Lecture 6. Concepts of Cellular Communications 07/10

1. General Principles of Cellular Telephony
2. Introduction
3. Mobile Phone Cells
4. Cellular Phone Concepts
5. Cellular Channel Concepts
6. Call Management
7. 2G Mobile Phones
8. 2G GSM Phones
9. CDMA: IS-95 (Qualcomm)
10. 3G Mobile Phones: Digital Voice and Data
11. UMTS Services
12. W- CDMA
13. Features

1. Multiple access and Multiplexing.

The FDMA access scheme is based on the **FDM process**, which provides different frequency bands to transmit data-streams.

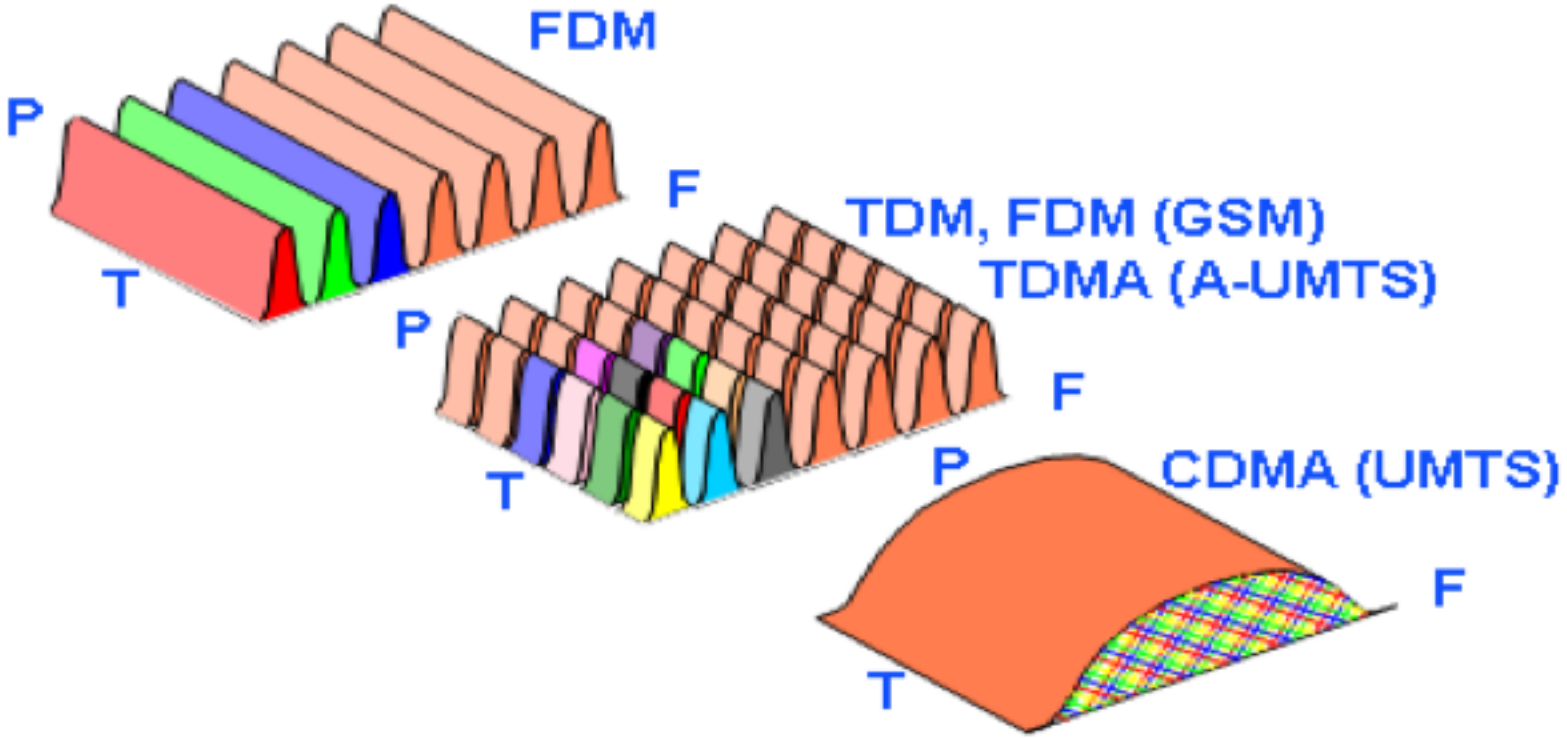
The TDMA access scheme is based on the TDM process, that provides different time-slots to different data-streams.

G2, G3 & G4 cellular systems are based on a combination of **TDMA** and **FDMA.** Each frequency channel is divided into **8 (6)** timeslots, **7(5)** of which are used for **7(5)** phone calls, and **1** for signaling data **(MAHO - Mobile Assisted Handoff).**

The CDMA scheme is based on spread spectrum, (a wider radio spectrum in Hertz is used to transmit data with low rate. Several messages are sent simultaneously over the same carrier frequency, using different spreading codes.

1a. Multiple access and Multiplexing.

Process that permits simultaneous transmissions of multiple signals over one physical circuit.



2. The Mobile Telephone System, Cell Networks

Three main multiplexing schemes:
FDMA, TDMA, and CDMA.

TDMA– IS-54; IS-136 -North American Standard
D-AMPS -Digital Advance Mobile Phone Systems

CDMA- CDMA – Code Division Multiple Access
cdma2000, W-CDMA/UMTS

FDMA- GSM - Pan-European Digital Cellular
(Group Special Mobile); (Global System for Mobile)
PDC - Personal Digital Cellular, Japanese
Iridium-Mobile Communication Satellite
UMTS-. Universal Mobile Transport Service

3. Cellular Wireless Network Evolution

CELL

First Generation: Analog Voice (1946)

AMPS: Advance Mobile Phone Systems (1982)

Residential cordless phone

Second Generation: Digital Voice (1990)

IS-54; IS-136: North American Standard - TDMA (1996)

IS-95: CDMA (Qualcomm) (1993)

GSM: Pan-European Digital Cellular (1991)

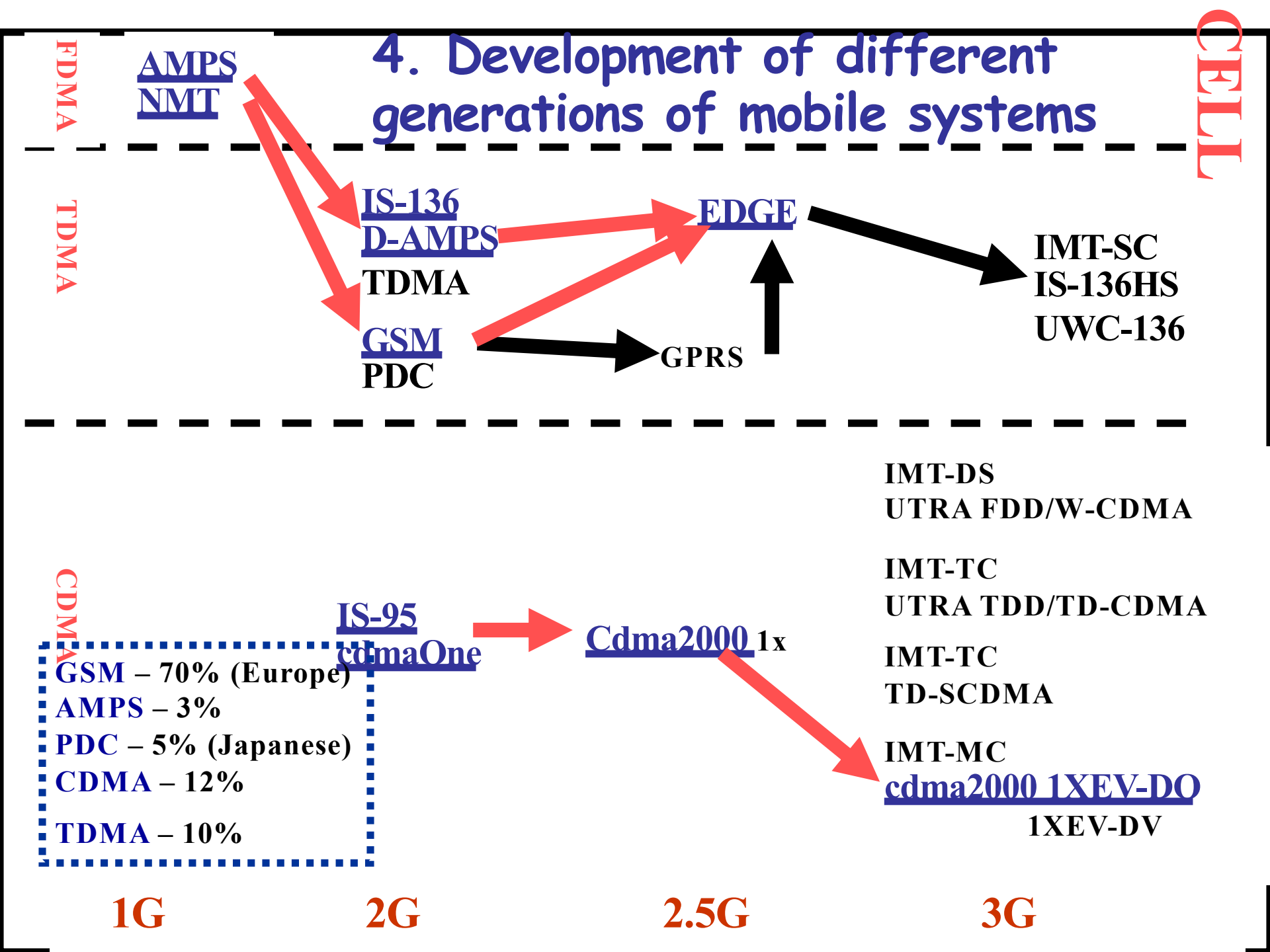
Iridium , 2002: Mobile Communication Satellite (1998)

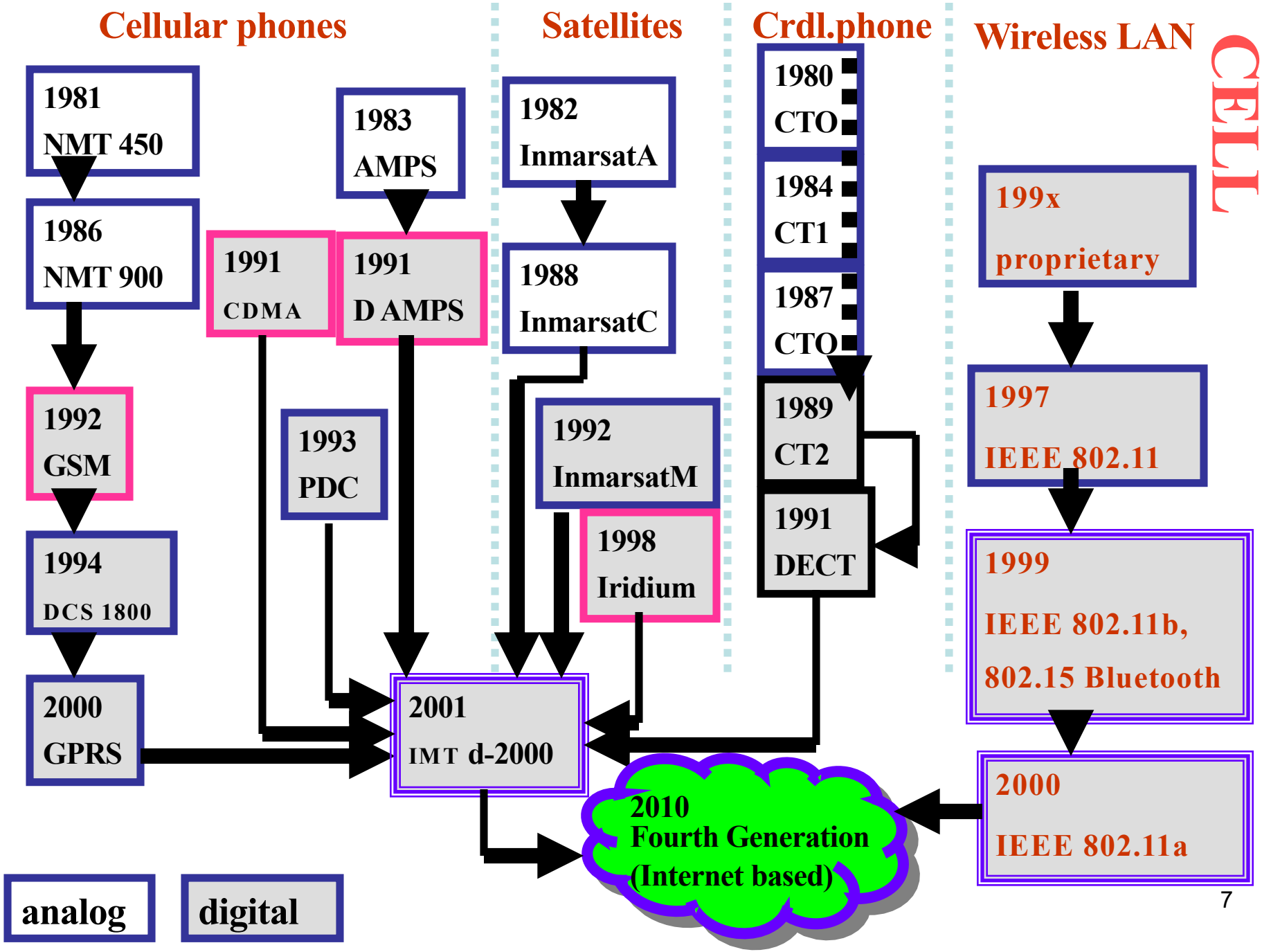
Third Generation: Digital Voice and Data (2000)

IMT-2000 (cdma2000, W-CDMA/UMTS)- Combines the functions of: Cellular, Cordless, Wireless LANs, Paging, Bluetooth, etc. Supports multimedia services: Data, Voice, Video, Image, (Using VLSI-very large scale integration schemes)

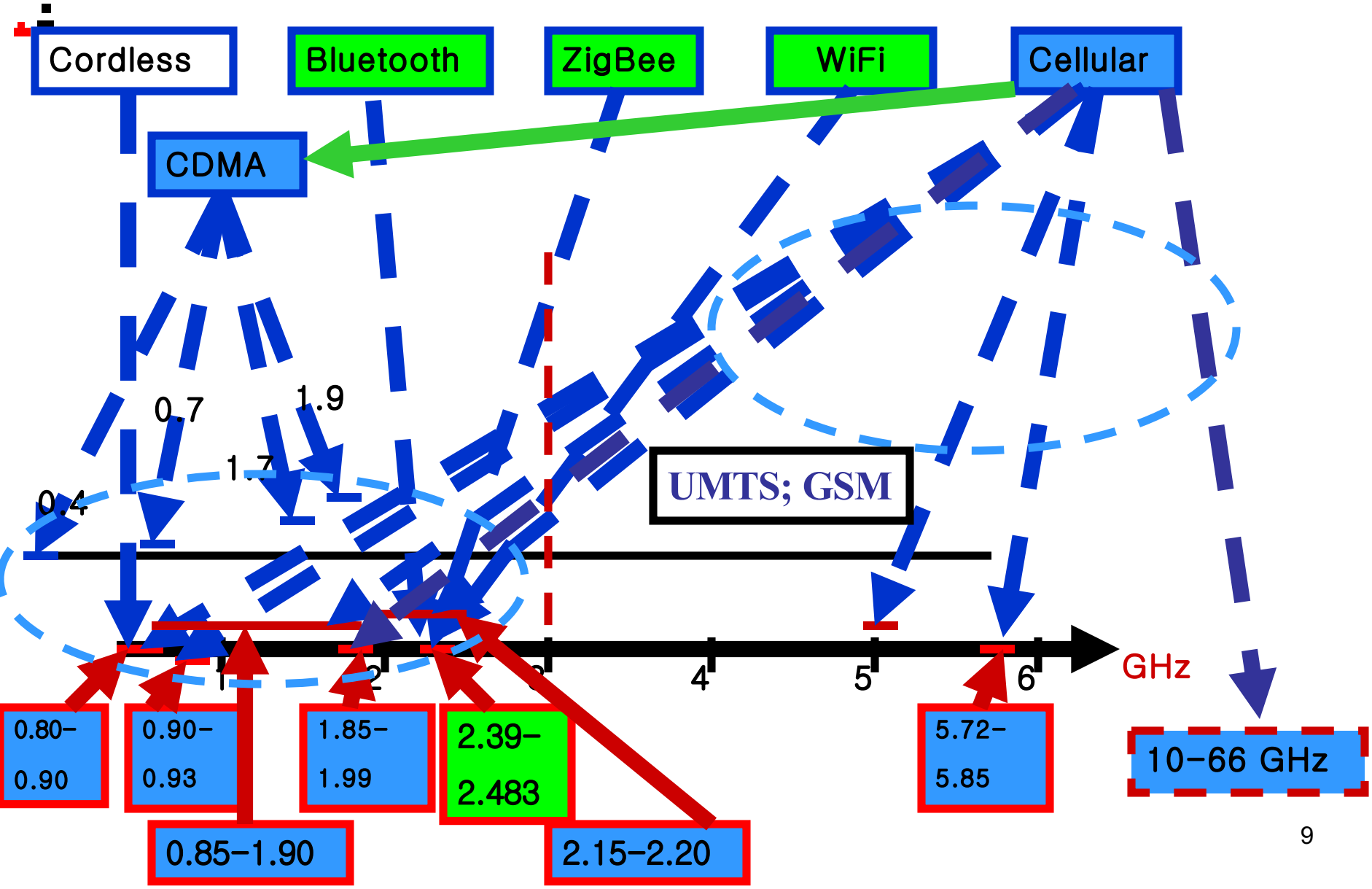
Fourth Generation (2010)- Internet based

4. Development of different generations of mobile systems




Cellular phones
Satellites
Crdl.phone
Wireless LAN
CELL
1981
NMT 450
1986
NMT 900
1992
GSM
1994
DCS 1800
2000
GPRS
1983
AMPS
1991
CDMA
1991
D AMPS
1993
PDC
1982
InmarsatA
1988
InmarsatC
1992
InmarsatM
1998
Iridium
1980
CTO
1984
CT1
1987
CTO
1989
CT2
1991
DECT
199x
proprietary
1997
IEEE 802.11
1999
IEEE 802.11b,
802.15 Bluetooth
2000
IEEE 802.11a
2001
IMT d-2000
2010
Fourth Generation
(Internet based)
analog
digital

4. Wireless Services



Absorption

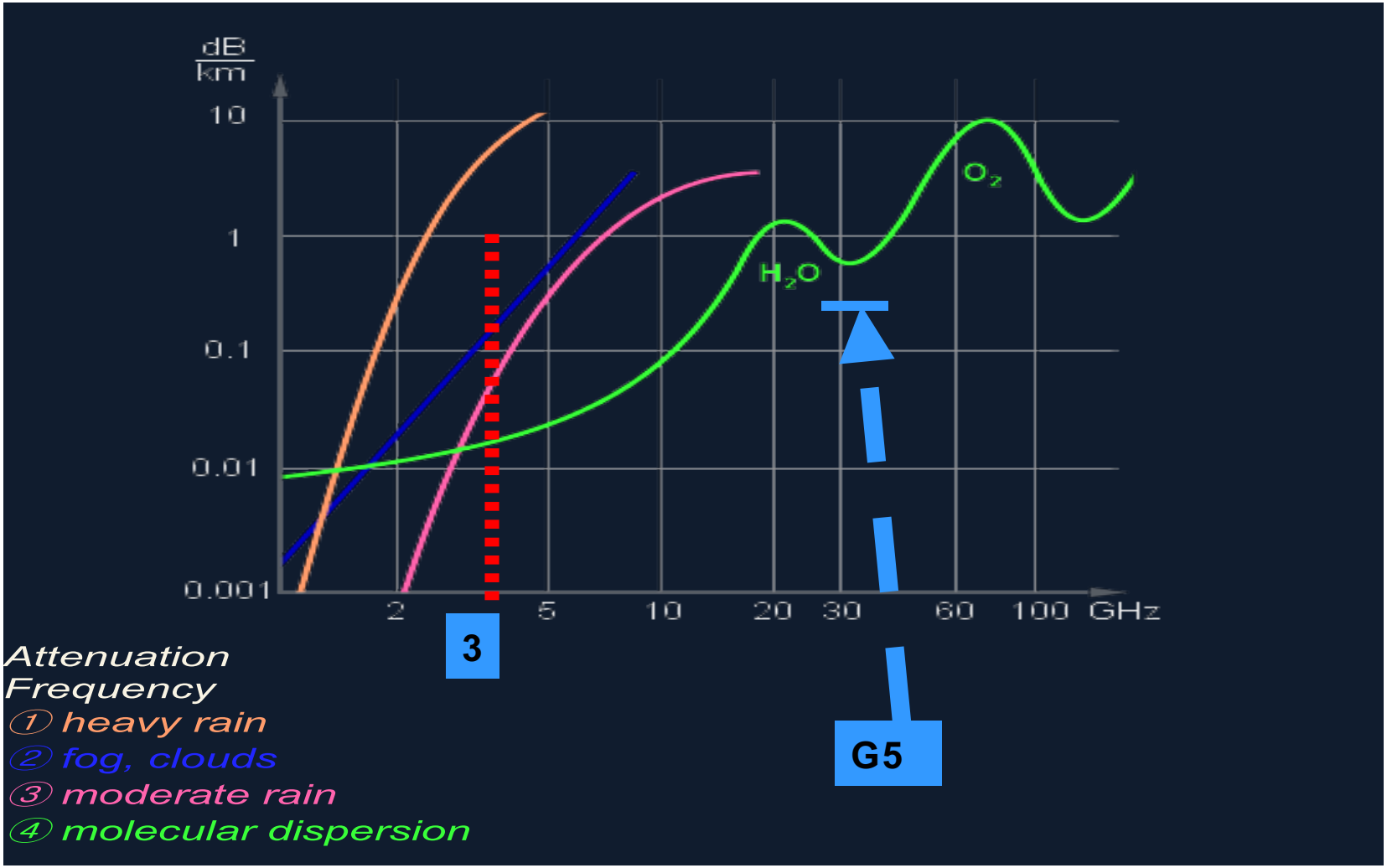
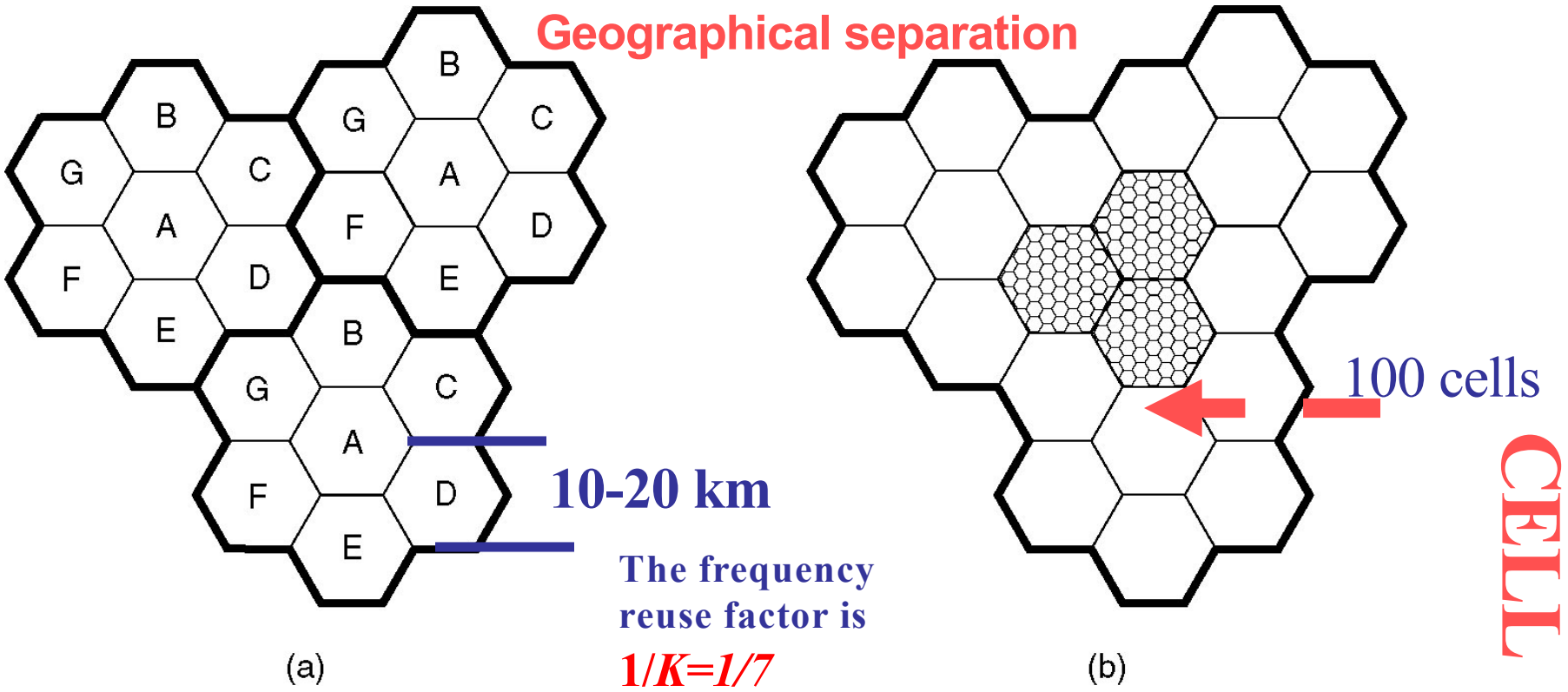


Figure 1: Electromagnetic absorption of the earth's atmosphere

The electromagnetic wave may be partially or totally absorbed by an absorbing medium due to atomic and molecular

The absorption of electromagnetic radiation is insignificant at low frequencies less than 3 Gigahertzes (or a wavelength longer than ten centimeters

5. Cellular Phone Concepts



- Each of these cells is assigned multiple frequencies *(f1 – fn)* and have corresponding radio base stations.
- Frequencies are not reused in a group of 7 adjacent cells
- To add more users, smaller cells can be used.
- In each cell are duplex: uplink and downlink)

7. Cellular Phone Concepts

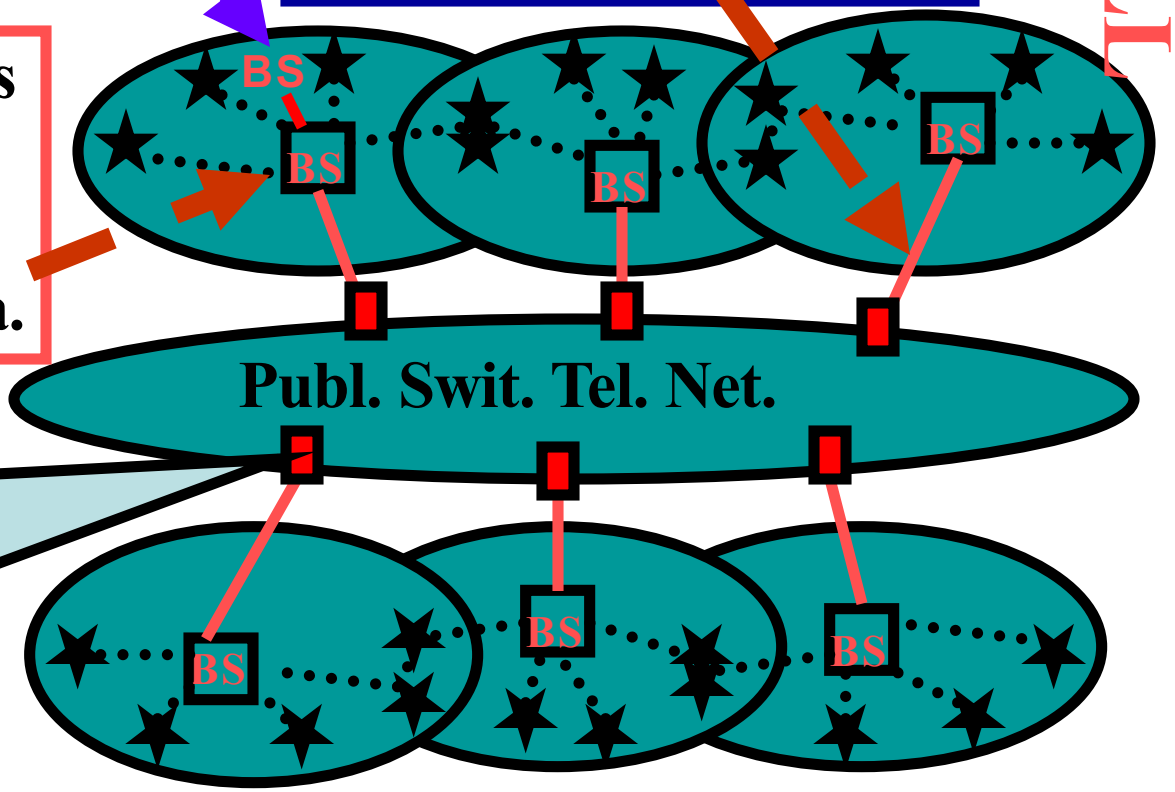
- Geographical separation
- Capacity (freq.) reuse
- Backbone connectivity

Subject of G5 technology

Hand-held telephone 0.6 watts
Car transmitters are 3 watts,
Maximum. by the FCC.

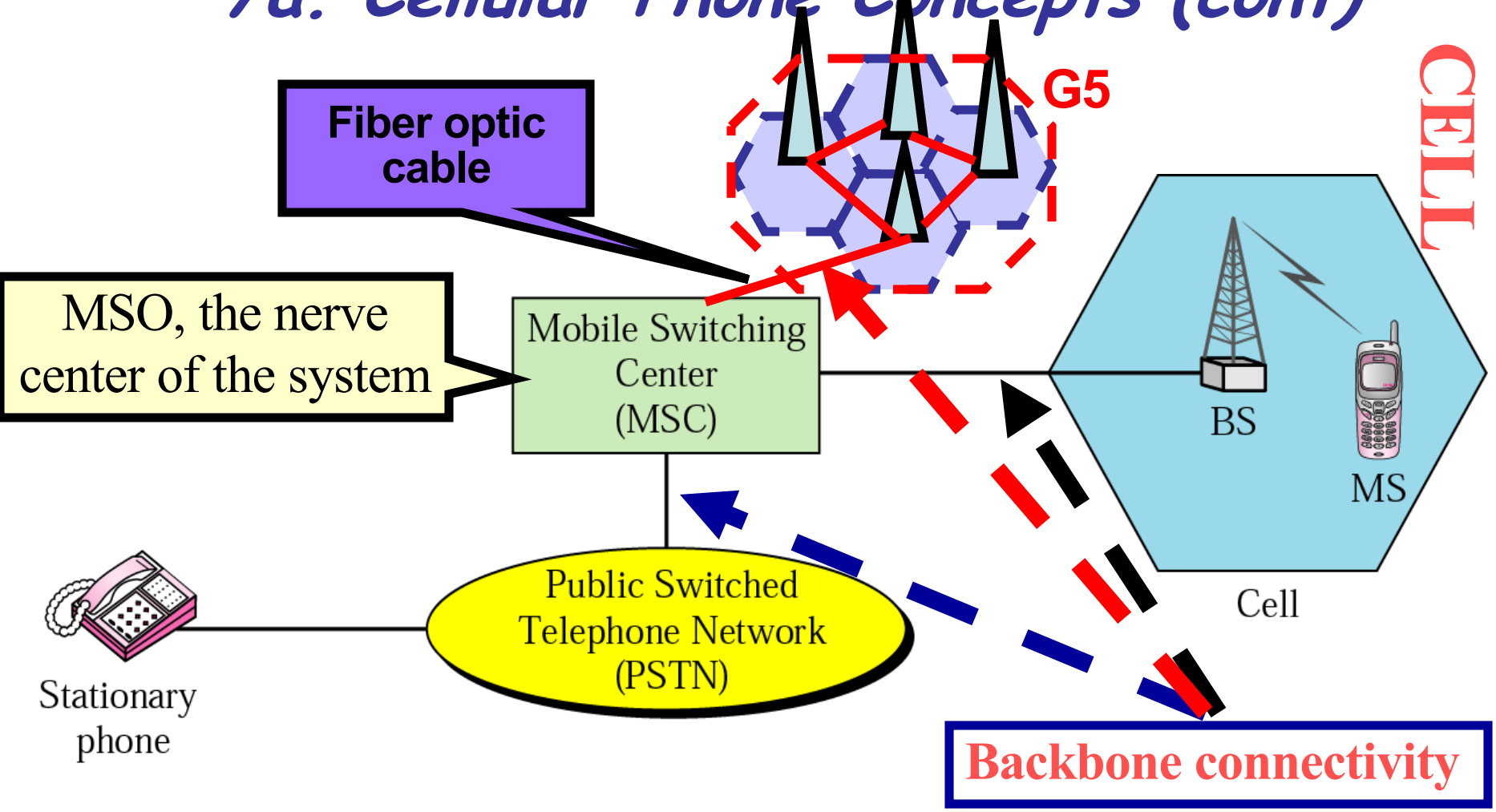
Backbone connectivity

The base station consists of a computers and transmitter/receiver connected to an antenna.



MTSO (Mobile Telephone Switching office)-
MSC (Mobile Switching Center).

7a. Cellular Phone Concepts (cont)



If MS leave a cell, its BS asks the surrounding BS how much power they are getting from it. The BS then transfers ownership to the cell getting the strongest power

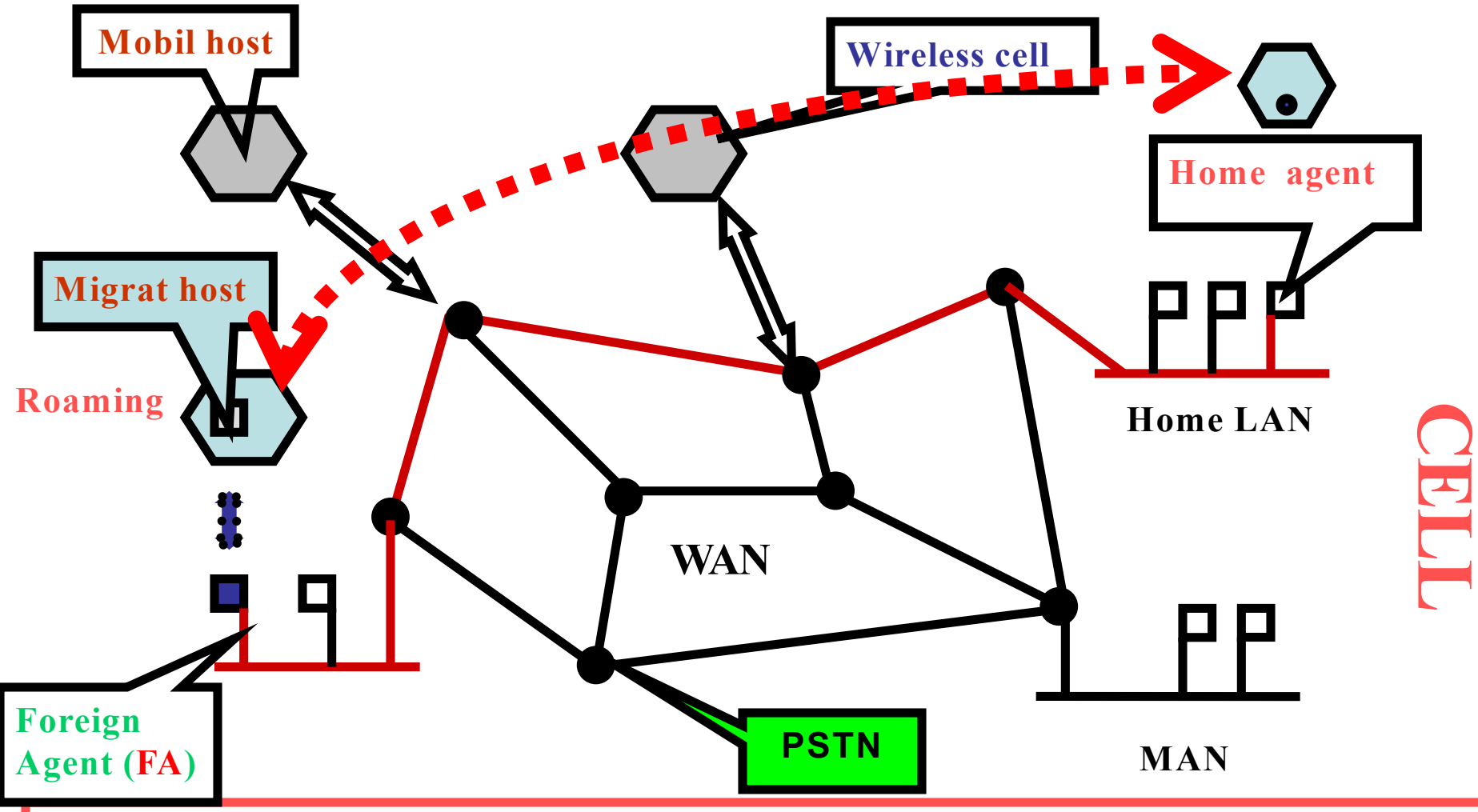
The frequency reuse factor is *1/K* where *K* is the number of cells which cannot use the same set of *f* for transmission.

Common values for the frequency reuse factor are 1/3, 1/4, 1/7, 1/9 and 1/12 (or 3, 4, 7, 9 and 12 depending on notation).

N sector antennas can serve N different sectors. *N* is typically 3. A **reuse pattern** of ***N/K***. Current **reuse patterns are 3/7 (North American AMPS), 6/4 (Motorola NAMPS), and 3/4 (GSM).**

If the total available bandwidth is *B*, each cell can only use a number of frequency channels corresponding to a bandwidth of *B/K*, and each sector can use a bandwidth of *B/NK*.

8. Routing for Mobile Hosts (cont)



Stationary hosts (SH); Migratory hosts (MH); Roaming host (RH)

Foreign agent (FA) keep track of all **MH** visiting the area

9. MH registration procedure

a). Periodically, each **FA broadcasts** a packet announcing **its existence and address**. A **newly-arrived MH** may:

1) wait for these messages, or

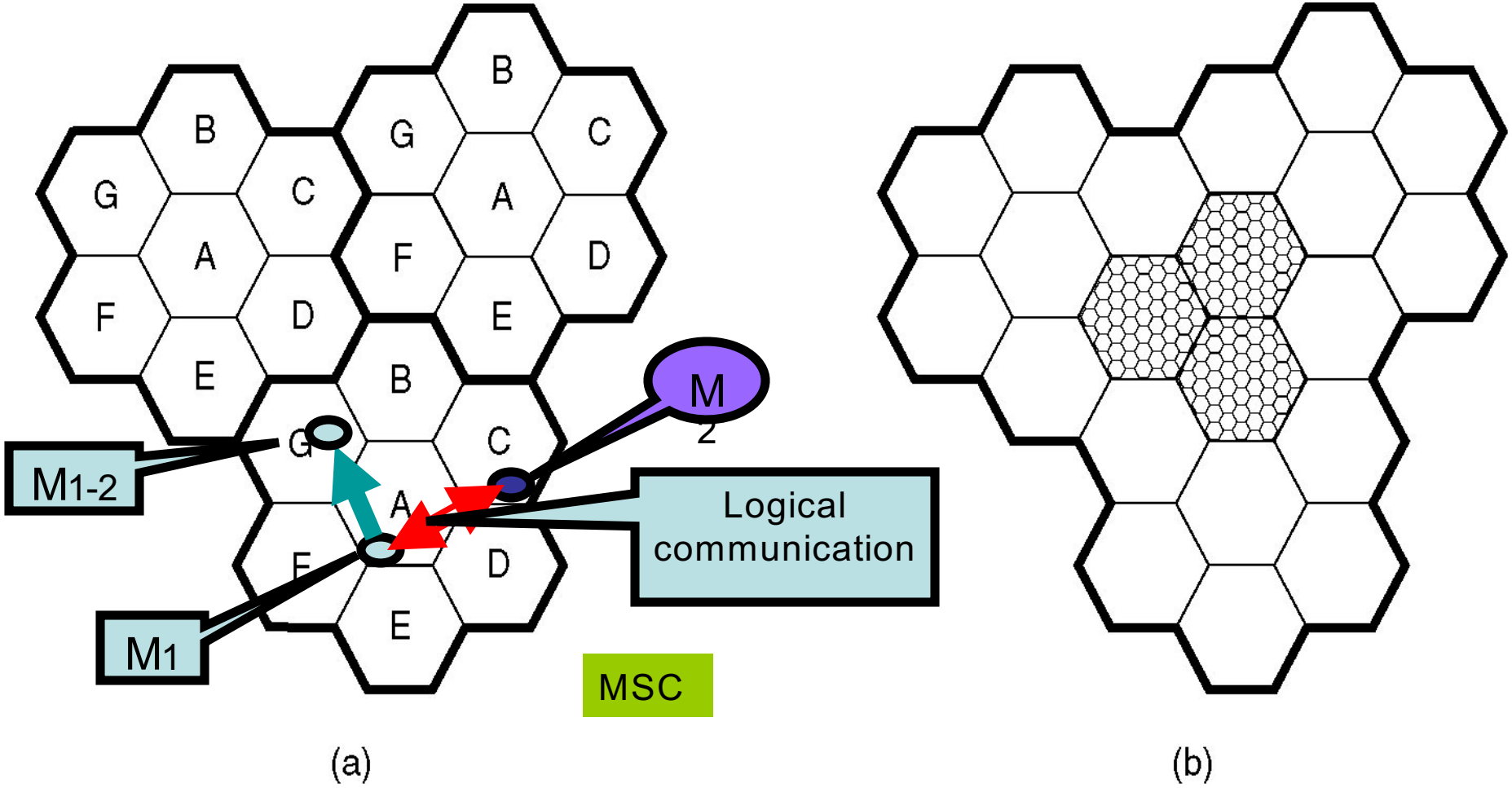
2) MH can broadcast a packet: "**Are there any FA around**"**?**

b) The MH registers with the FA its home address, current DLL address, and some security information.

c) The **FA** contacts the MH's **HA** and says: **One of your host is over here**. The message from the **FA** to the **HA** contains the **FA**'s network address. It also includes the security information to inform the **HA** that the **MH** is there.

d) The home agent examines the security information, to prove that it was generated within the past few seconds. If it is happy, **it tells the FA to proceed**.

e) When the **FA** gets the **ACK** from the **HA**, it makes an entry in its tables and informs the **MH** that it is now **registered.**



FDMA >???; FDMA/ TDMA >??? CDMA >???

9. Handoff (Cellular Concepts, cont)

Handoff: Transfer of a MS from one cell to another (0.3 sec.)
(Each BS constantly monitors the received power from each MS).

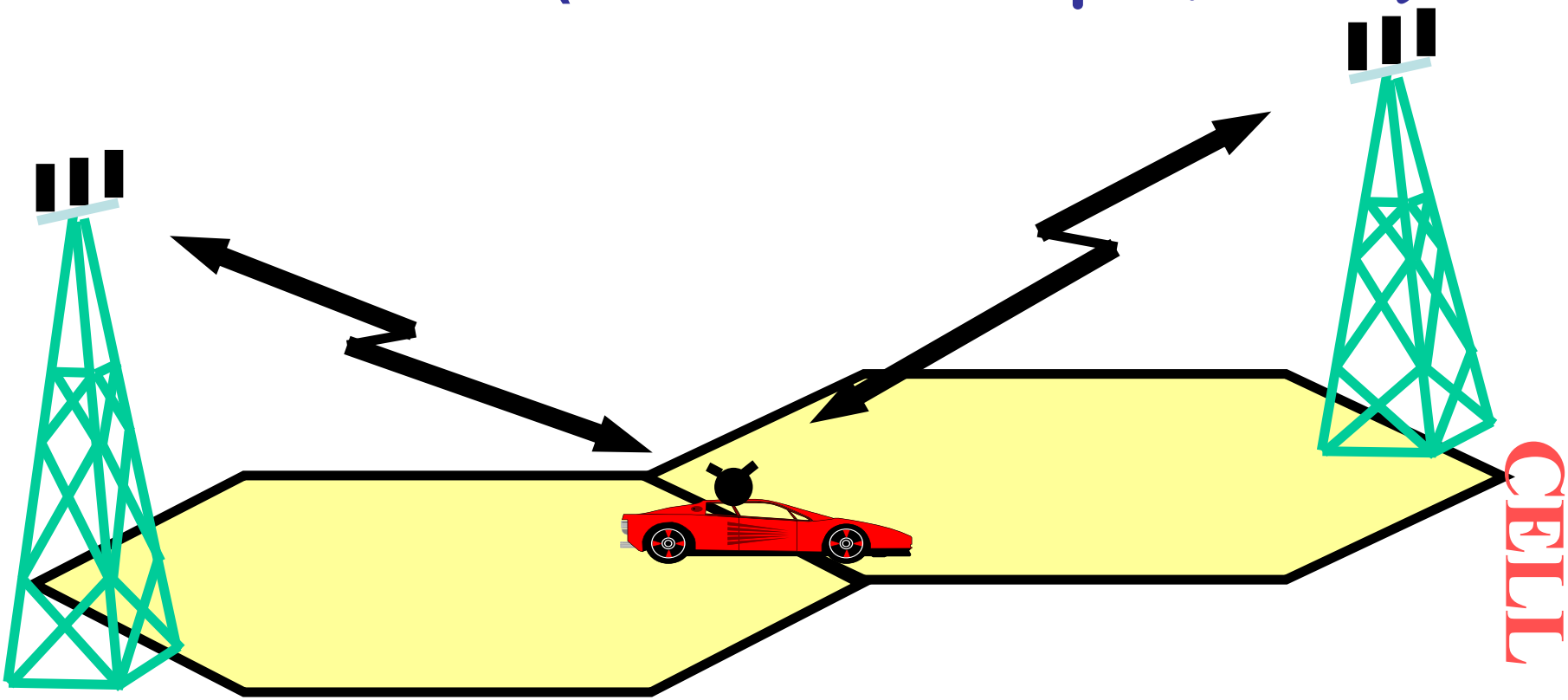
When power drops below **threshold**, **BS** asks neighbor **BS** (with **stronger received power**) to pick up the **MS**, on a new channel, (the old is not reused in adjacent cells) - **handoff.**

Hard handoff: User must switch from one frequency to another. The old BS drops the MS before the new one acquires it. If the new one is unable to acquire it, the MS is **disconnected abruptly**.

Soft Handoff: The MS is acquired by the new BS before the previous one drops (**available only with CDMA**), the MS needs to be able to tune to two frequencies at the same time. Neither first nor second generation devices can do this.

CELL

9a. Handoff (Cellular Concepts, cont)



- **Soft Handoff:** simultaneous radio link between MS and different BSs
- **Hard handoff:** The old BS drops the MS before the new one acquires it.

10. Cellular Channel Concepts

CELL

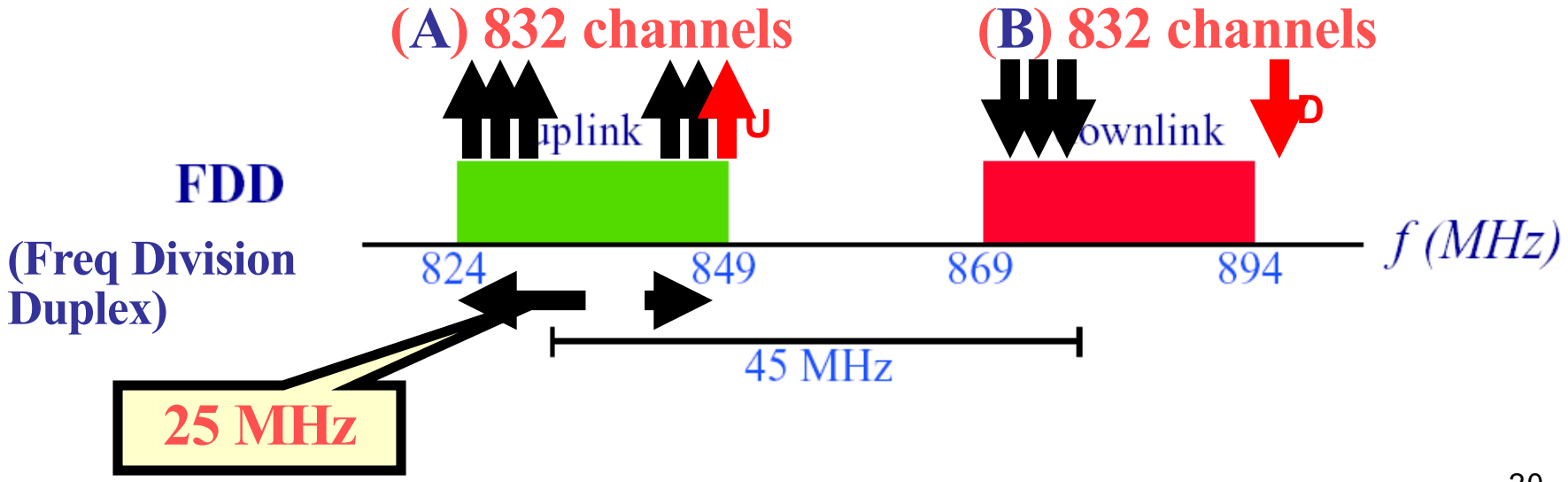
AMPS: physical layer

AMPS uses FDD to separate the channels.

Radio bands

– 832 duplex (paired) channels

Each simplex channels is 30 KHz wide. 832 x 30 =**24960 KHz**



FDD & TDD duplexing

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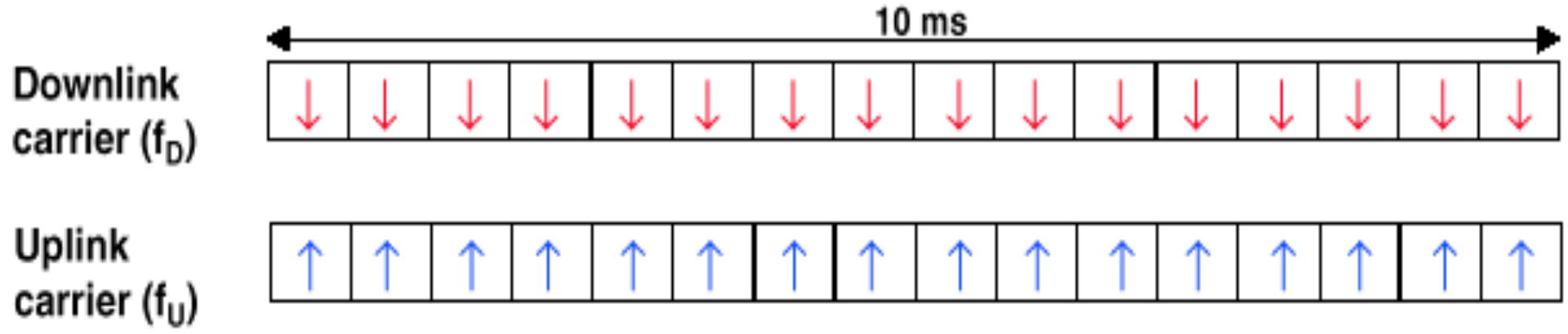
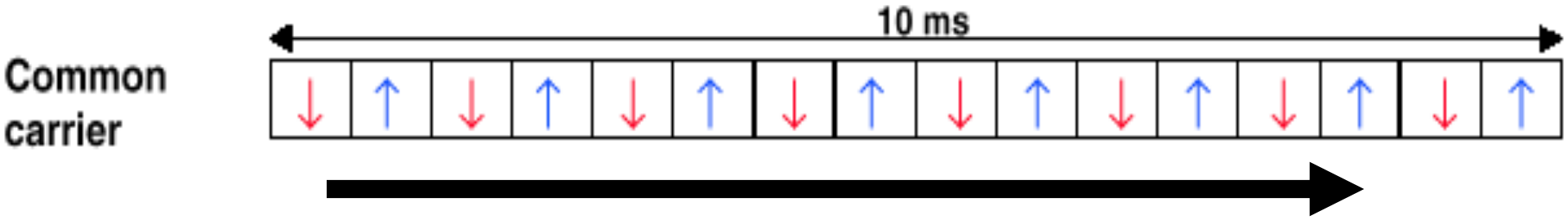
FDD (Frequency Division Duplex)



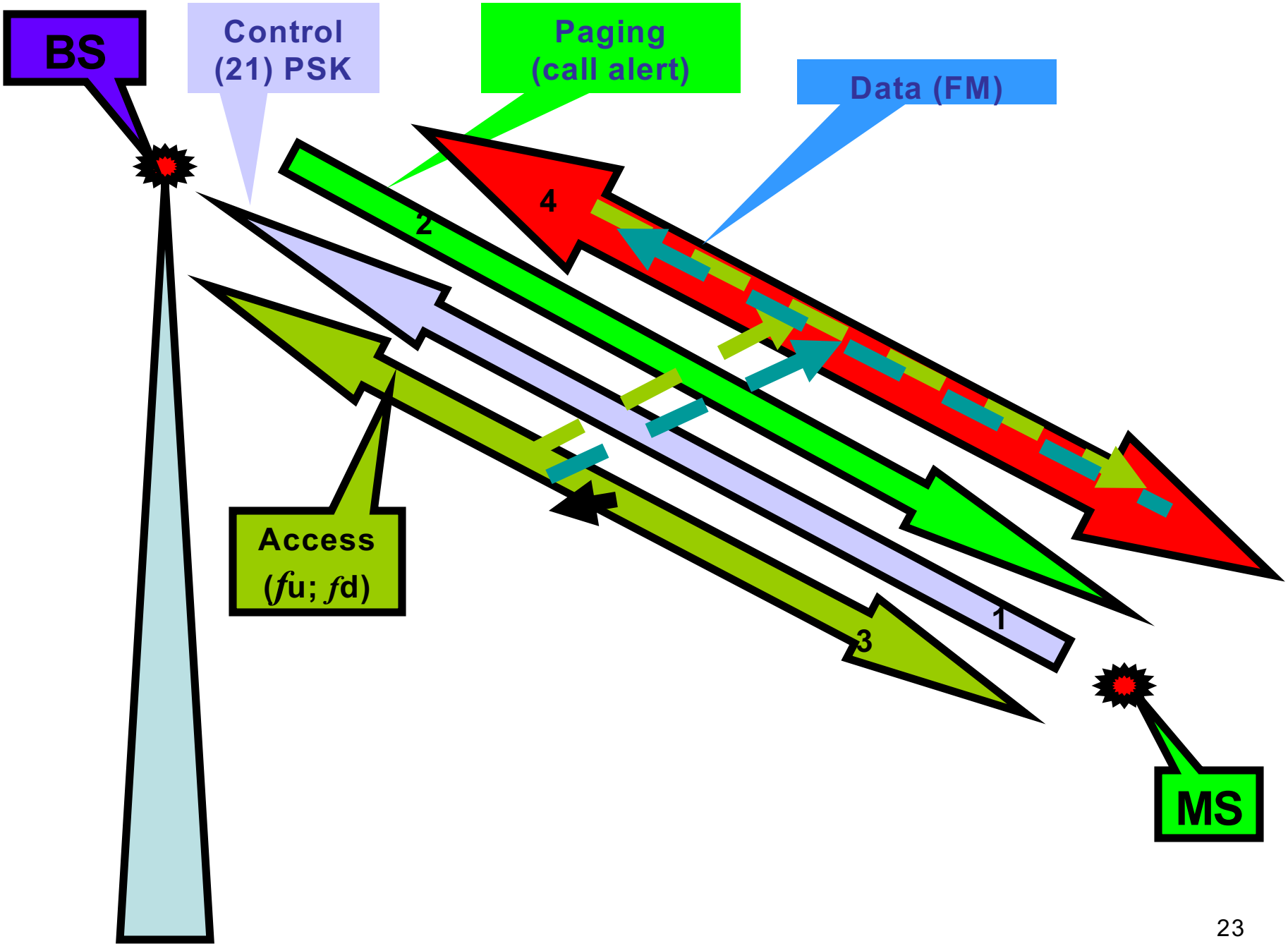
TDD (Time Division Duplex)



10c. Channel Categories

832 channels are divided into **four categories**:

1. **Control (BS to MS) (=21)** to manage the system (**PSK**) **channels are reserved for control, and are wired into a Programmable Read-Only Memory (PROM)**
2. **Access (bidirectional)** for call setup and channel assignment channels "U" and "D".
3. **Paging (BS to MS)** to alert users to calls for them.
4. **Data (bidirectional: "U" and "D")** for voice, fax, or data. (**FM**)


BS
Control
(21) PSK
Paging
(call alert)
Data (FM)
4
2
Access
(fu; fd)
1
3
MS

10d. Call Management: To register and make a phone call

A. Each **MS** has a **32-bit serial** number and a **10-digit phone** number in its **PROM**.

1. When phone is switched **ON**, it scans a **PROM** list of **21 control channels** to find the most powerful signal.
2. **PROM** transmits its **ID number** to the (**MSC**) – which informs the home **MSC** **(registration is done every 15 min)**.

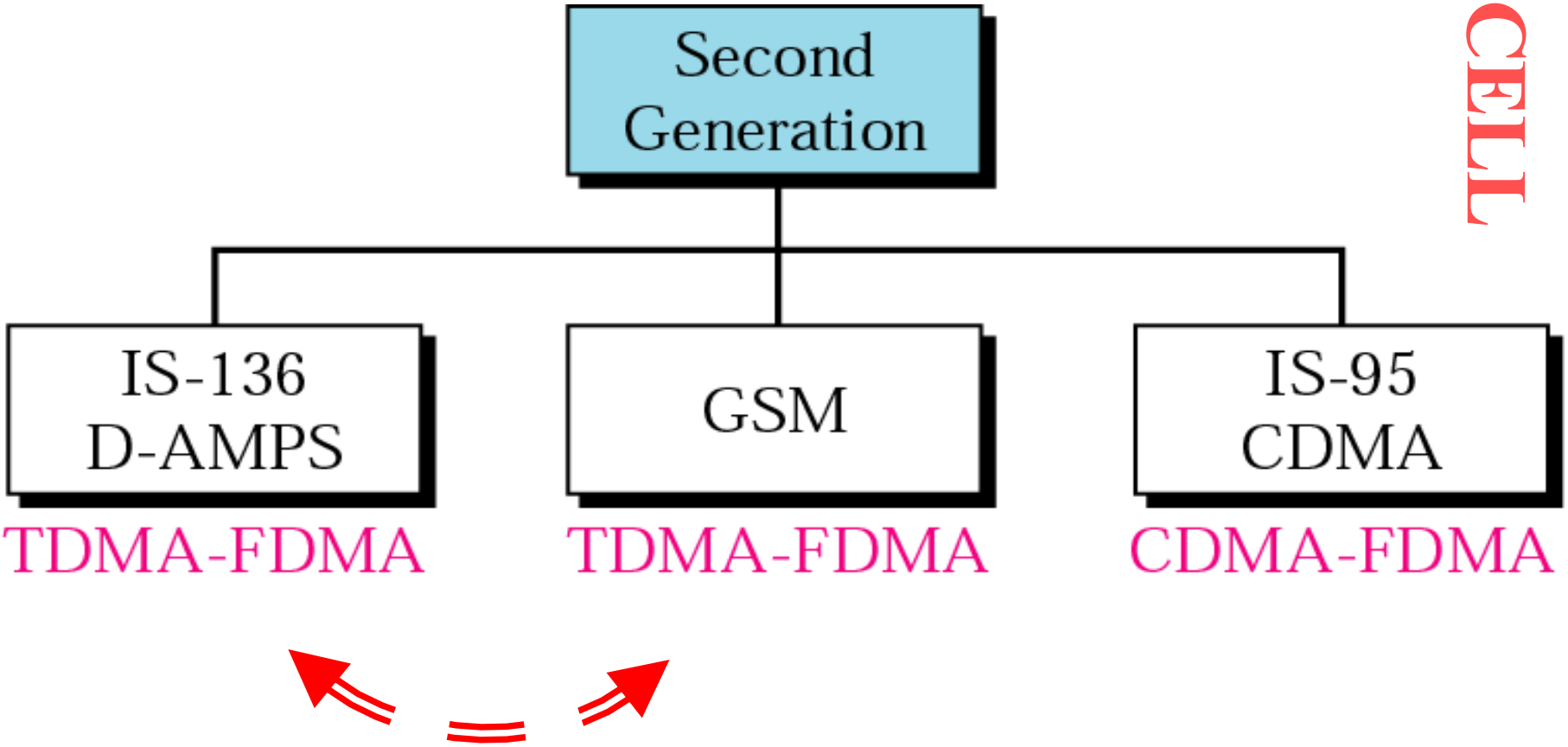
B. **To make a call**, user transmits destination Ph # on **access channel**; **MSC will assign an idle data channel (frequency)**

1. At the same time **MSC pages** the destination cell for the other party **(idle phone listens on all page channels).**
2. **All the control information, is sent in digital form, multiple times, and with an error-correcting code, even though the voice channels themselves are analog.**

10e. Incoming calls

C. **To accept Incoming calls**, all idle phones continuously **listen** to the **paging channel** to detect messages directed to them. When a call is sent to a **MS**, a packet is sent to the caller's home **MTSO** to find out where it is. A packet is then sent to the **BS** in its current cell, which then sends a broadcast on the **paging channel** of the form **"Unit 14, are you there?"** The called phone then responds with **"Yes"** on the **access channel**. The BS then says something like **"Unit 14, call for you on Data channel U and channel D".** At this point, the called phone switches to **channel U and D** and starts making ringing sound.

11. cellular phone systems



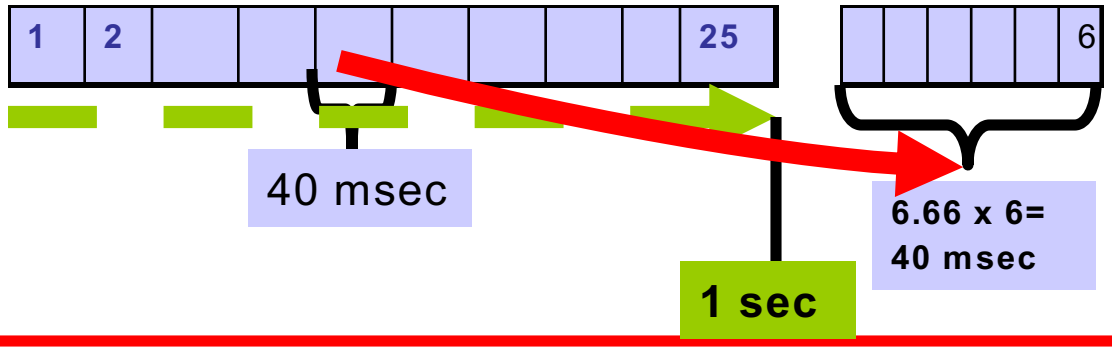
11a. 2G; Phones: Digital Voice

Four systems are: D-AMPS, GSM, CDMA, and PDC
(Personal Digital Cellular, Japanese)

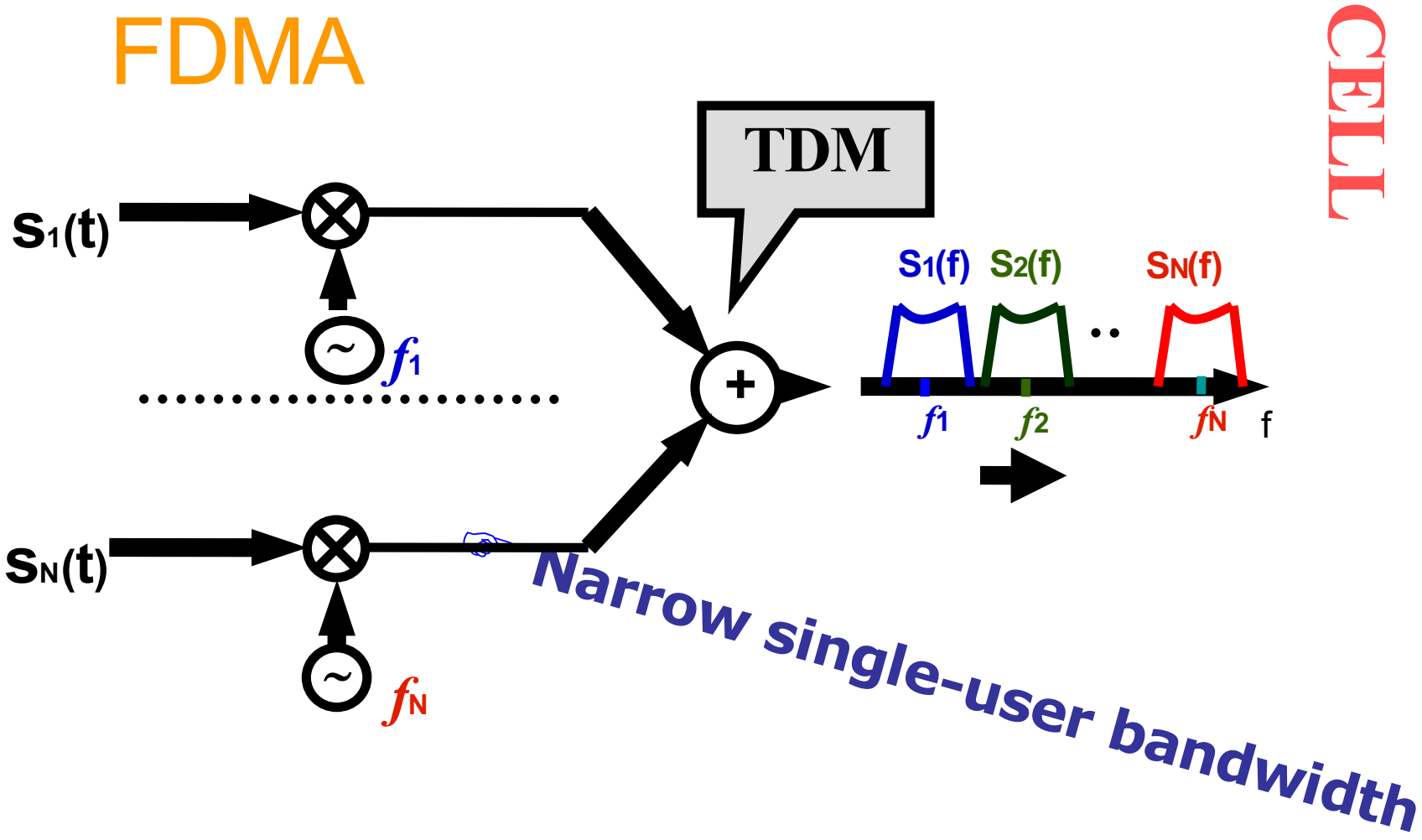
FDD: 1850-1910 MHz Upst.; 1930-1990 MHz Downst.
Waves are 16 cm long, ¼-wave antenna is 4 cm long.

D-AMPS can use both the 850 MHz and 1900 MHz bands.
The voice signal picked up by the microphone is digitized and compressed.

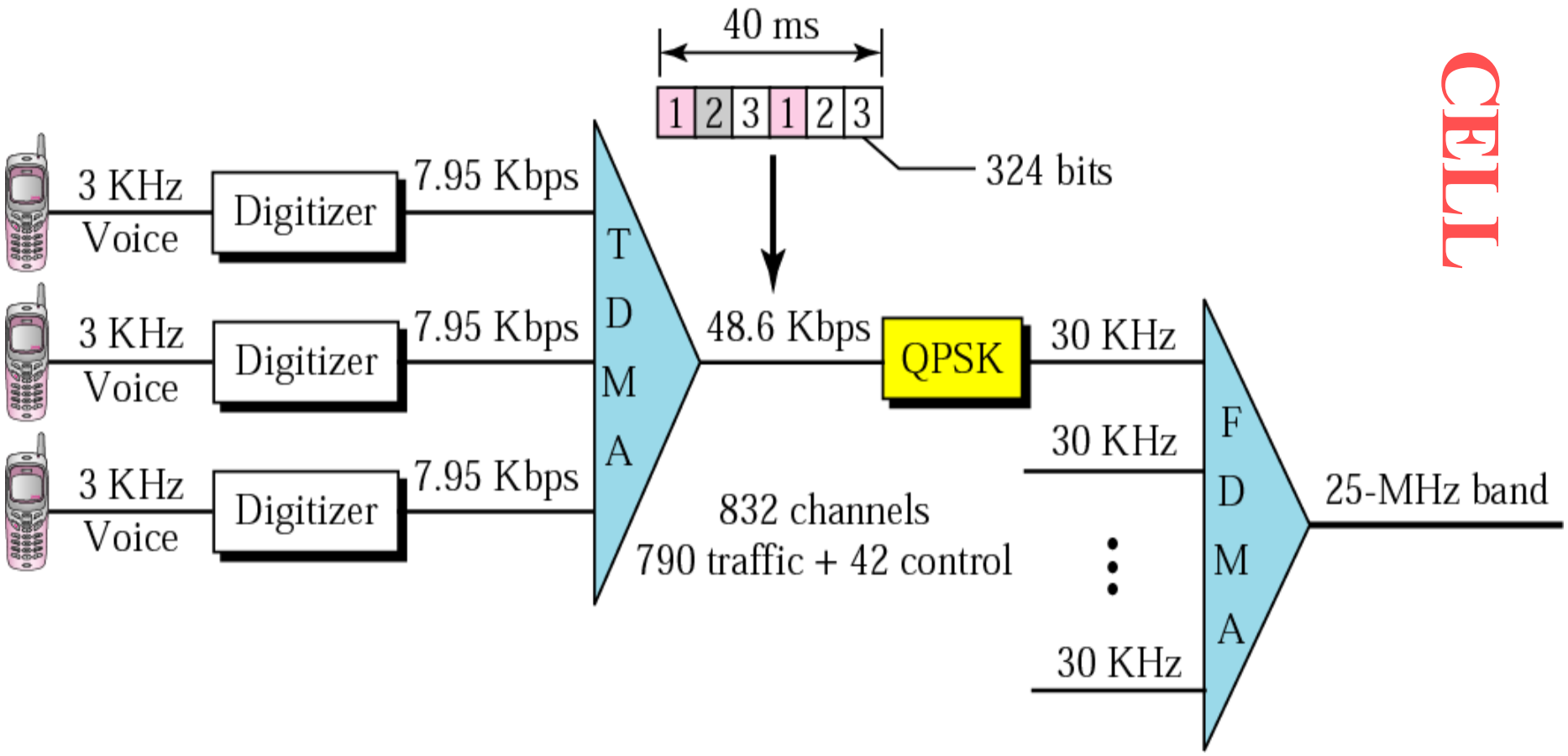
- The compression is done in the telephone.
- 3 users can share a single frequency pair using TDM. Each frequency pair supports 25 frames/sec of 40 msec each.
- Each of 25 frames is divided into 6 time slots of 6.66 msec each, (6.66msec x 6=39.96 msec); Data Modulation: PCM



10.b D-AMPS, or IS-136, is a digital cellular phone system using TDMA and FDMA.



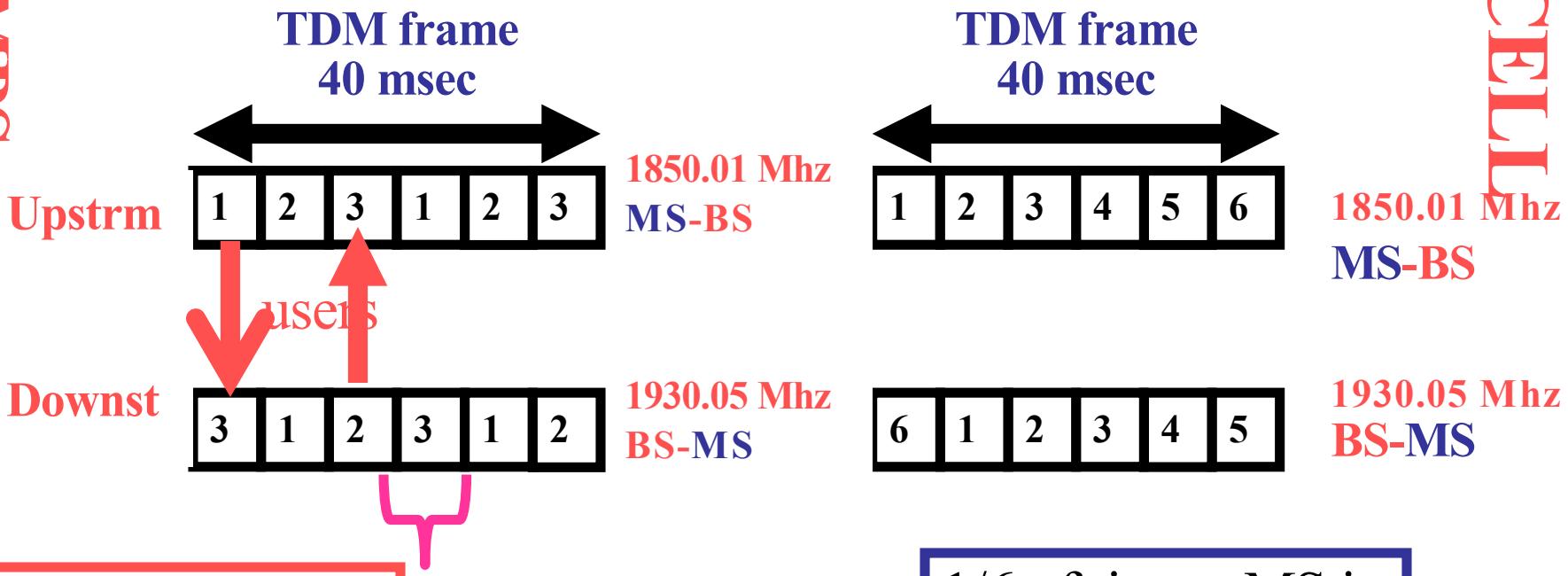
11c. D-AMPS


40 ms
1 2 3 1 2 3
324 bits
CELL
3 KHz
Voice
Digitizer
7.95 Kbps
3 KHz
Voice
Digitizer
7.95 Kbps
3 KHz
Voice
Digitizer
7.95 Kbps
TDMA
48.6 Kbps
QPSK
30 KHz
30 KHz
30 KHz
832 channels
790 traffic + 42 control
FDMA
25-MHz band

D-AMPS

(a) D-AMPS Data channel with three users.
(b) D-AMPS channel with six users

CELL



1/3 of time a MS is idle = line quality measurement

1/6 of time a MS is idle = line quality measurement

It uses these idle slots to measure the line quality. It takes about 0.3 sec to do the handoff. =MAHO (Mobile Assisted Handoff).

12. D-AMPS; IS-54, IS-136

D-AMPS CELL

Channel multiplxg	FDMA +6 TDM slots
Uplink (initially) (later)	824-849 MHz; 832 channels (x 6=4992) 1850-1910 MHz
Downlink (initially) (later)	869-894 MHz; 832 channels (x 6=4992) 1930-1990 MHz
Channel BW	30 kHz
FDD separation	45 MHz
Modulation	FM (traffic, voice); PSK (control) PCM
Channel Rate	48.6 kbps
Voice compression	56 kbps to 8 kbps; PCM
TDM frames	25 frames, 40 msec each
Time slots	6 slots, 6.67 msec each; (25x6=150 msec)

13. 2G: GSM Phones (Group Special Mobile) (Global System for Mobile)

- Pan-European Cellular Standard: **2G; Digital**
- **FDD: (890-915 MHz Upstr; 935-960 MHz Downstr.)**
- 124 frequency carriers; 8 channels per carrier
- **Carrier spacing**: 200 KHz (Narrowband TDM)
- **Modulation**: PSK
- FHSS modulation **(217.6 hops/s)** to overcome multipath fading.
- **First approximation, GSM is similar to D-AMPS.**

See #29 #31

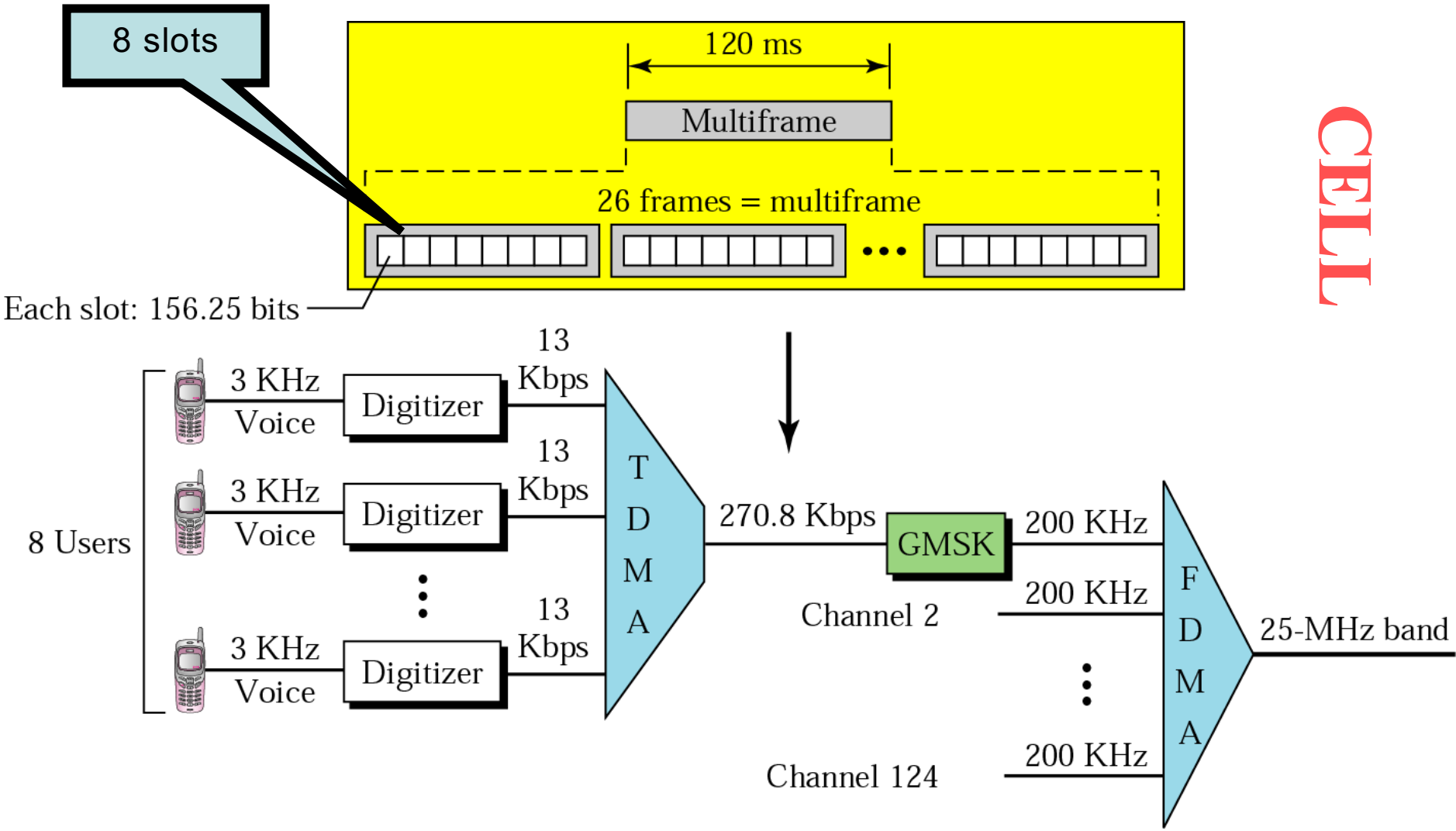
14. 2G- GSM is similar to 2G- D-AMPS.

CELL

D-AMPS is used in the U.S. and in Japan (modified).
Everywhere else in the world used GSM

GSM	D-AMPS
FDM	FDM
Dual simplex channels	Dual simplex channels
Single frequency pair is split by TDM (8)	Single frequency pair is split by TDM (6)
Channel 200 kHzwide	Channel 30 kHz wide
Higher data rate	

GSM (cont)



Compare with slide #27 & #29

GSM system

- A GSM system has 124 pairs of simplex channels;
- Each 200 kHz wide.
- Supports eight separate slots, using TDM
- Each active station is assigned one time slot on one channel pair.
- 992 channels (124x8) can be supported in each cell, but many of them are not available, to avoid frequency conflict with neighboring cells.
- Transmittion and receiving does not happen in the same time slot because the GSM radios cannot transmit and receive at the same time and it takes time to switch from one to the other.

Control Channels (CC)

GSM CELL

- CC used to manage the system.
- The broadcast control channel (BCC) is a continuous stream from the BS containing the BS's identity and the channel status. All MS monitor their signal strength.
- The dedicated control channel (DCC) is used for location updating, registration, and call setup. In particular, each BS maintains a database of MS. Information needed to maintain this database.
- The common control channel (CCC), which is split up into three logical sub-channels:

1. The paging channel CC3a), which the BS uses to announce incoming calls. Each MS monitors it continuously to watch for call it should answer.
2. The random access channel (CC3b). This allows users to request a slot on the dedicated control channel. If two requests collide, they are garbled and have to be retried.
3. The access grant channel (CC3c). Announces assigned slot.

GSM: Compare with slide 31

Channel multiplexing	FDM+8 TDM slots
Uplink (GSM900) (DCS1800)	890-915 MHz; 125 channels (x8=1000) 1710-1785 MHz
Downlink (900) (DCS1800)	935-960 MHz; 125 channels (x8=1000) 1805-1880 MHz
Channel Bandwidth	200 kHz
FDD separation	45 (900) / 95 (1800) MHz
Modulation	FSK
Channels	Brdcst. Cont; Ded. Cont; Comn. Cont.==Paging.+Rndm. Access+Acc. Grnt.
Channel Rate	13 kbps
TDM frames	24 frames, 120 msec each
Time slots	8 slots, 0.577 msec each; (24x8=192)

CELL

14. CDMA: IS-95; (QUALCOMM)

CDMA CELL

- Based on DSSS
- Two frequency bands (1.25 MHz), one for forward channel (**cell-site to subscriber**) and one for reverse channel (**subscriber to cell-site**)
- **Sprint PCS = CDMA;**
- **AT&T + Wireless = D-AMPS.**
- CDMA allows reuse of same spectrum over all cells.

Network capacity improvement:

IS-95 is a digital cellular phone system using CDMA/DSSS.

14a. CDMA (cont)

CDMA

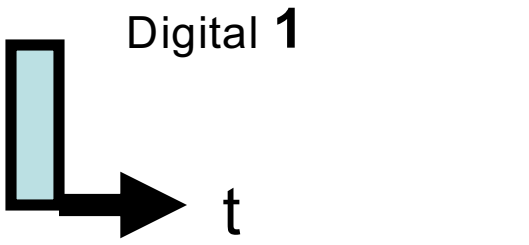
- **CDMA** is different from D-AMPS, and GSM.
- Instead of FDM each with hundreds narrow channels (GSM; D-AMPS), **CDMA each station transmits over the entire frequency spectrum all the time**.
- Multiple transmissions are separated by unique **"code"** for each user;=**code set partitioning**

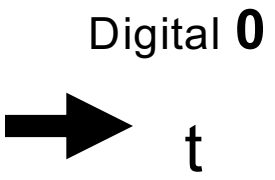
CELL

- All users share same frequency, but each user has own "**chipping**" sequence (i.e., code) to encode data.
- Chipping rate > data rate
- ***Encoded signal*** = **original data bit X chipping sequence**
- ***Decoding*=** **inner product of encoded signal X chipping sequence**
- allows multiple users to "coexist" and transmit

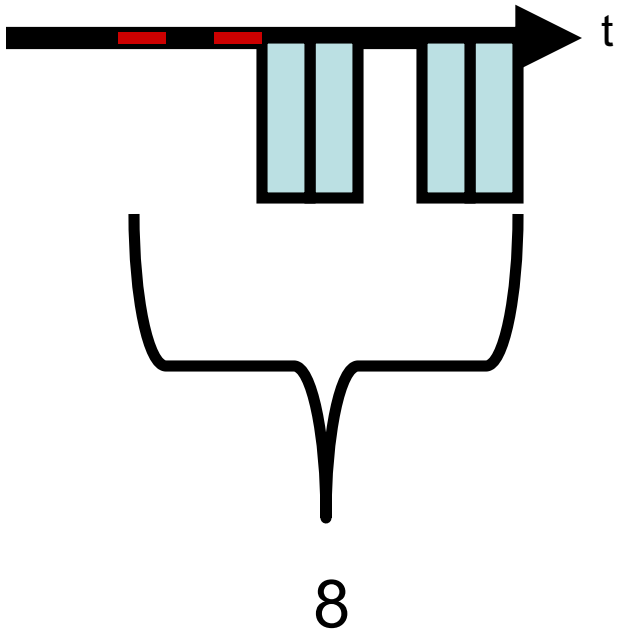
14c. CDMA (cont)

- Each bit time is subdivided into ***m*** **short** intervals called **chips**. Typically: ***m*=8, 64 or 128 chips / bit**.
- Each station is assigned a unique **m-bit** code called a **chip sequence**. For **m=8**, if station **A** is assigned the chip sequence **00011011**, it sends a **1** bit by sending **00011011** and a **0** bit by sending complimentary **11100100**.
- Increasing the amount of information ***b*** bits/sec to ***mb*** chips/sec can only be done if the bandwidth available is increased by a factor of ***m***,
- **With GSM; D-AMPS** If we have a **1-MHz** band available for **100** stations, with FDM each station would have **10 kHz** BW, and could send at **10 kbps** (assuming 1 bit/Hz).
- **With CDMA**, each station uses the full **1 MHz**, so the chip rate is **1 m chip/sec**. (With fewer then **100 chips per bit**, **(calculation-100 x 8=800 KHz)** the effective bandwidth per station is higher for CDMA than FDM.



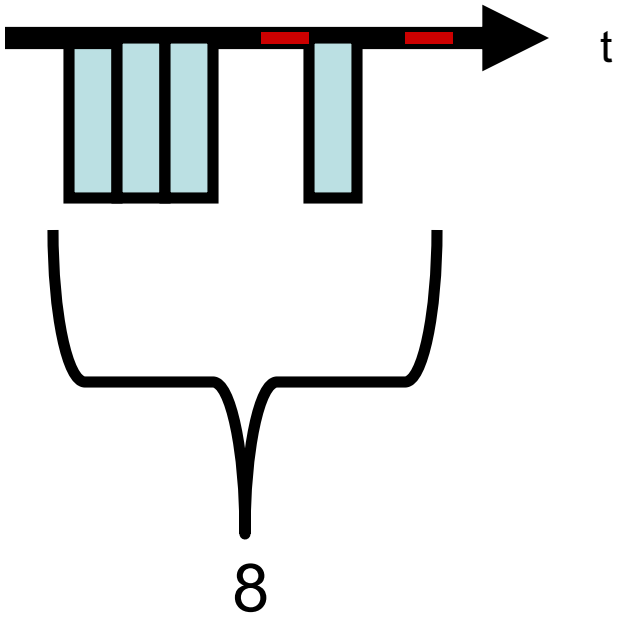


chip sequence for digital 1



b x 8

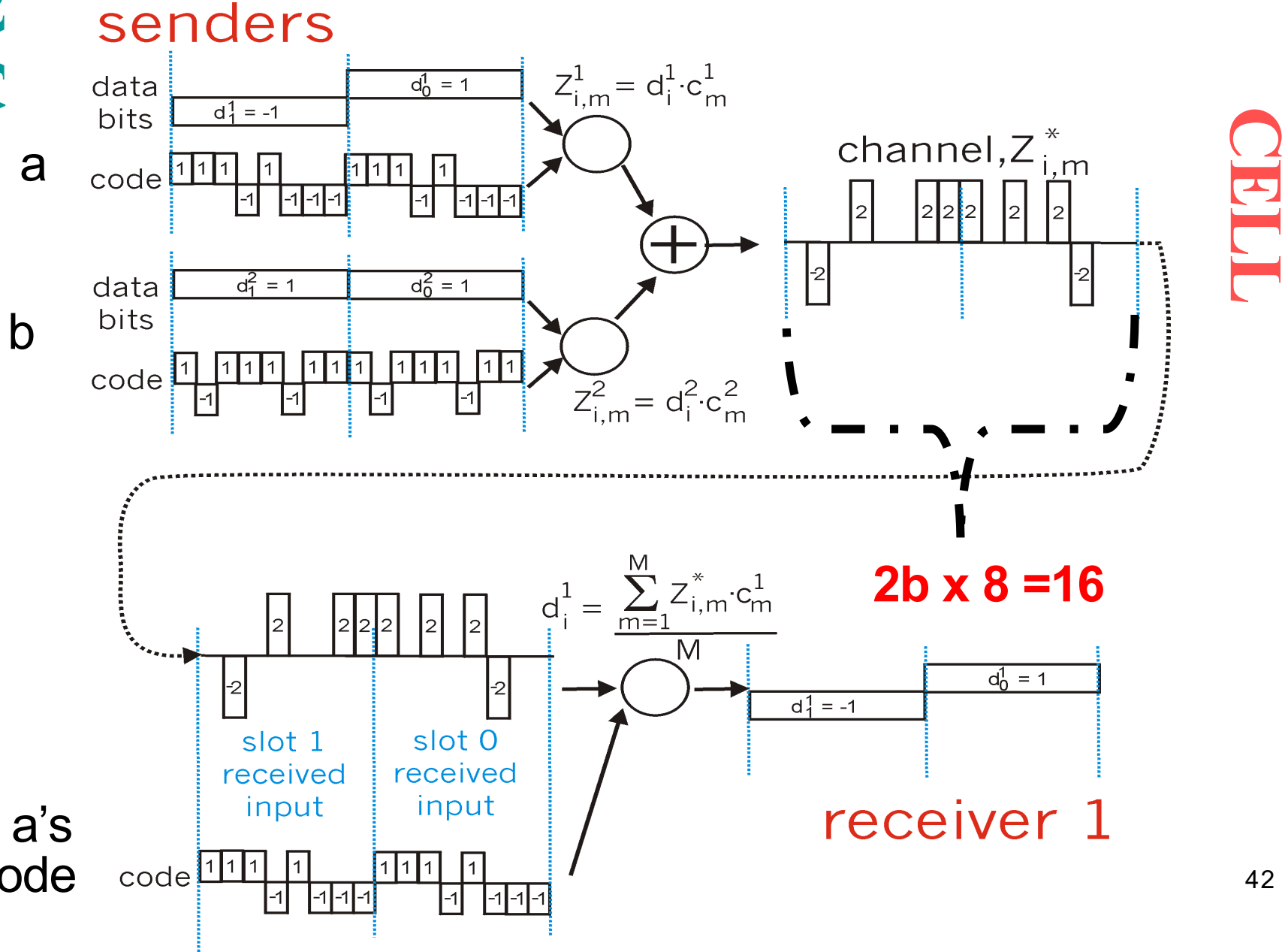
chip sequence for digital 0



CDMA

14b. CDMA: two-sender interference

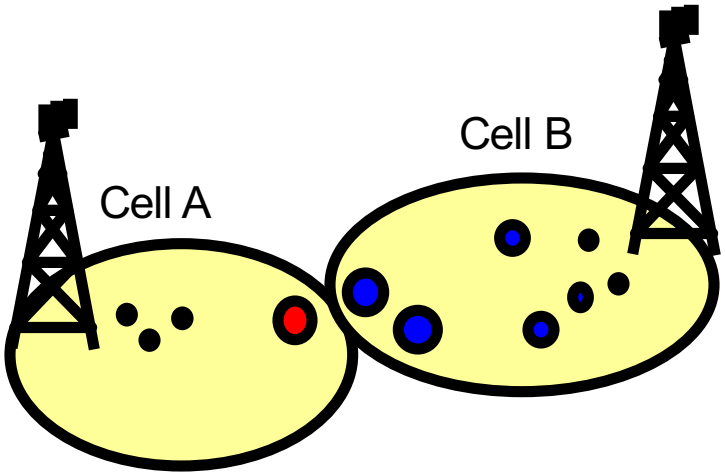
CELL



CDMA (cont'd)

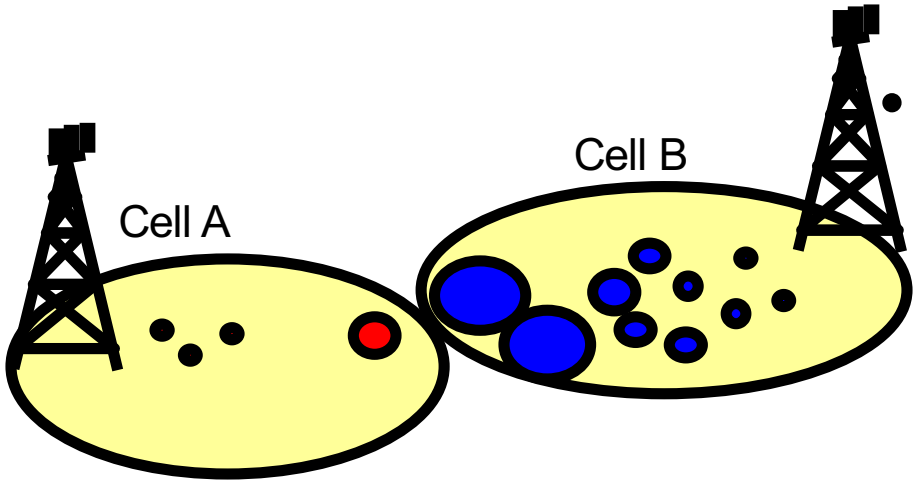
- Each transmitting station gets its **own chip sequence**. The **receiver must know station's chip sequence in advance**.
- Receiver **listens all the senders** at once by running the decoding algorithm for each of them in **parallel.**
- CDMA is typically used for **wireless systems** (**no Ad Hoc).** The power levels received at the BS depend on how far away the transmitters are.
- CDMA operates in a band of **1.25 MHz** (versus **30 kHz** for **D-AMPS** and **200 kHz** for **GSM**), but it supports many more users in that band than either of other systems.
- In practice, **the bandwidth available in CDMA for each user often is much better than for GSM.**

15. CDMA: cell breathing



- Uniform traffic distribution and low load: MS Tx power depends mainly on path loss.

CELL



- Raising traffic in a cell: users in that cell are forced to increase the Tx power level in order to react to increased interference.

3G

16. Third-Generation Mobil Phones;

- 3rd called **IMT-2000**; (**1992**)
  1. The **year** into service;
  2. Operate frequency (**in MHz**),
  3. The bandwidth (**in kHz**).
- Finally: 2Mbps has problems, due to the difficulty of performing **handoff quickly**.
- More realistic is: **2 Mbps** for stationary indoor users,
  384 kbps for walking, and
  144 kbps for connections in cars.
- **IMT-2000 network basic services:**
  1. **High-quality voice transmission.**
  2. **Messaging (replacing e-mail, fax, chat, etc.).**
  3. **Multimedia (music, viewing videos, films, televisions).**
  4. **Internet access (Web, pages with audio and video).**

CELL

17. CDMA2000

Key features:

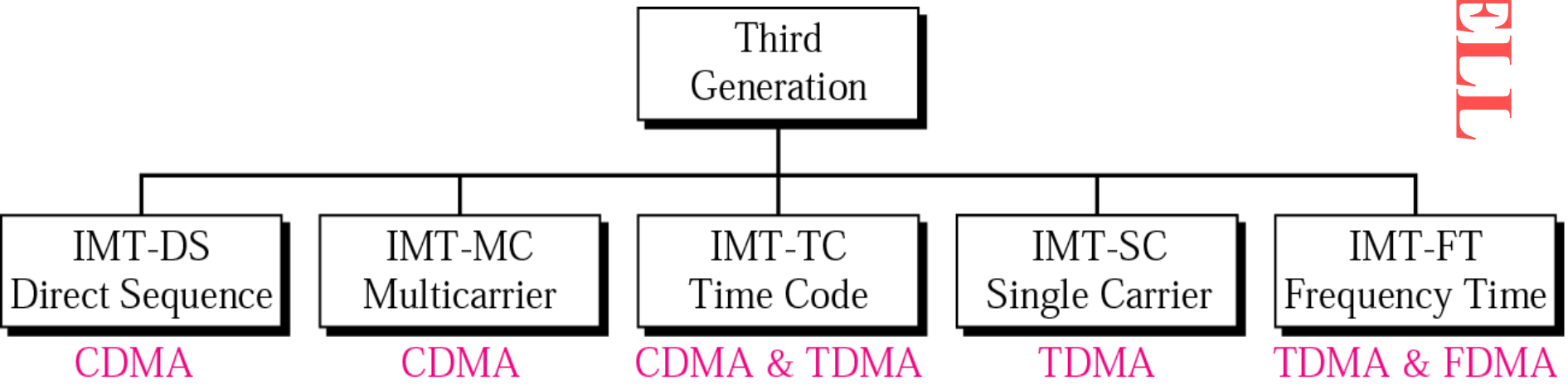
CDMA2000 system uses one or more available 1.25 MHz channels for each direction.

1. **Higher Data Throughput. Today's commercial CDMA2000 networks support a peak data rate of 2.4 Mbps.**
2. **Frequency Band Flexibility. CDMA2000 networks have been arranged in the 450, 800, 1700, and 1900 MHz bands.**
3. **CDMA2000, (Qualcomm). It uses a DSSS design, basically an extension of IS-95; With backward compatible with IS-95; It also uses a 5-MHz bandwidth. NOT interworks with GSM; Cannot hand off calls to a GSM cell (or D-AMPS).**

18. 3G Cellular Phone Systems

The main goal of third-generation cellular telephony is to provide universal personal communication.

CELL



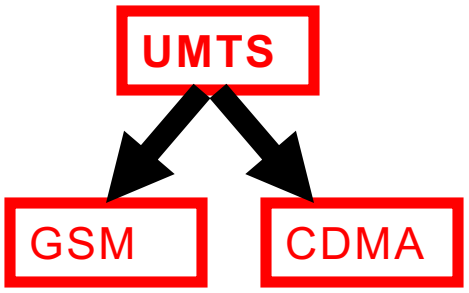
IMT - International Mobile Telecommunications

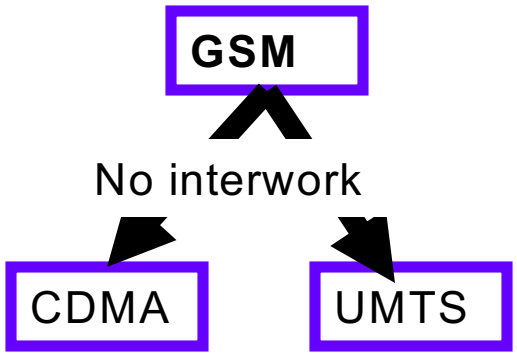
19. UMTS

Requirements

- **384 Kbps for full area coverage**
- **2 Mbps for local area coverage**
- **variable bit rate**
- **packet traffic support**
- **flexibility (eg, multiple, multimedia streams on a single connection)**

  UMTS system uses DSSS; It runs in a 5 MHz band;
- **Interworks with GSM networks, but not vise versa.**





20. Cellular Evolution (cont)

- **Third Generation (3G) : W-CDMA**

– Combines the functions of: cellular, cordless, wireless LANs, paging etc.

– Supports multimedia services (data, voice, video, image)

– Before full 3G was designed high performance systems (**2.5G**):

(a) GPRS (for GSM)

(b) EDGE (for GSM)

(c) 1xRTT (for CDMA)

- the final system: **UMTS, CDMA 2000, WCDMA**

CELL

21. Universal Mobile Telecommunications System (UMTS)

UMTS Is a third generation mobile cellular system for networks based on the **GSM standard**. UMTS is a component of the International Telecommunications Union **IMT-2000 standard set** and compares with the **CDMA2000 standard set** for networks. UMTS uses wideband code division multiple access (W-CDMA) radio access technology to offer greater spectral efficiency and bandwidth.
UMTS specifies a network system, which includes the radio access network and the authentication of users via **SIM** (**subscriber identity module**) cards.

CDMA2000 (IMT Multi-Carrier), and **UMTS** requires new base stations and new frequency allocations.
The **CDMA** scheme is based on **SS**, meaning that a wider spectrum in Hertz is used than the data rate of each of the transferred bit streams, and several message signals are transferred simultaneously over the same carrier frequency, utilizing different spreading codes. The wide bandwidth makes it possible to send with a very poor signal-to-noise ratio of much less than 1 (less than 0 dB) according to the Shannon formula, meaning that the transmission power can be reduced to a level below the level of the noise and co-channel interference (cross talk) from other message signals sharing the same frequency. One form is direct sequence spread spectrum **(DS-CDMA),** used for example in **3G** cell phone systems.

UMTS services

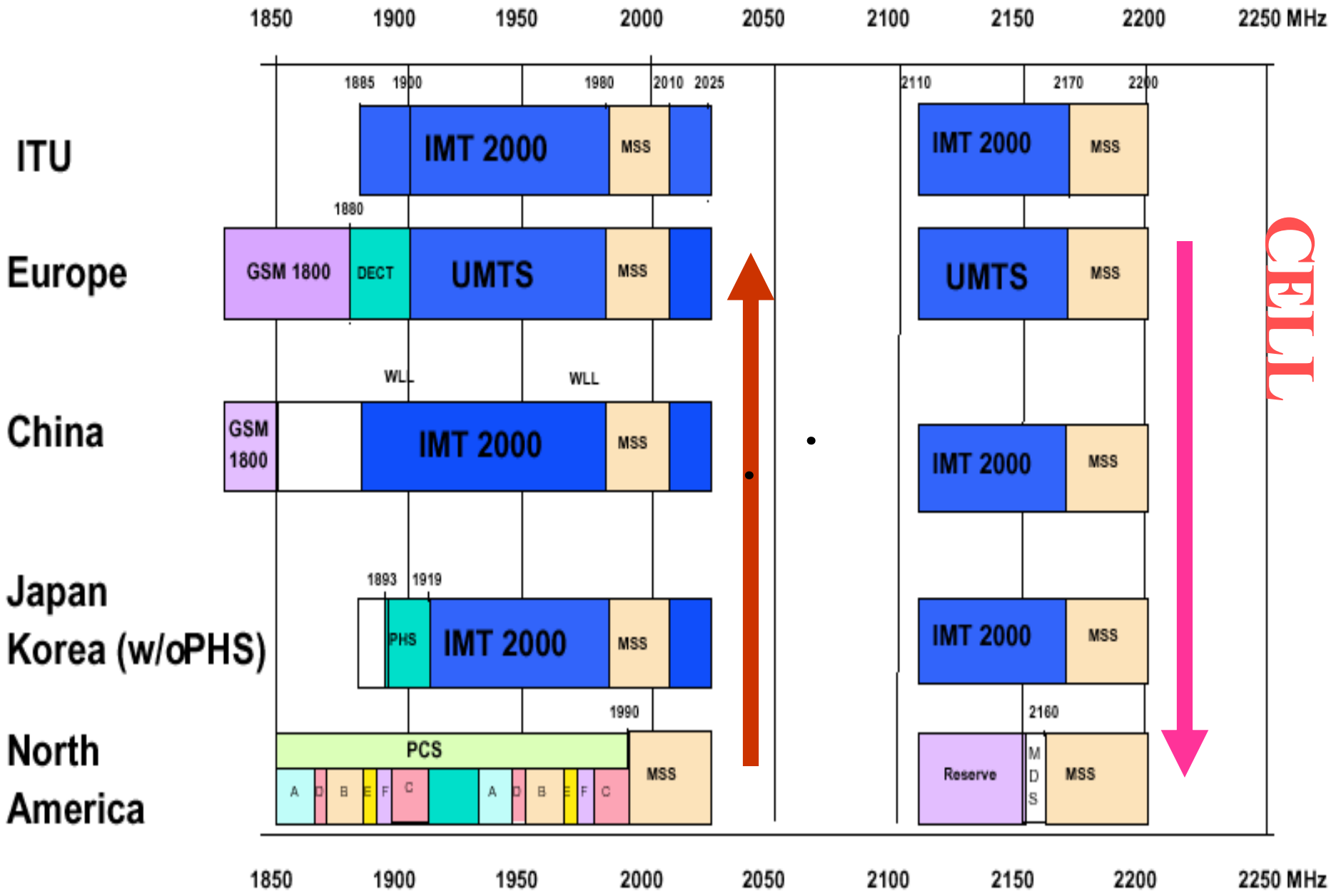
- Videoconference
- Video streaming
- Video on demand

UMTS services

- Interactive Map
- Localization Service
- Navigation System
- …

CELL

UMTS frequency map 3G & 4G .



23. 4G is a successor to the 3G and 2G families

In 2008, the ITU-R specified the **IMT-Advanced** requirements for 4G standards, setting peak speed for 4G service at **100 Mbs** for high mobility communication (such as from trains and cars) and **1 Gbps** for low mobility communication (stationary users).

LTE (**Long-Term Evolution)** for commonly marketed as **4G LTE**, is for wireless communication of high-speed data for mobile phones. It is based on the:**GSM/EDGE & UMT/HSPA** network technologies, the capacity and speed using a different radio interface. First available LTE service was launched on December 14, 2009.

A 4G system provide a comprehensive and secure all-IP-based mobile solution to laptop computer, **smart phones** and other mobile devices. Facilities such **IP telephony,** gaming services, and streamed multimedia provided to users.

4G is a smartphone with Operating System.

In 1999 released the first smartphones, combined telephony and computing, it became widespread in the late 2000s. Smartphones **have the ability to: place and receive voice/video calls and create and receive text messages, have personal digital assistants, a media player, video games, GPS navigator, digital camera and digital video camera.**

Smartphones can access the Internet through cellular frequencies or WiFi. They have a color display with a graphical user interface. The display is almost always a touch-screen and sometimes additionally a touch-enabled keyboard to type words and numbers and press.

Worldwide operating system market share for

Android	iOS	Windows	Others
81.7%	17.9%	0.3%	0.1%

Mobile operating systems

- **Android** is a mobile operating system developed by **Google**. It is an open source platform with proprietary components.(2008).
- **iOS (iPhone OS)** is a proprietary mobile operating system developed by **Apple Inc.** primarily for its iPhone product line. The iPhone was first unveiled in 2007. The device introduced design concepts that have been adopted by modern smartphone platforms.
- **Windows 10 Mobile** (Windows Phone) is from **Microsoft**. It is closed source and proprietary. It has the third largest installed base on smartphones behind Android and iOS (2010).
- It is integrated with Microsoft services such as **OneDrive and Office, Xbox Music, Xbox Video, Xbox**. Also integrated with many other non-Microsoft services such as **Facebook and Google accounts**.

Discontinued operating systems

- **BlackBerry 10** (In early 2010s), is based on their BlackBerry Tablet OS, to replace the BlackBerry OS. While the company has started to release smartphone based on the Android operating system.
- **BlackBerry OS** (In 1999), RIM released its first BlackBerry devices, providing secure real-time push-email communications on wireless devices. Services such as BlackBerry Messenger provide the integration of all communications into a single inbox.
- **Windows Mobile.** Windows Mobile was based on the Windows CE kernel and first appeared as the Pocket PC 2000 operating system. Throughout its lifespan, the operating system was available in both touch-screen and non-touch-screen formats.
- **Firefox OS** was demonstrated by Mozilla in February 2012. It was designed to have a complete community-based alternative system for mobile devices, using open standards and HTML5 applications.
- **Ubuntu Touch (Ubuntu Phone)** is a mobile version of the Ubuntu operating system developed by Canonical UK Ltd and Ubuntu Community. It is designed primarily for touchscreen mobile devices such as smartphones and tablet computers.

5th generation wireless systems

5G are the proposed next telecommunications standards beyond the current 4G/IMT-Advanced standards.

5G planning aims **capacity > than current 4G**, supporting **device-to-device** and massive machine communications.
5G research and development also aims at **lower latency** than 4G equipment and **lower battery consumption**.
There is currently no standard for 5G deployments.
The Next Generation Mobile Network Alliance defines the following requirements that a 5G standard should fulfill:
*Data rates of **tens of Mbps** for tens of thousands of users.
*Data rates of **100 Mbps** for metropolitan areas.
***1 Gbps** simultaneously to many workers on the same office floor

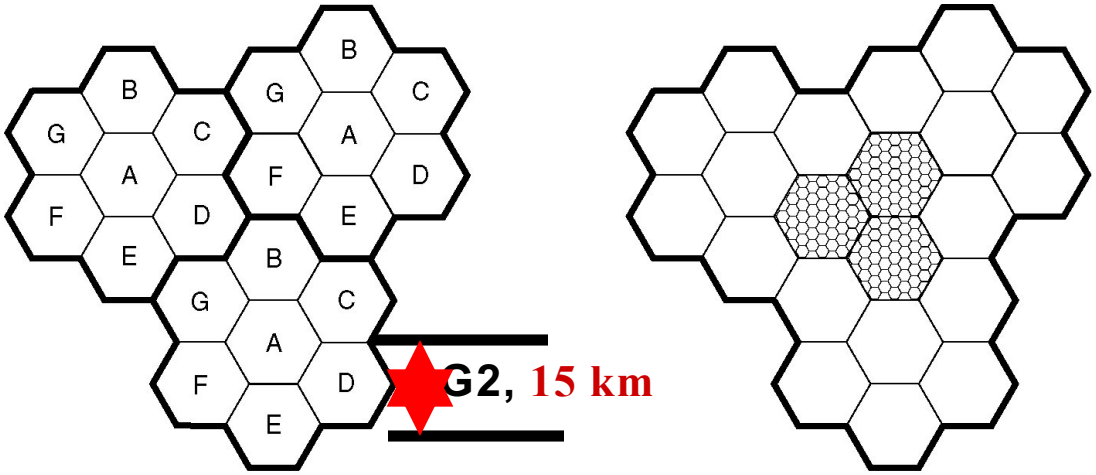
5G should be rolled out by 2020

G1-G5

- New mobile generations are typically assigned new frequency bands and wider spectral bandwidth per frequency channel (**1G up to 30 kHz, 2G up to 200 kHz, 3G up to 5 MHz, and 4G up to 20 MHz**).
- The higher frequencies would overlap with transmissions of communication satellites.
- Previous mobile generations have substantial increase in bit rate (i.e. physical layer) up to 1 gigabit per second to be offered by 4G.
- The U.S. Federal Communications Commission (FCC) approved the spectrum for **5G,** including the **28 GHz**, **37 GHz** and **39 GHz** bands, on July, 2016. (see slide 10).

G1-G5

- 1. $$L_f = 32.45 + 20\log_{10} f_c(MHz) + 20\log_{10} d(km)$$
- 2.



- 3. G1 f=0.9MHz; G2 f=1.9Mhz; G3 f=2.4GHz; G4 f=5.8 GHz; G5 f=28GHz,37GHz & 39GHz

- 4. FCC restriction for Hand-held telephone =0.6 watts
- ?. Using 1. + 2. +3. +4 concepts, what you can conclude <u>for G5 network</u> ???

Has been recorded three very distinct 5G network visions:

- **A super-efficient mobile network** that delivers a better performing network for lower investment cost.
- **A super-fast mobile network** comprising the next generation of small cells densely clustered to give a contiguous coverage over at least urban areas and getting the "wide-area mobility."
- **A combined fiber-wireless network** that uses, for the first time for wireless Internet access, the millimeter wave bands (20 – 60 GHz) that allow very-wide-bandwidth radio channels able to support data-access speeds of up to **10 Gbs.**

The connection essentially comprises "short" wireless links on the end of local fiber optic cable.

See slides 12 & 13