Cellular Mobile Communication-2

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نیمسال اول ۱۴۰۲
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2G

Advantages:

The digital voice encoding allows digital error checking

- increase sound quality
- lowers the noise level

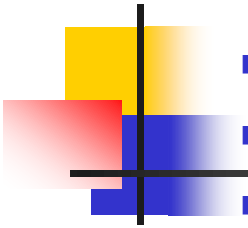
Going all-digital allowed for the introduction of digital data transfer.

- SMS –"short message service"
- E-mail

Disadvantages:

- Cell towers had a limited coverage area.
- Built mainly for voice services and slow data.

Second Generation…



- Higher quality signals
- Higher data rates
- Support of digital services
- Greater capacity
- Digital traffic channels
  - Support digital data
  - Voice traffic digitized
  - User traffic (data or digitized voice) converted to analog signal for transmission
- Encryption
  - Simple to encrypt digital traffic
- Error detection and correction
  - Very clear voice reception
- Channel access
  - Channel dynamically shared by users via Time division multiple access (TDMA) or code division multiple access (CDMA)

برخی استانداردهای نسل دوم

Digital cellular, still narrowband for voice, some data, TDMA & CDMA, Higher rate than 1G.

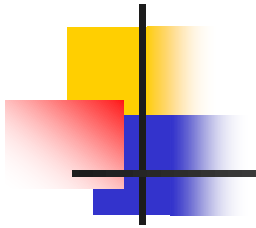
- 1991: Personal Digital Cellular (PDC), Japan
- 1992: Global System for Mobile (GSM), Europe

  Authentication by SIM card, A5-1,2,3: voice, data and signaling encryption
- 1992: Digital AMPS (D-AMPS or IS-54, IS-136), US
- 1995: IS-95, Hong Kong

خصوصیات فناوری های نسل دوم

System (Country)	GSM (Europe)	IS-54/136 (U.S.A)	IS-95 (U.S.A)	CT-2 (Europe /Asia)	CT-3/ DTC-900 (Sweden)	DECT (Europe)
Access Technology	TDMA/ FDMA	TDMA/ FDMA	CDMA/ FDMA	FDMA	TDMA/ FDMA	TDMA/ FDMA
Primary Use	Cellular	Cellular	Cellular	Cordless	Cordless	Cellular/ Cordless
Frequency band • Base Station • Mobile Station	 935-960 890-915	 869-894 824-849	 869-894 824-849	 864-868	 862-866	 1800-1900
Duplexing	FDD	FDD	FDD	TDD	TDD	TDD
Channels bandwidth	200 kHz	30 kHz	1,250 kHz	100 kHz	1000 kHz	1728 kHz
Modulation	GMSK	$\pi/4$ DQPSK	BPSK/QPSK	GFSK	GFSK	GFSK
Power/Ave. power	600 (mW)	600/200 (mW)	1000/125 (mW)	10/5 (mW)	80/5 (mW)	250/10 (mW)
Freq Assignment	Dynamic	Fixed		Dynamic	Dynamic	Dynamic
Frequency band • Base Station • Mobile Station	 Y Y	 Y Y	 Y Y	 N N	 N N	 N N
Speech Coding	RPE-LTP	VSELF	QCELP	ADPCM	ADPCM	ADPCM
Speech Rate	13 (kbps)	7.95 (kbps)	8 (variable)	32 (kbps)	32 (kbps)	32 (kbps)
Speech channel	8	3	-	1	8	12
Baud Rate (kbps)	270.833	48.6	-	72	640	1152
Channel Coding	R = ½, CC	R = ½, CC	R = ½, CC	None	CRC	CRC
Frame Duration	20 (ms)	40 (ms)	4.615 (ms)	2 (ms)	16 (ms)	10 (ms)

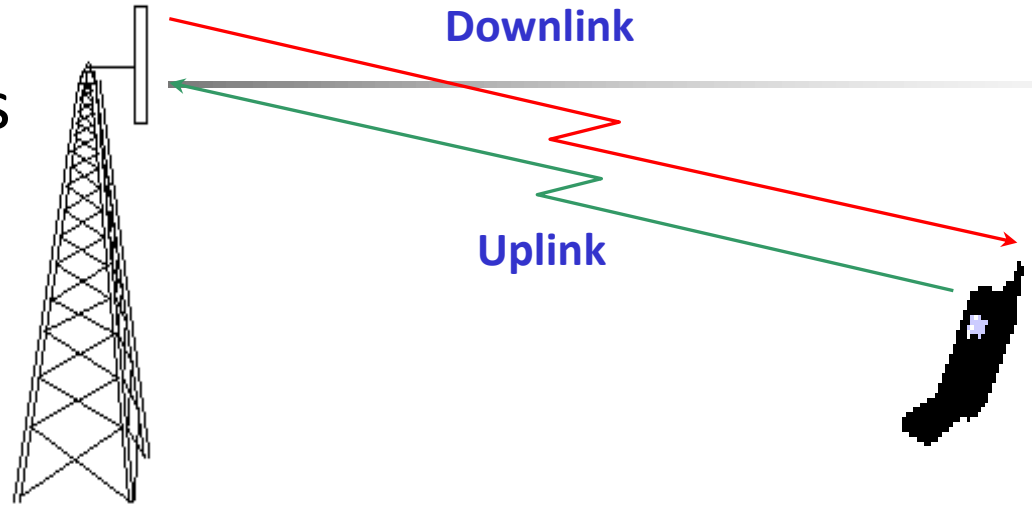
GSM



- 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

GSM Channels

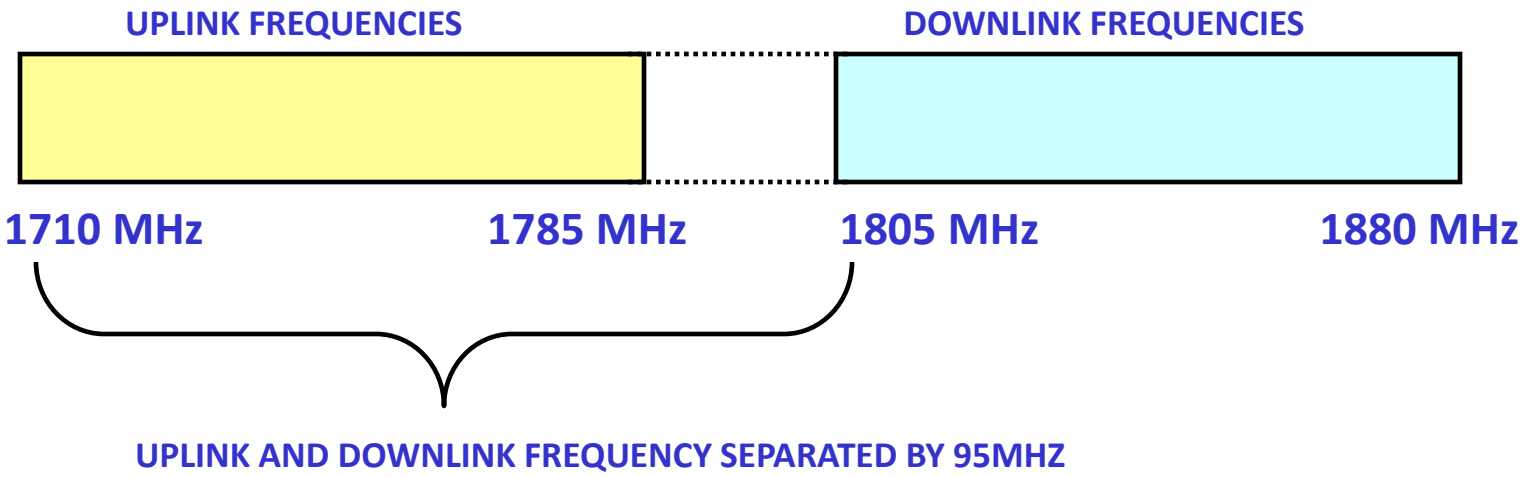
Channels



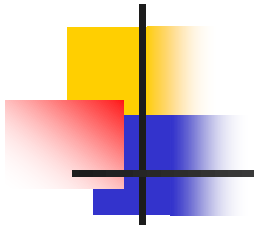
- Physical Channel: Each timeslot on a carrier is referred to as a physical channel
- Logical Channel: Variety of information is transmitted between the MS and BTS. Different types of logical channels:
  - Traffic channel
  - Control Channel

GSM Frequencies

- Originally designed on 900MHz range, now also available on 800MHz, 1800MHz and 1900 MHz ranges.
- Separate Uplink and Downlink frequencies
  - One example channel on the 1800 MHz frequency band, where RF carriers are space every 200 MHz

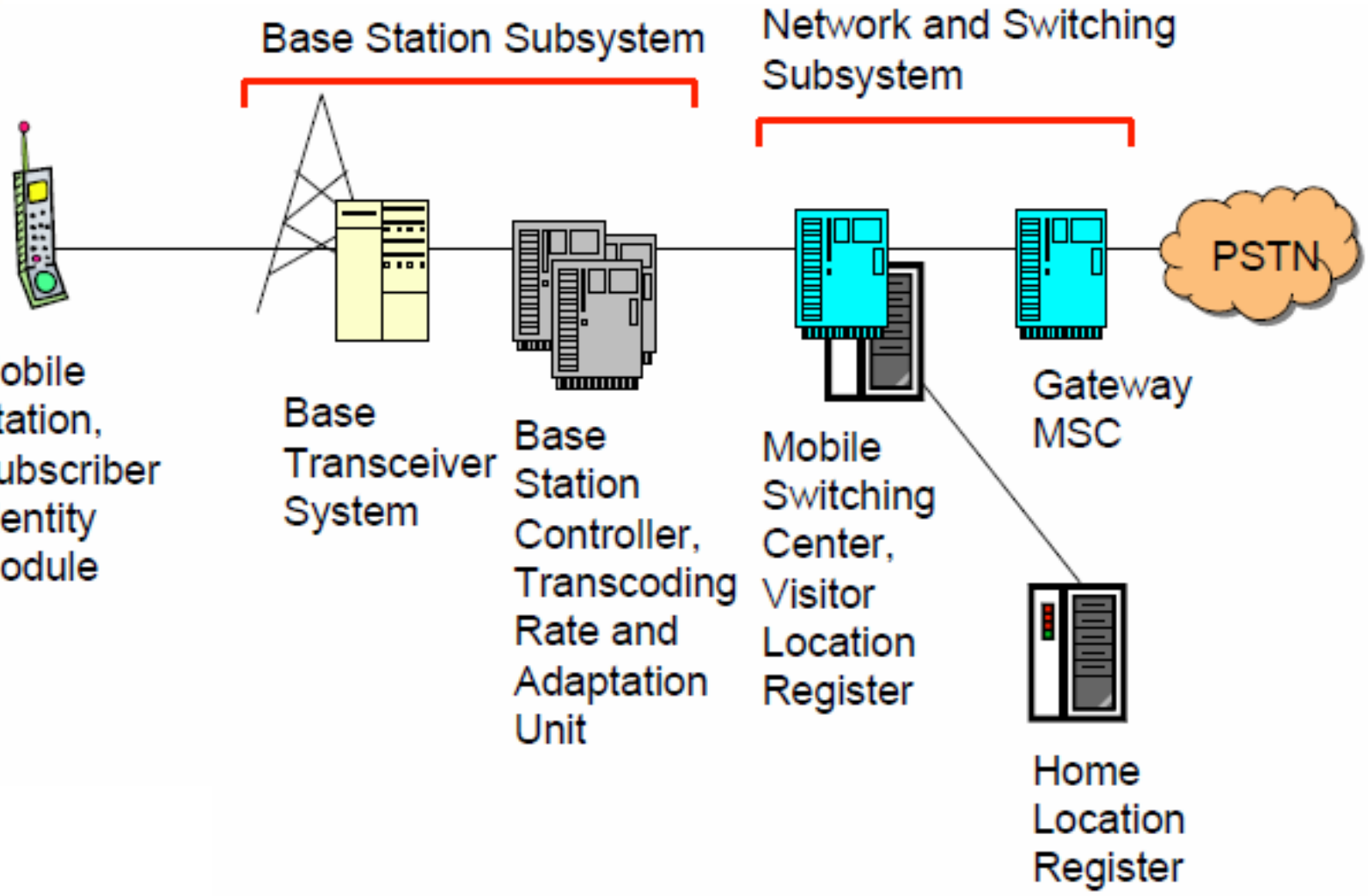


GSM Services

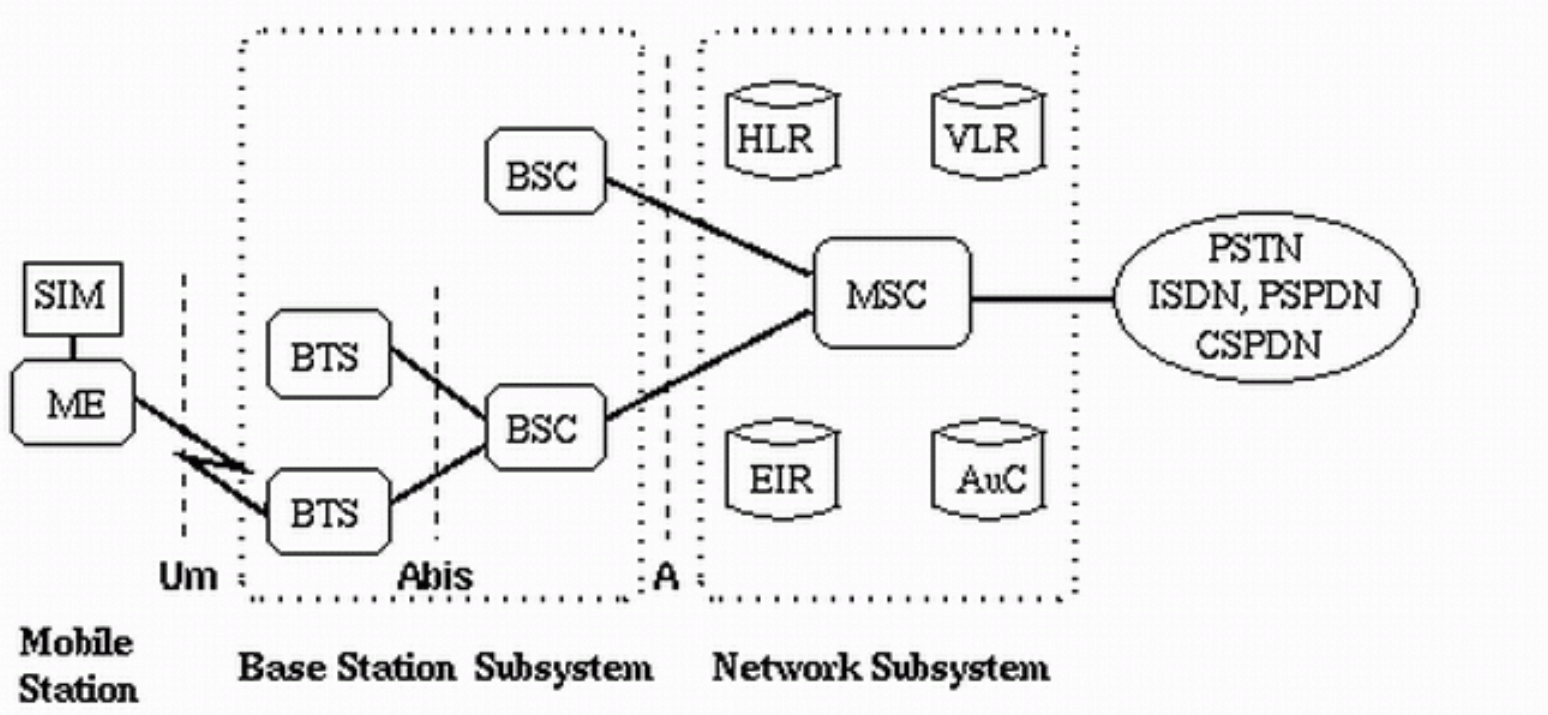


- Voice, 3.1 kHz
- Short Message Service (SMS)
  - 1985 GSM standard that allows messages of at most 160 chars. (incl. spaces) to be sent between handsets and other stations
  - Over 2.4 *billion* people use it; multi-billion $ industry
- General Packet Radio Service (GPRS)
  - GSM upgrade that provides 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 Architecture

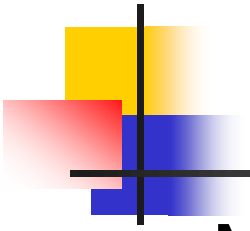


Network Structure…



SIM Subscriber Identity Module
ME Mobile Equipment
BTS Base Transceiver Station
BSC Base Station Controller
HLR Home Location Register
VLR Visitor Location Register
MSC Mobile services Switching Center
EIR Equipment Identity Register
AuC Authentication Center

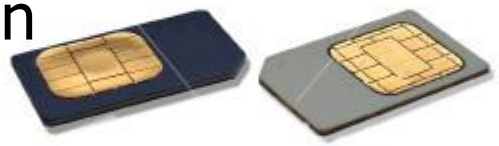
Mobile Station (MS)



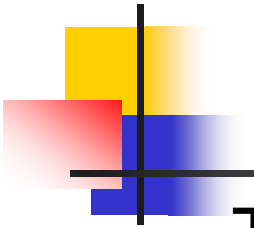
- MS is the user's handset and has two parts
- Mobile Equipment
  - Radio equipment
  - User interface
  - Processing capability and memory required for various tasks
    - Call signalling
    - Encryption
    - SMS
  - Equipment IMEI number
- Subscriber Identity Module

Subscriber Identity Module

- A small smart card
- Encryption codes needed to identify the subscriber
- Subscriber IMSI number
- Subscriber's own information (telephone directory)
- Third party applications (banking etc.)
- Can also be used in other systems besides GSM, e.g., some WLAN access points accept SIM based user authentication

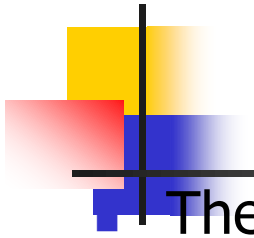


Base Station Subsystem



- 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



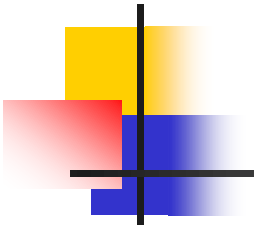
- The backbone of a GSM network is a telephone network with additional cellular network capabilities
- Mobile Switching Center (MSC)
  - An typical telephony exchange (ISDN exchange) which supports mobile communications
  - Visitor Location Register (VLR)
    - A database, part of the MSC
    - Contains 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

Databases

HLR : *Home Location Register*, contains static information of subscribers and location update data

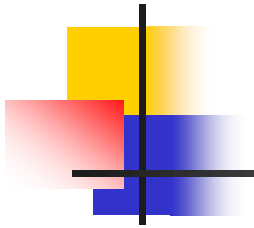
- VLR : *Visitor Location Register*, embedded in MSC to avoid delay, contains current location information of handsets
- AUC : *Authentication Center*, stores secret keys for authentication and encryption of the radio channel
- EIR : *Equipment Identity Register*, contains a list of all valid mobile equipment in the network, by its International Mobile Equipment Identity (IMEI)

Home Location Register



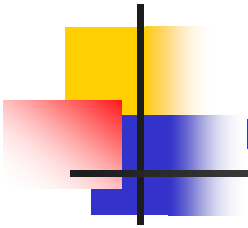
- One database per operator
- Contains all the permanent subscriber information
  - MSISDN (Mobile Subscriber ISDN number) is the telephone number of the subscriber
  - International Mobile Subscriber Identity (IMSI) is a 15 digit code used to identify the subscriber
    - It incorporates a country code 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.

Other Systems



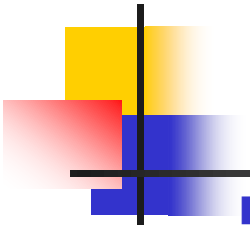
- Operations Support System
  - The management network for the whole GSM network
  - Usually vendor dependent
  - Very loosely specified in the GSM standards
- Value added services
  - Voice mail
  - Call forwarding
  - Group calls
- Short Message Service Center
  - Stores and forwards the SMS messages
  - Like an E-mail server
  - Required to operate the SMS services

Location Updates



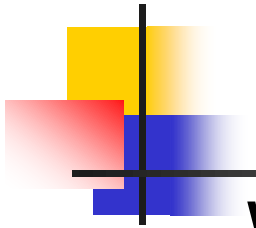
- The cells overlap and usually a mobile station can ‘see’ several transceivers (BTSes)
- The MS monitors the identifier for the BSC controlling the cells
- When the mobile station reaches a new BSC’s area, it requests an location update
- The update is forwarded to the MSC, entered into the VLR, the old BSC is notified and an acknowledgement is passed back

Handoff (Handover)



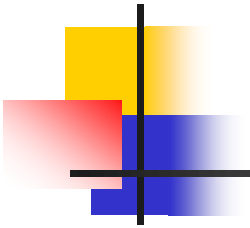
- When a call is in process, the changes in location need special processing
- Within a BSS, the BSC, which knows the current radio link configuration (including feedbacks from the MS), prepares an available channel in the new BTS
- The MS is told to switch over to the new BTS
- This is called a hard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

Roaming



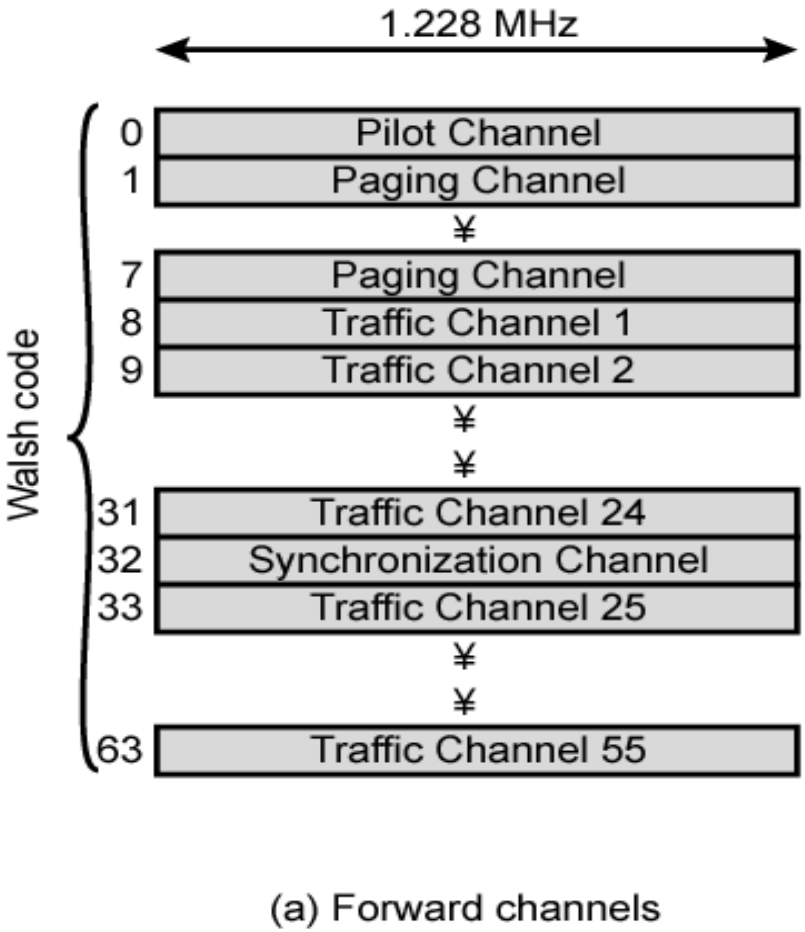
- When a MS enters another operators network, it can be allowed to use the services of this operator
  - Operator to operator agreements and contracts
  - Higher billing
- The MS is identified by the information in the SIM card and the identification request is forwarded to the home operator
  - The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

IS-95

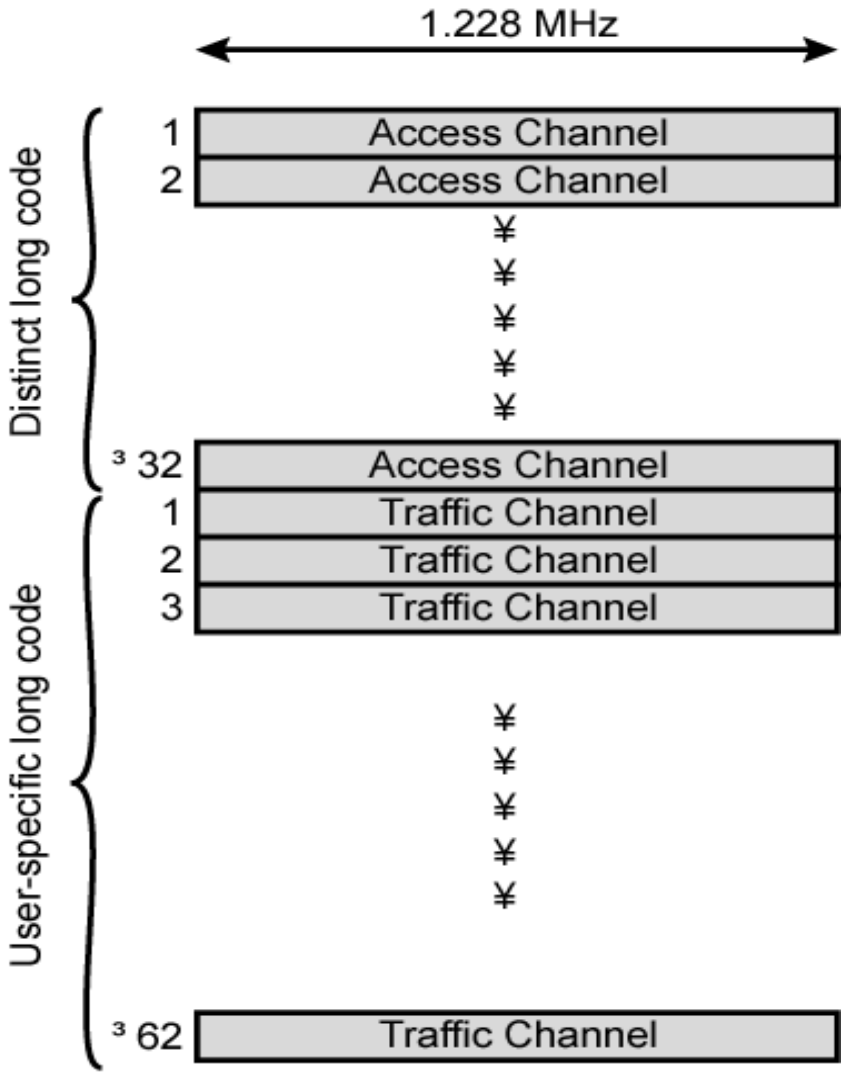


- Second generation CDMA scheme
- Primarily deployed in North America
- Transmission structures different on forward and reverse links

IS-95 Channel Structure



(a) Forward channels

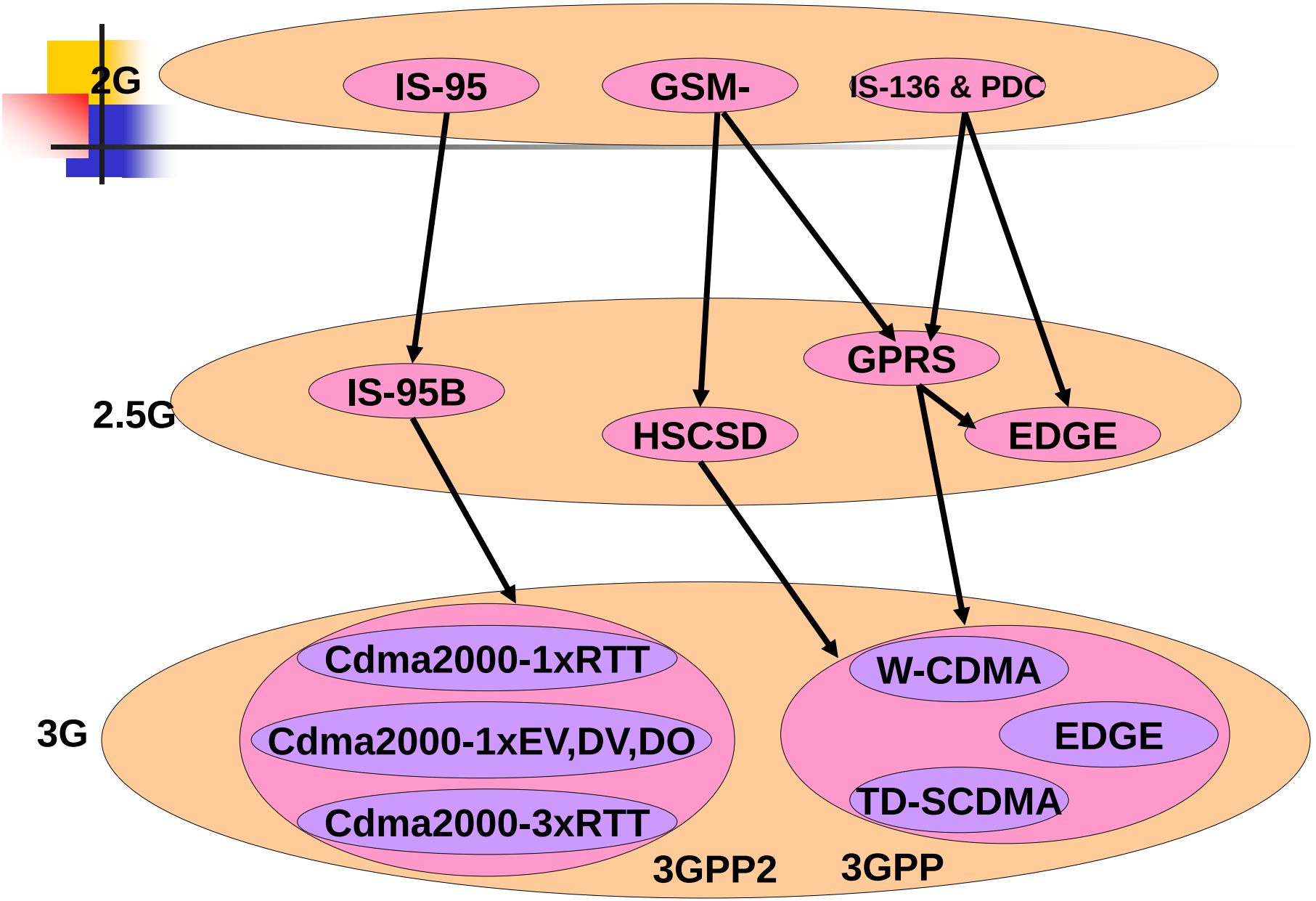


(b) Reverse channels

DSSS:
Discrete Sequence Spread Spectrum

- Spreads 19.2 kbps to 1.2288 Mbps
- Using one row of Walsh matrix
  - Assigned to mobile station during call setup
  - If 0 presented to XOR, 64 bits of assigned row sent
  - If 1 presented, bitwise XOR of row sent
- Final bit rate 1.2288 Mbps
- Bit stream modulated onto carrier using QPSK
  - Data split into I and Q Data in each channel XORed with unique short code
    - Pseudorandom numbers from 15-bit-long shift register

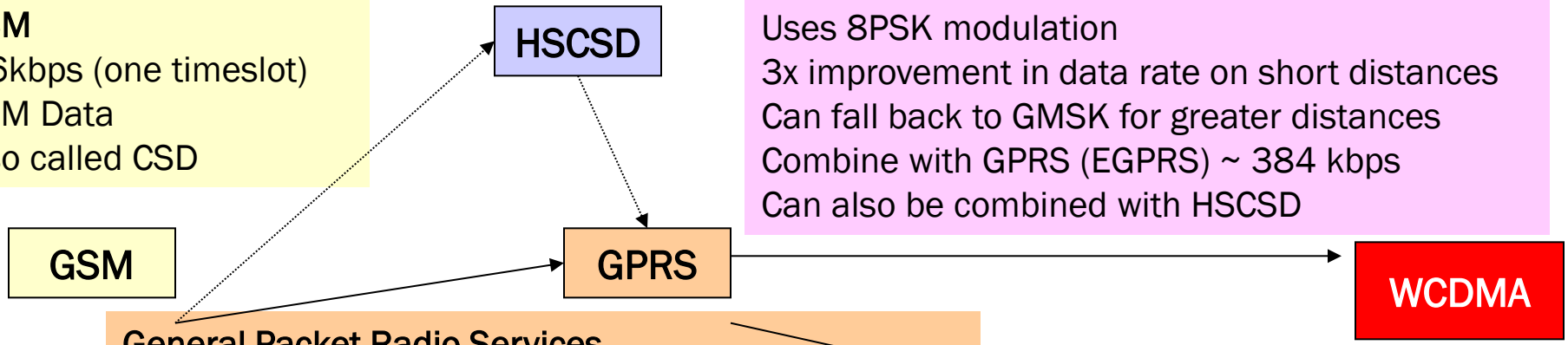
Evolution from 2G



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)

2.5G

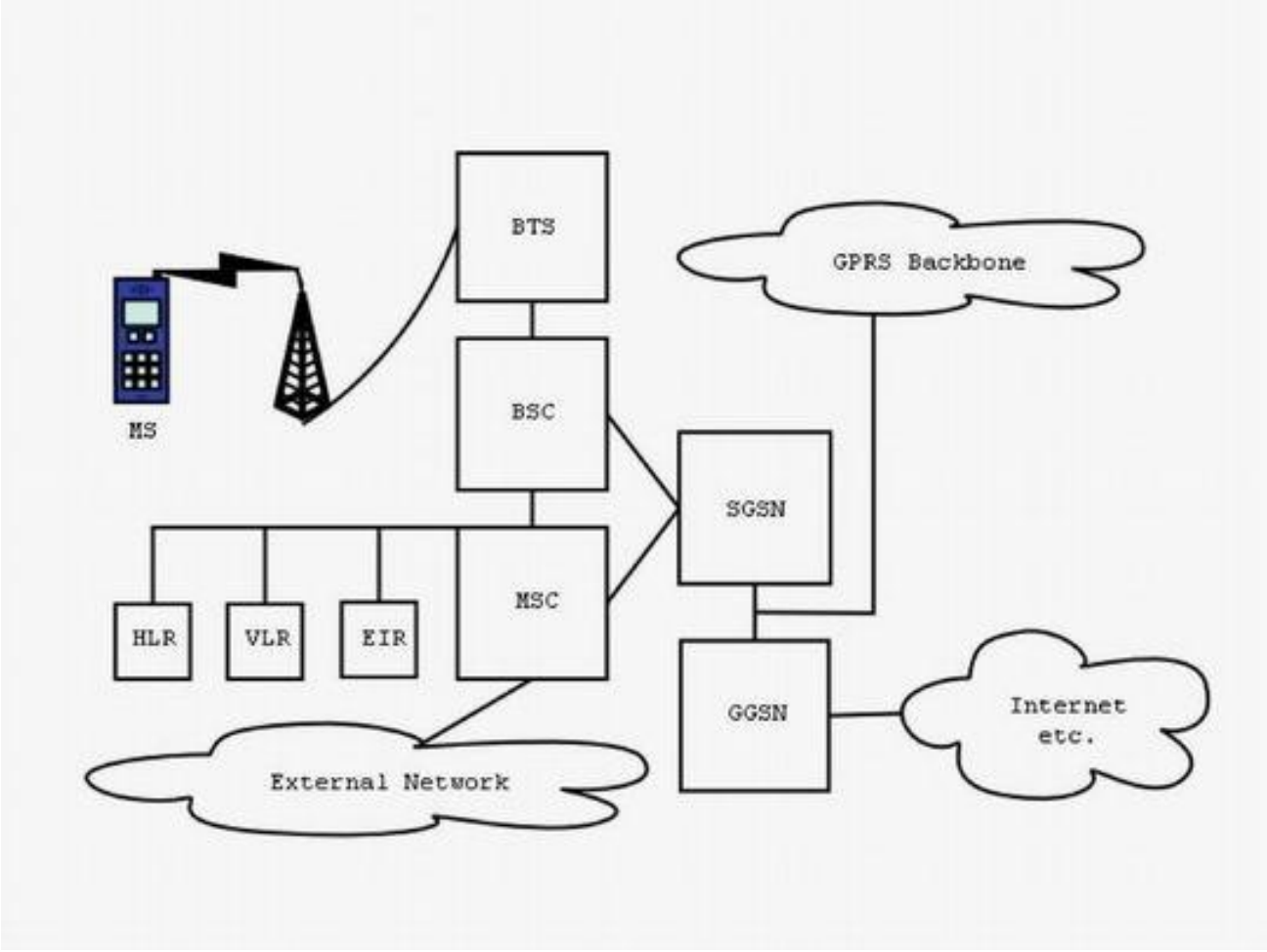
- Lies somewhere between **2G** and **3G**.
- The development of **2.5G** has been viewed as a stepping-stone towards **3G**.
- Was prompted by the demand for better data services and access to the internet.
- Provides faster services than **2G**, but not as faster as advanced as the newer **3G** systems.
- Extends the capabilities of **2G** systems by providing additional features, such as a packet-switched connection(**GPRS**) in the **TDMA**-based GSM system, and enhanced data rates (**HSCSD** and **EDGE**).

GPRS: General Packet Radio Services.

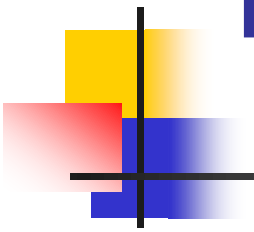
EDGE: Enhanced Data for Global Evolution.

HSCSD: High Speed circuit-switched data.

GPRS

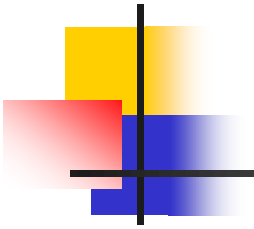

BTS
GPRS Backbone
BSC
MS
SGSN
MSC
HLR
VLR
EIR
GGSN
Internet
etc.
External Network

Network nodes



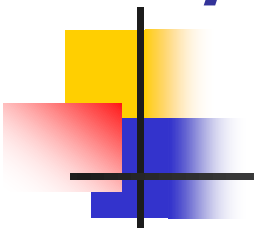
- GGSN: *Gateway GSM Support Node*,
- Protocol transferring, data encapsulation, a connection to external networks
- SGSN: *Service GSM Support Node*,
- Communicate with HLR and mobile handsets, authorization and admission control, charging, mobility management

Data communications



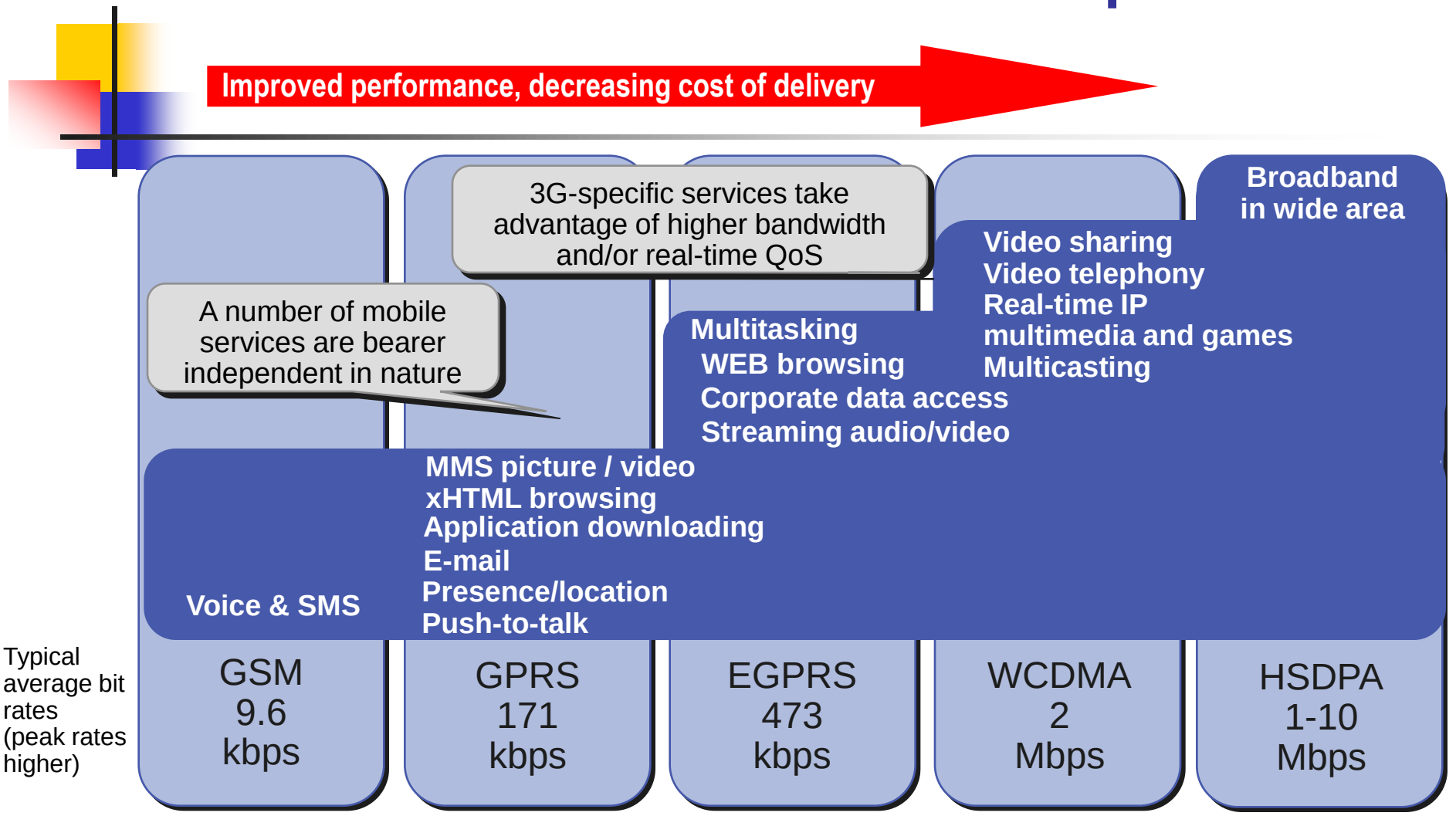
- In GSM, one user occupies one traffic channel to exchange voice/data information
- In GPRS, up to 8 traffic channels(a whole carrier) can be dynamically combined together for one data communication application
- The theoretically maximum data transmission rate: 14.4k bps * 8 = 115.2k bps

Advantages of GPRS

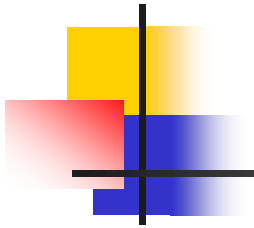


- Higher data rate
- Seamless connection to internet
- Packet switching rather than circuit switch, bandwidth is only used when the data is actually used, even though it is always connected
- A primary step to 3G

Service Roadmap



3G



- Large capacity and broadband capabilities. •Allows the transmission of 384kbps for mobile systems and up to 2Mbps.

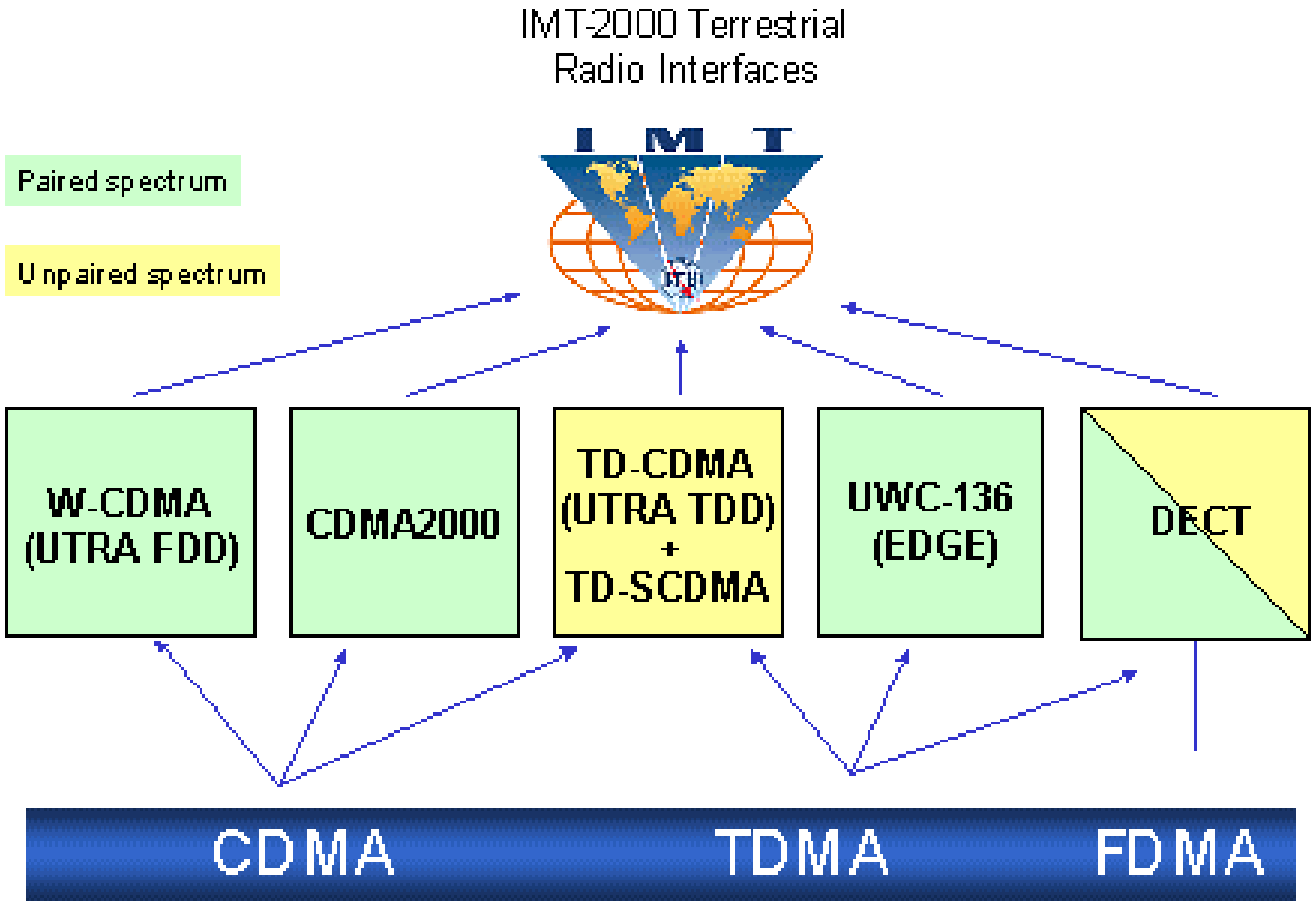
•Increased spectrum efficiency –5Mhz–

-A greater number of users that can be simultaneously supported by a radio frequency bandwidth.

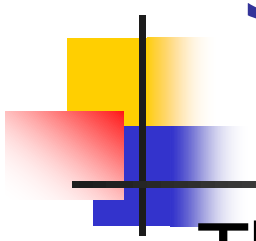
- High data rates at lower incremental cost than 2G.
- Global roaming

3G Overview

- 3G is created by ITU-T and is called IMT-2000



3G-Standards

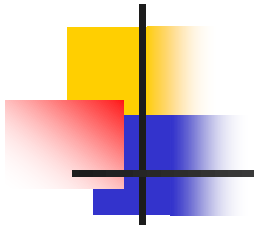


- Three CDMA standards approved by ITU:
- Direct Spread CDMA(WCDMA) : Europe, Japan
- Multi-Carrier CDMA(CDMA 2000) : North America
- TD-Synchronous CDMA(CDMA TDD) : Europe, China

3G's Goals

- Objective to provide fairly high-speed wireless communications to support multimedia, data, and video in addition to voice
- ITU's International Mobile Telecommunications for the year 2000 (IMT-2000) initiative defined ITU's view of third-generation capabilities as:
  - Voice quality comparable to PSTN
  - 144 kbps available to users in vehicles over large areas
  - 384 kbps available to pedestrians over small areas
  - Support for 2.048 Mbps for office use
  - Symmetrical and asymmetrical data rates
  - Support for packet-switched and circuit-switched services
  - Adaptive interface to Internet
  - More efficient use of available spectrum
  - Support for variety of mobile equipment
  - Flexibility to allow introduction of new services and technologies

3G



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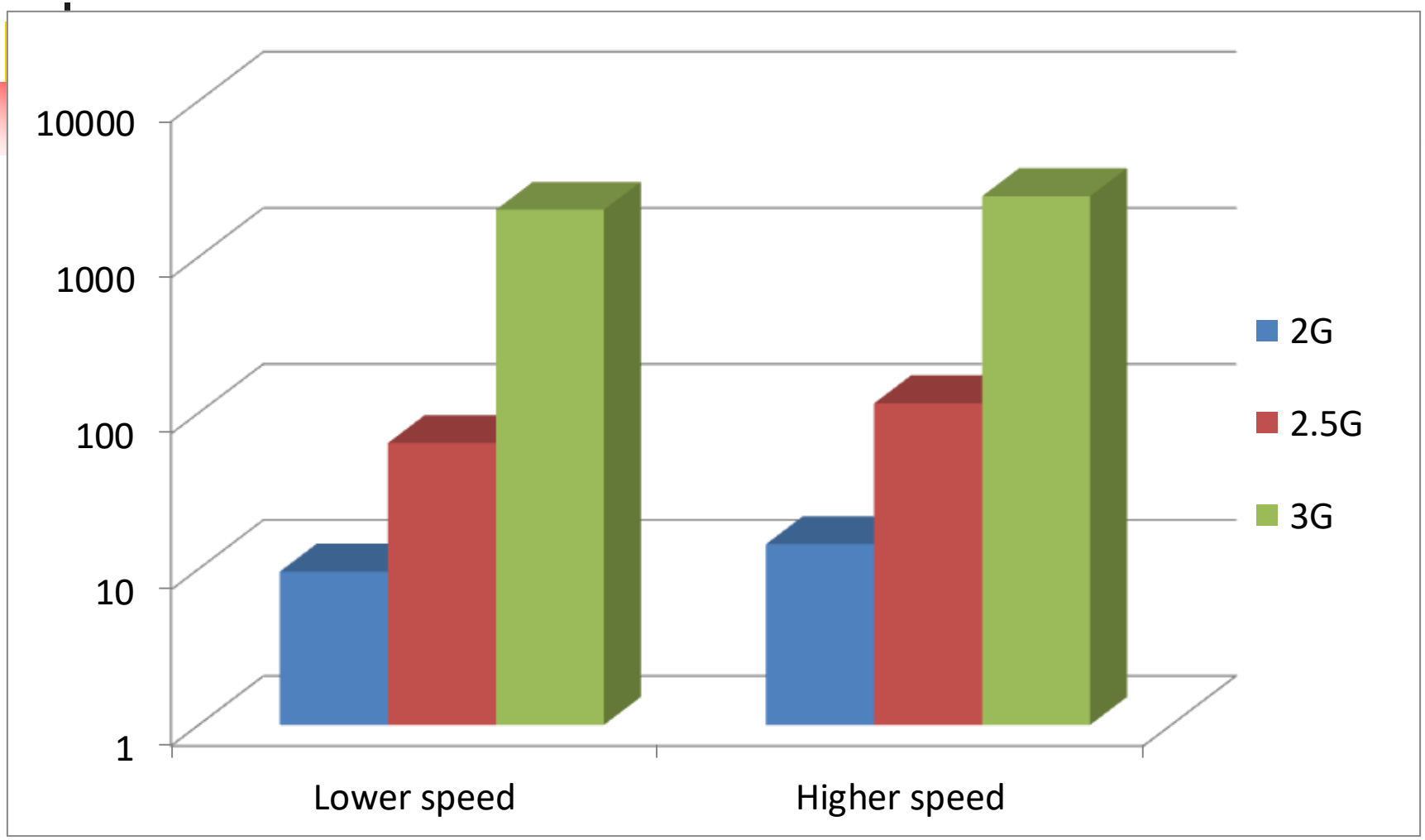
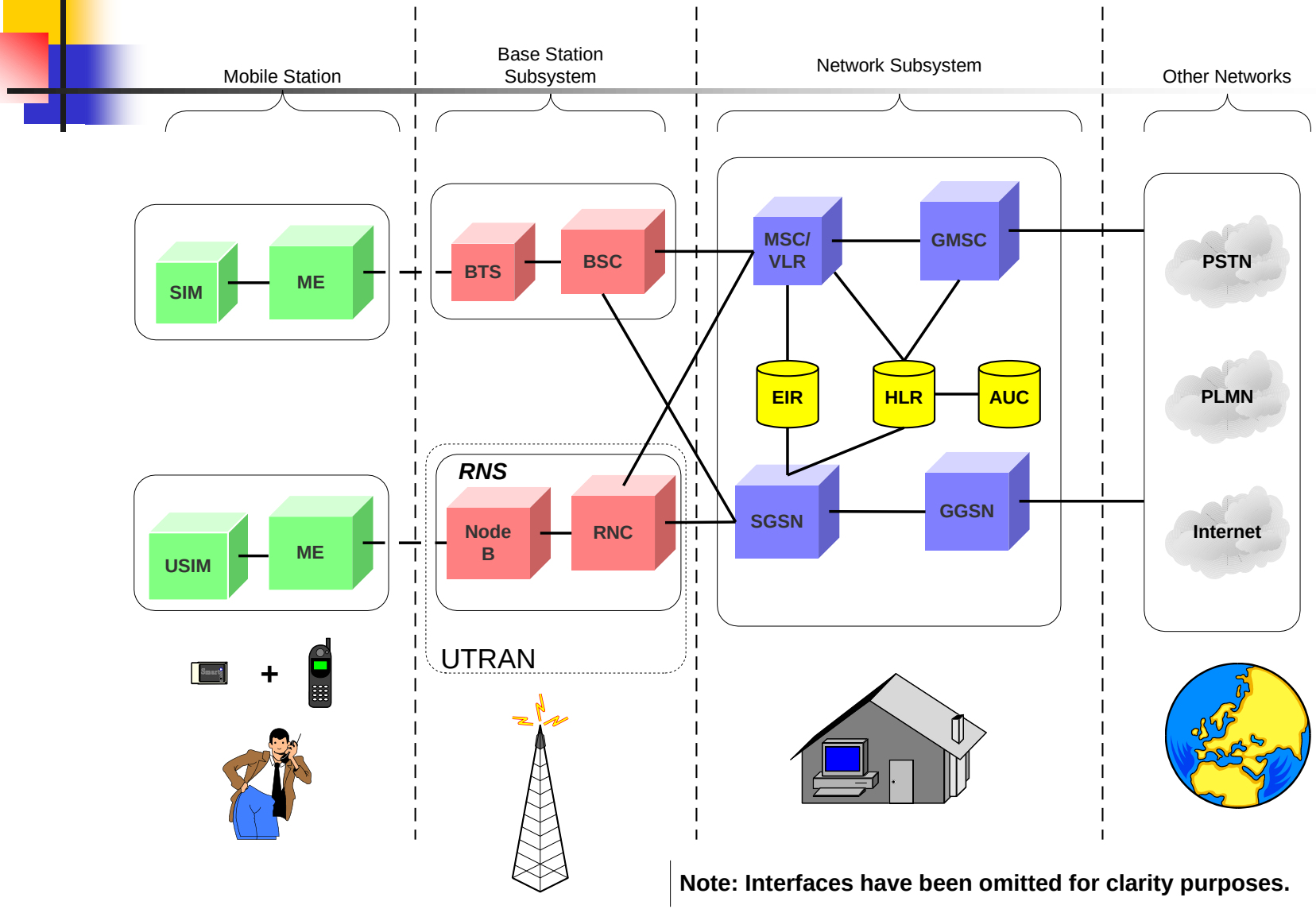
Data Rates Comparison (Kbps)



UMTS

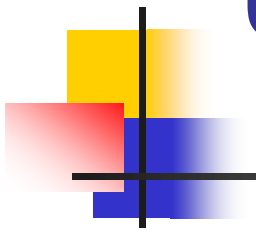
- Universal Mobile Telecommunications System (UMTS)
- UMTS is an upgrade from GSM via GPRS or EDGE
- The standardization work for UMTS is carried out by Third Generation Partnership Project (3GPP)
- Data rates of UMTS are:
  - 144 kbps for rural
  - 384 kbps for urban outdoor
  - 2048 kbps for indoor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

UMTS Architecture



Note: Interfaces have been omitted for clarity purposes.

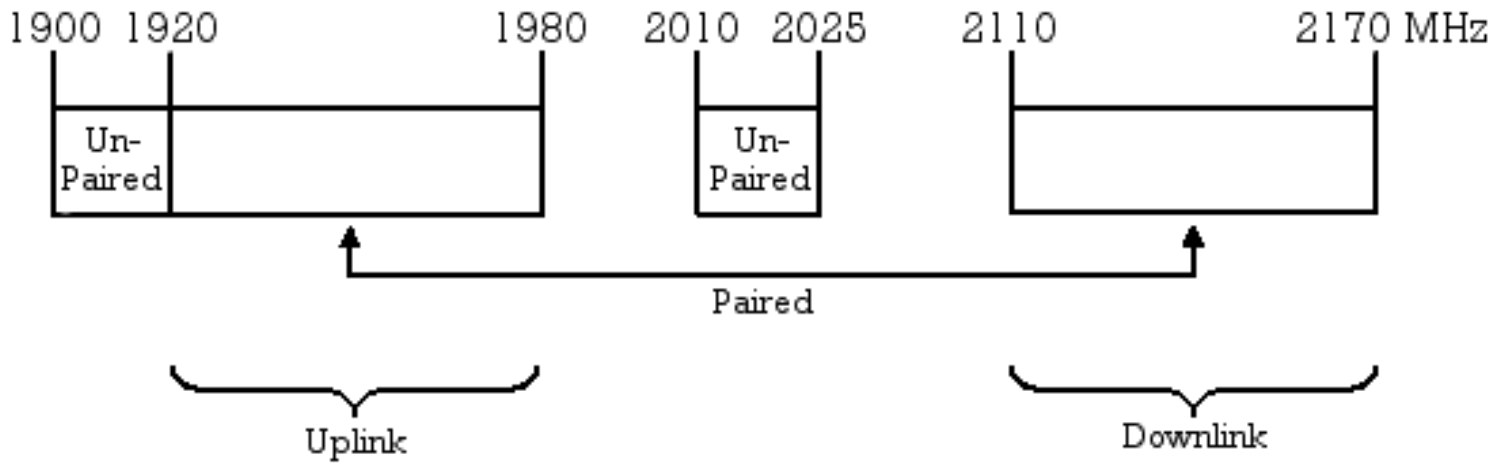
UMTS Network Architecture



- 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

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.

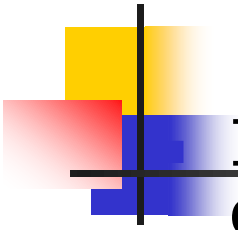


UTRAN

(UMTS Terrestrial Radio Access Network)

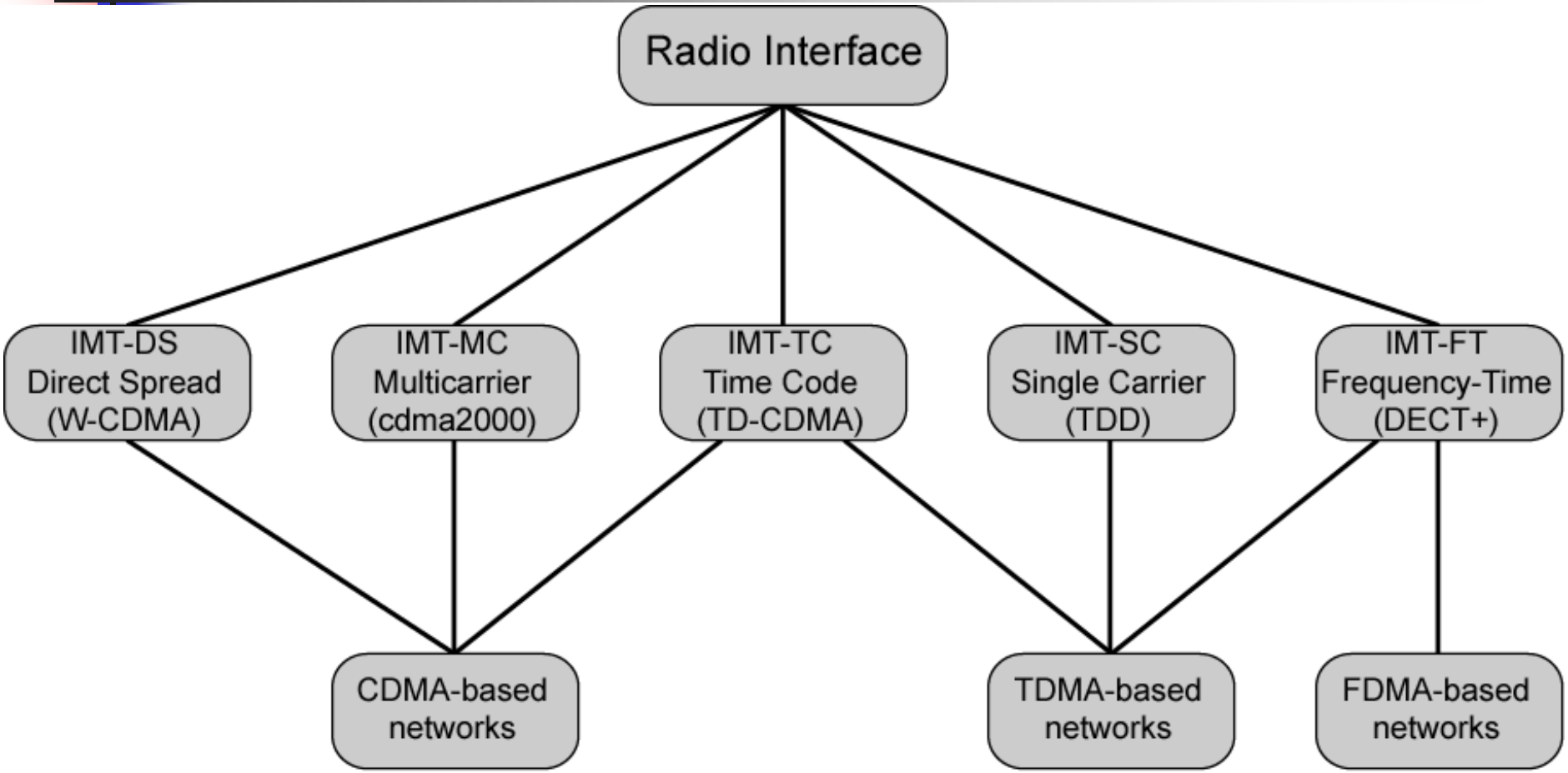
- Wide band CDMA technology is selected for UTRAN air interface
  - WCDMA
  - TD-SCDMA
- Base stations are referred to as Node-B and control equipment for Node-B is called as Radio Network Controller (RNC).
  - Functions of Node-B are
    - Air Interface Tx/Rx
    - Modulation/Demodulation
  - Functions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

Alternative Interfaces (1)



- IMT-2000 specification covers set of radio interfaces for optimized performance in different radio environments
- Five alternatives to enable smooth evolution from existing systems
- Alternatives reflect evolution from second generation
- Two specifications grow out of work at European Telecommunications Standards Institute (ETSI)
  - Develop a UMTS (universal mobile telecommunications system) as Europe's 3G wireless standard
  - Includes two standards
    - Wideband CDMA, or W-CDMA
      - Fully exploits CDMA technology
      - Provides high data rates with efficient use of bandwidth
    - IMT-TC, or TD-CDMA
      - Combination of W-CDMA and TDMA technology
      - Intended to provide upgrade path for TDMA-based GSM systems

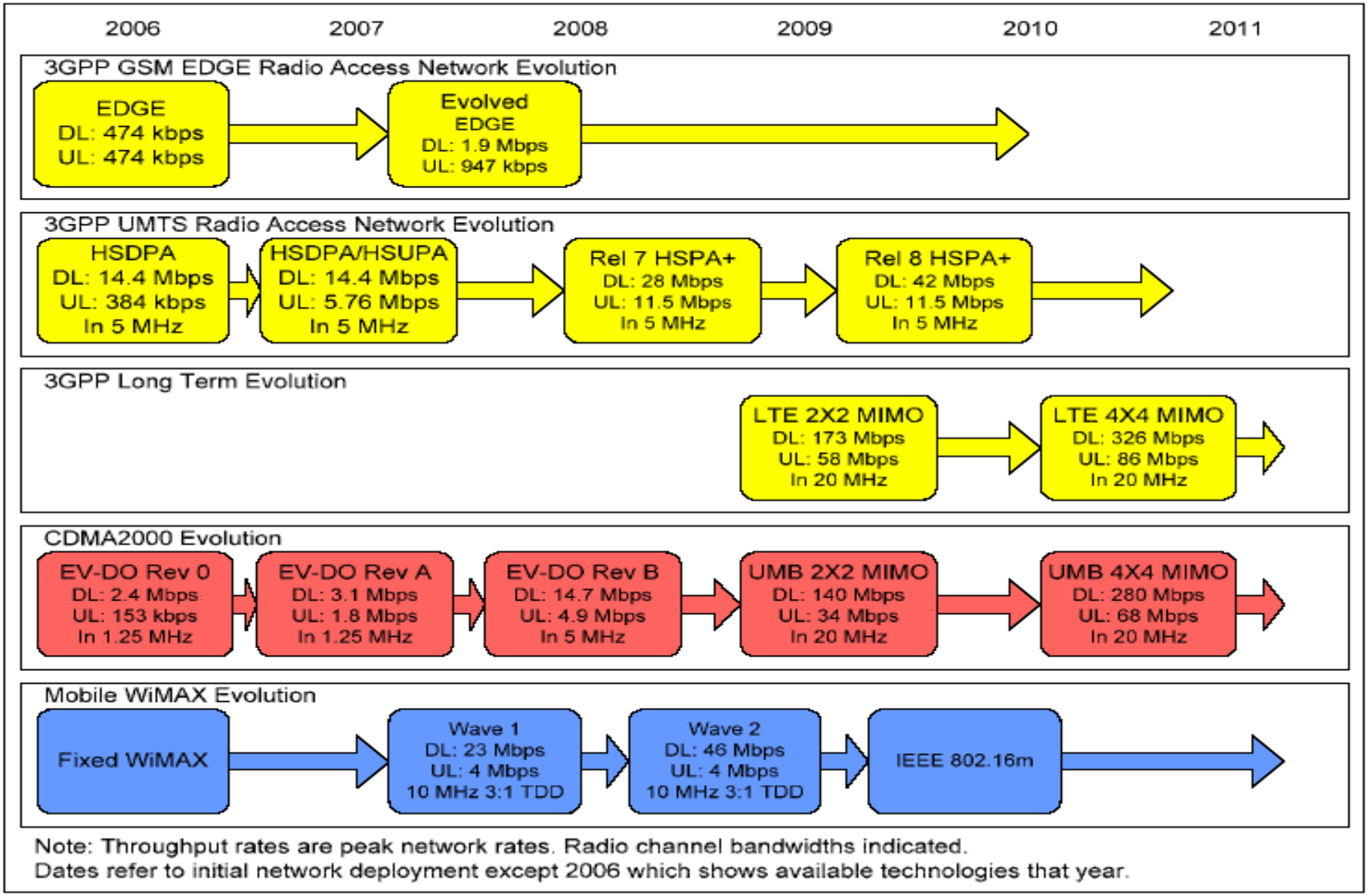
IMT-2000
Terrestrial Radio Interfaces



Alternative Interfaces (2)

- CDMA2000
  - North American origin
  - Similar to, but incompatible with, W-CDMA
    - In part because standards use different chip rates
    - Also, cdma2000 uses multicarrier, not used with W-CDMA
- IMT-SC designed for TDMA-only networks
- IMT-FC can be used by both TDMA and FDMA carriers
  - To provide some 3G services
  - Outgrowth of Digital European Cordless Telecommunications (DECT) standard

Figure 3: Evolution of TDMA, CDMA, and OFDM Systems



Note: Throughput rates are peak network rates. Radio channel bandwidths indicated.
Dates refer to initial network deployment except 2006 which shows available technologies that year.

Major Wireless Technologies

Technology	EDGE/HSPA/LTE	CDMA2000/UMB	IEEE 802.16e WiMAX
Subscribers	Over 2.5 billion today; 3.4 billion expected by 2009	351 million[65] today; slower growth expected than GSM/UMTS	Less than 100 million by 2012
Maturity	Extremely mature	Extremely mature	Emerging/immature
Adoption	Cellular operators globally	Cellular operators globally	Extremely limited to date
Coverage	Global	Global with the general exception of Western Europe	None
Devices	Broad selection of GSM/EDGE/UMTS/ HSPA devices	Broad selection of 1xRTT/EV-DO devices	None yet; initial devices likely to emphasize data
Radio Technology	Highly optimized TDMA for EDGE, highly optimized CDMA for HSPA, highly optimized OFDMA for LTE	Highly optimized CDMA for Rev 0/A/B, highly optimized OFDMA for Rev C	Optimized OFDMA in Wave 1, highly optimized OFDMA in Wave 2

Major Wireless Technologies…

Technology	EDGE/HSPA/LTE	CDMA2000/UMB	IEEE 802.16e WiMAX
Spectral Efficiency	Very high with HSPA, matches OFDMA approaches in 5 MHz with HSPA+	Very high with EV-DO Rev A/B	Very high, but not higher than HSPA+
Throughput Capabilities	Peak downlink user-achievable rates of over 3 Mbps today, with significantly higher rates in the future	Peak downlink user-achievable rates of over 1.5 Mbps, with significantly higher rates in the future	Peak downlink user-achievable rates will depend on network design
Latency	As low as 70 msec with HSPA today, with much lower latency in the future	As low as 70 msec with EV-DO Rev A, with much lower latency in the future	To be determined
Voice Capability	Extremely efficient circuit-voice available today; smoothest migration to VoIP of any technology	Extremely efficient circuit-voice available today EV-DO radio channels with VoIP cannot support circuit-voice users	Relatively inefficient VoIP initially; more efficient in later stages Voice coverage will be much more limited than cellular
Simultaneous Voice and Data	Available with UMTS today	Not available today Available with VoIP	Potentially available, though initial services will emphasize data
Efficient Spectrum Usage	Entire UMTS radio channel available for any mix of voice and high-speed data	Radio channel today limited to either voice/medium speed data or high-speed data only	Efficient for data-centric networks only until later versions

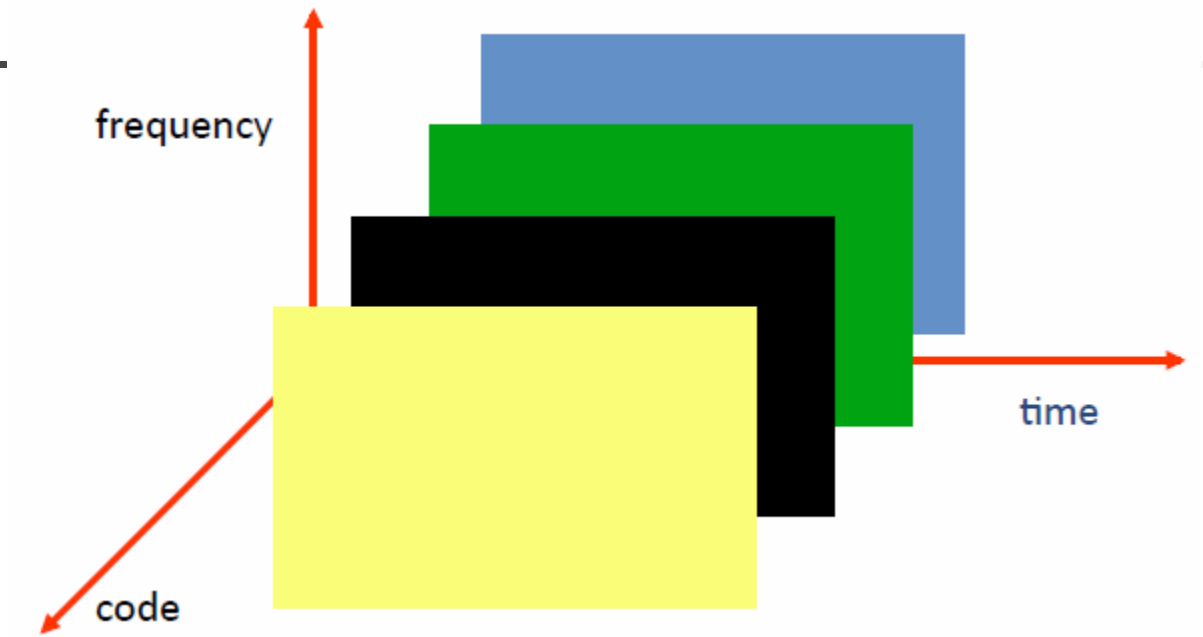
3.5G (HSPA)

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

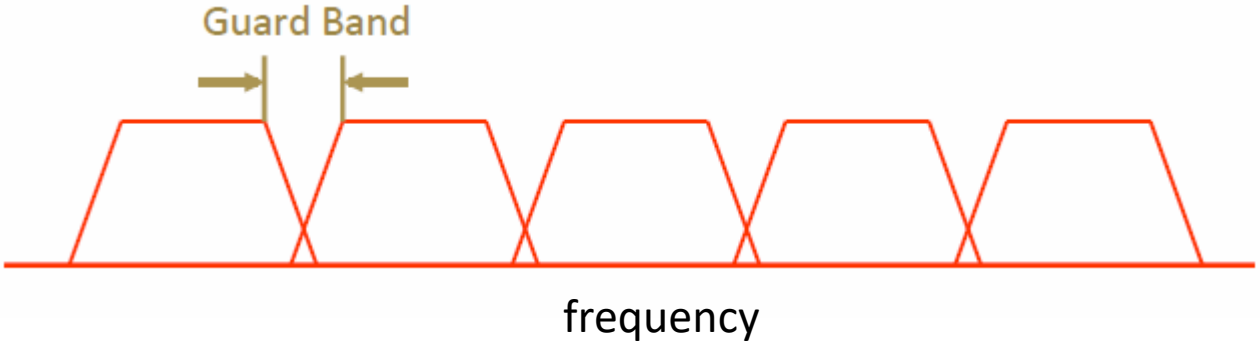
Multiple Access Schemes



3 orthogonal Schemes:

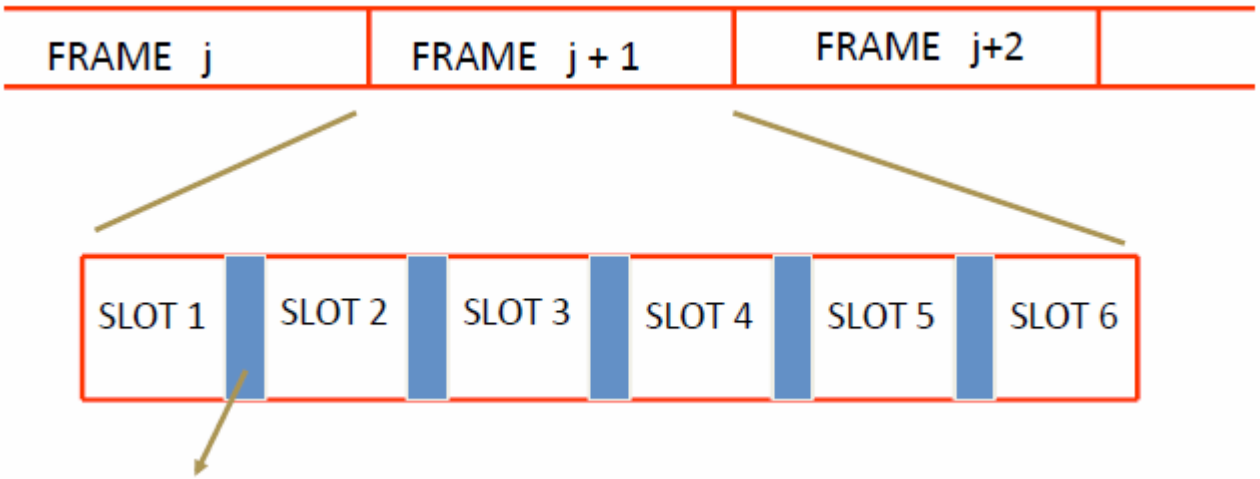
- Frequency Division Multiple Access (FDMA)
- Time Division Multiple Access (TDMA)
- Code Division Multiple Access (CDMA)

Frequency Division Multiple Access



- 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

Time Division Multiple Access



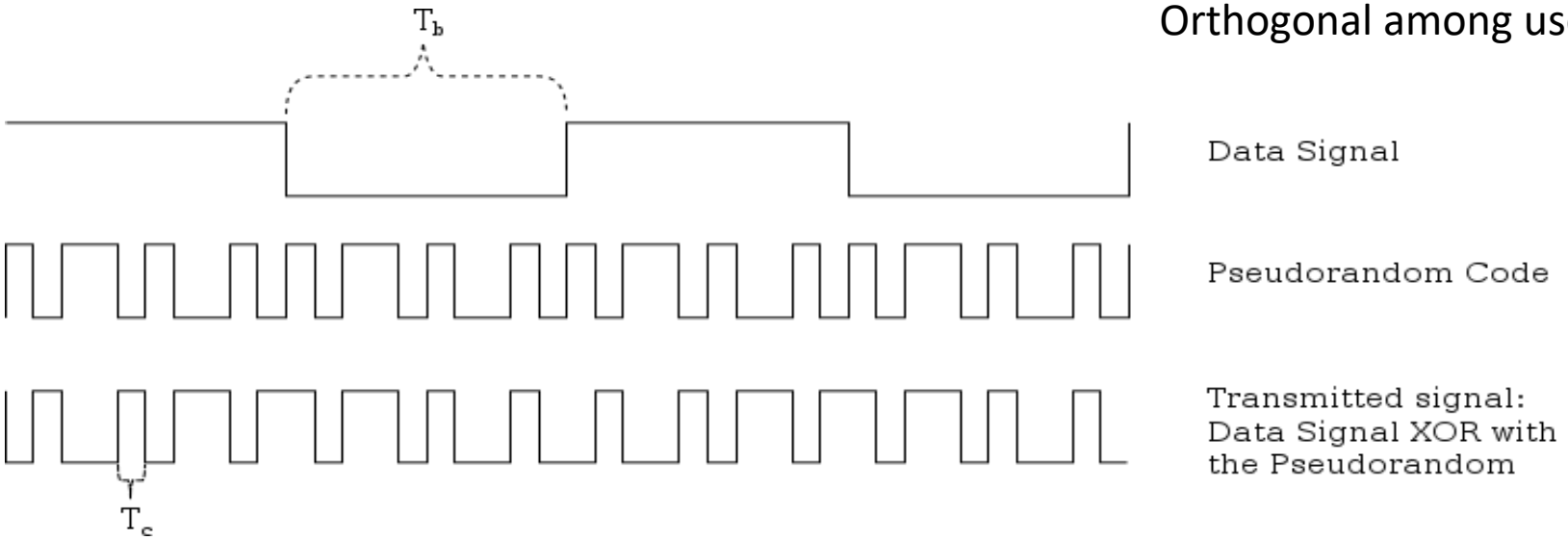
Guard time – signal transmitted by mobile terminals at different locations do no arrive at the base station at the same time

- 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

Code Division Multiple Access

- 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



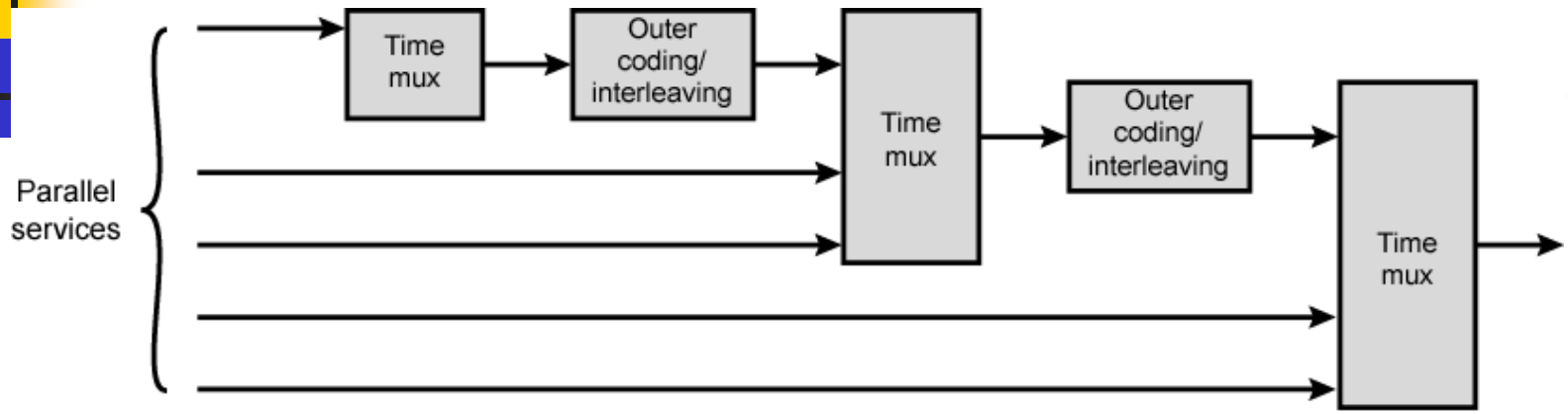
CDMA Design Considerations
Bandwidth and Chip Rate

- Dominant technology for 3G systems is CDMA
  - Three different CDMA schemes have been adopted
  - Share some common design issues
- Bandwidth
  - Limit channel usage to 5 MHz
  - Higher bandwidth improves the receiver's ability to resolve multipath
  - But available spectrum is limited by competing needs
  - 5 MHz reasonable upper limit on what can be allocated for 3G
  - 5 MHz is enoughfordata rates of 144 and 384 kHz
- Chip rate
  - Given bandwidth, chip rate depends on desired data rate, need for error control, and bandwidth limitations
  - Chip rate of 3 Mcps or more reasonable

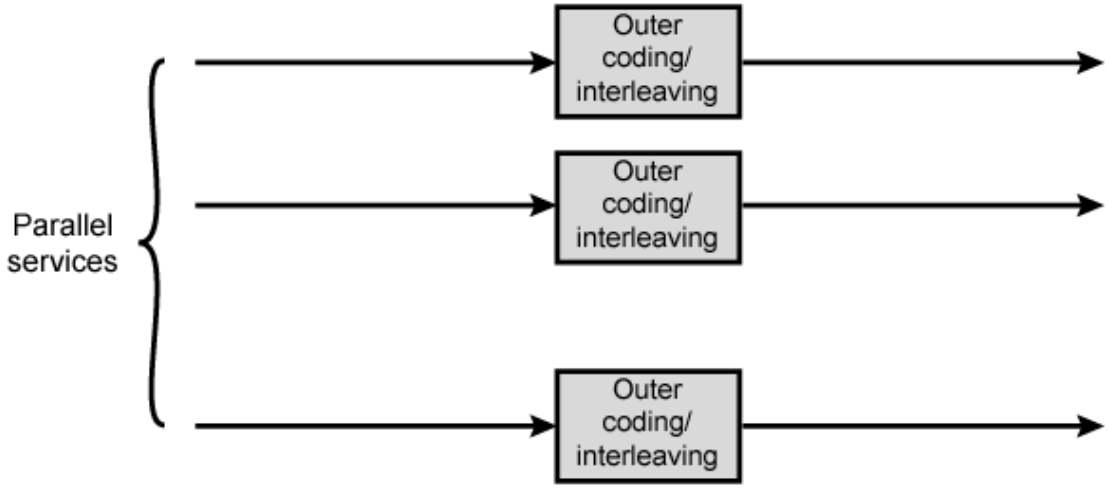
CDMA Design Considerations
Multi-rate

- Provision of multiple fixed-data-rate logical channels to a given user
- Different data rates provided on different logical channels
- Traffic on each logical channel can be switched independently through wireless fixed networks to different destinations
- Flexibly support multiple simultaneous applications from user
- Efficiently use available capacity by only providing the capacity required for each service
- Achieved with TDMA scheme within single CDMA channel
  - Different number of slots per frame assigned for different data rates
  - Subchannels at a given data rate protected by error correction and interleaving techniques
- Alternative: use multiple CDMA codes
  - Separate coding and interleaving
  - Map them to separate CDMA channels

Time and Code Multiplexing



(a) Time multiplexing



(b) Code multiplexing