EE359 – Lecture 19 Outline

● **Announcements**
  ● HW due Fri; last HW posted, due Sunday 12/10 at 4 pm (no late HWs)
  ● Last lecture Thu 12/7 10-11:50 (course review + advanced topics)
  ● Final exam info on next slide
  ● Final exam 12/13, 12:15pm-3:15pm in Thornton 102
  ● Final projects must be posted 12/9 at midnight.
  ● 25 bonus points for course evaluations (online)

● **Random Access**

● **Cellular System Design**

● **Multiuser Detection**

● **Area spectral efficiency**
Final Exam Announcements

- Final 12/13/2017, 12:15-3:15pm in Thornton 102 (here)
- Similar format to MT, but longer: open book, notes.
  - If you need a book or calculator, let us know by 12/8 (Fri)
- Practice finals posted (10 bonus points)
  - Turn in for solns, by exam for bonus pts
- Course summary and bonus lecture on advanced topics Thursday 10-11:50am, here
- Final review and discussion section: Monday, 12/11, 2-4pm, Packard 364.
OHs leading up to final exam

- Mine
  - This week: today and Thu after class, Fri 12-1pm & by appt.
  - Next week: Sun 12/10: 5-6pm, Tue 12/11 10:30-12 & by appt.

- TAs:
  - Wednesday, 12/6, 2-5pm Tom Email OH
  - Wednesday, 12/6, 5-6pm Discussion session
  - Thursday, 12/7, 5-6pm Milind OH
  - Thursday, 12/7, 6-7pm Milind Email OH
  - Saturday, 12/9, 2-4pm Tom OH (HW8 + Exam questions)
  - Monday, 12/11, 2-4pm Final review
  - Monday, 12/11, 4-6pm Tom OH
  - Tuesday, 12/12 2-4pm Milind OH
  - Wednesday, 12/13, 9:30am-11:30am, Tom OH
Review of Last Lecture
Direct Sequence Spread Spectrum

- Bit sequence modulated by chip sequence

- Spreads bandwidth by large factor (G)
- Despread by multiplying by $s_c(t)$ again ($s_c^2(t)=1$)
- Mitigates ISI and narrowband interference
Review Continued
ISI/Interference Rejection and RAKE Receivers

- **Narrowband Interference Rejection (1/K)**

- **Multipath Rejection (Autocorrelation $\rho(\tau)$)**

- **RAKE RX coherently combines multipath**
Multiuser Channels

**Downlink (Broadcast Channel or BC):**
One Transmitter to Many Receivers.

**Uplink (Multiple Access Channel or MAC):**
Many Transmitters to One Receiver.

Uplink and Downlink typically duplexed in time or frequency

Full-duplex radios are being considered for 5G systems
Review Continued:
Bandwidth Sharing in Multiple Access

- Frequency Division
  - OFDMA

- Time Division

- Code Division
  - Code cross-correlation dictates interference
  - Multiuser Detection

- Space Division (SDMA)

- Hybrid Schemes
Random Access

- In multiple access, channels are assigned by a centralized controller
  - Requires a central controller and control channel
  - Inefficient for short and/or infrequent data transmissions
- In random access, users access channel randomly when they have data to send
  - A simple random access scheme will be explored in homework

ALOHA Schemes (not on exams/HW)
- Data is packetized.
- Packets occupy a given time interval

- Pure ALOHA
  - send packet whenever data is available
  - a collision occurs for any partial overlap of packets (nonorthogonal slots)
  - Packets received in error are retransmitted after random delay interval (avoids subsequent collisions).

- Slotted ALOHA
  - same as ALOHA but with packet slotting
  - packets sent during predefined timeslots
  - A collision occurs when packets overlap, but there is no partial overlap of packets
  - Packets received in error are retransmitted after random delay interval.
Cellular System Design

- Frequencies/time slots/codes reused at spatially-separated locations
  - Exploits power falloff with distance.
  - Best efficiency obtained with minimum reuse distance
- Base stations perform centralized control functions
  - Call setup, handoff, routing, etc.
- Ideally, interference results in SINR above desired target.
  - The SINR depends on base station locations, user locations, propagation conditions, and interference reduction techniques.
  - System capacity is interference-limited as SINR must be above target
  - MIMO introduces diversity-multiplexing-interference reduction tradeoff
  - Multiuser detection reduces inter/intracell interference: increases capacity
Multiuser Detection

- Multiuser detection (MUD) exploits the fact that the structure of the interference is known
  - Maximum likelihood: exponentially complex in number of users $N$
  - Successive interference cancellation (SIC)

Why not ubiquitous today? Power, A/D Precision, Error propagation
Area Spectral Efficiency (ASE)

- System capacity due to optimal cell size and/or reuse distance: \( A_e = \Sigma R_i / (0.25D^2\pi) \) bps/Hz/Km^2.

Area Spectral Efficiency
\[ \Lambda = 0.25D^2\pi \]

- S/I increases with reuse distance (increases link capacity).
- Tradeoff between reuse distance and link spectral efficiency (bps/Hz).
- Capacity increases exponentially as cell size decreases
- Future cellular systems will be hierarchical
  - Large cells for coverage, small cells for capacity
Main Points

- Random access more efficient than multiple access for short/infrequent data transmission

- Cellular systems reuse time/freq/codes in space
  - Interference managed to meet SINR targets
  - Interference reduction increases capacity
  - MIMO trades diversity-multiplexing-interference reduction

- Multiuser detection mitigates interference through joint or successive detection

- Area spectral efficiency captures system capacity as a function of cell size and reuse distance
  - Small cells and reuse 1 distance typical of next-gen cellular