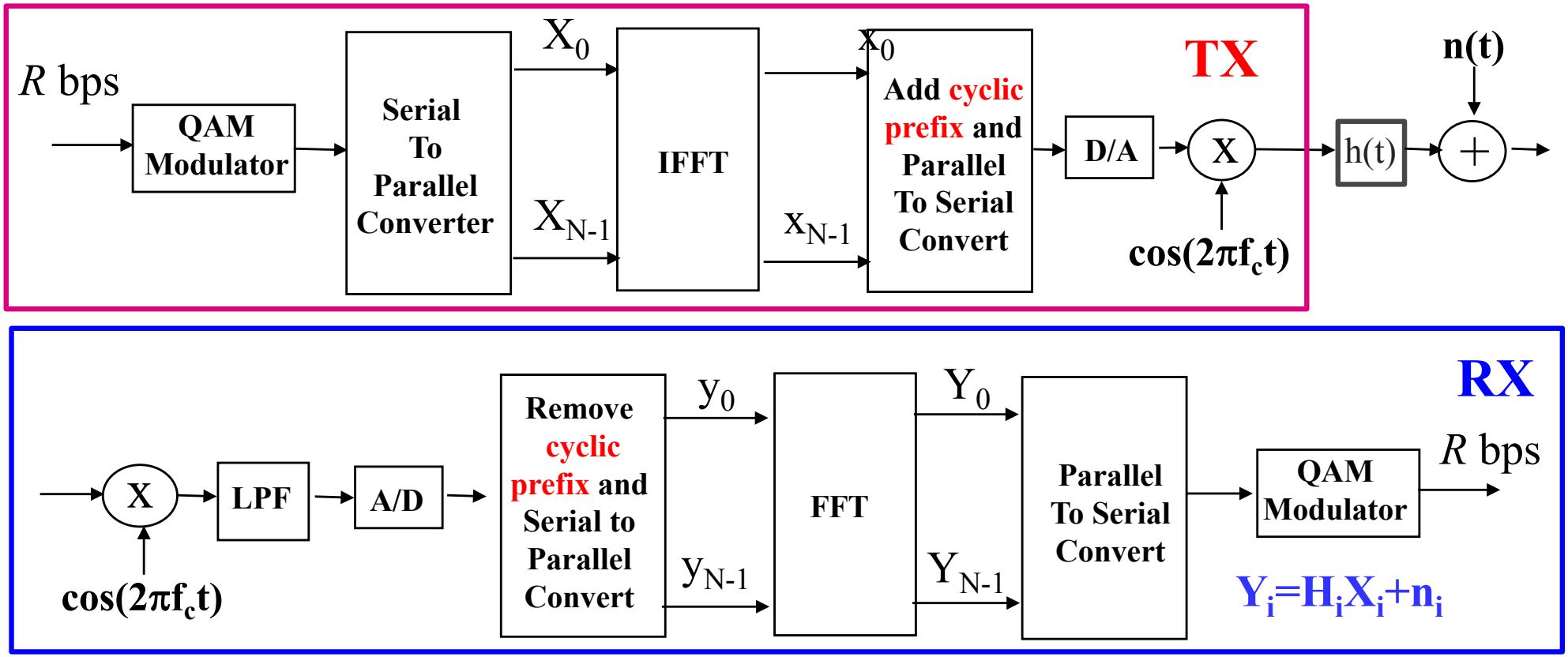
EE359 – Lecture 18 Outline

- Announcements
  - HW due Fri; last HW posted, due Sunday 12/10 at 4 pm (no late HWs)
  - Lecture next Thu 12/7 10-11:50 (course review+advanced topics)
  - Final info (coverage, format, extra OHs, etc) given in 12/5 lecture
  - Final exam 12/13, 12:15pm-3:15pm in Thornton 102
  - Final projects must be posted 12/9 at midnight.
- Spread Spectrum
  - Direct sequence (DSSS)
  - ISI and Interference Rejection of DSSS
  - RAKE Receiver
- Multiuser Systems
  - Multiple access techniques
  - Random access techniques

Review of Last Lecture

MCM, Overlapping Subcarriers and FFT Implementation (OFDM)

- MCM splits high rate data stream into lower rate flat-fading substreams
- Overlapping subcarriers reduces BW by factor of 2
- Modulate symbols with IFFT at TX, Reverse structure (with FFT) in RX
- Cyclic prefix makes linear convolution of channel circular, so no interference between FFT blocks in RX processing



Review Continued
OFDM Design Issues

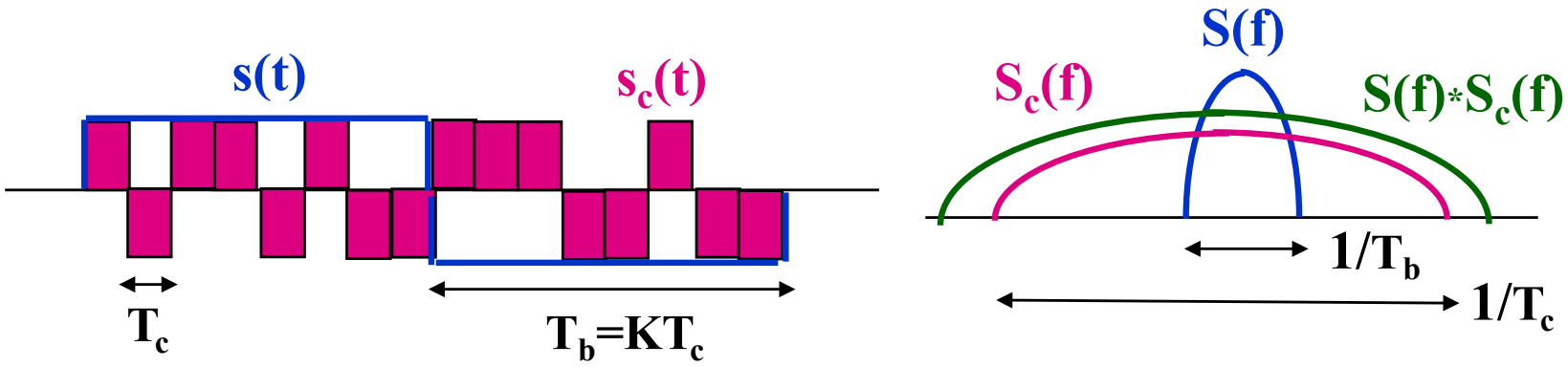
- Timing/frequency offset:
  - Impacts subcarrier orthogonality; self-interference
- Peak-to-Average Power Ratio (PAPR)
  - Adding subcarrier signals creates large signal peaks
  - Solve with clipping or PAPR-optimized coding
- Mitigation for fading across subcarriers
  - Precoding (fading inversion): Used in DSL as there is minimal deep fades, not used in wireless systems
  - Adaptive modulation: data rate (and power) adapted to subcarrier SNR. Used in LTE and 802.11a-g-n-ac
  - Coding across subcarriers: bits are encoded into a block code of length N for N subcarriers. Each coded symbol is sent on a different subcarrier.

Intro. to Spread Spectrum

- Modulation that increases signal bandwidth
  - Spreads modulated signal over wider BW $B \sim 1/T_s$ than needed for transmission ($R=\log_2(M)/T_s$)
  - Mitigates or coherently combines ISI
  - Mitigates narrowband interference/jamming
  - Hides signal below noise (DSSS) or makes it hard to track (FH)
  - Also used as a multiple access technique
- Two types
  - Frequency Hopping:
    - Narrowband signal hopped over wide bandwidth
  - Direction Sequence:
    - Modulated signal multiplied by faster chip sequence

Direct Sequence Spread Spectrum

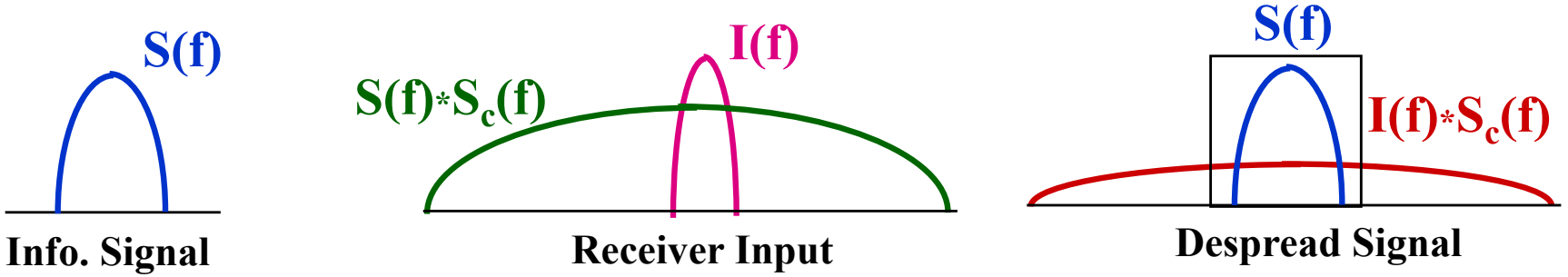
- Bit sequence modulated by chip sequence



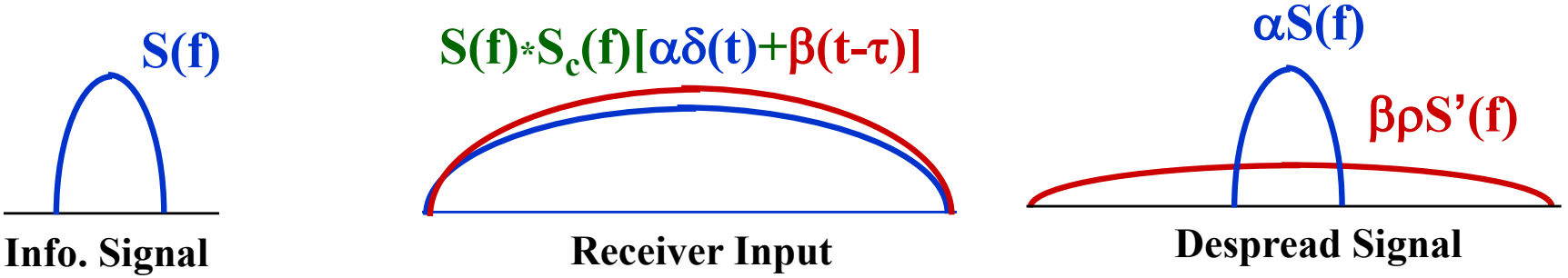
- Spreads bandwidth by large factor (G)
- Despread by multiplying by $s_c(t)$ again ($s_c^2(t)=1$)
- Mitigates ISI and narrowband interference

ISI and Interference Rejection

- Narrowband Interference Rejection (1/K)



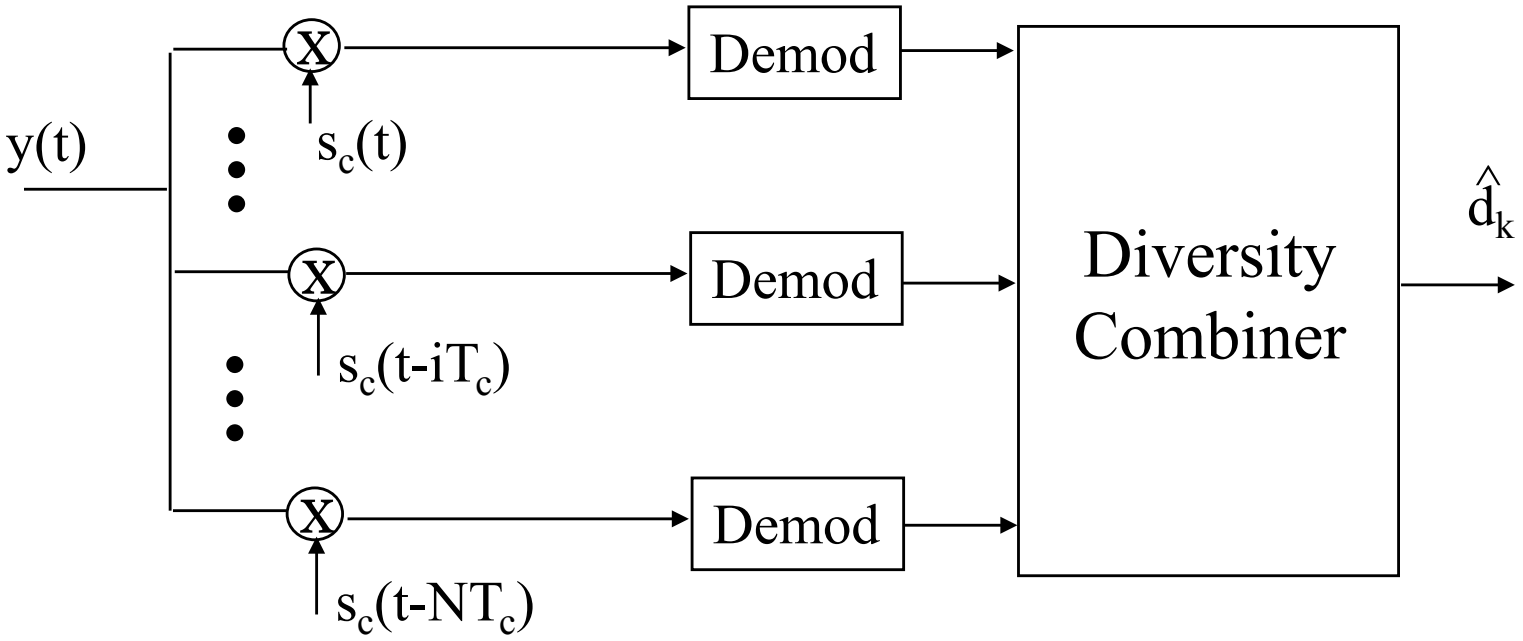
- Multipath Rejection (Autocorrelation ρ(τ))



Can coherently combine all multipath components via a RAKE receiver

RAKE Receiver

- Multibranch receiver
  - Branches synchronized to different MP components

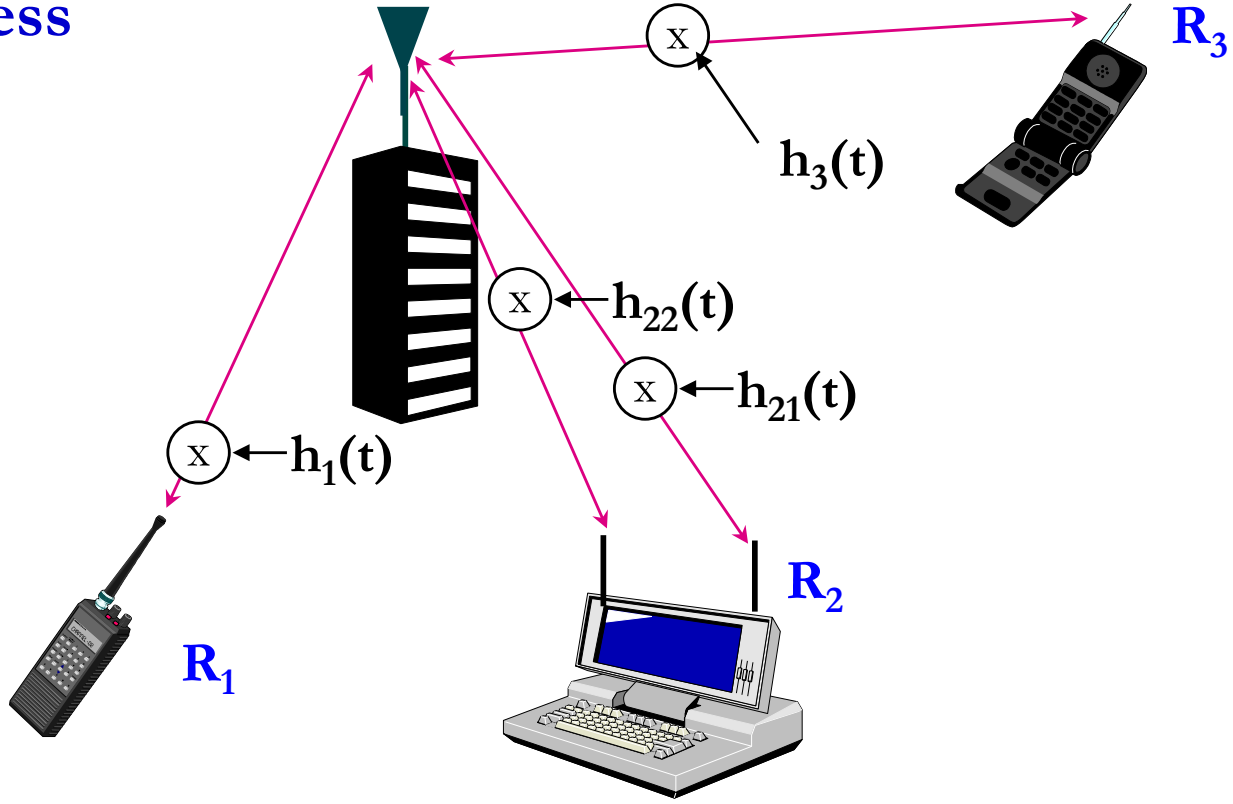


- These components can be coherently combined
  - Use SC, MRC, or EGC

Multiuser Channels: Uplink and Downlink

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

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



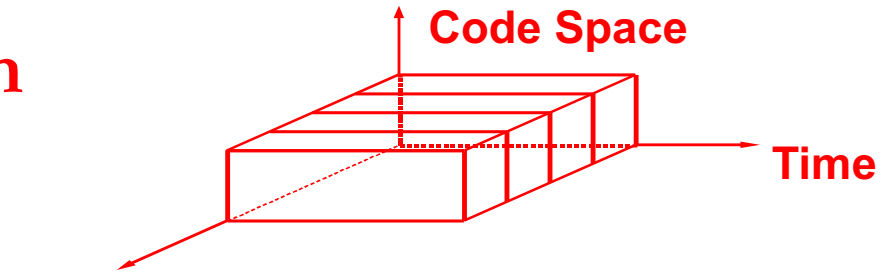
Uplink and Downlink typically duplexed in time or frequency

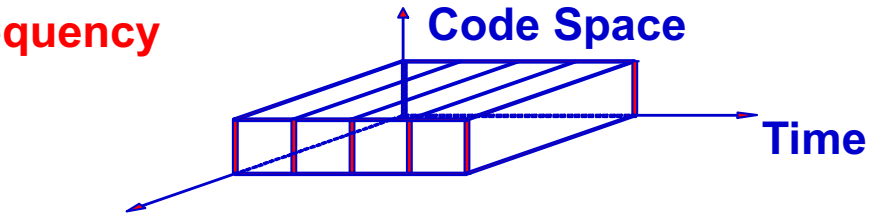
Full-duplex radios are being considered for 5G systems

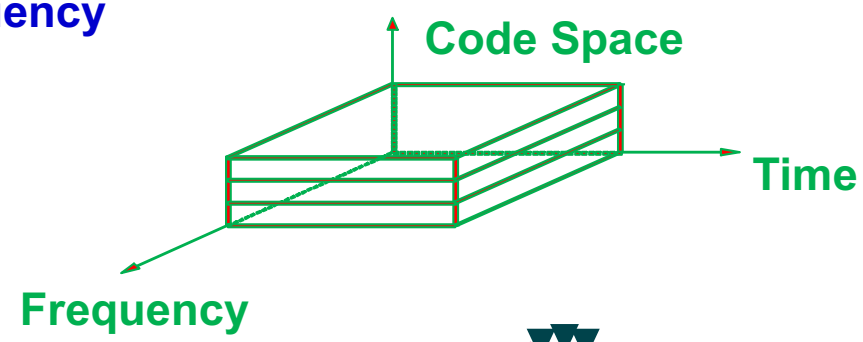
Bandwidth Sharing in Multiple Access

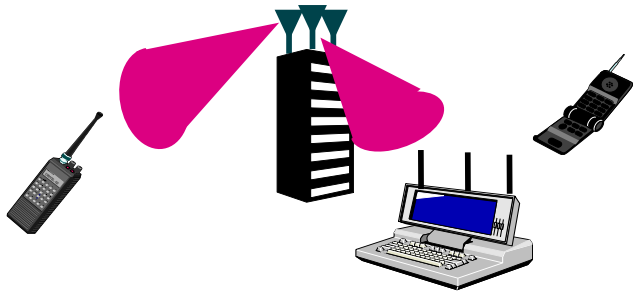
Channels assigned by central controller

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





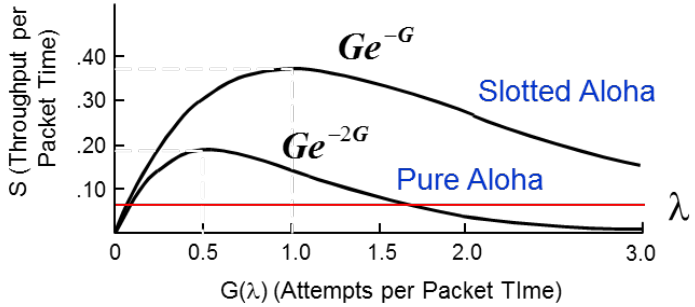




Random vs. Multiple Access

- 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.

Main Points

- Spread spectrum increases signal bandwidth above that required for information transmission
- Benefits of spread spectrum:
  - ISI/narrowband interference rejection by spreading gain
  - Also used as a multiuser/multiple access technique
- Multiple access: users can share the same spectrum via time/frequency/code/space division
- Random access more efficient than multiple access for short/infrequent data transmission