

Information & Communication Technologies for the Internet-of-Things

Cellular Architectures

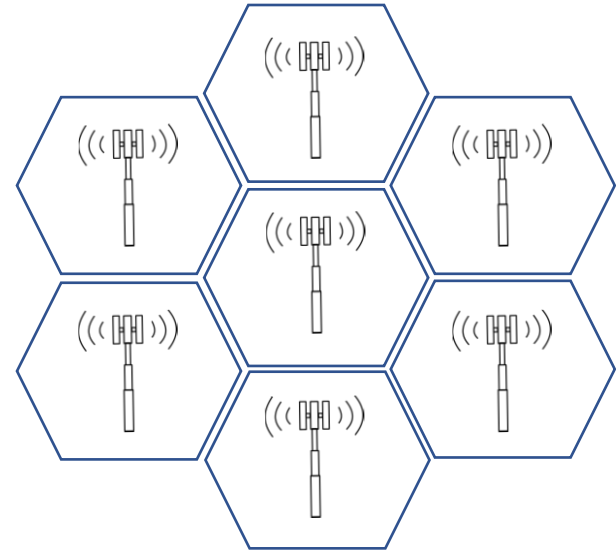
Pedro Santos

Fully original content.

Outline

- Cellular Architectures
- Cellular Technological Ecosystem
- Physical Layer of Cellular Communications

Why Cellular?



Cellular Technologies

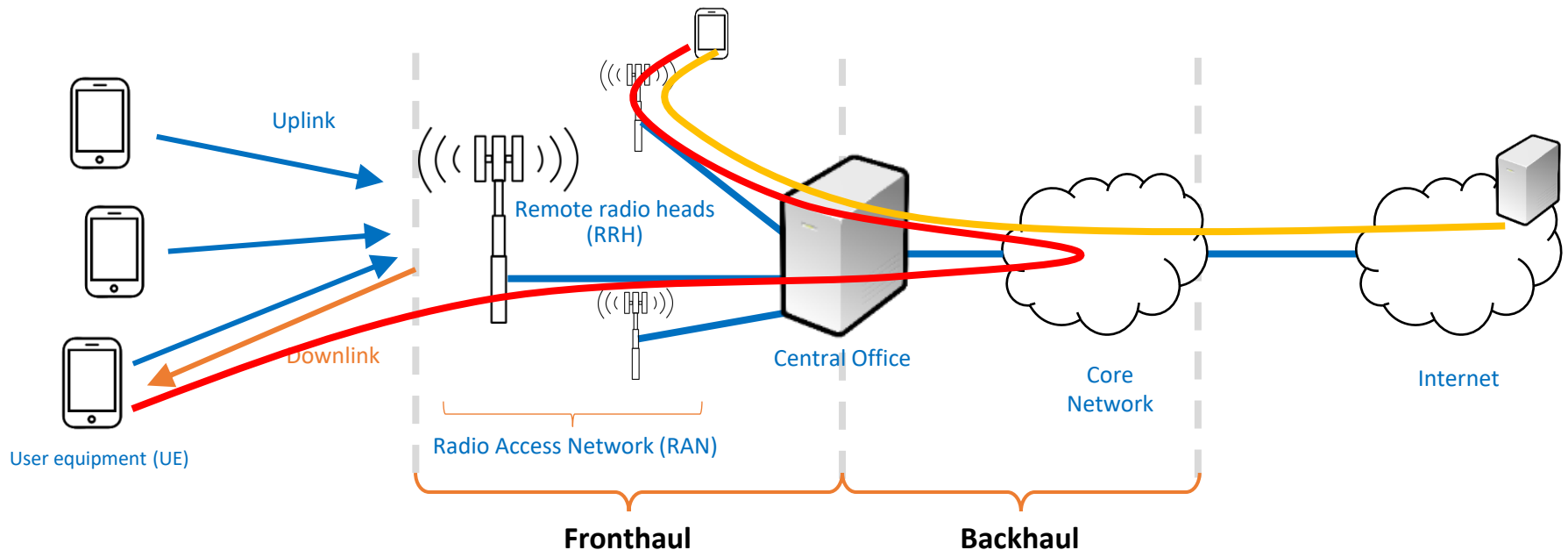
- Technology development for cellular systems
 - Driven by 3GPP – a standardization body that includes most OEMs and operators
 - Cellular specifications are formalized in Releases – currently Release 16
- Massive MIMO
 - Emerging technology
- C-V2X / NR-V2X
 - In cellular terminology, a ‘sidelink’ that complements
- Cellular Service Stack



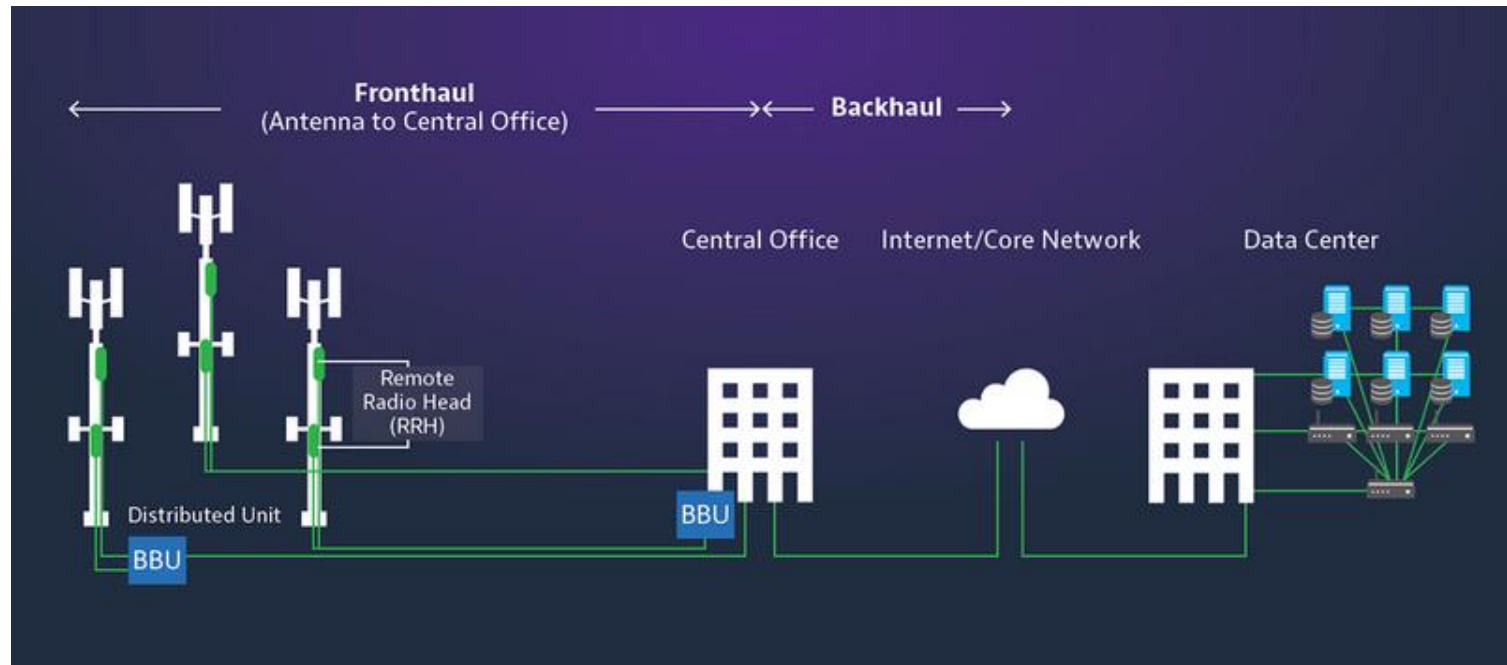
Commercial brand	Name of technical specification	Stand. Body	Time-frame
1G	N/A	N/A	1980
2G	Global System for Mobile Communications (GSM)	ETSI	1990
3G	Universal Media Telecommunications System (UMTS)	3GPP	2000
4G	Long-Term Evolution (LTE)	3GPP	2010
5G	New Radio (NR)	3GPP	2020

Cellular Architectures and Asymmetric

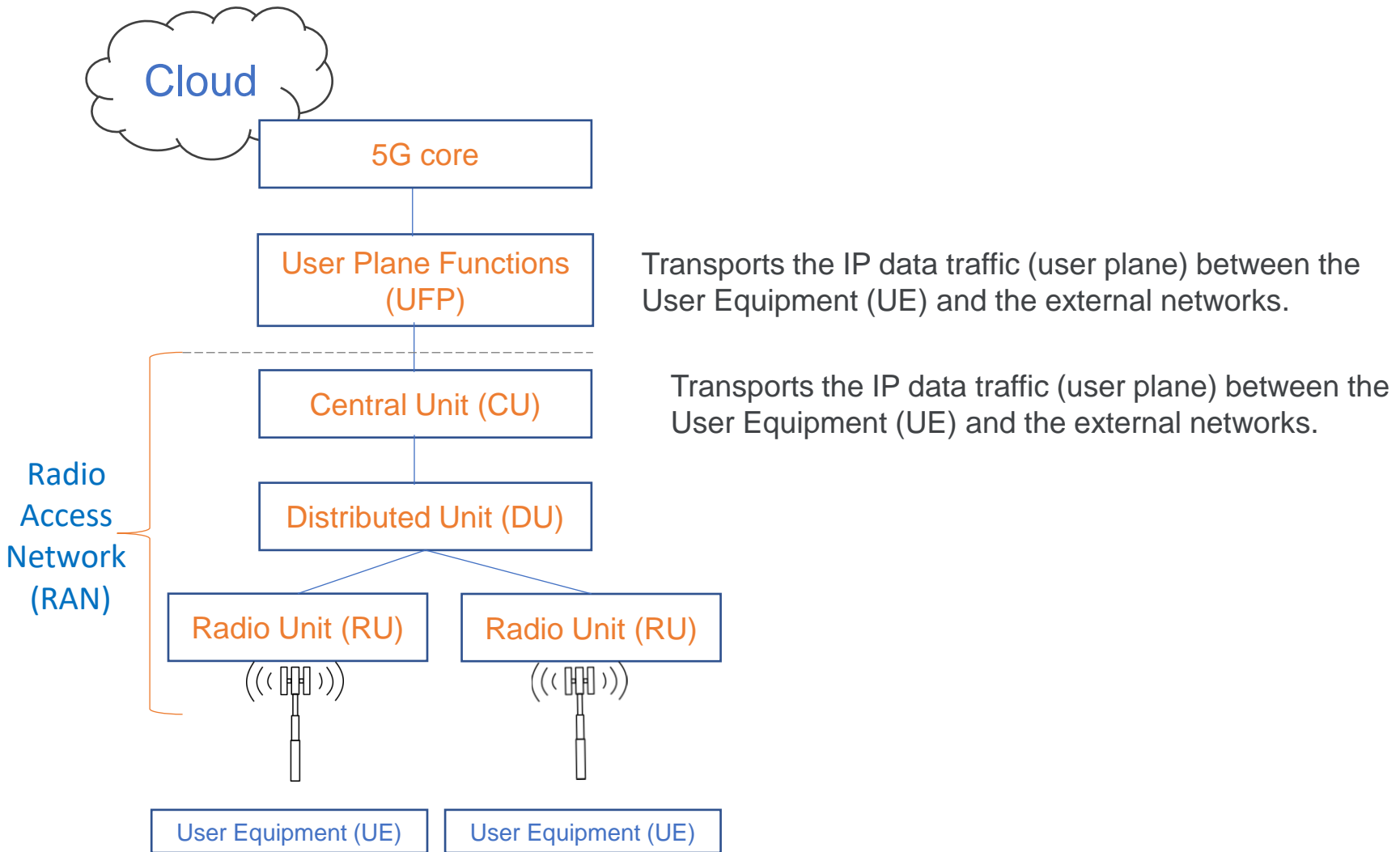
- The most prominent example of Wide-Area Networks (WAN) are **cellular** networks (and thus sometimes the terms WAN and cellular are used interchangeably)

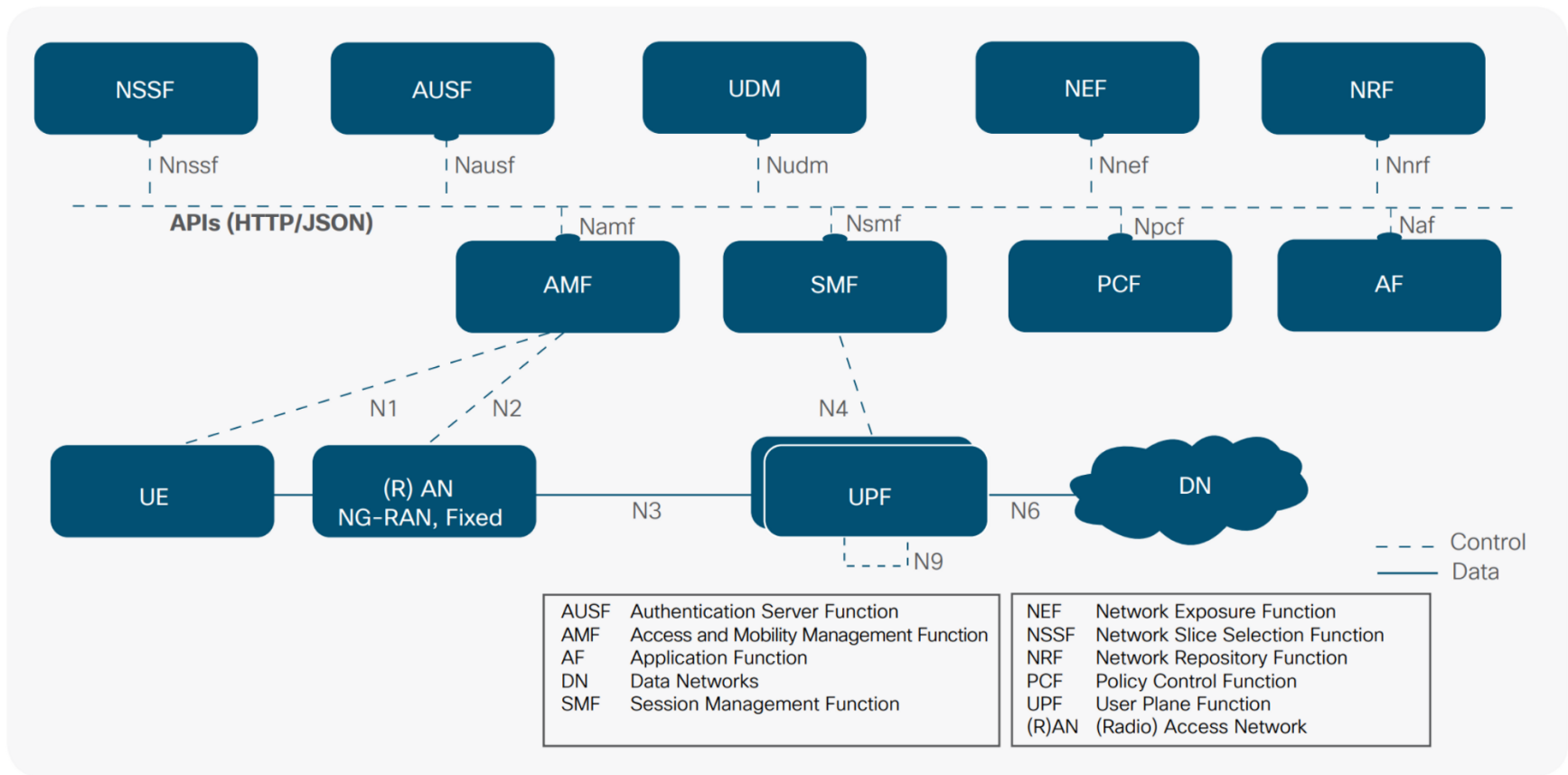


Cellular Architectures

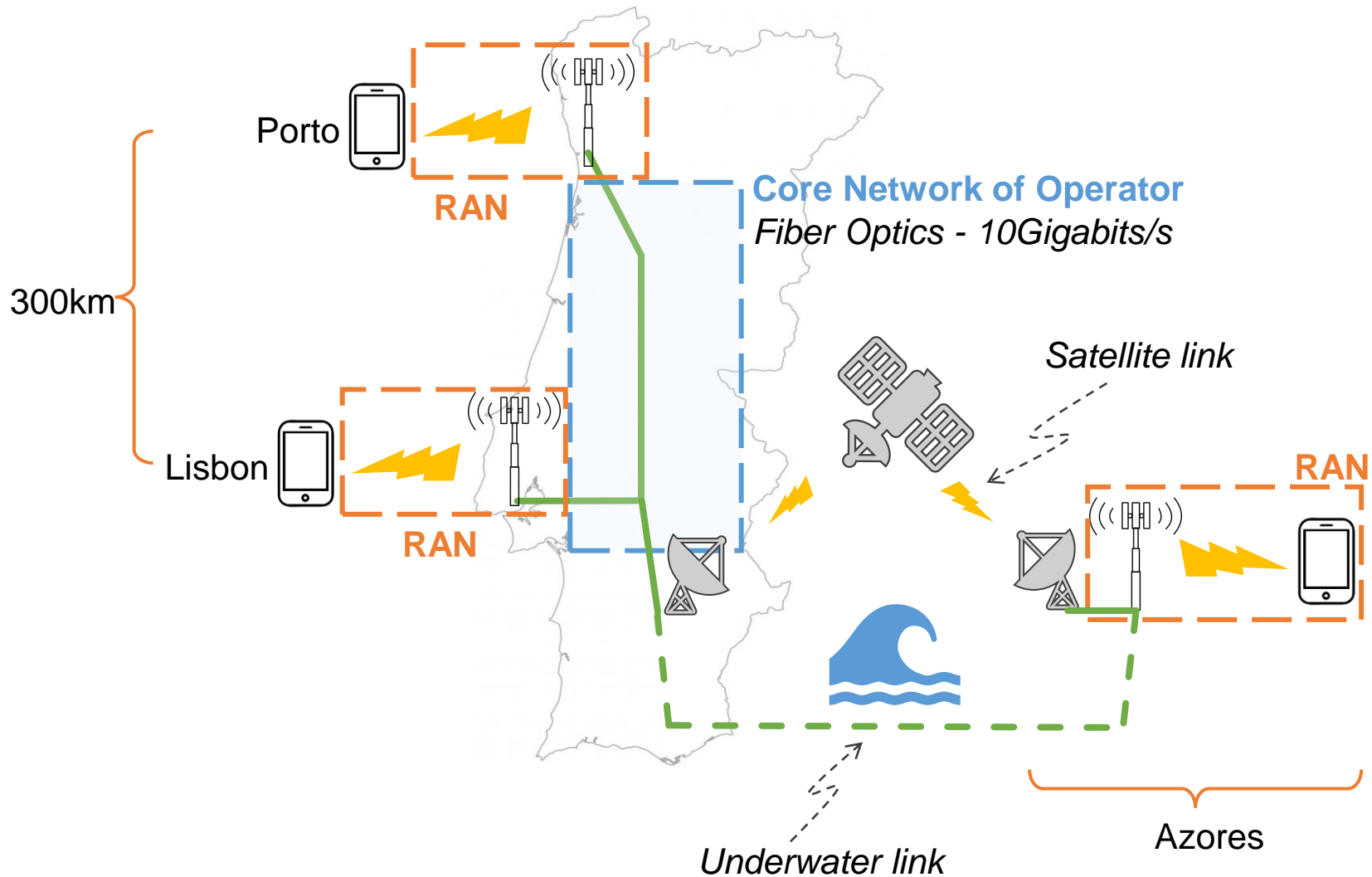


Vertical Architecture





Core Network & RANs – Spatial Relation



Spectrum Assignment in LTE

- Spectrum usage in LTE

- LTE carriers can be [1.4, 3, 5, 10, 15, 20] MHz wide (defined in the standard)
- **Physical Resource Blocks (PRBs)** are 180kHz sub-divisions that correspond to smallest chunk of data
- For 10MHz carrier, we get 50 PRBs

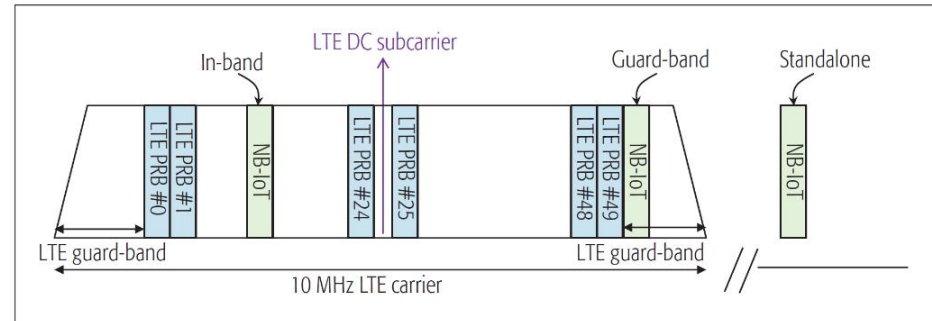


Figure 1. Examples of NB-IoT stand-alone deployment and LTE in-band and guard-band deployments.

- NB-IoT was designed to be compatible with GSM and LTE

- NB-IoT requires a bandwidth of 180 kHz for downlink and uplink
- In GSM: Replace one GSM carrier (200 kHz) with NB-IoT
- In LTE: Allocate one PRB of 180 kHz to NB-IoT
 - In-band: using one of the regular PRBs
 - Guard-band: using unused space that borders the PRBs of that carrier

A Primer on Cellular Physical Layer

Inside a PRB

- Modulation: **OFDM**

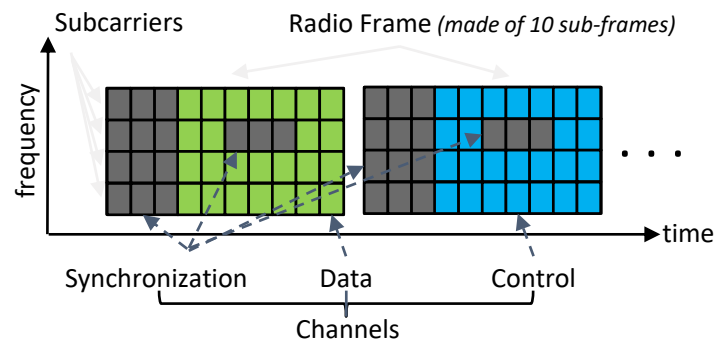
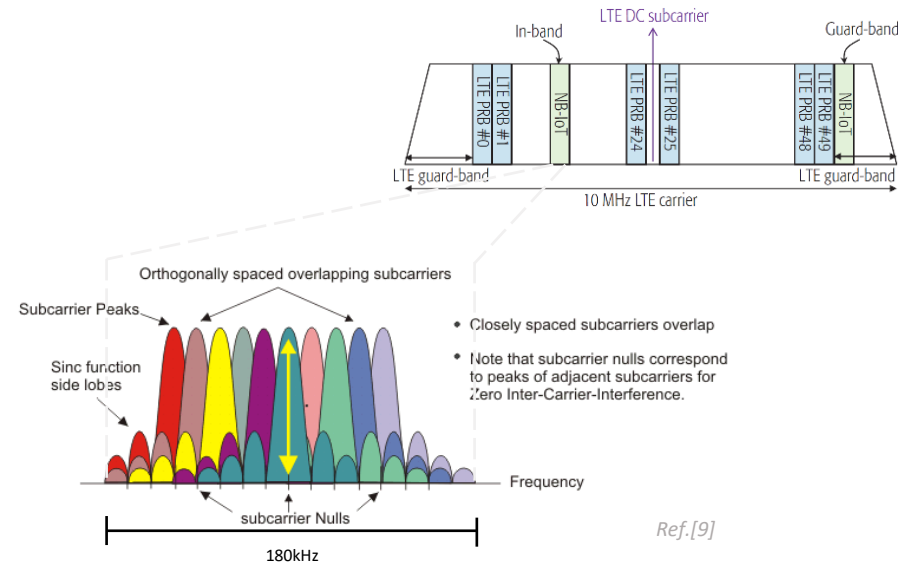
- *Orthogonal Frequency Division Multiple Access*
- Number of subcarriers can vary, e.g., 12, 48, 64
- Different modulations are possible, e.g., QPSK, 16QAM, 64QAM

- Time: **Frame**

- Frames are composed of 10 sub-frames

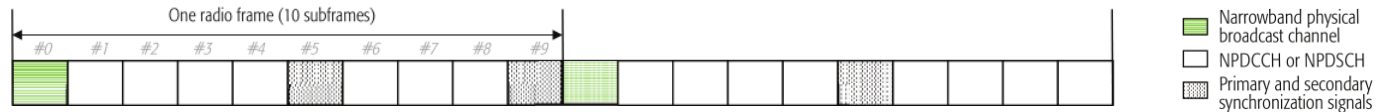
- **Channels:**

- For synchronization, control, and data
- Channels are **logical**, i.e.: their implementation is mapped into well defined physical resources (frequencies and sub-frames)
- Synchronism between UE and BE is a key aspect of cellular operation (unlike SigFox)

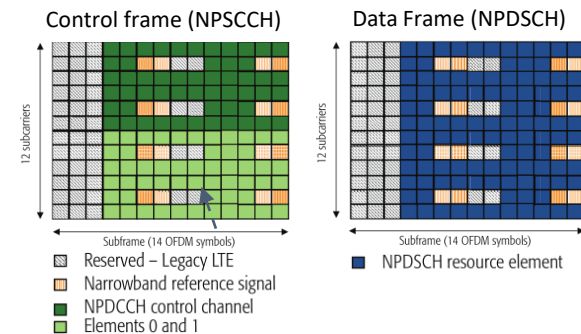


NB-IoT Physical Layer – Downlink (BS to UE)

- Modulation: orthogonal frequency-division multiple access (OFDMA)
- Two consecutive DL frames have the following structure:



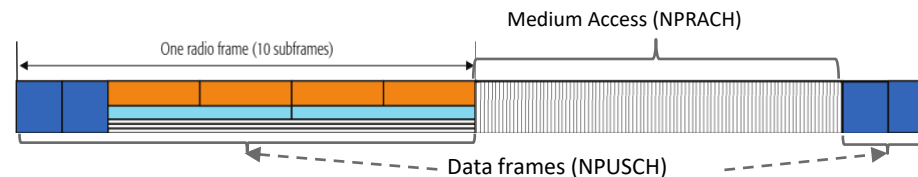
- Three channels:
 - **Synchronization** (NPSS/NSSS – NB primary/secondary sync. signals)
- (The following can be transmitted at any white sub-frame.)
- **Control channel** (NPDCCH - NB physical downlink control channel)
- **Data channel** (NPDSCH - NB physical downlink shared channel)



Ref.[6]

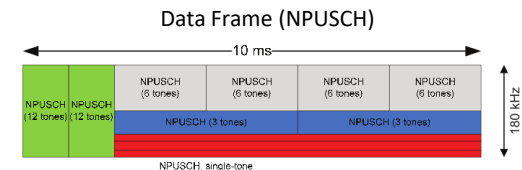
NB-IoT Physical Layer – Uplink (UE to BS)

- Modulation: single-carrier frequency-division multiple access (SC-FDMA)
- Two consecutive UL frames have the following structure:

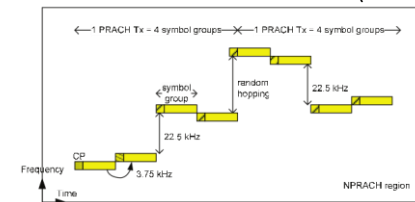


Two channels:

- **Data frames (NPUSCH - NB physical uplink shared channel)**
 - A data package can be split per multiple sub-carriers and/or subframes
- **Random Medium Access (NPRACH - NB physical random access channel)**
 - Allows UE to request a uplink to BS by sending a random tone sequence
 - If correctly received, BS schedules transmissions for that UE



Random Medium Access Channel (NPRACH)



Ref.[6]

6G vs 5G.

COMPARISON OF FEATURES OF 5G AND 6G NETWORK

Features	5G NR	6G
Peak data rates	20Gbps	~1 Tbps
Latency	1ms	Less than 1ms
Area traffic capacity	10Mb/s/m ²	1Gb/s/m ²
Frequency bands	Sub 6GHz mmWave (24-52.6 GHz)	Sub 6GHz mmWave band Terahertz band (Visible light band)
Connection density	1M devices/Km ²	10M devices/Km ²
Device Services	Reliable connectivity of devices.	Physical interaction in real-time scenarios.
Network Type	SDN, NFV, Slicing	SDN, NFV, Intelligent cloud, AI-based Slicing. Machine Learning, Deep Learning.
Computing Technique	Fog Computing, cloud computing	Quantum Computing, Edge computing
Mobility	500 Km/h	> 700 Km/h
Technology	D2D communication, Ultra-dense Network, Relaying, Small Cell Access, NOMA.	Visible Light Communication, Quantum Communication, Hybrid Access, Haptic technology, Adaptive Resource Allocation.
Applications	360° Video, UHD video, AR, VR, IoT, Smart city, Smart Home.	Holographic imaging, Haptic communication, Telerobotics, Teledriving, AR/VR/XR, Tele-education, Internet of Everything

Thank you