W

EE 597 — July 13, 2016

About the midterm exam:

Q2 & Q3

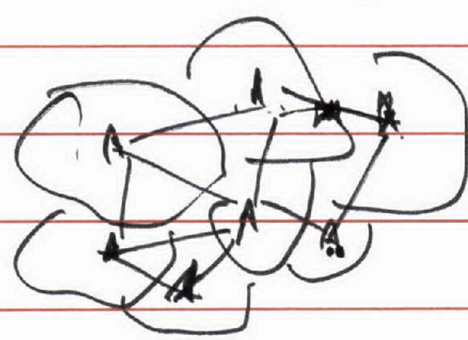
└ involved modeling of the problem
- identifying relevant expressions or conditions
- formulating the optimization problem
- stochastic channels.

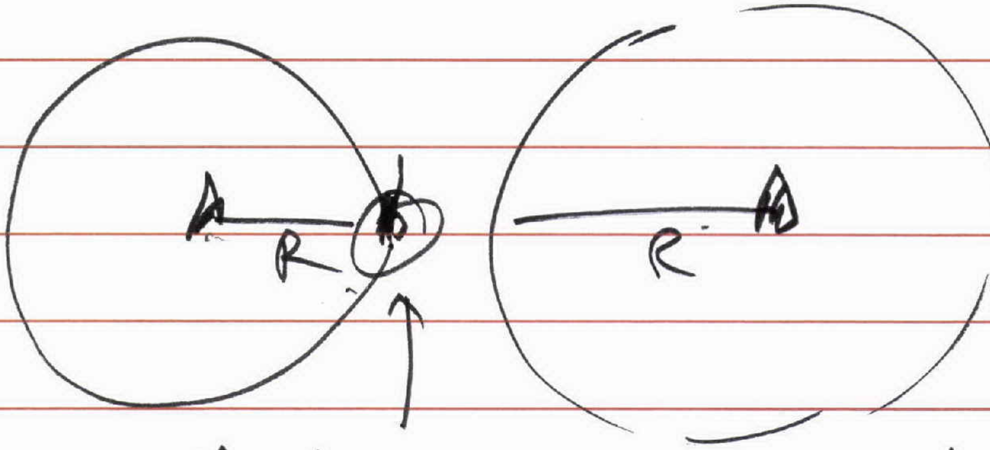
needs the 503 prereq.

Why do we bring in Probability into Wireless Networks?

How much do we really need?

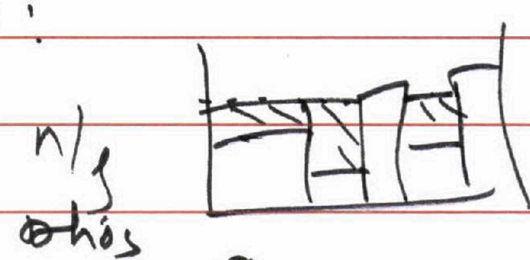
E.g.: (log normal fading) ← channel quality is random





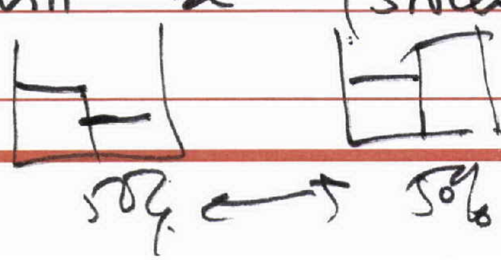
cell-Edge user experiencing the lowest SINR

Waterfilling:



only suitable for slow fading channels.

For fast fading, the (g/n) ratios will be (stochastically varying)

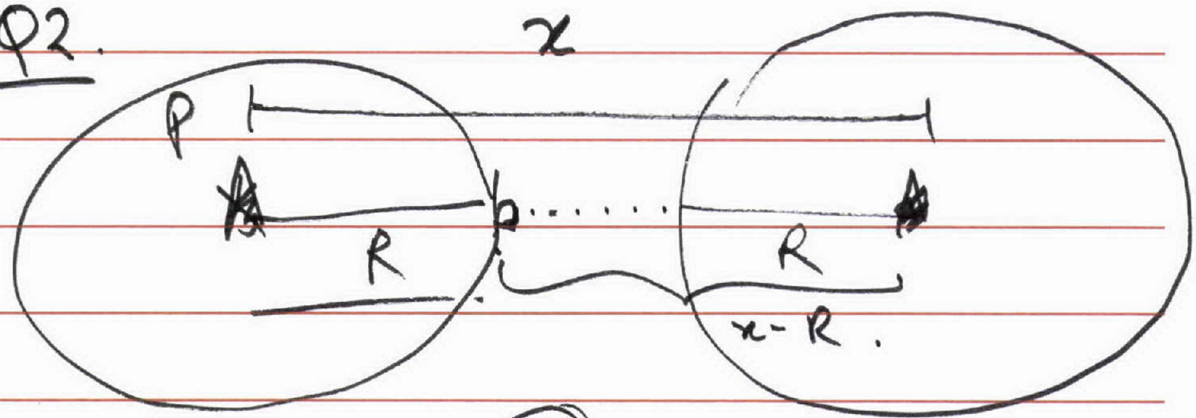


Time constant of change determines whether we can solve the problem as a classical/deterministic optimization problem or as a stochastic/probabilistic optimization problem.

typically: given some variable that has a distribution, & the performance objective depends on it. Goal: max the Expected Performance.

i.e it is unknown / has uncertainty.

Q2.



a). $SINR = \dfrac{S}{I+N}$ $\quad x-R.$

$$\frac{P \cdot \left(\frac{R}{d_0}\right)^{-\eta} \cdot K \cdot \psi_1}{P \cdot \left(\frac{x-R}{d_0}\right)^{-\eta} \cdot K \cdot \psi_2 + N} > T$$

lognormal r.v.

both lognormal r.v.

b) Rewrite in the log scale: $\sim N(0, \sigma^2)$

$$SIR_{dB} = P_{dBm} - \eta 10 \log_{10}\left(\frac{R}{d_0}\right) + \psi_{1_{dB}} - \left(P_{dBm} - \eta 10 \log_{10}\left(\frac{x-R}{d_0}\right) + \psi_{2}{dB}\right)$$

$Y \sim N(0, 2\sigma^2)$

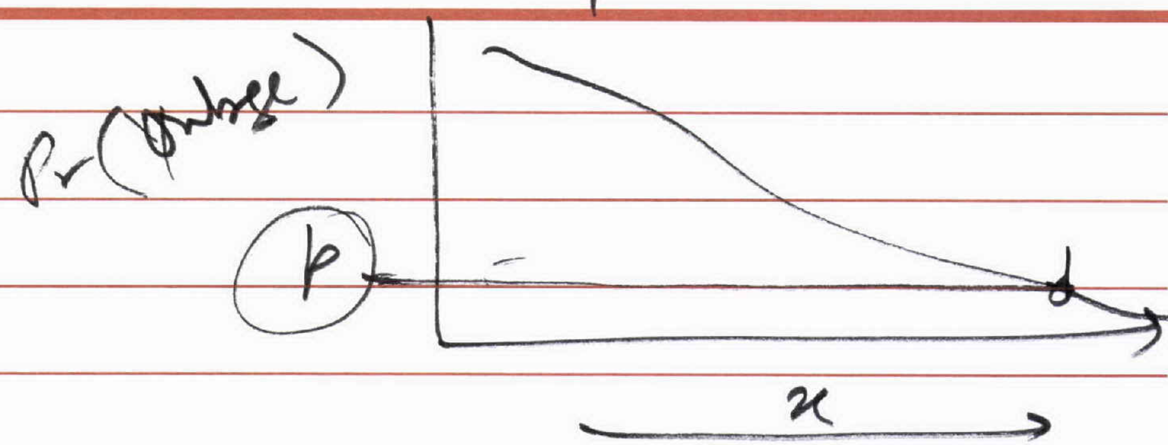
for outage

$$\Psi_{1dB} - \Psi_{2dB} - \eta 10\log_{10}(R) + \eta 10\log_{10}(R-x) < T_{dB}$$

Normal r.v.

$$Y < T_{dB} - \eta 10\log_{10}(R) + \eta 10\log_{10}(R-x)$$

Pr of outage → $cdf_Y(\;\;)$



Q3. max the expected Sum Rate:

$$\log\left(1 + \frac{P_1 g_1}{n_1}\right) +$$

$$0.5 \log\left(1 + \frac{P_2 g_2}{n_2}\right)$$

$$0.5 \log\left(1 + \frac{P_2 G_2}{N_2}\right)$$

$$? \quad \log\left(1 + 0.5 P_2 \frac{g_2}{n_2} + 0.5 P_2 \frac{G_2}{N_2}\right)$$

Expected Rate for ch 2. Expected SNR.

$$E[f(X)] \neq f(E[X])$$

Expected (log(1+SNR)) ≠ log(1+E[SNR])

Can also formulate as:

$$f(x) = \log\left(1 + x\frac{g_1}{n_1}\right) +$$

$$\frac{1}{2}\left(\log\left(1 + (P_{tot} - x)\cdot\frac{g_2}{N_2}\right) + \log\left(1 + (P_{tot} - x)\frac{G_2}{N_2}\right)\right)$$

$$0 \le x \le P_{tot}$$

$$\frac{d f(x)}{dx} = 0$$

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more general case: arbitrary pmf for each channel.

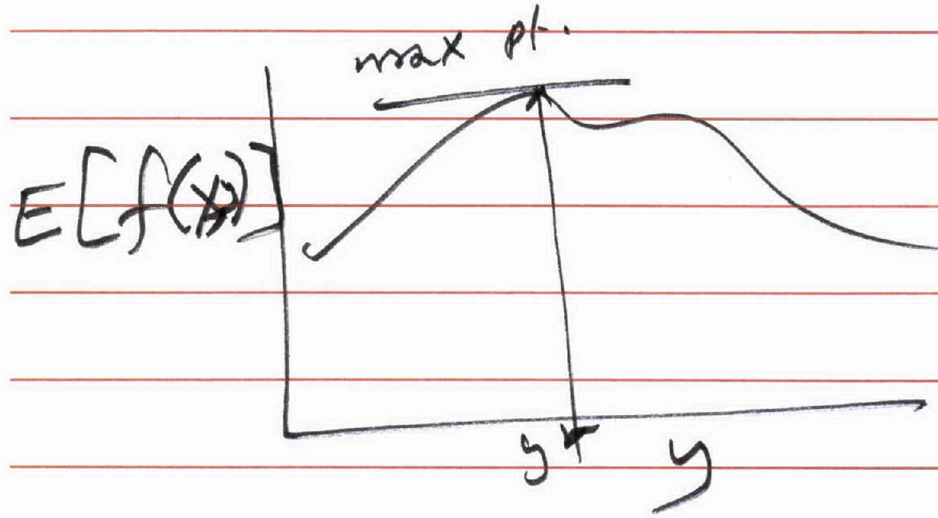
$$\text{Rate 1} = E[\log(1 + SNR_1)]$$

$$\text{Rate 2} = E[\log(1 + SNR_2)]$$

$$E[f(X)] = \sum_{x_k} P_X(x_k)\cdot f(x_k)$$

$$\log\left(1 + P_1\frac{g_1}{n_1}\right)$$

x_k



r.v.

say the r.v. / parameter(s) with uncertainty in the problem is $\underline{X}$ (random vector)

The design variable(s) which we can control (to improve performance) is → $\underline{y}$

deterministic, not random

Performance metric $f(\underline{X}, \underline{y})$

depends on uncertain env. & the design variable

In the waterfilling pblm:

$f(\underline{X}, \underline{y})$ metric: sum of expected rates.

$$E[\log(1+SNR_1)] + E[\log(1+SNR_2)]$$

$\underline{X}$, $\underline{y}$

$$SNR_1 = P_1 \frac{g_1}{n_1} \qquad SNR_2 = P_2 \frac{g_2}{n_2}$$

$\underline{y}$

$$\underset{\underline{X}}{E}[f(\underline{X}, \underline{y})] \leftarrow g(\underline{y})$$

is expectation wrt to the (jt.) distribution of $\underline{X}$

It is a deterministic function of y alone, has no dep. on $\underline{X}$ anymore.

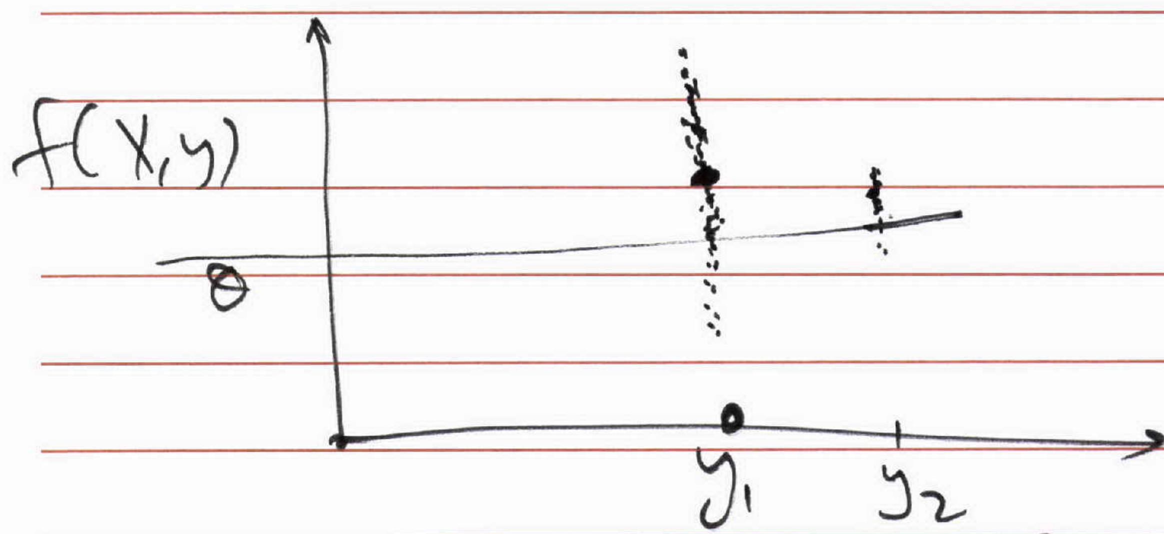
Goal:
$$\max_{y} g(y)$$

Given uncertain environment $\underline{X}$, design $\underline{y}$, performance metric $f(\underline{X}, \underline{y})$

1. max $E[f(\underline{X}, \underline{y})]$

2. ensure that $Pr[f(\underline{X}, y) < \theta]$ is as low as possible.
also θ is $f(y)$

Performance for a fixed y.



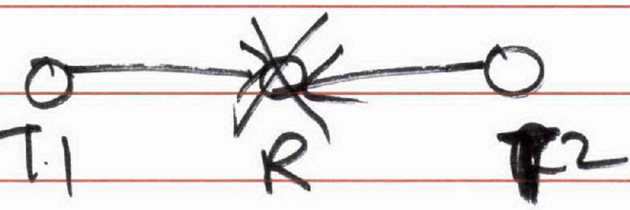
$$E[f(X, y_1)] > E[f(X, y_2)]$$

but $Pr[f(X, y_2) < \theta] > Pr[f(X, y_1) < \theta]$

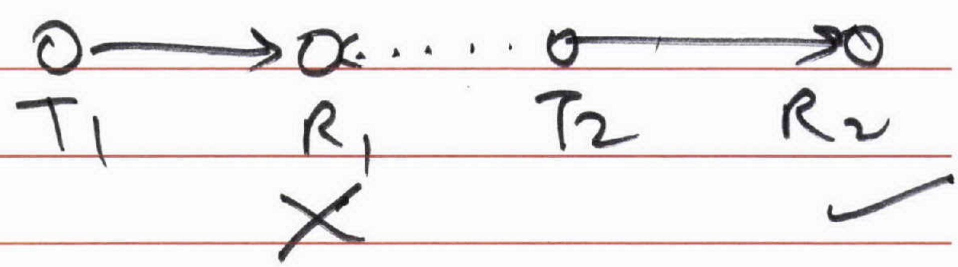
Wrap up on LINK/MAC layer

RTS-CTS mechanism for CSMA

Hidden Node/Terminal Problem.



"Unexpected" Collisions



~~prbm occurs because~~
sensing is at the sender

sender sends RTS - request to send

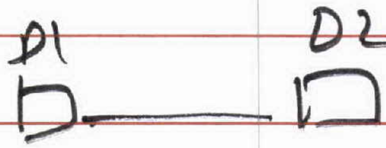
Rcvr sends CTS - clear to send, if channel is free at the receiver.

Reduces collisions but has higher overhead

New Class of MAC protocols have been developed in the last 10-15 years for "Low-Power Wireless Embedded Devices" that are a significant part of the future IoT systems

Internet of Things

Often involve Energy-constrained devices running on batteries, that for long lifetimes must spend a lot of time asleep.



option 1: schedule the sleep (Synchronous sleep) periods & only communicate during known active times.

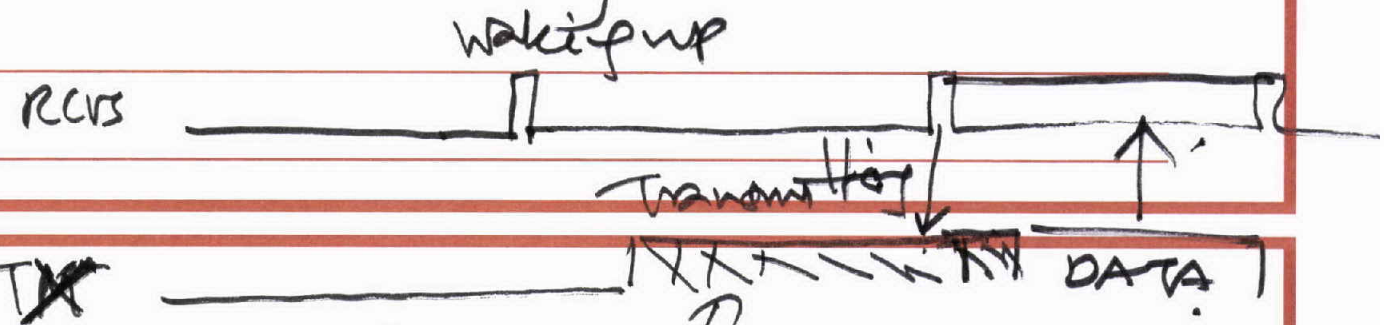
a). low power devices are typically using cheap HW → get desynchronized

b) mobility

Option 2 Asynchronous sleep.

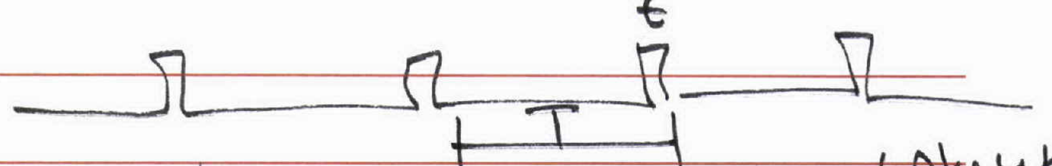
1. Transmitter - Initiated schemes
2. Receiver - Initiated schemes.

1. Also called Low Power Listening:



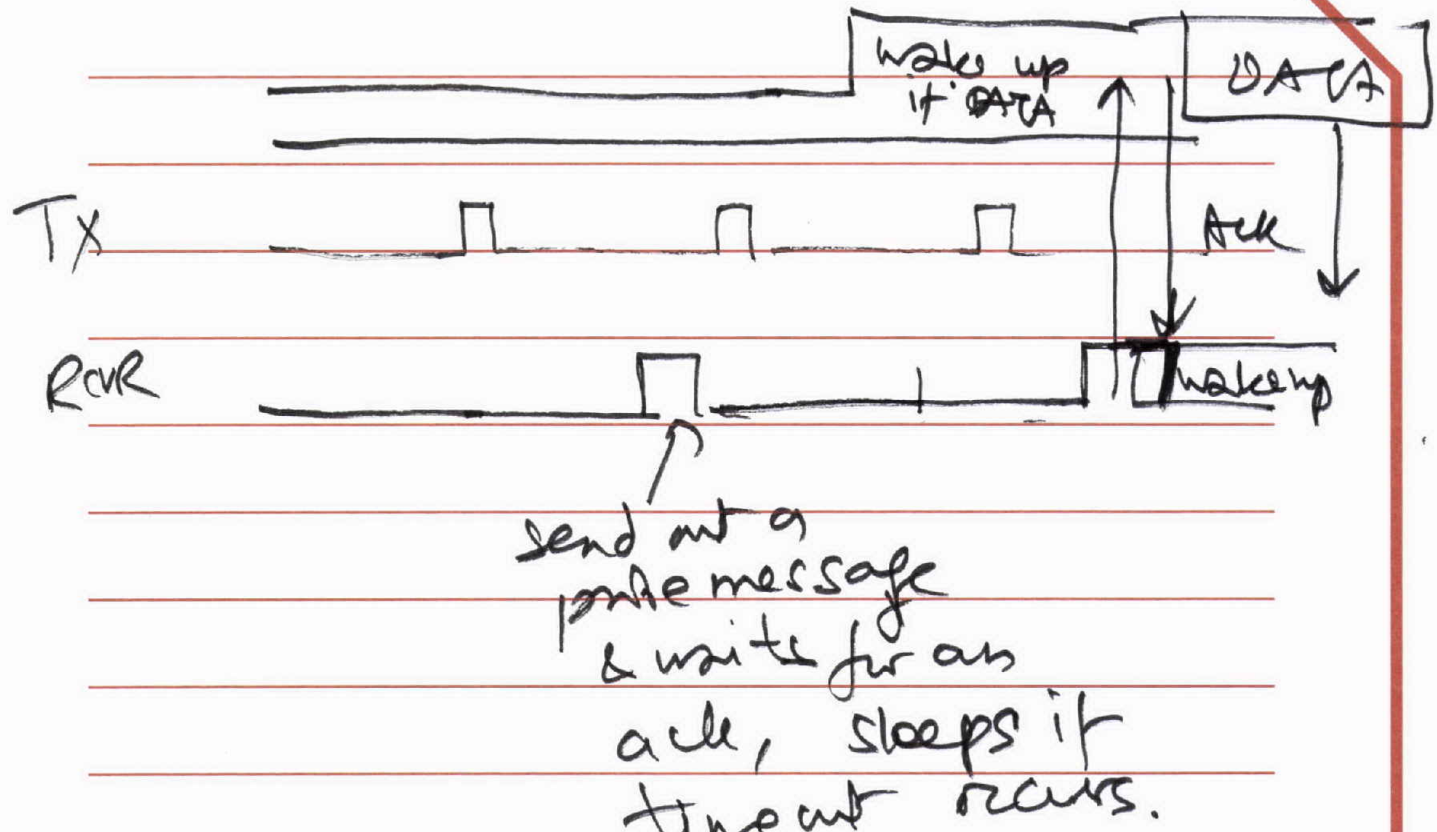
how long? (Long) preamble

common case: (no data)



$\frac{t}{T}$ = duty cycle: $\frac{\text{wakeup}}{\text{total period}}$

Preamble length > total period length.
T



Many Asynchronous Duty Cycled Sleep based MAC protocols (LPL XMAC AMAC) exist for Low Power Wireless/IoT devices.