RADFORD UNIVERSITY

Wireless Communication

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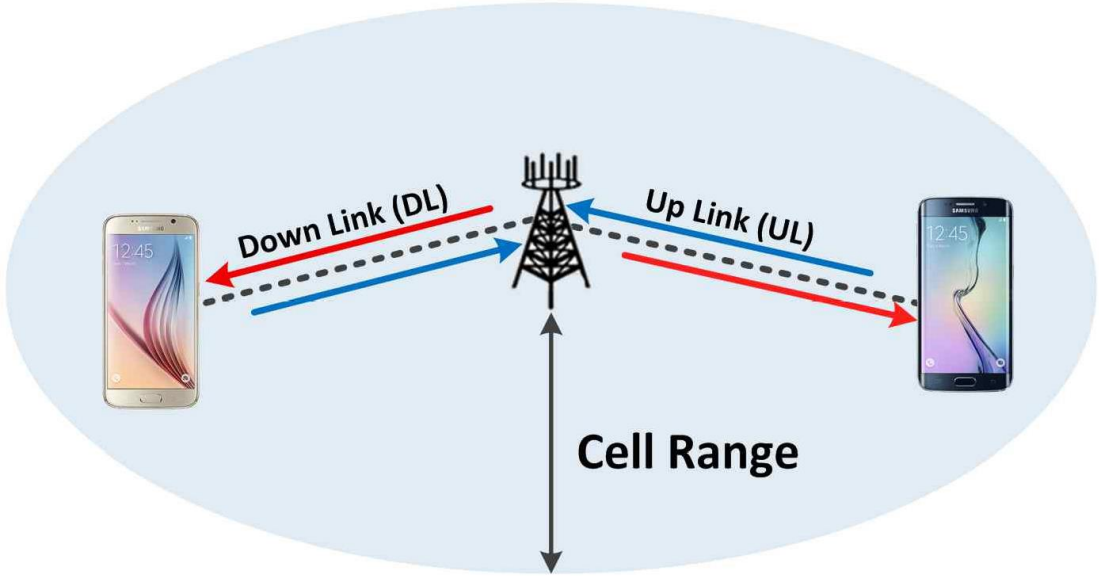
Key Reference:
Prof. Jong-Moon Chung's Lecture Notes at Yonsei University

Wireless Communications

- Bluetooth
- Wi-Fi
- **Mobile Communications**
- LTE
- LTE-Advanced

Mobile Communications Handover

- Downlink & Uplink

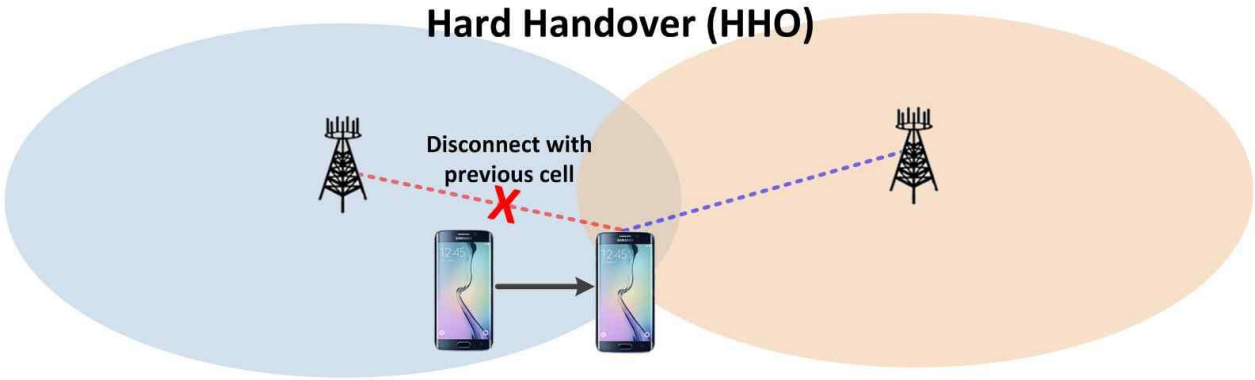


Mobile Communications Handover

- **Handover**

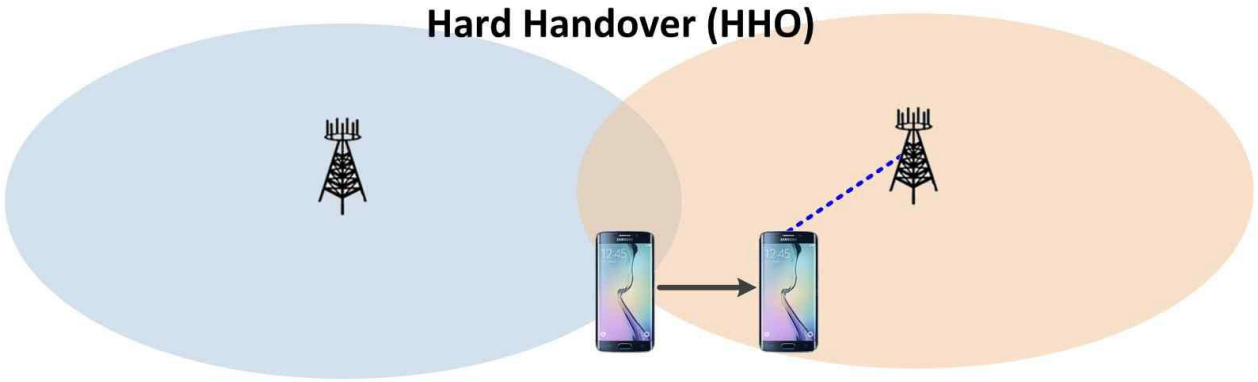
Mobile Communications Handover

- **Handover**



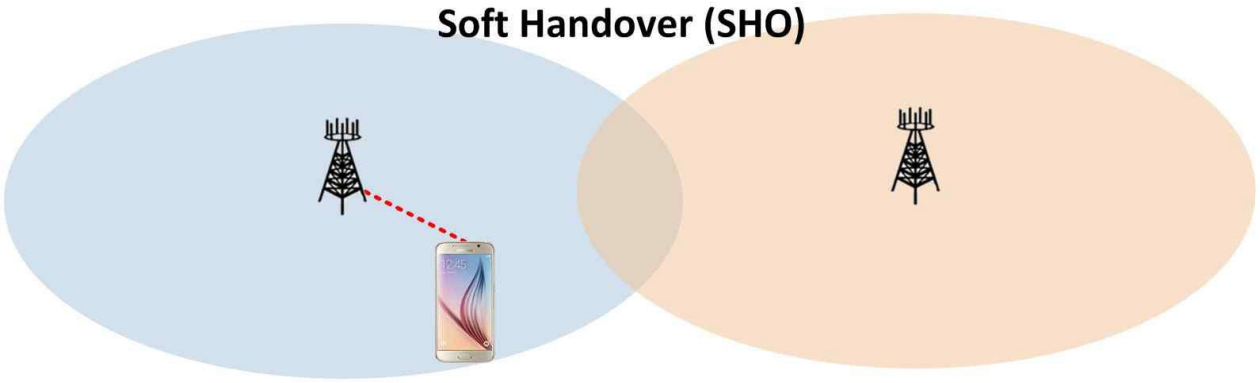
Mobile Communications Handover

- **Handover**



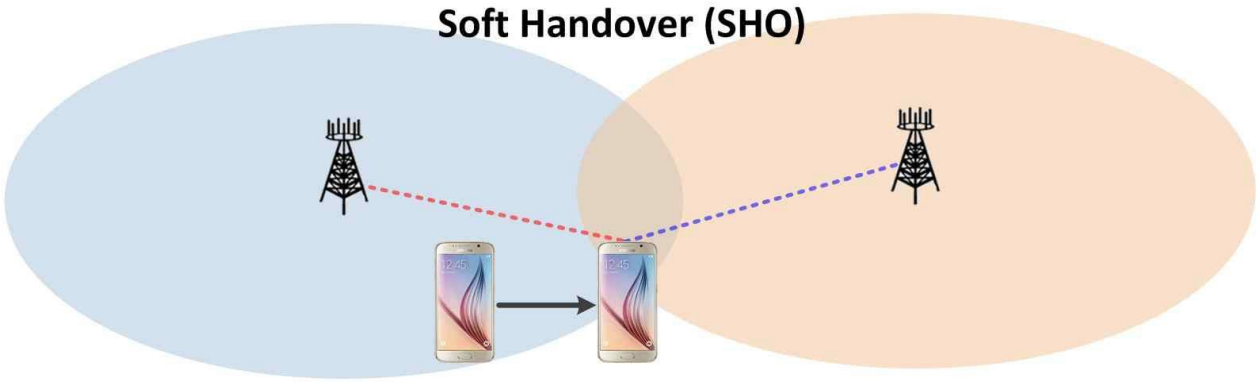
Mobile Communications Handover

- **Handover**



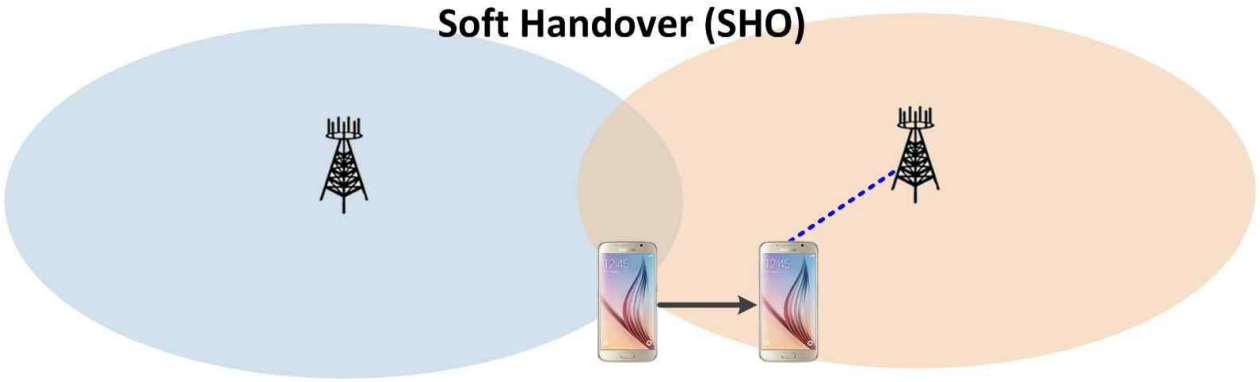
Mobile Communications Handover

- **Handover**

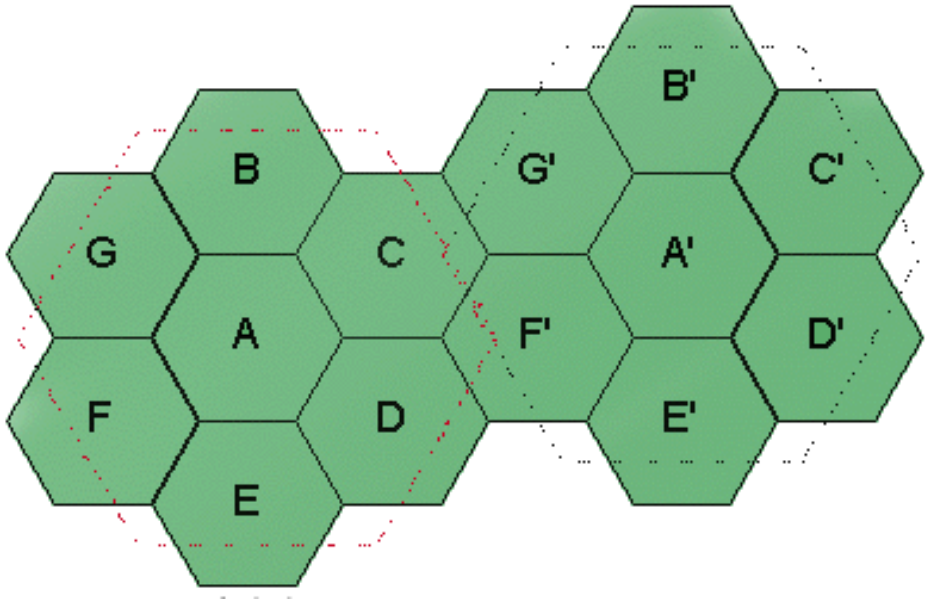


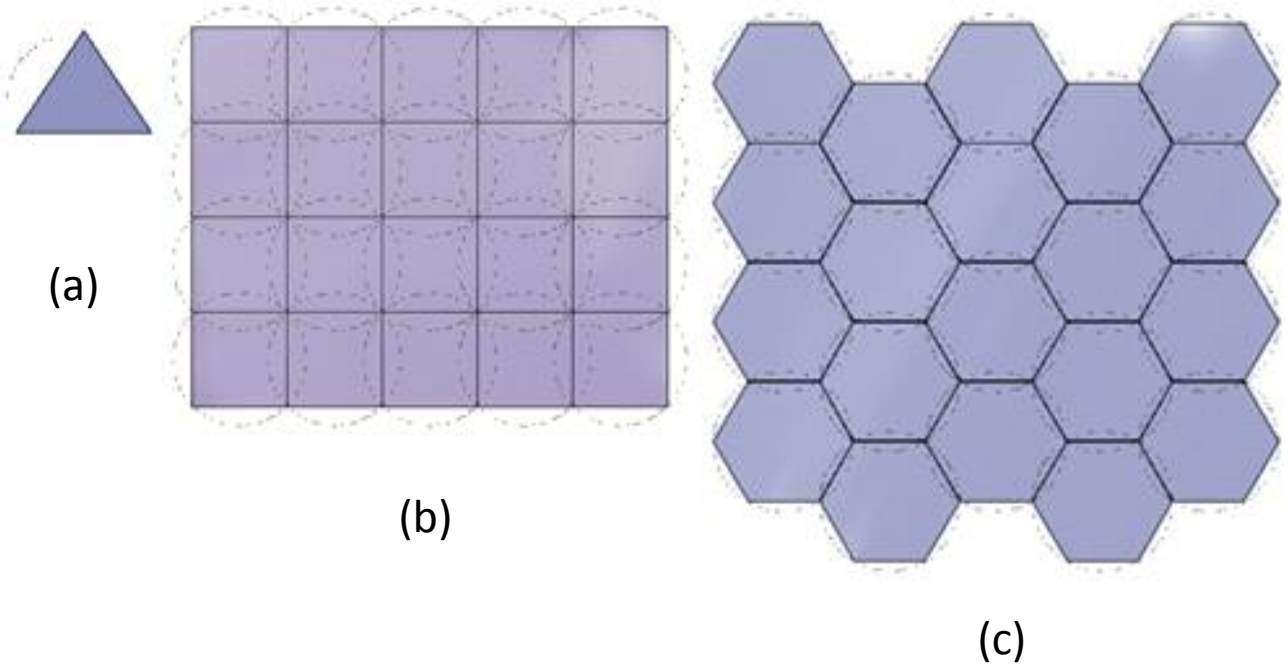
Mobile Communications Handover

- **Handover**

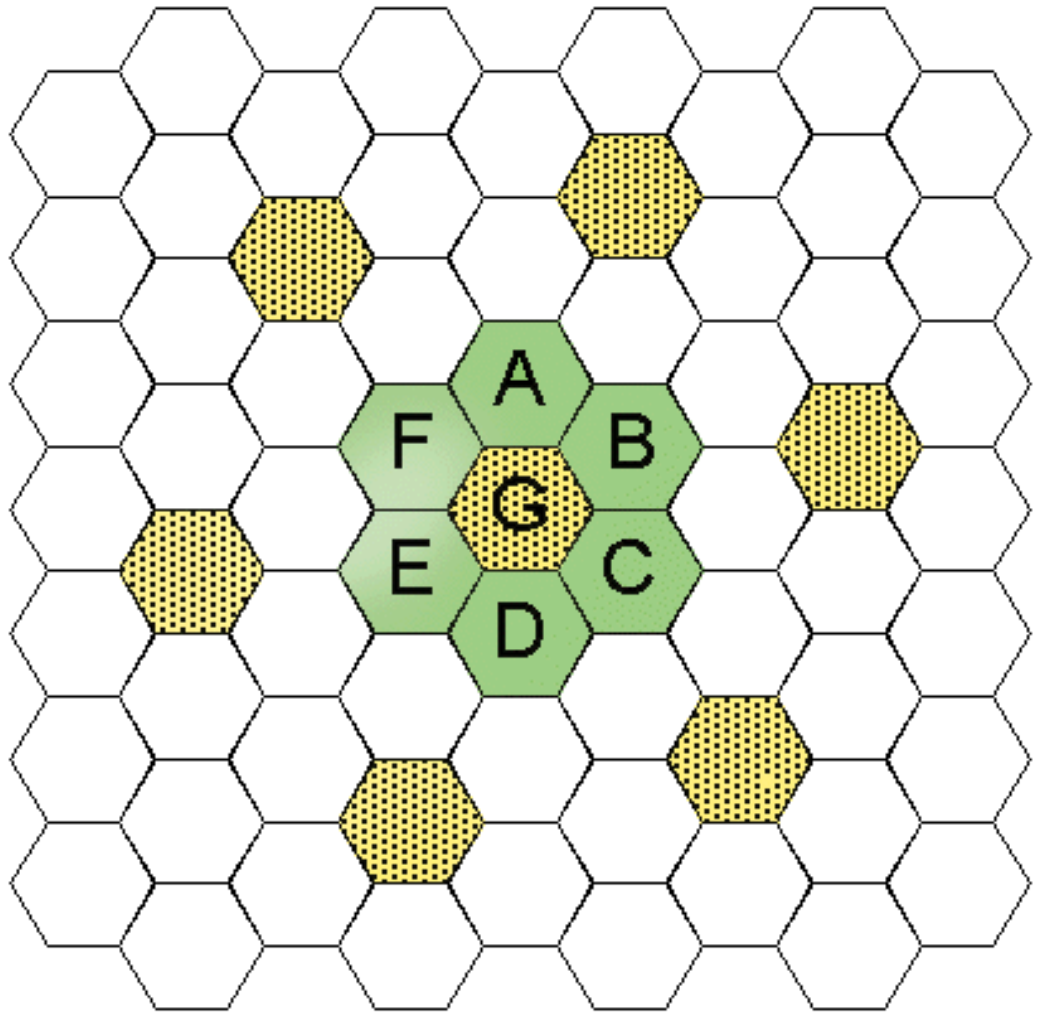


What is Cellular?





Possible Cell Arrangement


A
F
B
G
E
C
D

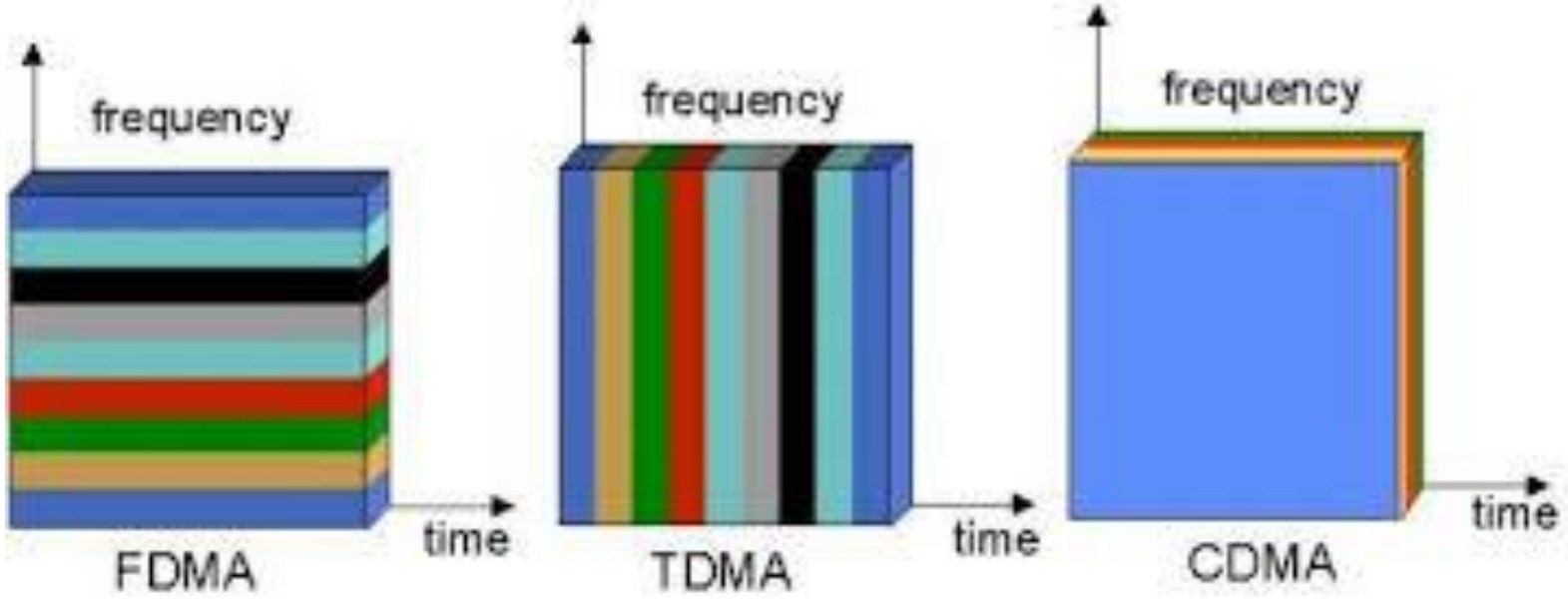
To Overcome the Limited Frequency Band

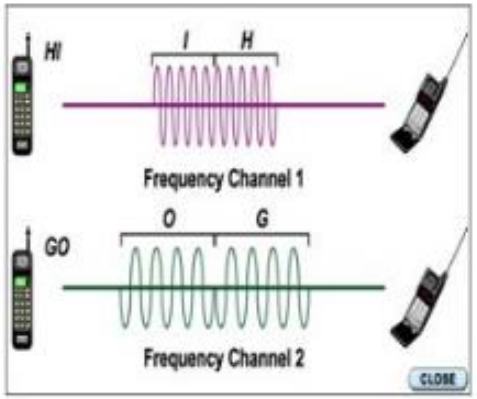
- Cellular Technology
  - Increase reusability by increase the number of cells
- Multiple Access Technology
  - Allow multiple users to share a frequency band

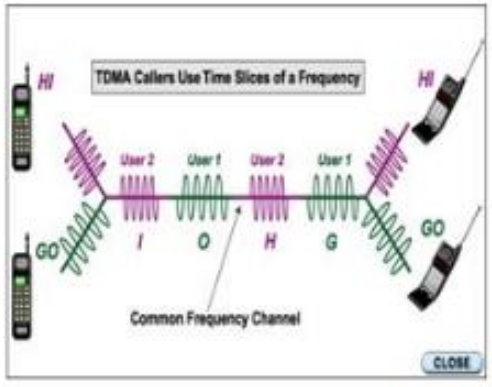
Types of Multiple Access Technology

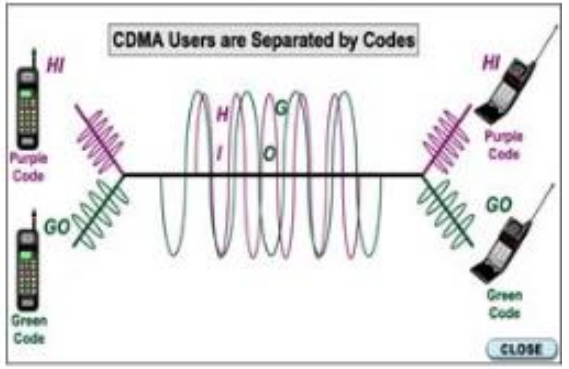
- FDMA (Frequency Division Multiple Access)
- TDMA (Time Division Multiple Access)
- CDMA (Code Division Multiple Access)

FDMA, TDMA, and CDMA









FDMA

- Filter is needed at the receiver.
- In a given frequency band
  - Large number of subchannels = Large number of users supported
    - Narrower subchannels ➔ Low quality of sound & More interference
    - Closer subchannels ➔ More interference
- Due to interference, a guard band is necessary

TDMA

- Time slot, Time gate
- IS-54 TDMA
  - In the US
  - Sets of 3 time slots in 30KHz
- IS-136 TDMA
  - In the US
  - Sets of 6 time slots in 30KHz
- GSM (Global System for Mobile)
  - In Europe
  - Sets of 8 time slots in 200KHz

CDMA

- Multiple signals in the same frequency band and in the same time slot.
- Each signal uses a different code (i.e., a spread spectrum code)
- Originally Spread Spectrum technology for a military use.
  - More secure against an eavesdropping
  - More resilient against a noise
- The receiver, must know:
  - Spread spectrum code
  - The time the code was generated ➔ Need to be synchronized
    - Currently use GPS (Global Positioning System)

CDMA

- Spread Spectrum
  - (ex) a signal with 10KHz ➔ (125 times) 1.25MHz, a signal strength becomes a lot weaker. Like dropping a drop of ink in a water cup. Since the signal is extremely weak, it sounds like one of a noise

  ➔ (advantage)
    - interference between signals will decrease.
    - Impact of a noise will affect to a small portion of the signal ➔ improve the quality of sounds

CDMA

- White Noise (= Write Gaussian Noise)
  - Well-known noise ➔ it can be eliminated using a filter
- Spread Spectrum
  - Using PN Sequence (Pseudo random Noise Sequence)

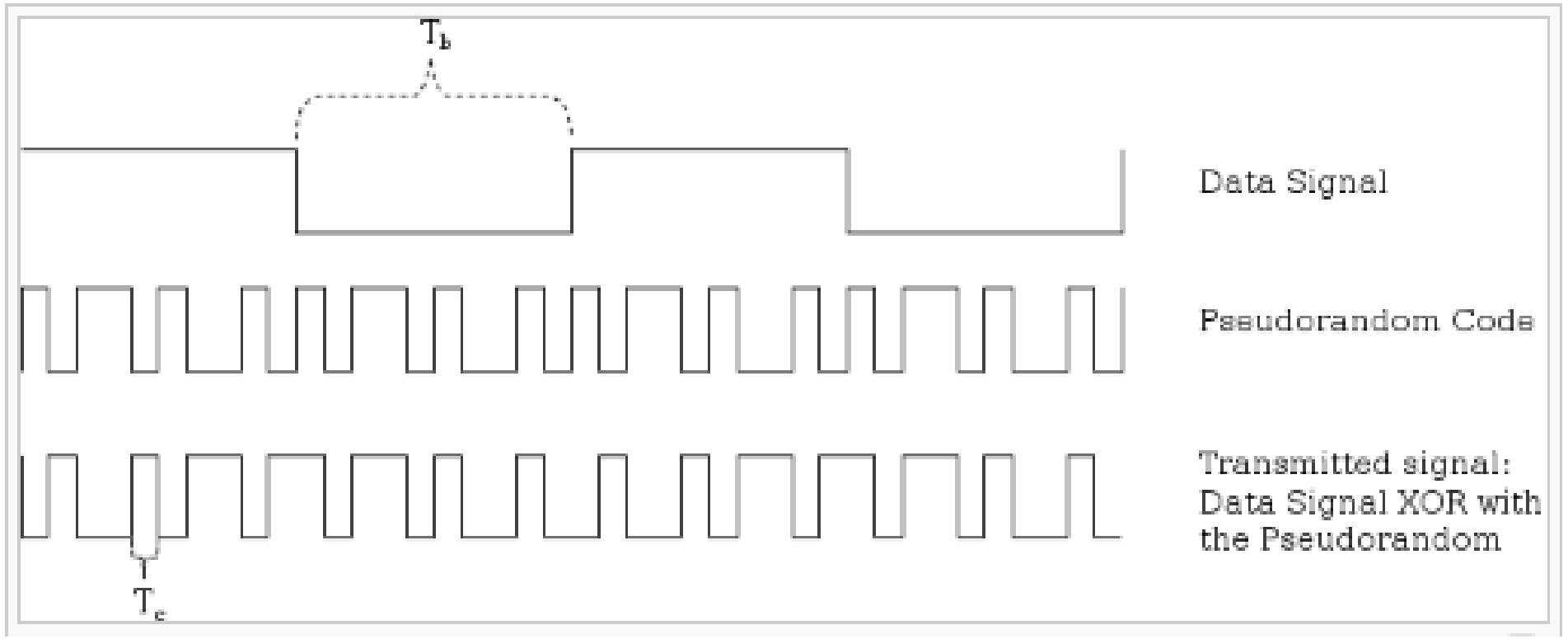
    (ex) water in the water + a drop of ink example

    Original Signal (Analog) → Convert to a digital signal → XOR with PN Sequence → Modulated Analog signal
  - Receiver: Accept only the signal with the same PN sequence
    - i.e. the receiver can demodulate the CDMA signal which it knows the PN sequence.
  - Each communication pair uses a different PN Sequence

CDMA: Spread Codes

$$\frac{1}{N}\int_0^T p_i(t)\,p_j(t)\,dt = \begin{cases} 1, & i = j \\ 0, & i \neq j \end{cases}$$

CDMA: Generation of a CDMA Signal



CDMA: Example

- User 1
  - Data = 01
  - Spread Code (PN Sequence) = 10101010
  - CDMA Signal with XOR =
- User 2
  - Data = 11
  - Spread Code (PN Sequence) = 00001111
  - CDMA Signal with XOR =
- User 3
  - Data = 00
  - Spread Code (PN Sequence) = 11001100
  - CDMA Signal with XOR =

CDMA: Combining CDMA Signals

- Convert 1s and 0s to a digital signal
  - 1: -A pulse
  - 0: A pulse
- Add
  - CDMA Signal of User 1 =
  - CDMA Signal of User 2 =
  - CDMA Signal of User 3 =
- Combined Signal =

CDMA: At the Receiver

- Receiver of User 1
  - Receive the combined signal =
  - Multiply the Spread Code (PN Sequence) to the received signal
    - PN Sequence of the User 1 = 10101010
  - Recover the original signal from the User 1 =

Mobile Communications

- **Mobile Phone Evolution**
  - 1st Generation (1G)
    - AMPS
  - 2nd Generation (2G)
    - GSM, IS-95 (cdmaOne)
  - 3rd Generation (3G)
    - UMTS (WCDMA), CDMA2000
  - 4th Generation (4G)
    - LTE-A

List of Mobile Phone Generations

V·T·E	Cellular network standards	[hide]
List of mobile phone generations		
0G (radio telephones)	MTS · MTA - MTB - MTC - MTD · IMTS · AMTS · OLT · Autoradiopuhelin · B-Netz	
1G	AMPS family	AMPS (TIA/EIA/IS-3, ANSI/TIA/EIA-553) · N-AMPS (TIA/EIA/IS-91) · TACS · ETACS
	Other	NMT · C-450 · Hicap · Mobitex · DataTAC
2G	GSM/3GPP family	GSM · CSD · HSCSD
	3GPP2 family	cdmaOne (TIA/EIA/IS-95 and ANSI-J-STD 008)
	AMPS family	D-AMPS (IS-54 and IS-136)
	Other	CDPD · iDEN · PDC · PHS
2G transitional (2.5G, 2.75G)	GSM/3GPP family	GPRS · EDGE/EGPRS (UWC-136)
	3GPP2 family	CDMA2000 1X (TIA/EIA/IS-2000) · CDMA2000 1X Advanced
	Other	WiDEN
3G (IMT-2000)	3GPP family	UMTS (UTRA-FDD / W-CDMA · UTRA-TDD LCR / TD-SCDMA · UTRA-TDD HCR / TD-CDMA)
	3GPP2 family	CDMA2000 1xEV-DO Release 0 (TIA/IS-856)
3G transitional (3.5G, 3.75G, 3.9G)	3GPP family	HSPA (HSDPA · HSUPA) · HSPA+ · LTE (E-UTRA)
	3GPP2 family	CDMA2000 1xEV-DO Revision A (TIA/EIA/IS-856-A) · EV-DO Revision B (TIA/EIA/IS-856-B) · EV-DO Revision C
	IEEE family	Mobile WiMAX (IEEE 802.16e) · Flash-OFDM · iBurst (IEEE 802.20)
4G (IMT Advanced)	3GPP family	LTE Advanced (E-UTRA) · LTE Advanced pro (4.5G pro) · LTE Advanced(pre 5G) (4.9G)
	IEEE family	WiMAX (IEEE 802.16m)
Proposed	5G	
Related articles	Cellular networks · Mobile telephony · History · List of standards · Comparison of standards · Channel access methods · Spectral efficiency comparison table · Cellular frequencies · GSM frequency bands · UMTS frequency bands · Mobile broadband · NGMN Alliance · MIMO	

AMPS

- **Advanced Mobile Phone System (AMPS)**
  - **1st Generation (1G) mobile cellular phone**
  - **Analog standard using FDMA (Frequency Division Multiple Access)**
  - **Developed by Bell Labs**
  - **Introduced in North America in Oct. 1983**

GSM

- **Global System for Mobile Communications (GSM)**
  - **2nd Generation (2G) mobile cellular phone: Digital system**
  - **Introduced in Finland in 1991**
  - **Dominant global standard**
    - **Over 90% market share**
    - **Operated in over 219 countries & territories**

GSM

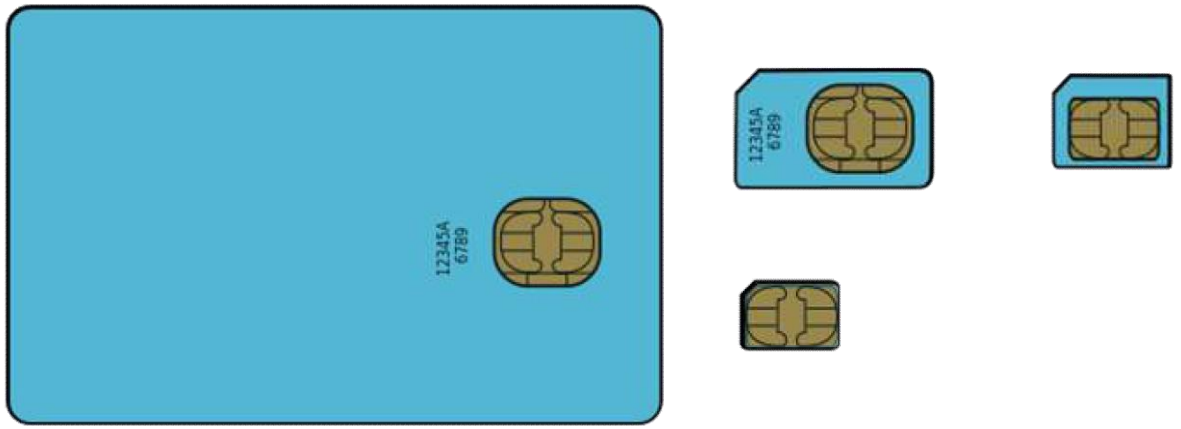
- **Global System for Mobile Communications (GSM)**
  - **GSM uses TDMA & FDMA combined**
    - **TDMA (Time Division Multiple Access)**
    - **FDMA (Frequency Division Multiple Access)**

GSM

- **Global System for Mobile Communication (GSM)**
  - **GSM supports voice calls and data transfer speeds up to 9.6 kbps, and SMS (Short Message Service)**

GSM

- **SIM (Subscriber Identity Module)**
  - **SIM is a detachable smart card**
  - **SIM contains user subscription information and phone book**



GSM

- **SIM Advantages**
  - **SIM enables a user to maintain user information even after switching cellular phones**
  - **Or, by changing ones SIM a user can change cellular phone operators while using the same the mobile phone**

IS-95: cdmaOne

- **IS-95**
  - **IS-95 (Interim Standard 95) is the first CDMA based 2G digital cellular standard**
    - **Why CDMA?**
      CDMA performs well against (narrow band) interference and (multipath) signal fading
  - **cdmaOne is the brand name for IS-95 that was developed by Qualcomm**

IS-95: cdmaOne

- **IS-95**
  - **Hutchison launched the first commercial cdmaOne network in Hong Kong in September 1995**
  - **IS-95 traffic channels support voice or data at bit rates of up to 14.4 kbps**

UMTS

- **Universal Mobile Telecommunications System (UMTS)**
  - **3rd Generation (3G) mobile cellular system**
  - **Evolution of GSM**
  - **UTRA (UMTS Terrestrial Radio Access) supports several different terrestrial air interfaces**

UMTS

- **Universal Mobile Telecommunications System (UMTS)**
  - **Multiuser Access in UTRA can be supported by UTRA-FDD or UTRA-TDD**
    - **FDD (Frequency Division Duplex)**
    - **TDD (Time Division Duplex)**

UMTS: WCDMA

- **WCDMA (Wideband Code Division Multiple Access)**
  - **3rd Generation (3G) mobile cellular system that uses the UTRA-FDD mode**
  - **3GPP (3rd Generation Partnership Project) Release 99**
    - **Up to 2 Mbps data rate**

UMTS: WCDMA

- **WCDMA**
  - First commercial network opened in Japan is 2001
  - Seamless mobility for voice and packet data applications
  - QoS (Quality of Service) differentiation for high efficiency of service delivery
  - Simultaneous voice and data support
  - Interworks with existing GSM networks

CDMA2000

- **CDMA2000**
  - **3G mobile cellular system**
  - **Standardized by 3GPP2**
  - **Evolution of IS-95 cdmaOne standards**
    - **Uses CDMA & TDMA**
      - **CDMA (Code Division Multiple Access)**
      - **TDMA (Time Division Multiple Access)**

CDMA2000

- **CDMA2000**
  - **Initially used in North America and South Korea (Republic of Korea)**

CDMA2000

CDMA2000 1xEV-DO

- CDMA2000 1xEV-DO (Evolution-Data Optimized) enables 2.4 Mbps data rate
- CDMA2000 1xEV-DO network launched in South Korea on January 2002

CDMA2000

- **CDMA2000 1xEV-DO**
  - **Regarded as the first 3G system based on ITU standards**
    - **ITU (International Telecommunication Union) is the specialized agency for information and communication technology of the UN (United Nations)**

HSDPA

- **High-Speed Downlink Packet Access (HSDPA)**
  - **Enhanced 3G mobile communications protocol**
  - **Evolution of UMTS for higher data speeds and capacity**
  - **Belongs to the HSPA (High-Speed Packet Access) family of protocols**

HSDPA

- **High-Speed Downlink Packet Access (HSDPA)**
  - **HSDPA commercial networks became available in 2005**
  - **Peak Data Rate**
    - **Downlink: 14 Mbps (Release 5)**

EV-DO Rev. A

- **EV-DO Rev. A (Revision A)**
  - **Peak Data Rate**
    - **Downlink: 3.1 Mbps**
    - **Uplink: 1.8 Mbps**
  - **Launched in the USA on October 2006**
  - **VoIP support based on low latency and low bit rate communications**

EV-DO Rev. A

- **EV-DO Rev. A**
  - **Enhanced Access Channel MAC**
    - **Decreased connection establishment time**
  - **Multi-User Packet technology enables the ability for more than one user to share the same timeslot**
  - **QoS (Quality of Service) flags included for QoS control**

HSPA+

- **Evolved High-Speed Packet Access (HSPA+)**
  - **HSPA+ all IP network first launched in Hong Kong in 2009**
  - **WCDMA (UMTS) based 3G enhancement**
  - **HSPA+ is a HSPA evolution**

HSPA+

- **Evolved High-Speed Packet Access (HSPA+)**
  - **Peak Data Rate**
    - **Downlink: 168 Mbps**
    - **Uplink: 22 Mbps**
  - **MIMO (Multiple-Input & Multiple-Output) multiple-antenna technique applied**
    - **Why MIMO? MIMO uses uncorrelated multiple antennas both at the transmitter and receiver to increase the data rate while using the same signal bandwidth as a single antenna system.**

HSPA+

- **Evolved High-Speed Packet Access (HSPA+)**
  - **Higher Date Rate Accomplished by**
    - **MIMO multiple-antenna technique**
    - **Higher order modulation (64QAM)**
    - **Dual-Cell HSDPA is used to combine**
    - **multiple cells into one**

EV-DO Rev B

- **EV-DO Rev. B (Revision B)**
  - **EV-DO Rev. B was first deployed in Indonesia on January 2010**
  - **Multi-Carrier evolution of Rev. A**
  - **Higher data rates per carrier**
    - **Downlink Peak**
      - **4.9 Mbps per carrier**
    - **Uplink Peak**
      - **1.8 Mbps per carrier**

EV-DO Rev B

- **EV-DO Rev. B**
  - **Reduced latency from statistical multiplexing across channels → Reduced delay → Improved QoS**
  - **Longer talk-time & standby time**
  - **Hybrid frequency re-use & Reduced interference at Cell Edges and Adjacent Sectors → Improved QoS at the Cell Edge**

EV-DO Rev B

- **EV-DO Rev. B**
  - **More Efficient Asymmetric Data Rate Support**
    - **Downlink ≠ Uplink Data Rates**
    - **Asymmetric Service Examples**
      - **File transfer**
      - **Web browsing**
      - **Multimedia content delivery**
      - **etc.**

EV-DO Rev B

- **Long-Term Evolution (LTE)**
  - **LTE launched in North American on September 2010 with the Samsung SCH-R900**
  - **Deployed on both GSM and the CDMA mobile operators**

EV-DO Rev B

- **Long-Term Evolution (LTE)**
  - **Peak Data Rate (Release 8)**
    - **Downlink: 300 Mbps**
    - **Uplink: 75 Mbps**

LTE-A

- **LTE-A (LTE-Advanced)**
  - **Considered as a 4G technology based on the ITU-R IMT-Advanced process**
  - **Peak Data Rate (Release 10)**
    - **Downlink: 3 Gbps**
    - **Uplink: 1.5 Gbps**

LTE-A

- **LTE-A (LTE-Advanced)**
  - **LTE-A incorporates higher order MIMO (4×4 and beyond) and allows multiple carriers to be bonded into a single stream**

References

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- Image Source: FDMA, TDMA, CDMA comparison, slidePlayer.com