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UESTC4004
Digital Communications

Multiples Access Schemes

Lecture Overview

- Duplexing 双工
  - FDD: Frequency division duplexing 频分~
  - TDD: Time division duplexing 时分~
- 多址接入 Multiples Access Schemes
  - FDMA : Frequency division Multiple Access 频分多址
  - TDMA : Time division Multiple Access 时分~
  - SSMA : Spread spectrum Multiple Access 频展~

Introduction

一个频段（信道）

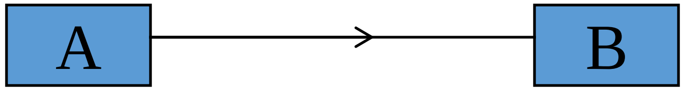
分给不同的人同时使用

- Multiple access schemes are used to allow multiple users to share simultaneously a finite amount of radio spectrum
- Sharing of spectrum is required to increase capacity
- For high quality communication this sharing of spectrum should not degrade performance of the system
- Duplexing is generally required

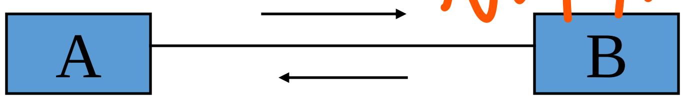
双工

Duplexing

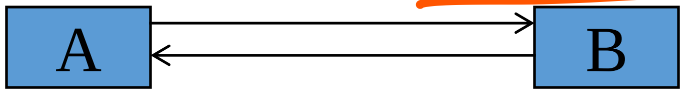
- To transmit and receive simultaneously: Possible using
  - frequency domain techniques
  - time domain techniques
- Classification of communication systems according to their connectivity
  - Simplex: ‘A’ is transmitter while ‘B’ is receiver throughout communication, e.g., radio



  - Half-duplex: A node can transmit as well as receive but can not transmit and receiver simultaneously, e.g., walkie-talkie 对讲机



  - Full Duplex: Nodes can transmit and receive simultaneously, e.g., mobile phone



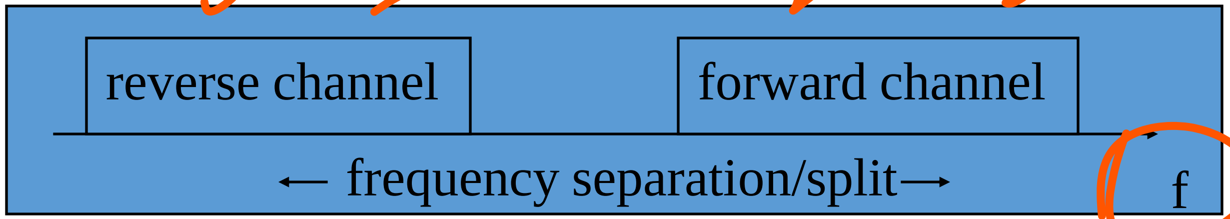
Frequency division duplexing (FDD)

- two bands of frequencies for every user
  - forward band or downlink (for traffic from Base station to mobile unit)
  - reverse band or uplink (for traffic from mobile unit to Base station)
- duplexer needed
- frequency separation between forward band and reverse band is constant throughout the system

移动 $\xrightarrow{\text{上链}}$ 基站 (反带)

移动 $\xleftarrow[\text{下链}]{}$ 基站 (正带)

移→基　　　　基→移



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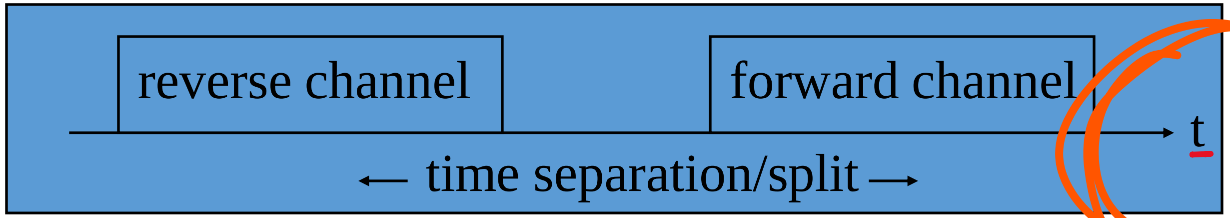
Time division duplexing (TDD)

- uses different time slots for forward and reverse link
  - forward time slot
  - reverse time slot
- no duplexer is required (a simple switch can be used)
- Communication is not full-duplex

half



Trade-offs b/w FDD and TDD

- FDD
  - Provides individual radio frequencies to each user hence, transceiver should work on two frequency bands
  - Frequency allocation must be carefully coordinated with Out-of-band users
  - Duplexer needed

用2个不同频段

- TDD
  - Single frequency hence simple transceiver
  - Duplexer not needed, a switch can do the job
  - There is time latency, communication is not full-duplex

用1个不同频段

接收发送
(2个时间)

Multiple Access Techniques in Wireless Communication System

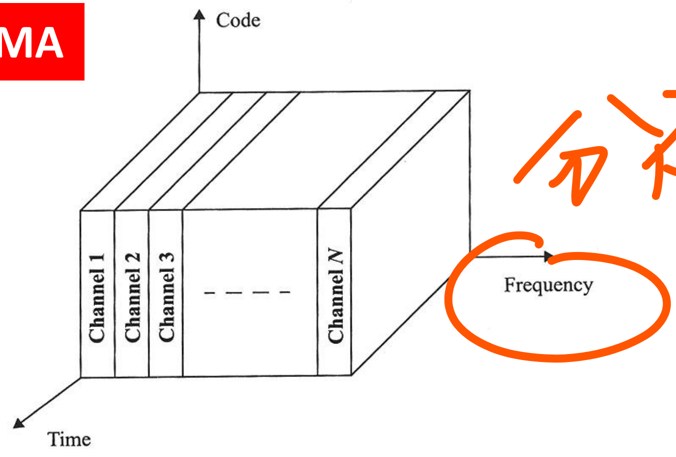
多址接入

- Frequency division multiple access (FDMA) 频
- Time division multiple access (TDMA) 时
- Code division multiple access (CDMA) 码
- Space division multiple access (SDMA) 空

分

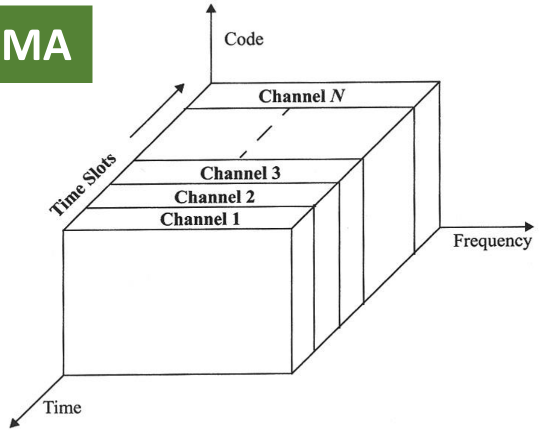
Multiple Access Techniques

FDMA



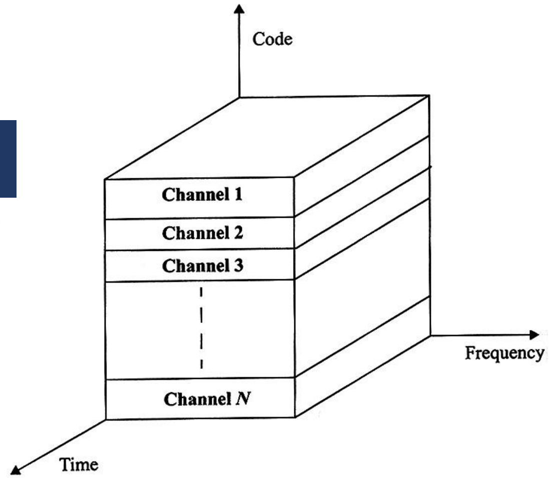
分不同频段

TDMA

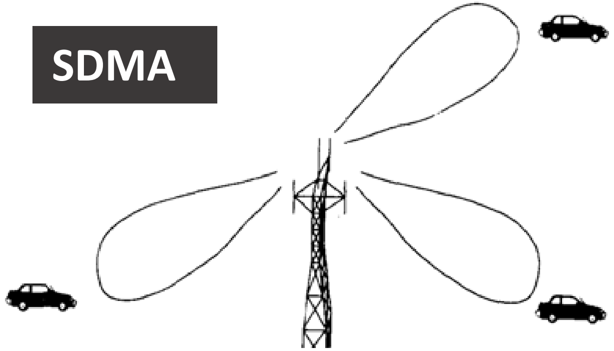


分不同时间(片段)

CDMA

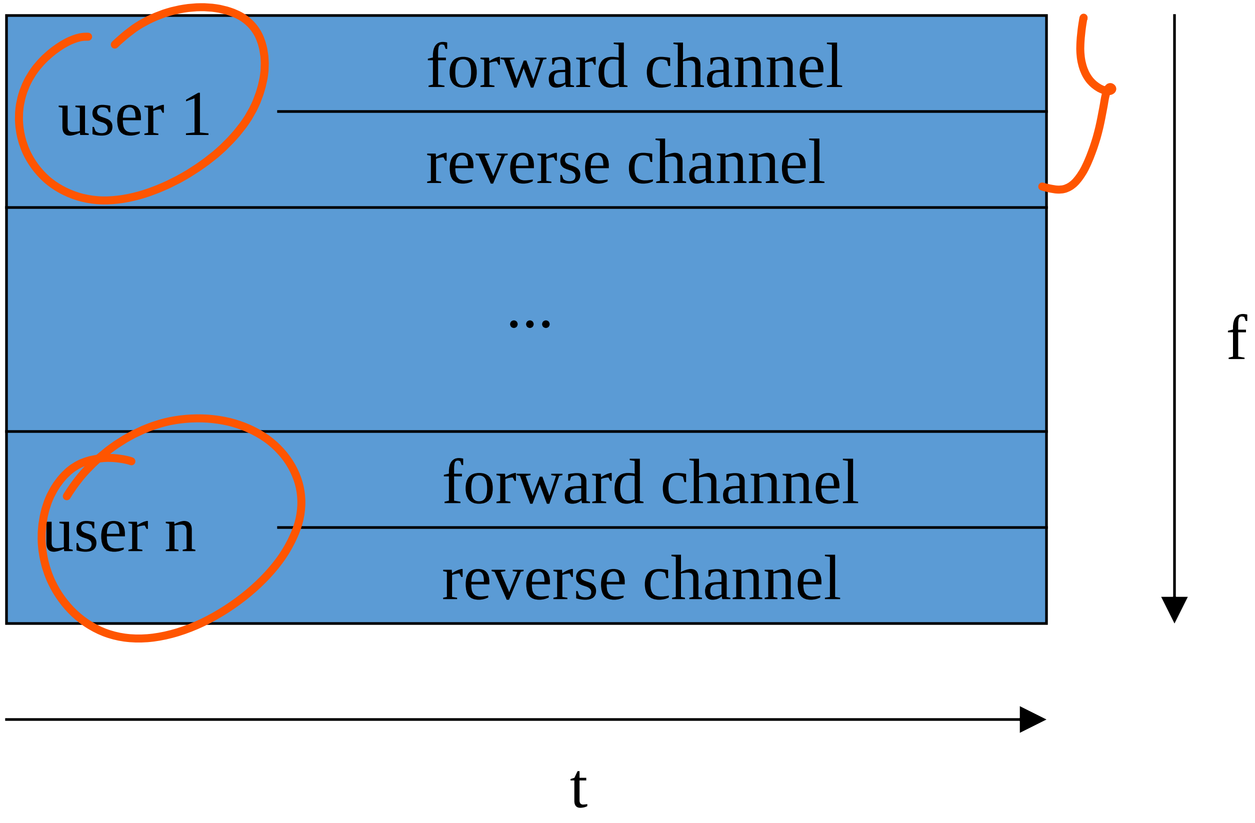


SDMA



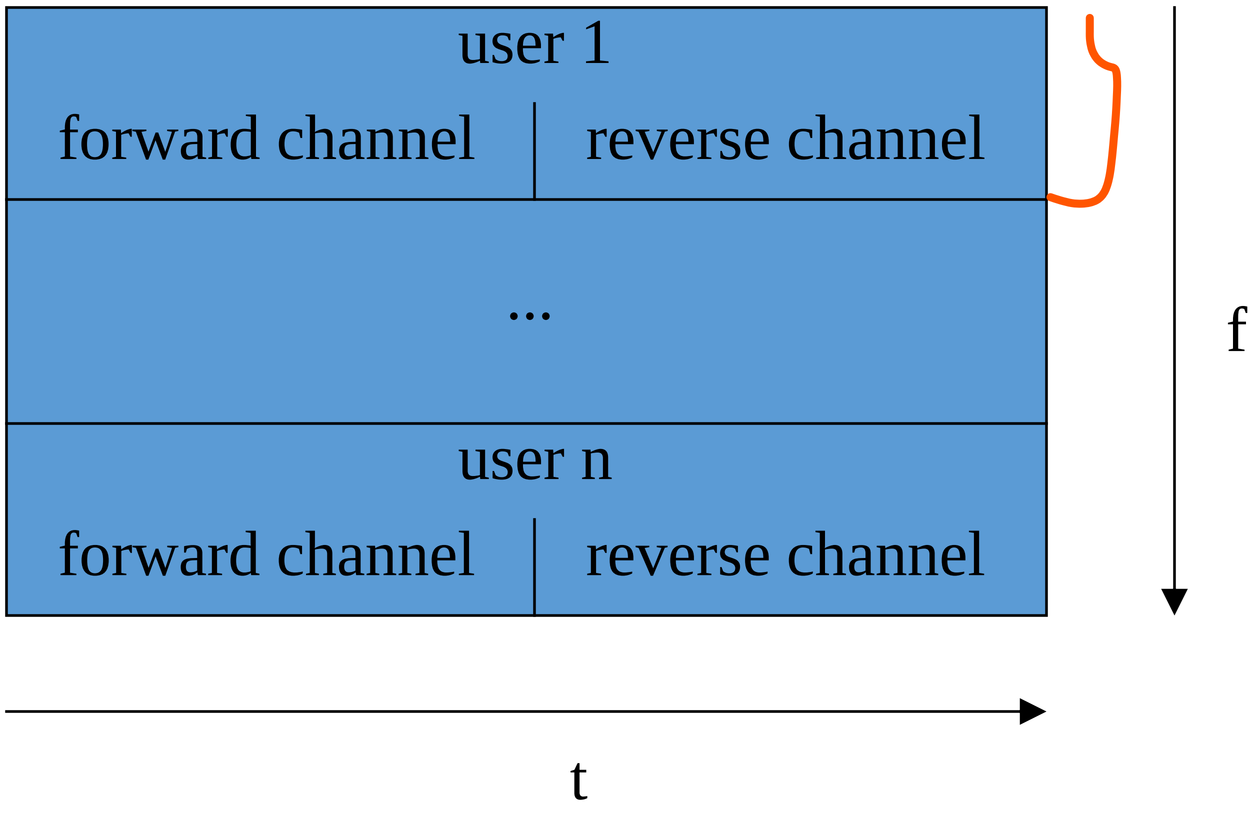
分不同方向

FDMA/FDD

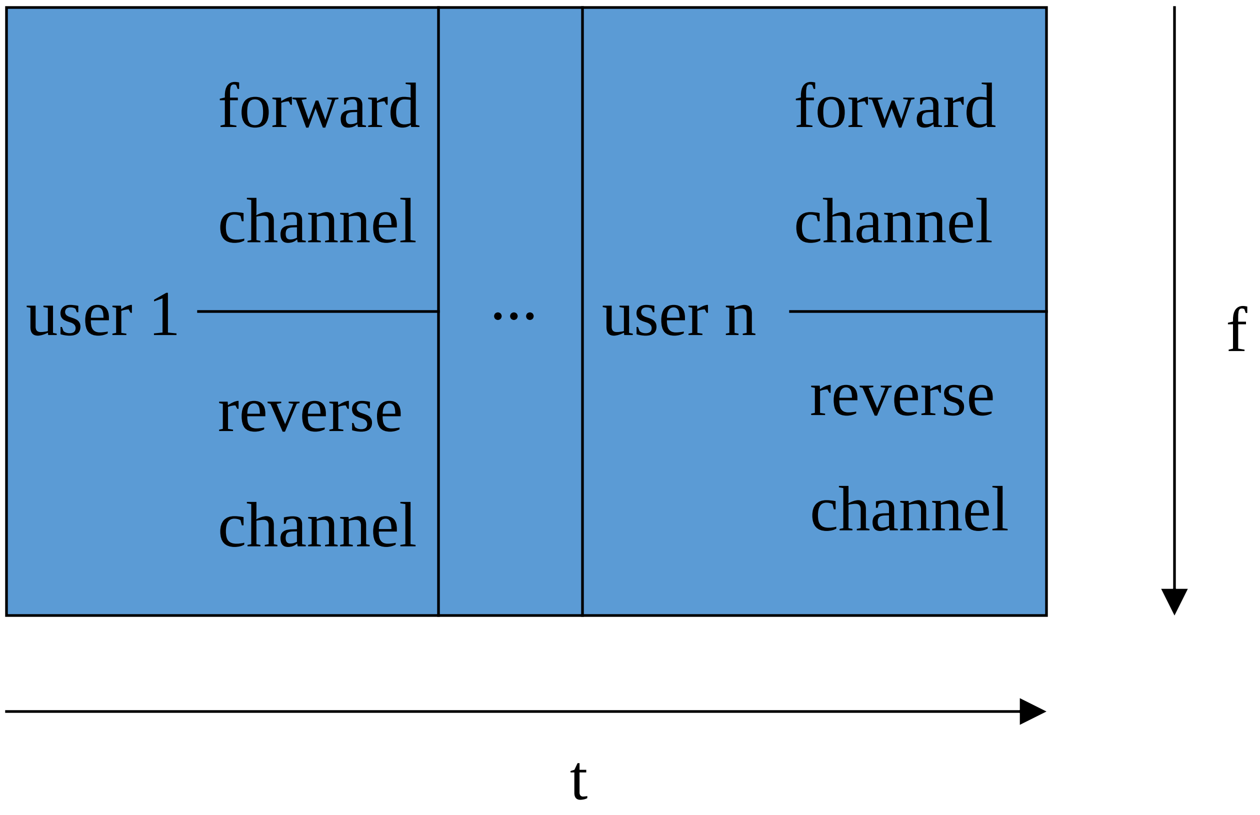


user 1
forward channel
reverse channel
...
user n
forward channel
reverse channel
f
t

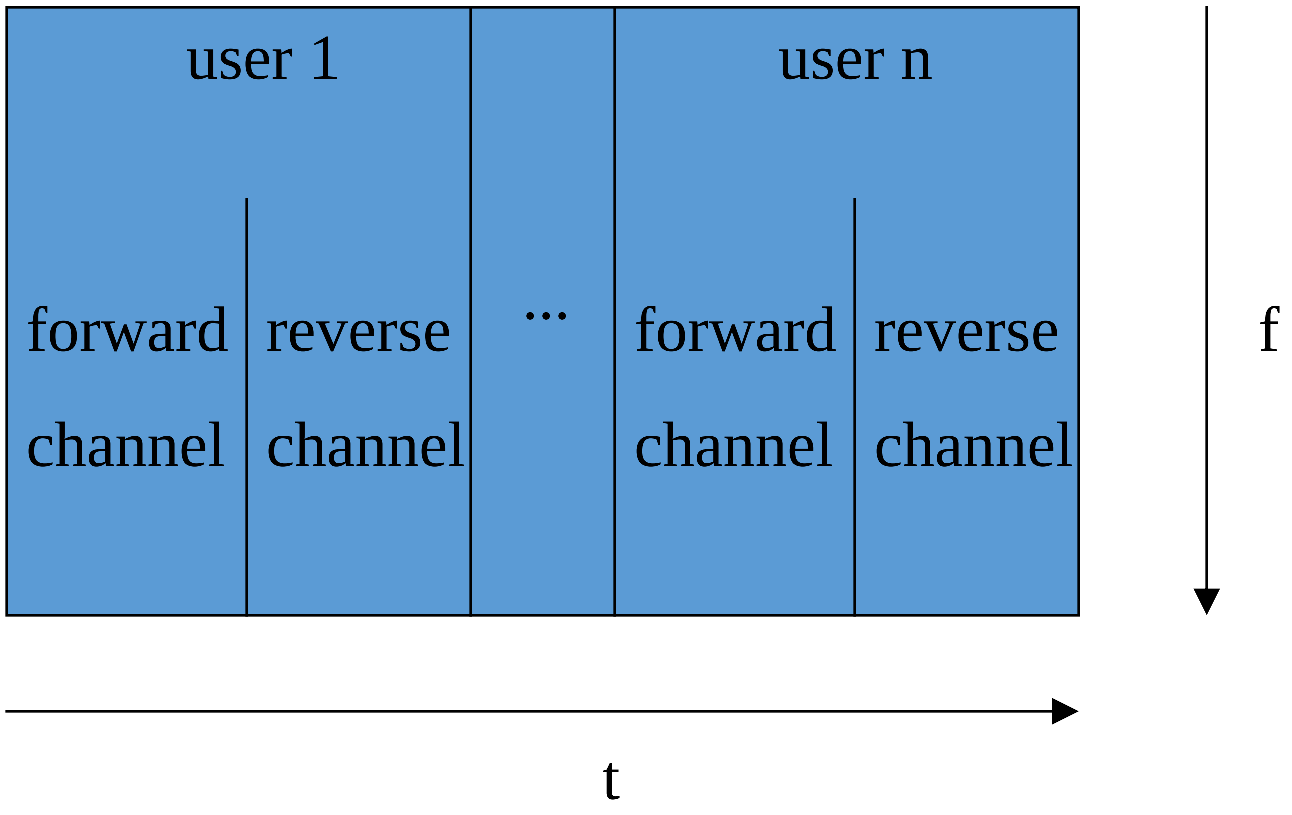
FDMA/TDD


user 1
forward channel
reverse channel
...
user n
forward channel
reverse channel
f
t

TDMA/FDD


forward
channel
user 1
reverse
channel
...
user n
forward
channel
reverse
channel
f
t

TDMA/TDD



user 1
user n
forward channel
reverse channel
...
forward channel
reverse channel
f
t

Multiple Access Techniques in use

Cellular System	Multiple Access Technique
Advanced Mobile Phone System (AMPS)	FDMA/FDD
Global System for Mobile (GSM)	TDMA/FDD
US Digital Cellular (USDC)	TDMA/FDD
Digital European Cordless Telephone (DECT)	FDMA/TDD
US Narrowband Spread Spectrum (IS-95)	CDMA/FDD

Frequency division multiple access FDMA

- one phone circuit per channel
空闲
- idle time causes wasting of resources
- simultaneously and continuously transmitting
- usually implemented in narrowband systems
- Complexity of FDMA mobile systems is lower compared to TDMA
- FDMA uses duplexers
- for example: AMPS is a FDMA system with bandwidth of 30 kHz

FDMA compared to TDMA

- fewer bits for synchronization
- fewer bits for framing
- higher costs for duplexer used in base station and subscriber units
- FDMA requires RF filtering to minimize adjacent channel interference
- FDMA uses guard bands to prevent interference. This wastes very useful and scarce frequency resources.

FDMA

频道数

The number of channel that can simultaneously supported is given by

total

$$\boxed{N = \frac{B_t - 2B_g}{B_c}}$$

B_t is the total spectrum
B_g is the guard band allocated at the edge of the allocated spectrum
B_c is the channel bandwidth

都是 Hz.

Example:
If B_t is 12.5 MHz, B_g is 10 KHz, and B_c is 30 KHz, find the number of channels available in an FDMA system.

The number of channels available in the FDMA system is given as

$$N = \frac{12.5 \times 10^6 - 2(10 \times 10^3)}{30 \times 10^3} = 416 \text{ channels}$$

Time Division Multiple Access

- Time slots
- one user per slot
- Buffer and burst method
- Non-continuous transmission

每人一槽

Advantage:

Total bandwidth is utilized

Disadvantage:

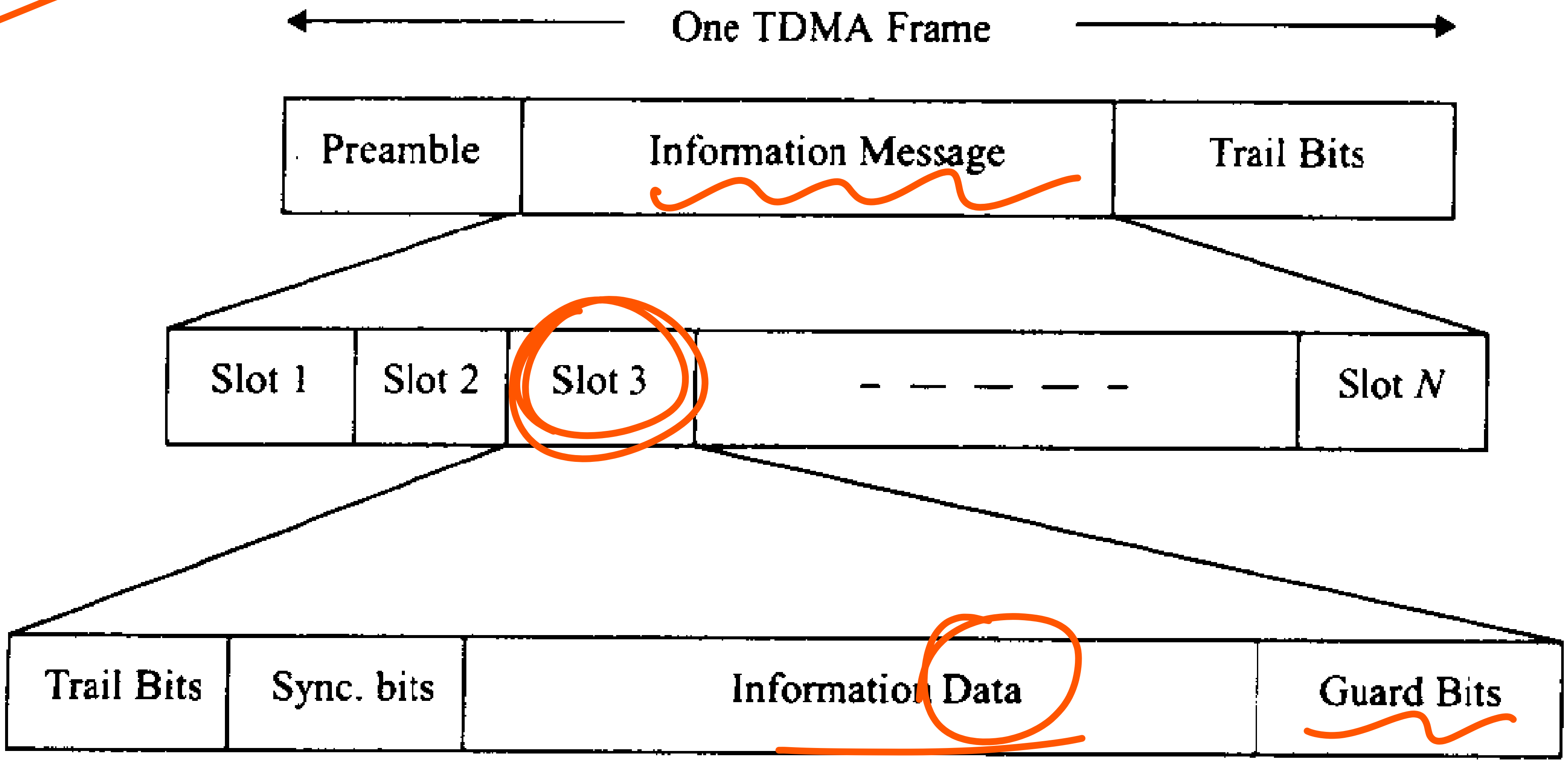
Strict Burst Timing is required at the earth station

Features of TDMA

- a single carrier frequency for several users
- transmission in bursts
- handoff process much simpler (can listen when idle)
- Low battery consumption
- Bandwidth can be supplied on demand
- high synchronization overhead

TDMA

时分多址帧



TDMA frame structure

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TDMA (cont.)

每帧8个槽

Example

If GSM uses a frame structure where each frame consists of 8 times slots, an each time slot contains 156.25 bits, and data is transmitted at 270.833 kbps in the channel, find (a) the duration of a bit, (b) the time duration of a slot, (c) the time duration of a frame, and (d) how long must a user occupying a single time slot to wait between two simultaneous transmissions.

$T_b = \frac{1}{R_b}$

Solution

(a) The time duration of a bit, $\boxed{T_b = \frac{1}{270.833 kbps}} = 3.692\ \mu s$

(b) The time duration of a slot, $T_{slot} = 156.25 \times T_b = 0.577\ ms$

1slot = 156.25b

(c) The time duration of a frame, $T_f = 8 \times T_{slot} = 4.615\ ms$

1frame = 8slot

(d) A user has to wait 4.615 ms, the arrival time of a new frame, for its next transmission

T_f 等1帧时间

TDMA (cont.)

每信道的slot个数

The number of TDMA channel slots that can be provided in a TDMA system is given by

总槽数

$$N = \frac{m(B_t - 2B_g)}{B_c}$$

- m is the number of TDMA slot per channel
- B_t is the total spectrum allocation
- B_g is the guard band allocated at the edge of the allocated spectrum
- B_c is the channel bandwidth

Example:

Consider Global System for Mobile, which is a TDMA/FDD system that uses 25 MHz for the forward link, which is broken into radio channels of 200 KHz. If 8 speech channels are supported on a single radio channel, and if no guard band is assumed, find the number of simultaneous user that can be accommodated in GSM.

The number of simultaneous user that can be accommodated in GSM is given as

$$N = \frac{8 \times 25\ MHz}{200\ kHz} = 1000$$

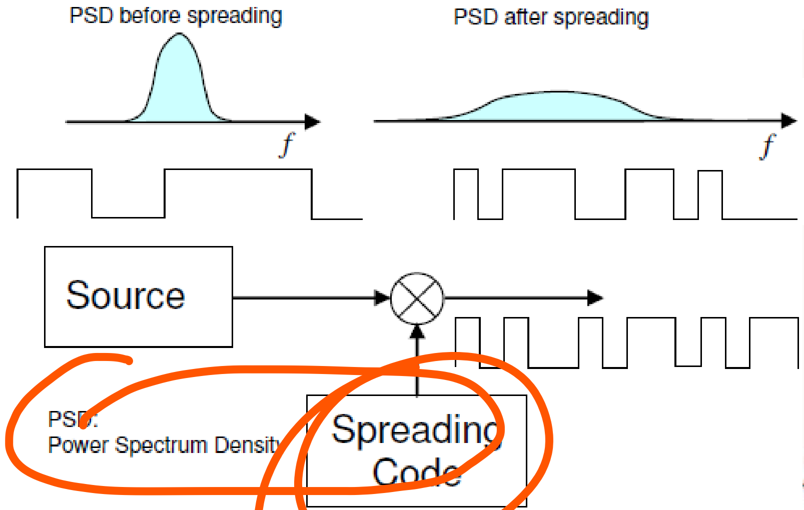
Thus, GSM can accommodate 1000 simultaneous users.

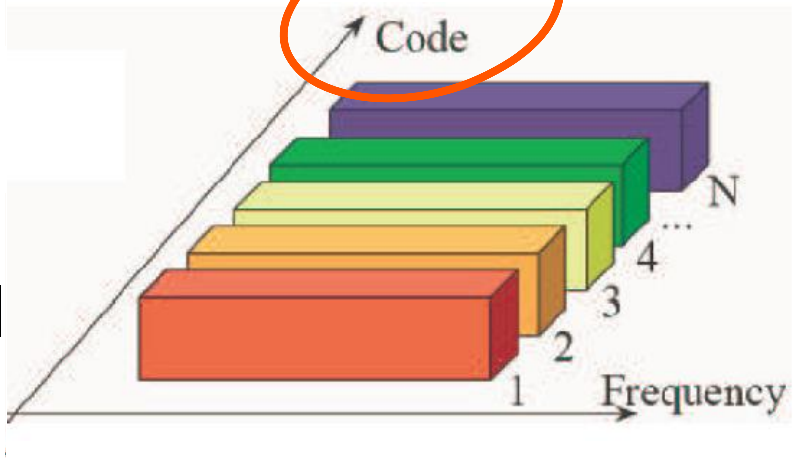
展频

Spread Spectrum Multiple Access (SSMA)

- SSMA user Signals have transmission BW that is several orders of magnitude greater than the minimum required BW
- A Pseudo-noise sequence converts a narrow band signal to a wideband noise-like signal before transmission 伪噪声
- SSMA not BW efficient when used by a single user
- Many users can share the same BW without interfering with one another
- Type of SSMA techniques:
  - Frequency hoped multiple access (FHMA)
  - Direct sequence multiple access (DS) or Code division multiple access (CDMA)

CDMA 码分是展频





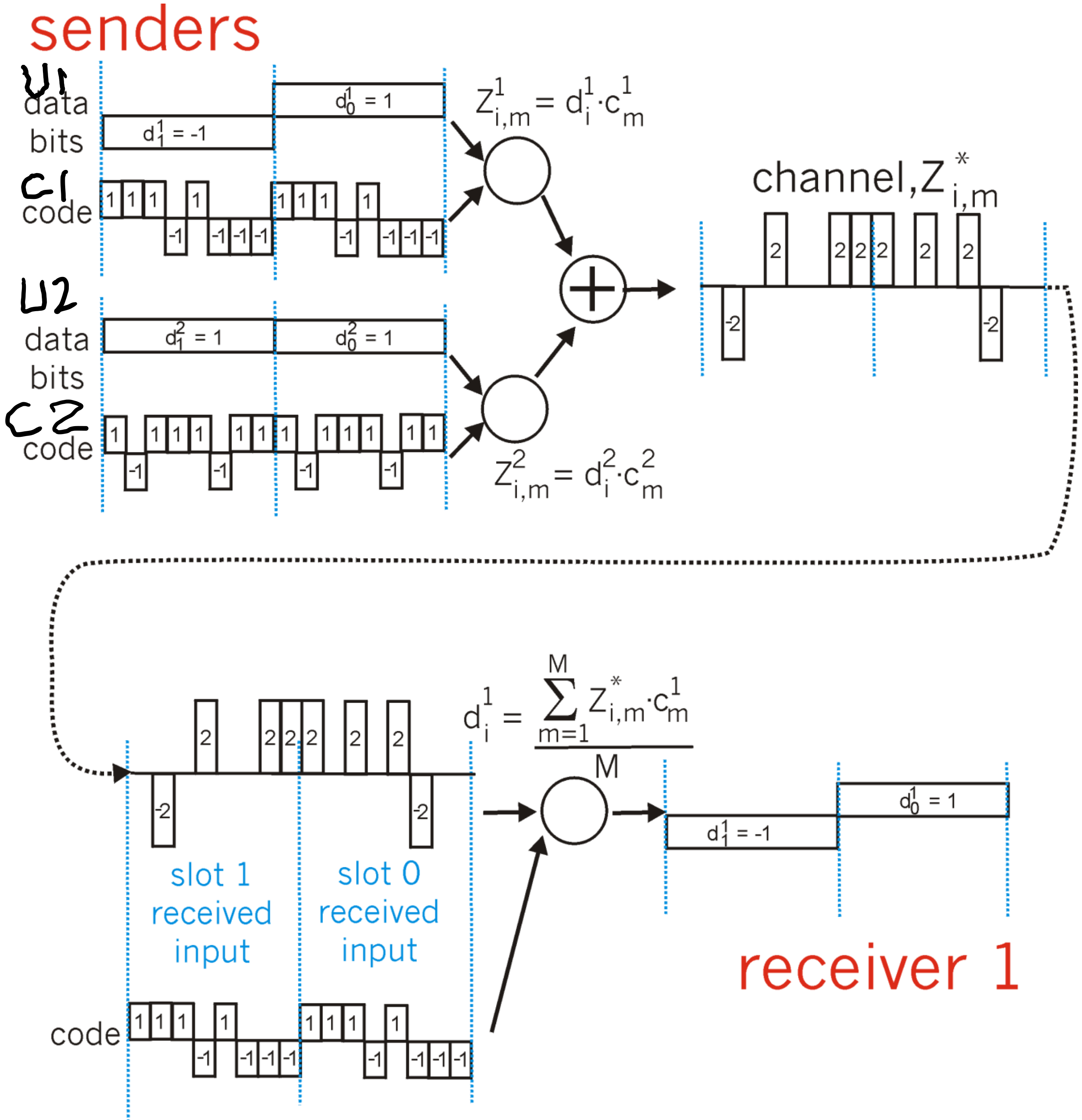
- In CDMA or spread spectrum systems each user occupies much wider bandwidth than what is needed to accommodate their data rate.
- Achieved by multiplying the source data by a spreading signal/code (chip rate) thus increasing the transmitted signal bandwidth.
- At the receiver the reverse process is performed to extract the original data.

CDMA

- Narrowband signals is multiplied by a very large bandwidth signal called the spreading signal.
- The spreading signal is pseudo noise code sequence that has a chip rate which is orders of magnitudes greater than data rate of the message
- All users use the same carrier frequency and transmit simultaneously
- Each user has its own pseudo random code word which is approximately orthogonal to other codewords

伪随机码

CDMA Example



Challenges to Commercializing CDMA

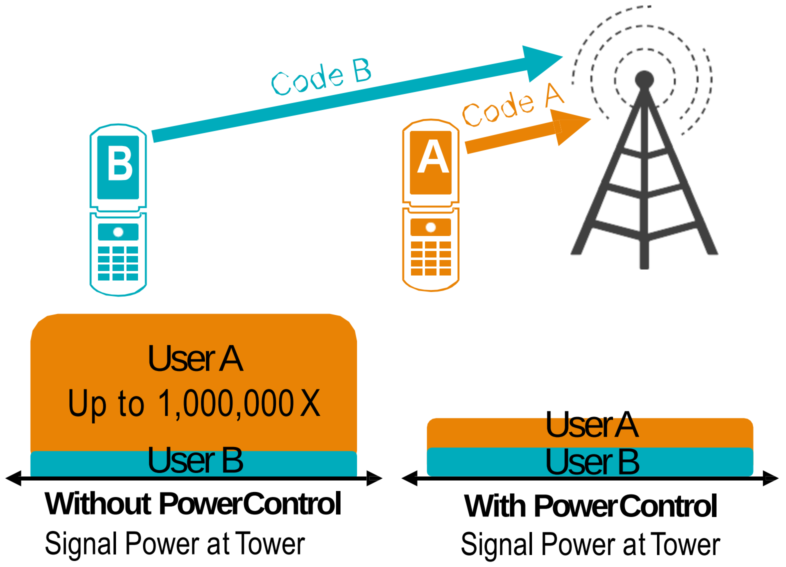
1

Near-Far Power Challenge

Users close to the tower overpower the uplink signal minimizing capacity on the shared channel

Solution:

Continuous control of transmit power based on signal strength



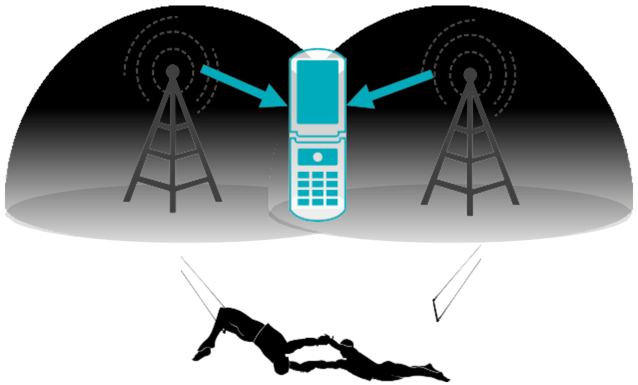
2

Cell-Edge Challenge

Interference caused by users in close proximity, on the same frequency, and communicating with different towers

Solution:

Users simultaneously communicate with multiple towers at cell edge



+ Soft (vs. Hard) Handoffs

Additional benefit of simultaneous connections – more reliable handoffs

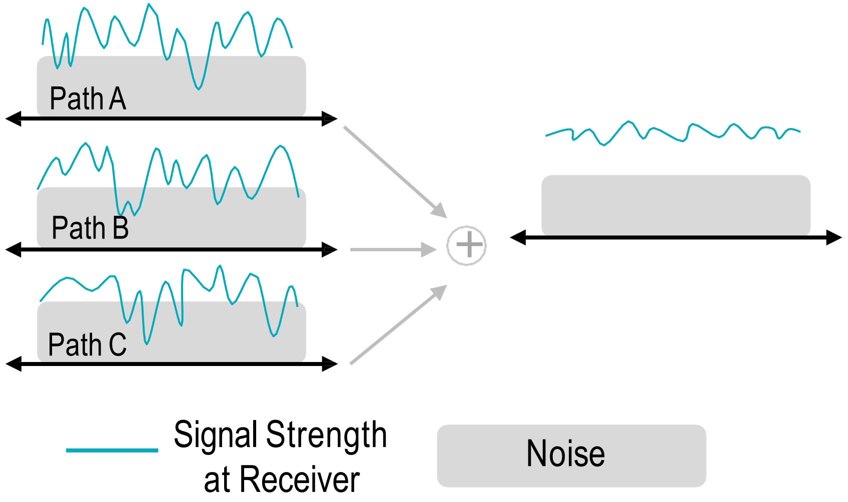
3

Multipath Fading Challenge

Interference caused by the reception of the same signal over multiple paths resulting in poor signal-to-noise ratio

Solution:

Advanced ("rake") receivers combine energy of multiple signal paths



Review Questions

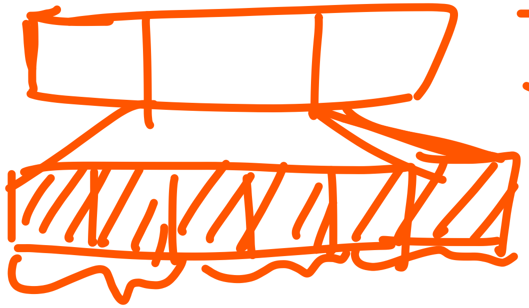
FDMA $N = \frac{B_t - 2B_g}{B_c}$ | TDMA $N = m\left(\frac{B_t - 2B_g}{B_c}\right)$

Bc (channel BandW)

Bt

Espe

- Consider a more efficient digital system in Example 1, with high-level modulation (so that only $10\ KHz$ channel are required for digital voice signal) and with tighter filtering (so that only $5\ KHz$ guard bands are required on band edges). How many users can be supported in the same $12.5\ MHz$ of spectrum for this efficient digital system? [1249]
- If a normal GSM time slot consists of six trailing bits, 8.25 guard bits, 26 training bits, and two burst of 58 bits of data, find the frame efficiency [74.24%]
- The GSM TDMA system uses a 270.8333 kbps data rate to support eight users per frame. (a) What is the raw data provided for each user? (b) if guard, time, ramp-up time, and synchronization bits occupy 10.1 kbps, determine the traffic efficiency for each user. [33.85 kbps, 70%]



frame

$\frac{48.6 \times 2}{6}$

$48.6 \div 3 = 16.2$ kbps.

- The Digital Cellular TDMA system uses 48.6 kbps data rate to support three users per frame. Each user occupies two of the six time slot per frame. What is the raw data rate provides for each user [16.2 kbps]
- Assume each reverse channel frame contains six time slot with 324 bits per time slot, and within each time slot, assume there are six guard bits, six bits reserved for ramp-up, 28 synchronization bits, 12 control bits, 12 bits for supervisory control signals, and 260 data bits. Determine the frame efficiency for the Digital Cellular TDMA System [80.2%]

$6+6+28+12+12+260=324$

$(260/324) \times 100\% = 80.2\%$