ECS455: Chapter 4

Multiple Access

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Duplexing

- Allow the subscriber to send "simultaneously" information to the base station while receiving information from the base station.
  - Talk and listen simultaneously.
- Definitions:
  - **Forward channel** or **downlink (DL)** is used for communication from the infrastructure to the users/stations
  - **Reverse channel** or **uplink (UL)** is used for communication from users/stations back to the infrastructure.
- Two techniques
  1. Frequency division duplexing (FDD)
  2. Time division duplexing (TDD)

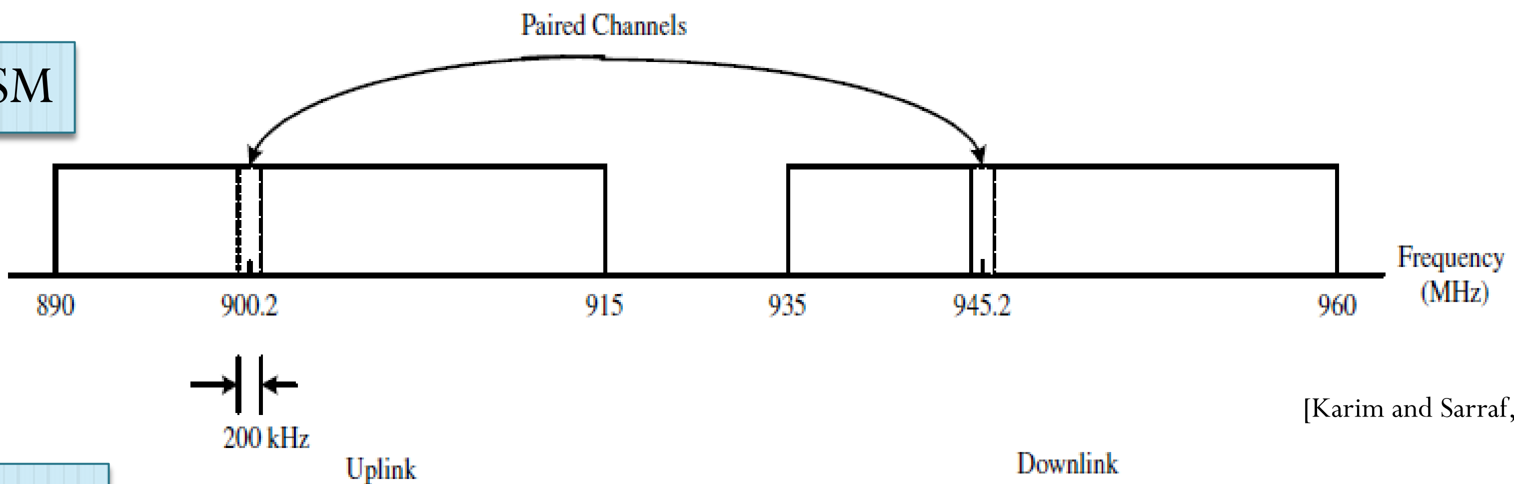
[Rappaport, 2002, Ch 9]

Frequency Division Duplexing (FDD)

- Provide ***two distinct bands*** of frequencies (simplex channels) for every user.
- The **forward band** provides traffic from the base station to the mobile.
- The **reverse band** provides traffic from the mobile to the base station.
- Any *duplex* channel actually consists of two *simplex* channels (a forward and reverse).
- Most commercial cellular systems are based on FDD.

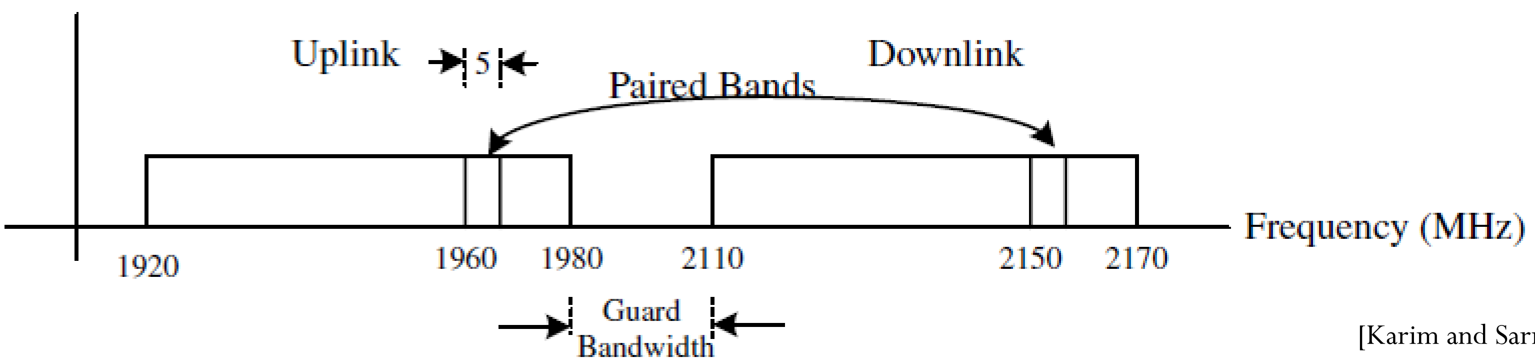
FDD Examples

GSM



[Karim and Sarraf, 2002, Fig 5-1]

UMTS



[Karim and Sarraf, 2002, Fig 6-1]

Time Division Duplexing (TDD)

- The UL and DL data are transmitted on the **same carrier frequency** at different times. (Taking turns)
  - Use time instead of frequency to provide both forward and reverse links.
  - Each *duplex* channel has both a **forward time slot** and a **reverse time slot**.
- If the *time separation* between the forward and reverse lime slot is *small*, then the transmission and reception of data *appears* simultaneous to the users at both the subscriber unit and on the base station side.
- Used in Bluetooth and Mobile WiMAX
- Each transceiver operates as either a transmitter or receiver on the same frequency

Problems of FDD

- Each transceiver simultaneously transmits and receives radio signals
  - The signals transmitted and received can vary by more than 100 dB.
  - The signals in each direction need to occupy bands that are ***separated far apart*** (tens of MHz)
- A device called a **duplexer** is required to filter out any interference between the two bands.

[Tse and Viswanath, 2005, Ch 4, p 121]

Advantages of FDD

- TDD frames need to incorporate guard periods **equal to the max round trip propagation delay** to avoid interference between uplink and downlink under worst-case conditions.
- There is a **time latency** created by TDD due to the fact that communications is not full duplex in the truest sense.
    - This latency creates inherent sensitivities to propagation delays of individual users.

Advantages of TDD

- Duplexer is not required.
- Enable *adjustment* of the downlink/uplink ratio to efficiently support *asymmetric* DL/UL traffic.
  - With FDD, DL and UL always have fixed and generally, equal DL and UL *bandwidths*.
- Assure ***channel reciprocity*** for better support of link adaptation, MIMO and other closed loop advanced antenna technologies.
- Ability to implement in ***nonpaired spectrum***
  - FDD requires a pair of channels
  - TDD only requires a single channel for both DL and UL providing greater flexibility for adaptation to varied global spectrum allocations.

Parameter	Fixed WiMAX	Mobile WiMAX	HSPA	1x EV-DO Rev A	Wi-Fi
Standards	IEEE 802.16-2004	IEEE 802.16e-2005	3GPP Release 6	3GPP2	IEEE 802.11a/g/n
Peak down link data rate	9.4Mbps in 3.5MHz with 3:1 DL-to-UL ratio TDD; 6.1Mbps with 1:1	46Mbps[a] with 3:1 DL- to-UL ratio TDD; 32Mbps with 1:1	14.4Mbps using all 15 codes; 7.2Mbps with 10 codes	3.1Mbps; Rev. B will support 4.9Mbps	54 Mbps[b] shared using 802.11a/g; more than 100Mbps peak layer 2 through-put using 802.11n
Peak uplink data rate	3.3Mbps in 3.5MHz using 3:1 DL-to-UL ratio; 6.5Mbps with 1:1	7Mbps in 10MHz using 3:1 DL-to-UL ratio; 4Mbps using 1:1	1.4Mbps initially; 5.8Mbps later	1.8Mbps	
Bandwidth	3.5MHz and 7MHz in 3.5GHz band; 10MHz in 5.8GHz band	3.5MHz, 7MHz, 5MHz, 10MHz, and 8.75MHz initially	5MHz	1.25MHz	20MHz for 802.11a/g; 20/40MHz for 802.11n
Modulation	QPSK, 16 QAM, 64 QAM	QPSK, 16 QAM, 64 QAM	QPSK, 16 QAM	QPSK, 8 PSK, 16 QAM	BPSK, QPSK, 16 QAM, 64 QAM
Multiplexing	TDM	TDM/OFDMA	TDM/CDMA	TDM/ CDMA	CSMA
Duplexing	TDD, FDD	TDD initially	FDD	FDD	TDD
Frequency	3.5GHz and 5.8GHz initially	2.3GHz, 2.5GHz, and 3.5GHz initially	800/900/1,800/ 1,900/ 2,100MHz	800/900/ 1,800/ 1,900MHz	2.4GHz, 5GHz
Coverage (typical)	3–5 miles	< 2 miles	1–3 miles	1–3 miles	< 100 ft indoors; < 1000 ft outdoors
Mobility	Not applicable	Mid	High	High	Low

Multiple Access Techniques

- Allow **many** mobile users to **share** simultaneously a finite amount of radio spectrum.
- For high quality communications, this must be done without severe degradation in the performance of the system.
- Important access techniques
  1. Frequency division multiple access (FDMA)
  2. Time division multiple access (TDMA)
  3. Spread spectrum multiple access (SSMA)
     - Frequency Hopped Multiple Access (FHMA)
     - Code division multiple access (CDMA)
  4. Space division multiple access (SDMA)
  5. Random access
     - ALOHA

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Frequency division multiple access (FDMA)

- The *oldest* multiple access scheme for wireless communications.
- Used exclusively for multiple access in 1G down to individual resource units or physical channels.
- Assign individual channels to individual users.
  - Different carrier frequency is assigned to each user so that the resulting spectra do not overlap.
  - During the period of the call, no other user can share the same channel.
- **Band-pass filtering** (or heterodyning) enables separate demodulation of each channel.

FDMA (2)

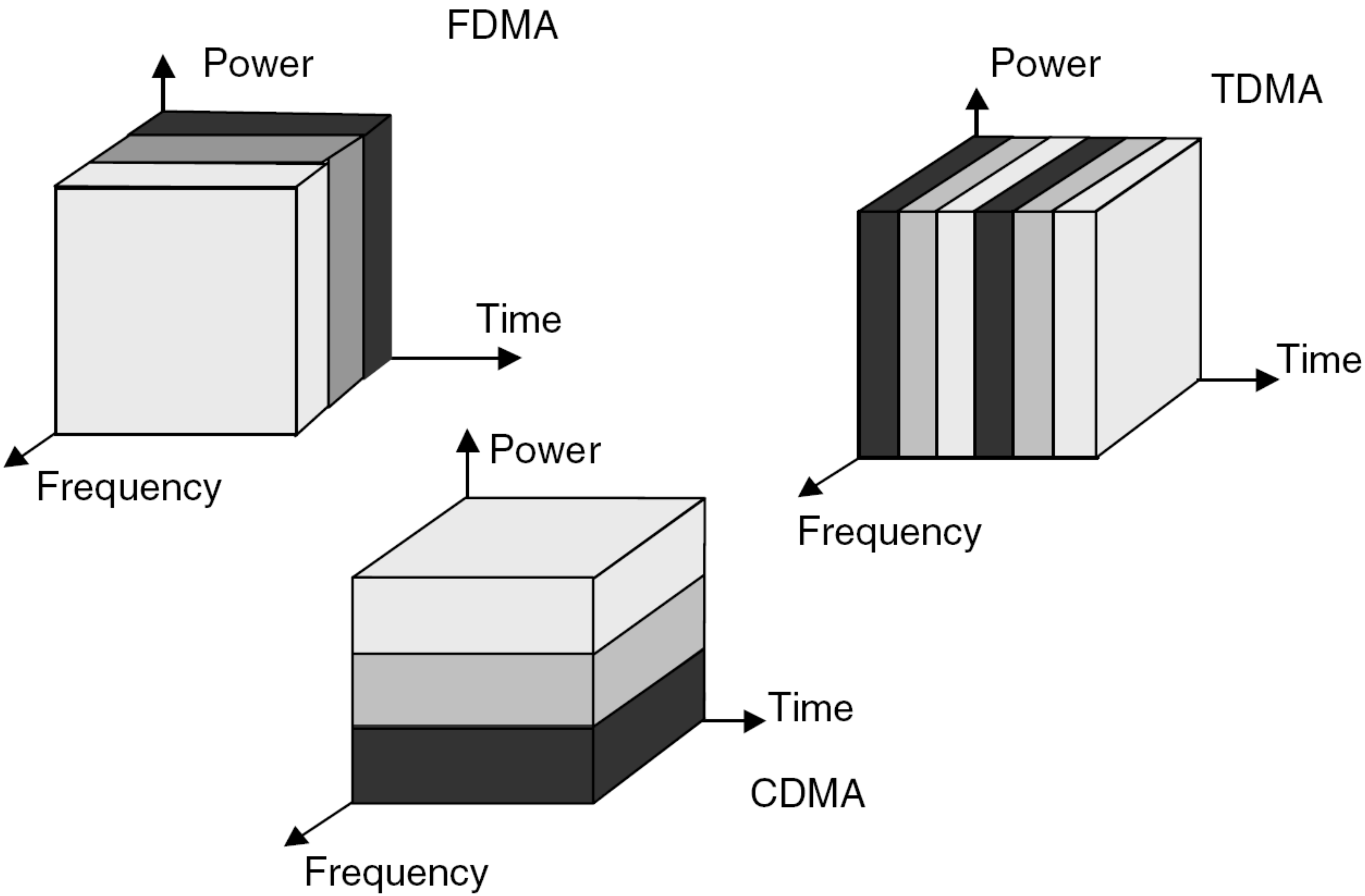
- If an FDMA channel is not in use, then it sits idle and can**not** be used by other users to increase or share capacity.
  - It is essentially a wasted resource.
- In FDD systems, the users are assigned a channel as a pair of frequencies.

[Rappaport, 2002, Ch 9, p. 449]

Time division multiple access (TDMA)

- Divide the radio spectrum into **time slots**.
- In each slot only one user is allowed to either transmit or receive.
- A channel may be thought of as a particular time slot that reoccurs every frame, where *N* time slots comprise a frame.
- Transmit data in a **buffer-and-burst method**
  - The transmission for any user is non-continuous.
  - Digital data and digital modulation must be used with TDMA.
  - This results in low battery consumption, since the subscriber transmitter can be turned off when not in use (which is most of the time).
- An obvious choice in the 1980s for digital mobile communications.

FDMA vs. TDMA

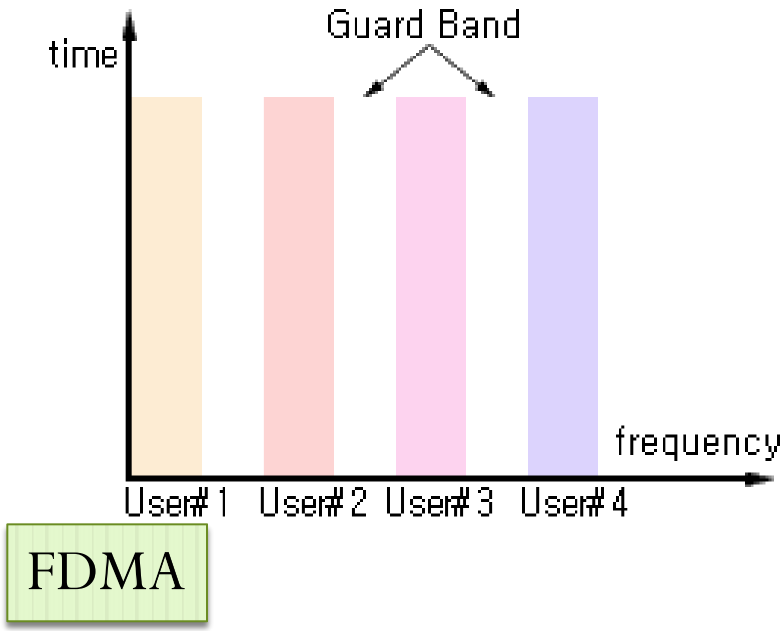


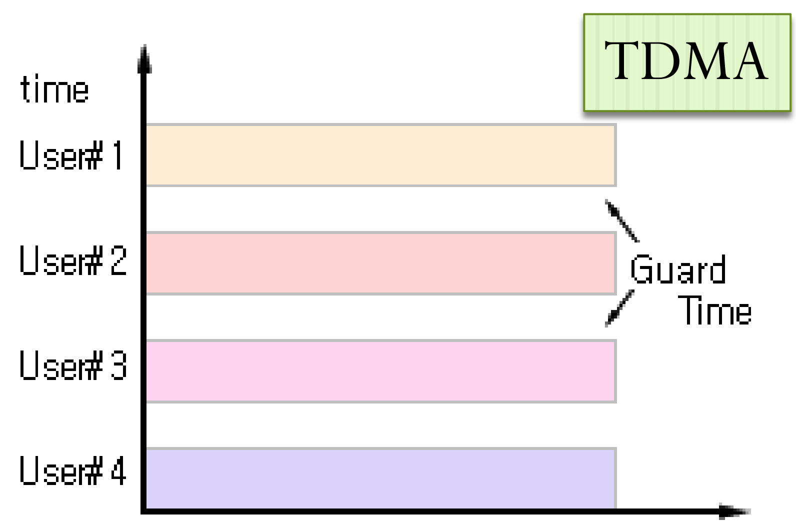
FDMA
Power
Time
Frequency
Power
TDMA
Time
Frequency
Power
Time
CDMA
Frequency

Tradeoffs

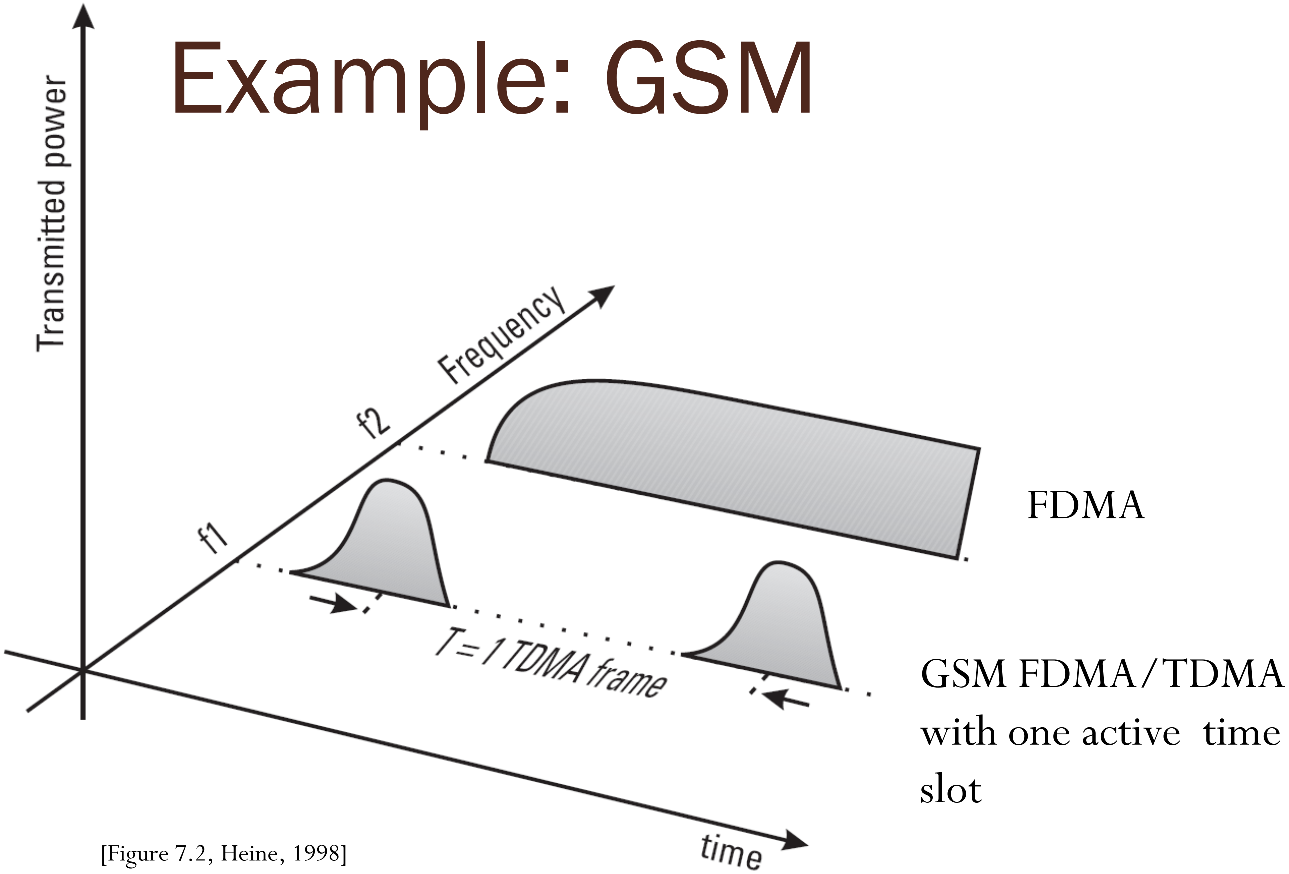
- TDMA transmissions are slotted
  - Require the receivers to be **synchronized** for each data burst.
  - **Guard times** are necessary to separate users. This results in larger overheads.
  - FDMA allows completely **uncoordinated transmission** in the time domain
    - No time synchronization among users is required.
- The complexity of FDMA mobile systems is lower when compared to TDMA systems, though this is changing as digital signal processing methods improve for TDMA.
- Since FDMA is a continuous transmission scheme, fewer bits are needed for **overhead** purposes (such as synchronization and framing bits) as compared to TDMA.
- FDMA needs to use costly **bandpass filters**.
  - For TDMA, no filters are required to separate individual physical channels.

Guard Band vs. Guard Time





Example: GSM



[Figure 7.2, Heine, 1998]

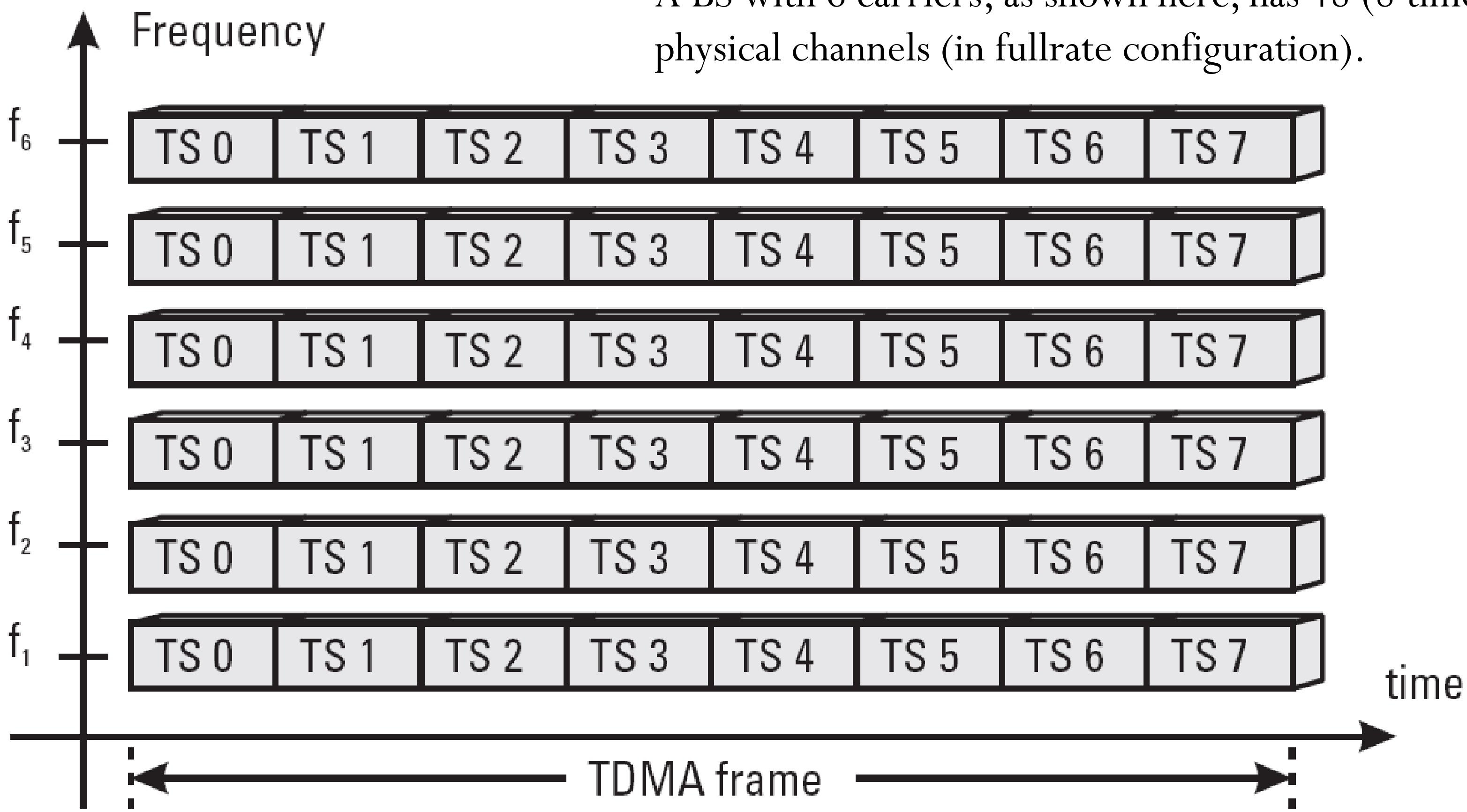
- GSM utilizes a combination of FDMA and TDMA
- Two-dimensional channel structure

- Each narrowband channel has bandwidth 200 kHz.
- Time is divided into slots of length T =577 μs.

The FDMA/TDMA structure of GSM

- In full-rate configuration, eight time slots (TSs) are mapped on every frequency.

A BS with 6 carriers, as shown here, has 48 (8 times 6) physical channels (in fullrate configuration).



[Figure 7.1, Heine, 1998]

Classifications of Medium Access Control (MAC)