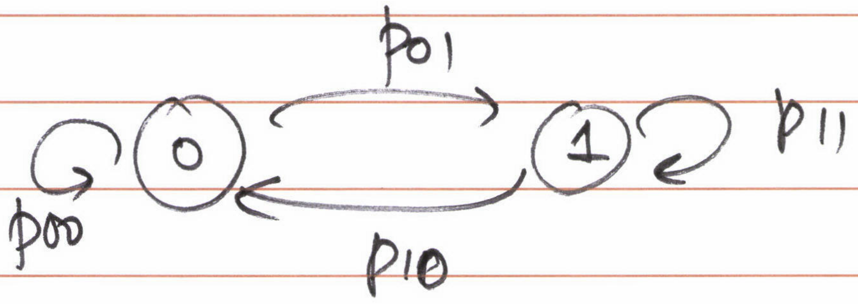
- Propagation models:
  simple path loss
- fading distributions / Shading distributions:
  - Log-normal
  - Rayleigh
  - Nakagami-m

  } - Outage Prob.
  - Average Prob. of error
- Time varying fading model
  - Markovian fading process

slow vs. fast fading:
depends on mobility / dynamics in the environment



2-state Markov Channel



$$\pi_0 = \frac{p_{10}}{p_{10} + p_{01}} \qquad \pi_1 = \frac{p_{01}}{p_{01} + p_{10}}$$

$$= 1 - \pi_0$$

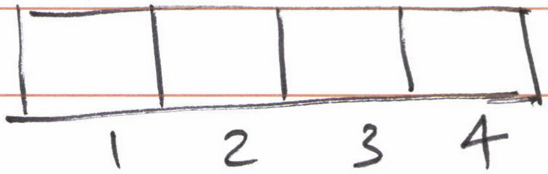
"Slow fading" $p_{01} = 0.2$ & $p_{10} = 0.2$

"fast fading" $p_{01} = 0.9$ & $p_{10} = 0.9$

$$\boxed{\begin{aligned} \pi_1 &= 1/2. \\ \pi_0 &= 1/2 \end{aligned}}$$

Digression: Example of way the 2-state Gilbert-Elliot model

Opportunistic Spectrum Access (Cognitive Radio)



Model each channel as a Gilbert Eliot channel, i.e.

Markovian w/ 2 state 0 - bad
1 - good.

$\mathbb{P}$ matrix is the same for each channel

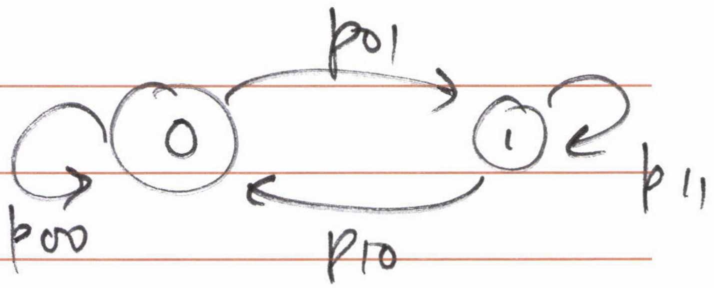
at each time the transmitter can pick 1 channel to sense & the receiver is synchronized.

The goal is to maximize the total Data transferred.

Ch 1	0	0	1	1	1	1	0
Ch 2	0	1	1	0	0	1	1
Ch 3	1	1	1	1	1	0	0
Ch 4	0	0	0	0	1	1	1

→ time

$$\underbrace{p_{11} > p_{01}}_{\text{positive correlation}}$$



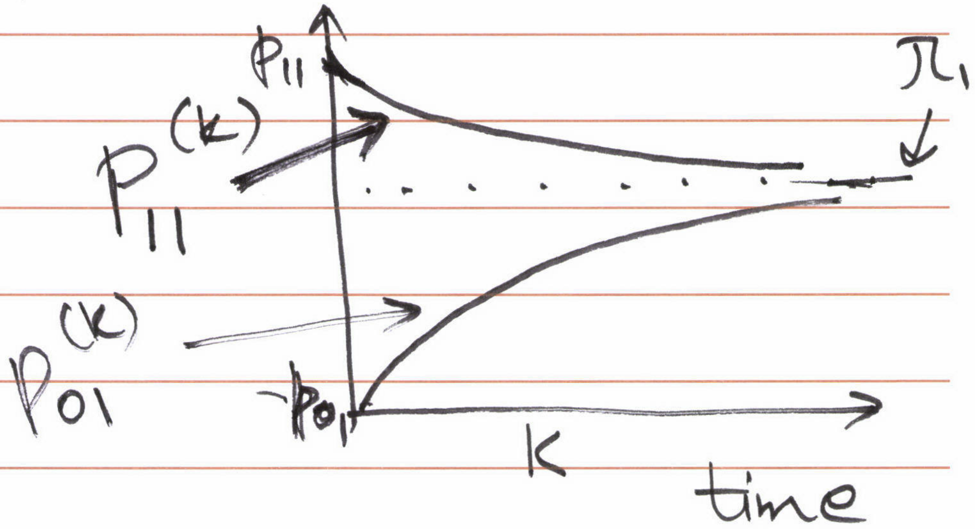
"slow" fading

Turns out that the optimal policy is a Round Robin policy:

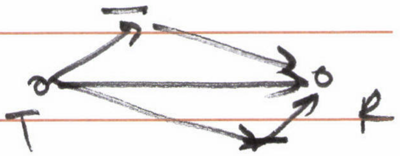
stick with the same channel if it is presently in state 1 (gd)

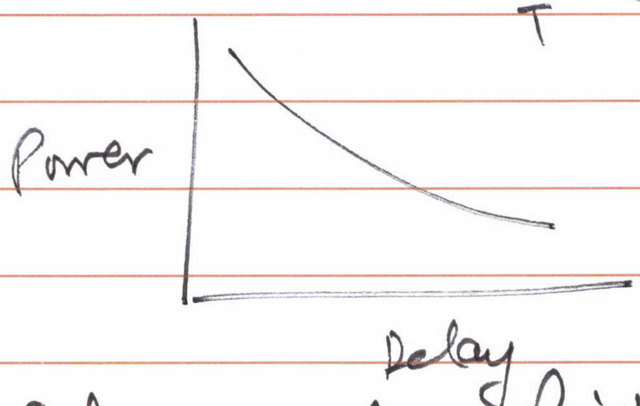
else switch to the next channel in circular order

$p_{01} < \pi_1 < p_{11}$

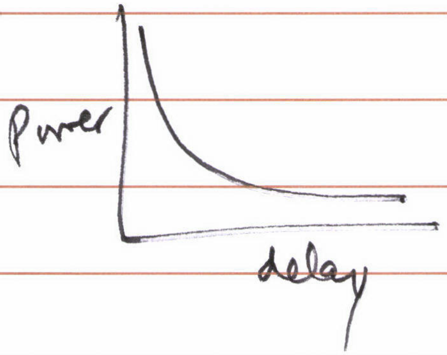


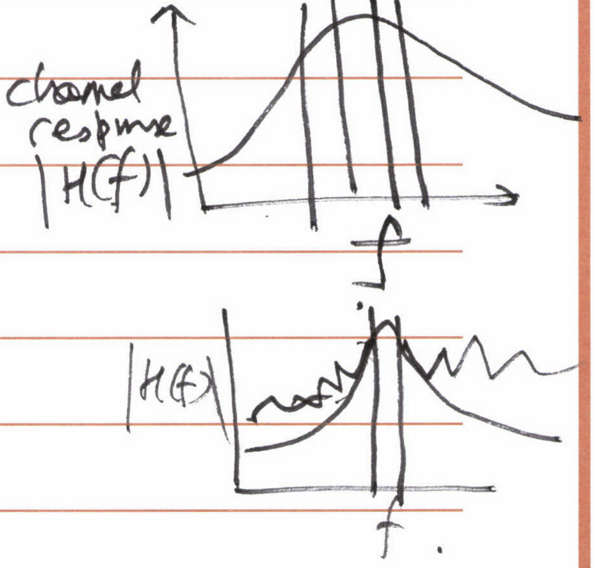
Delay Spread

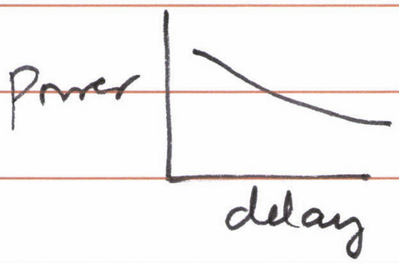




If the Delay spread is high, From a frequency perspective, the channel will show frequency-specific attenuation / distortion → frequency selective fading







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$$B_c \propto \frac{1}{\sigma_D}$$

Coherence Bandwidth $\propto \dfrac{1}{\text{Delay Spread}}$

If B_c is large → flat fading

" small → frequency-selective fading

Power delay profile $A(\tau)$

Average delay spread $= \dfrac{\int_0^\infty \tau A(\tau)\,d\tau}{\int_0^\infty A(\tau)\,d\tau} = \mu_D$

$\approx$

(Expectation)

RMS delay spread $\sigma_D = \sqrt{\dfrac{\int_0^\infty (\mu-\tau)^2 A(\tau)\,d\tau}{\int_0^\infty A(\tau)\,d\tau}}$

$\approx$

(std. deviation)

Small scale : ~10's nanosecond

large scale : ≈ 10 μs

Inter-Symbol Interference :

smearing of adjacent symbols

To avoid ISI

$$T_s > 10\sigma_D$$

e.g.

σ_D : 10ns $T_s > 100$ ns/symbol

i.e. Symbol rate < 10 M~~s~~symbols/sec

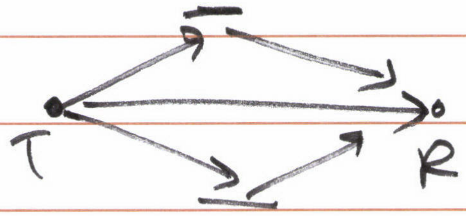
σ_D : 1μs $T_s > 10$ μs/symbol

symbol rate < 100 ksymbols/sec

ISI solutions:

- Equalization : Corrects for the freq. distortion (requires learning/training)
- OFDM : divide data stream into multiple lower-rate subcarrier streams
- Rake Receiver for CDMA

Mobility



Doppler Spread : frequency shifts due to mobility

$$f_d \propto \frac{V_{max}}{\lambda_c}$$

Coherence time $\propto \frac{1}{\text{Doppler Spread}}$

$$T_c \propto \frac{1}{f_d}$$

When T_c is high, we say the channel is showing slow fading when it is low, we have fast fading.

Two complementary perspectives on Fading in Wireless channels

Flat vs Frequency Selective	Slow vs Fast
• Caused by different lengths of multipath components	• caused by mobility
• Delay Spread Coherence BW	• Doppler Spread Coherence Time
• depends on $A(\tau)$	• depends on velocity V_{max}
• ISI	• duration of fade
	• lower/higher overhead for training/learning the channel state

learning the channel state is feasible.

	Slow	fast
Flat	most benign	Coding increase power based on fading margin
Freq. Selective	Equalization	most harsh coding + OFDM

Coming up:

- Coding
- OFDM
- CDMA
- Diversity & MIMO

phy layer topics in Wireless Networks