Invited Talk

4G Wireless Networks and Research Issues

Prof. Jenhui Chen, 陳仁暉 副教授
Tel: (03) 211-8800 Ext: 5990
Email: jhchen@mail.cgu.edu.tw
URL: http://www.csie.cgu.edu.tw/~jhchen

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Outline

The Evolution of Wireless Technologies

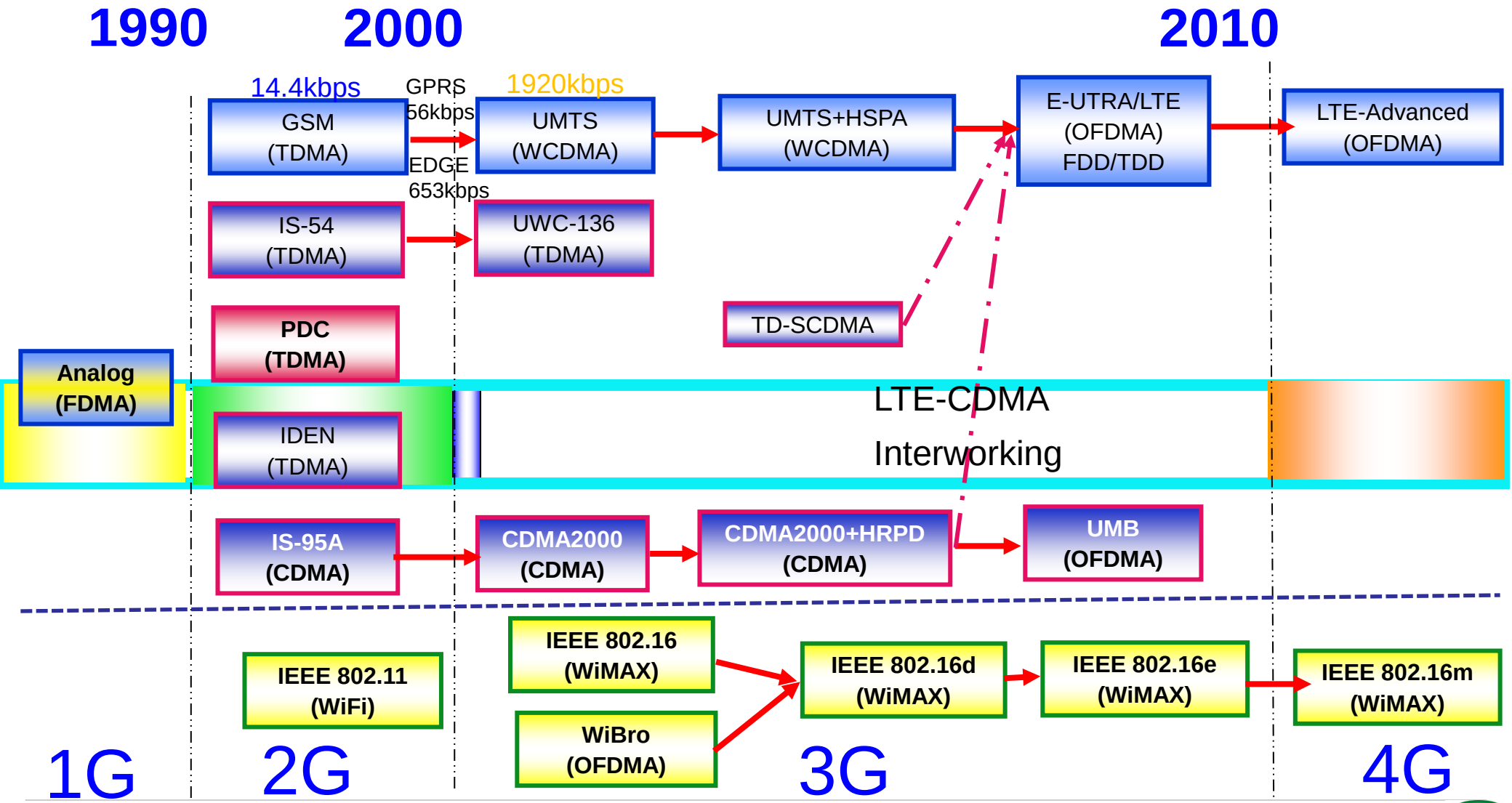
The history of telecommunication and its evolution

- 1G (Advanced Mobile Phone System, AMPS)
- 2G (Globe System for Mobile Communications, GSM), CDMA
- 2.5G (General Packet Radio System, GPRS)
- 2.75 (Enhanced Data rates for GSM Evolution, EDGE)
- 3G (IMT-2000): (UMTS (WCDMA), B3G (LTE, WiMAX)
- 4G (LTE-Advanced)

Data Communications

- 4G LTE-A

Wireless Technology Evolution



Group Special Mobile

GSM (2G)

A Framework for Studying Personal Communications Systems

Architecture

Air Interface Layers

– Sets of techniques for transferring information between base stations and terminals

Radio Transmission (layer 1)

– Modulation/source coding/channel coding/interleaving/diversity reception/channel equalization

– Spectrum efficiency

Logical Channels (layer 2)

– To address the fact that different information types have different requirements, system segregate the information into logical channels

- Control channel, traffic channel, and other

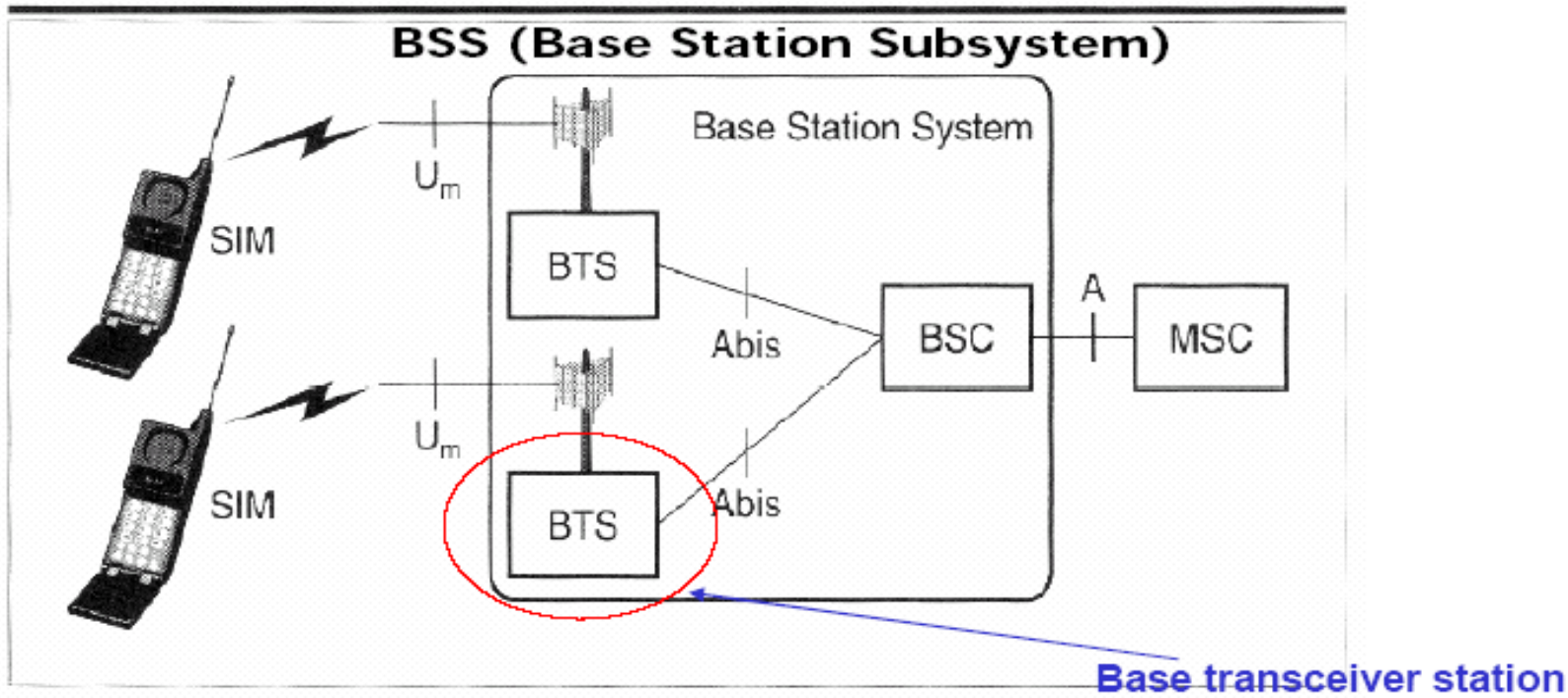
Messages (layer 3)

- Layer 3 sends messages to layer 2, which divides it into packets and adds its own information
- Structure indicate the nature of the information (Handoff vs. Power Control)

Network Operations

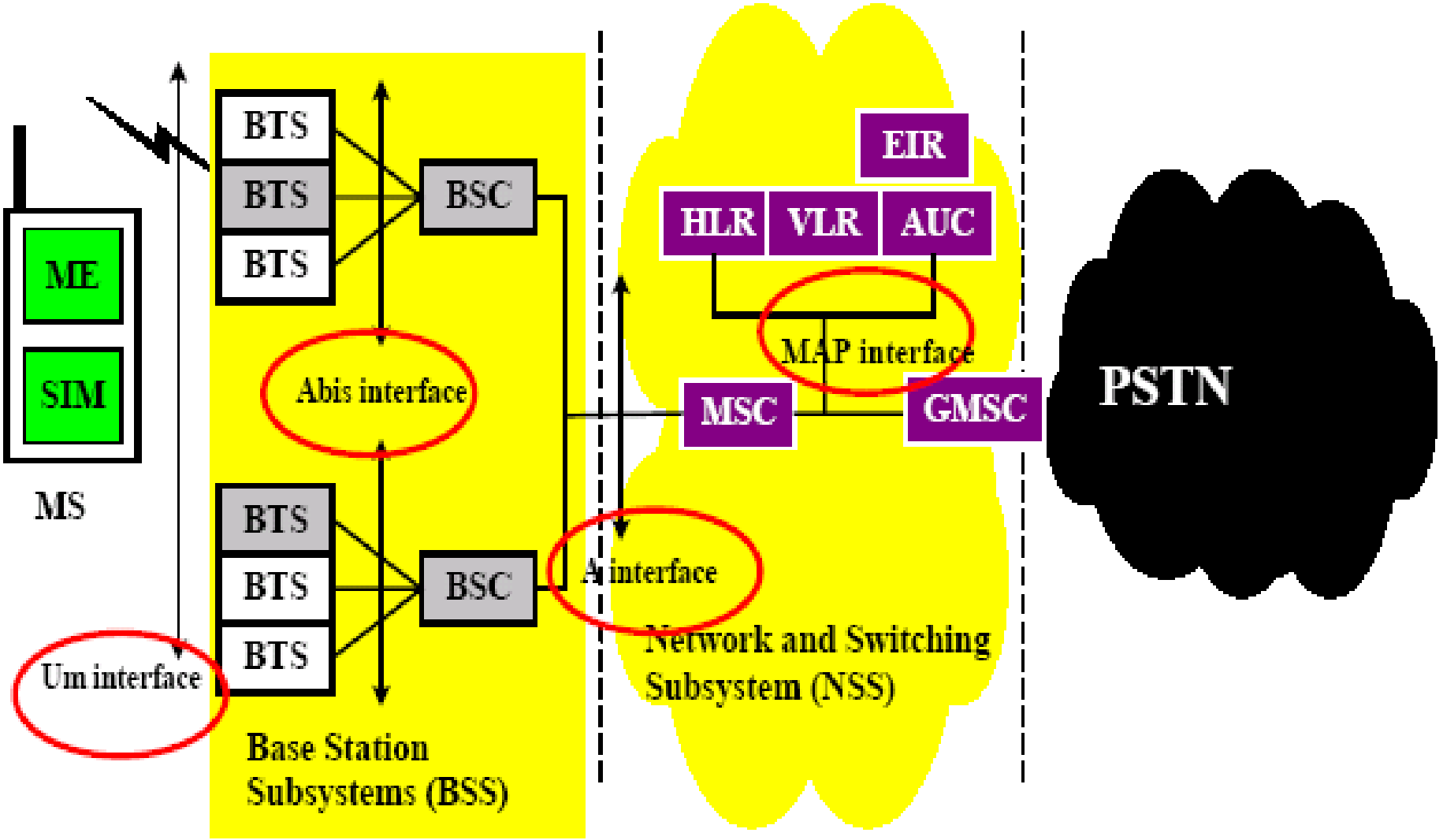
GSM Architecture II

BSS



BTS : Base Transceiver Station
BSC : Base Station Controller
MSC : Mobile Switch Center

GSM Network System Architecture



Base Station System (BSS)

- The Base Station System (BSS) connects the MS and NSS.
- BSS contains
  - Base transceiver station (BTS)
  - Base station controller (BSC)

Base Transceiver Station (BTS)

Base Transceiver Station (BTS) contains

- **Transmitter**
- **Receiver**
- **Signaling equipment specific to the radio interface in order to contact the MSs.**
- Transcoder/Rate Adapter Unit (TRAU)

▪ **GSM-specific speech encoding/decoding and rate adaptation in data transmission**

▪ PCM to/from GSM Speech coding

GSM Logical and Physical Channels

Um interface:

- **Between BTS and MS**
- **Various** logical channels **are mapped to** physical channels

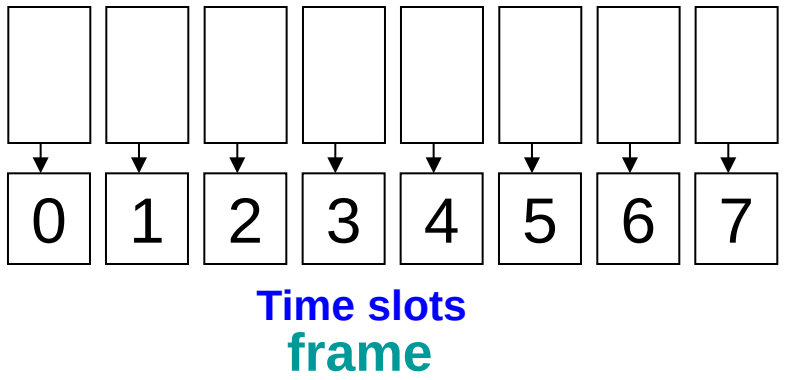
A physical channel is defined as timeslot

- **with timeslot number in a sequence of TDMA frames**

8 physical channels mapped onto 8 timeslots within TDMA frame per frequency carrier

logical channels

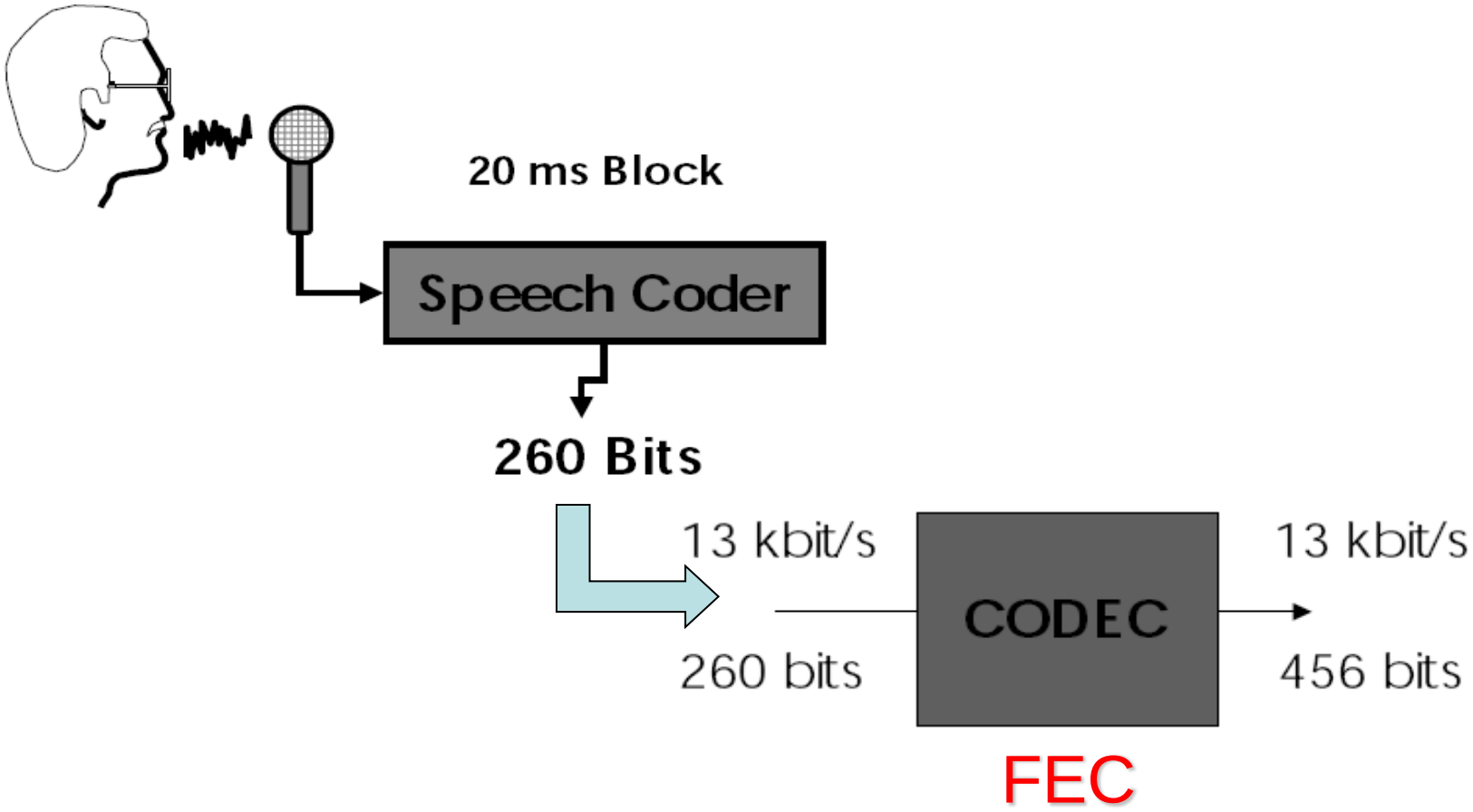
physical channels



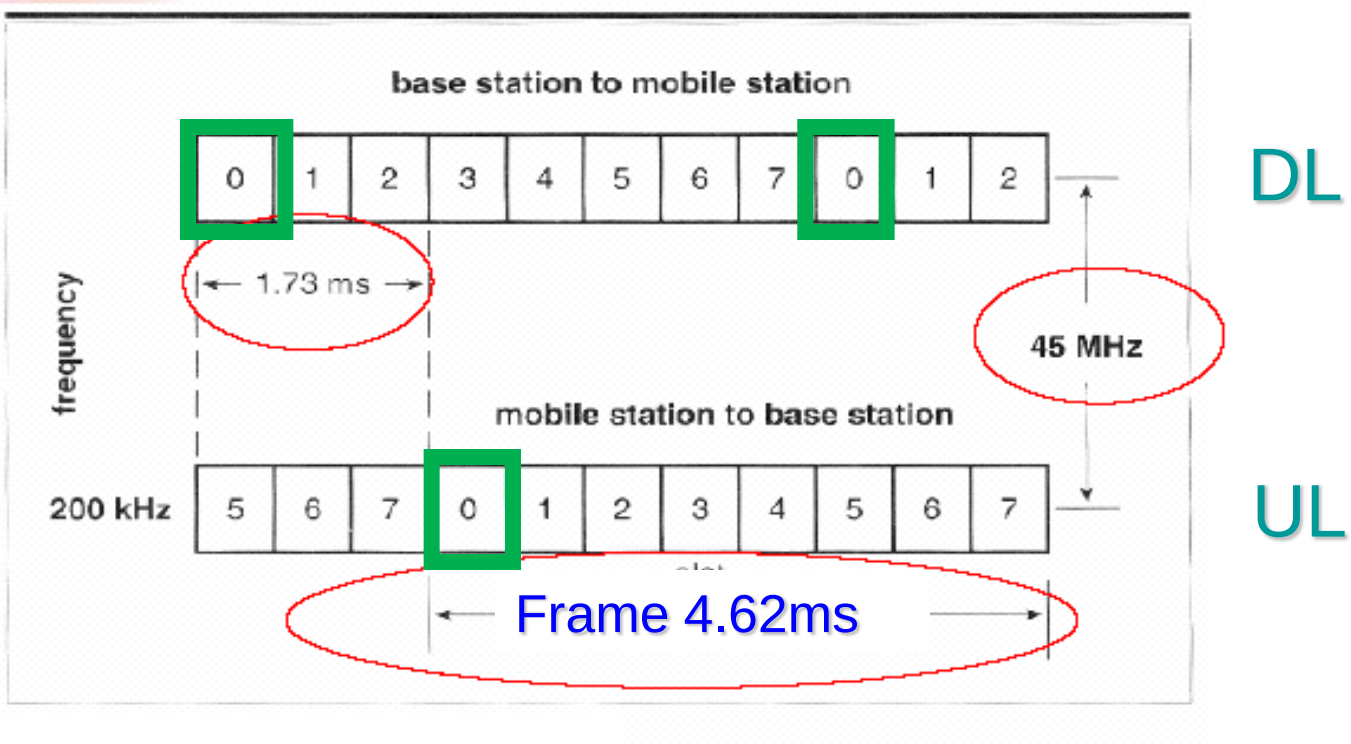
Speech Coder

Full data rate : 260bits/20ms = 13kbps

Half data rate : 130bits/20ms = 6.5kbps



Radio Transmission – Physical Channels



125 carriers per direction = 25 MHz / 200 kHz

Control channel (DL BCH and UL RACH)

General Packet Radio Service

GPRS (2.5G)

GSM System Disadvantages

Voice Communication

Using Short Message Service (SMS) to transmit data

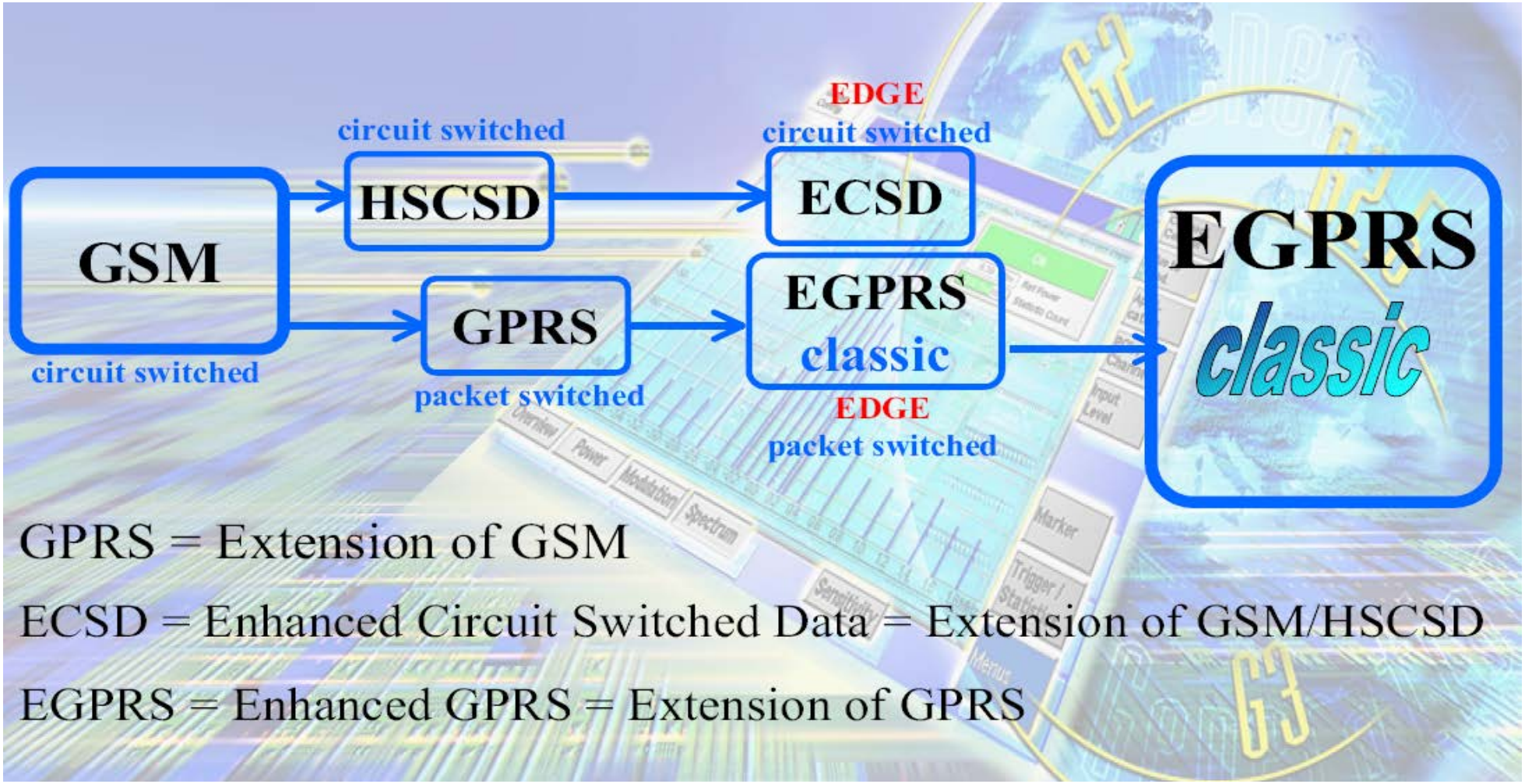
Using Circuit-Switch

- **The HSCSD (High-Speed Circuit-Switched Data) can achieve high speed by allocating multiple slots but fail to efficiently handle bursty data applications such as Web browsing.**

Disadvantages:

- **The transmit speed is too slow (9.6 Kbps or 14.4 Kbps)**
- **No support of multimedia data: audio and video**
- **Low efficiency for bandwidth**
- **Too expensive to support multimedia services**

Evolution from GSM



Technologies (2.5G)

Technology	Mode of Data Transfer	Modulation	Bundling of Timeslots
GSM	Circuit Switched	GMSK	1 Timeslot
HSCSD	Circuit Switched	GMSK	Up to 8
GPRS	Packet Switched	GMSK	Up to 8
ECSD	Circuit Switched	GMSK + 8PSK	Up to 8
EGPRS	Packet Switched	GMSK + 8PSK	Up to 8

- **The modulation type that is used in GSM is the Gaussian minimum shift keying (GMSK).**
  - In GSMK, every symbol that is transmitted represents one bit: that is, each shift in the phase represents one bit.

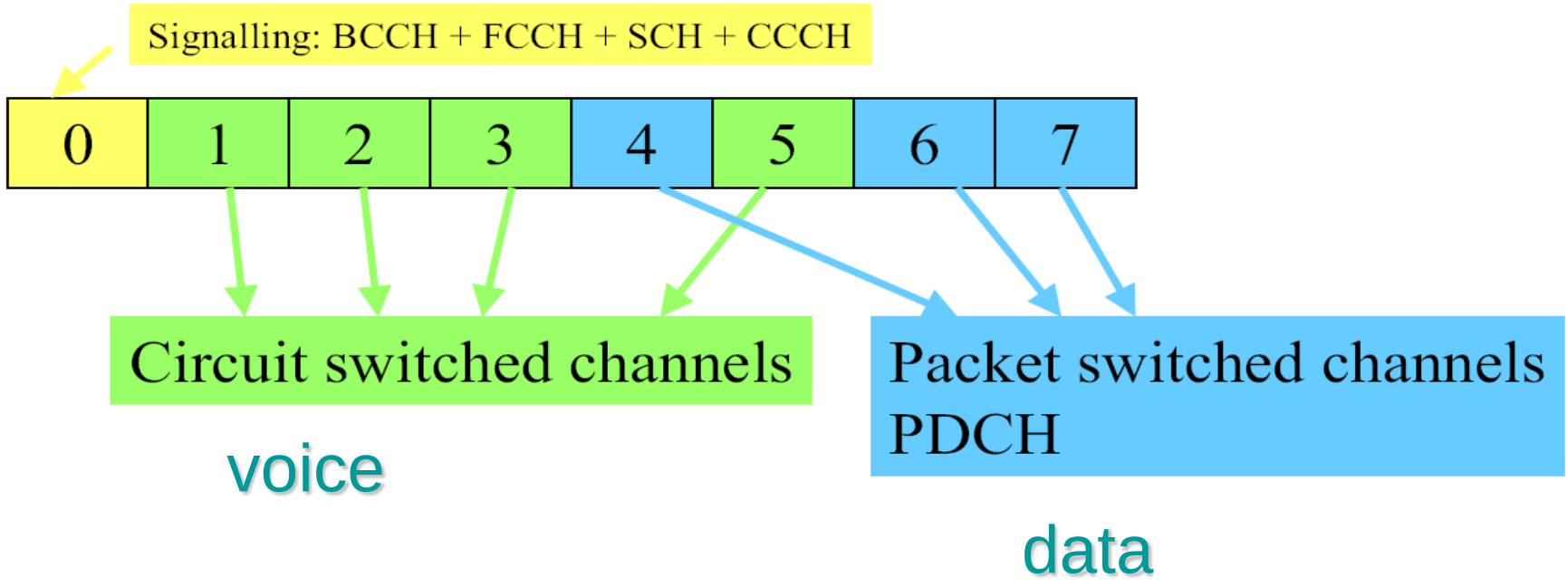
GPRS (General Packet Radio Service)

- **Starting from 1994, ETSI (European Telecommunications Standard Institute) initiates the GPRS work**
- **A packet-switched protocol**
- **A new infrastructure is introduced to GPRS for the packet services.**

GPRS

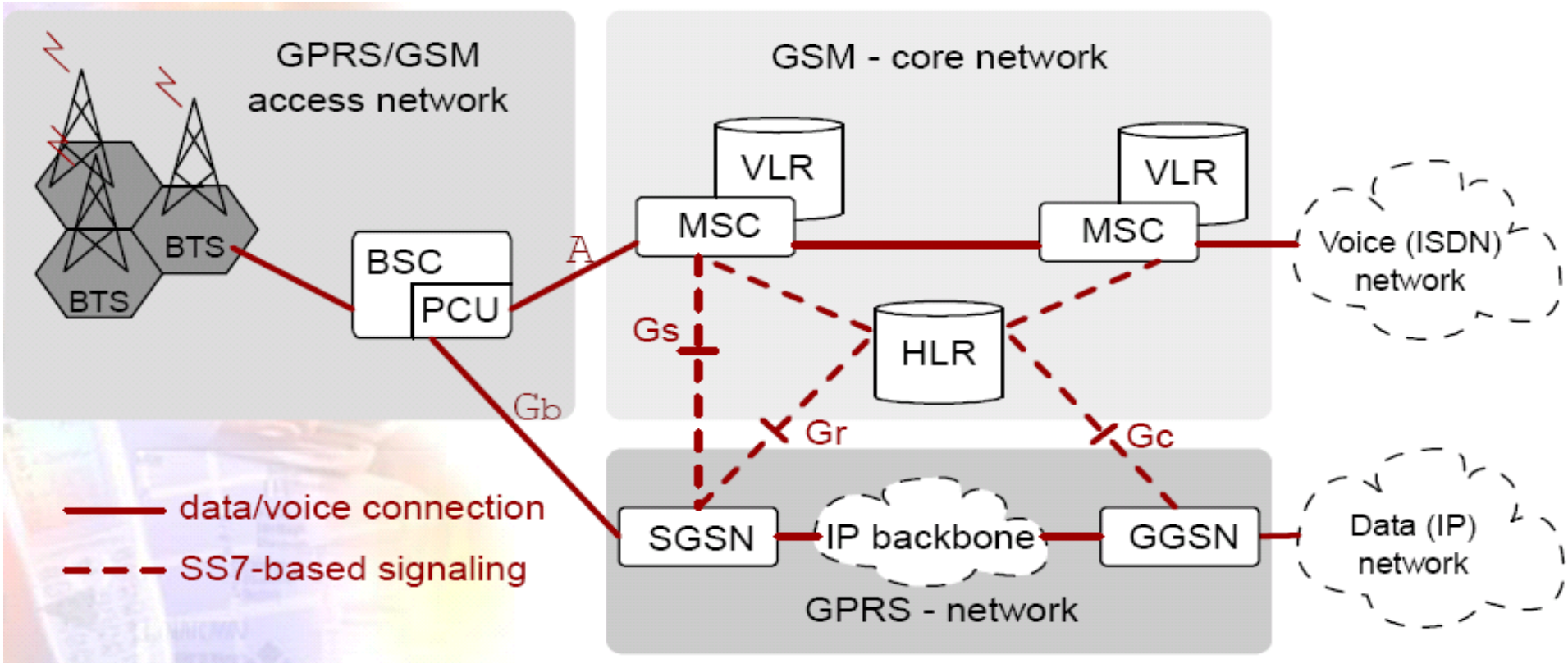
- **Packet overlay of existing GSM (Digital) circuit switched voice-based network**
- **Using packet-switching and is more suitable for bursty traffic**
  - **TCP/IP-based**
    - **Allows data packets to be conveyed across the mobile network using packet switching**
- **"Always on" / "always connected"**
  - **After initial 'log-on', user is permanently connected to IP services**
- **New concept – bandwidth on demand**
  - **Network resources only used when information ready**
  - **More efficient utilization of air-time**

Bandwidth on Demand



New PDCH : Packet Data Channel

GSM/GPRS System Architecture



PCU: Packet Control Unit

BTS: Base Station Subsystem

Enhanced Data for GSM Evolution

EDGE (2.75G)

Overview

EDGE is a further development of GSM data service HSCSD and GPRS.

- **Enhanced Circuit-Switched Data (ECSD) is the circuit-switched,**
- **Enhanced GPRS (EGPRS) is the packet-switched part.**

– The major changes over GSM standard are made in the radio interface.

Objective: increase data transmission rates (3x) and spectrum efficiency and facilitate new applications and increased capacity for mobile use

–we focus on the packet-switched enhancement for GPRS, called EGPRS

Technologies (2.5G - 2.75G)

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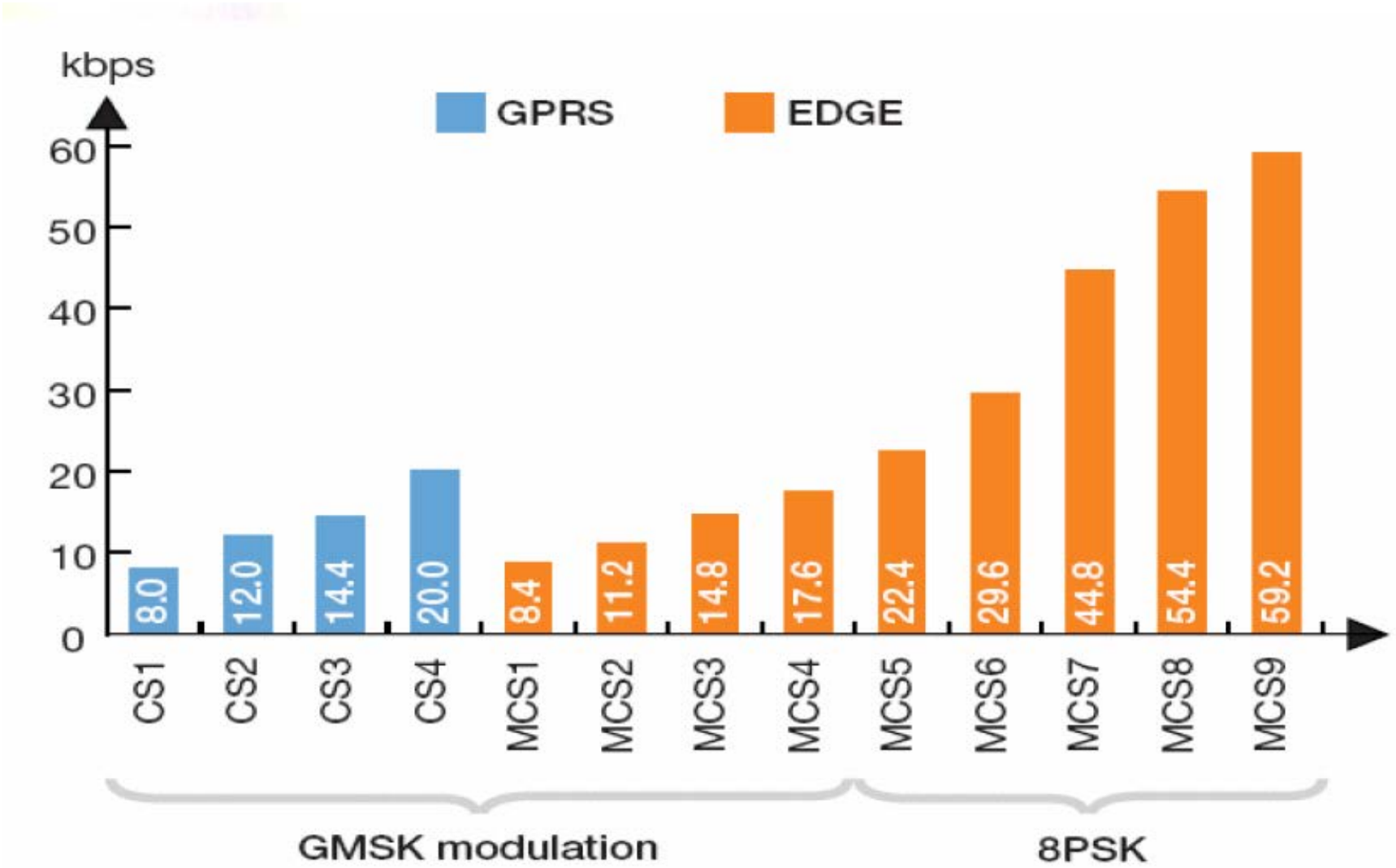
Data Rate


kbps
GPRS
EDGE
60
50
40
30
20
10
0
8.0
12.0
14.4
20.0
8.4
11.2
14.8
17.6
22.4
29.6
44.8
54.4
59.2
CS1
CS2
CS3
CS4
MCS1
MCS2
MCS3
MCS4
MCS5
MCS6
MCS7
MCS8
MCS9
GMSK modulation
8PSK

Universal Mobile Telecommunication Systems

UMTS (3G)

Outline

The 3GPP Long Term Evolution (LTE) represents a major advance in cellular technology. LTE is designed to meet carrier needs for high-speed data and media transport as well as high-capacity voice support well into the next decade. LTE is well positioned to meet the requirements of next-generation mobile networks. It will enable operators to offer high performance, mass-market mobile broadband services, through a combination of high bit-rates and system throughput – in both the uplink and downlink – with low latency.

LTE infrastructure is designed to be as simple as possible to deploy and operate, through flexible technology that can be deployed in a wide variety of frequency bands. LTE offers scalable bandwidths, from less than 5MHz up to 20MHz, together with support for both FDD paired and TDD unpaired spectrum. The LTE–SAE architecture reduces the number of nodes, supports flexible network configurations and provides a high level of service availability. Furthermore, LTE–SAE will interoperate with GSM, WCDMA/HSPA, TD-SCDMA and CDMA.

What is “IMT-2000”

IMT-2000 (International Mobile Telecommunications-2000) is the personalized global multi-media service, which unifies all the various mobile telephone system specs.

Services

- **global roaming service**
- **multimedia communications**

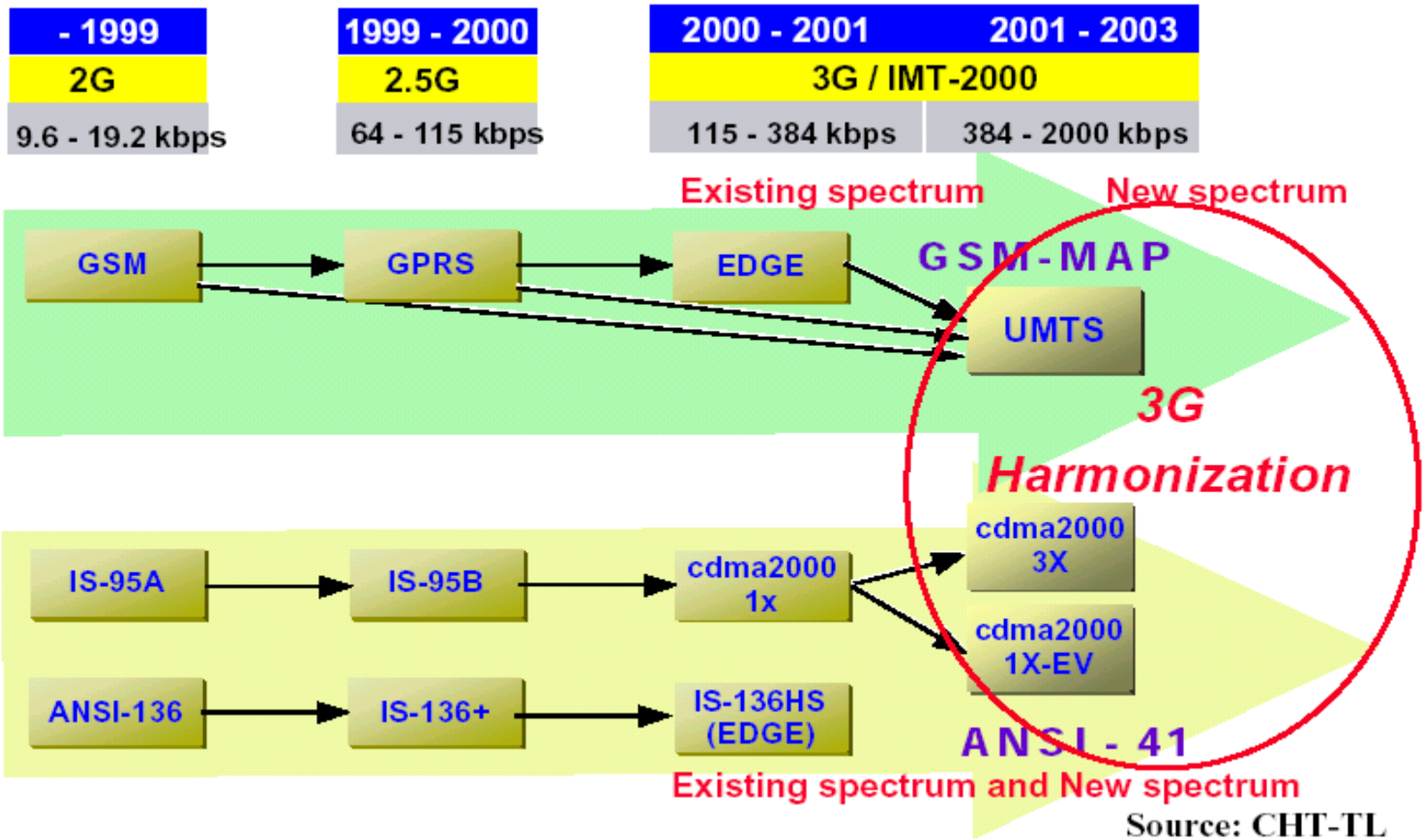
This is “ 3rd Generation Mobile Communication System”

- **ITU (International Telecommunication Union)**
- **IMT-2000**
  - **Year 2000 Ready**
  - **Operate at 2000 MHz**
  - **Provide 2000 Kbps Data Rate (100x than GPRS)**
- **3G Data Rate Requirement**
  - **Vehicular -- 144 Kbps**
  - **Pedestrian --- 384 Kbps**
  - **Indoor --- 2Mbps**

3GPP and SDOs

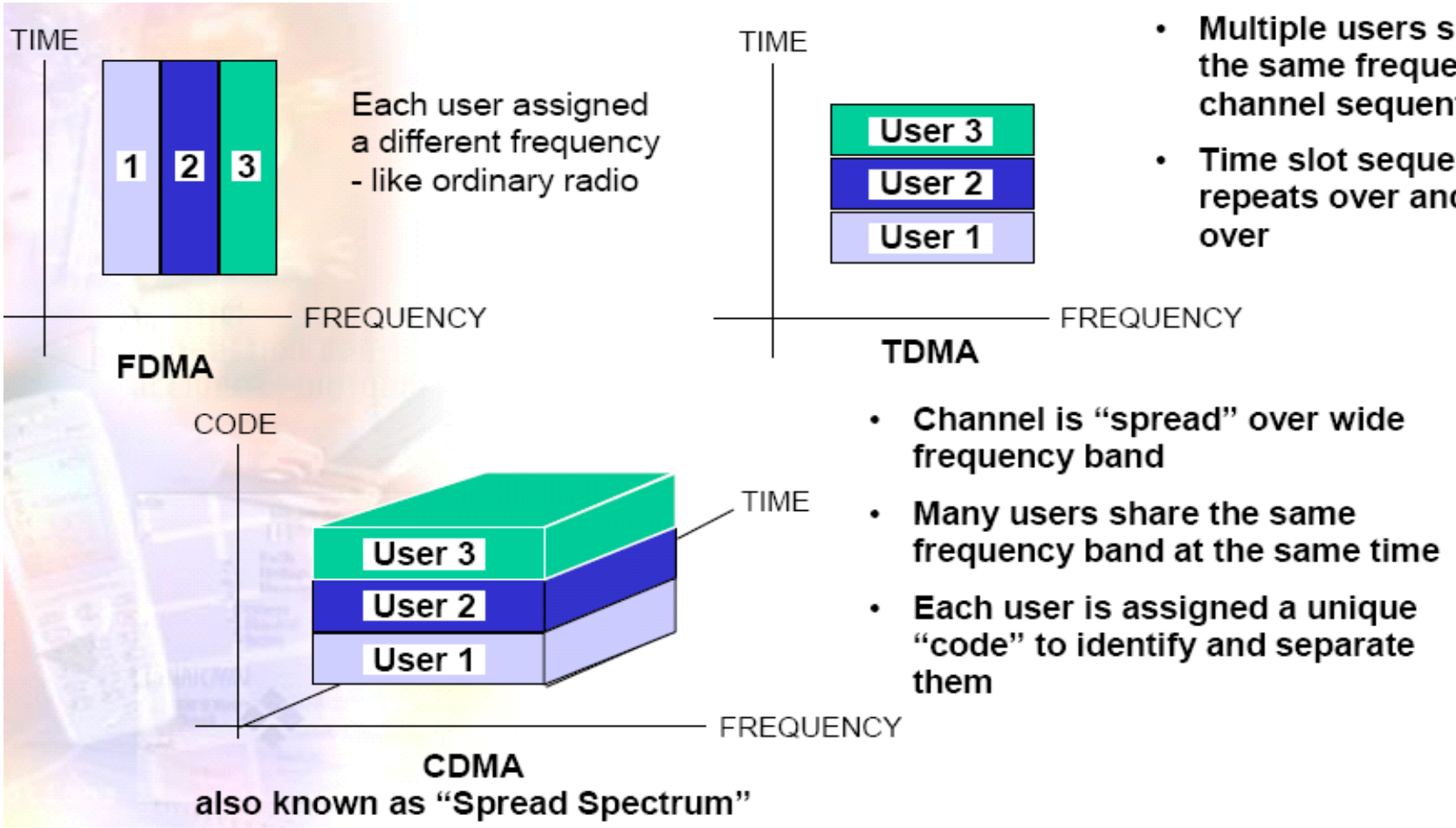
ARIB	**Association of Radio Industries and Businesses (Japan)**
ATIS	**Alliance for Telecommunications Industry Solutions (USA, Canada, Mexico)**
CCSA	**China Communications Standard Association (China)**
ETSI	**(European Telecommunications Standard Institute (Europe))**
TTA	**Telecommunications Technology Association (Korea)**
TTC	**Telecommunication Technology Committee (Japan)**

IMT-2000 Evolution



Multiple Access Methods

Multiple users share the available spectrum

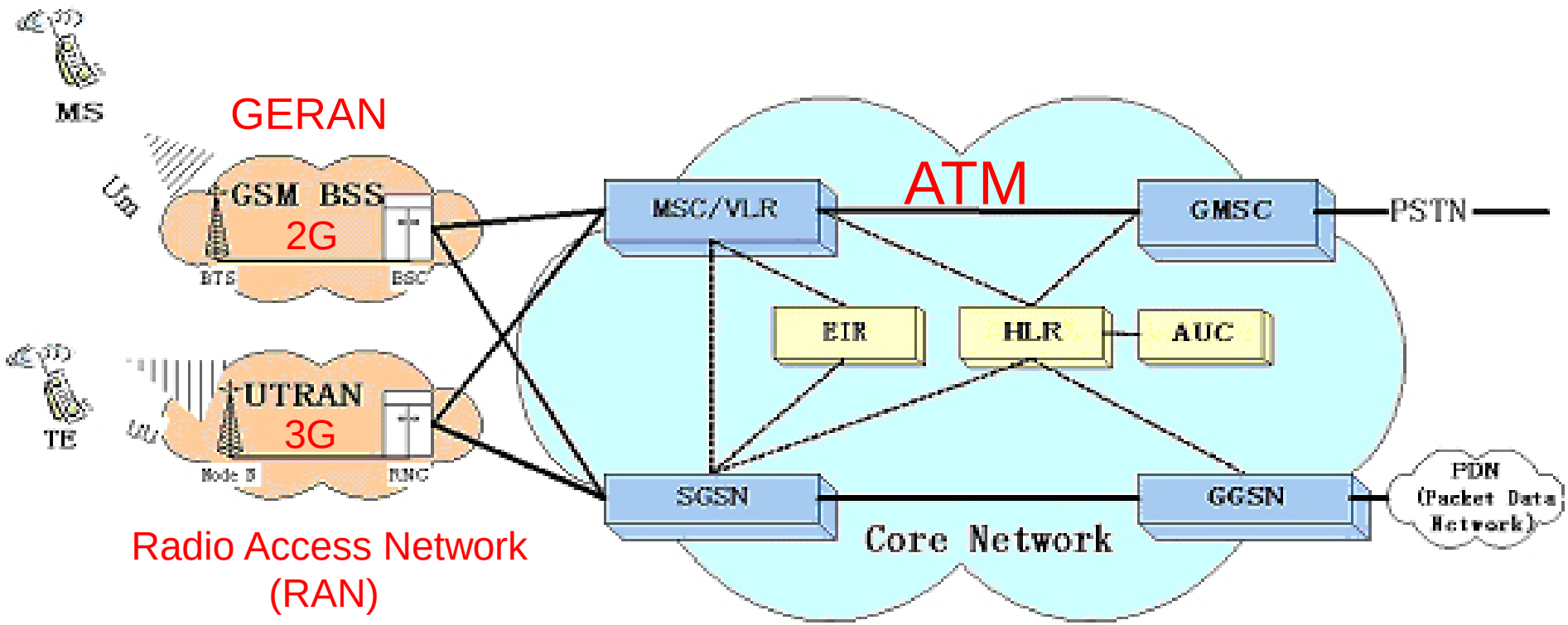


- Multiple users share the same frequency channel sequentially
- Time slot sequence repeats over and over

- Channel is "spread" over wide frequency band
- Many users share the same frequency band at the same time
- Each user is assigned a unique "code" to identify and separate them

3GPP R99 UMTS Core Network

Similar to GSM/GPRS core network



BSS : BS subsystem

UTRAN : UMTS Terrestrial Radio Access Network

GERAN : GSM/EDGE Radio Access Network

IMT-2000 Short History (1/3)

1988 : RACE I (Research of Advanced Communication Technologies in Europe) program

- Basic research work

1992-1995 : RACE II program

- CDMA-based CODIT (Code Division Testbed)
- TDMA-based ATDMA (Advanced TDMA Mobile Access) air interface

1995 : ACTS (Advanced Communication Technologies and Service) Program

- FRAMES (Future Radio Wideband Multiple Access System) project
  - FMA1 : Wideband TDMA
  - FMA2 : Wideband CDMA

1997 : ARIB Evaluation approval by ITU

1998 early : 3GPP creation

1998 June : ETSI selection

- 15 RTT proposals were submitted (10 for Terrestrial, 5 for Satellite)

1998 Sep. : 3GPP2 creation

1999 July : 3G harmonization

IMT-2000 Short History (2/3)

2000 May : 5 terrestrial RTT standards are formal approval by ITU

2008 : Approve new tech. OFDMA as the 6-th RTT standard (from IEEE)

Release 4 (2001 Q2)

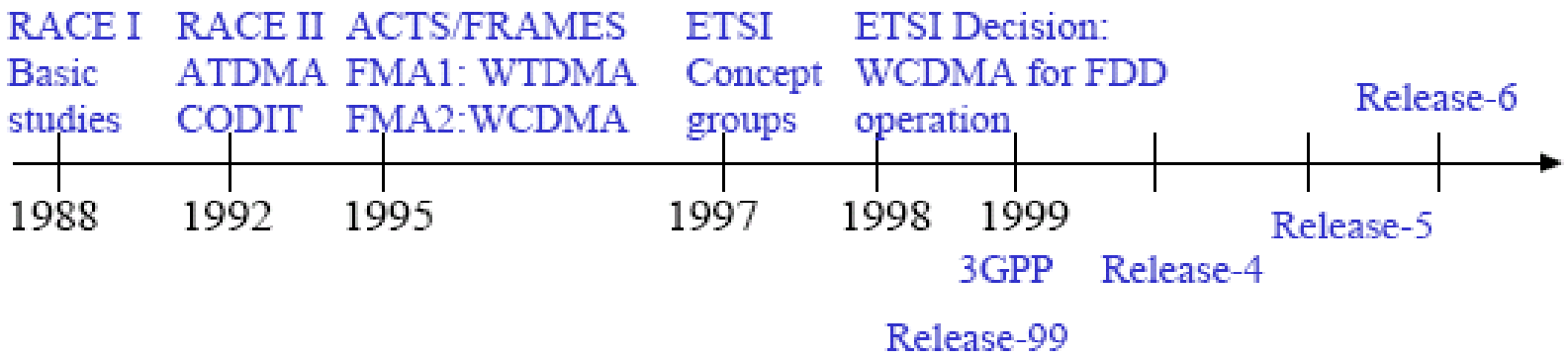
- Originally called the Release 2000 - added features including an All-IP Core Network

Release 5 (2002 Q1)

- Introduced IMS and HSDPA

Release 6 (2004 Q4)

- Integrated operation with WLAN networks and adds HSUPA, MBMS, enhancements to IMS such as Push to Talk over Cellular (PoC)



IMT-2000 Short History (3/3)

Release 7 (2007 Q4)

- Focuses on decreasing latency, improvements to QoS and real-time applications such as VoIP
- also focus on HSPA+ (High Speed Packet Access Evolution), MIMO, SIM high-speed protocol and contactless front-end interface (Near Field Communication enabling operators to deliver contactless services like mobile payments), EDGE Evolution.

Release 8 (In progress, not ready before Mar 2009)

- Long Term Evolution (LTE), All-IP Network (SAE).
- It constitutes UMTS as an entirely IP based fourth-generation network.

Release 9 (In progress, expected to be frozen in Dec 2009)

- SAES Enhancements, WiMAX and LTE/UMTS Interoperability

Release 10 (4G, LTE-A)

- LTE-Advanced

Release 11 (LTE-A)

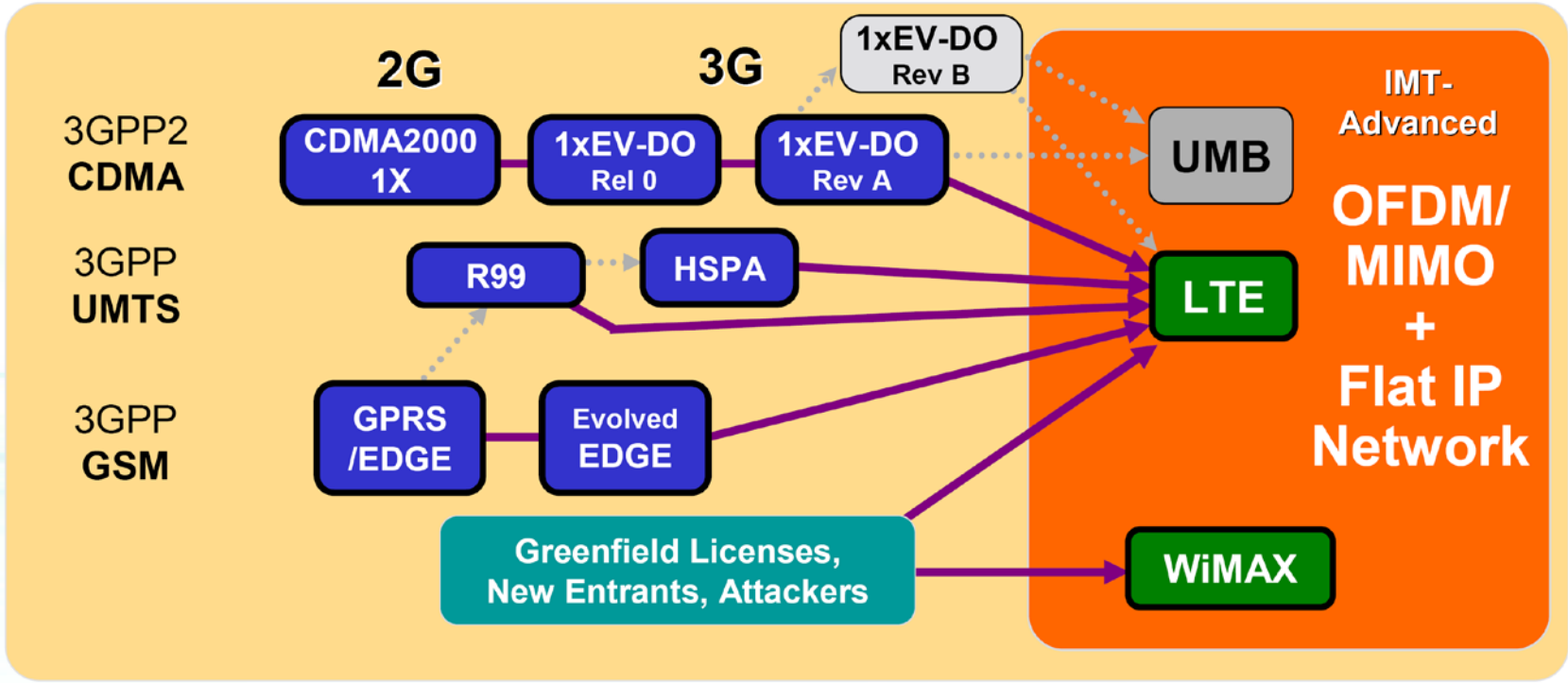
- LTE-Advanced

- **Release 12 (5G, LTE-B (Beyond), in progress)**

Long Term Evolution

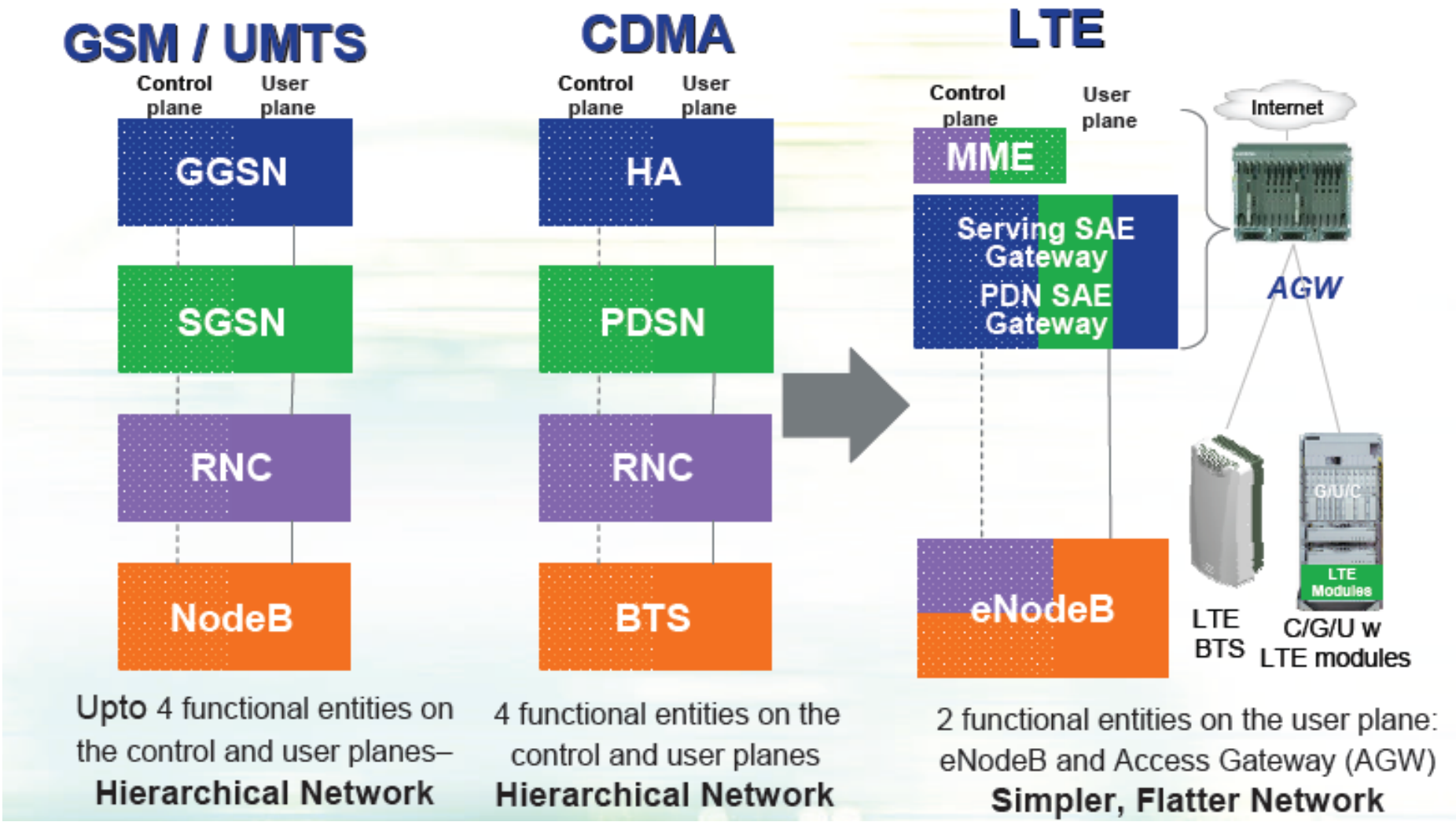
LTE (3.5G)

Mobile Broadband Technology



Network Evolution : Made Simple

Leveraging Efficient Routing and Low Cost of IP



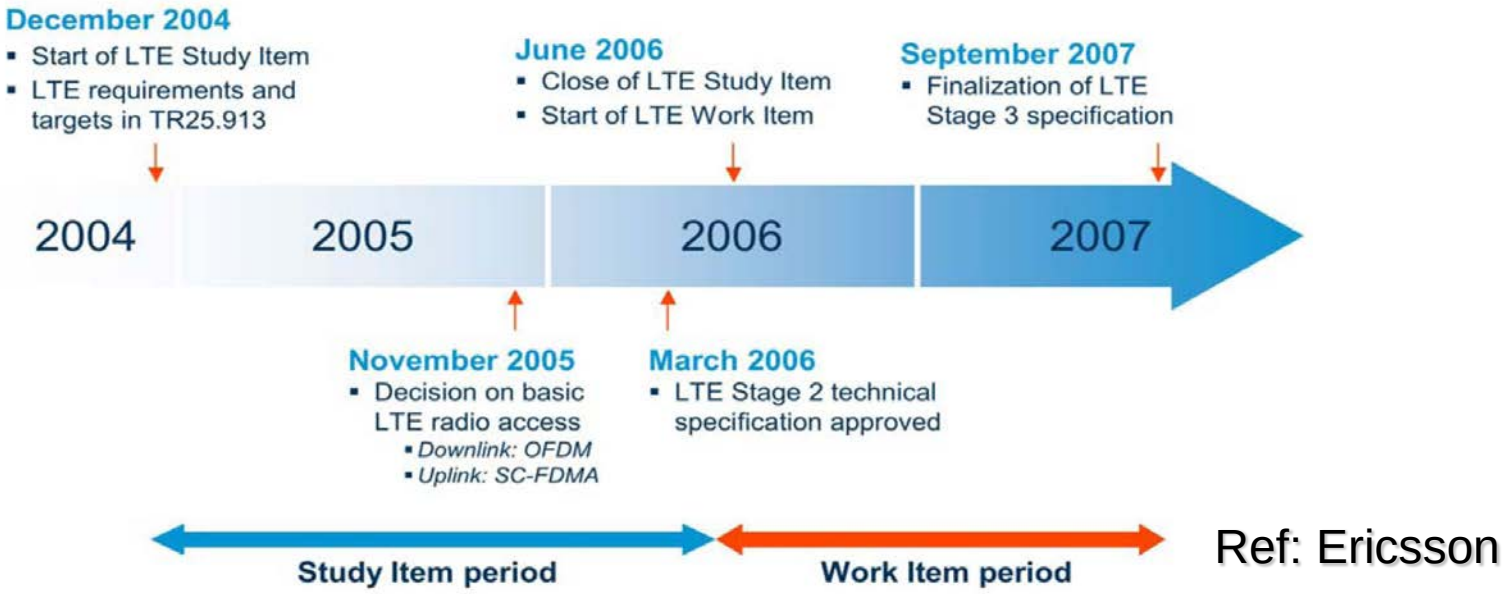
LTE History

LTE is the next major step in mobile radio communications, and will be introduced in 3rd Generation Partnership Project (3GPP) Release 8.

The starting point for LTE standardization was the 3GPP RAN Evolution Workshop, held in November 2004 in Toronto, Canada.

A study item was started in December 2004.

- **3GPP *TR 25.913 Feasibility Study of Evolved UTRA and UTRAN***



Ref: Ericsson

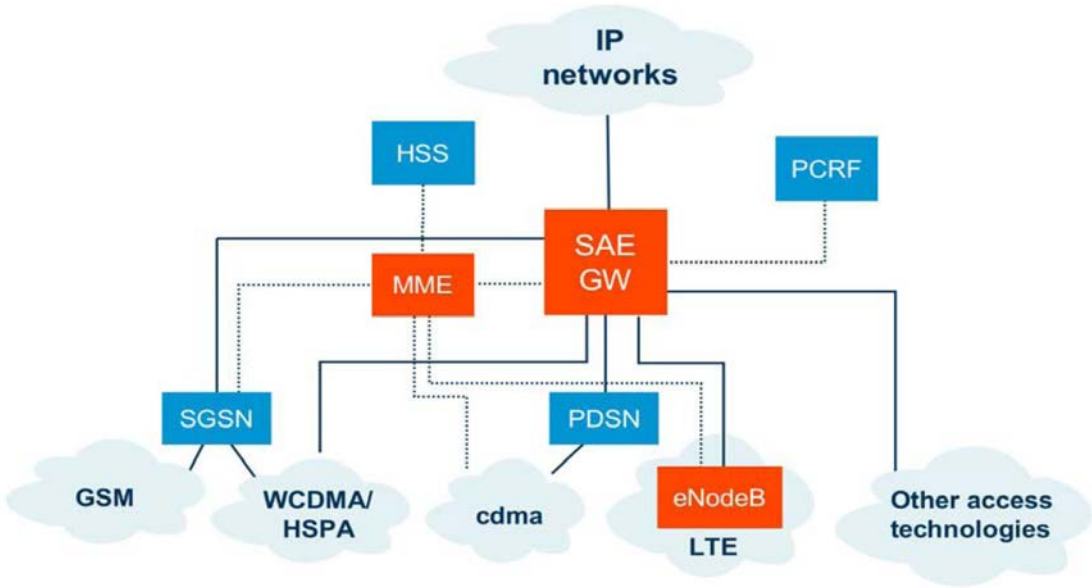
System Architecture Evolution (SAE)

Packet core networks are also evolving to the flat System Architecture Evolution (SAE) architecture.

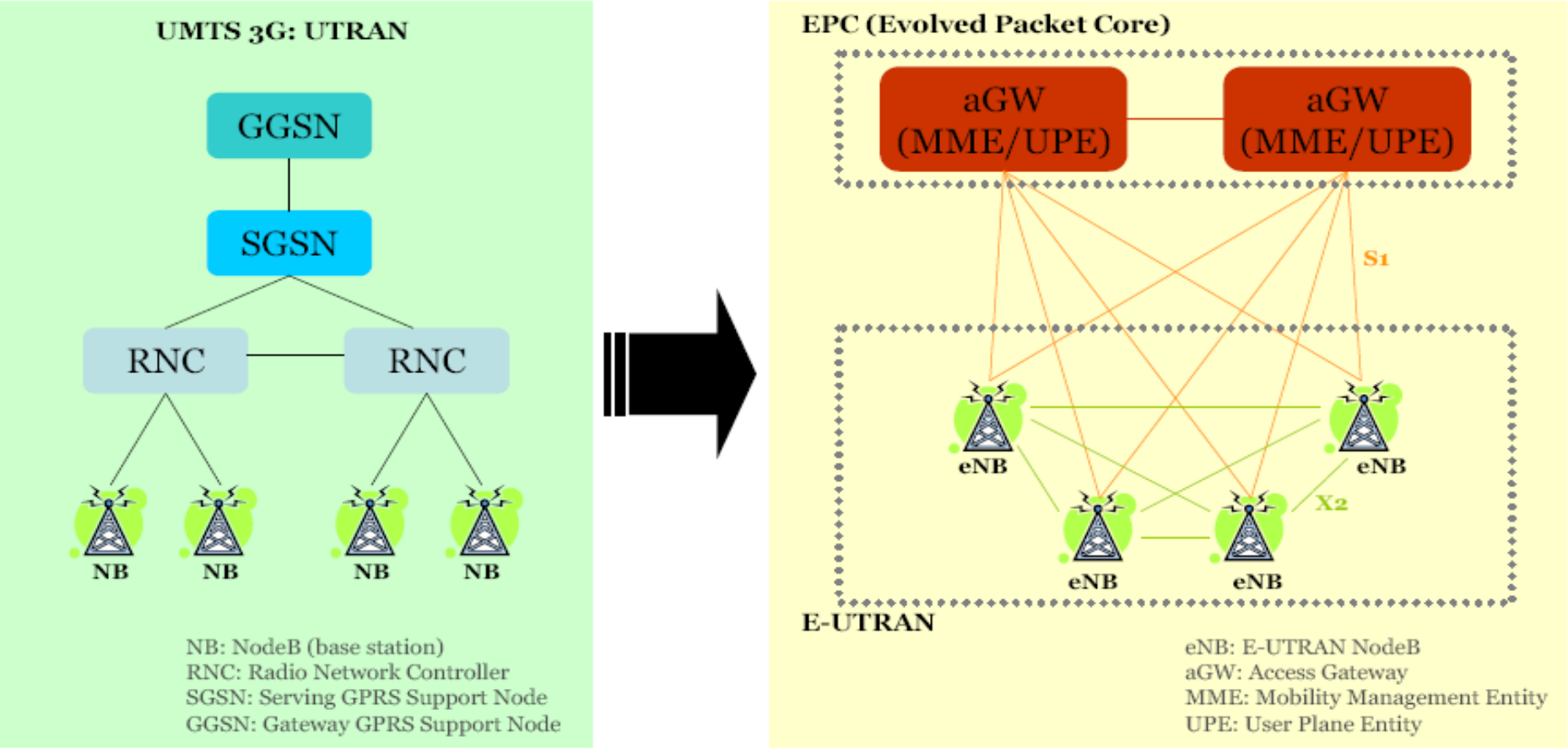
- **This new architecture is designed to optimize network performance, improve cost-efficiency and facilitate the uptake of mass-market IPbased services.**

There are only two nodes in the SAE architecture user plane:

- **LTE base station (eNodeB) and**
- **SAE Gateway**

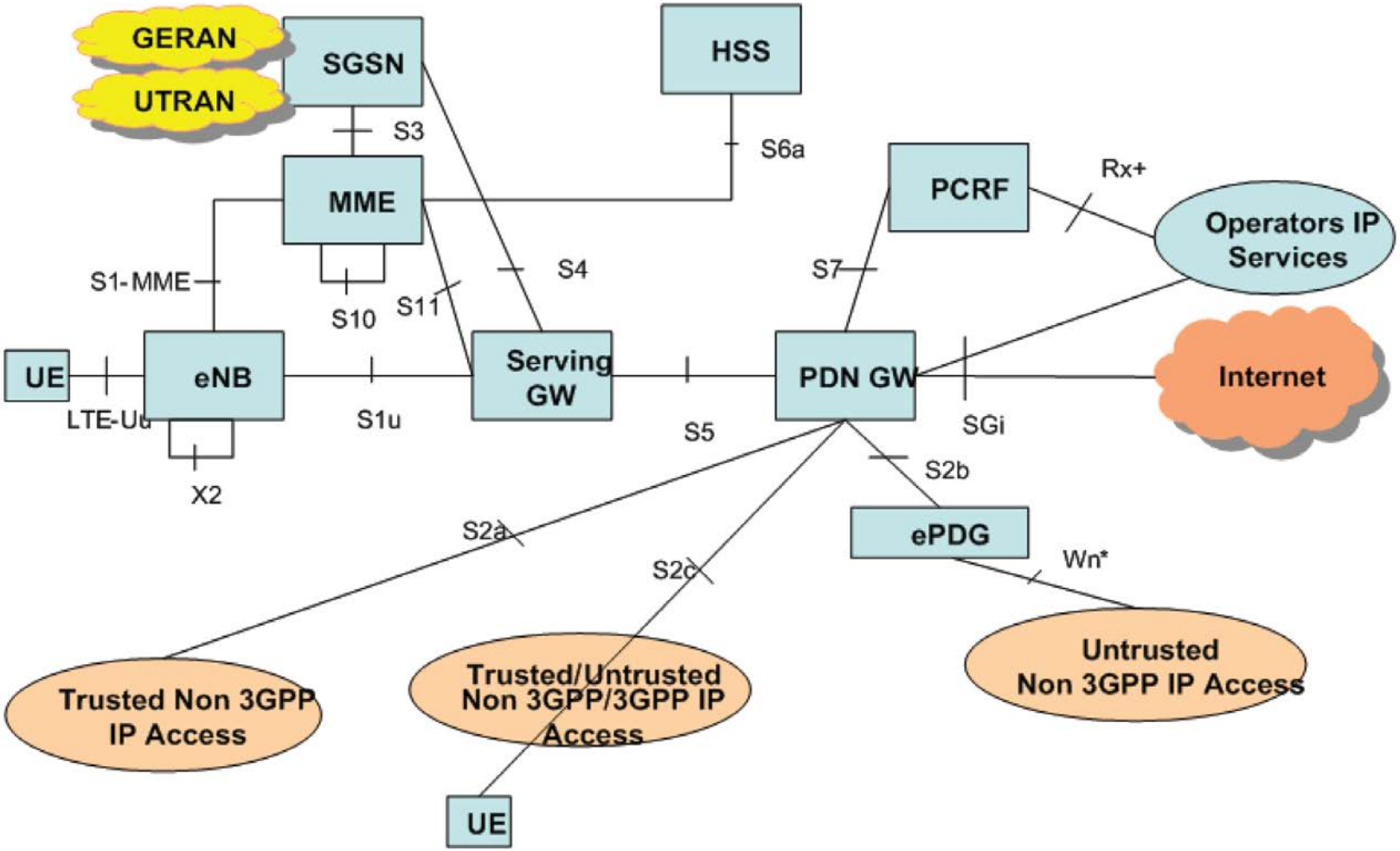


LTE Network Architecture



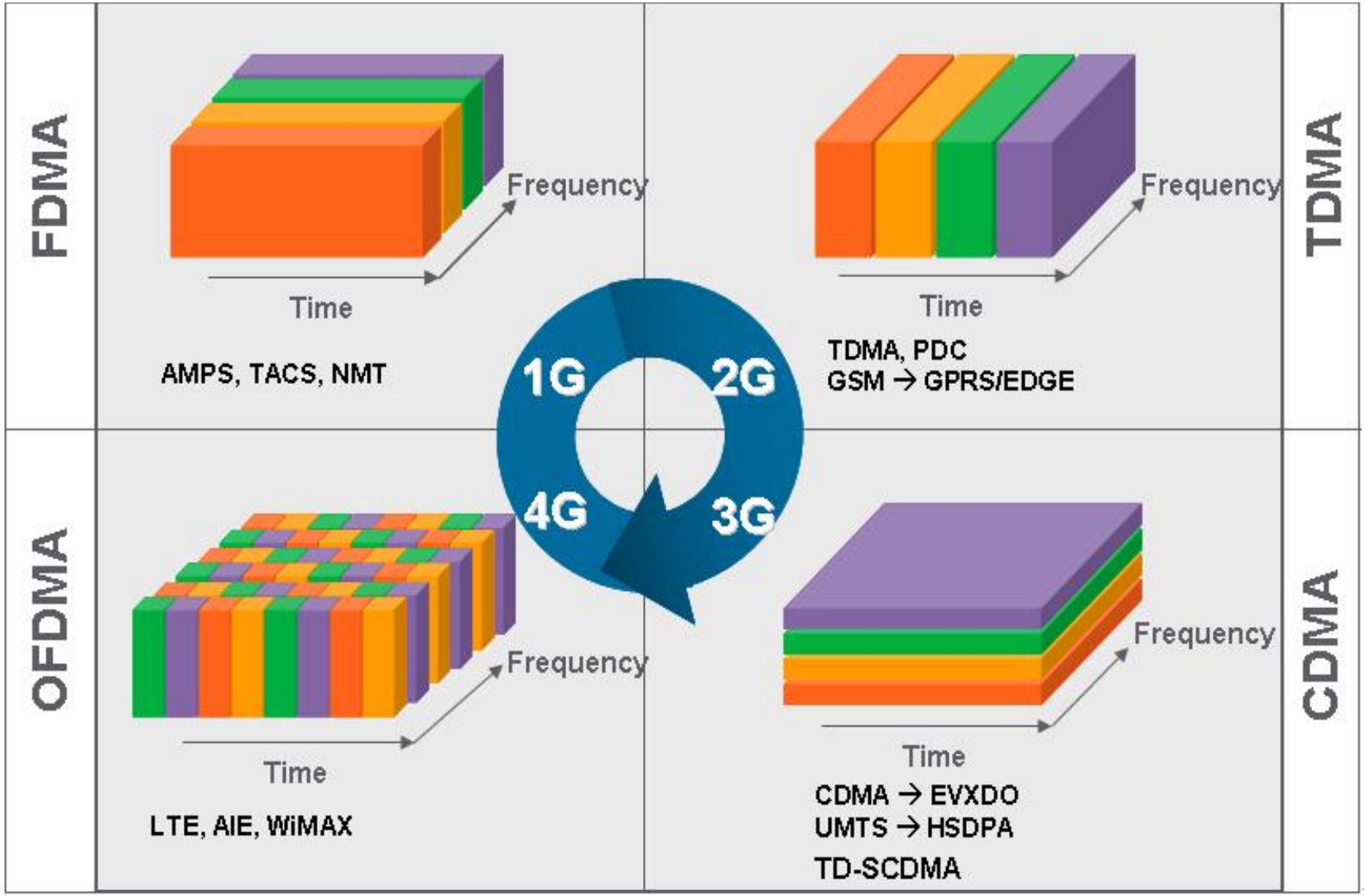
[Source:Technical Overview of 3GPP Long Term Evolution (LTE) Hyung G. Myung
http://hgmyung.googlepages.com/3gppLTE.pdf

High Level Architecture

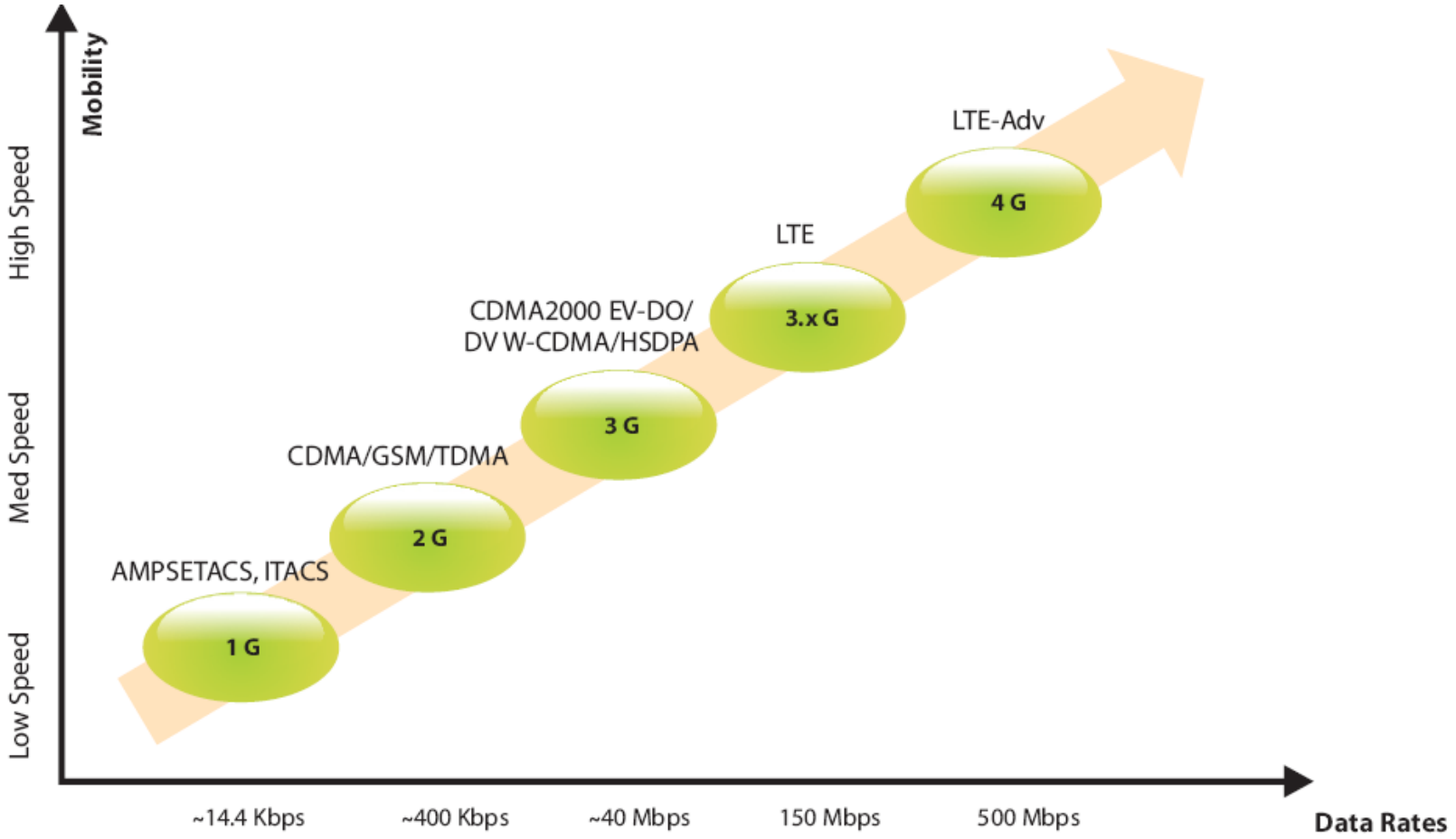


(Untrusted non-3GPP access requires ePDG in the data path)

Modulation Evolution

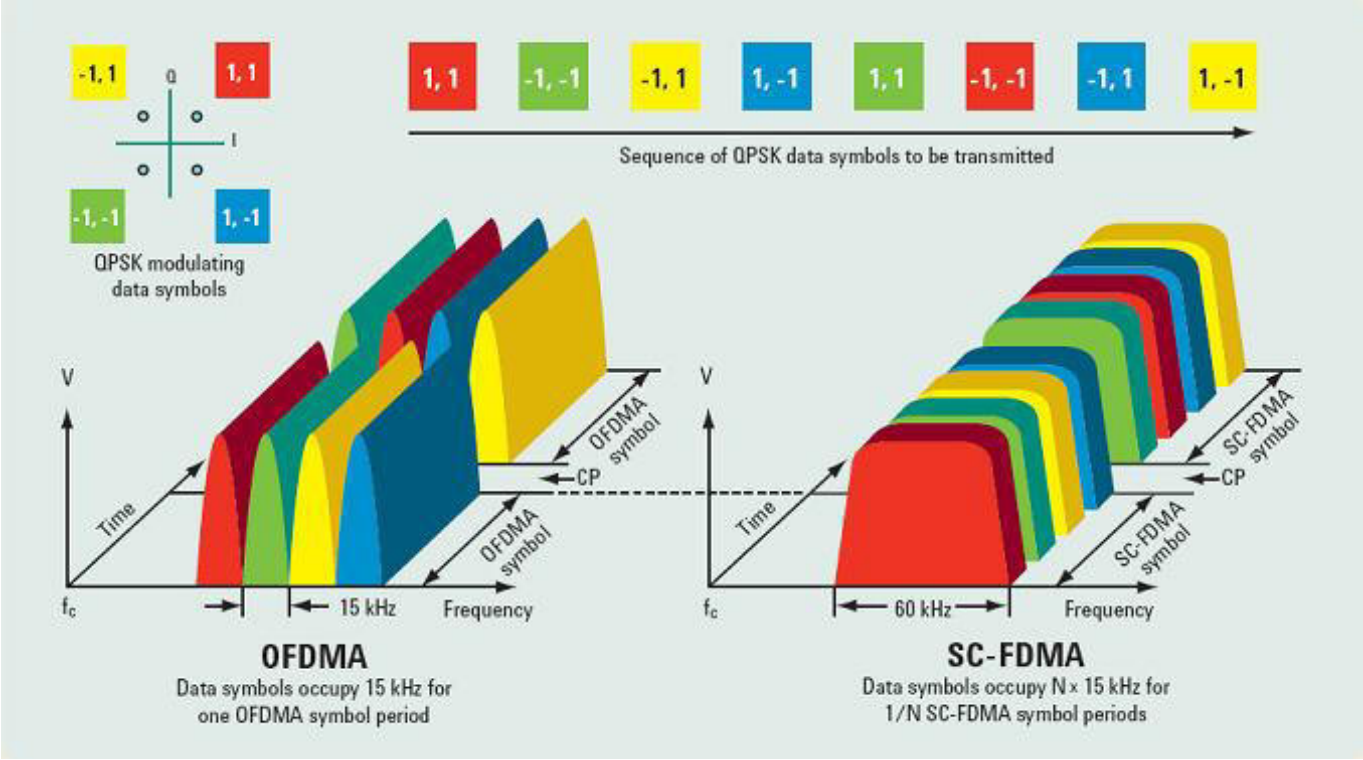


Evolution of Radio Access Technologies



LTE Downlink (OFDMA) Uplink (SC-FDMA)

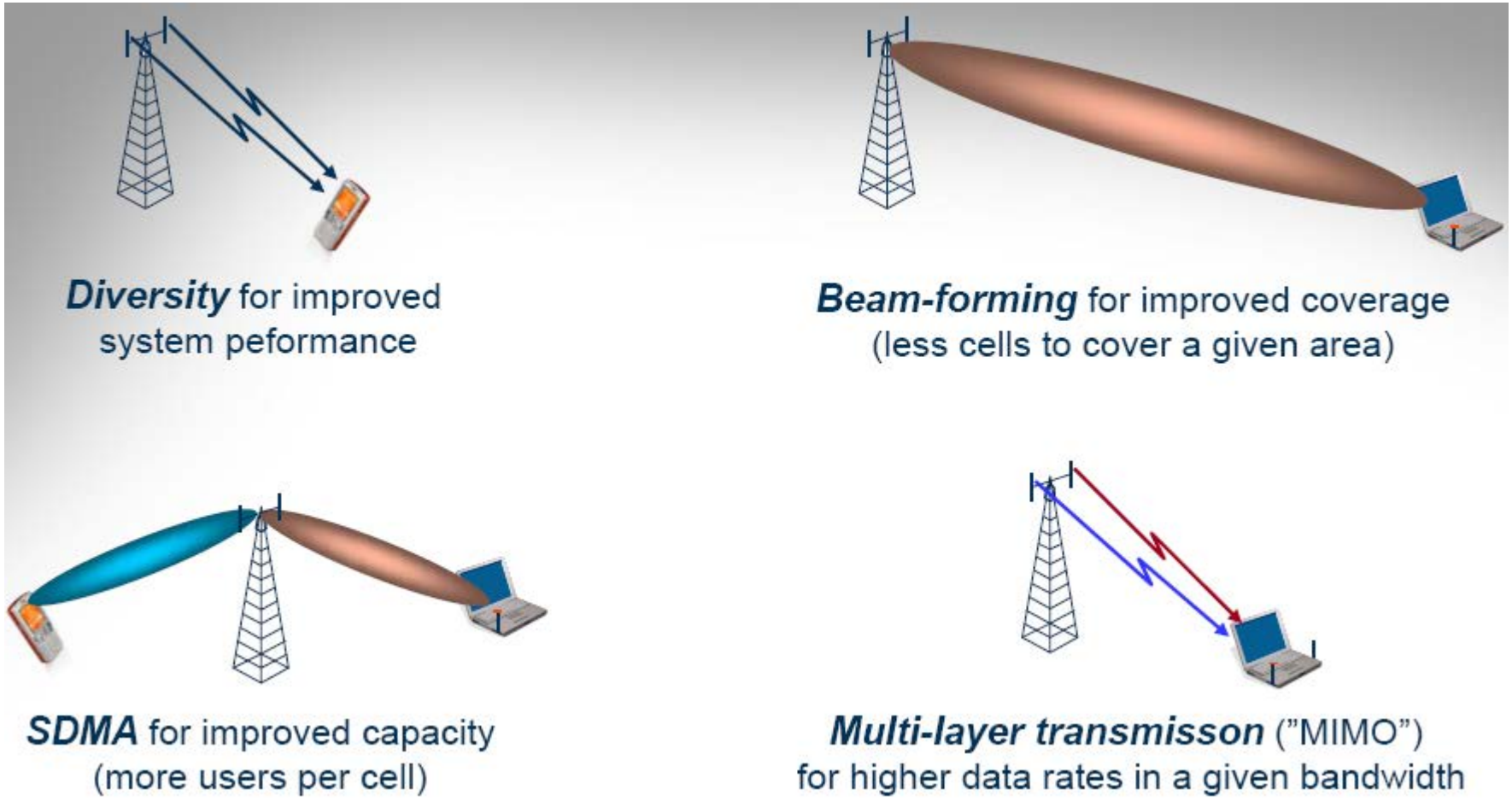
SC-FDMA is a new single carrier multiple access technique which has similar structure and performance to OFDMA



A salient advantage of SC-FDMA over OFDM is low to Peak to Average Power Ratio (PAPR) :

Increasing battery life

Multi-Antenna Techniques



Enhanced Multi-antenna Transmission Techniques

- **In LTE-A, the MIMO scheme has to be further improved in the area of spectrum efficiency, average cell through put and cell edge performances**
- **In LTE-A the antenna configurations of 8x8 in DL and 4x4 in UL are planned**

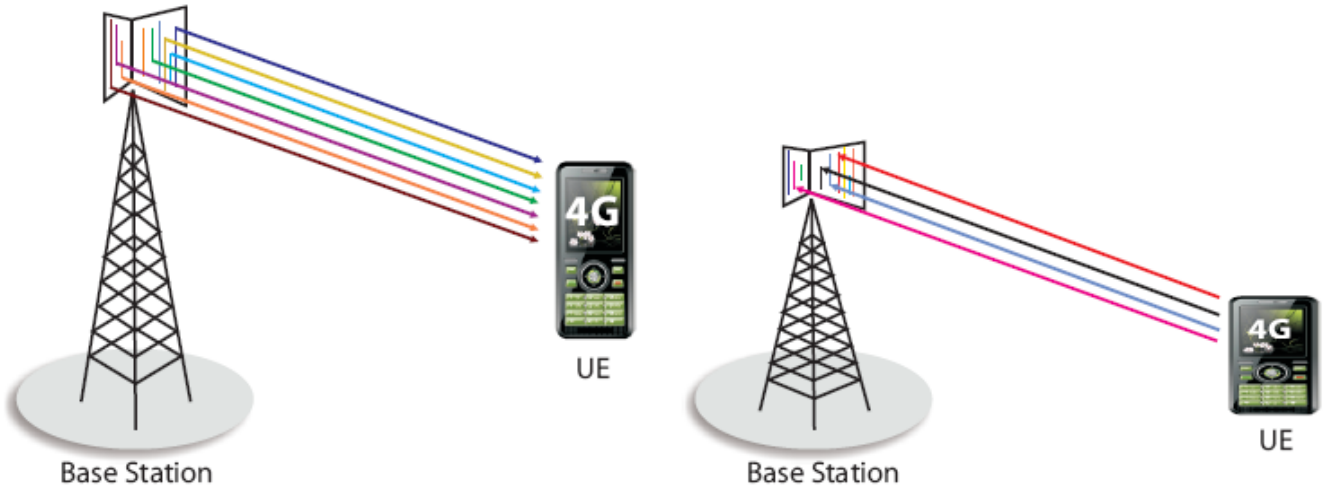
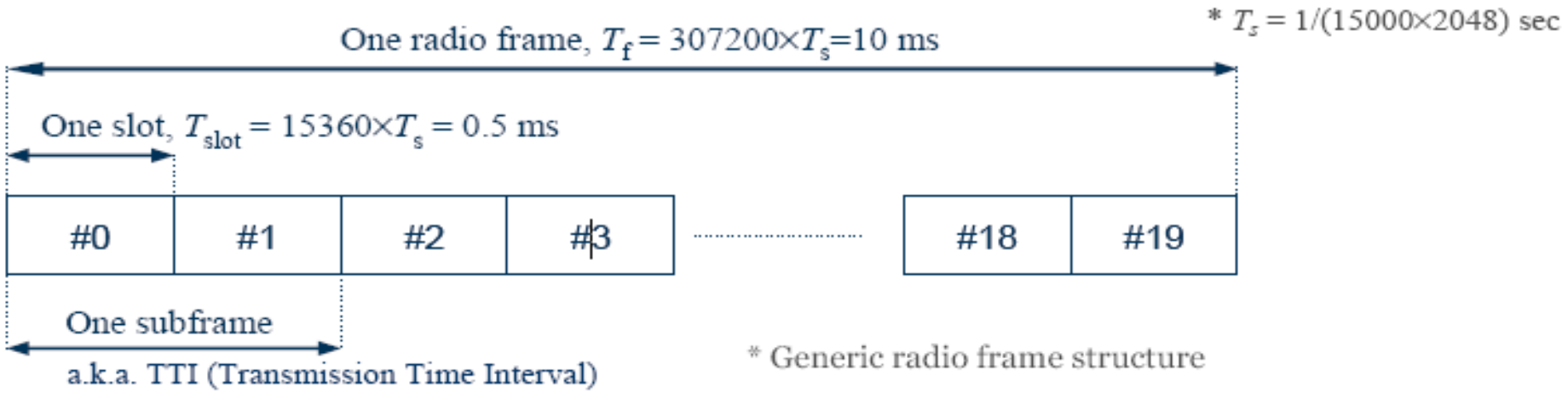


Figure 9 : MIMO Tx & Rx Schemes LTE-A (8 X 4 MIMO)

Long Term Evolution Advanced

LTE-A (4G)

LTE Frame Structure

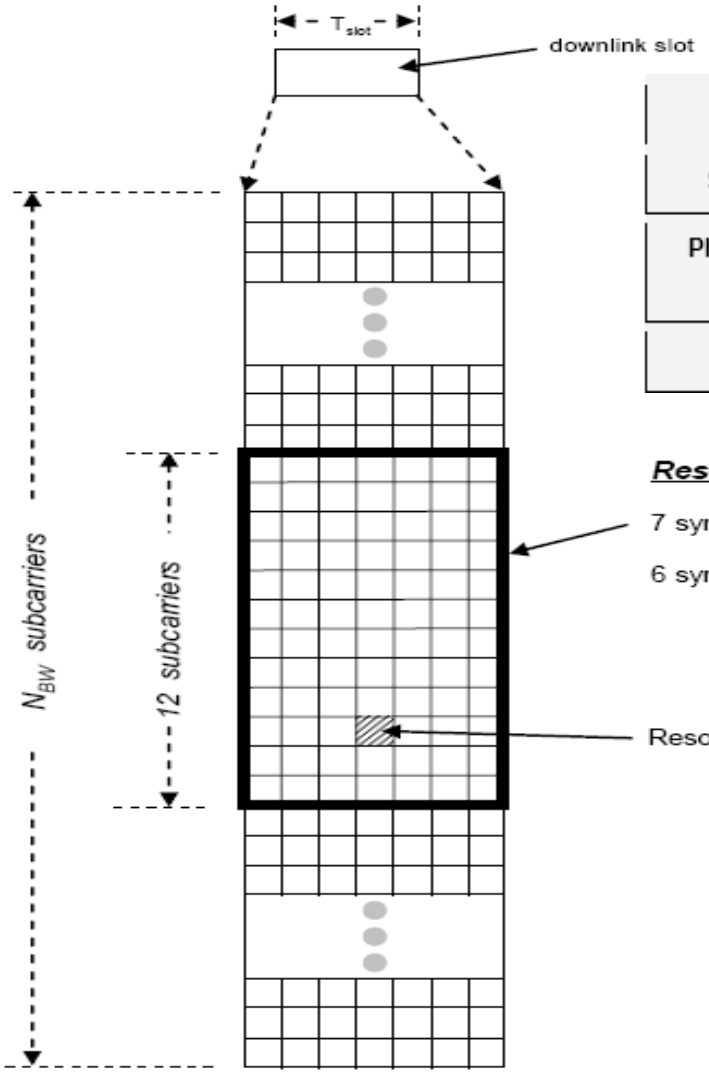


One element that is shared by the LTE Downlink and Uplink is the generic frame structure. The LTE specifications define both FDD and TDD modes of operation. This generic frame structure is used with FDD. Alternative frame structures are defined for use with TDD.

LTE frames are 10 msec in duration. They are divided into 10 subframes, each subframe being 1.0 msec long. Each subframe is further divided into two slots, each of 0.5 msec duration. Slots consist of either 6 or 7 ODFM symbols, depending on whether the normal or extended cyclic prefix is employed

[source: 3GPP TR 25.814]

Generic Frame structure



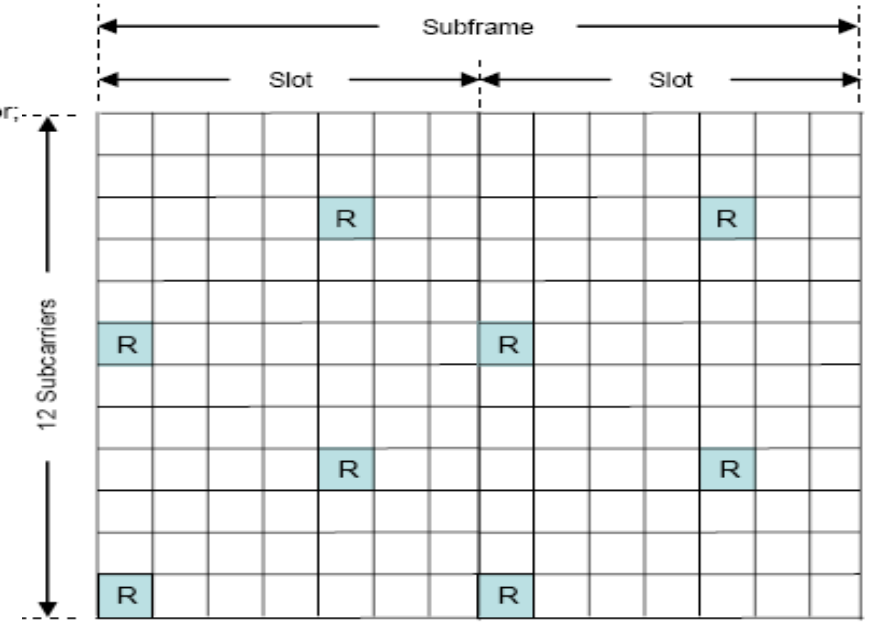
Available Downlink Bandwidth is Divided into Physical Resource Blocks

Bandwidth (MHz)	1.25	2.5	5.0	10.0	15.0	20.0
Subcarrier bandwidth (kHz)	15					
Physical resource block (PRB) bandwidth (kHz)	180					
Number of available PRBs	6	12	25	50	75	100

Resource Block:

7 symbols X 12 subcarriers (short CP), or;

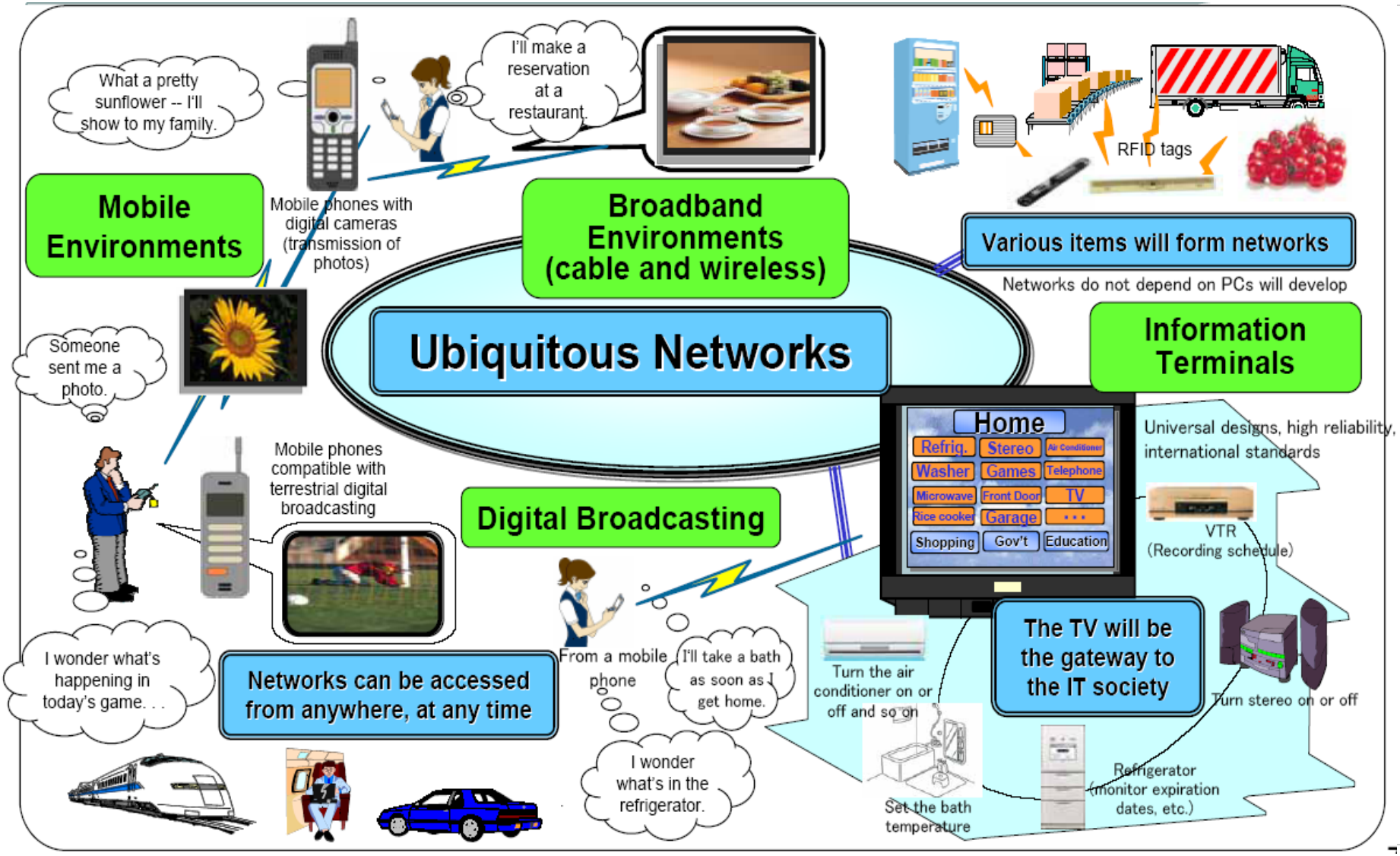
6 symbols X 12 subcarriers (long CP)



LTE Reference Signals are Interspersed Among Resource Elements

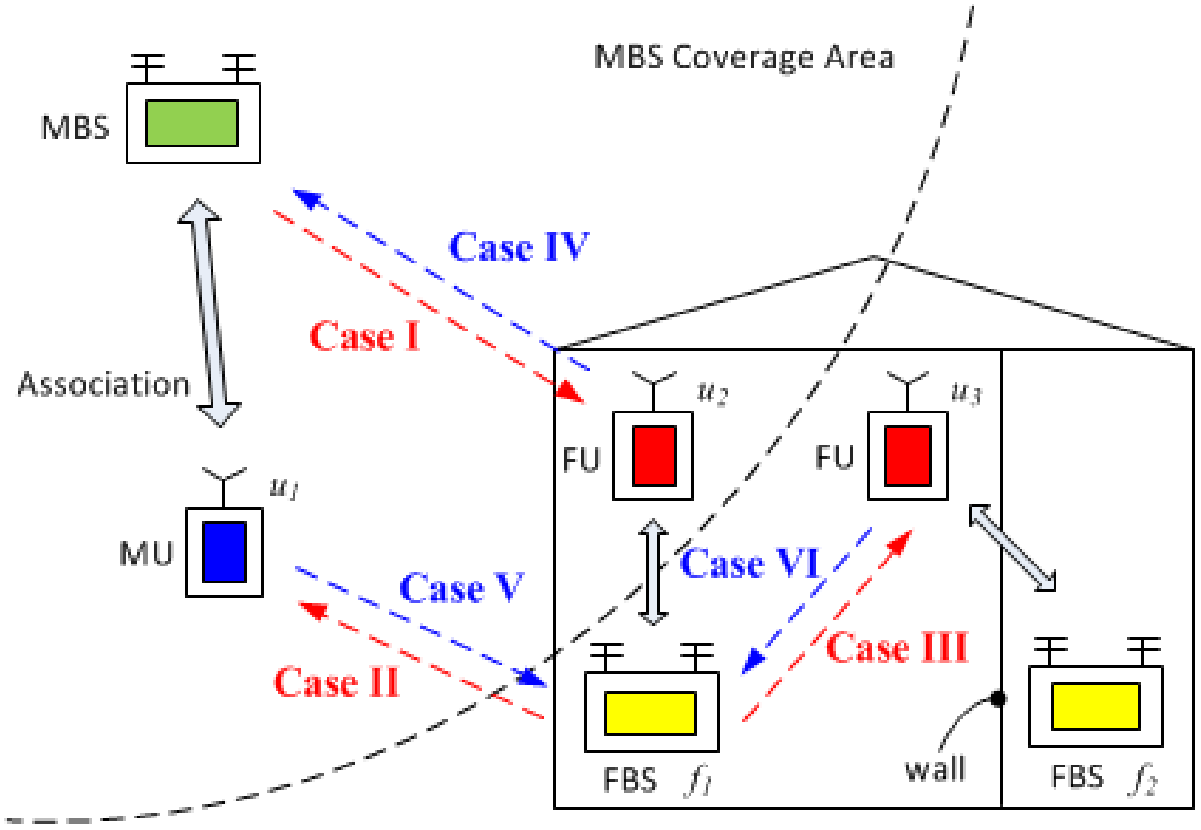
[source: 3GPP TR 25.814]

Vision of 4G

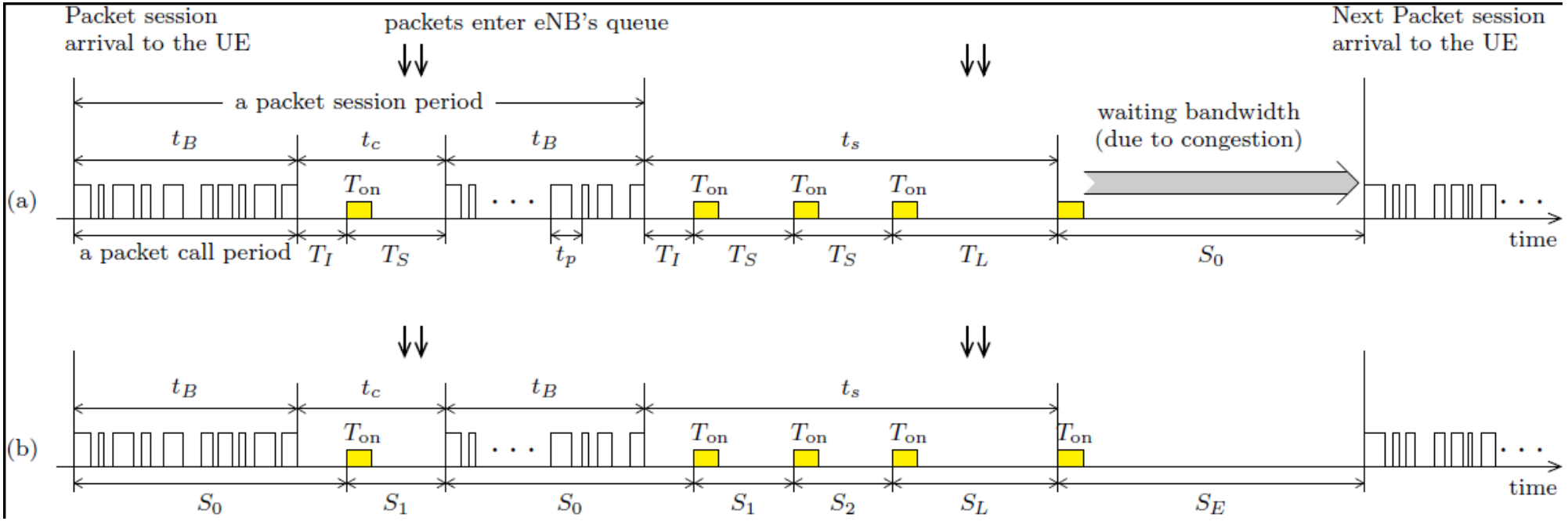

What a pretty sunflower -- I'll show to my family.
I'll make a reservation at a restaurant.
Mobile Environments
Mobile phones with digital cameras (transmission of photos)
Broadband Environments (cable and wireless)
RFID tags
Various items will form networks
Networks do not depend on PCs will develop
Someone sent me a photo.
Ubiquitous Networks
Information Terminals
Home
Refrig.
Stereo
Air Conditioner
Washer
Games
Telephone
Microwave
Front Door
TV
Rice cooker
Garage
Shopping
Gov't
Education
Universal designs, high reliability, international standards
Mobile phones compatible with terrestrial digital broadcasting
Digital Broadcasting
VTR (Recording schedule)
I wonder what's happening in today's game. . .
Networks can be accessed from anywhere, at any time
From a mobile phone
I'll take a bath as soon as I get home.
The TV will be the gateway to the IT society
Turn the air conditioner on or off and so on
Turn stereo on or off
I wonder what's in the refrigerator.
Set the bath temperature
Refrigerator (monitor expiration dates, etc.)

N-Tier Heterogeneous Networks Interference Management

- **Femtocell, Small Cell, Macro Cell interference management**



Power Saving in Bursty Traffic



LTE Beyond

LTE-B (5G)

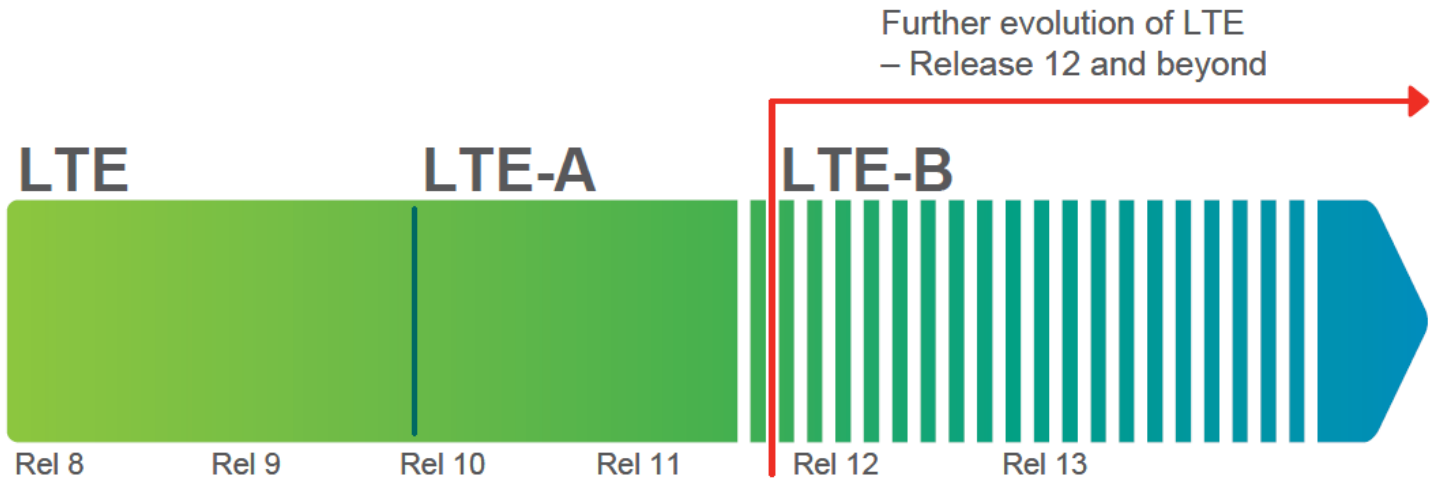
The evolution of LTE beyond LTE-A

Challenges:

- A massive growth in the number of connected devices.
- A massive growth in traffic volume.
- An increasingly wide range of applications with varying requirements and characteristics.

Mainly places should be taken

- General enhancements applicable to a wide range of scenarios and use cases.
- Enhancements specifically targeting small-cell/local-area deployments.
- Enhancements specifically targeting new use cases, such as machine-type communication (MTC) and national security and public safety services (NSPS)



Key Challenges

The traffic of wireless communication systems has grown dramatically over the past 10 years and there is no indication this growth will slow down.

The range of applications, with corresponding requirements and characteristics, that need to be covered by future wireless communication systems will expand tremendously.

Massive growth in
Connected devices

Massive amount of communicating machines

"50 billion devices"

Massive growth in
Traffic volume

Further expansion of mobile broadband
Additional users and increased usage
+
New use cases due to communicating machines

"1000"x in 10 years

Wide range of
Requirements and characteristics

Multi-Gbps in specific scenarios

Tens of Mbps almost everywhere

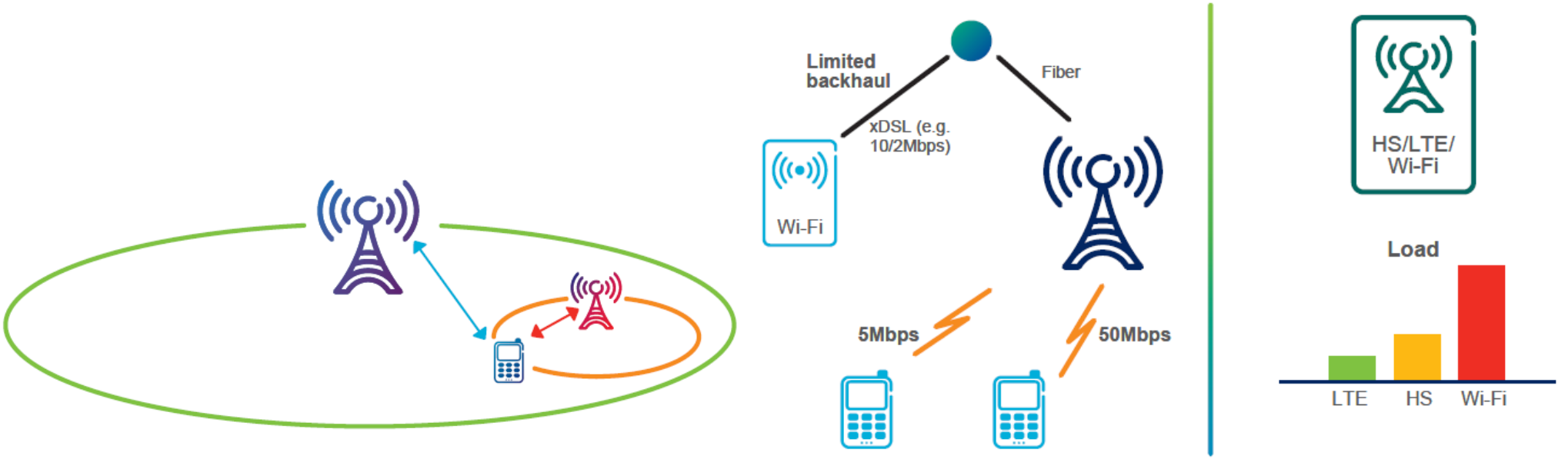
New requirements and characteristics due to communication machines

Small-Cell and Local-Area Deployment

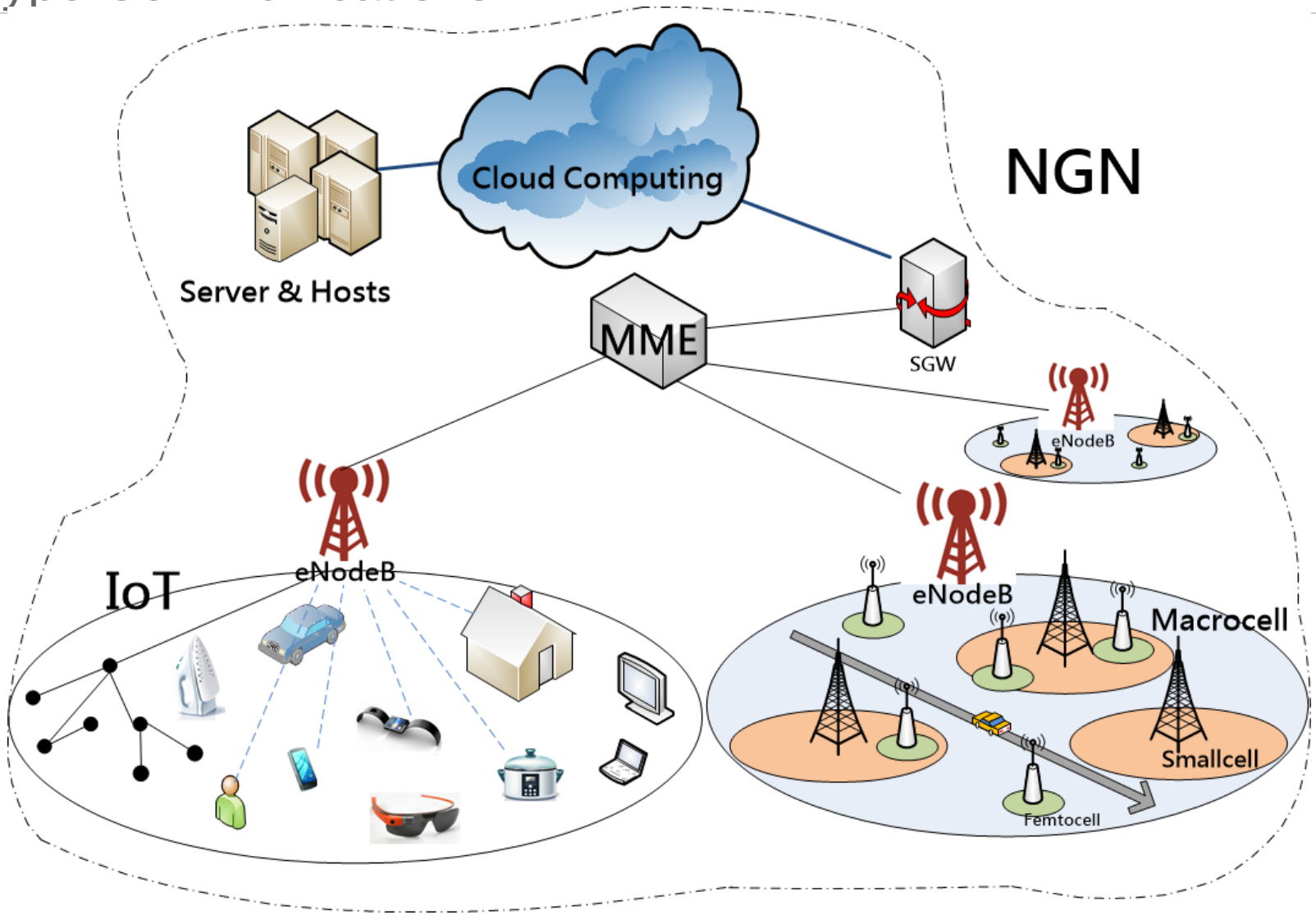
Macro assistance including dual connectivity may provide several benefits:

- Enhanced support for mobility
- Low overhead transmissions from the low-power layer
- Energy-efficient load balancing
- Per-link optimization

Integration of Wi-Fi with LTE

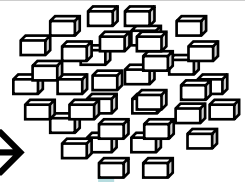


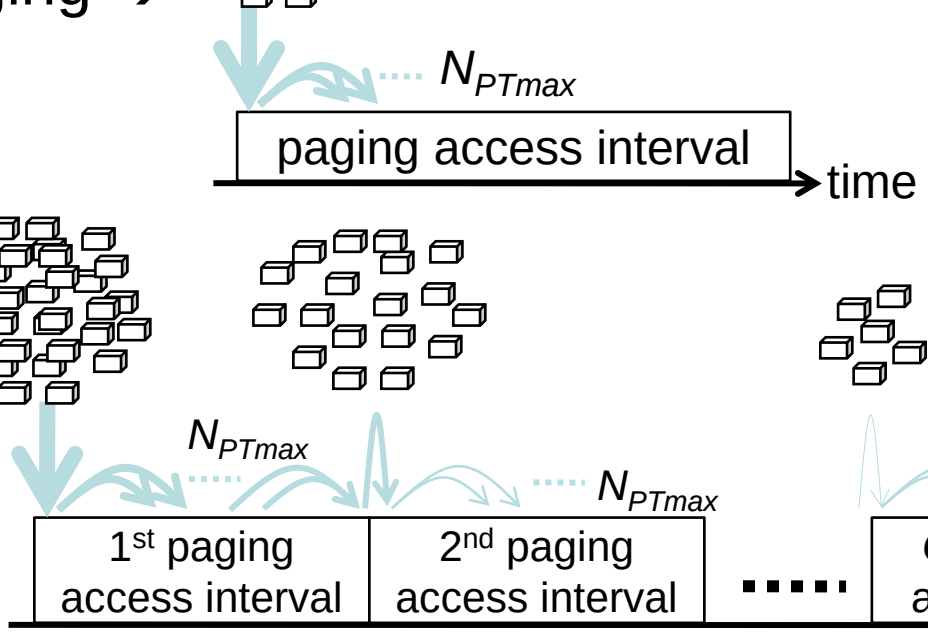
Machine-Type Communications



Stragies

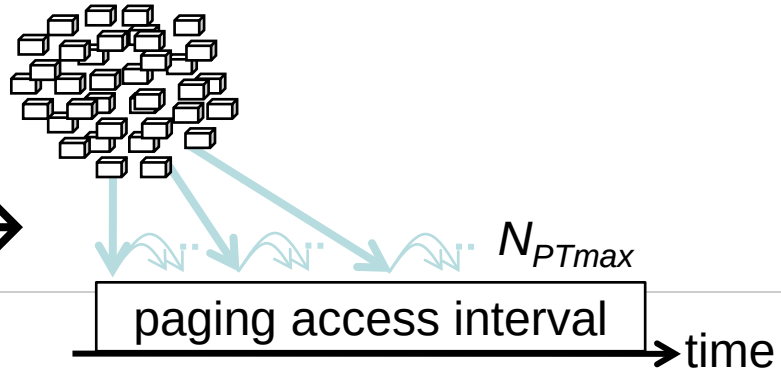
Pure Group Paging →





Consecutive Group Paging →

Group Paging with Pre-backoff →



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Questions

Thank You for Your Attention