EE359 – Lecture 19 Outline

- Announcements
  - Text lecture questions: Andrea (6507668317) or Tom (8602713721)
  - OHs via Skype or Zoom
  - Last HW due Fri midnight
  - Last lecture Thu 3/12 1:30-3:30 (course review+advanced topics)
  - Final exam info on next slide
  - Final projects must be posted 3/14 at midnight.
  - Bonus points: make your own HW problem; course evaluations (online)
  - Will announce typo gift card winners after final exam
- Multiple Access
- Random Access
- Cellular System Design
- Multiuser Detection
- Area spectral efficiency

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Final Exam Announcements

- Final 3/17, 3:30-6:30, test emailed, send back photo of exam book or scanned copy
- Covers Chapters 9, 10, 12, 13.1-13.2, 13.4, 14.1-14.4, 15.1-15.4 (+ earlier chps)
- Similar format to MT, but longer: open book, notes, no Wi-Fi or Matlab or collaboration with others.
- Practice finals posted (10 bonus points)
  - Turn in for solns, by exam for bonus pts
- Course summary and bonus lecture Th 1:30-3:30pm
- Final review and discussion section during Tom's regular OHs Wednesday (on Zoom)
- Extra OHs: Andrea, M 3-4pm, T 10:30-11:30 and 1:30-2:30; Tom: F 5-6pm, M 10-11 and 5-6pm (live or via Skype)

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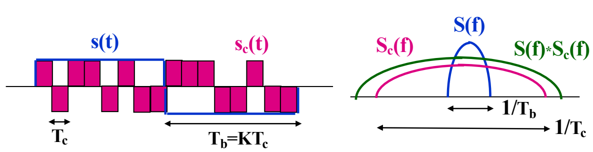
Review of Last Lecture
Direct Sequence Spread Spectrum

- 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

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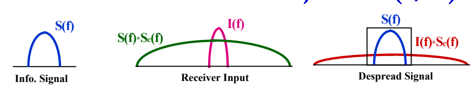
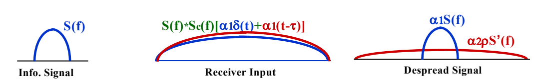
Review Continued
ISI/Interference Rejection and RAKE Receivers

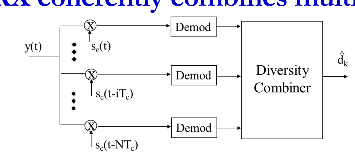
- Narrowband Interference Rejection (1/K)



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



- RAKE RX coherently combines multipath



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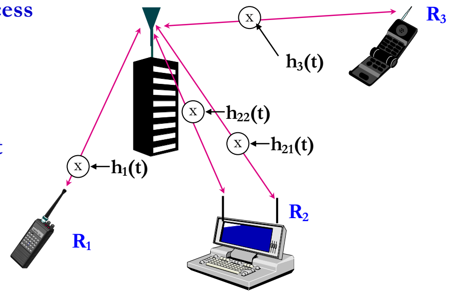
Review Continued
Multiuser Channels

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

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



Uplink and Downlink typically duplexed in time or frequency

Full-duplex radios are being considered for 5G systems

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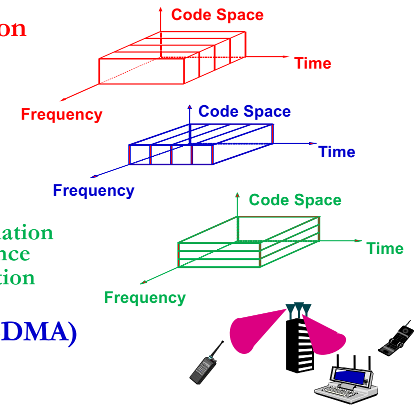
Review Continued:
Bandwidth Sharing in Multiple Access

- Frequency Division
  - OFDMA
- Time Division
- Code Division
  - Code cross-correlation dictates interference
  - Multiuser Detection
- Space Division (SDMA)
- Hybrid Schemes



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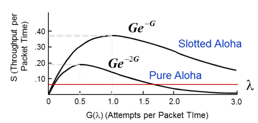
Random Access

- 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.

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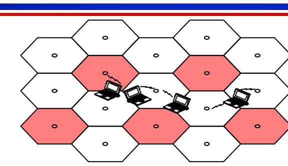
Cellular System Design



- 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

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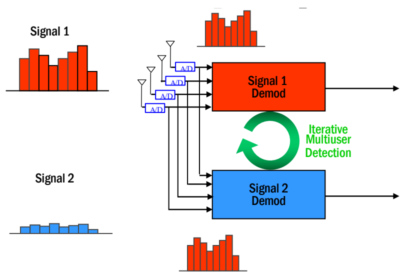
Multiuser Detection

- 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) has near-far problem



Why not ubiquitous today? Power, A/D Precision, Error propagation

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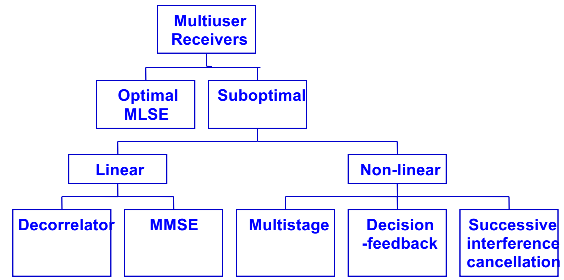
MUD Algorithms
(not in lecture/HW/exams)



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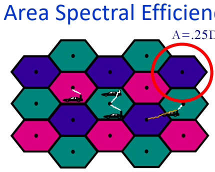
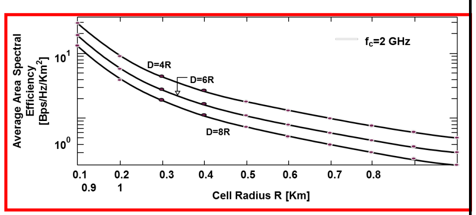
Area Spectral Efficiency (ASE)

- System capacity due to optimal cell size and/or reuse distance: $A_e = \Sigma R_i/(.25D^2\pi)$ bps/Hz/Km^2.

Area Spectral Efficiency





- 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

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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

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