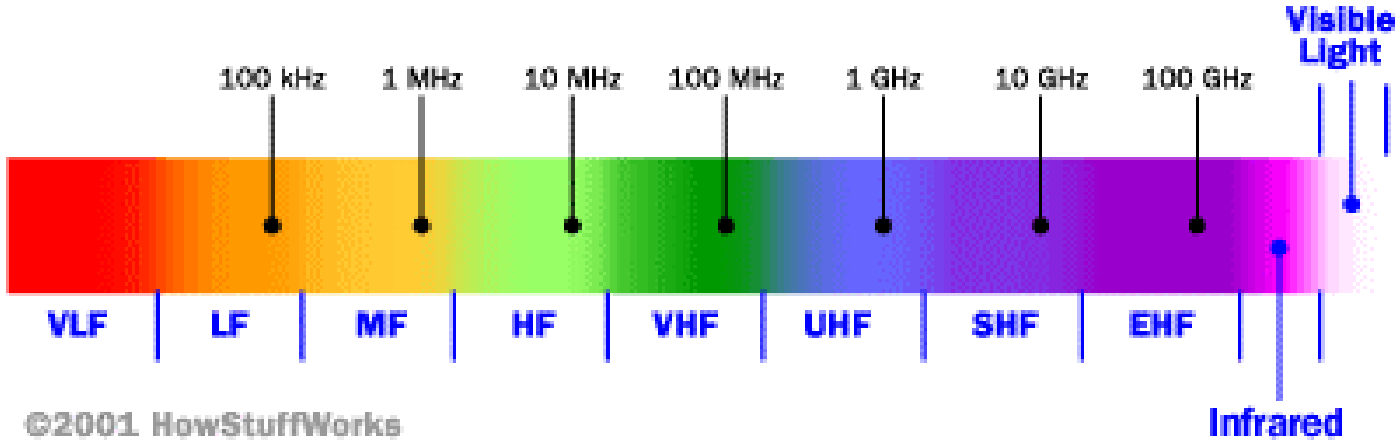
Telecommunication systems

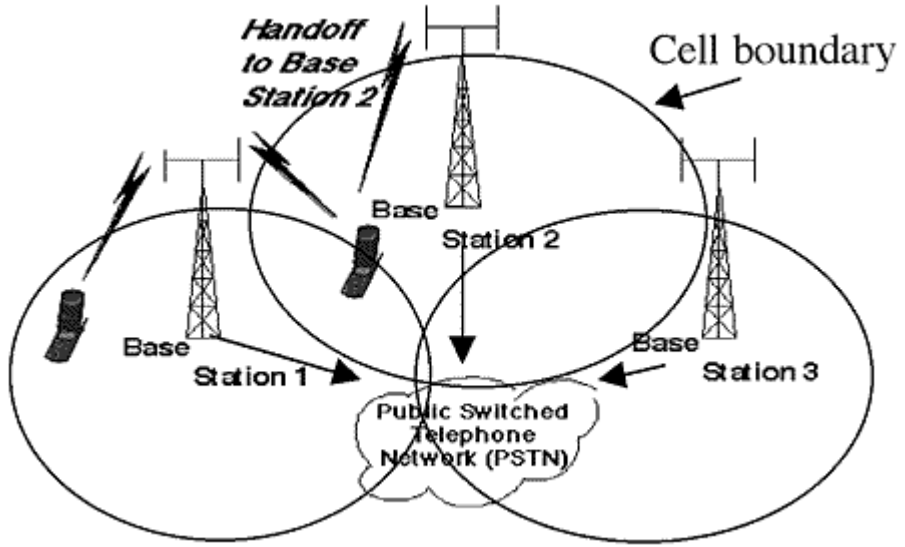
Cellular Network Basics

- Cellular network/telephony is a *radio*-based technology; radio waves are electromagnetic waves that *antennas* propagate
- Most signals are in the 850 MHz, 900 MHz, 1800 MHz, and 1900 MHz frequency bands



Cellular Network

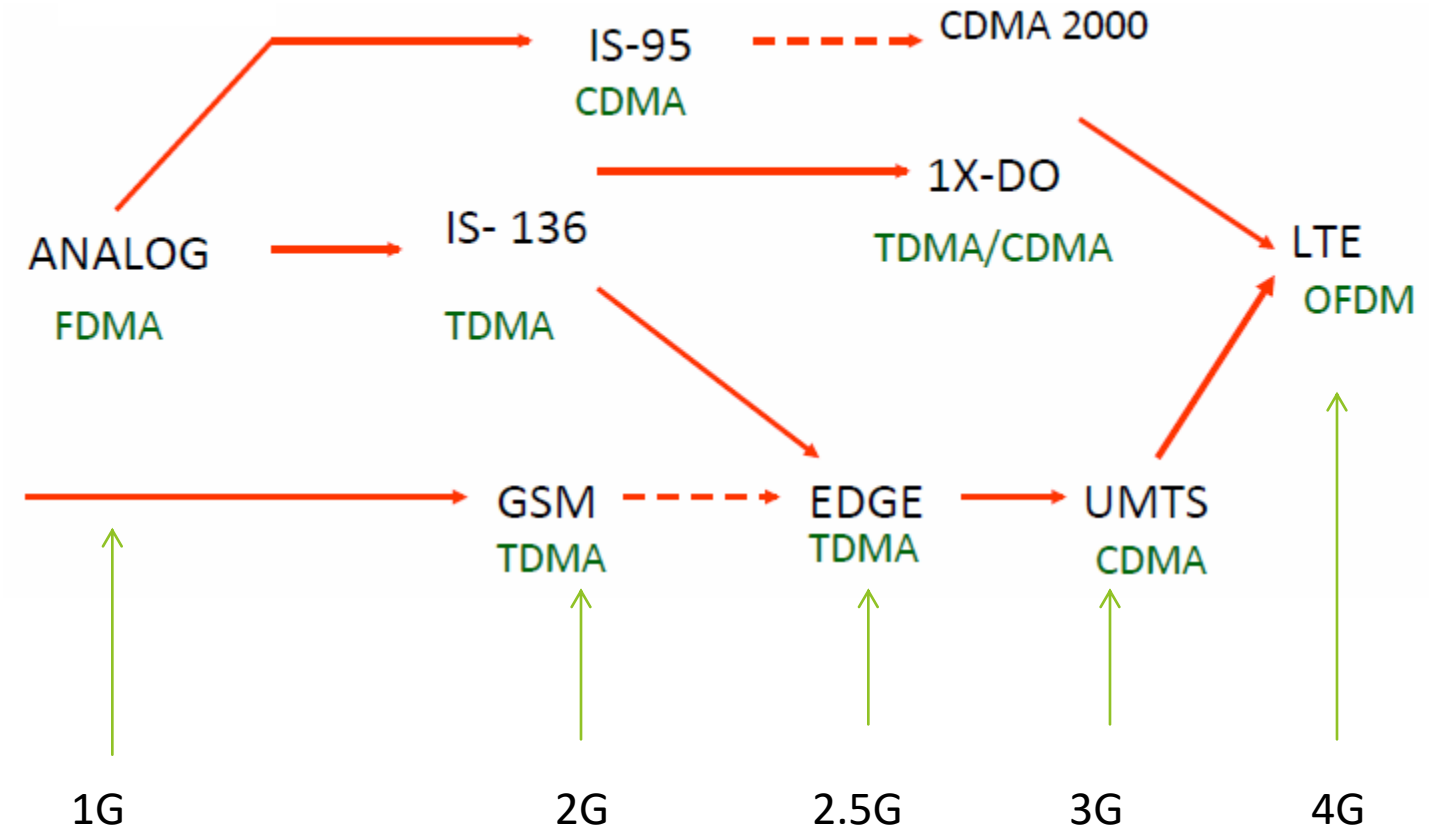
- Base stations transmit to and receive from mobiles at the assigned spectrum
  - Multiple base stations use the same spectrum (spectral reuse)
- The service area of each base station is called a cell
- Each mobile terminal is typically served by the ‘closest’ base stations
  - Handoff when terminals move



Cellular Network Generations

- It is useful to think of cellular Network/telephony in terms of *generations*:
  - 0G: Briefcase-size mobile radio telephones
  - 1G: *Analog* cellular telephony
  - 2G: *Digital* cellular telephony
  - 3G: *High-speed* digital cellular telephony (including *video telephony*)
  - 4G: IP-based “anytime, anywhere” voice, data, and multimedia telephony at *faster* data rates than 3G (to be deployed in 2012–2015)

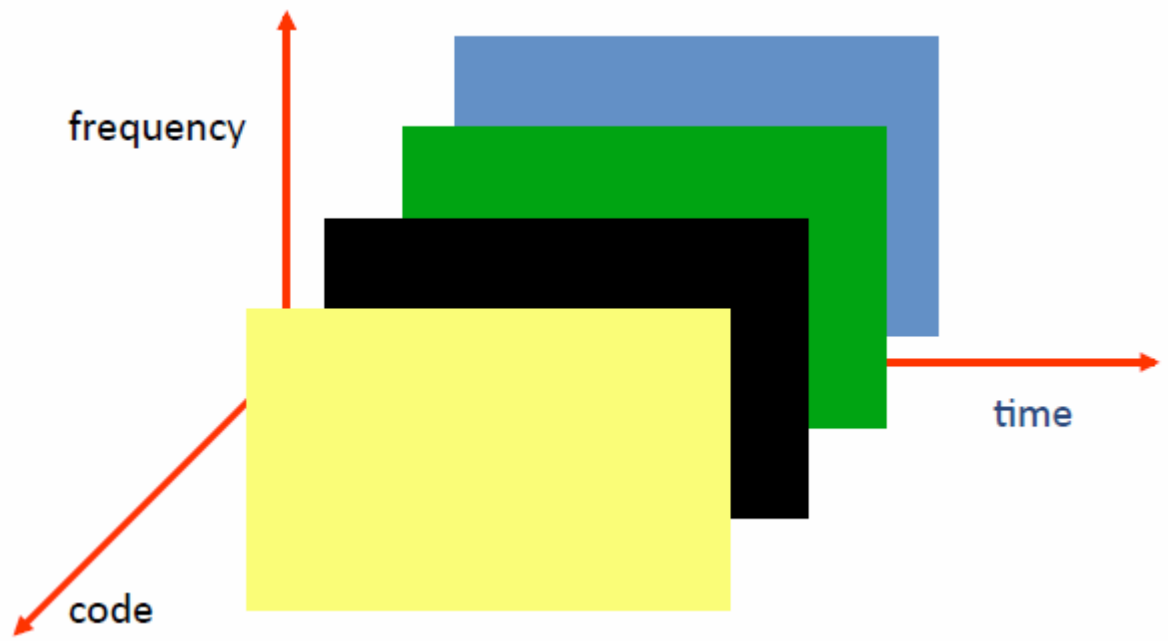
Evolution of Cellular Networks



The Multiple Access Problem

- The base stations need to serve many mobile terminals at the same time (both downlink and uplink)
- All mobiles in the cell need to transmit to the base station
- Interference among different senders and receivers
- So we need multiple access scheme

Multiple Access Schemes



3 orthogonal Schemes:

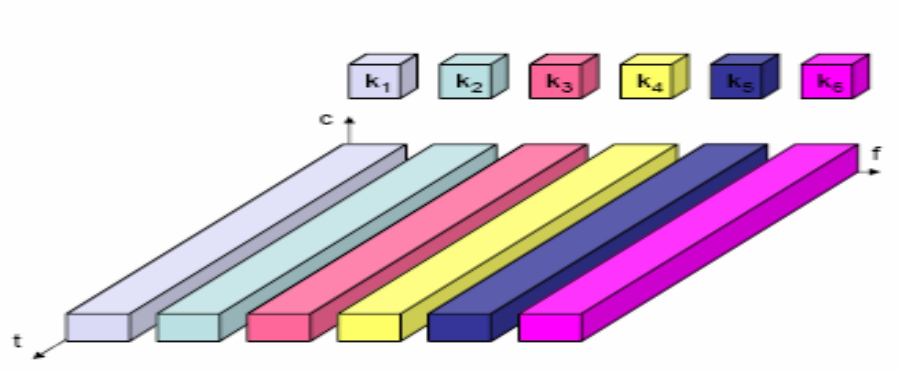
- Frequency Division Multiple Access (FDMA)
- Time Division Multiple Access (TDMA)
- Code Division Multiple Access (CDMA)

Frequency Division Multiple Access

- Cocktail Party Analogy: People create teams and discuss. There is a distance among them.
- Each mobile is assigned a separate frequency channel for the duration of the call
- Sufficient guard band is required to prevent adjacent channel interference
- Usually, mobile terminals will have one downlink frequency band and one uplink frequency band
- Different cellular network protocols use different frequencies
- Frequency is a precious and scare resource. We are running out of it
  - Cognitive radio

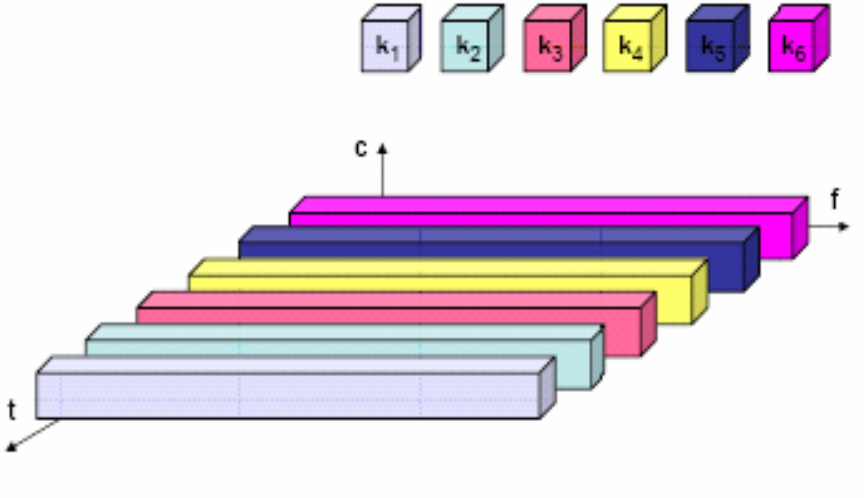
Frequency Division Multiple Access

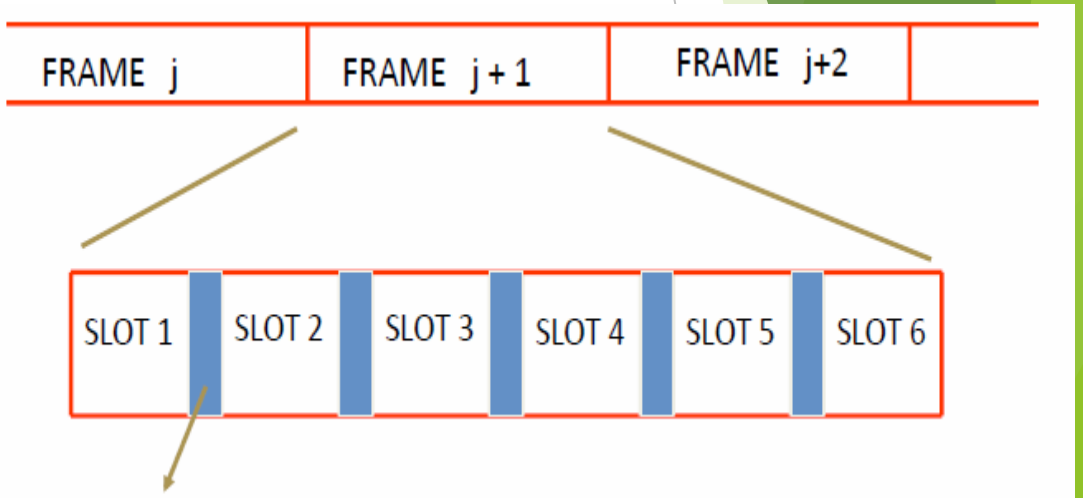
- (-) Requires guard band between channels
- (-) Waste of bandwidth if traffic is distributed unevenly
- Example: broadcast radio



Time Division Multiple Access

- Cocktail Party Analogy: People have access to the same room but each of them waits for his turn to speak.
- Precise synchronization necessary
- Time is divided into slots and only one mobile terminal transmits during each slot
  - Like during the lecture, only one can talk, but others may take the floor in turn
- Each user is given a specific slot. No competition in cellular network
  - Unlike Carrier Sensing Multiple Access (CSMA) in WiFi





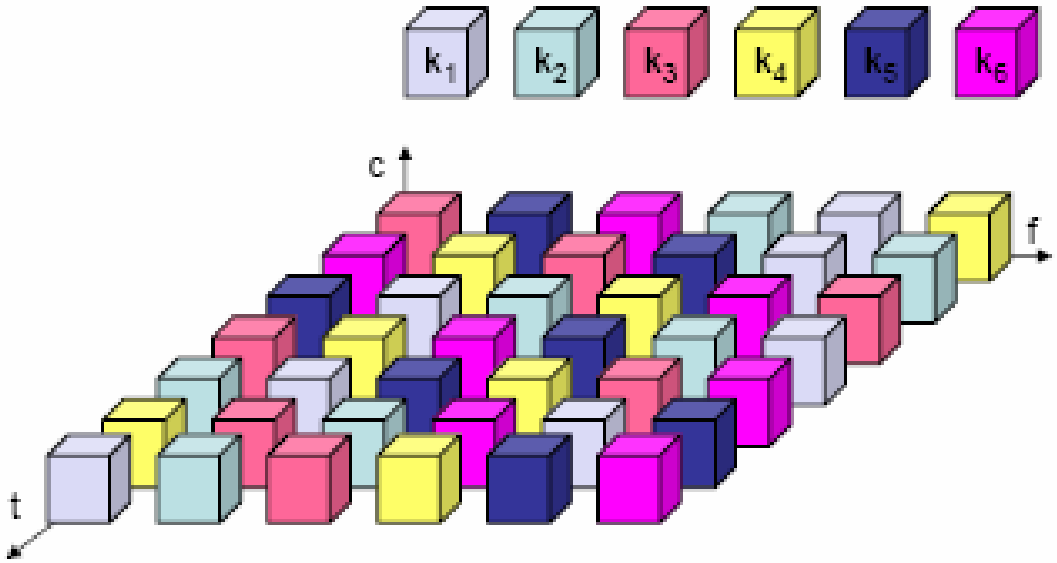
Guard time – signal transmitted by mobile terminals at different locations do no arrive at the base station at the same time

2G(GSM)

- Abbreviation for Global System for Mobile Communications
- Concurrent development in USA and Europe in the 1980's
- The European system was called GSM and deployed in the early 1990's
- Voice, 3.1 kHz
- Short Message Service (SMS)
  - 1985 GSM standard that allows messages of at most 160 chars. (incl. spaces) to be sent between handsets and other stations
  - Over 2.4 *billion* people use it; multi-billion $ industry
- General Packet Radio Service (GPRS)
  - GSM upgrade that provides IP-based packet data transmission up to 114 kbps
  - Users can "simultaneously" make calls and send data
  - GPRS provides "always on" Internet access and the Multimedia Messaging Service (MMS) whereby users can send rich text, audio, video messages to each other
  - Performance degrades as number of users increase
  - GPRS is an example of 2.5G telephony – 2G service similar to 3G

GSM Channels

- **Time and Frequency Division Multiple Access**
- Physical Channel: Each timeslot on a carrier is referred to as a physical channel
- Logical Channel: Variety of information is transmitted between the MS and BTS. Different types of logical channels:
  - Traffic channel
  - Control Channel



Base Station Subsystem

- Transcoding Rate and Adaptation Unit (TRAU)
  - Performs coding between the 64kbps PCM coding used in the backbone network and the 13 kbps coding used for the Mobile Station (MS)
- Base Station Controller (BSC)
  - Controls the channel (time slot) allocation implemented by the BTSes
  - Manages the handovers within BSS area
  - Knows which mobile stations are within the cell and informs the MSC/VLR about this
- Base Transceiver System (BTS)
  - Controls several transmitters
  - Each transmitter has 8 time slots, some used for signaling, on a specific frequency

Network and Switching Subsystem

- The backbone of a GSM network is a telephone network with additional cellular network capabilities
- Mobile Switching Center (MSC)
  - An typical telephony exchange (ISDN exchange) which supports mobile communications
  - Visitor Location Register (VLR)
    - A database, part of the MSC
    - Contains the location of the active Mobile Stations
- Gateway Mobile Switching Center (GMSC)
  - Links the system to PSTN and other operators
- Home Location Register (HLR)
  - Contain subscriber information, including authentication information in Authentication Center (AuC)
- Equipment Identity Register (EIR)
  - International Mobile Station Equipment Identity (IMEI) codes for e.g., blacklisting stolen phones

Home Location Register

- One database per operator
- Contains all the permanent subscriber information
  - MSISDN (Mobile Subscriber ISDN number) is the telephone number of the subscriber
  - International Mobile Subscriber Identity (IMSI) is a 15 digit code used to identify the subscriber
    - It incorporates a country code and operator code
  - IMSI code is used to link the MSISDN number to the subscriber's SIM (Subscriber Identity Module)
  - Charging information
  - Services available to the customer
- Also the subscriber's present Location Area Code, which refers to the MSC, which can connect to the MS.

Handoff (Handover)

- When a call is in process, the changes in location need special processing
- Within a BSS, the BSC, which knows the current radio link configuration (including feedbacks from the MS), prepares an available channel in the new BTS
- The MS is told to switch over to the new BTS
- This is called a hard handoff
  - In a soft handoff, the MS is connected to two BTSes simultaneously

Roaming

- When a MS enters another operators network, it can be allowed to use the services of this operator
  - Operator to operator agreements and contracts
  - Higher billing
- The MS is identified by the information in the SIM card and the identification request is forwarded to the home operator
  - The home HLR is updated to reflect the MS's current location

3G, 3.5G and 4G (LTE)

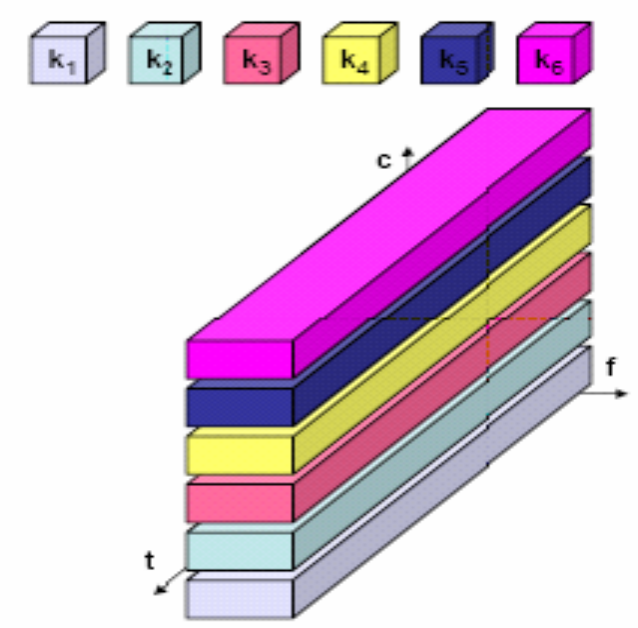
Moving to 3G

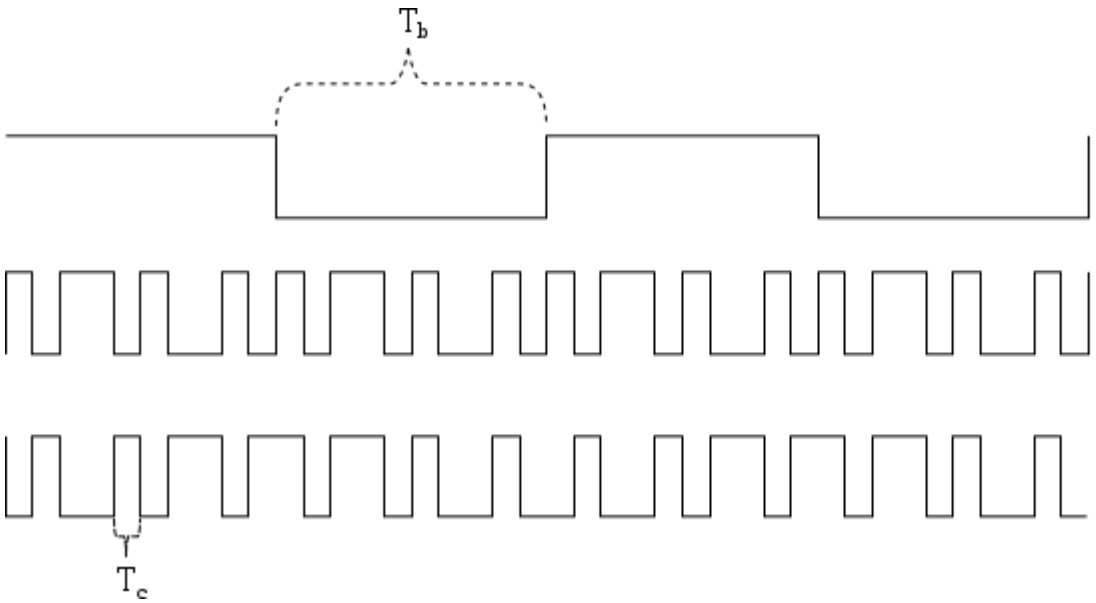
- faster and higher quality networks started supporting better services like video calling, video streaming, mobile gaming and fast Internet browsing, it resulted in the introduction of the 3rd generation mobile telecommunication standard (UMTS).

- 3G network were developed to offer high speed data and multimedia connectivity to subscribers

Code Division Multiple Access

- Cocktail Party Analogy: All people are in the same room together. They can all be talking the same time!
- Example: UMTS
- Use of orthogonal codes to separate different transmissions
- Each symbol of bit is transmitted as a larger number of bits using the user specific code – Spreading
  - Bandwidth occupied by the signal is much larger than the information transmission rate
  - But all users use the same frequency band together





Orthogonal among users

Data Signal

Pseudorandom Code

Transmitted signal:
Data Signal XOR with
the Pseudorandom

Code Division Multiple Access

- Each station is assigned a unique m-bit code (chip sequence)
- To send bit 1, station sends chip sequence.
- To send bit 0, station sends the complement.
- Example: 1 MHz band with 100 stations.
- FDMA
  - Each station a 10kHz band
  - Rate:10 kbps (Assume that you can send 1bit/Hz) cps.6
- CDMA
  - Each station uses the whole 1MHz band10
  - If <100 chips per bit Rate >10 kbps

Channel Partitioning (CDMA)

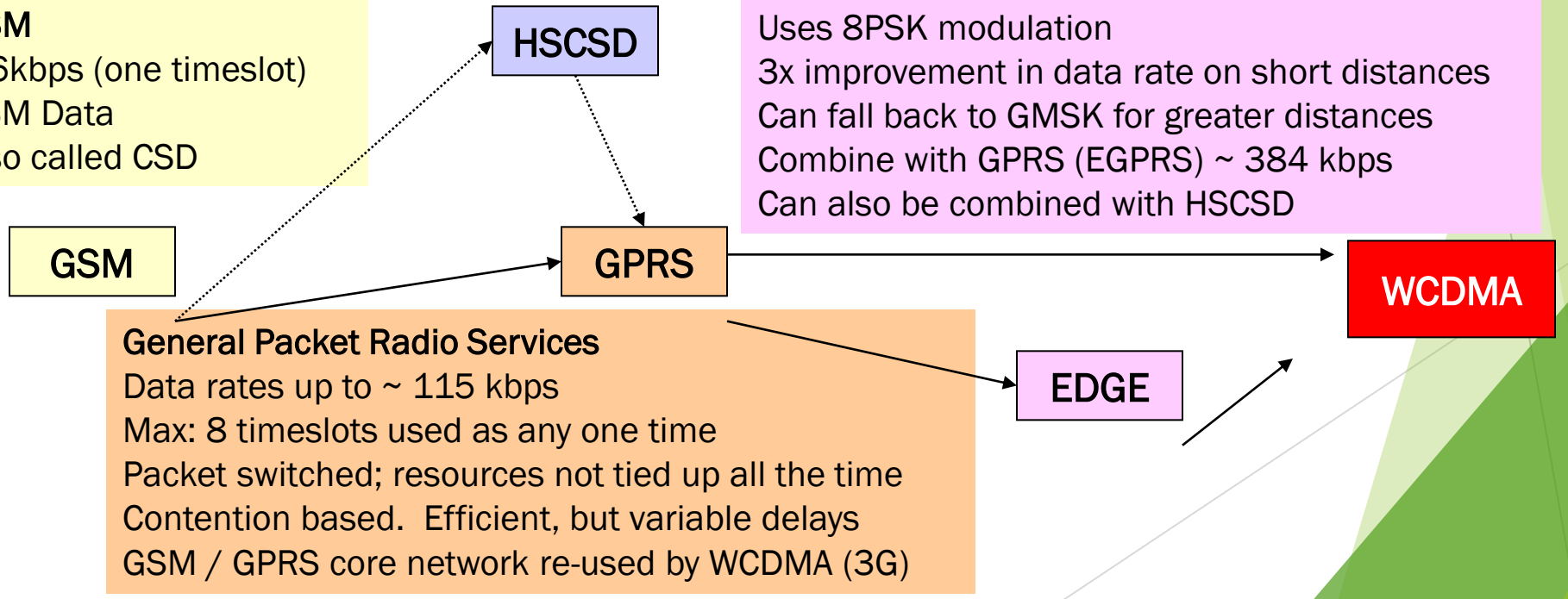
CDMA (Code Division Multiple Access)

- unique “code” assigned to each user; i.e., code set partitioning
- used mostly in wireless broadcast channels (cellular, satellite, etc)
- all users share same frequency, but each user has own “chipping” sequence (i.e., code) to encode data
- *encoded signal* = (original data) X (chipping sequence)
- *decoding:* inner-product of encoded signal and chipping sequence
- allows multiple users to “coexist” and transmit simultaneously with minimal interference (if codes are “orthogonal”)

GSM Evolution to 3G

High Speed Circuit Switched Data
Dedicate up to 4 timeslots for data connection ~ 50 kbps
Good for real-time applications c.w. GPRS
Inefficient -> ties up resources, even when nothing sent
Not as popular as GPRS (many skipping HSCSD)

GSM
9.6kbps (one timeslot)
GSM Data
Also called CSD



Enhanced Data Rates for Global Evolution
Uses 8PSK modulation
3x improvement in data rate on short distances
Can fall back to GMSK for greater distances
Combine with GPRS (EGPRS) ~ 384 kbps
Can also be combined with HSCSD

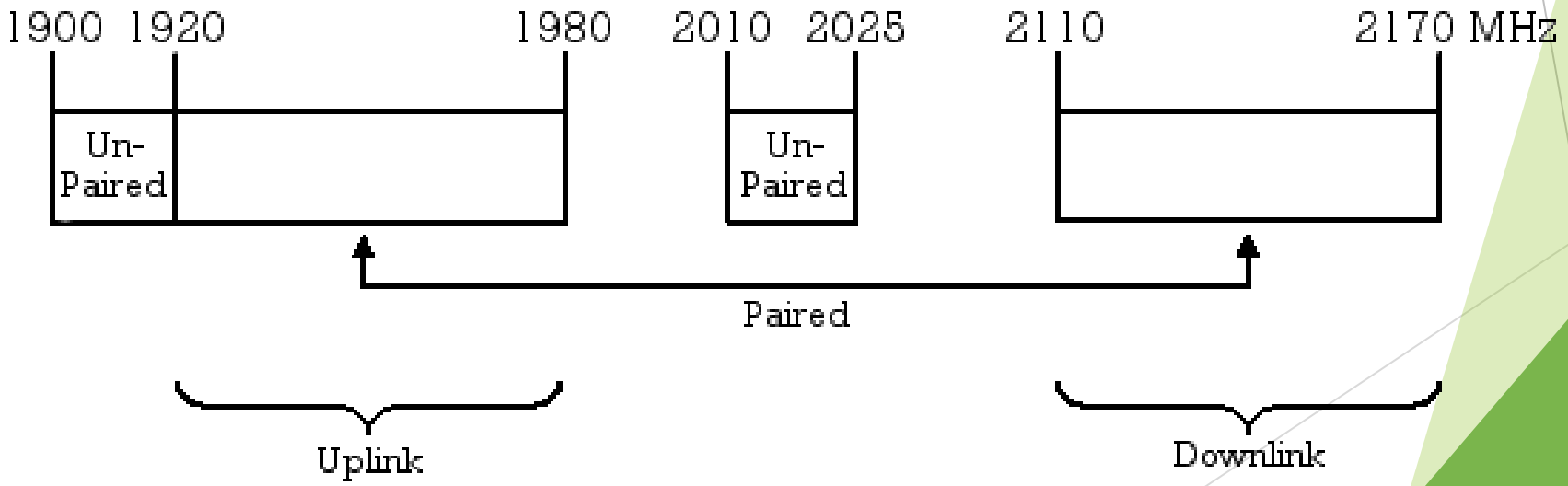
General Packet Radio Services
Data rates up to ~ 115 kbps
Max: 8 timeslots used as any one time
Packet switched; resources not tied up all the time
Contention based. Efficient, but variable delays
GSM / GPRS core network re-used by WCDMA (3G)

UMTS

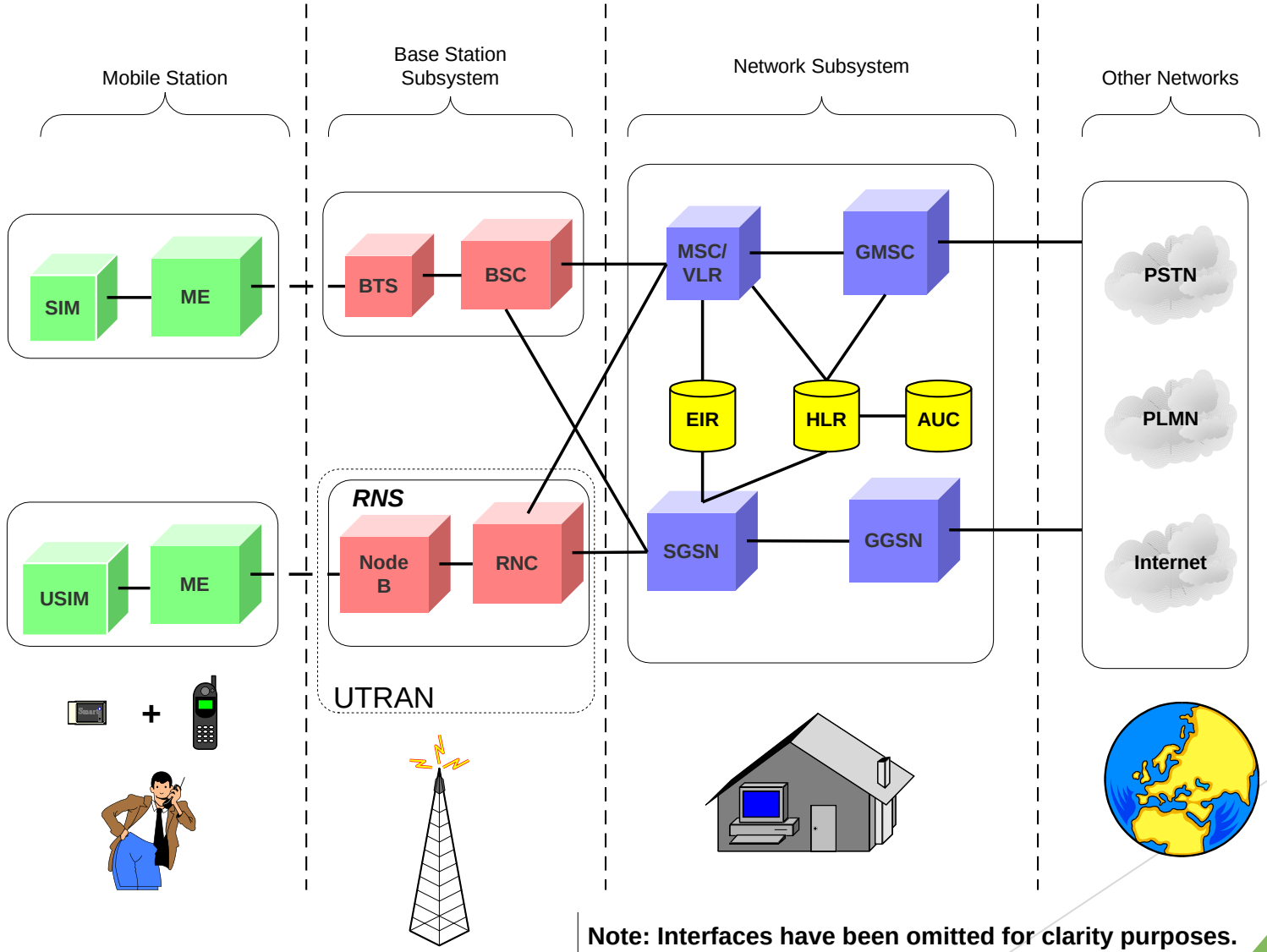
- Universal Mobile Telecommunications System (UMTS)
- UMTS is an upgrade from GSM via GPRS or EDGE
- The standardization work for UMTS is carried out by Third Generation Partnership Project (3GPP)
- Data rates of UMTS are:
  - 144 kbps for rural
  - 384 kbps for urban outdoor
  - 2048 kbps for indoor and low range outdoor
- Virtual Home Environment (VHE)

UMTS Frequency Spectrum

- UMTS Band
  - 1900-2025 MHz and 2110-2200 MHz for 3G transmission
  - In the US, 1710–1755 MHz and 2110–2155 MHz will be used instead, as the 1900 MHz band was already used.



UMTS Architecture



Note: Interfaces have been omitted for clarity purposes.

UMTS Network Architecture

- UMTS network architecture consists of three domains
  - Core Network (CN): Provide switching, routing and transit for user traffic
  - UMTS Terrestrial Radio Access Network (UTRAN): Provides the air interface access method for user equipment.
  - User Equipment (UE): Terminals work as air interface counterpart for base stations. The various identities are: IMSI, TMSI, P-TMSI, TLLI, MSISDN, IMEI, IMEISV

UTRAN

- Wide band CDMA technology is selected for UTRAN air interface
  - WCDMA
  - TD-SCDMA
- Base stations are referred to as Node-B and control equipment for Node-B is called as Radio Network Controller (RNC).
  - Functions of Node-B are
    - Air Interface Tx/Rx
    - Modulation/Demodulation
  - Functions of RNC are:
    - Radio Resource Control
    - Channel Allocation
    - Power Control Settings
    - Handover Control
    - Ciphering
    - Segmentation and reassembly

3.5G (HSPA)

- High Speed Packet Access (HSPA) is an amalgamation of two mobile telephony protocols, High Speed Downlink Packet Access (HSDPA) and High Speed Uplink Packet Access (HSUPA), that extends and improves the performance of existing WCDMA protocols
- 3.5G introduces many new features that will enhance the UMTS technology in future. 1xEV-DV already supports most of the features that will be provided in 3.5G. These include:
  - Adaptive Modulation and Coding
  - Fast Scheduling
  - Backward compatibility with 3G
  - Enhanced Air Interface