



Chapter 1

Introduction

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The History of Mobile Radio Communication (1/2)



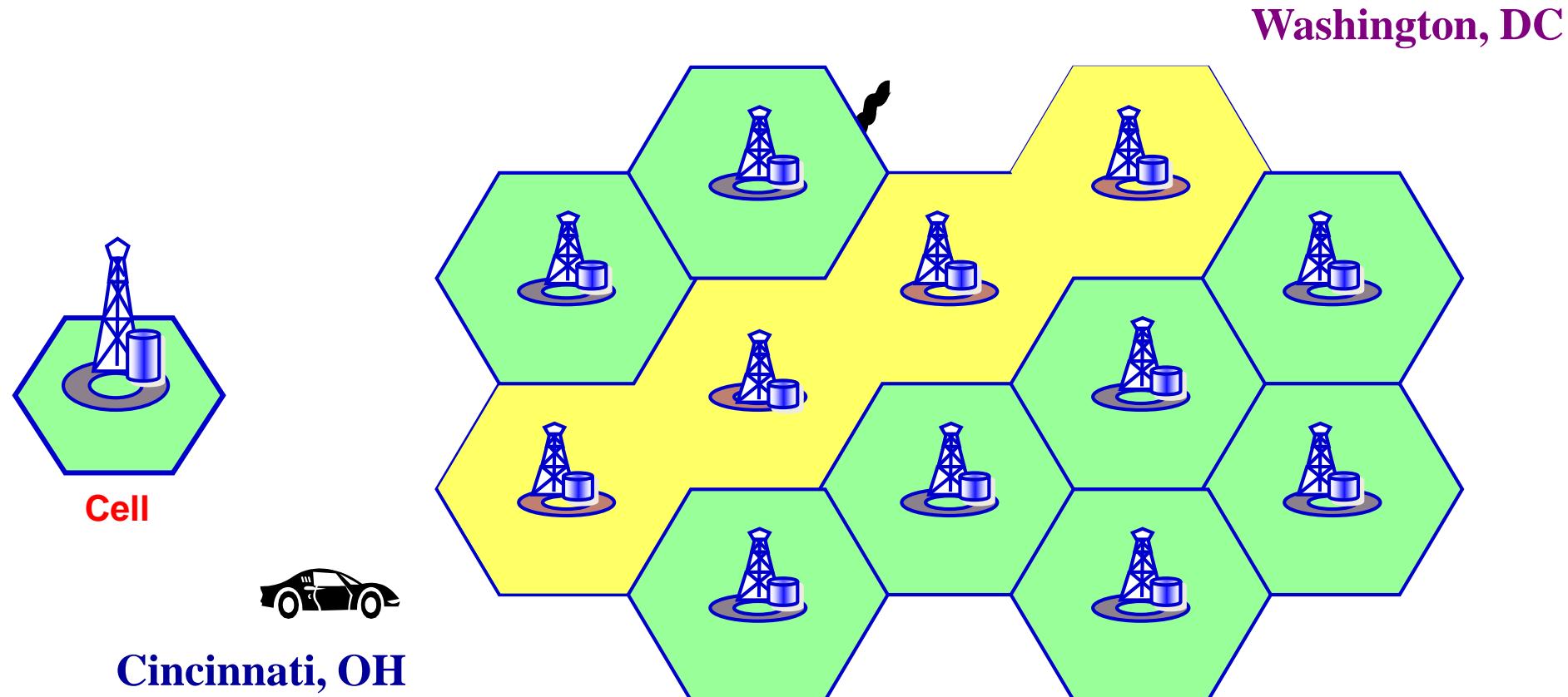
- 1880: Hertz – Initial demonstration of practical radio communication
- 1897: Marconi – Radio transmission to a tugboat over an 18 mi path
- 1988: **TDMA (Time Division Multiple Access)** voted as a digital cellular standard in North America
- 1992: **GSM (Global System for Mobile Communications)** operable in Germany D2 system

The History of Mobile Radio Communication (2/2)



- 1993: **CDMA (Code Division Multiple Access)** voted as another digital cellular standard in North America
- 1994: American TDMA operable in Seattle, Washington
- 1994: PDC (Personal Digital Cellular) operable in Tokyo, Japan
- 1994: Two of six broadband PCS (Personal Communication Service) license bands in auction
- 1995: World's first commercial launch of CDMA service (Hutchison Telecom, Hong Kong) (Dec. 1995)
- 1996: First Korean launch of cellular IS-95A service in Seoul (SK Telecom) (Apr. 1996)
- 1997: Broadband CDMA considered as one of the third generation mobile communication technologies for UMTS (Universal Mobile Telecommunication Systems) during the UMTS workshop conference held in Korea
- 1999: ITU (International Telecommunication Union) decides the next generation mobile communication systems
(e.g., WCDMA, cdma2000, TD-SCDMA etc)
- 2001: WCDMA Commercial service beginning from Oct. in Japan.

Universal Cell Phone Coverage



First Generation (1G) Cellular Systems and Services



1970s	Developments of radio and computer technologies for 800/900 MHz mobile communications
1976	WARC (World Administrative Radio Conference) allocates spectrum for cellular radio
1979	NTT (Nippon Telephone & Telegraph) introduces the first cellular system in Japan
1981	NMT (Nordic Mobile Telephone) 900 system introduced by Ericsson Radio System AB and deployed in Scandinavia
1984	AMPS (Advanced Mobile Phone Service) introduced by AT&T in North America

Second Generation (2G) Cellular Systems and Services

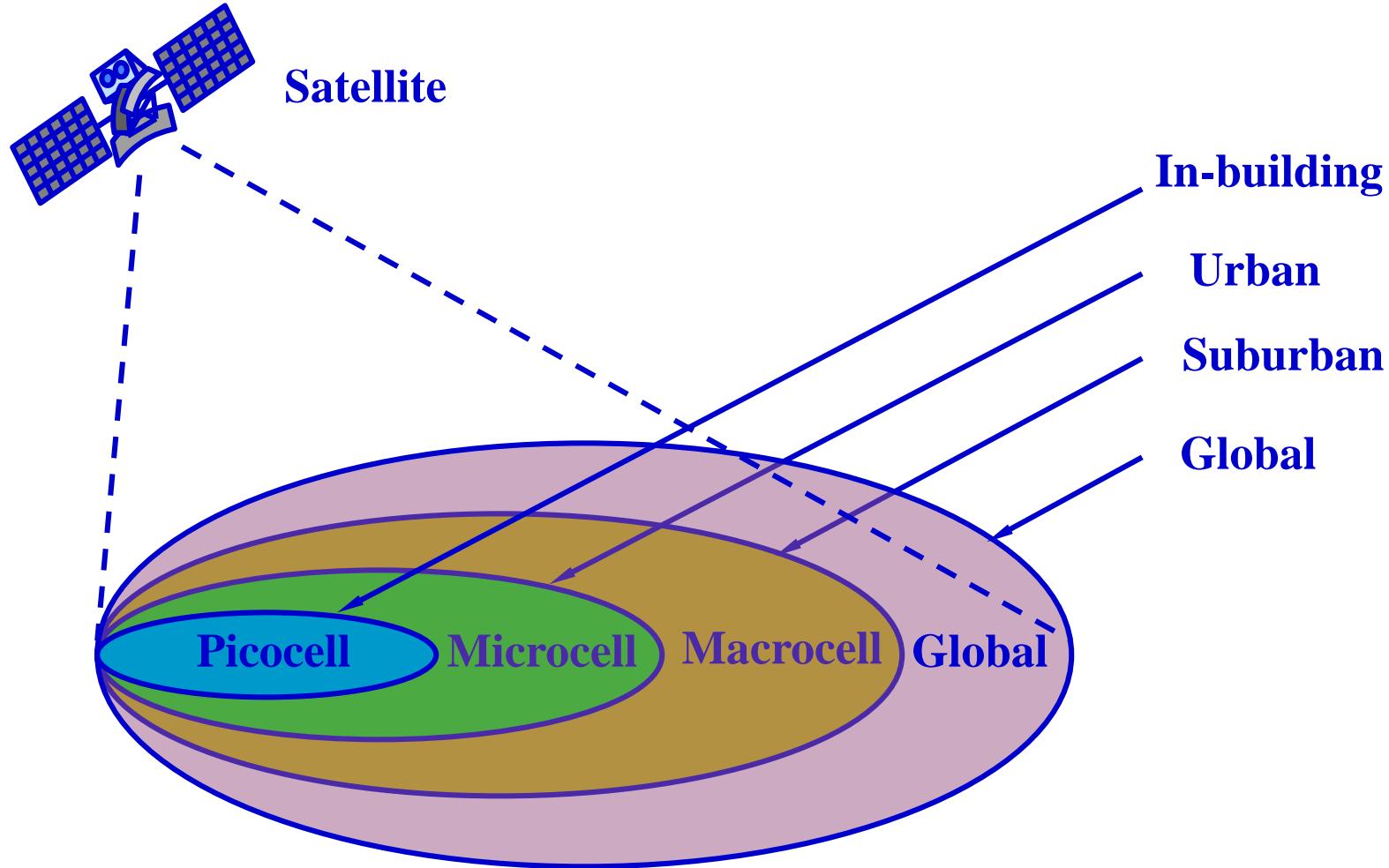


1982	CEPT (Conference Européenne des Post et Telecommunications) established GSM to define future Pan-European cellular Radio Standards
1990	Interim Standard IS-54 (USDC) adopted by TIA (Telecommunications Industry Association)
1990	Interim Standard IS-19B (NAMPS) adopted by TIA
1991	Japanese PDC (Personal Digital Cellular) system standardized by the MPT (Ministry of Posts and Telecommunications)
1992	Phase I GSM system is operational
1993	Interim Standard IS-95 (CDMA) adopted by TIA
1994	Interim Standard IS-136 adopted by TIA
1995	PCS Licenses issued in North America
1996	Phase II GSM operational
1997	North American PCS deploys GSM, IS-54, IS-95
1999	IS-54: North America IS-95: North America, Hong Kong, Israel, Japan, China, etc GSM: 110 countries

- IMT-2000 (International Mobile Telecommunications-2000):
⇒ Fulfill one's dream of anywhere, anytime communications a reality.
- Key Features of IMT-2000 include:
 - High degree of commonality of design worldwide;
 - Compatibility of services within IMT-2000 and with the fixed networks;
 - High quality;
 - Small terminal for worldwide use;
 - Worldwide roaming capability;
 - Capability for multimedia applications, and a wide range of services and terminals.

- Important Component of IMT-2000 is ability to provide high bearer rate capabilities:
 - 2 Mbps for fixed environment;
 - 384 Kbps for indoor/outdoor and pedestrian environment;
 - 144 kbps for vehicular environment.

Coverage Aspect of Mobile Communication Systems



- Cellular
- Wireless LAN(Local Area Network)/PAN(Personal Area Network)
- GPS(Global Positioning System)
- Satellite Based GPS
- Home Networking
- Ad Hoc Networks
- Sensor Networks
- Bluetooth

Fundamentals of Cellular Systems

- BS: Base Station
- MS: Mobile Station

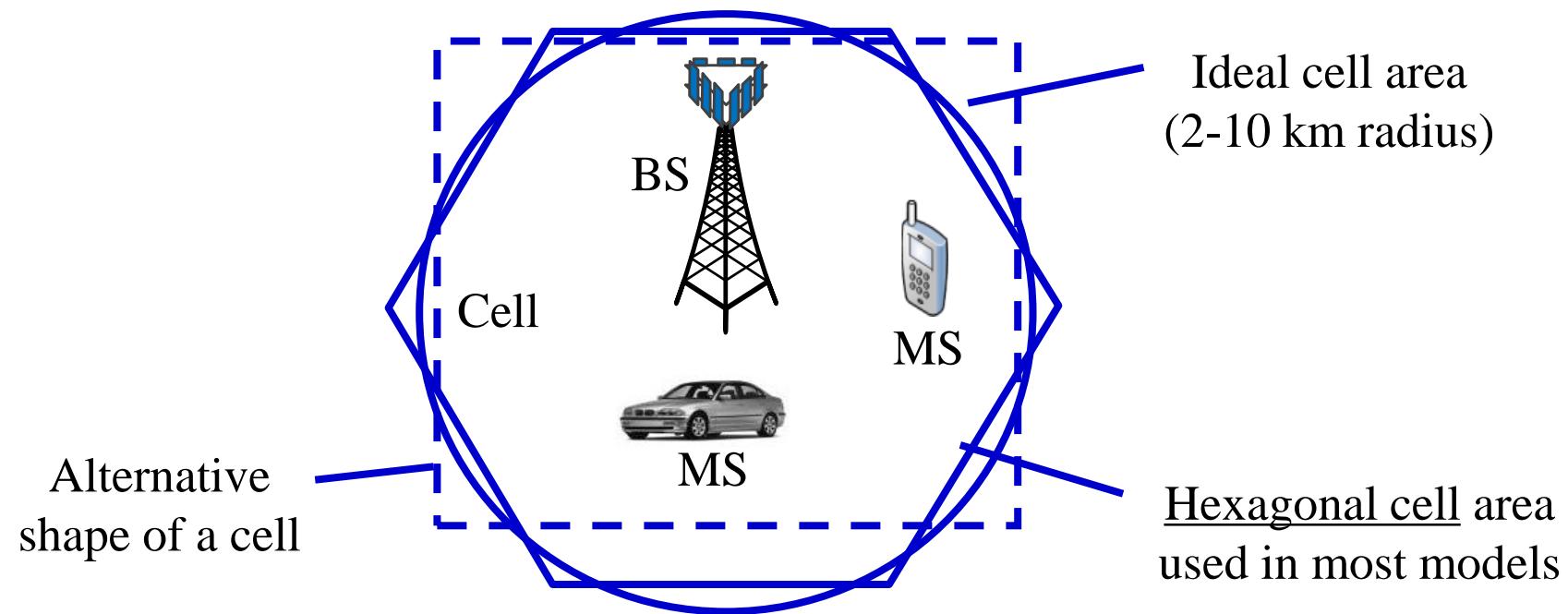
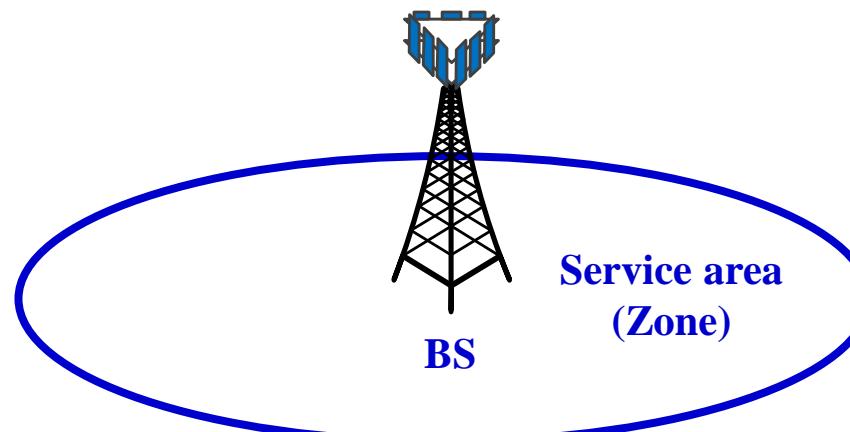


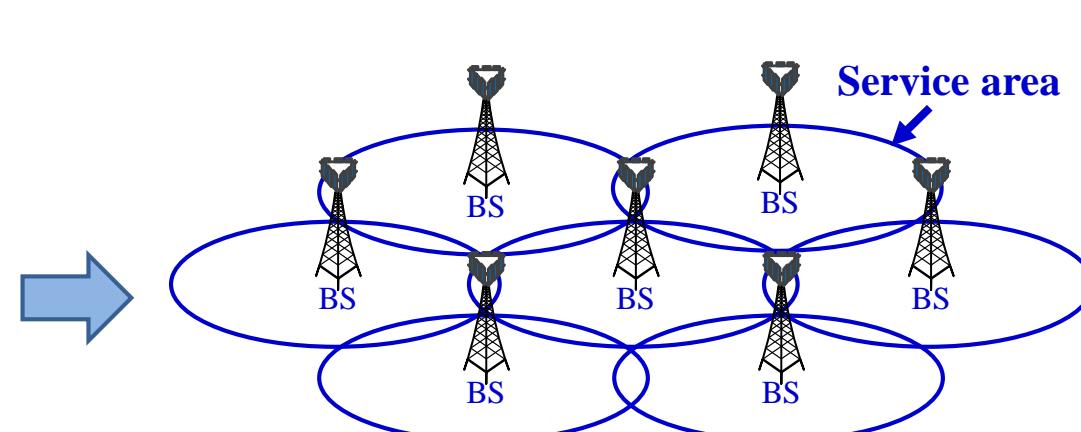
Illustration of a cell with a mobile station and a base station

Source : Introduction to Wireless & Mobile Systems (4th Ed.), Dharma Prakash Agrawal, CENGAGE Learning

- Early wireless systems
 - High-power transmitter → covers the entire service area
 - Requires huge amount of power → not suitable for many practical reasons.
- Cellular system
 - Replaced a large zone with a number of smaller hexagonal cells with a single BS covering a fraction of the area.



Early wireless system: Large zone

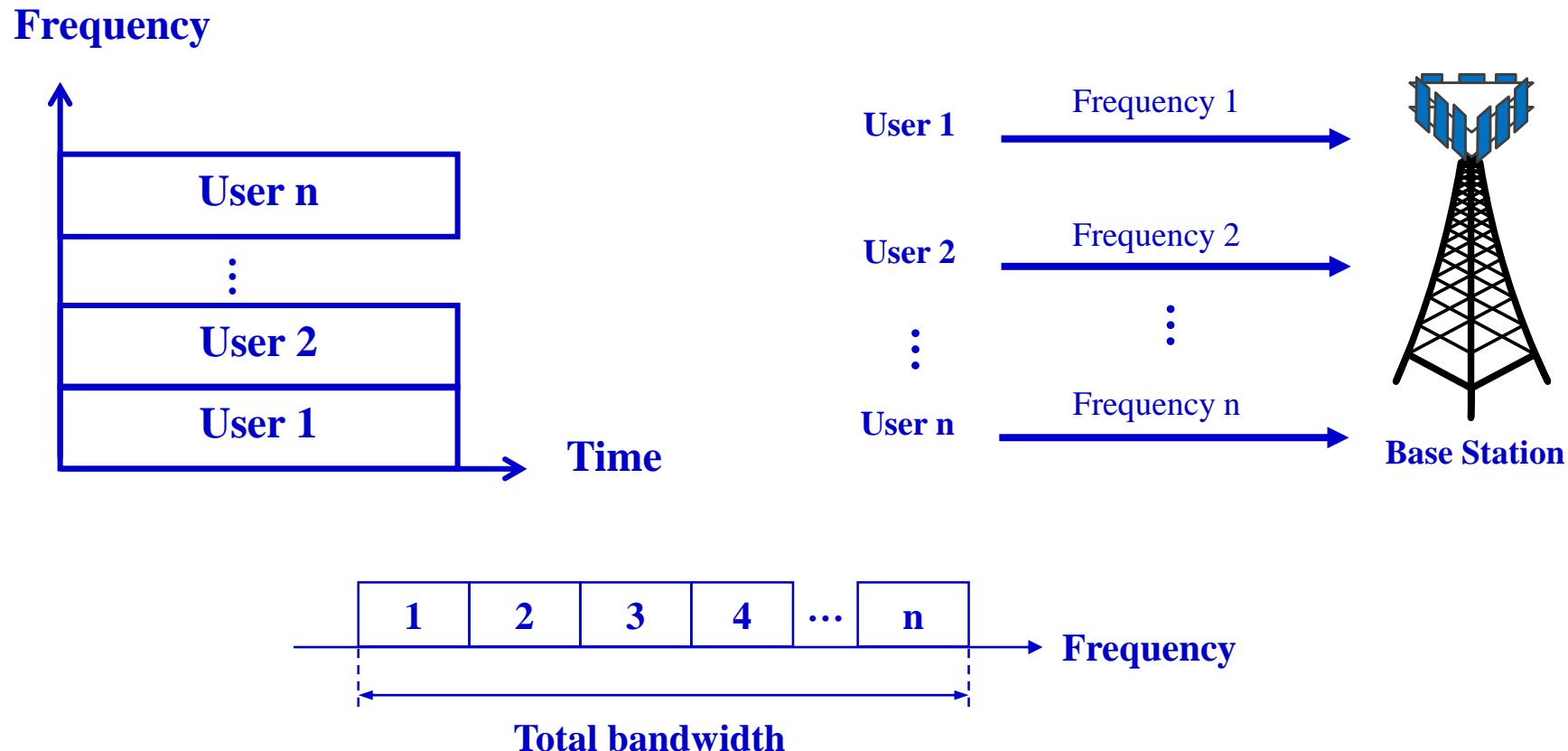


Cellular system: small cell size

Source : Introduction to Wireless & Mobile Systems (4th Ed.), Dharma Prakash Agrawal, CENGAGE Learning

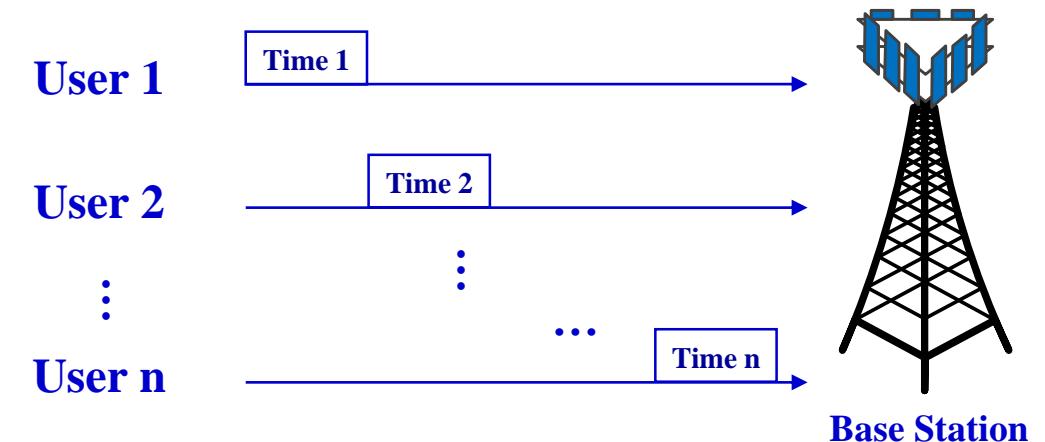
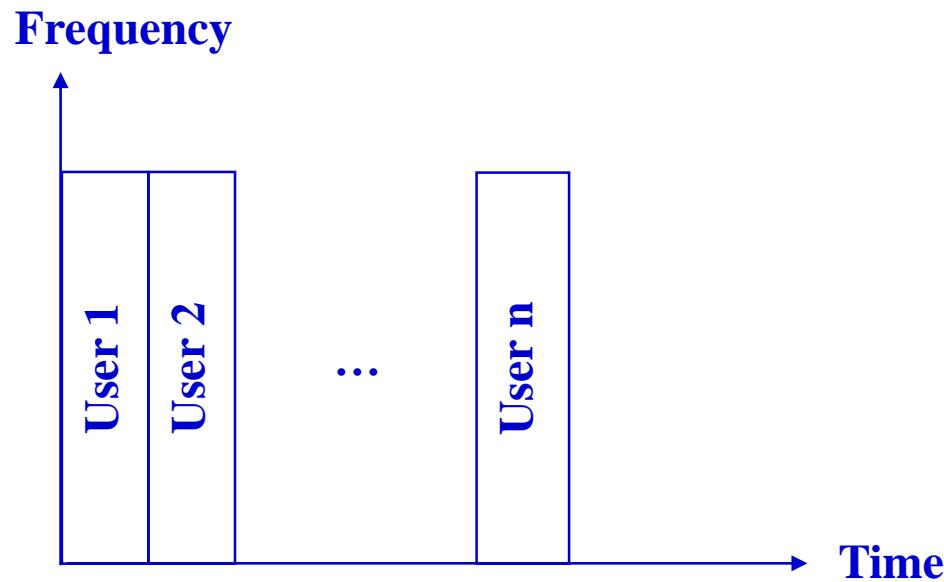
Freq. Division Multiple Access (FDMA)

- In FDMA, the allocated frequency band is divided into a number of subbands, called **channels**, and one channel is allocated by the BS to each user.



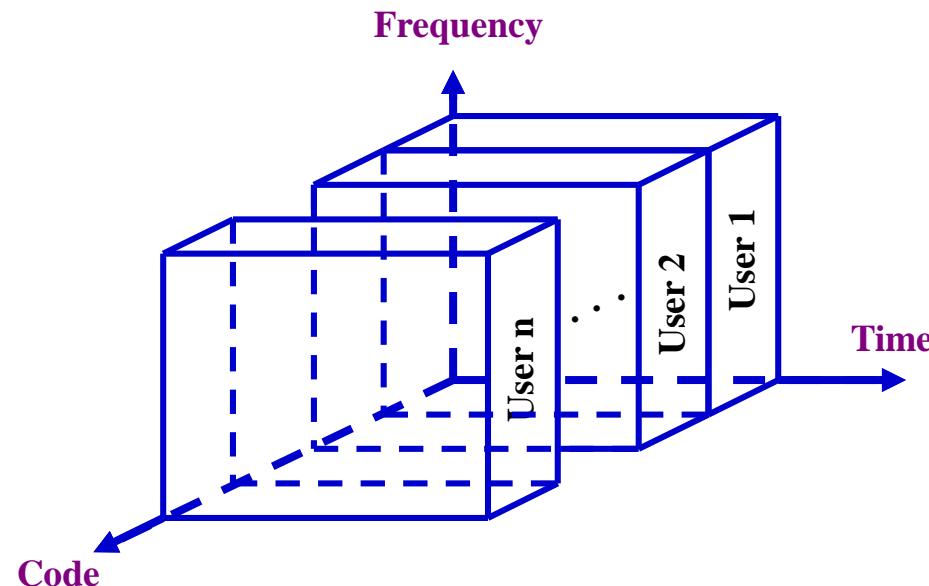
Time Division Multiple Access (TDMA)

- In TDMA, **one channel is used by several users**, with BS assigning time slots for different users, and each user is served in a round-robin method.
- GSM is based on TDMA



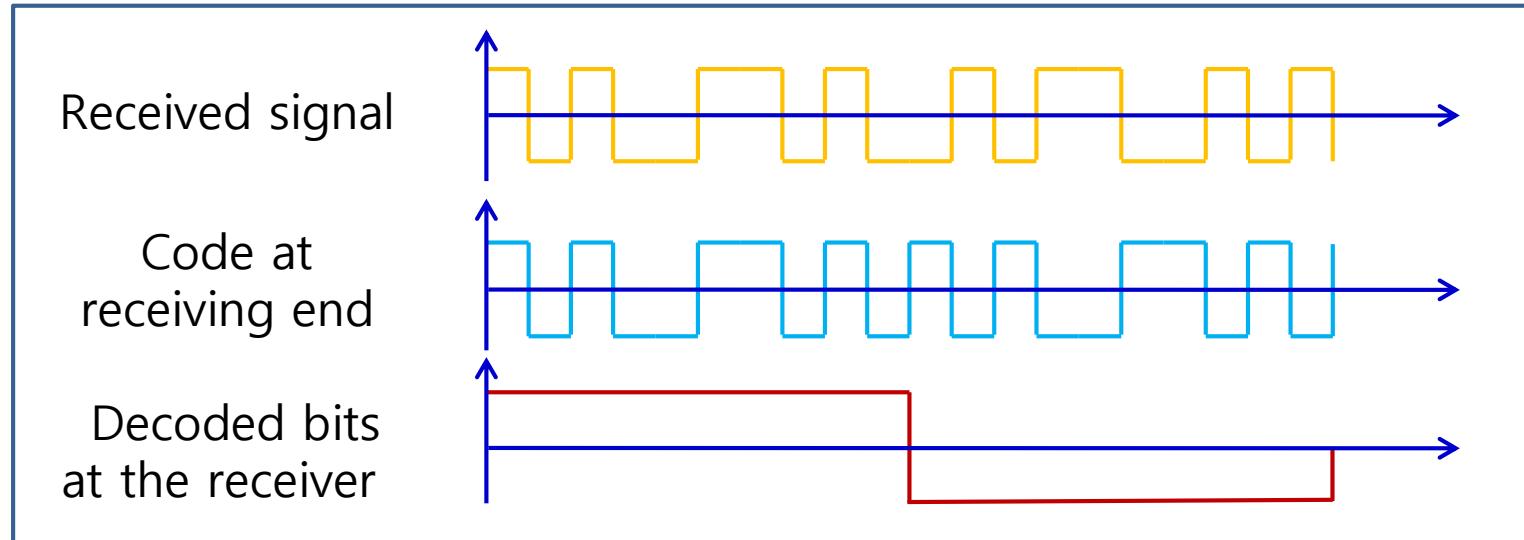
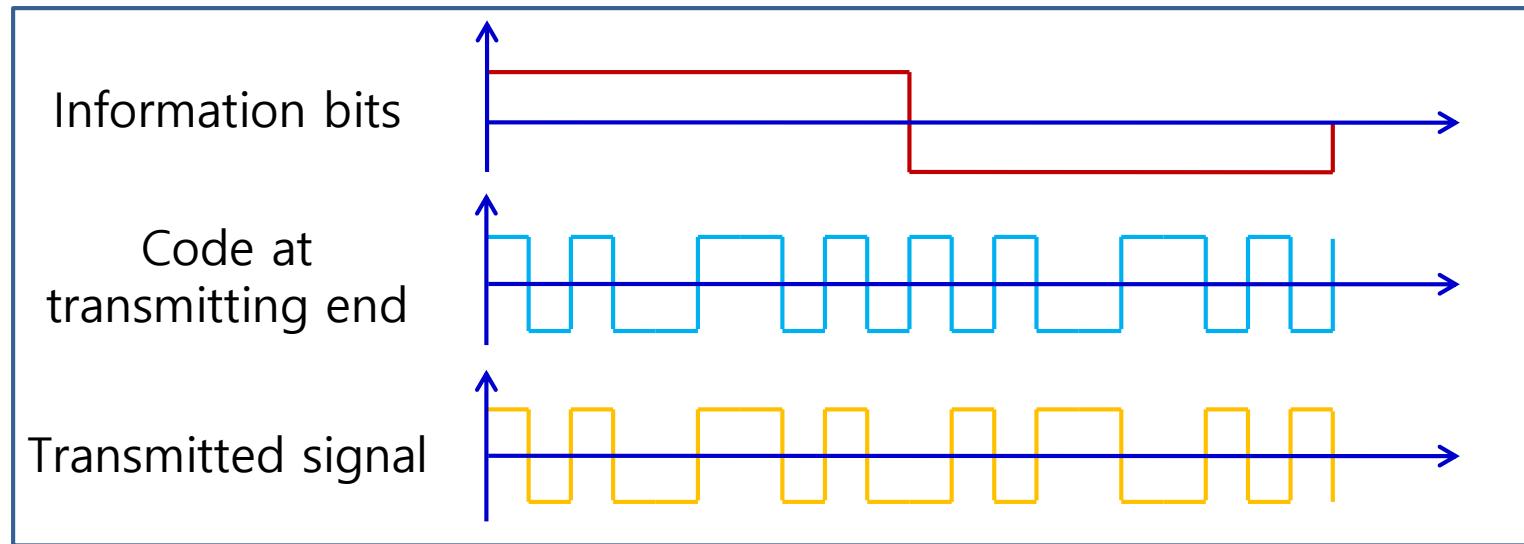
Code Division Multiple Access (CDMA)

- In CDMA, **one unique code** is assigned by the BS to each user and distinct codes are used for different users.
 - This code is employed by a user to mix with each bit of information before it is transmitted.
 - The same code is used to decode these encoded bits, and any variation of the code interprets the received information simply as noise.



Source : Introduction to Wireless & Mobile Systems (4th Ed.), Dharma Prakash Agrawal, CENGAGE Learning

Transmitted and Received Code in a CDMA System

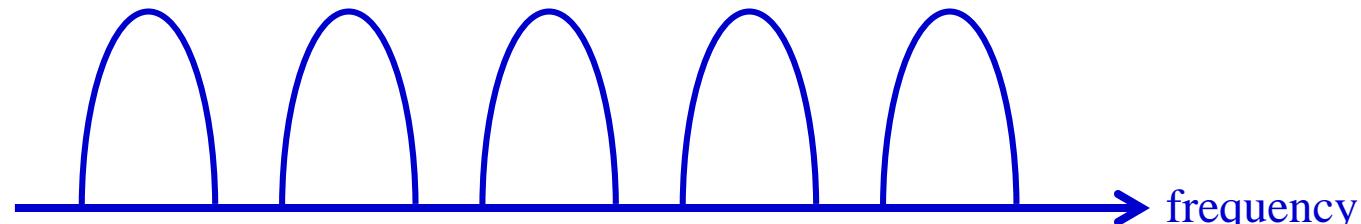


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OFDMA (Orthogonal Frequency Division Multiple Access)



- OFDMA is different from FDMA systems.
 - OFDMA is a multiple access scheme based on **OFDM**(Orthogonal Freq. Division Multiplexing)
 - OFDM is a broadband multicarrier modulation method that offers superior performance and benefits over traditional single-carrier modulation methods.



Conventional multicarrier modulation used in FDMA



Orthogonal multicarrier modulation used in OFDMA

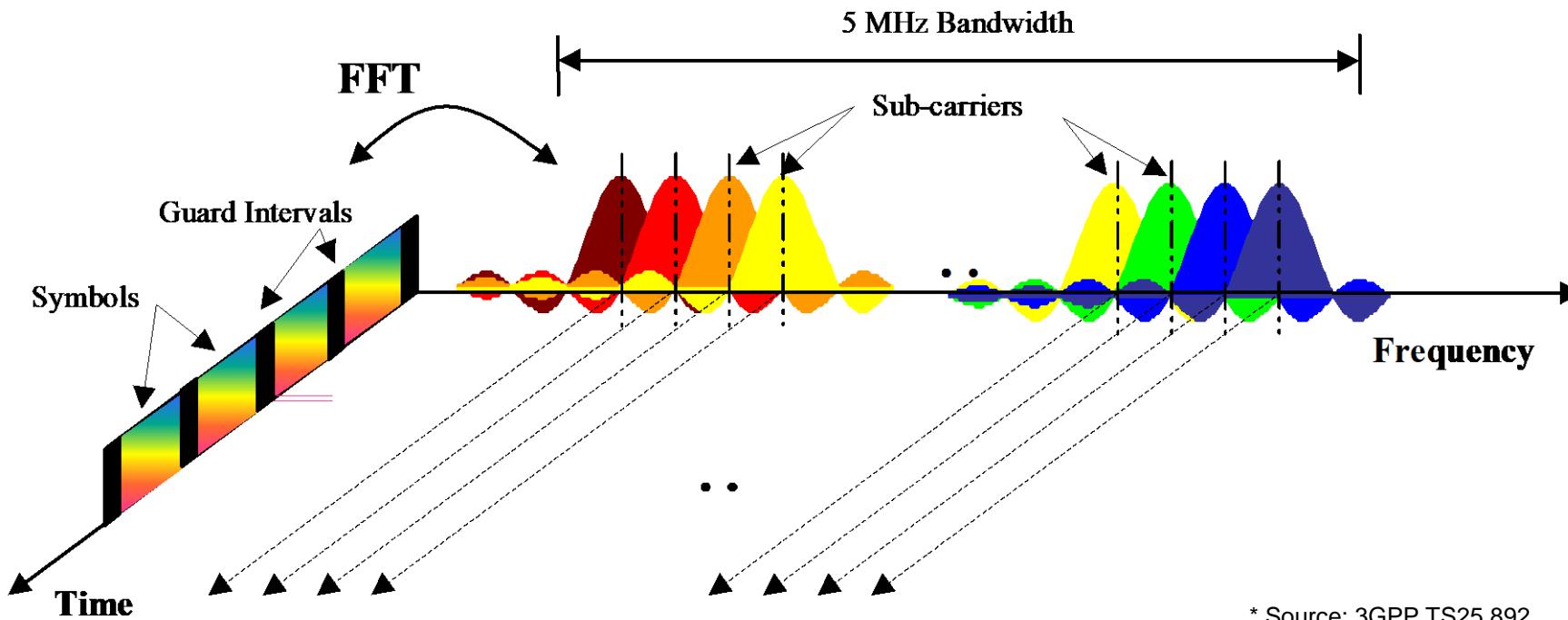
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OFDM (Orthogonal Frequency Division Multiplexing)

- Recently introduced
- Allowing parallel data transmission using multiple frequency channels
- In radio communications, reflection and diffractions cause the transmitted signal to arrive at the receiver traversing different path lengths.
⇒ ISI (Inter-Symbol Interference)
 - Since there are many objects such as buildings, automobiles, trees, etc., which can serve as obstacles, the radio signals are affected and scattered throughout the area.
- OFDM can decrease ISI
 - Converts a high-speed data stream to slow transmission of parallel bit streams and employing several channels
- OFDM provides super quality signals with decreased ISI.

OFDMA (Orthogonal Frequency Division Multiple Access)

- OFDMA (Orthogonal Frequency Division Multiple Access)
 - Using 2-dimensional resources in time & frequency domain
 - Scheduling by considering channel conditions and QoS of each user

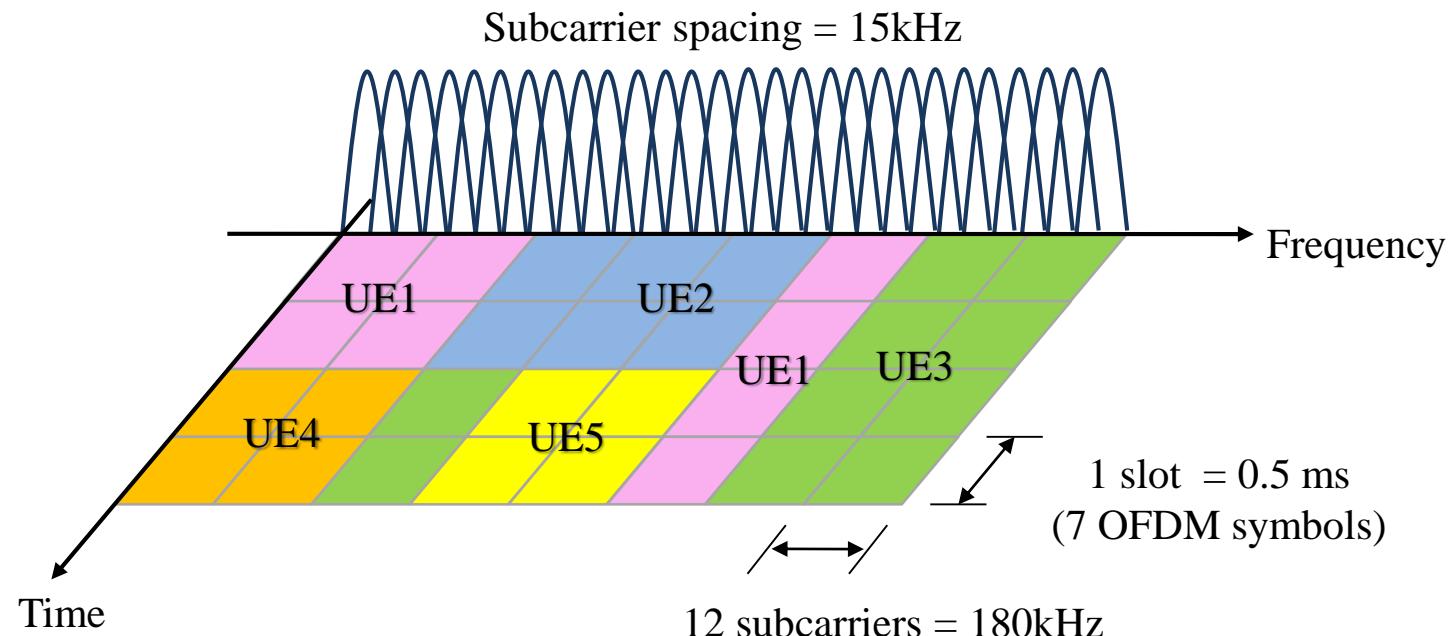


OFDMA (Orthogonal Frequency Division Multiple Access)



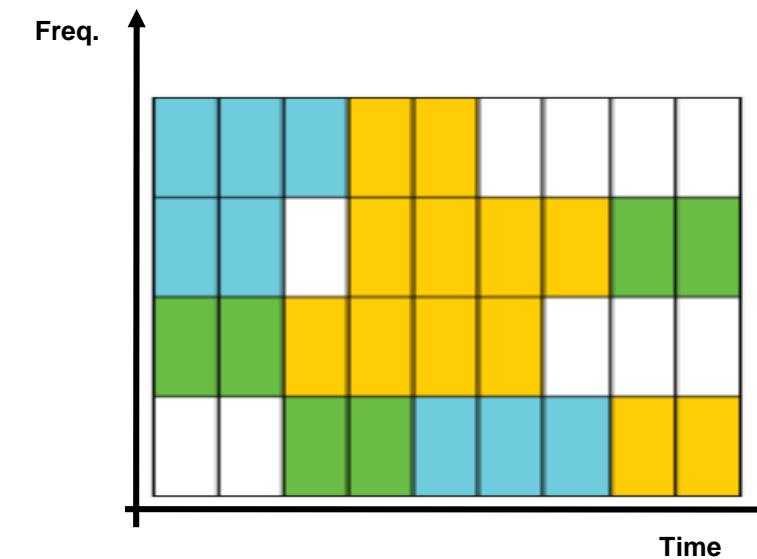
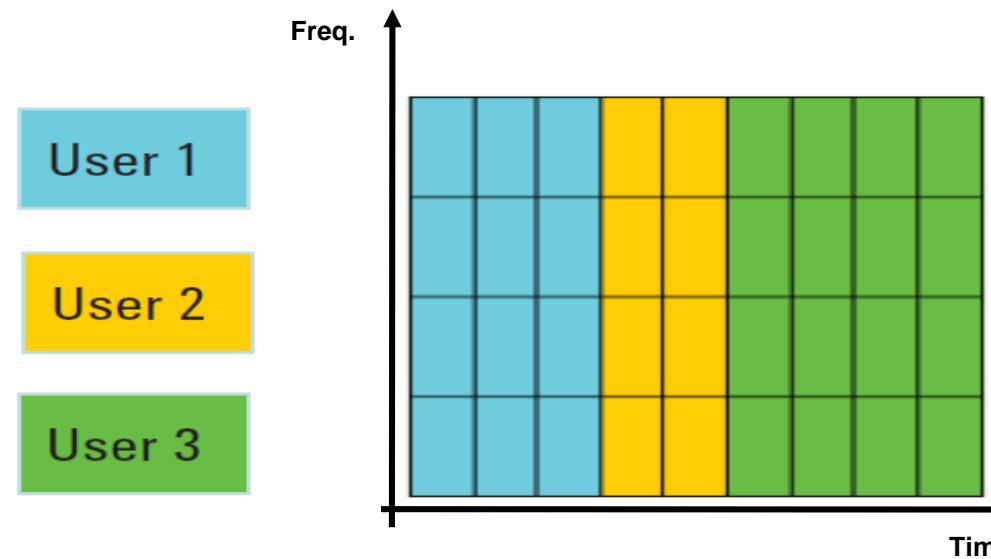
■ OFDMA in LTE

- Resource Block (RB) : the minimum unit of resource allocation
 - 0.5 ms x 180 kHz (12 subcarriers)
 - Uses RB pair (1 ms) for real scheduling



OFDMA (Orthogonal Frequency Division Multiple Access)

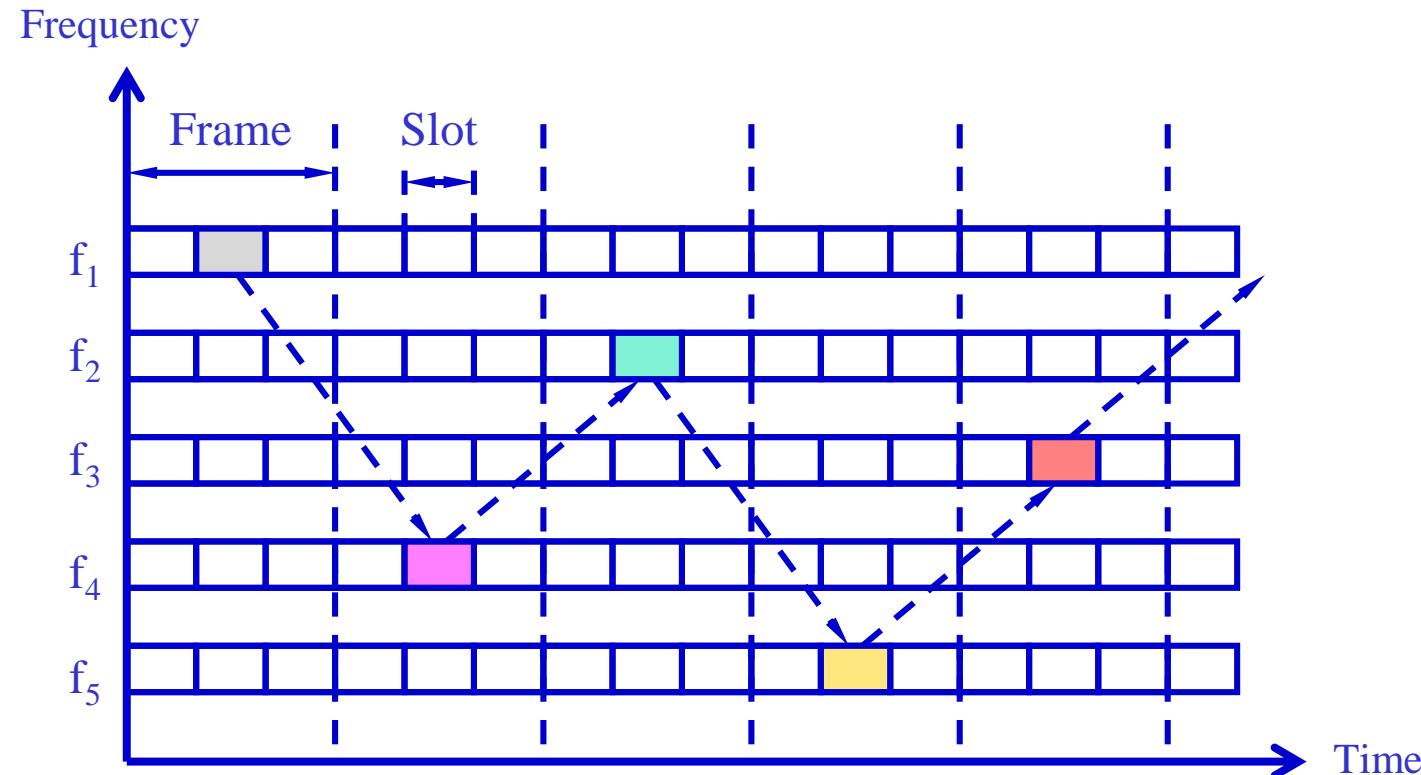
- For supporting multiple users simultaneously, a strictly OFDM system must employ TDMA or FDMA.
 - In order to accommodate multiple users efficiently, OFDMA is proposed.
- OFDM vs. OFDMA



- OFDMA
 - Allows multiple users to access the same channel at the same time.
- Current WLAN such as IEEE802.11a/g/n and IEEE802.16d (fixed service) are based on OFDM
- WiMAX(IEEE802.16e), **LTE**, **5G** uses OFDMA.

Frequency Hopping (FH) Systems

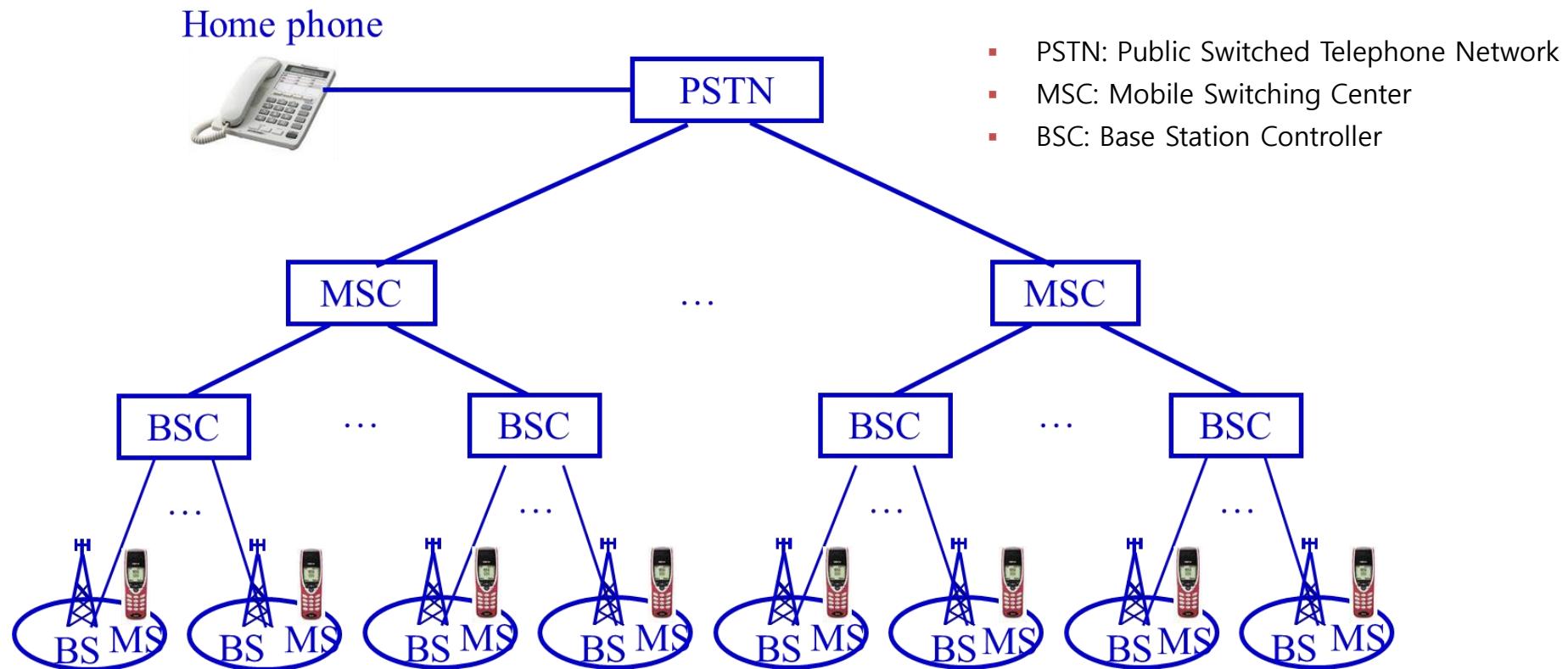
- For multiple users, different frequency hopping sequences (or patterns) can be used for transmitting information.
- Primarily introduced for defense (or military) purposes in the case of "jamming" effect.



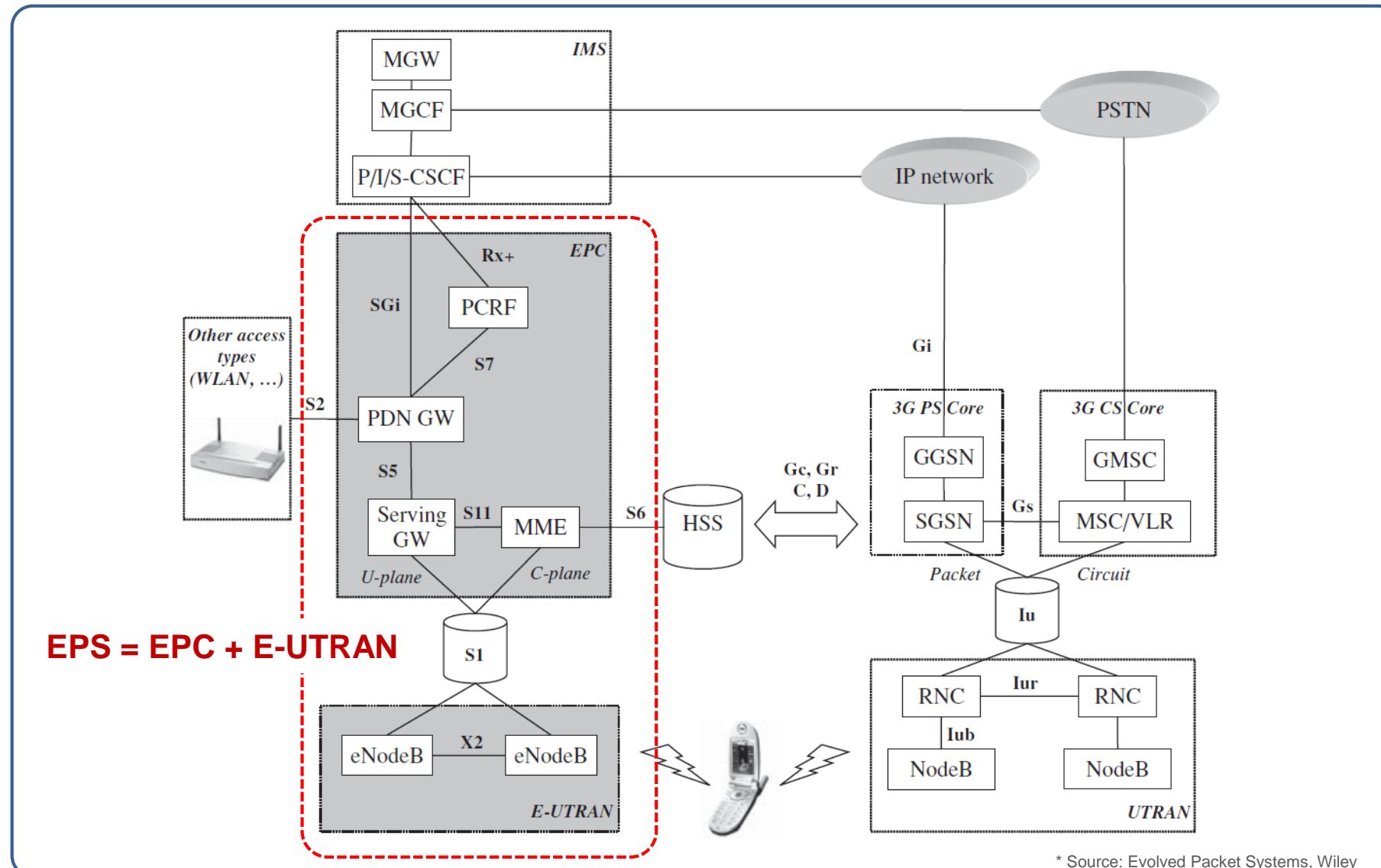
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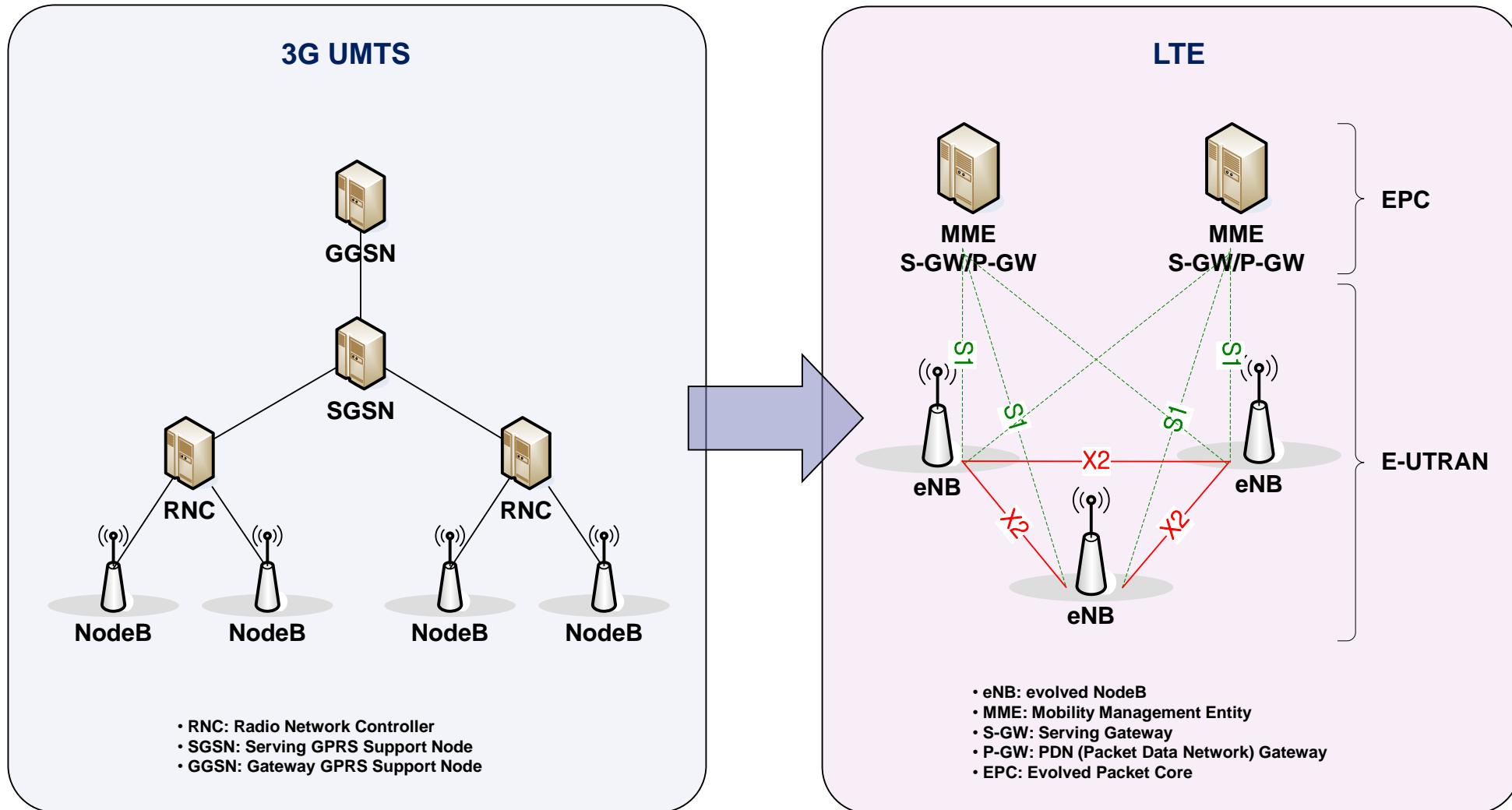
Cellular System Infrastructure

- 2G Cellular Systems (e.g. CDMA)
 - Circuit Switching (CS) Network



3G & 4G Network Architecture



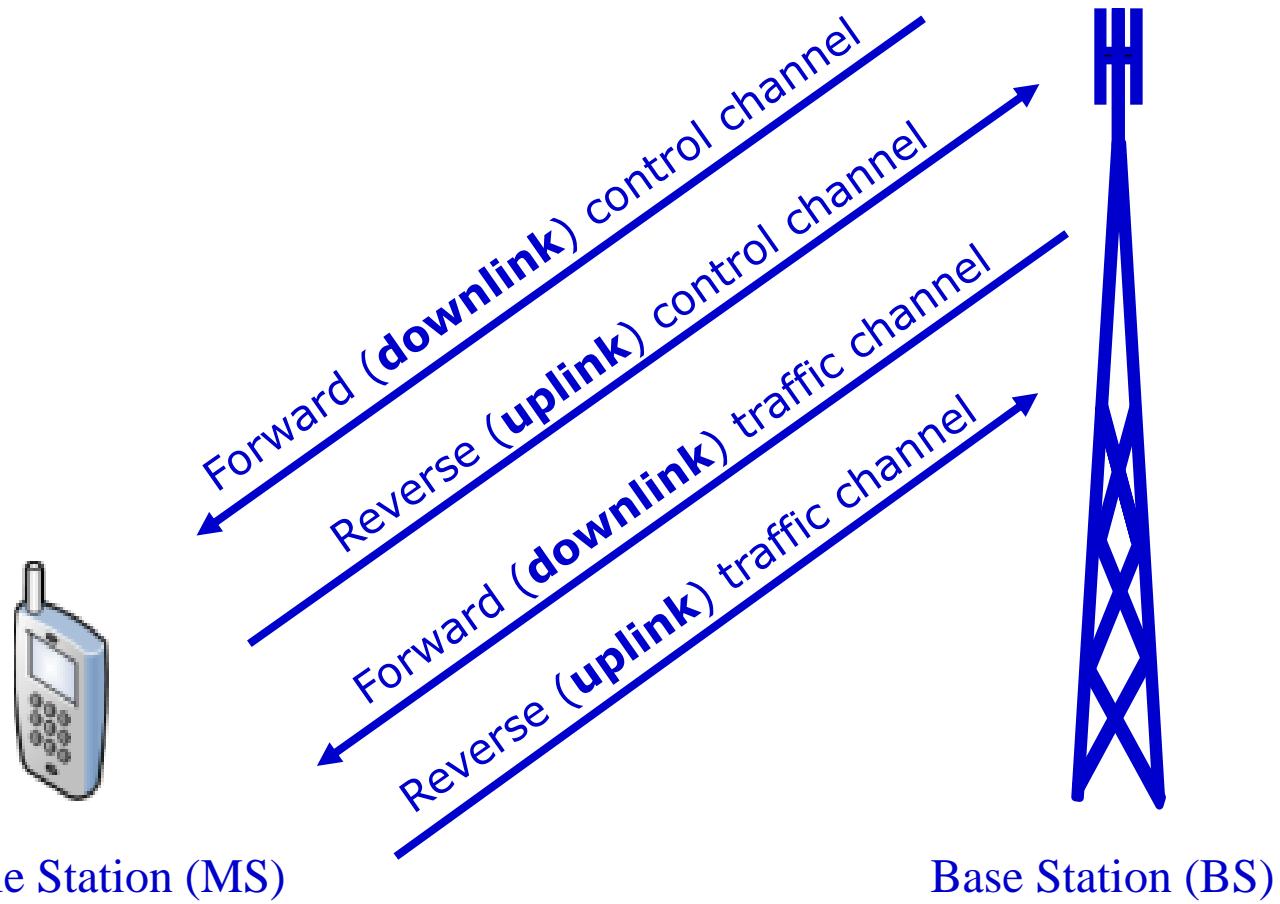


* Source: 3GPP TS 36.300

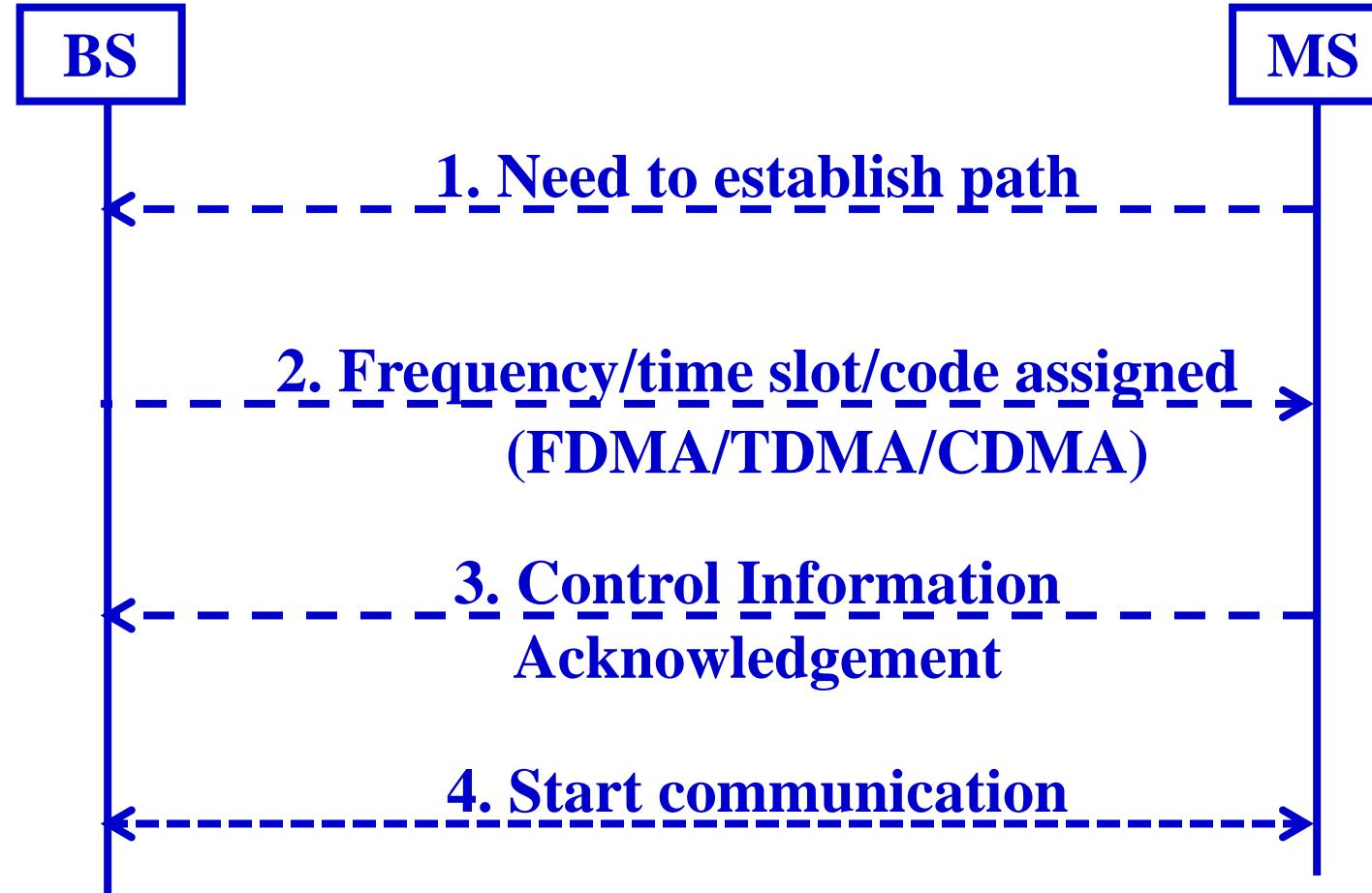
- Home Location Register (HLR) & Visitor Location Register (VLR)
 - Support mobility and enable the use of the same telephone number worldwide
 - HLR
 - Located at the MSC where the MS is registered and the initial home location for billing and access information is maintained.
 - Any incoming call, based on the called number, is directed to HLR of the home MSC and then HLR redirects the call to the MSC (and the BS) where the MS is currently located.
 - VLR
 - basically contains information about all visiting MSs in that particular MSC area.

Control Channel & Traffic Channel

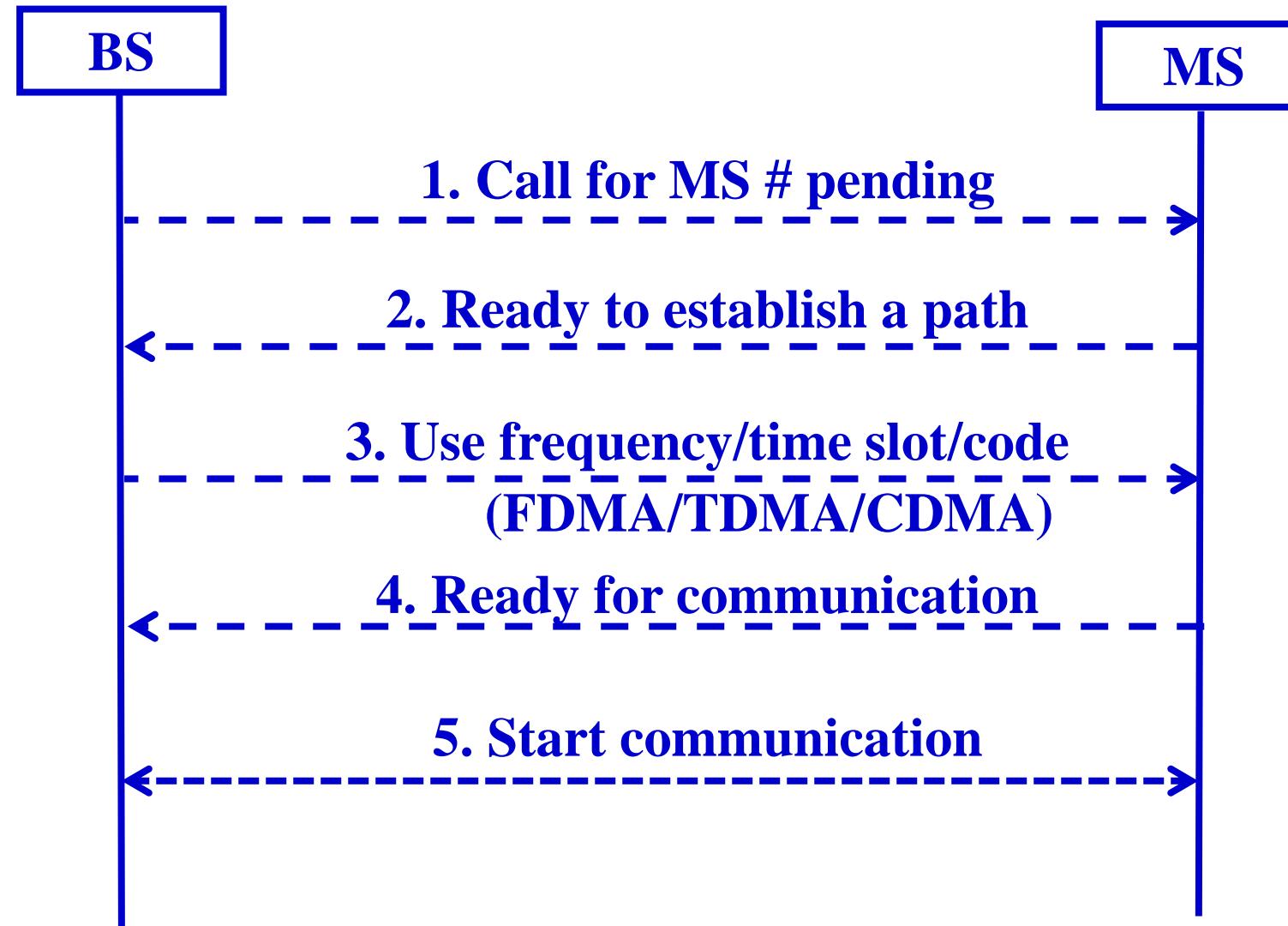
- Four Simplex Channels between BS and MS



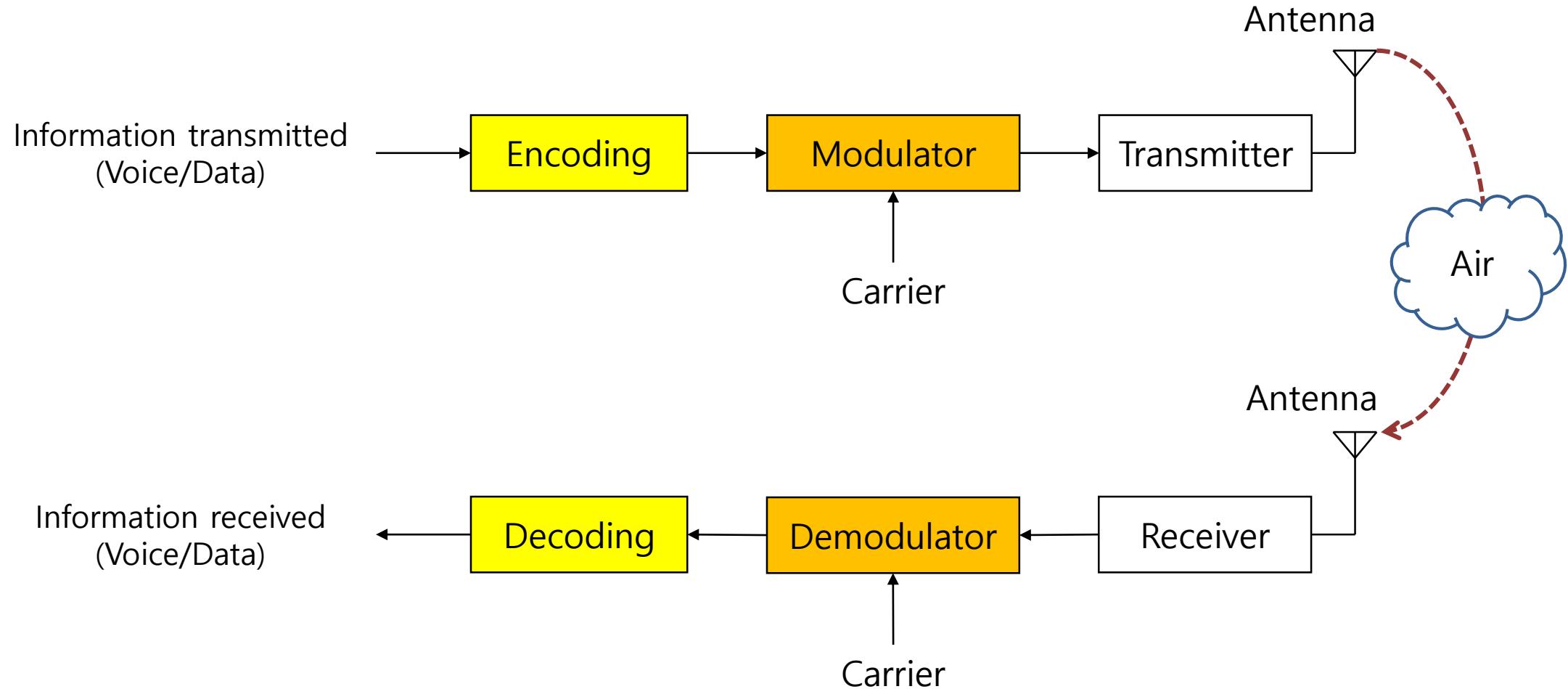
Steps for a Call Setup from MS to BS



Steps for a Call Setup from BS to MS



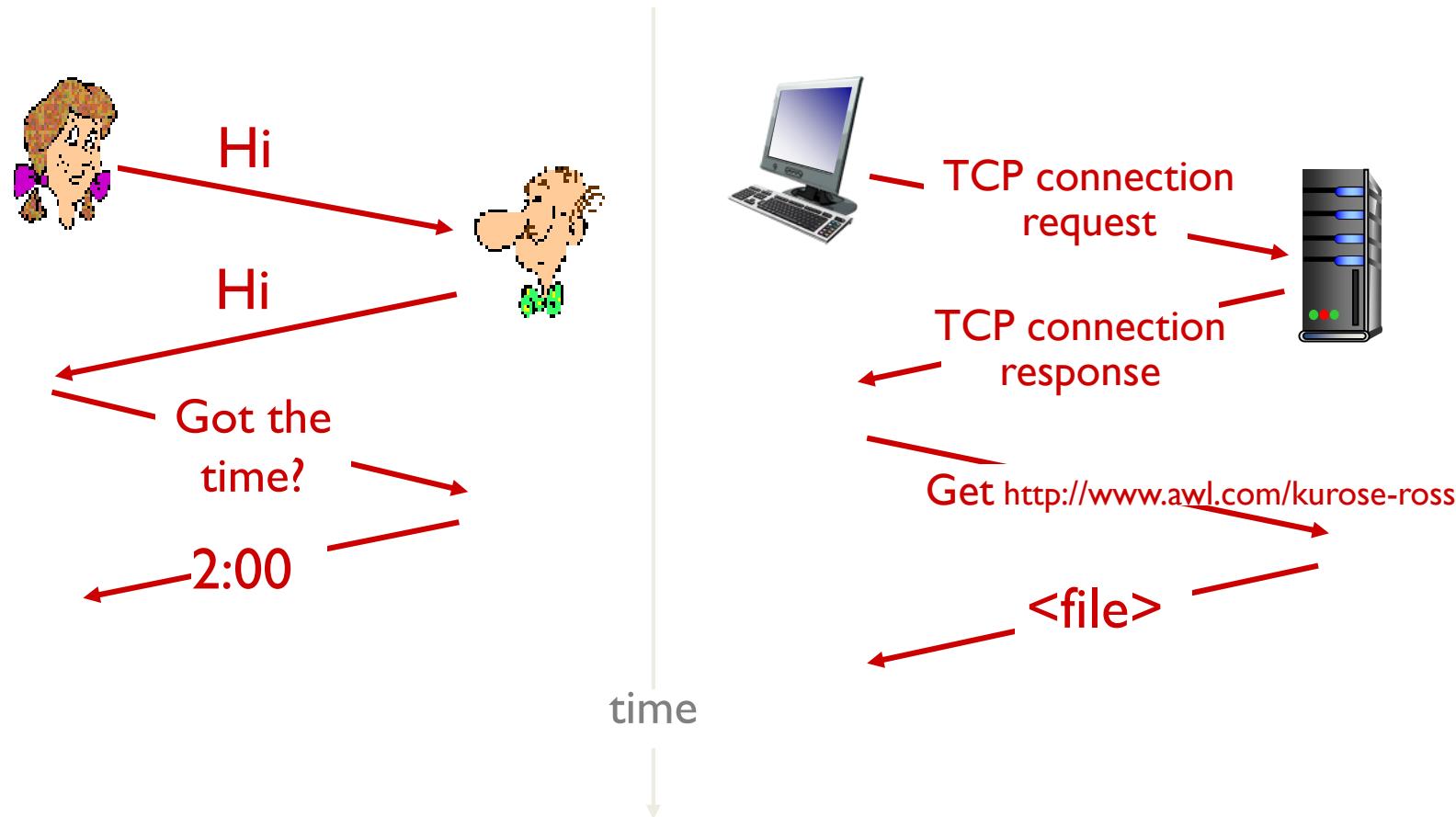
A Simplified Wireless Comm. System



- Satellite systems
 - Have been in use for several decades
 - Satellites, which are far away from the surface of the earth, can cover a wider area.
 - Only "Line of Sight (LOS)" communication is possible.
- Application Areas of Satellite Systems
 - Traditional Applications
 - Weather satellite
 - Radio and TV broadcasting
 - Military satellites
 - Navigation and localization (e.g. GPS)
 - Telecommunication Applications
 - Global telephone connections
 - Backbone for global networks
 - Global mobile communication

What is a protocol?

a human protocol and a computer network protocol:



Source : Computer Networking. A Top-down approach, James F. Kurose, Pearson International Edition

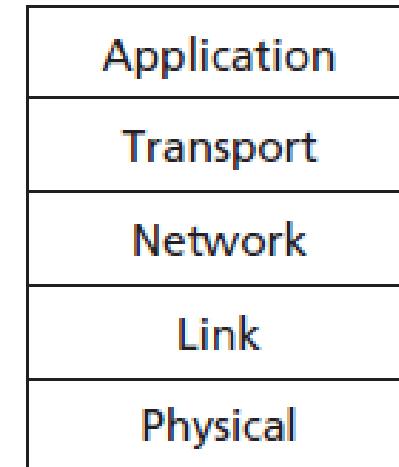
- Protocols?
 - A basic **set of rules** that are followed to provide systematic signaling steps for information exchange
- Open Systems Interconnections (OSI)
- Transmission Control Protocol (TCP)/IP
- Internet Protocol (IP)
 - Internet Protocol Version 4 (IPv4)
 - Internet Protocol Version 6 (IPv6)
 - Mobile IP

■ Protocol Stack

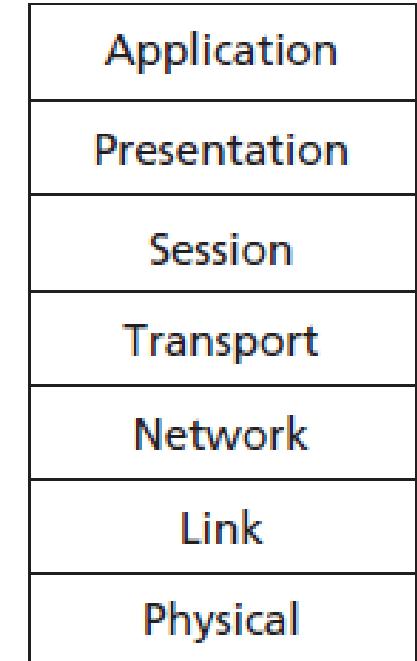
- The protocols of the various layers

■ Implementation of protocol layers

- Software, hardware, or combination of SW and HW

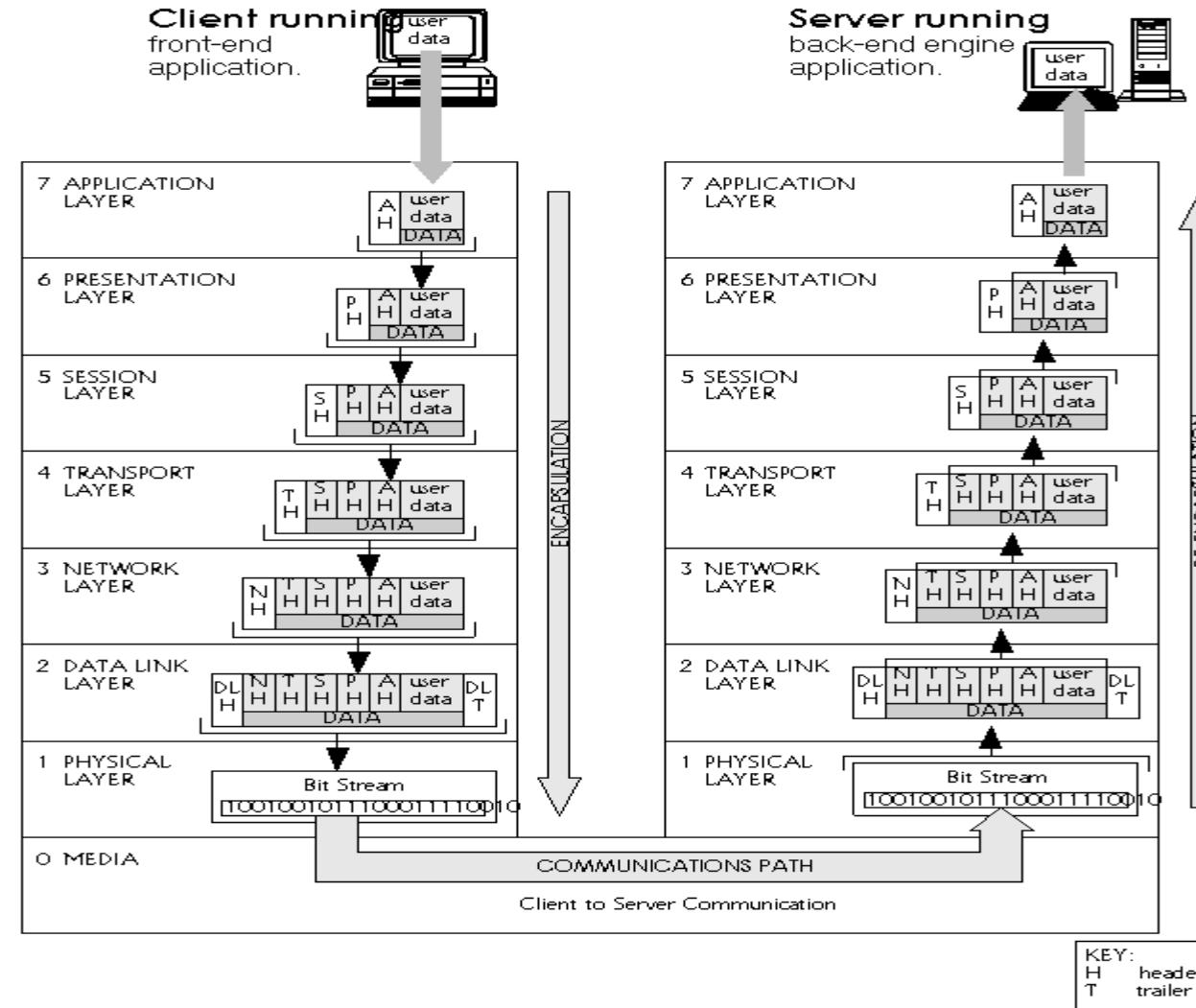


a. Five-layer
Internet
protocol stack



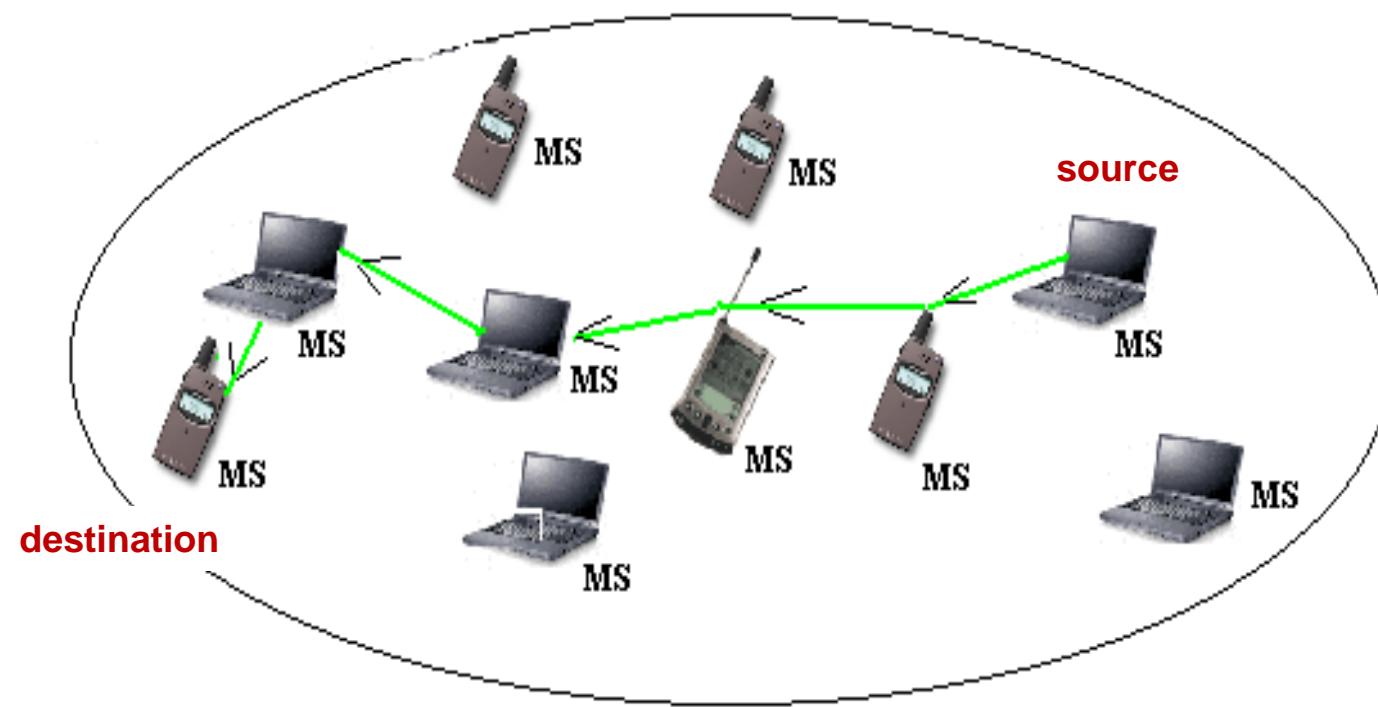
b. Seven-layer
ISO OSI
reference model

OSI 7 Layers



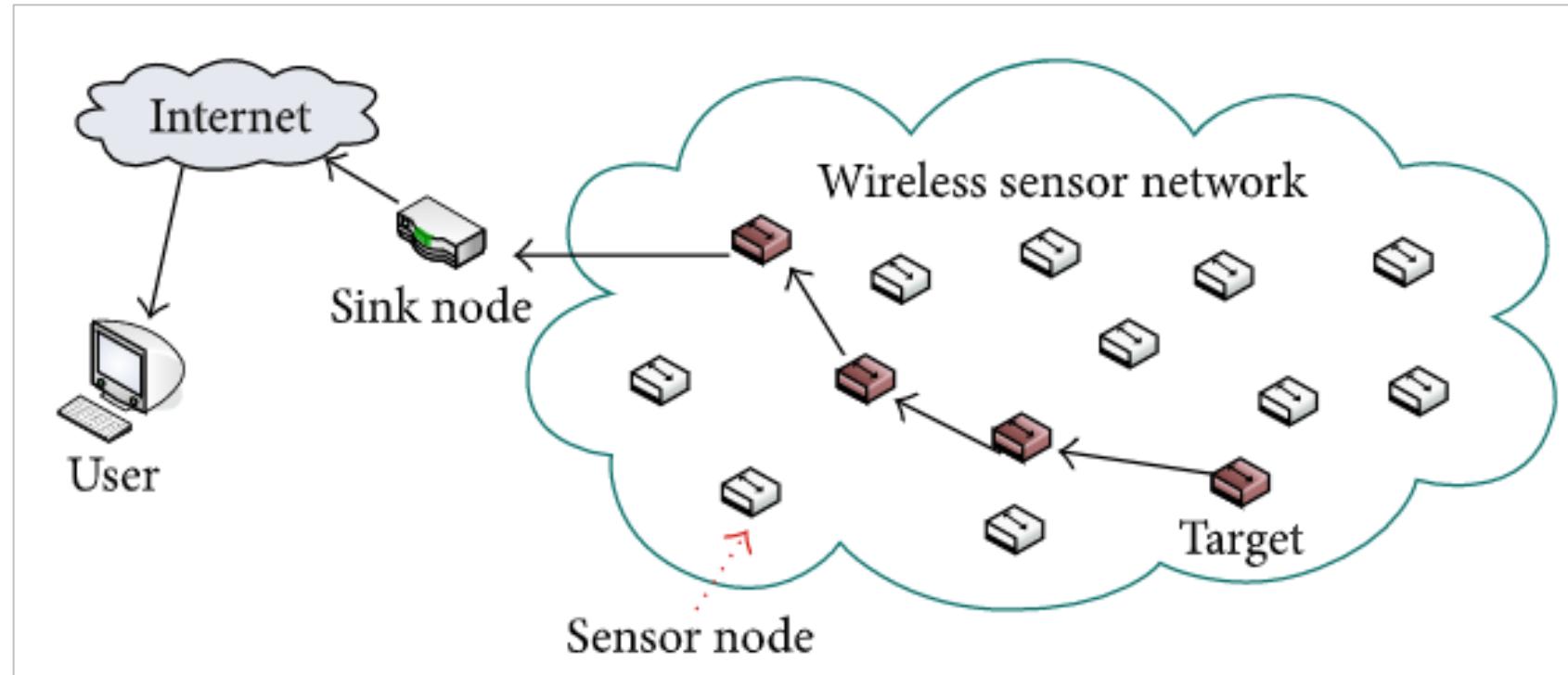
- Also written **ad-hoc** or **adhoc network**
 - A local network with wireless or temporary plug-in connection, in which mobile or portable devices are part of the network only while they are in close proximity.
- A Mobile Adhoc Network (MANET)
 - An autonomous system of mobile nodes, mobile hosts, or MSs (also serving as routers) connected by wireless links.
 - The routers are free to move at any speed in any direction and organize themselves randomly.
⇒ The network's wireless topology may dynamically change in an unpredictable manner.
(NO fixed infrastructure)
 - Information is forwarded in peer-to-peer (p2p) mode using multihop routing.

- MANET are basically peer-to-peer (p2p) multihop mobile wireless networks where information packets are transmitted in a store-and-forward method from source to destination, via intermediate nodes.



- Sensor Networks
 - Sensor networks are the newest members of one special class of wireless adhoc networks wherein a large number of tiny immobile sensors are planted on adhoc basis to sense and transmit some physical characteristics of the environment.
- Examples
 - Battlefield surveillance of enemy territory
 - A large number of sensors are dropped from an airplane so that activities on the ground can be detected and communicated.
 - Machinery prognosis
 - Bio-sensing
 - Environmental monitoring

- Wireless Sensor Network



Source: Journal of Sensors, 2015, "A Review on Sensor Network Issues and Robotics"

- Wireless LAN(Local Area Network)s
 - IEEE 802.11 a/b/g/n/ac/ad
- A special class of wireless local area and personal area networks (PAN) can cover smaller areas with low power transmission and have become increasingly important for both office and home.

Thank You !

