Evolution of Mobile Broadband

2G/3G/4G&5G – For 1st Year Students

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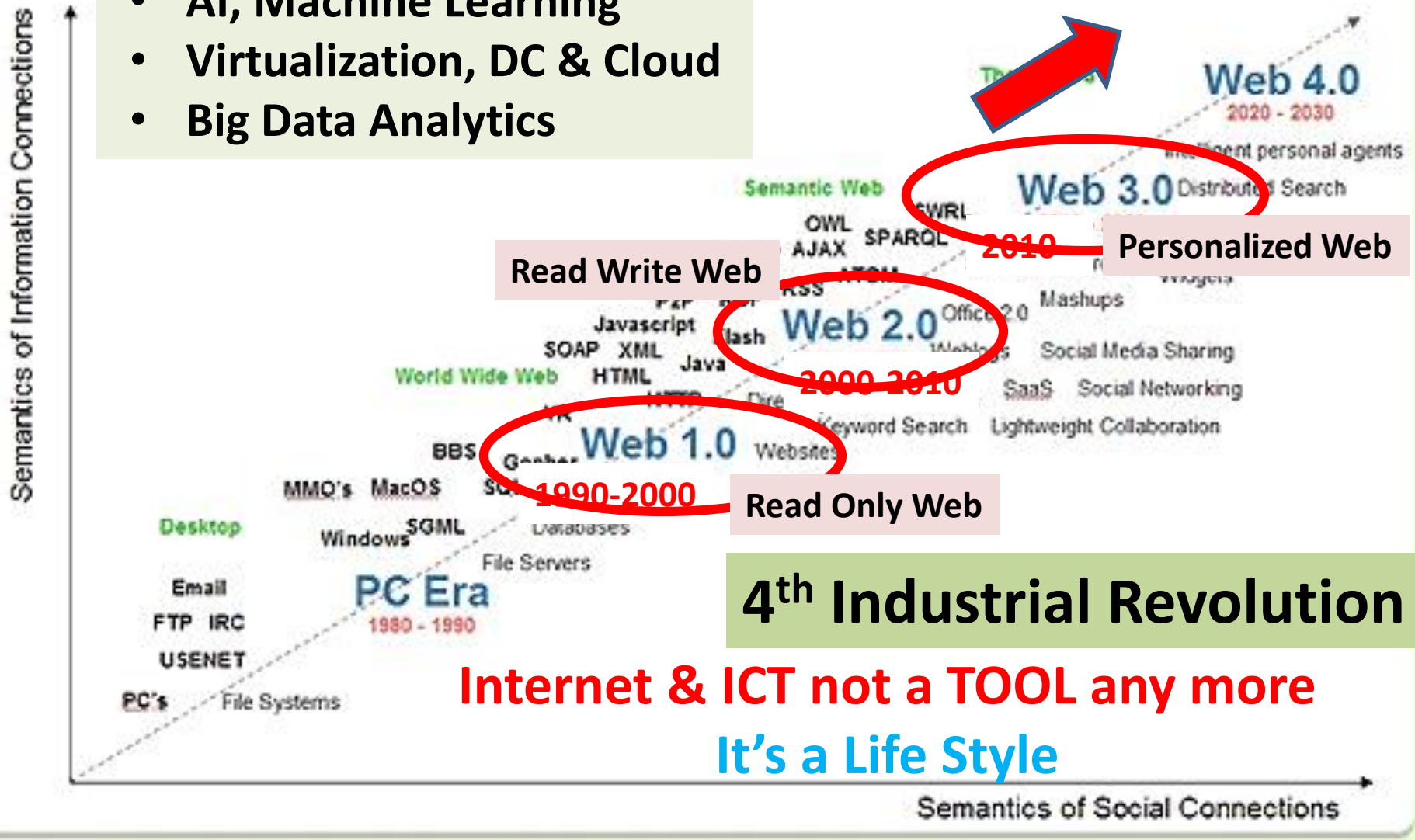
Evolution of the Internet & Technologies

- Mobile Broadband – 5G
- AI, Machine Learning
- Virtualization, DC & Cloud
- Big Data Analytics



4th Industrial Revolution

Internet & ICT not a TOOL any more

It's a Life Style

Source: Radar Networks & Nova Spivack, 2007 – www.radarnetworks.com

Telecommunications System

3 Basic segments:

1. Access Network (telephone & pair of wires/air)
2. Local Exchange/Switching
3. Transport Network/Transmission (carry signal between exchanges)

Core Network

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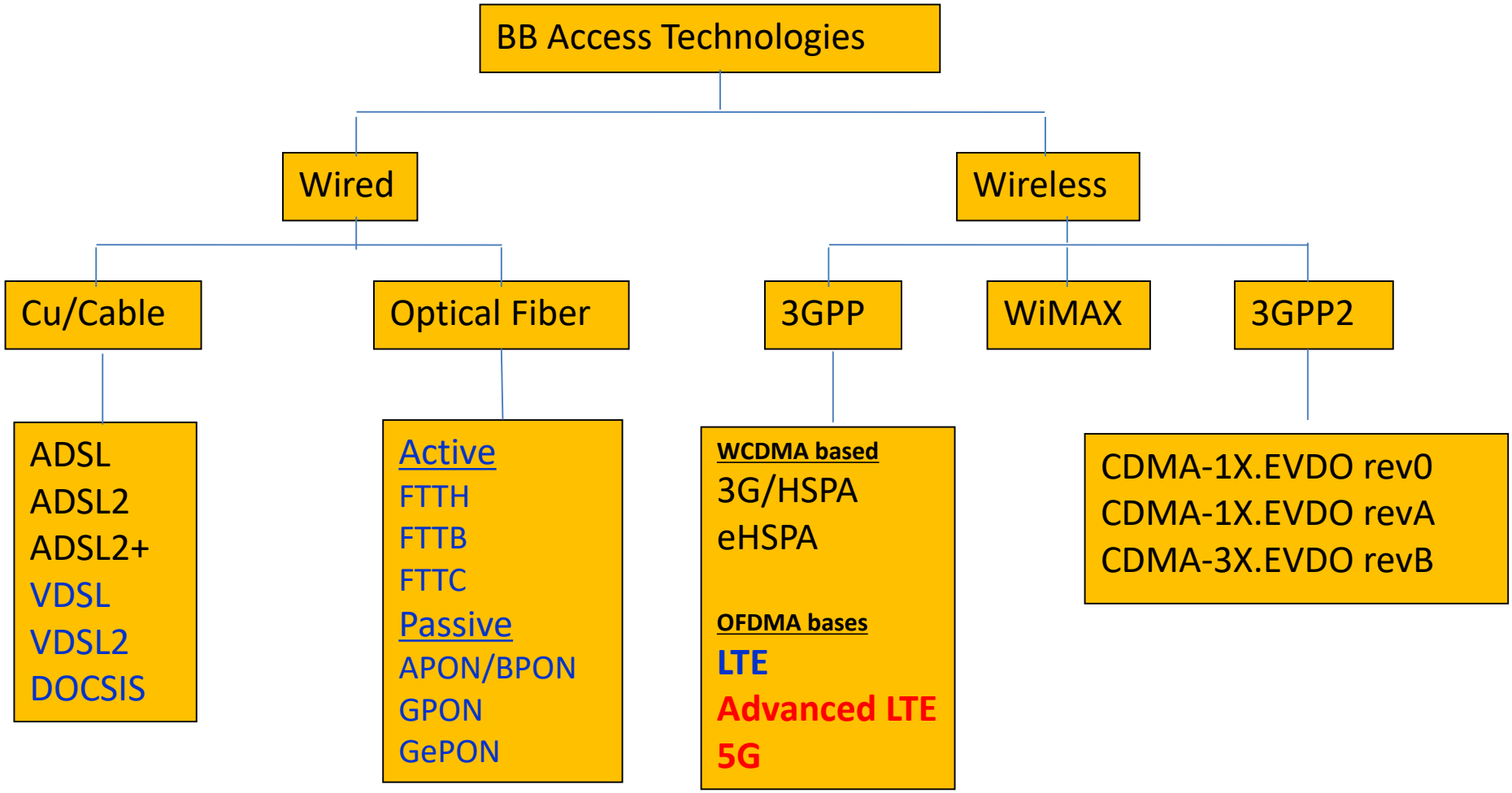
Access Technologies



DOCSIS-Data Over Cable Service Interface Specification
LTE- Long Term Evolution
HSPA - High Speed Packet Access

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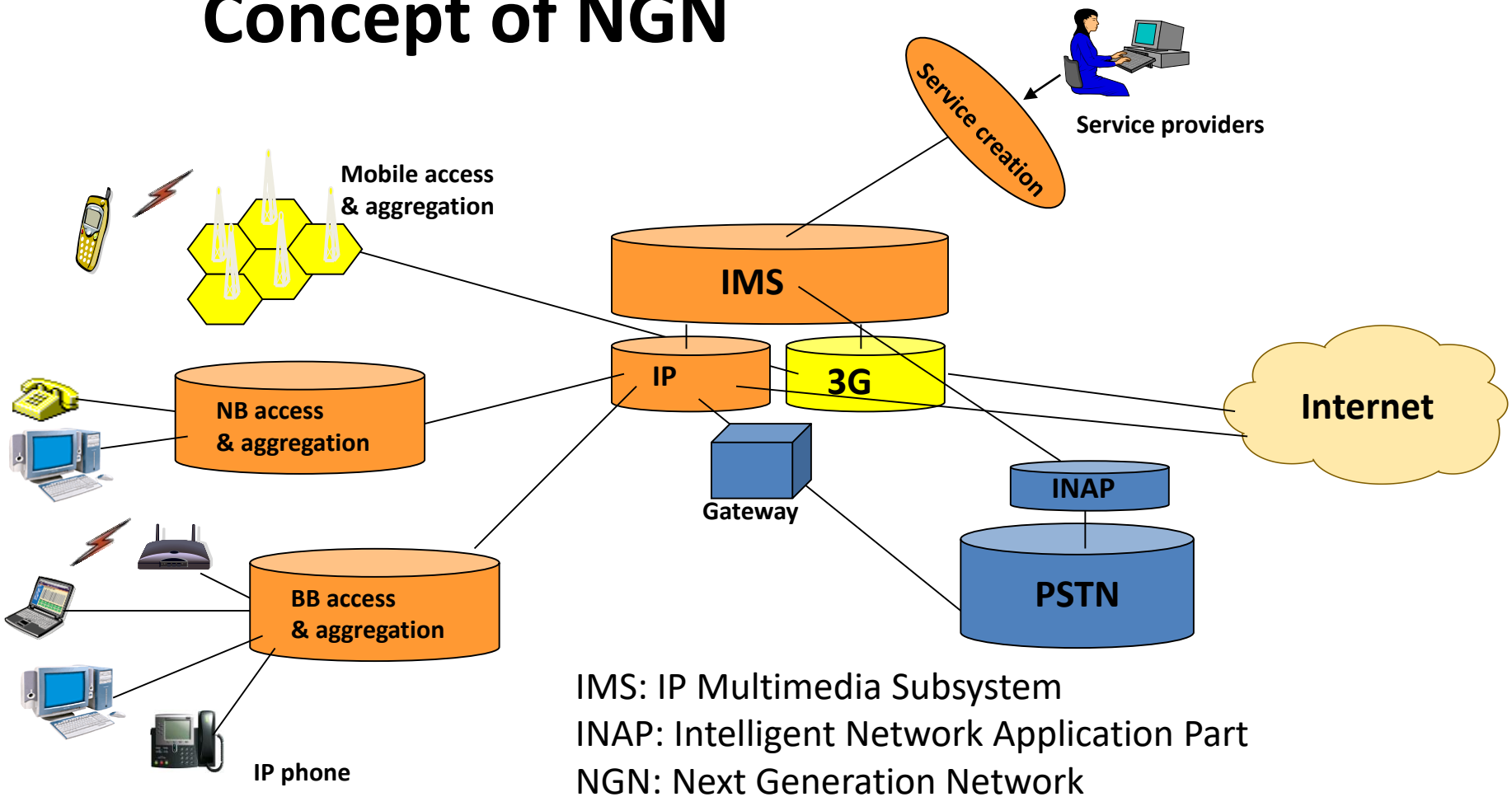
Concept of NGN

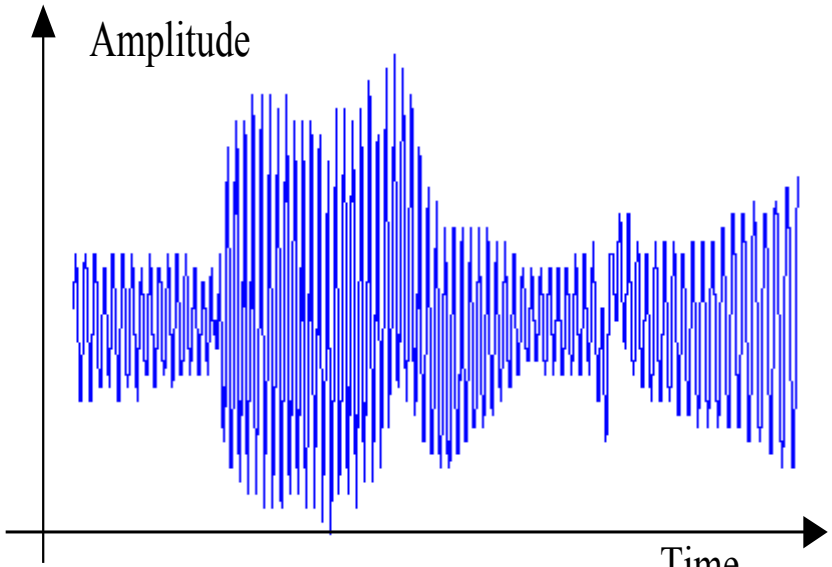


IMS: IP Multimedia Subsystem
INAP: Intelligent Network Application Part
NGN: Next Generation Network

Basic Concepts & Terminologies of Telecommunications

Signals

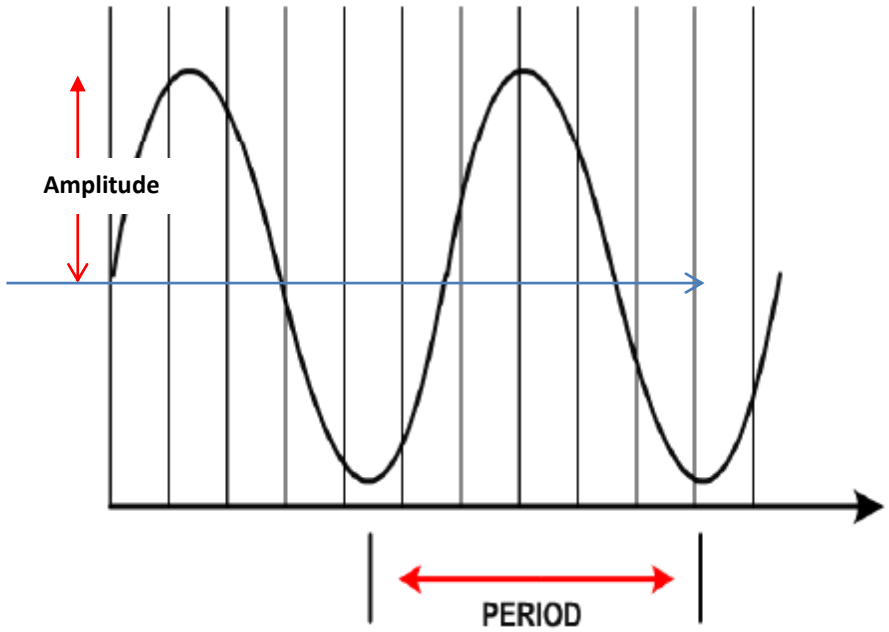
- In telecommunications, information is carried by signals
- Time-varying electrical or electromagnetic waveforms
- Carry information from source to destination



A speech waveform

Parameters of Waves

- **Amplitude** — The distance from zero to the maximum value of each alternation is called the amplitude.
- **Period** — The time it takes for a sine wave to complete one cycle is defined as the period of the waveform.



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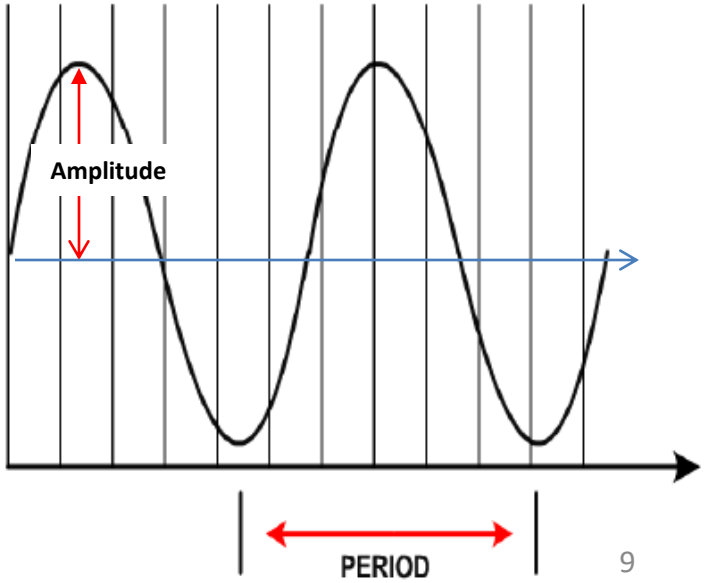
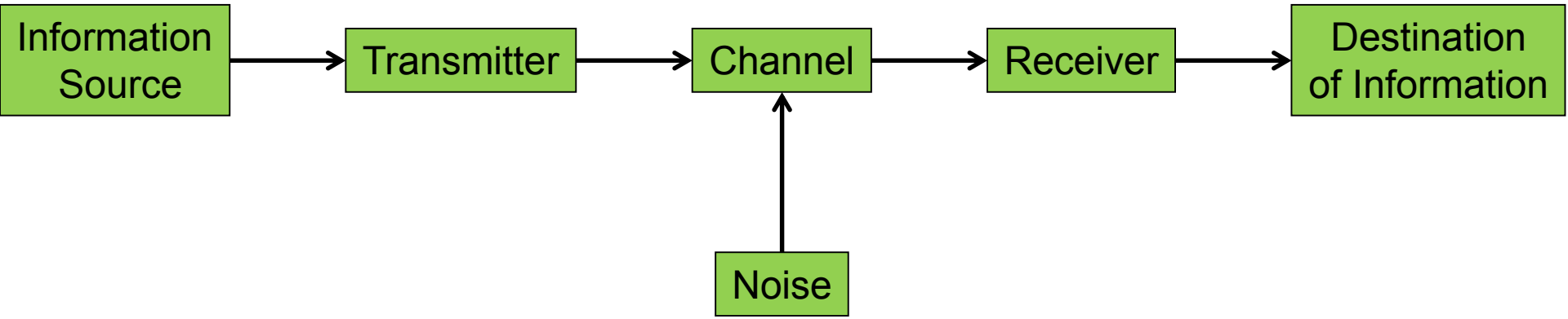
Parameters of Waves

- **Wavelength:**
  - Distance traveled by a sine wave during its period
  - Indicated by symbol λ

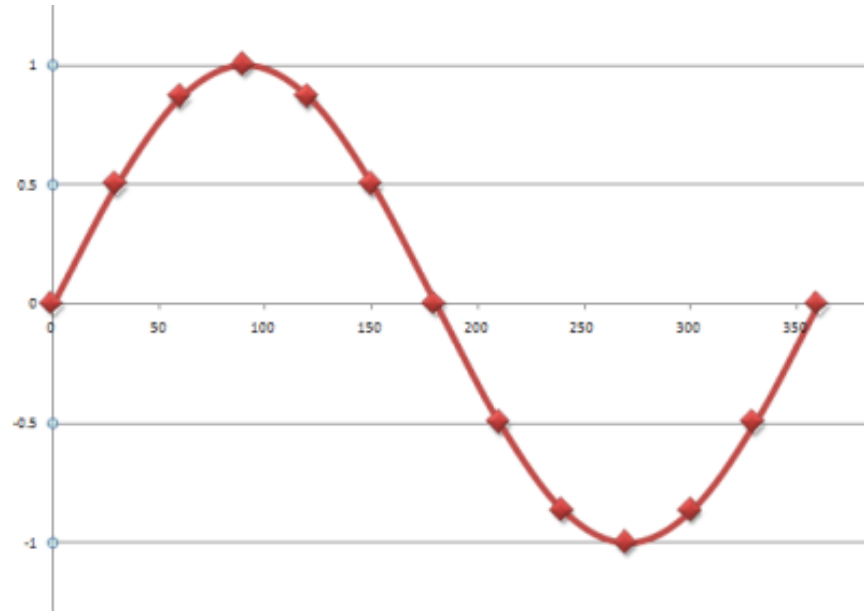
- **Frequency:**
  - Number of repetitions or cycles per unit time is the frequency
  - typically expressed in cycles per second, or Hz



Telecommunication System

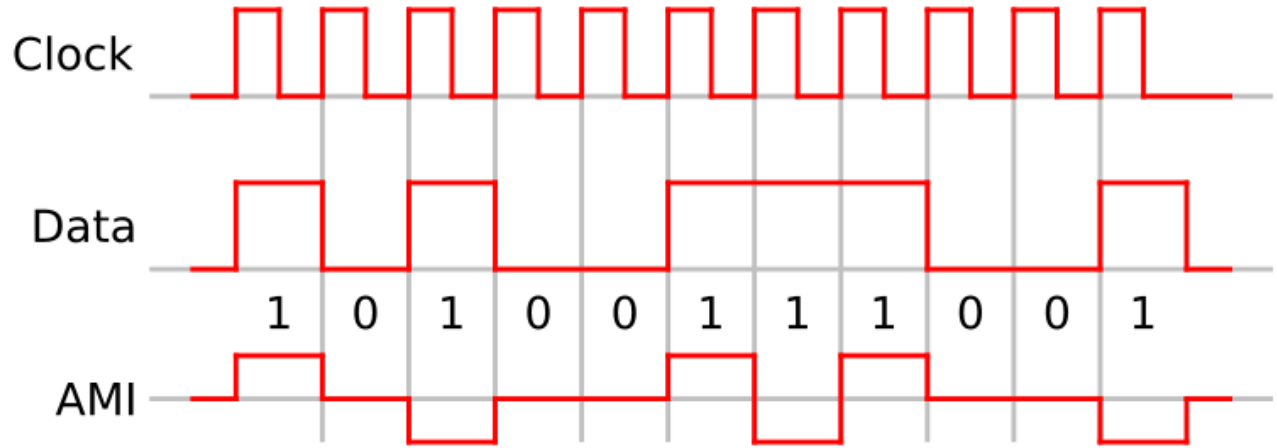


Analog Vs. Digital

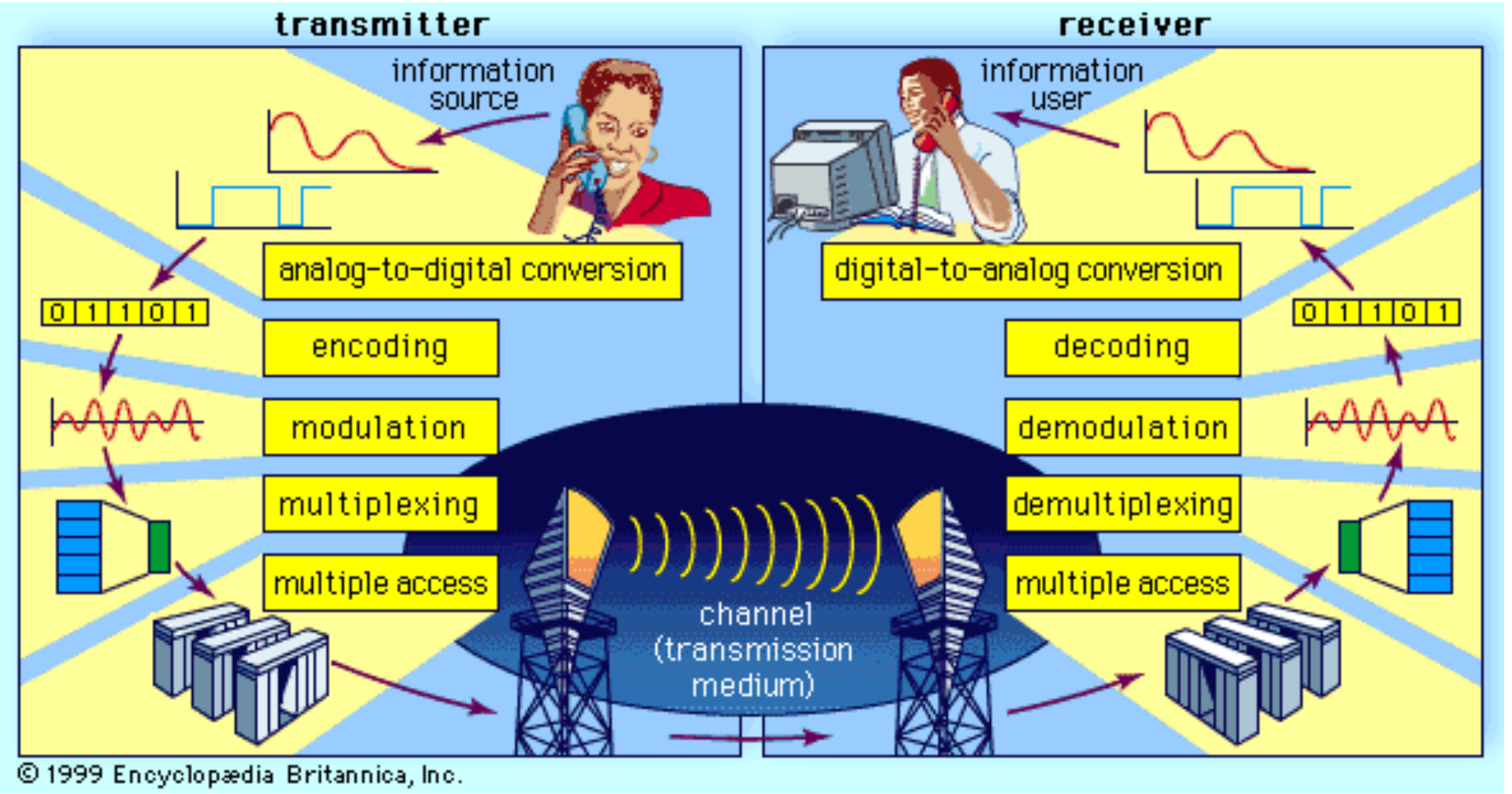


Analog

Digital



Main Functions of Transmitter & Receiver



LOS and NLOS Situations

- Transmission path between sender and receiver could be
  - Line-of-Sight (LOS)
  - Obstructed by buildings, mountains and foliage (NLOS)
- Even speed of motion effects the fading characteristics of the channel

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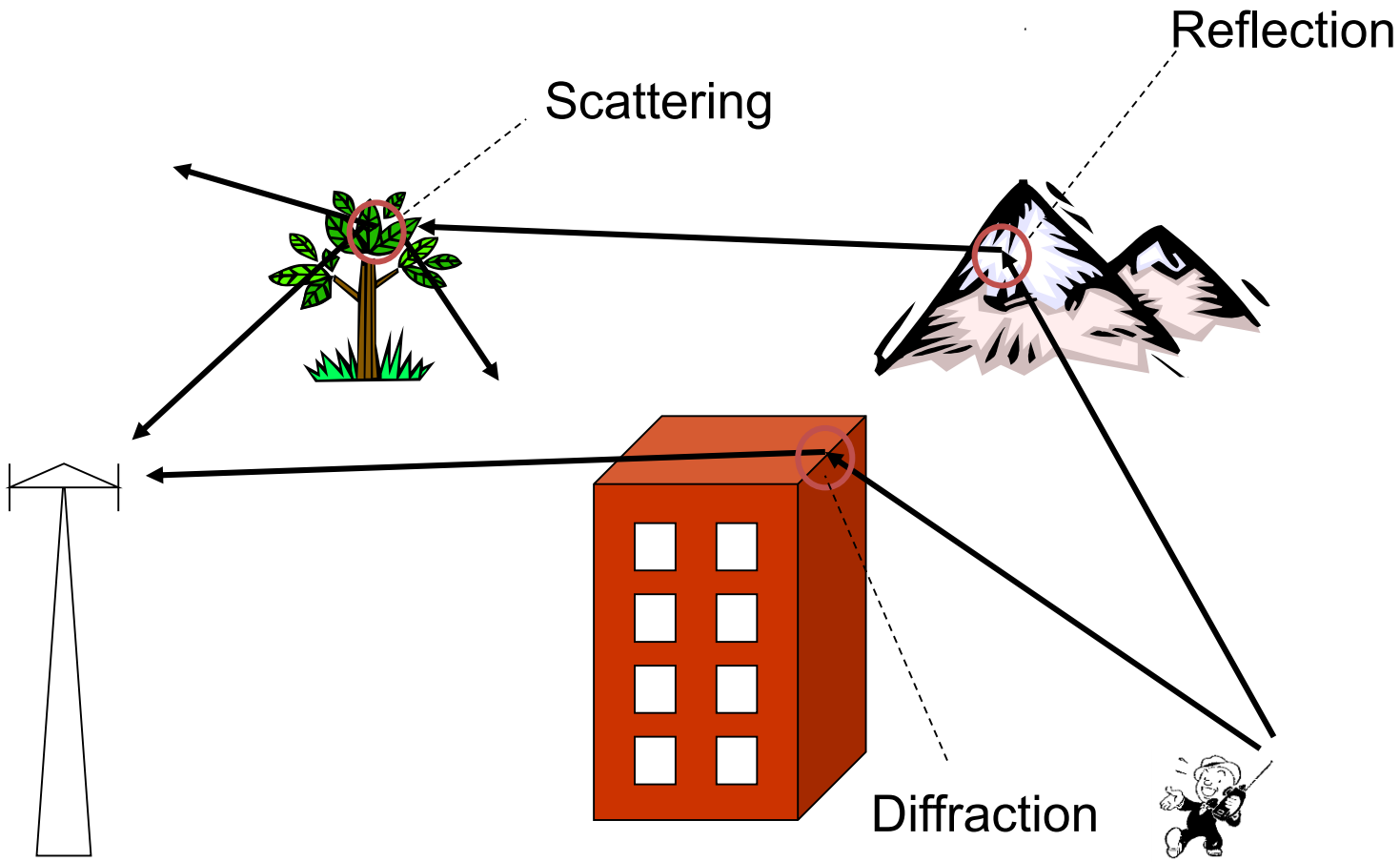
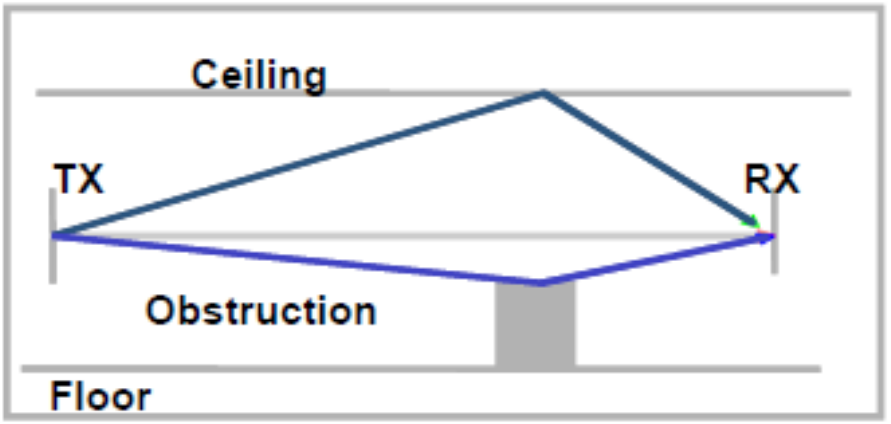
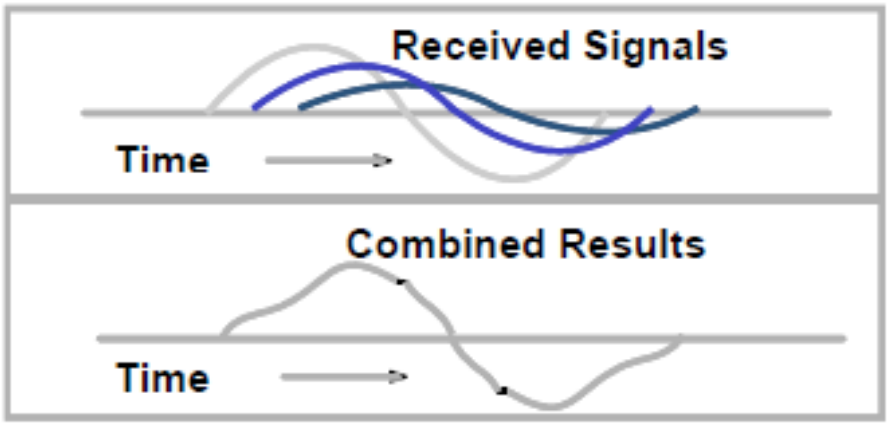
Radio Propagation Mechanisms



Multi Path Distortion

- Occurs when an RF signal has more than one path between a receiver transmitter
- When RF takes more than one path
  - Multiple signals cause distortion of the signal
  - Can cause high signal strength, yet low signal quality





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Modulation

Carrier Frequency:

- A carrier frequency is an electromagnetic wave that can combine with the information signal and carry it across the communications channel

Modulation:

- Process of varying a parameter of a **carrier** in accordance with *message* (baseband)

MODEM: **MO**dulation + **DEM**odulation

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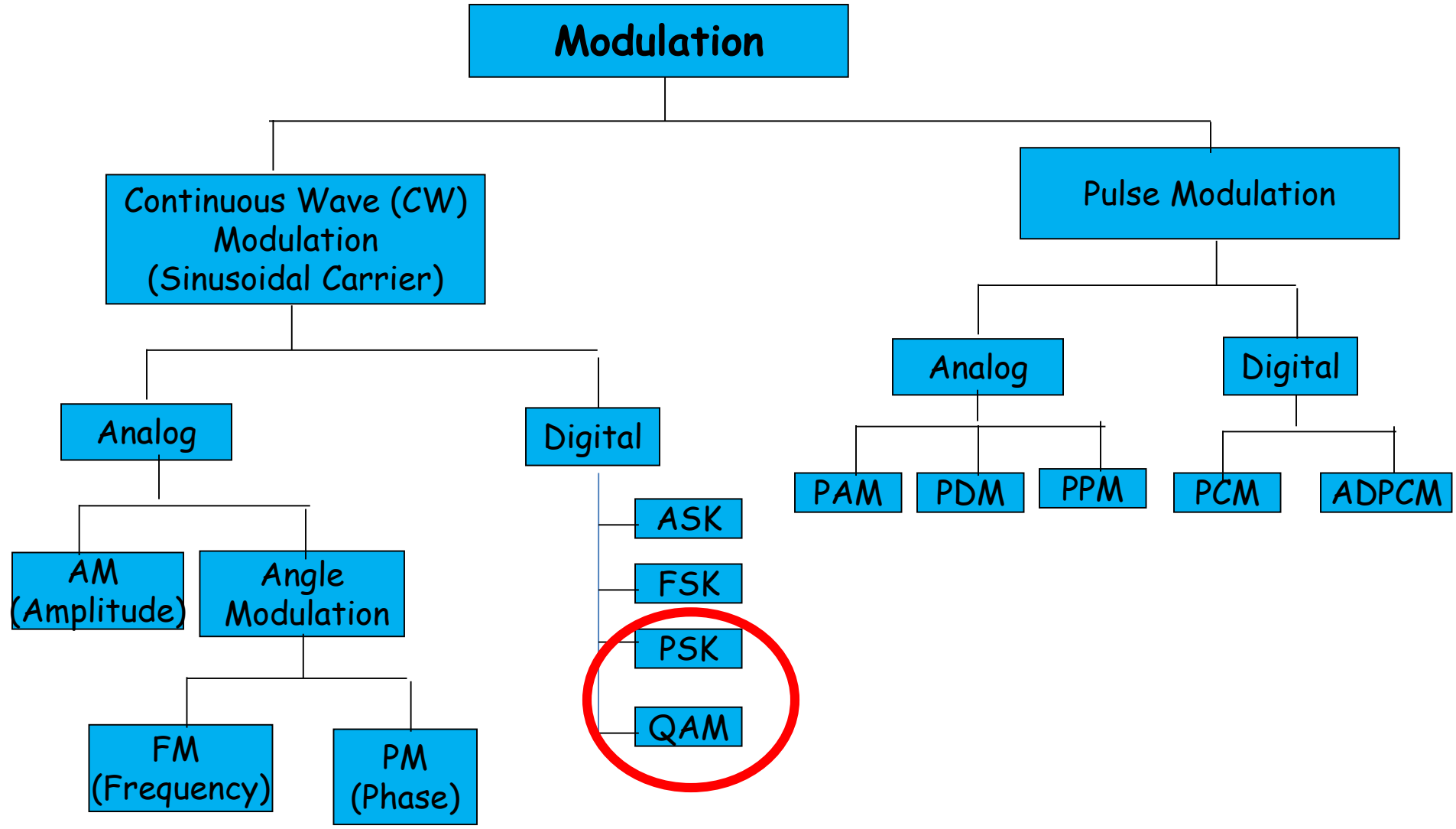
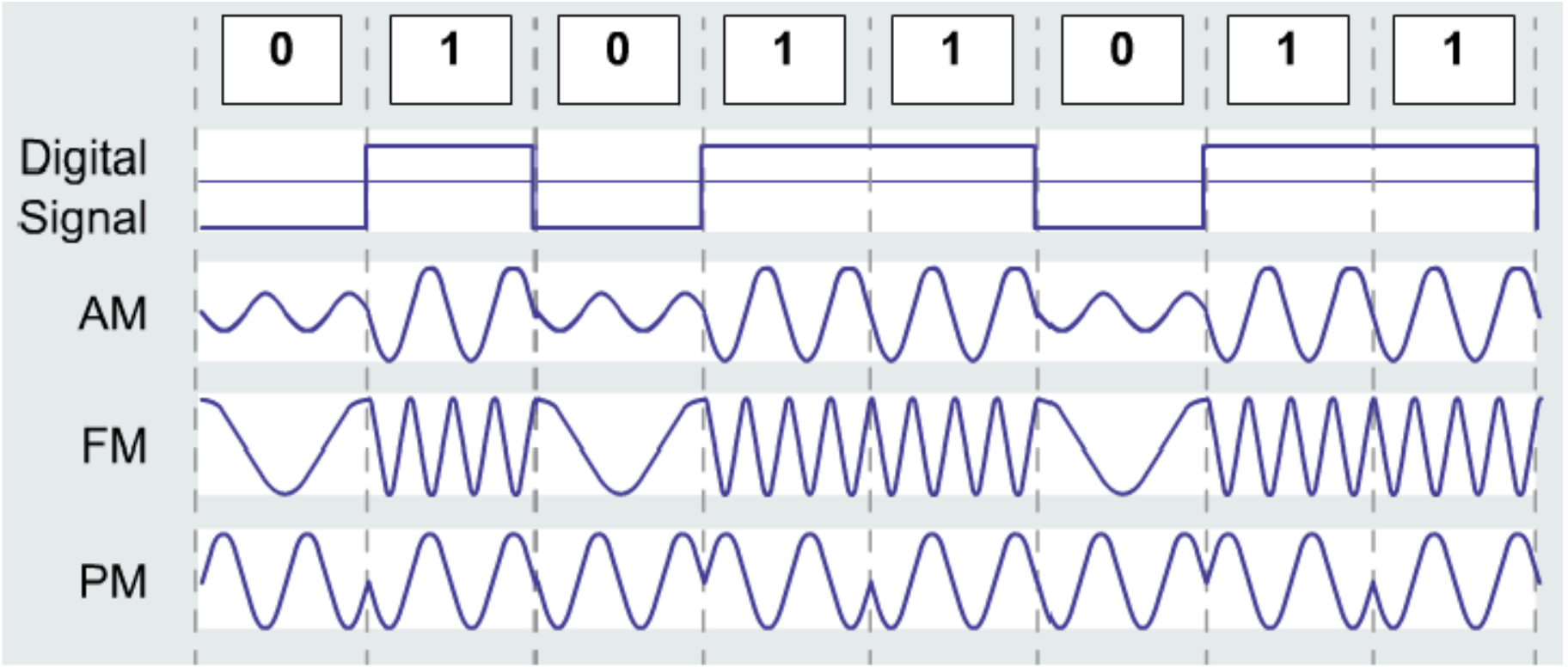
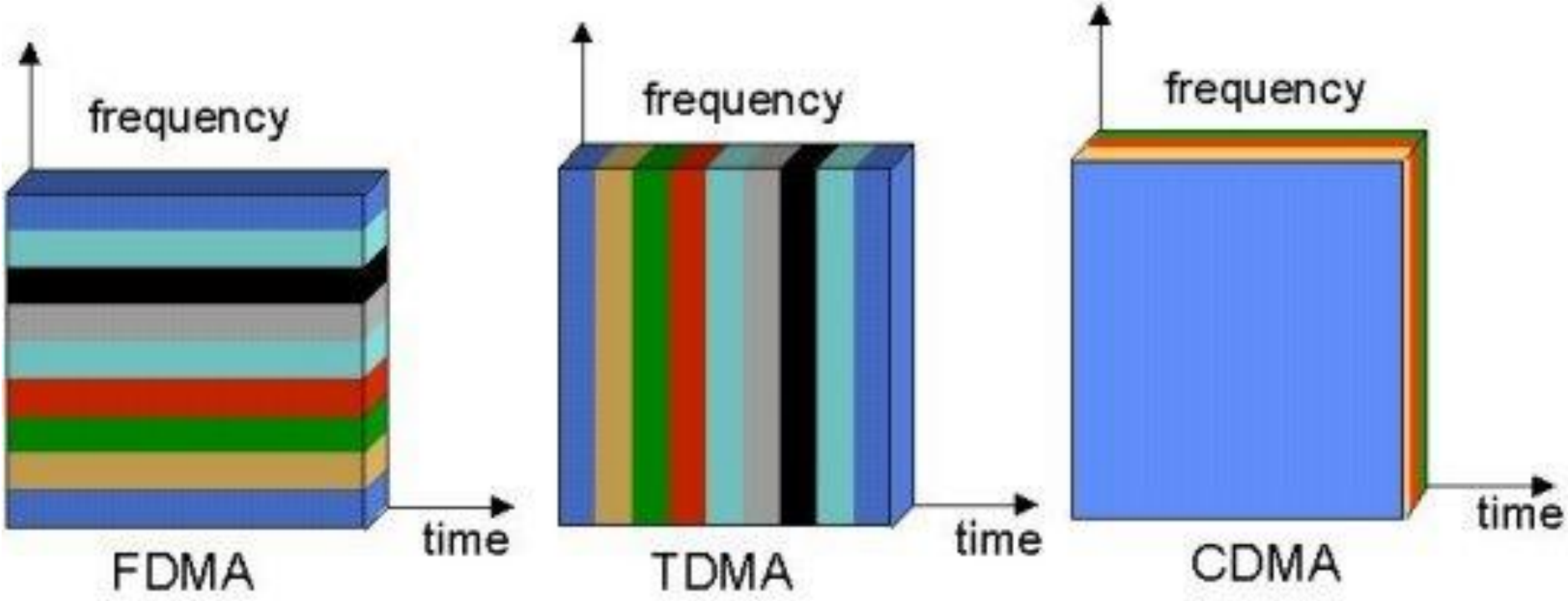
Modulation Techniques



Some Examples



Multiple Access Methods



Multiple Access Techniques

- **Time Division Multiple Access (TDMA)** — Each device can use the entire available spectrum in the cell, but only for a short period of time.
- **Frequency Division Multiple Access (FDMA)** — Each device can use a portion of the available spectrum, for as long as the device needs to, while in the cell.
- **Code Division Multiple Access (CDMA)** — Each device can use entire available spectrum all the time; Therefore considered as broadband

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Orthogonal Frequency Division Multiple Access (OFDMA)

Characteristics of OFDMA (Multi Carrier)

Strong points

- Suitable for broadband communications
  - Robust against multipath propagation
- Efficient use of frequency bandwidth
- Can be modulated using FFT/IFFT

Tradeoffs

- Sensitive for frequency and time offsets
- Peak to Average Power Ratio

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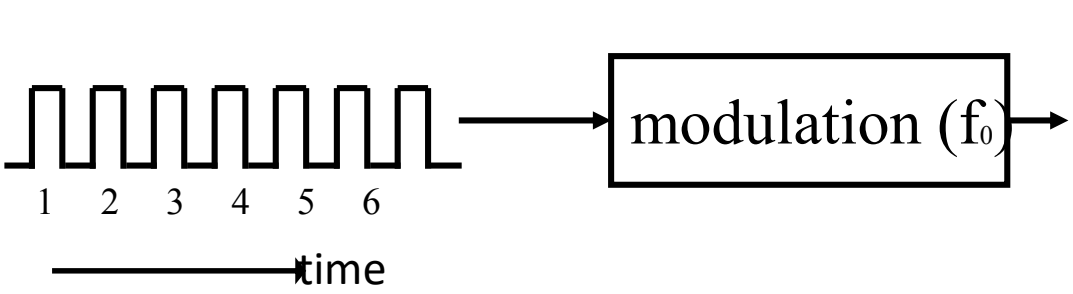
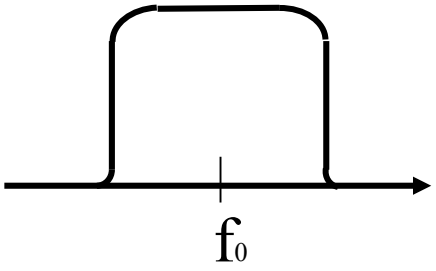
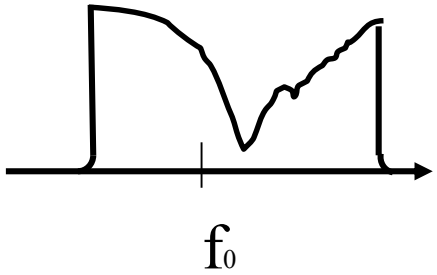
Robust Against Multipath Propagation 1/2

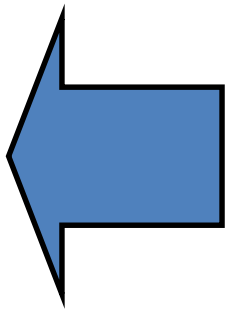
Single carrier







Loose all Information

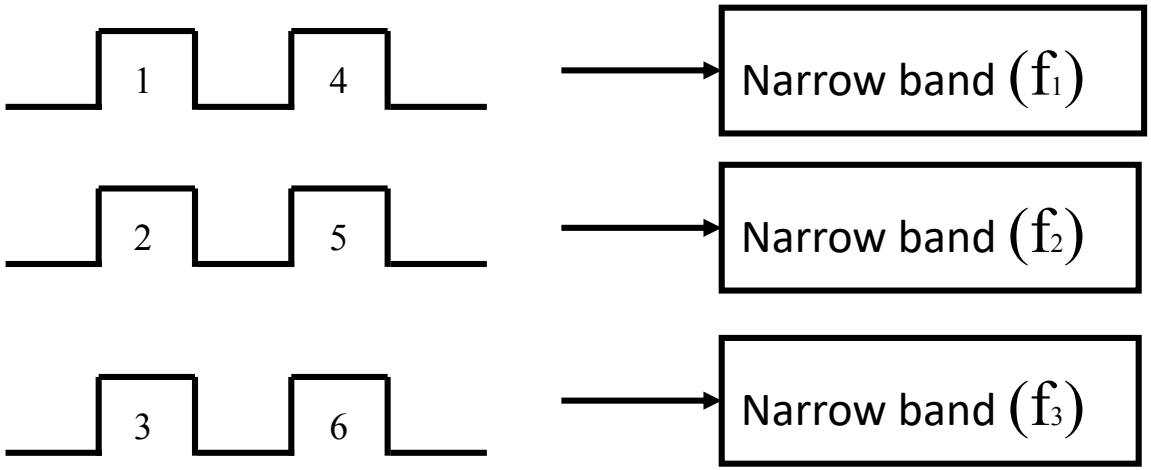


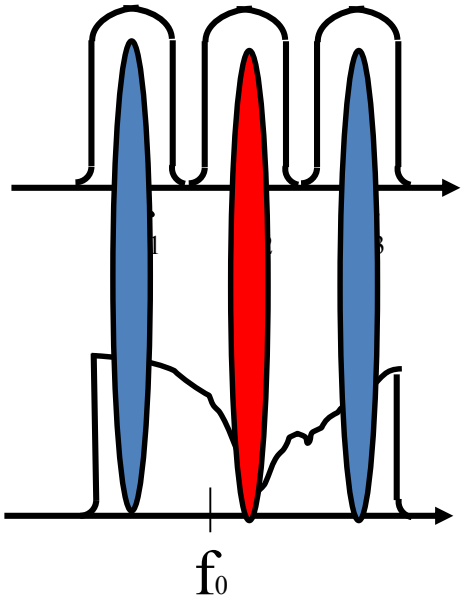
Frequency response for a multipath propagation environment

Robust against multipath propagation 2/2

OFDM is a multicarrier modulation system

Multicarrier

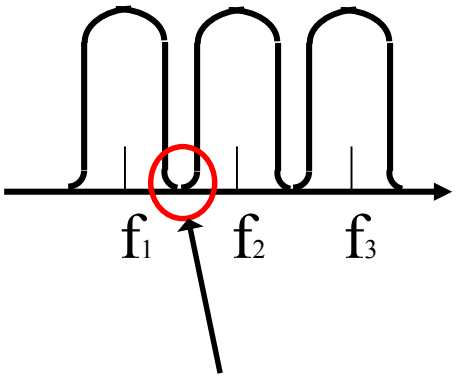




Frequency response for a multipath propagation environment

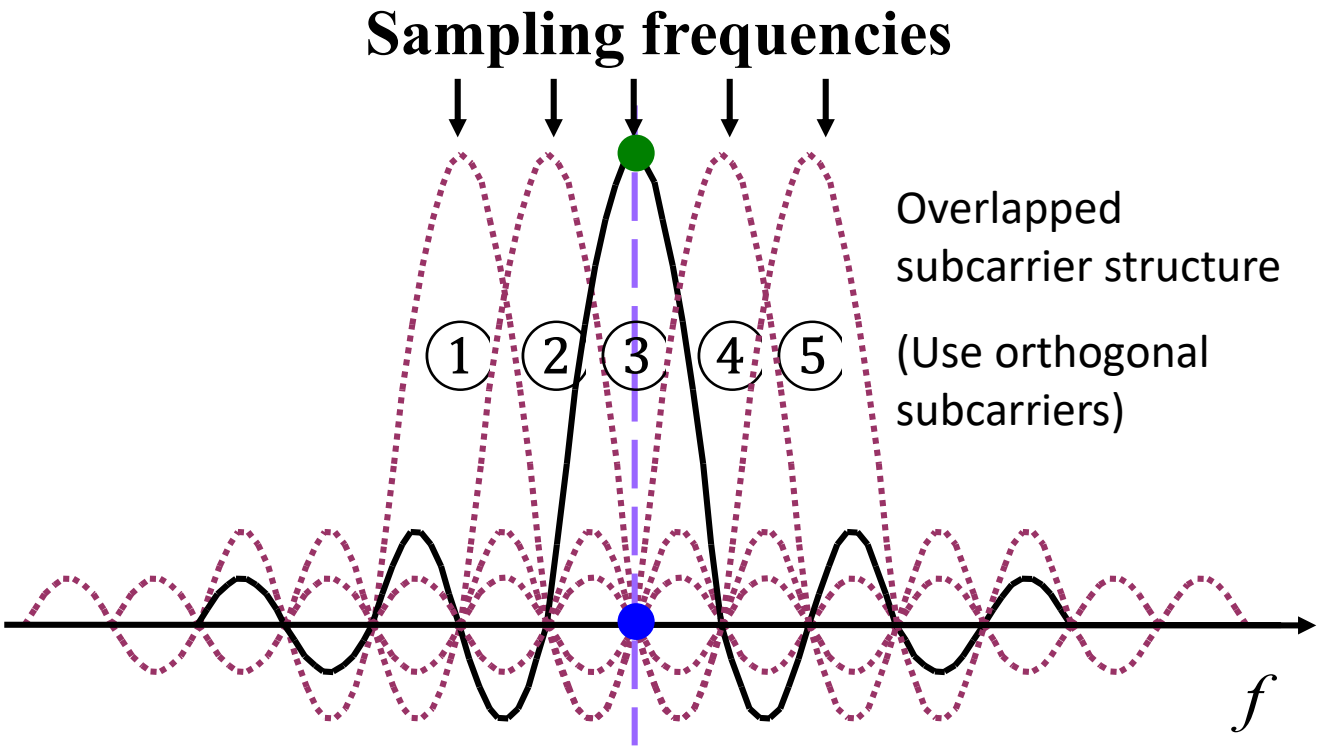
Efficient Use of Bandwidth

Multi carrier



Inefficient use of frequency

OFDM



No Inter Carrier Interference

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Multiple Access Methods

Full Spectrum of Operator- Divided into smaller Channels of 200kHz in GSM

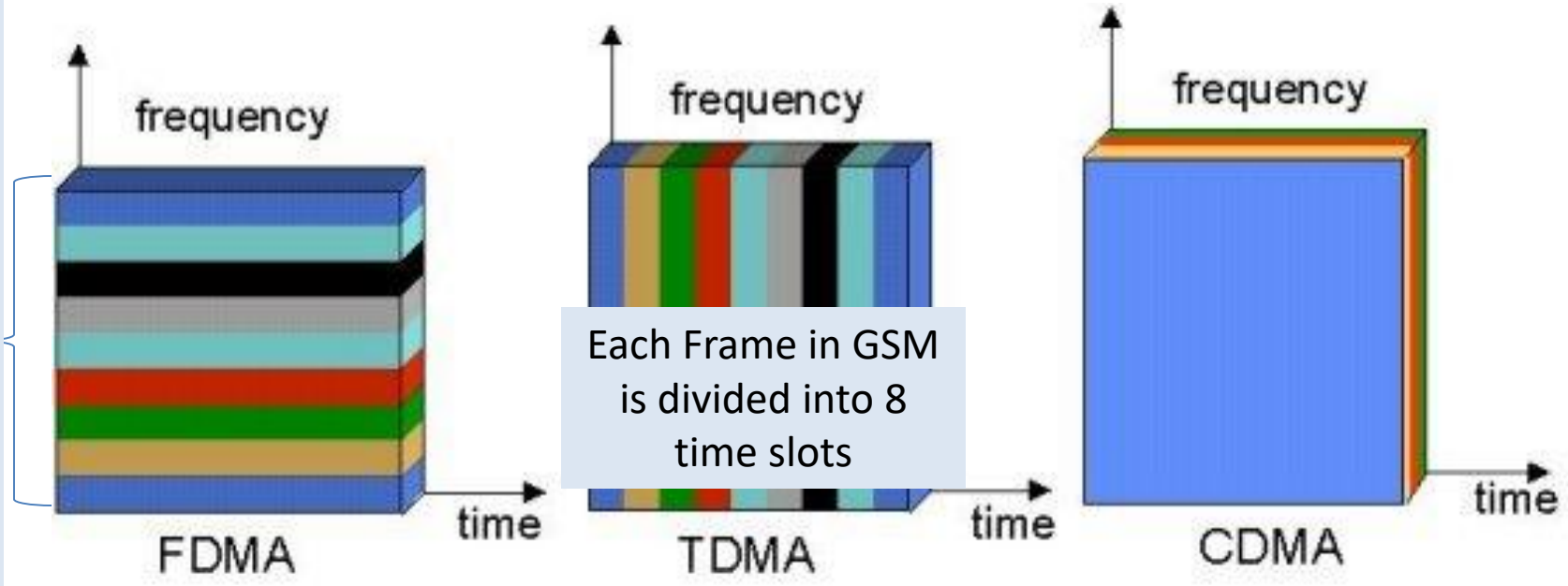

Fig. 3 Multiple Access Methods – FDMA, TDMA, and CDMA

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Mobile Radio Systems

- Examples
  - Cordless phone
  - Remote controller
  - Hand-held walkie-talkies
  - Pagers
  - Cellular telephone
  - Wireless LAN
- Mobile - any radio terminal that could be moved during operation
- Portable - hand-held and used at walking speed
- Subscriber - mobile or portable user

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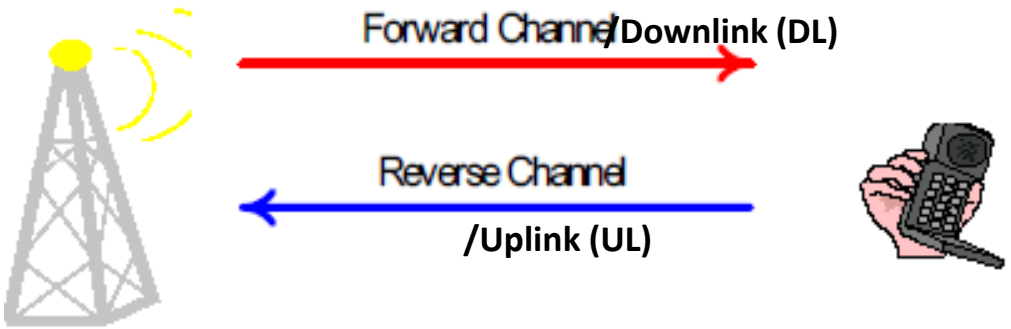
Mobile Radio Systems

- Classification of mobile radio transmission system
  - Simplex:
    - communication in only one direction
  - Half-duplex:
    - same radio channel for both transmission and reception (walkie-talkie)
  - Full-duplex:
    - simultaneous radio transmission and reception (FDD, TDD)



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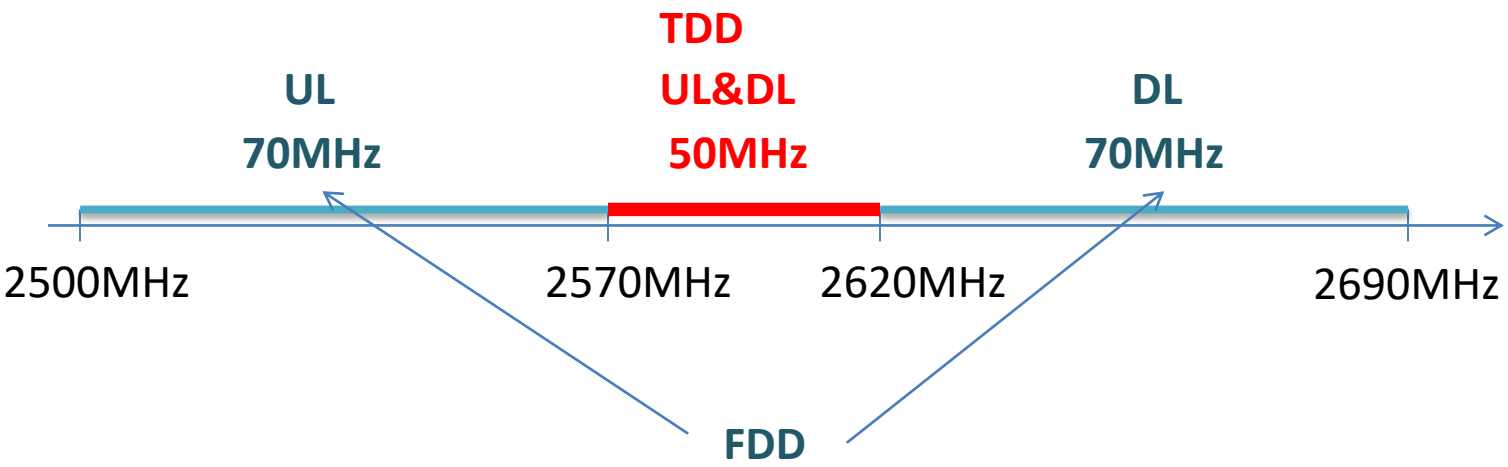
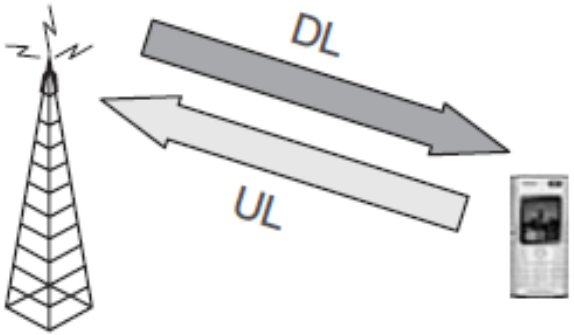
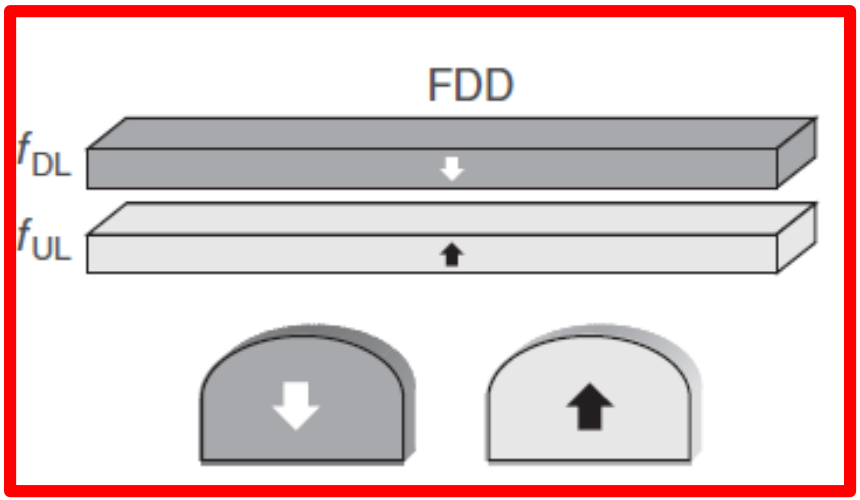
FDD vs. TDD

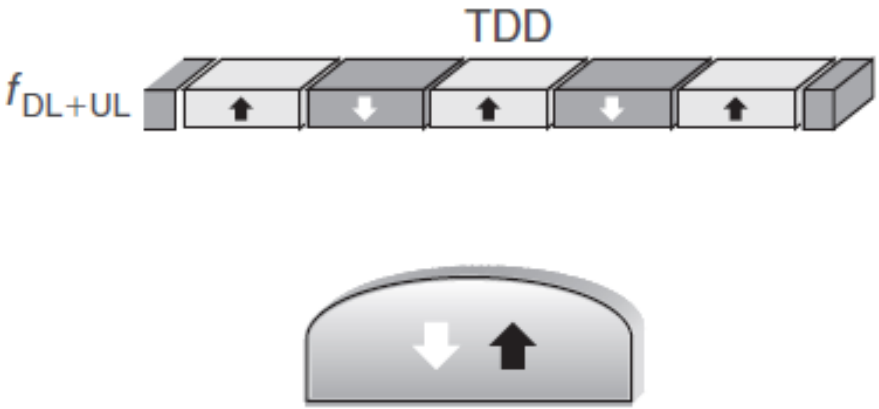
- Frequency Division Duplexing (FDD) uses two radio channel
  - Forward channel: base station to mobile user
  - Reverse channel: mobile user to base station
- Time Division Duplexing (TDD) shares a single radio channel in time



FDD vs. TDD

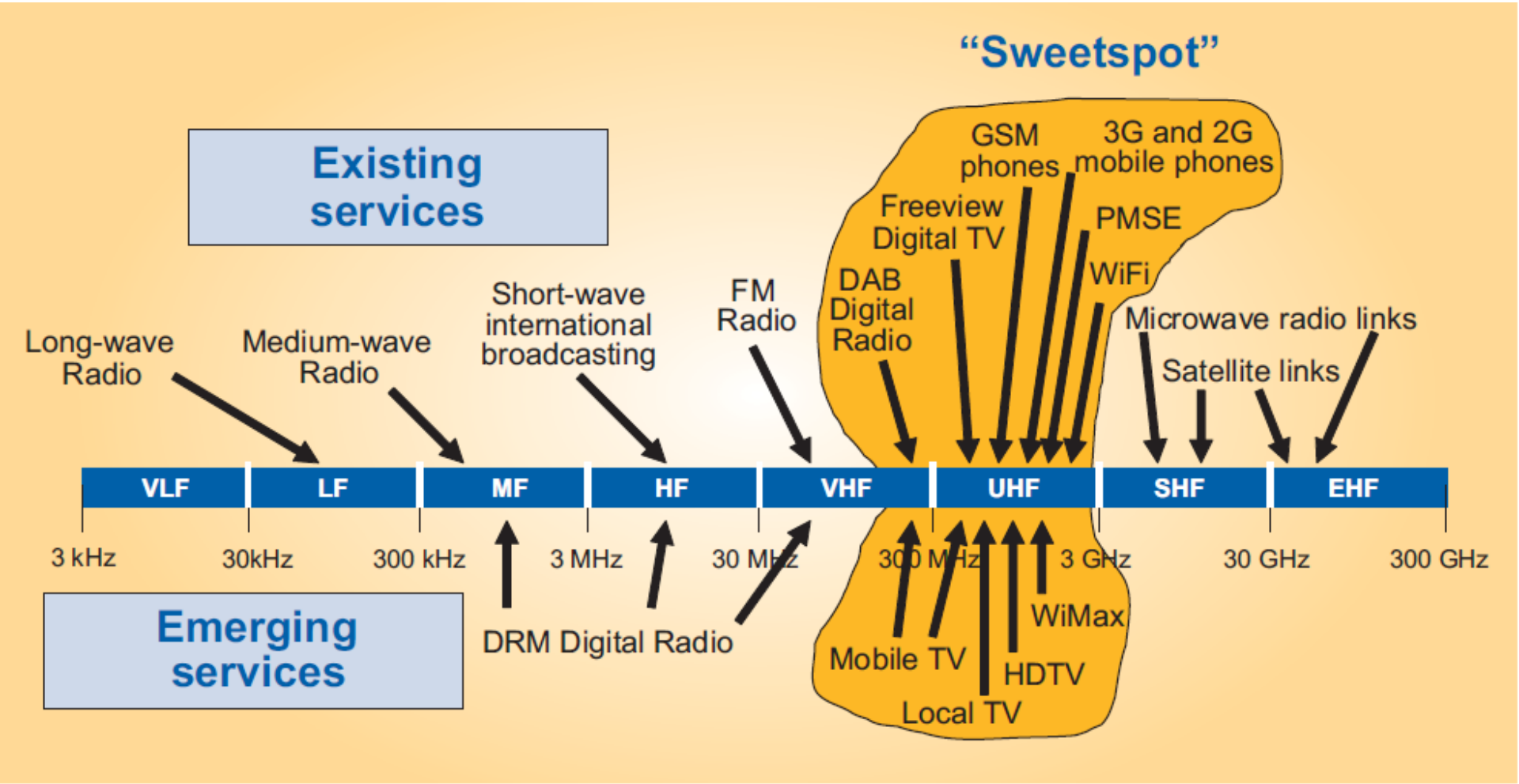






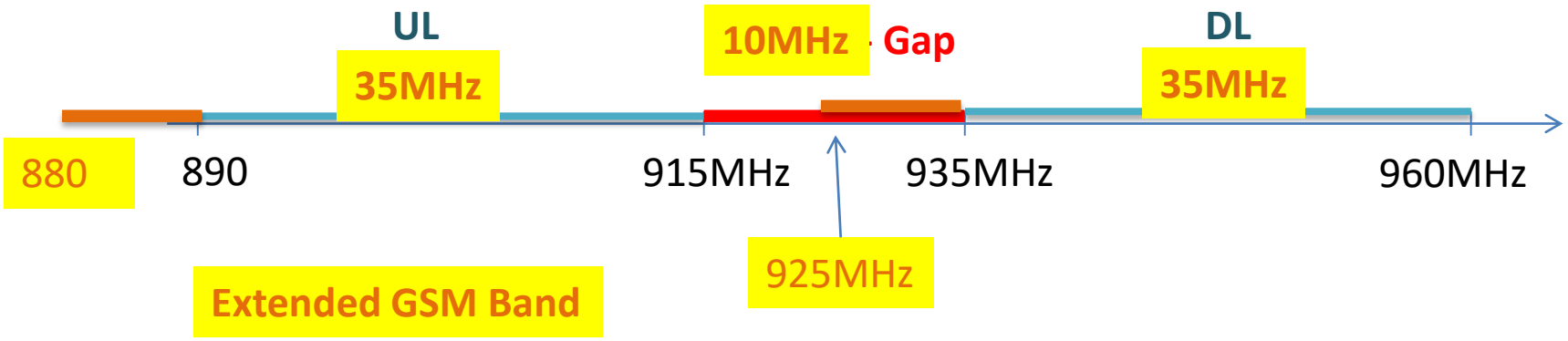
Spectrum

Emerging Services on EM Spectrum

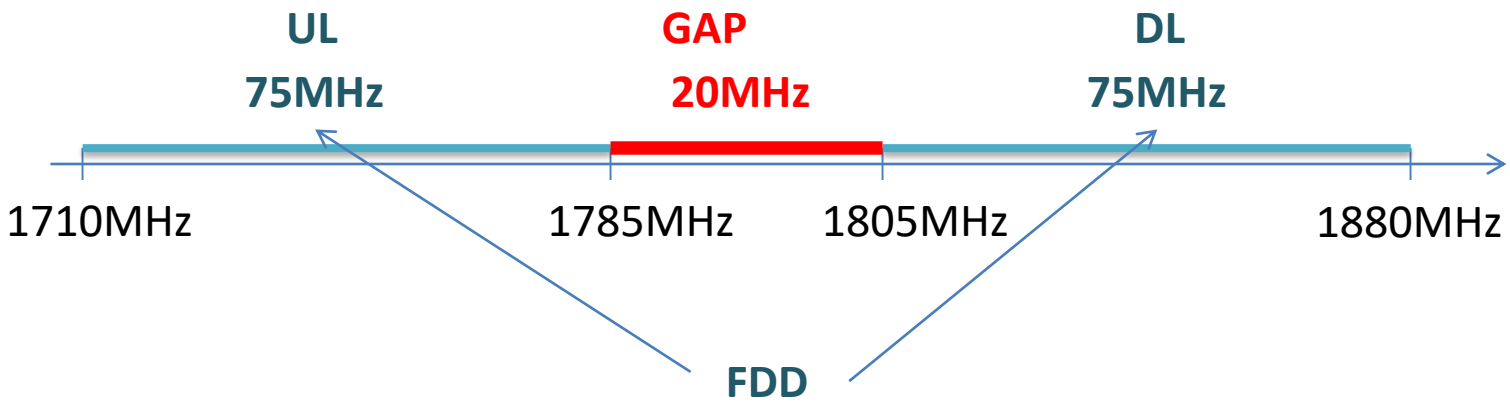


Spectrum Used in Sri Lanka

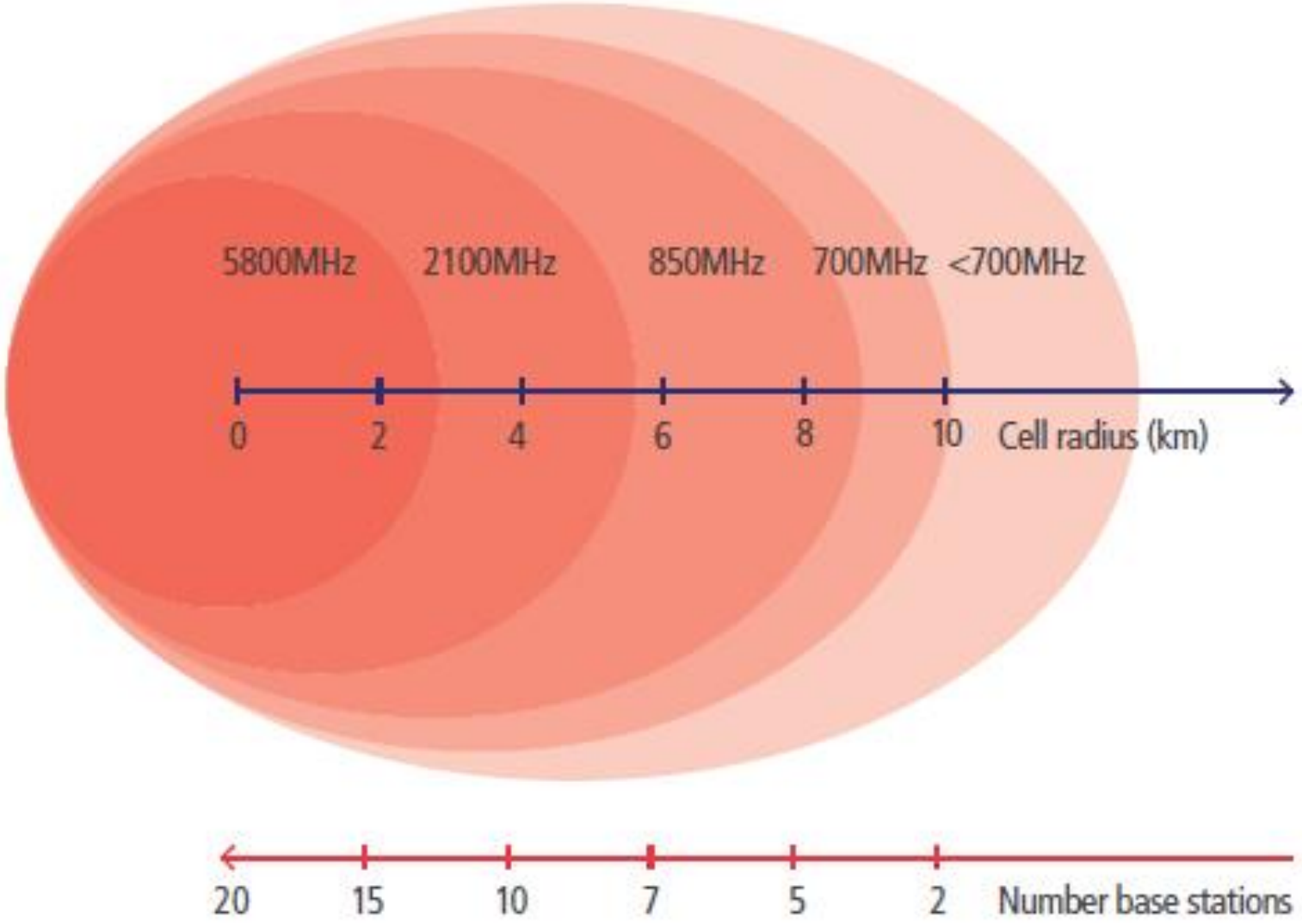
- **GSM 900 Band – (FDD)**



- **1800 Band – (FDD)**

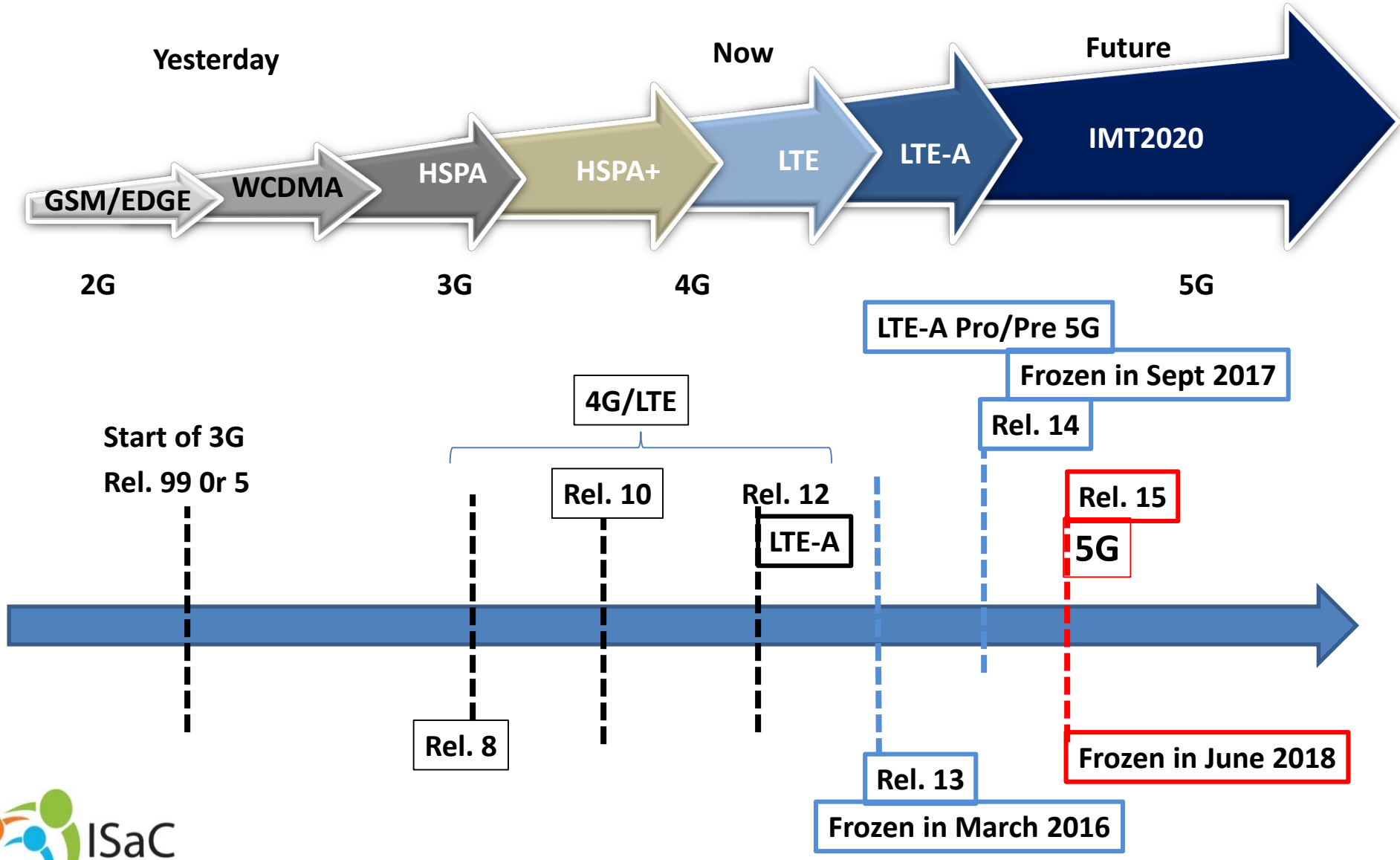


Importance of Profile of Spectrum

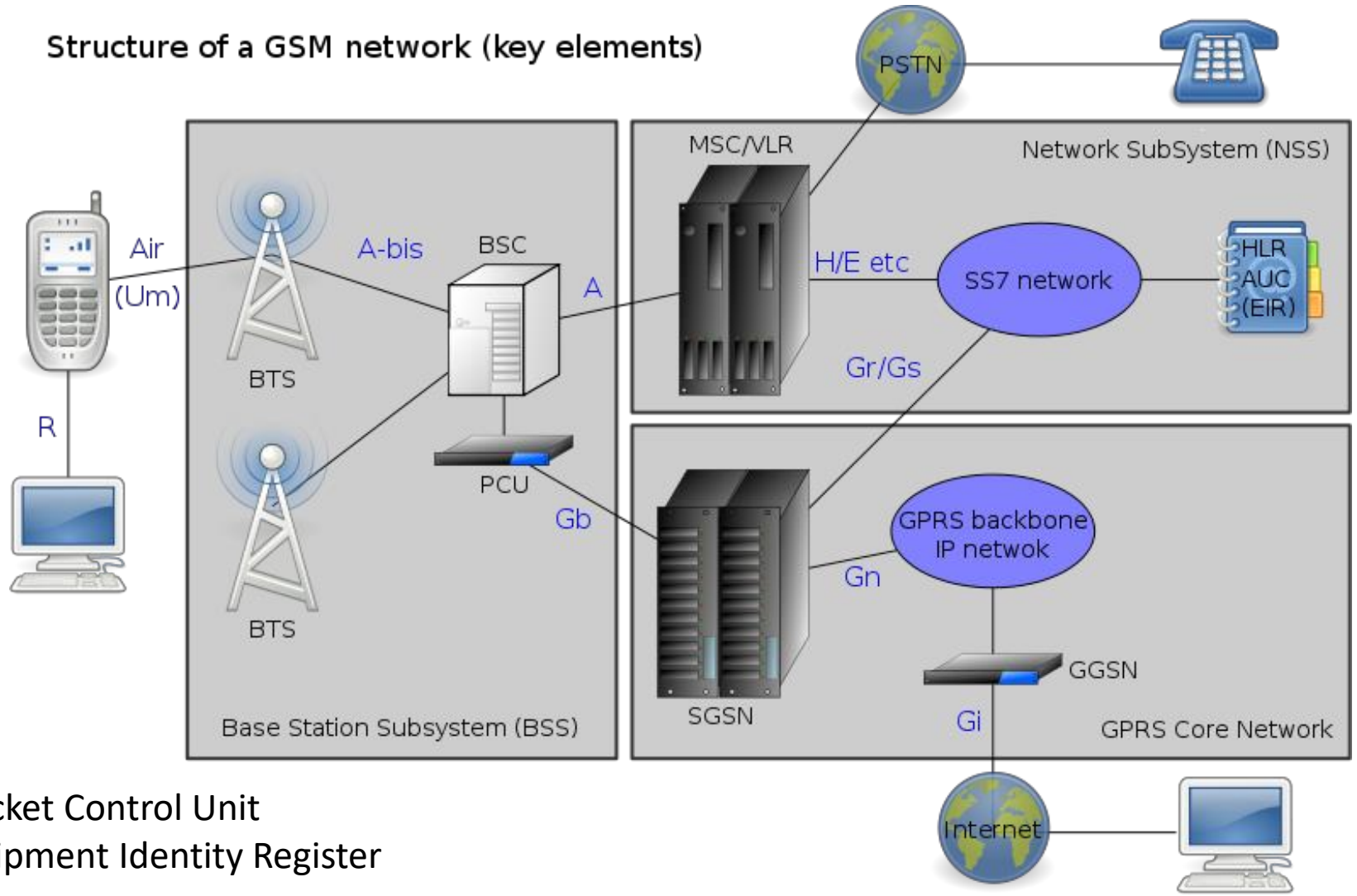


Source: BBC R&D, SFC Associates "The Mobile Provide"

Evolution of Mobile Communications - up to 5G

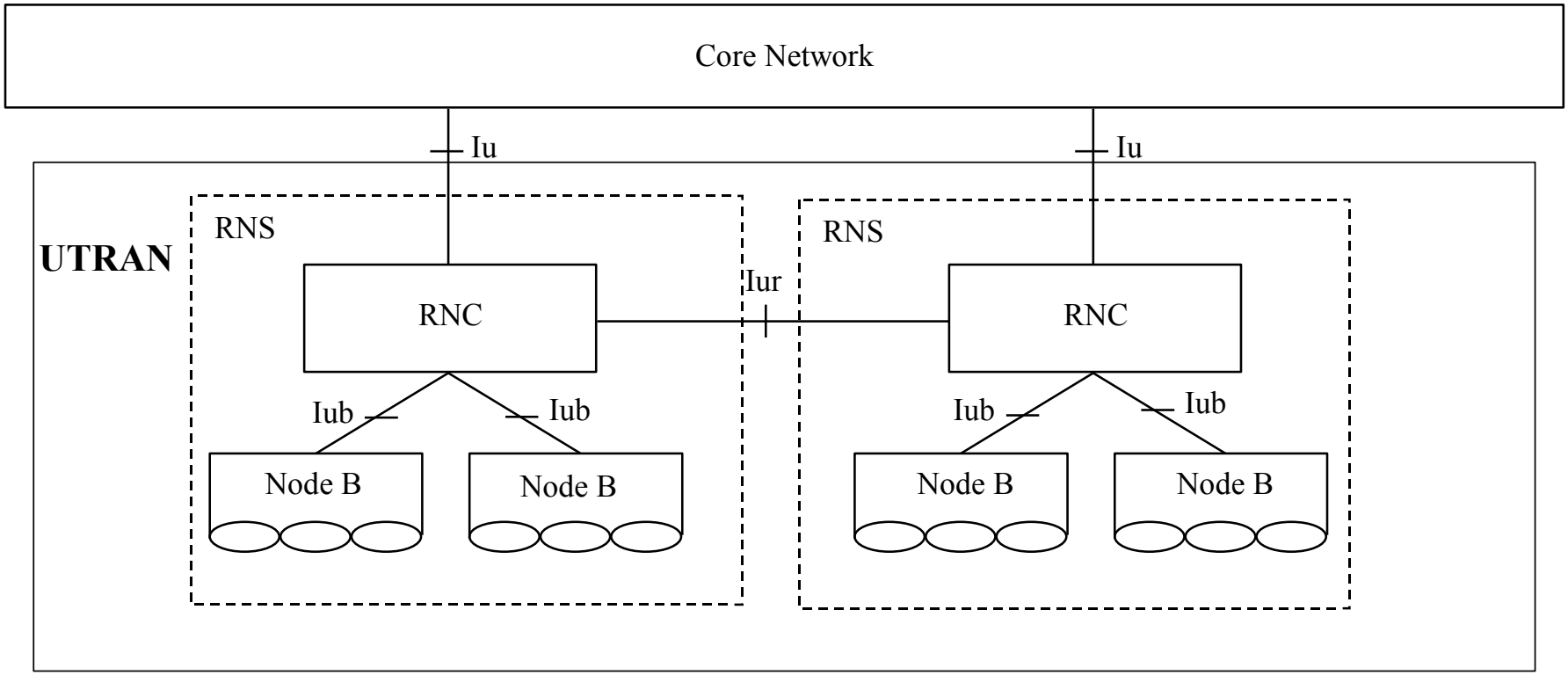


GSM Architecture



PCU – Packet Control Unit
EIR – Equipment Identity Register

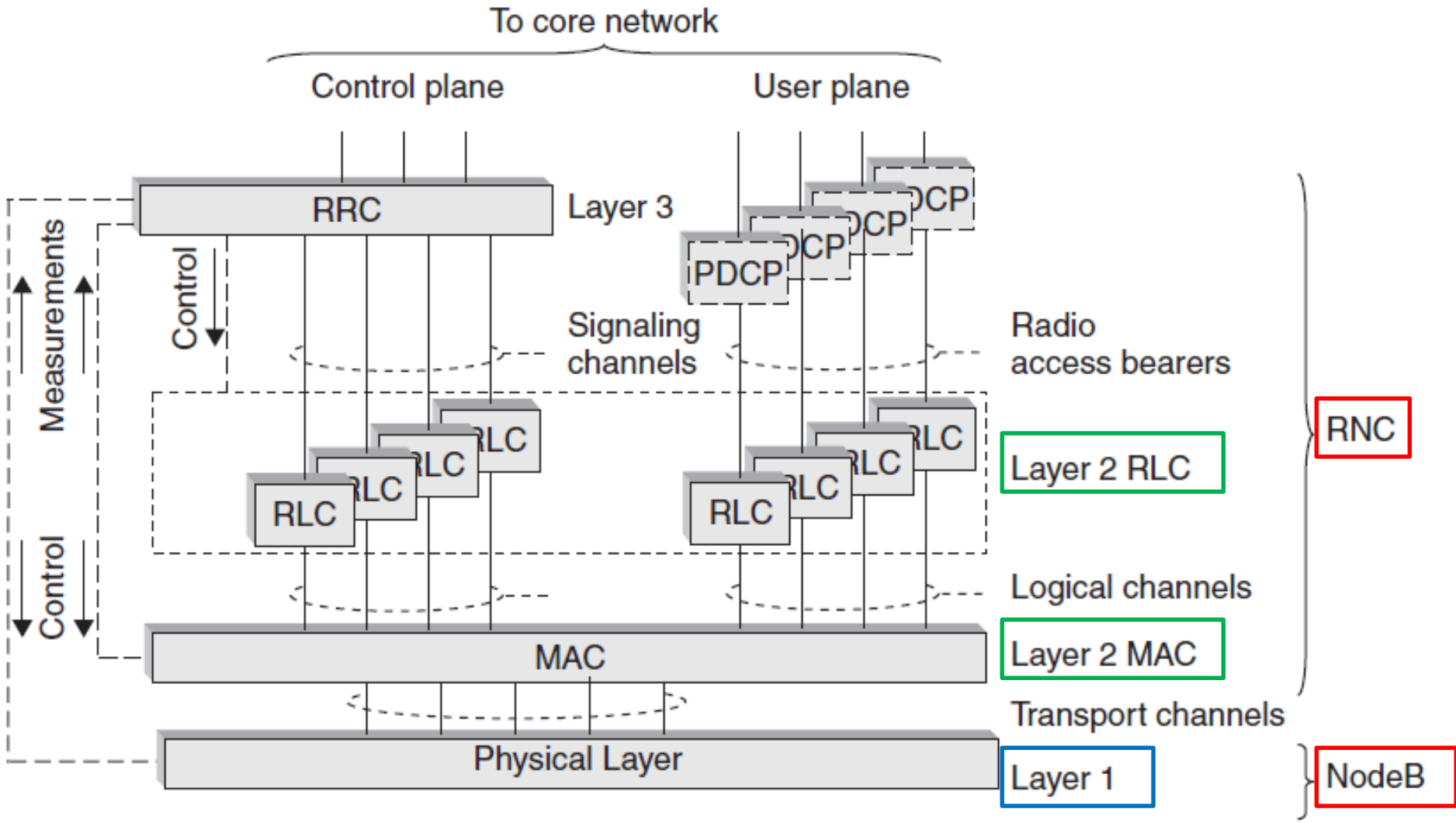
Overview of 3G UMTS Architecture



UMTS: Universal Mobile Tele-communications System
UTRAN: Universal Terrestrial Radio Access Network
RNS: Radio Network Sub System

Node B: Base Station
RNC: Radio Network Controller
Interfaces: Iu, Iub, Iur

Overview of 3G UMTS Architecture



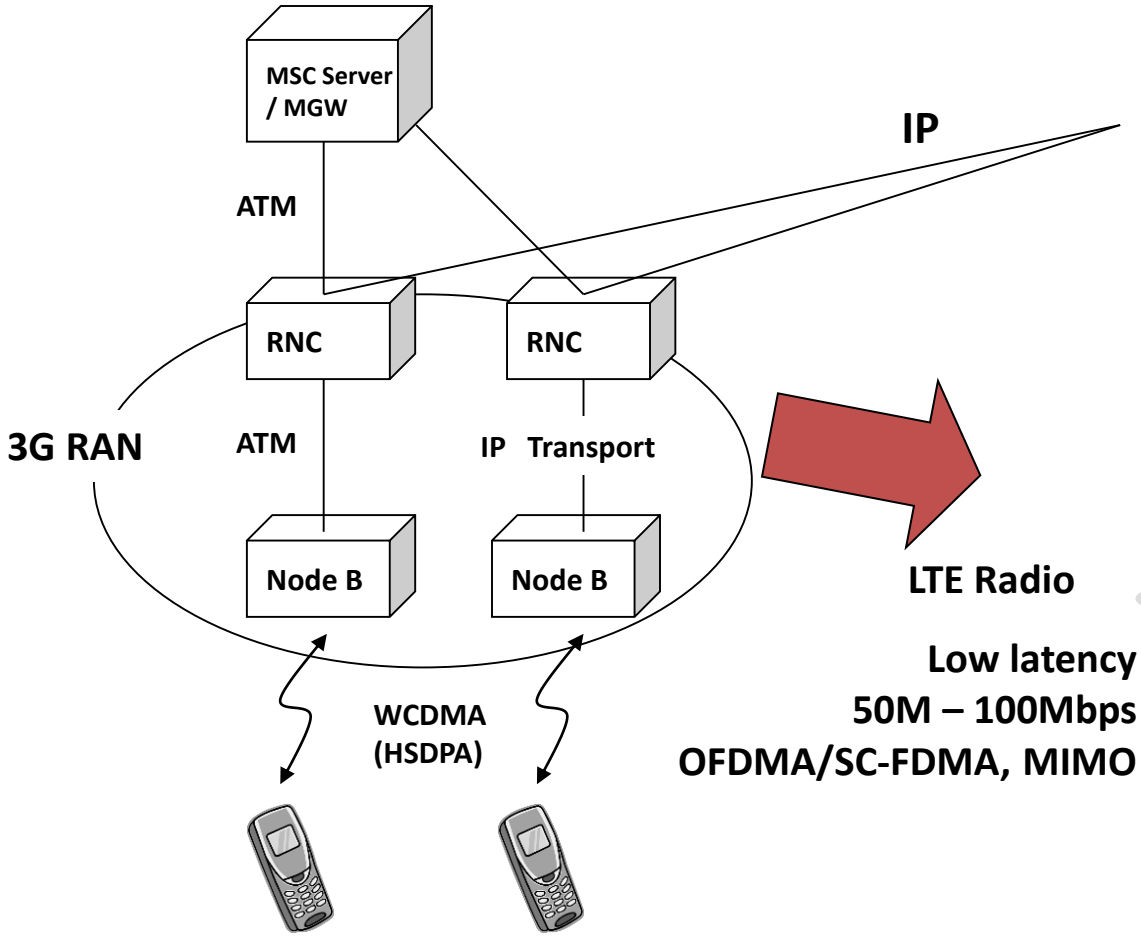
New RAN Architecture in LTE

New RAN Architecture
(2 Node architecture)

IP Routing

Low latency

Low-cost simple Architecture

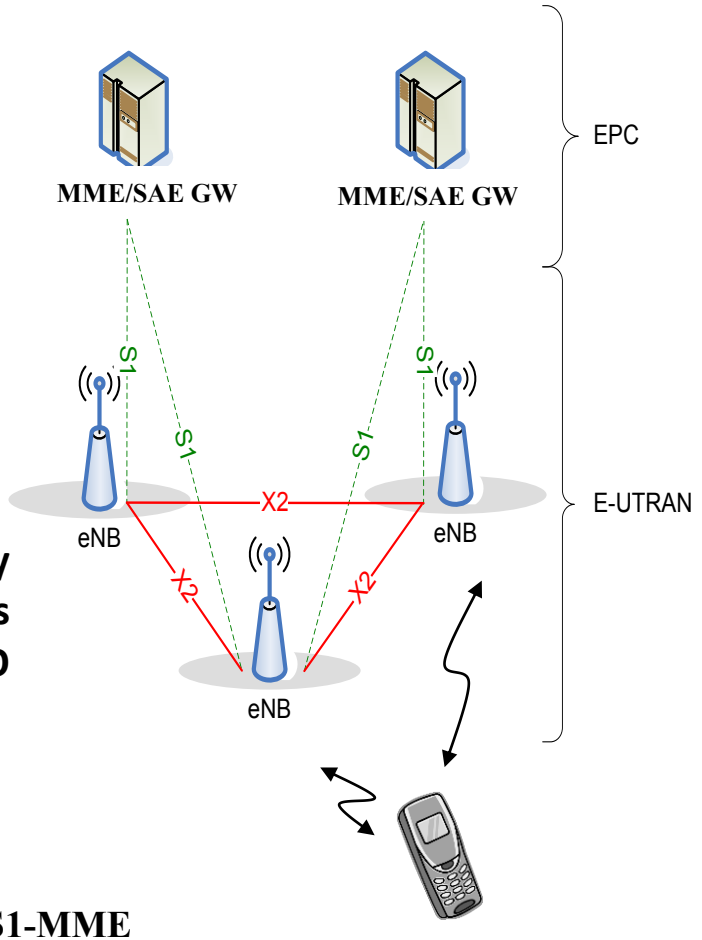


LTE Radio

Low latency

50M – 100Mbps

OFDMA/SC-FDMA, MIMO

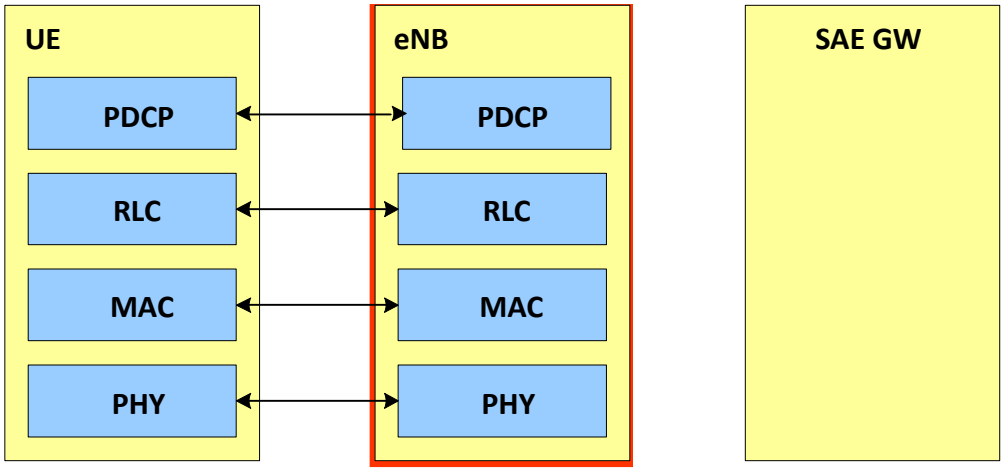


MME: Mobile management entity (Control plane):S1-MME

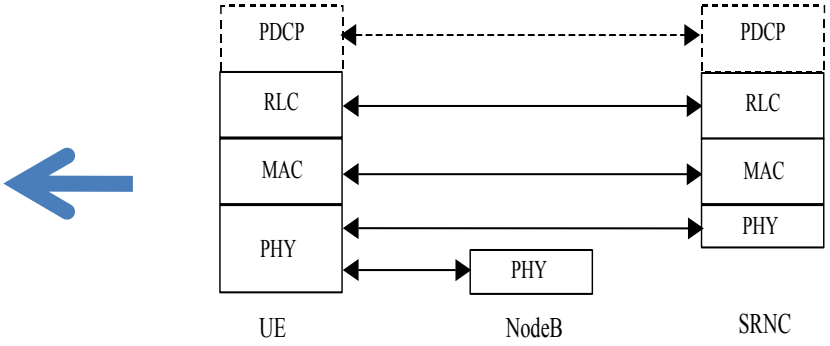
SAE GW: System Architecture Evolution Gateway (User plane):S1-U

eNB Protocol Stack

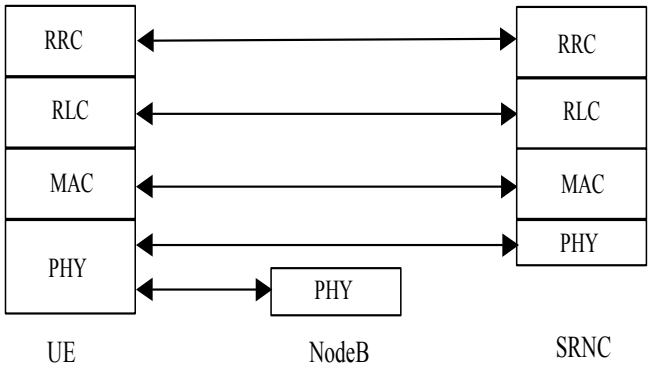
3GPP TS 36.300 V8.10.0 (2009-09)



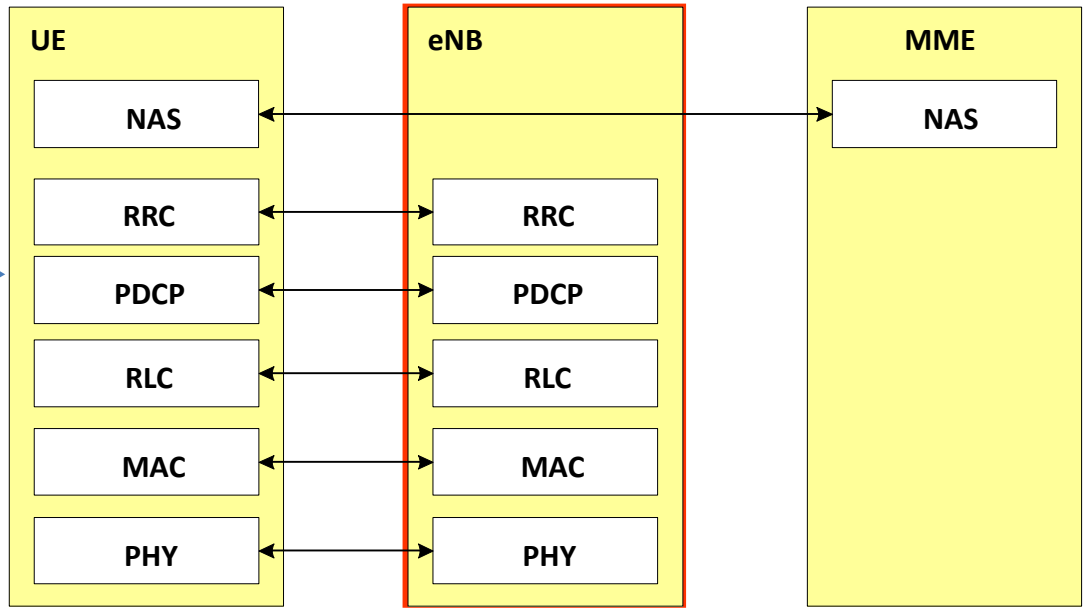
U-plane protocol stack in LTE



User Plane in 3G/HSPA



Control Plane in 3G/HSPA



C-plane protocol stack

3GPP Specifications

http://www.3gpp.org/specification-numbering

Radio aspects	25 series		05 series
CODECs	26 series	46 series	06 series
Data	27 series	47 series (none exists)	07 series
Signalling protocols ("stage 3") -(RSS-CN) and OAM&P and Charging (overflow from 32.- range)	28 series	48 series	08 series
Signalling protocols ("stage 3") - intra-fixed-network	29 series	49 series	09 series
Programme management	30 series	50 series	10 series
Subscriber Identity Module (SIM / USIM), IC Cards. Test specs.	31 series	51 series	11 series
OAM&P and Charging	32 series	52 series	12 series
Access requirements and test specifications			13 series (1)
Security aspects	33 series	(2)	(2)
UE and (U)SIM test specifications	34 series	(2)	11 series
Security algorithms (3)	35 series		(4)
LTE (Evolved UTRA), LTE-Advanced, LTE-Advanced Pro radio technology	36 series	-	-
Multiple radio access technology aspects	37 series	-	-
Radio technology beyond LTE	38 series	-	-

25 Series

Radio of 3G

33 Series

Security

36 Series

Radio of 4G

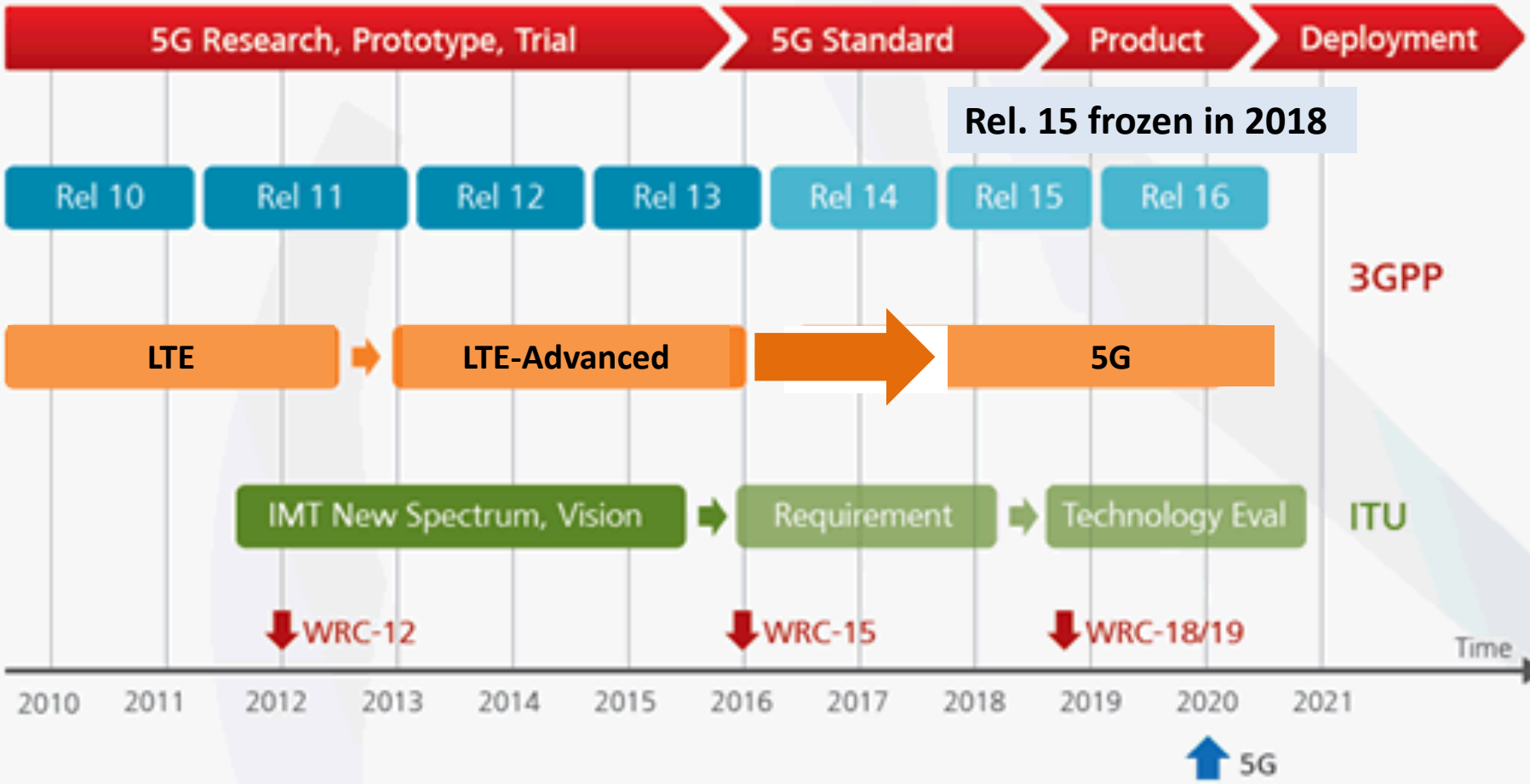
38 Series

Radio of 5G

Critical Communications World
May 15 -17, 2018
ETSI / 3GPP Exhibition Stand D18

3GPP tweets

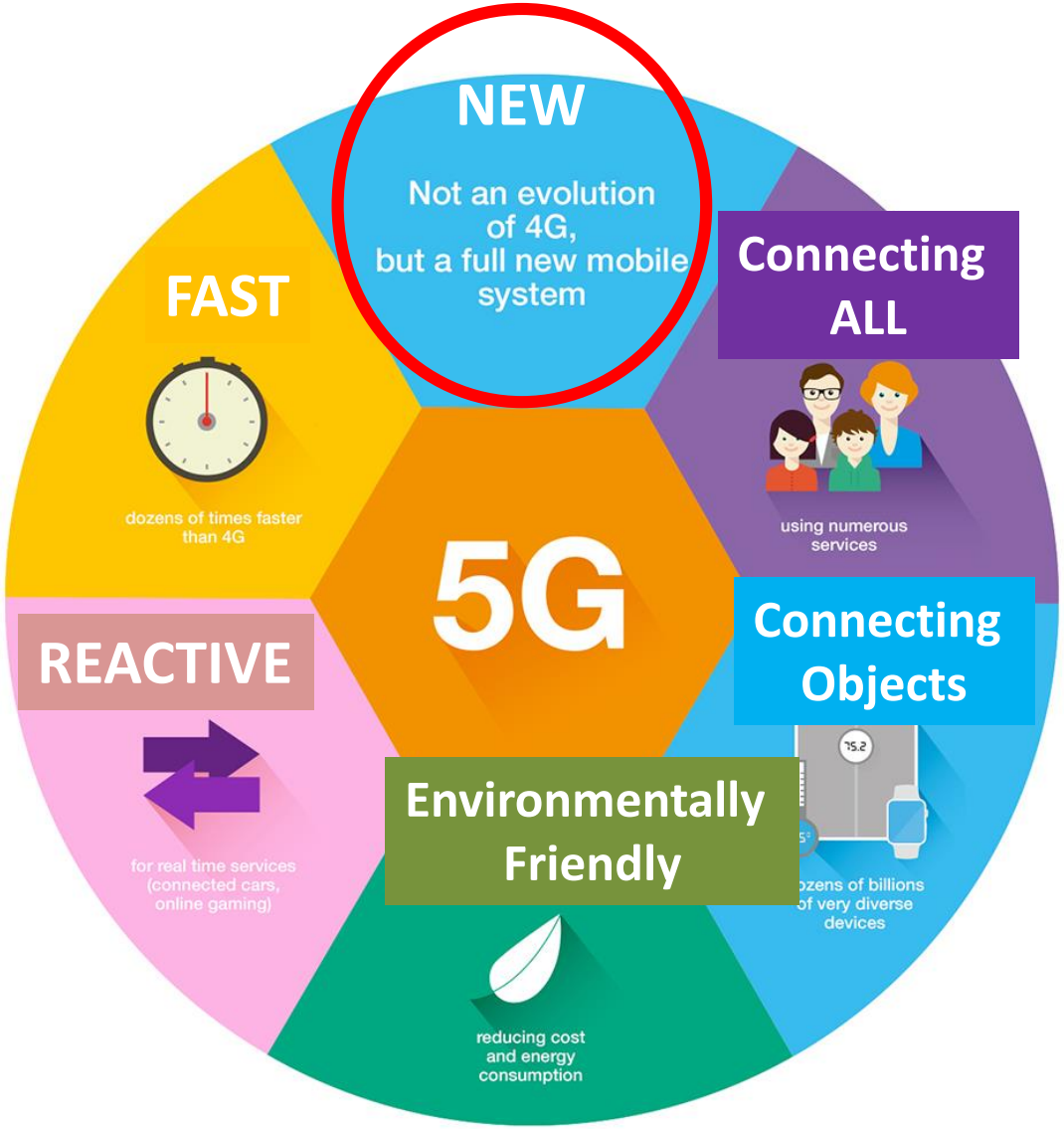
Standardization of 5G Time line (ITU & 3GPP)



Features of 5G

Flexibility

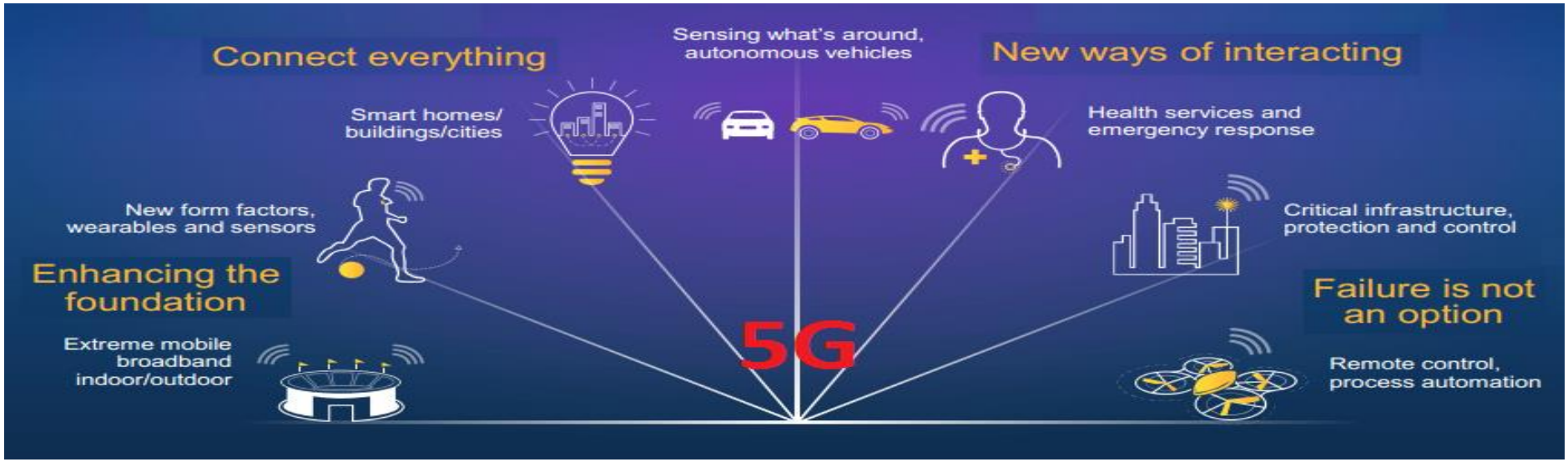
- Open
- Mobile
- Programmable
- Agile
- Sustainable

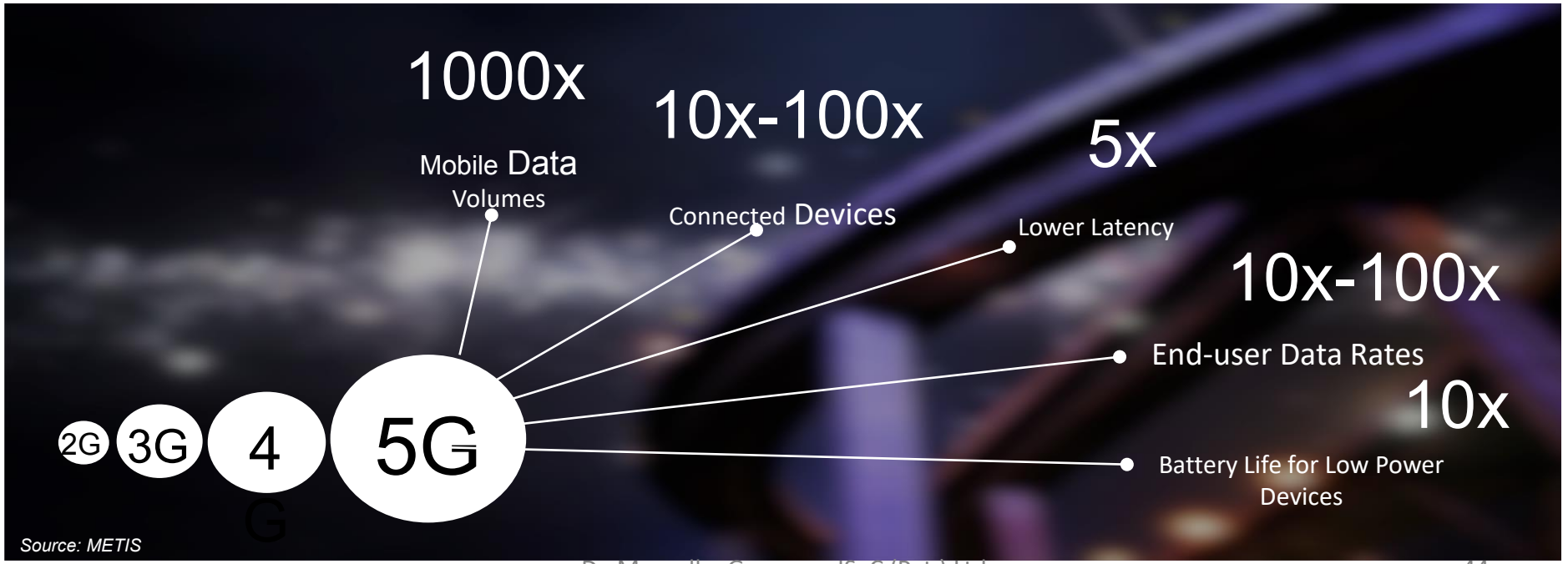


Robustness

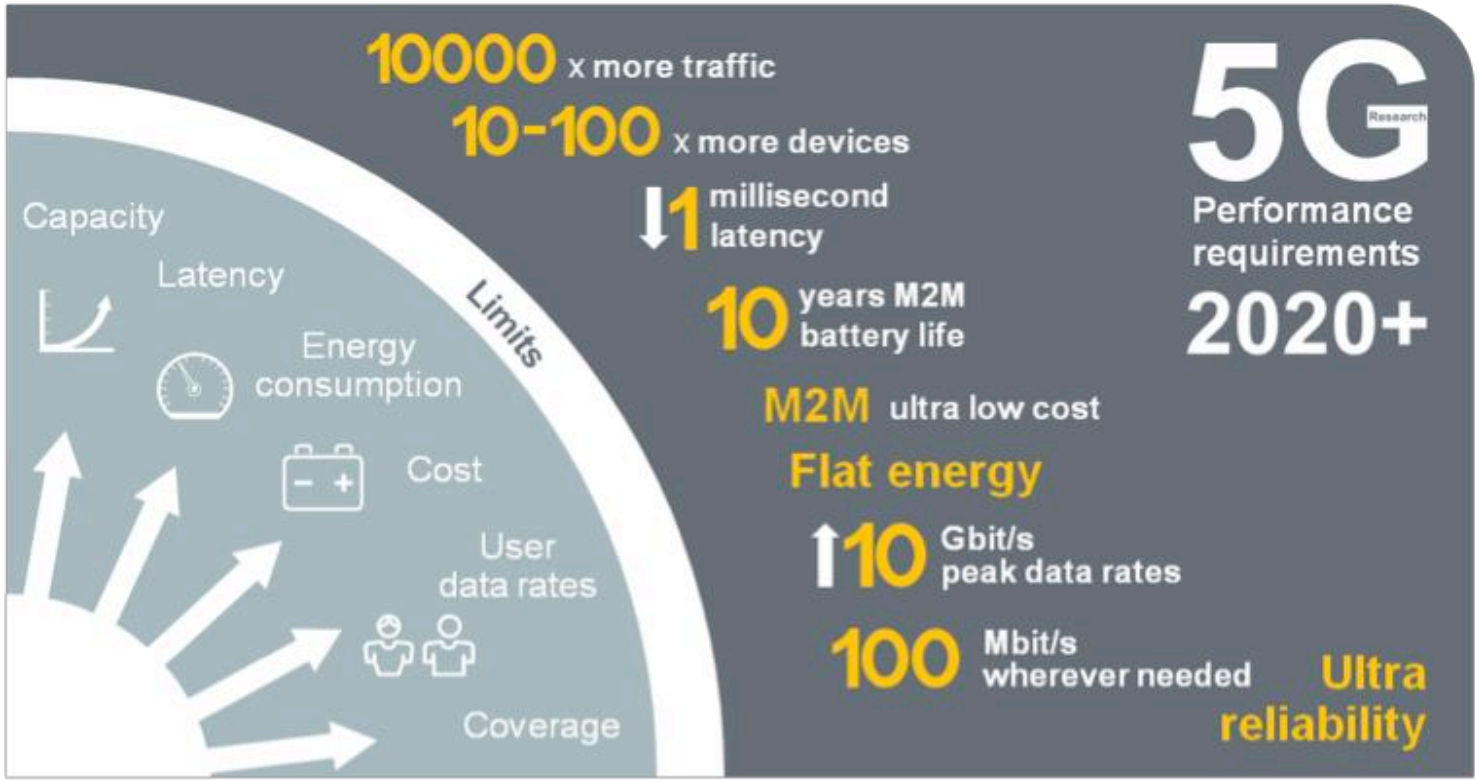
- Scalable
- Secure
- Reliable
- Standardized

5G: E2E Ecosystem to enable a fully mobile & connected society





5G Mobile Network Expected Performance



Multi domain performance

Energy Performance

Critical machine type of communications

Global standard

5G Top Use Cases

Interaction Human - IOT

Broadband Experience. Everywhere, Anytime.

Broadband experience everywhere anytime

Critical Machine Type Communication

Critical Control of Remote Devices

Smart Vehicles, Transport & Infrastructure

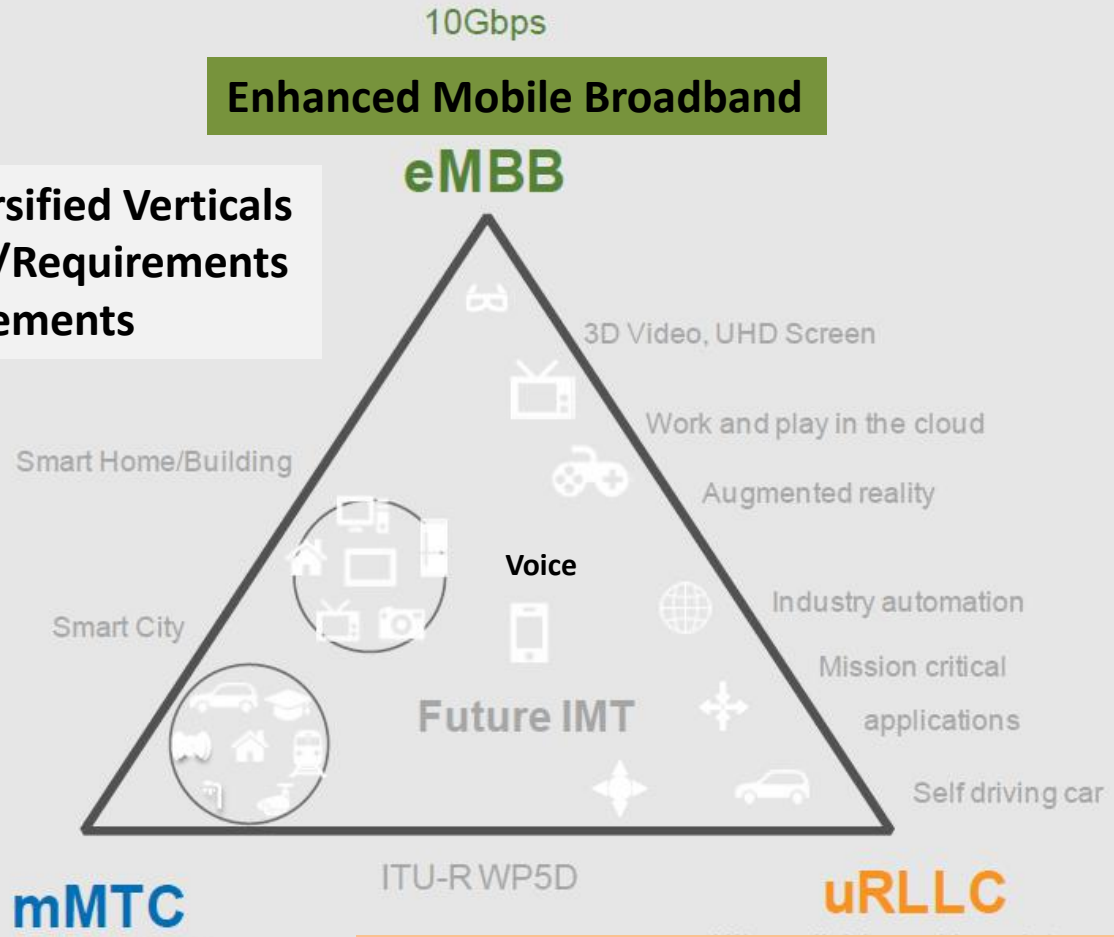
Massive Machine Type Communication

Media Everywhere

Mass market personalized TV

5G Mobile Services - 3 Categories ITU defined

- Support Digitization of Diversified Verticals
- Diversified business models/Requirements
- Diversified Technical Requirements

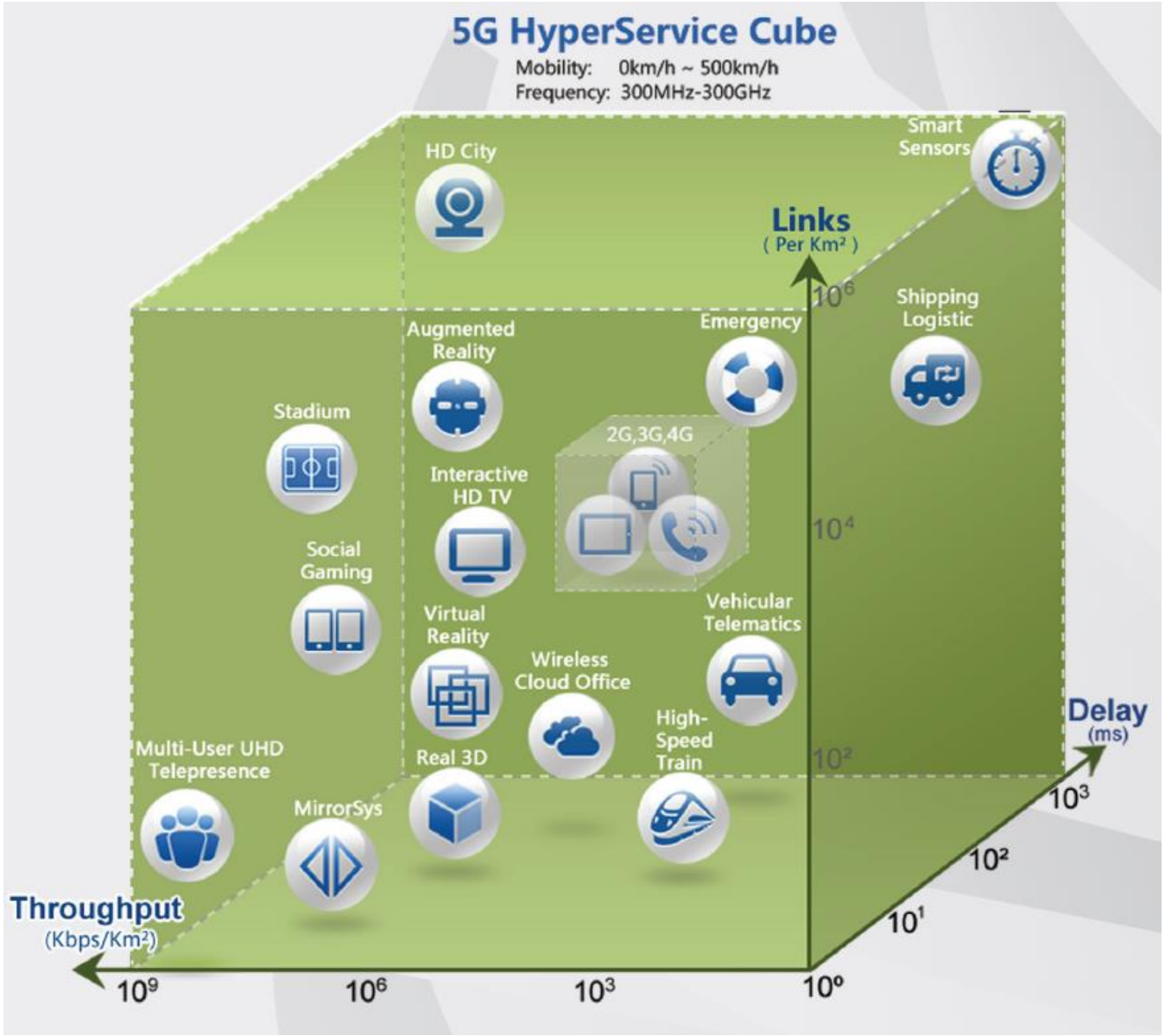


Massive Machine Type Communications

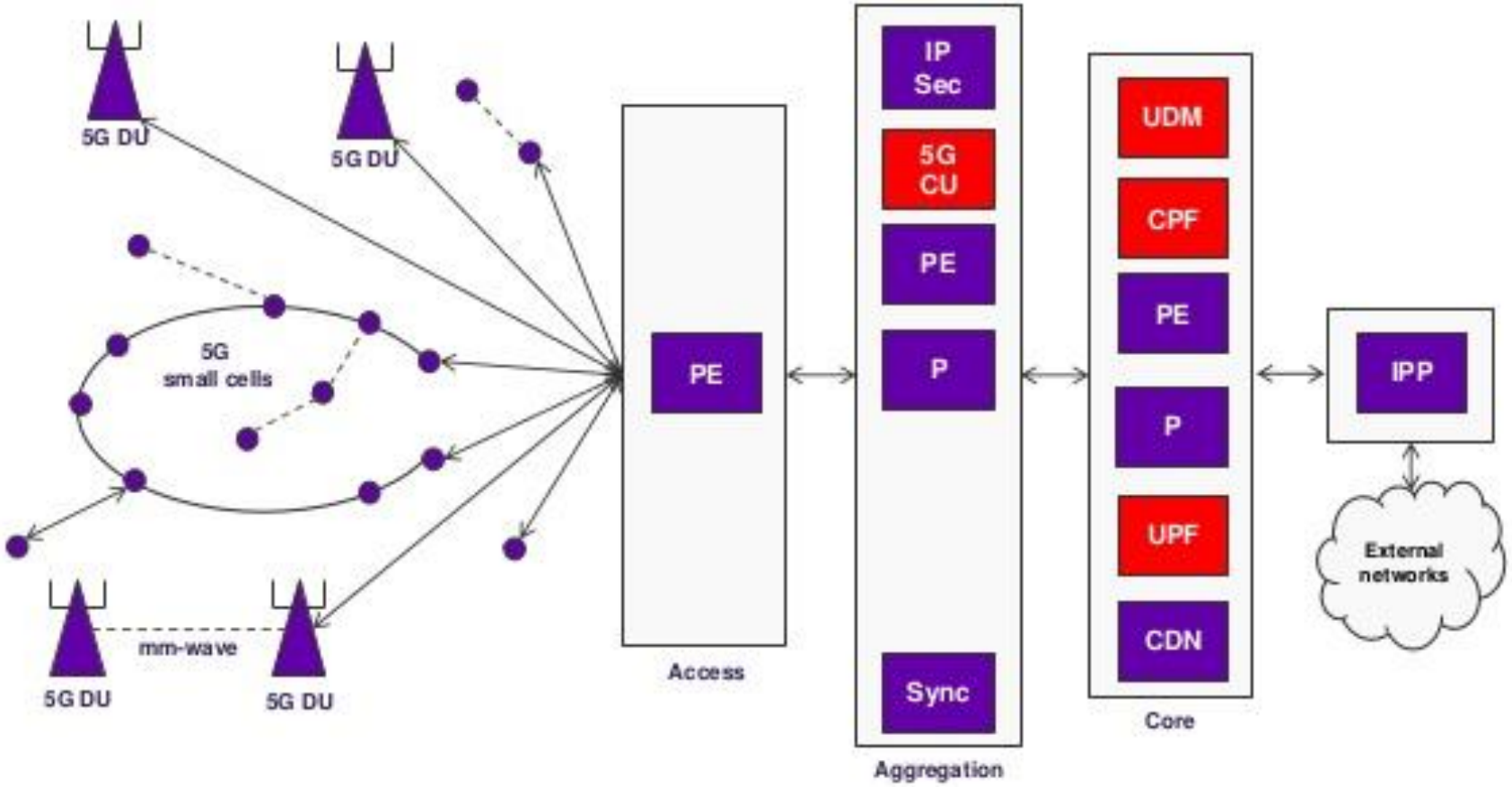
Ultra Reliable & Low Latency Communications

Diversified Performance Requirements

- **Latency** from 1ms-seconds
- Always-on **users per cell** from a few 100s - millions
- **Duty cycles** from 1ms - days
- **Signaling loads** from less than 1% to almost 100%



Conceptual 5G Network Architecture

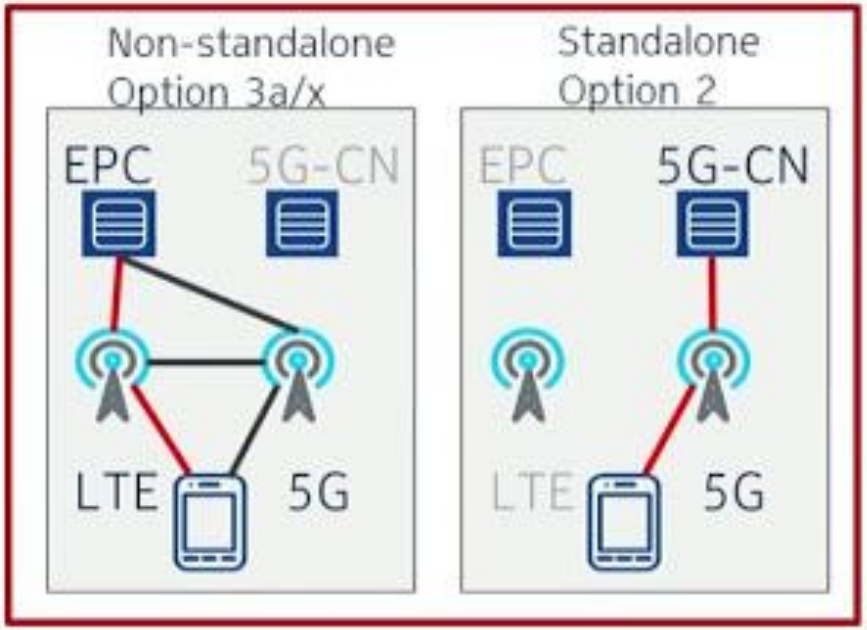


5G Architecture

- **5G System Architecture (5GS)**
  - **5G New Radio (NR) Access**
  - **New 5G Core (5GC) Network**
- **5GC is critical in providing all 5G services**

All architecture options remain within the scope of the NR WID

Option-3 family (non-standalone) is the ***focus until Dec/2017***



Option-2 (standalone) has best effort focus until Dec/2017, and afterwards with ***priority until June/2018***

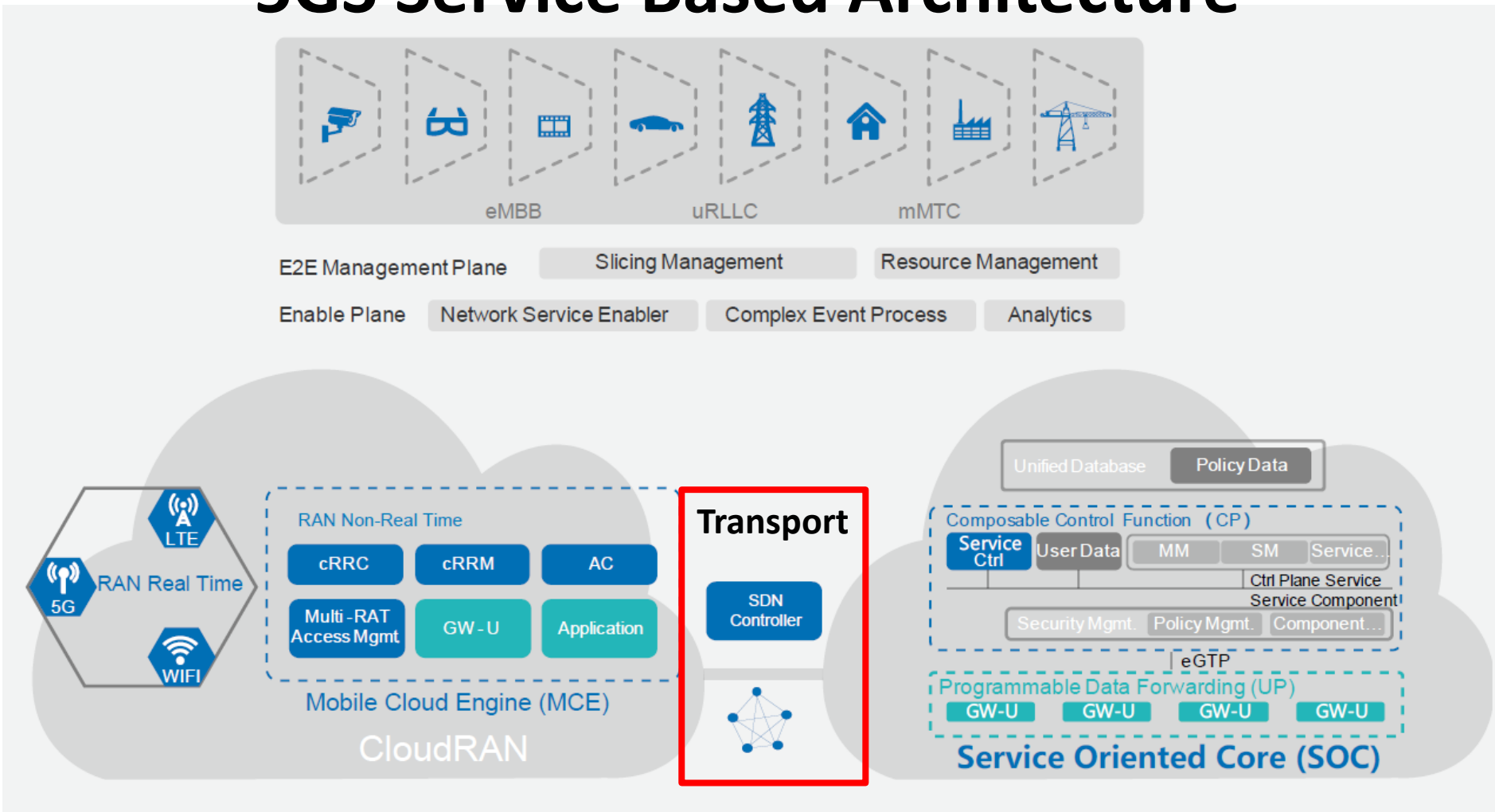
 7

5G Network Architecture Transformation: Driving Forces

- Complex networks with multiple services, standards, & site types
- Coordination of multi-connectivity technologies
- On-demand deployment of service anchors
- Flexible orchestration of network functions
- Shorter period of service deployment

- **Cloudifies** Access, Transport & Core with
  - Network Function Virtualization **(NFV)**
  - Software Defined Networking **(SDN)**

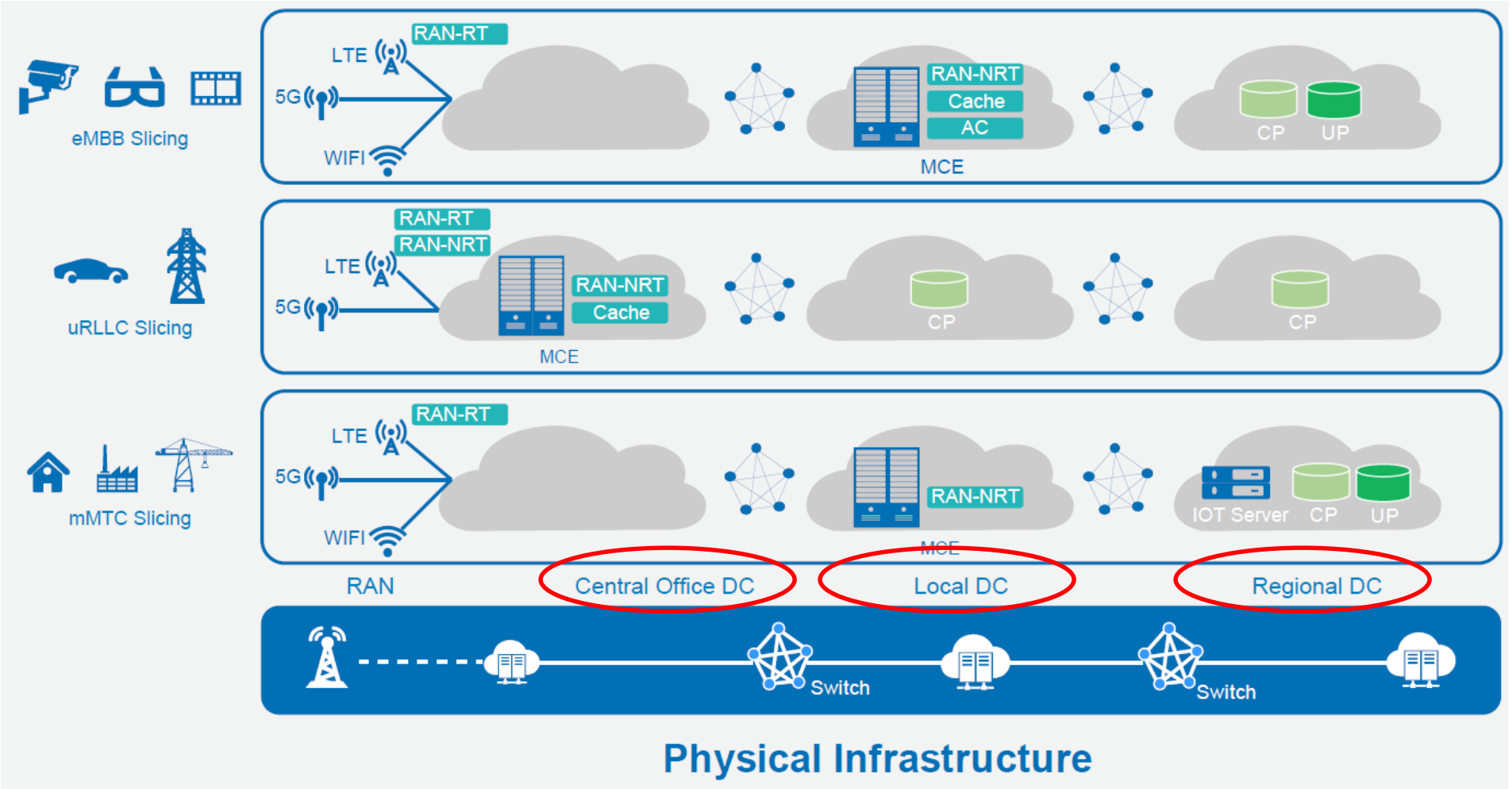
5GS Service Based Architecture



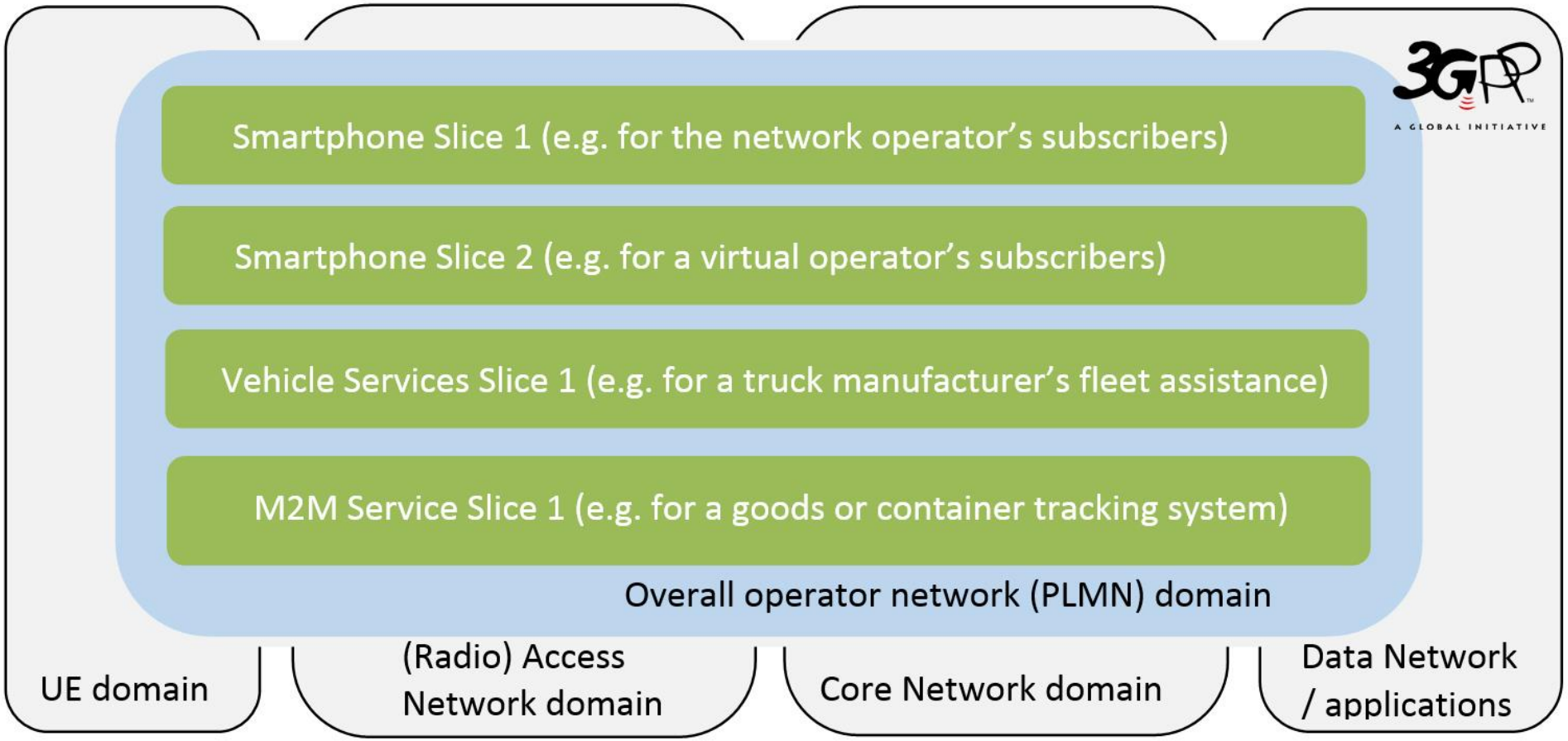
5G: . A Cloud-Native E2E Network

- Logically independent **Network Slicing** on a single network infrastructure
- **Data Center**-based **CLOUD** architecture to support various application scenarios
- **CloudRAN** to provide
  - Massive connections of **multiple standards**
  - Implement **on-demand** deployment of RAN functions
- Simplifies **CORE network architecture** through
  - control and user plane separation
  - component-based functions
  - unified database management
- Reduce OPeX through **AGILE** network O&M (& **Automation**)

Network Slicing



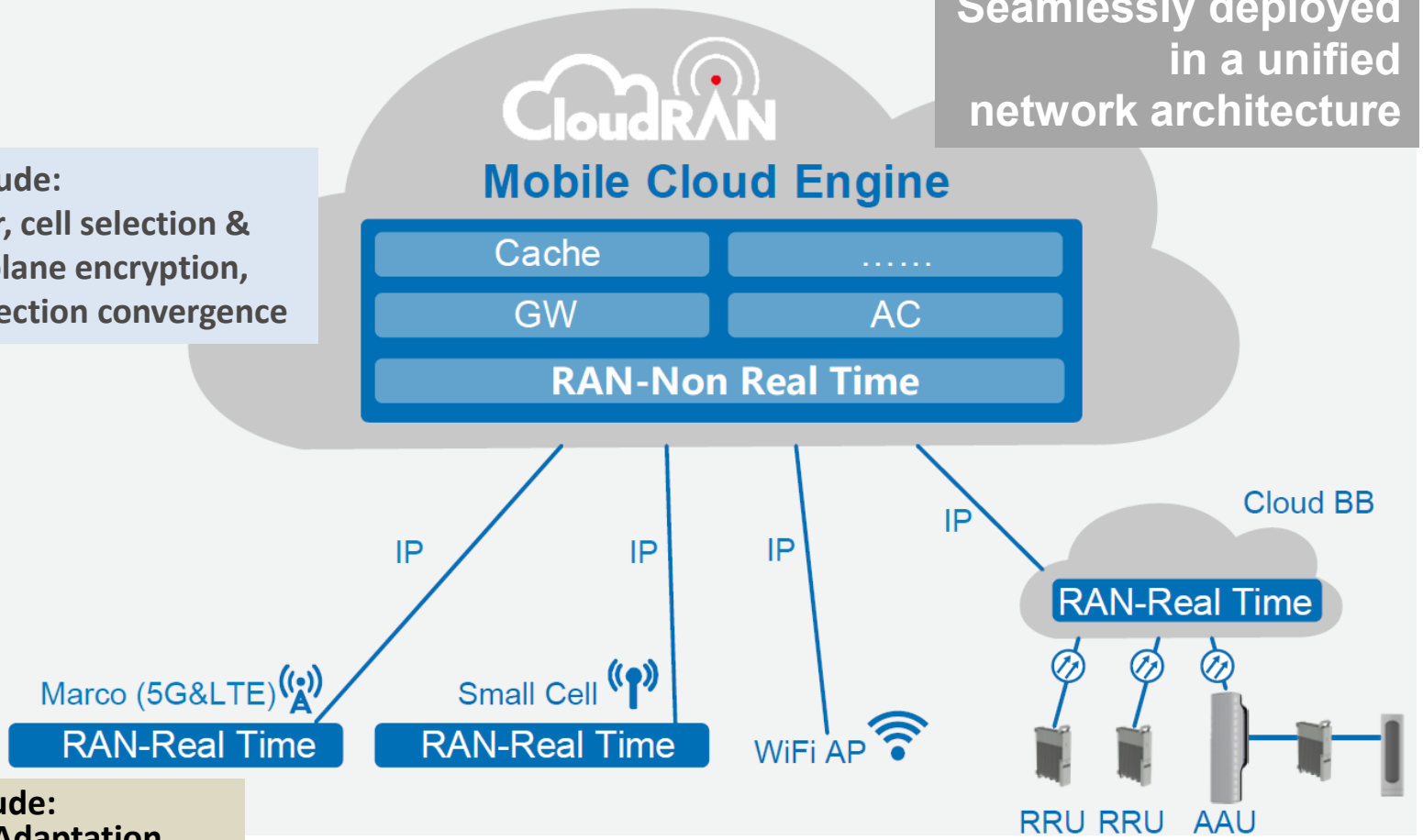
Network Slicing



Common Network Architecture across Different Technologies & Layers

Seamlessly deployed in a unified network architecture

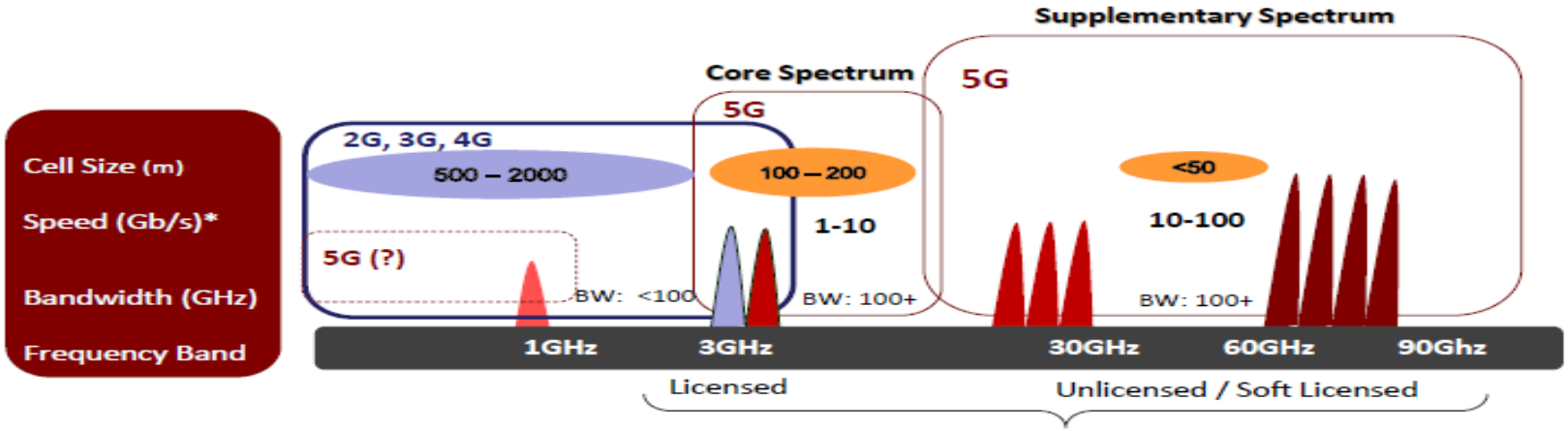
NRT functions include:
Inter cell handover, cell selection & reselection, user-plane encryption, and multiple connection convergence



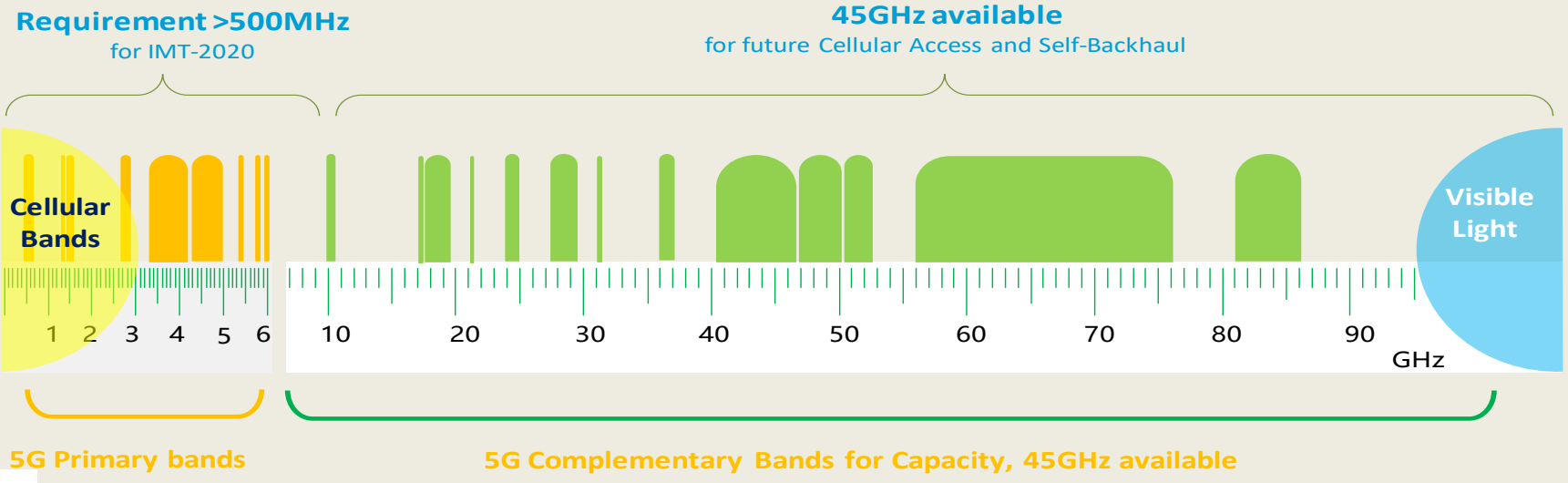
RT functions include:
Scheduling, Link Adaptation, Power Control, Interference coordination, Retransmission, Modulation, Coding

Spectrum Challenge

Spectrum remains a Challenge for 5G and for Wireless Industry



- ✓Best use of low (below 6Ghz) & high frequencies (mmWave) - Sub 6GHz as core spectrum, mmWave (10-100 GHz) for ultra dense access & backhaul, Supplementary Services
- ✓Ideally 100+ MHz channel bandwidth
- ✓Dynamic Spectrum Allocation
- ✓Coordinated Shared Access
- ✓ Use of temporal & local availability of spectrum
- ✓Carrier Aggregation



Three key frequency ranges are currently worthy of consideration for different 5G deployment scenarios

Sub-1 GHz

- Ideal **coverage band:** useful in rural areas and deep inside buildings
- Could not support extremely wide bandwidths and therefore enable the fastest possible data rates
- Helps to prevent a new digital divide
- Reaches more people in both developed, and developing, markets

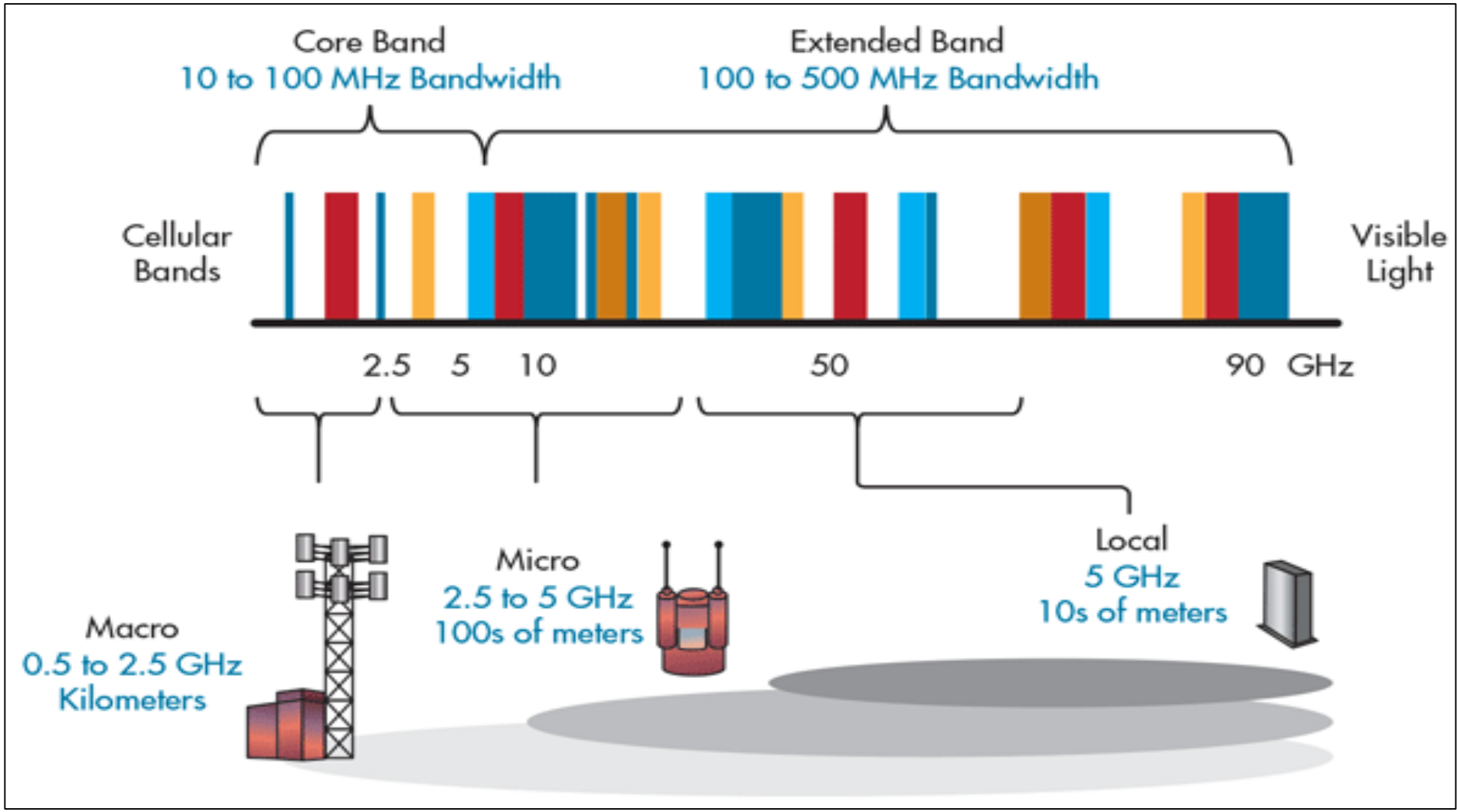
1-6 GHz

- Numerous mobile bands between 1-2.6 GHz, & when 5G technology is ready to deploy there may be others between 2.6 GHz and 4 GHz
- Offers a reasonable mixture of coverage & capacity. Unlikely to be able to support the highest potential 5G data rates without **carrier aggregation**

Above 6 GHz

- Supports wide channel sizes & therefore extremely fast data rates, and massive additional mobile network capacity, making it fertile territory for 5G research.
- Needs complimentary lower freq spectrum for inside building and rural coverage. Only favors small cell sizes

5G Bands and its impact on Cell size



Thank You

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