ISC-RS-3

Conception et exploitation de réseaux

Partie réseaux mobiles

Sanne STIJVE

Agenda

Cours

1. Introduction aux réseaux mobiles
2. Différents standards de réseaux mobiles
3. Architecture des réseaux LTE & 5G
4. Déploiement et exploitation de réseaux mobiles
5. Dimensionnement et planification cellulaire

2, 9 et 16 décembre 2025, 6, 13 et 20 janvier 2026

Travaux Pratiques

- Déploiement LoRaWAN

5 janvier 2026

- Dimensionnement / planification cellulaire

19 janvier 2026

Différents standards de réseaux mobiles

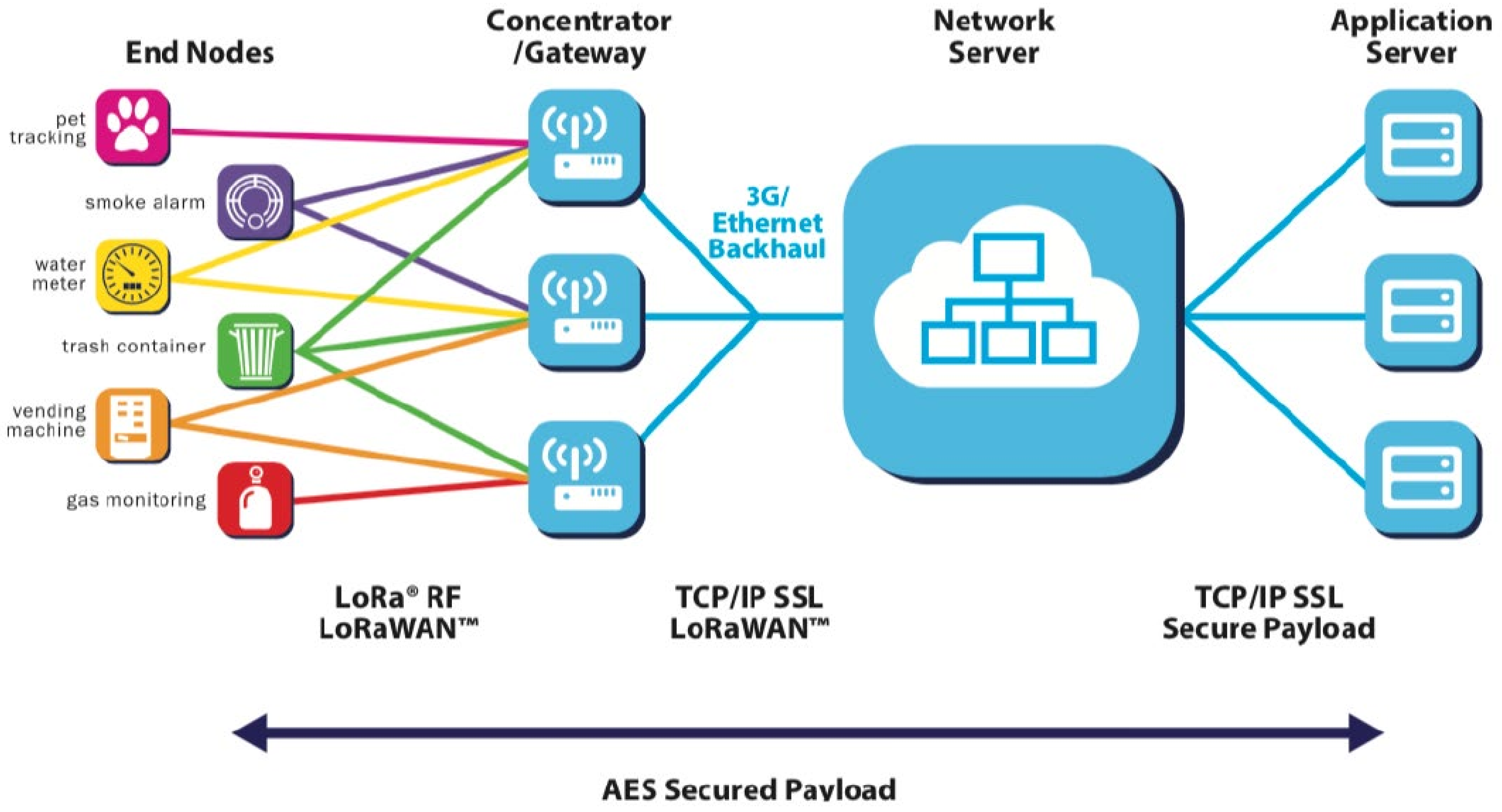
Sanne STIJVE

LoRa / LoRaWAN

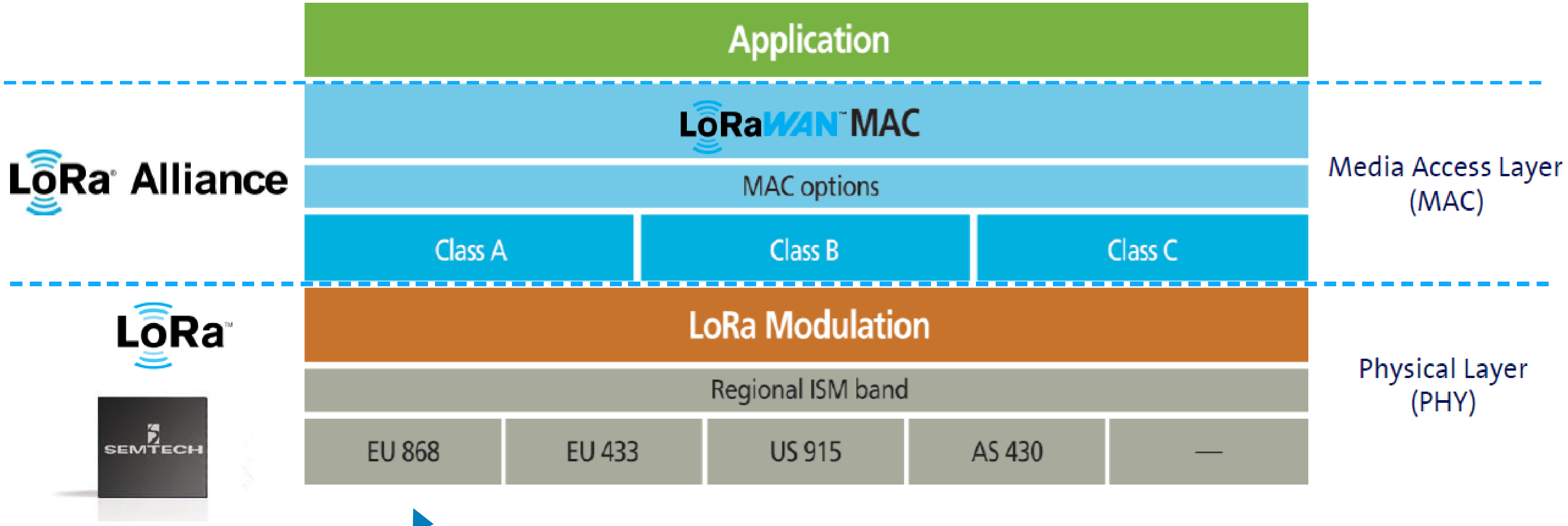
Caractéristiques d'un réseau LoRa / LoRaWAN

Caractéristiques de LoRa / LoRaWAN d'après l'un de ses promoteurs

Architecture LoRa / LoRaWAN



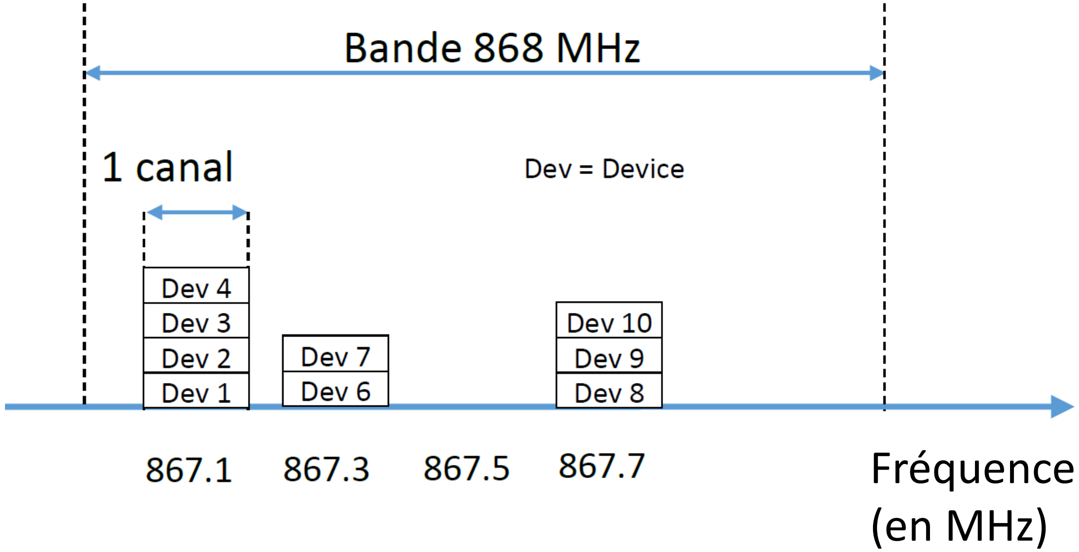
LoRaWAN "Stack"



Suisse

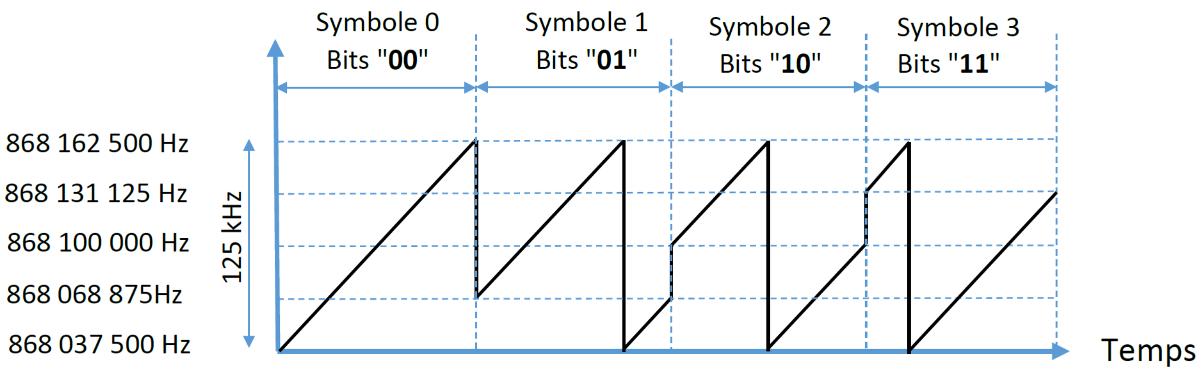
- La puissance d'émission est limitée à 25 mW (14dBm)
- Le dutycycle est limité à 1%
  (le temps de transmission total ne peut pas excéder p.ex. 36 sec / heure)

LoRa (interface radio)

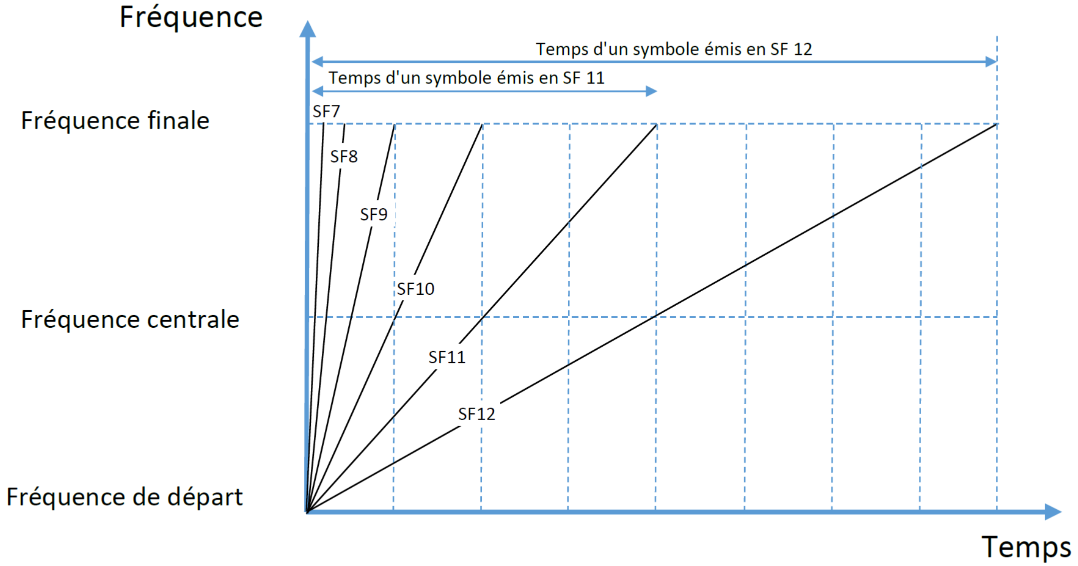


Bande passante de LoRa: 125 kHz ou 250 kHz

- Modulation « Chirp » de LoRa
- Spreading Factor = nombre de bits transmis par symbole



Symboles transmis en modulation LoRa en SF2 (cas théorique)



Source: LoRa - LoRaWAN et l'Internet des Objets, S. Montagny, Université Savoie Mt-Blanc

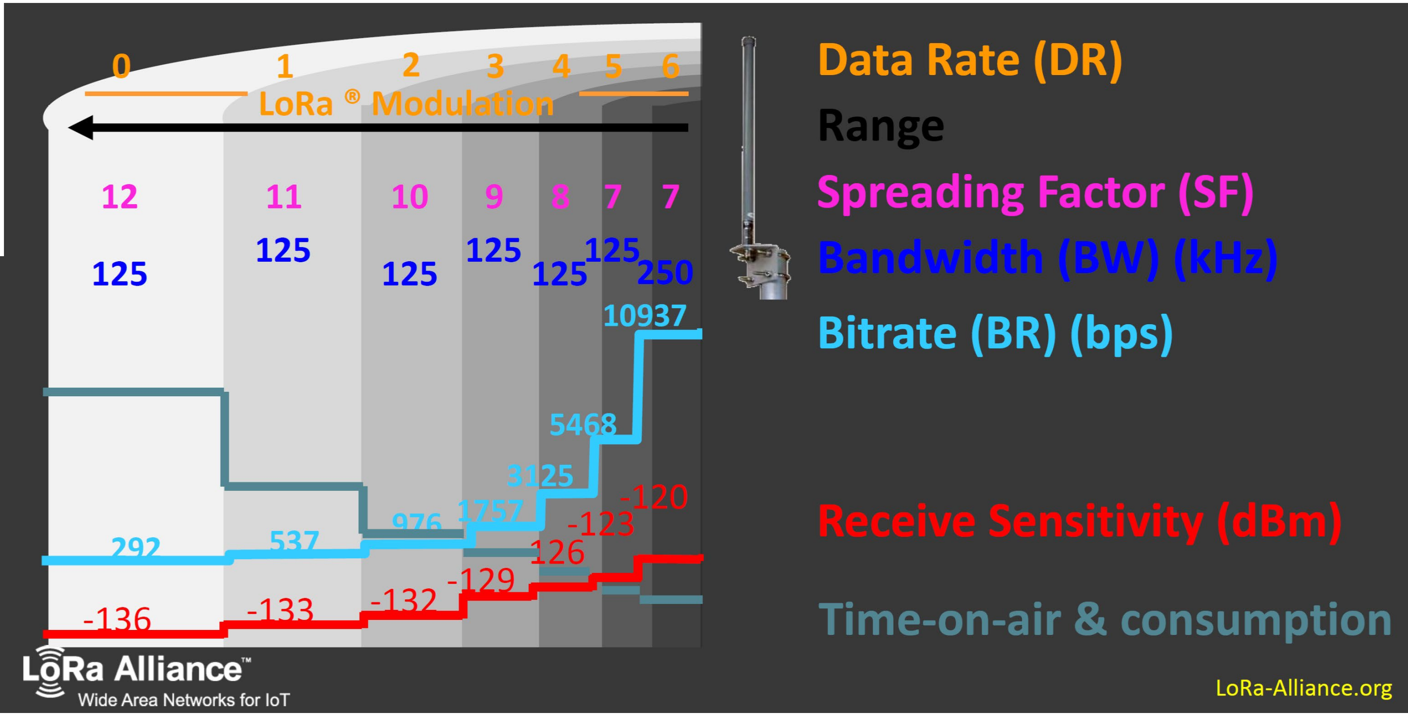
Relations débit vs. Spreading Factor vs. couverture vs. temps d'émission

Lower SF
↓
Shorter range
↓
Less time on air
↓
Lower energy consumption
↓
Higher data rate

Spreading Factor (For UL at 125 KHz)	Bit Rate	Range (Depends on Terrain)	Time on Air for an 11-byte payload
SF10	980 bps	8 km	371 ms
SF9	1760 bps	6 km	185 ms
SF8	3125 bps	4 km	103 ms
SF7	5470 bps	2 km	61 ms

ADR = Adaptive Data Rate

- LoRaWAN can auto-magically manage SF for each end-device:
  - To optimize for fastest data rate versus range
  - For maximize battery life, and
  - Achieves maximum network capacity



Tetra / Tetrapol

TETRA

Terrestrial Trunked Radio (ou TETRA)

Normes ETSI EN 300 392-1 et EN 300 392-2

- Spécialement conçu pour des cas d'usages tels que services de secours, forces de polices, ambulances et pompiers, services de transport public et pour l'armée.
- TETRA offre un canal radio partagé ouvert en permanence, et réservé à un groupe d'utilisateurs.
- Chaque utilisateur peut appuyer sur un bouton de son appareil pour parler, et tous les autres utilisateurs entendront sa voix.
  - Ceci permet d'établir une communication immédiate entre un utilisateur sur le terrain et un dispatcher, ou un groupe d'utilisateurs.
  - Les appels de groupe sont essentiels lorsque les instructions d'un officier ou d'un dispatcher doivent être entendues immédiatement par un groupe d'utilisateurs.

Systèmes de Secours

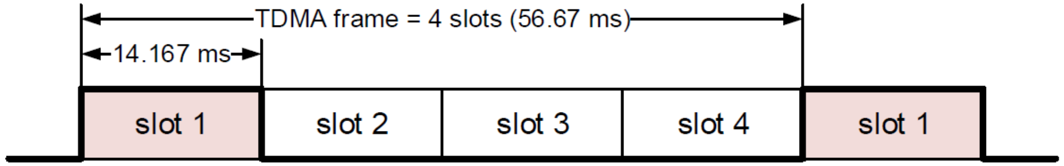
Numéro	Couple de Fréquence (MHz)	
	Bande 1	Bande 2
1	380-383	390-393
2	383-385	393-395

Systèmes Public

Numéro	Couple de Fréquence (MHz)	
	Bande 1	Bande 2
1	410-420	420-430
2	870-876	915-921
3	460-470	
4	385-390	395-399.9

Bandes de fréquences typiquement utilisées en Europe

Source: https://fr.wikipedia.org/wiki/Terrestrial_Trunked_Radio



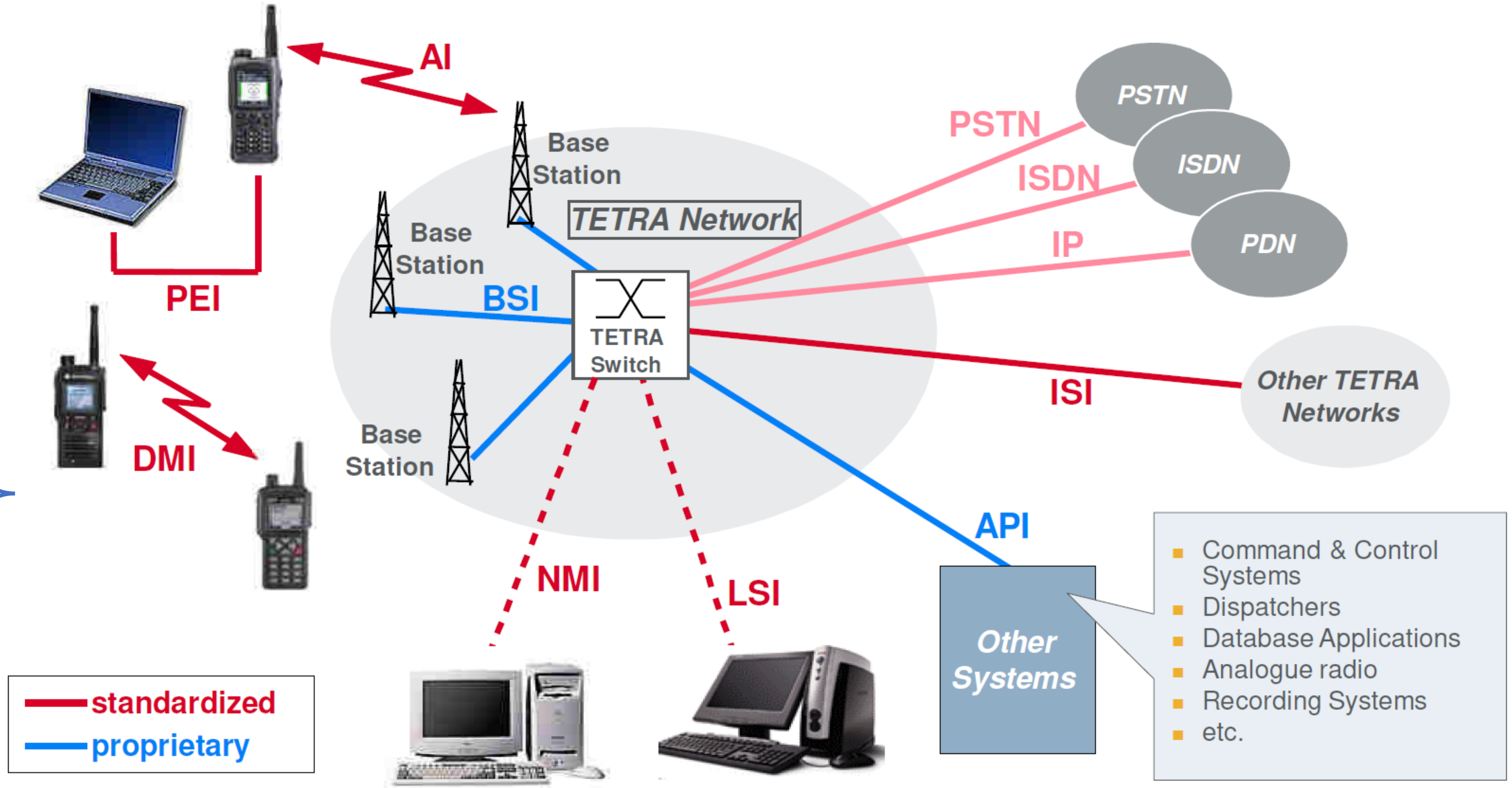
Structure TDMA en 4 slots

Architecture et interfaces d'un réseau Tetra

TETRA Direct Mode (DMO)

Portée (typique) :
- 500 - 2000 m en zones rurales
- 150 -300 m en zones urbaines

(puissance d'émission des appareils : 1 -3 W)



Wi-Fi

WLAN air interfaces (1/3)

Standard	Frequency range (GHz)	Number of channels	Bandwidth (MHz)	PHY Datarate (/s)	Modulation	Spreading	Channel access	max. Transmit power (mW EiRP)	Range (m)
DECT	1.88 - 1.90	10	0.864 (3dB)	0.8448 (GFSK) ⋮ 5.07 (64-QAM)	GFSK (B·T=0.5) π/2-DBPSK π/4-DQPSK ⋮ 16-QAM 64-QAM	no spreading	TDMA/FDM	250	300
Bluetooth	2.4 - 2.4835	79	1	1	GFSK	FHSS	TDD/FH	1 / 2.5 / 100	2 - 100
IEEE 802.11	2.4 - 2.4835	79	1	1	2-level GFSK	FHSS	CSMA/CA	100	20 - 100
			1	2	4-level GFSK				
		13	22	1	DBPSK	DSSS			
			22	2	DQPSK				
IEEE 802.11b	2.4 - 2.4835	13	22	1	DBPSK	DSSS	CSMA/CA	100	40 - 100
			22	2	DQPSK				
			22	5.5, 11	DBPSK / CCK / PBCC	DSSS	CSMA/CA	100	
IEEE 802.11g	2.4 - 2.4835	13	22	1	DBPSK	DSSS	CSMA/CA	100	40 - 140
			22	2	DQPSK				
			22	5.5, 11	DQPSK / CCK / PBCC				
			22	22, 33	8-PSK / ER-PBCC				
		3 / 7[d)]	22	6, 9	BPSK	DSSS / OFDM			

Source: WLAN Factsheet, Wireless Local Area Networks, Federal Office of Communications OFCOM, March 2023

WLAN air interfaces (2/3)

Standard	Frequency range (GHz)	Number of channels	Bandwidth (MHz)	PHY Datarate (/s)	Modulation	Spreading	Channel access	max. Transmit power (mW EiRP)	Range (m)
			22	12, 18	QPSK				
			22	24, 36	16-QAM				
			22	48, 54	64-QAM				
IEEE 802.11a	5.15 - 5.25 [a] 5.25 - 5.35 [a] [c]	4 [a]	20	same as IEEE 802.11h	same as IEEE 802.11h	OFDM 64 subcarriers (Δf = 312.5 kHz)	CSMA/CA / TDMA/TDD	Indoors 200	40 - 120
	5.47 - 5.725 [c]	15 [c]						1000	
IEEE 802.11h	5.15 - 5.35 [a]	8 [a]	20	6, 9 [b]	BPSK	OFDM 64 subcarriers (Δf = 312.5 kHz)	CSMA/CA / TDMA/TDD	Indoors 200	40 - 120
				12, 18 [b]	QPSK				
				24, 36 [b]	16-QAM				
				48 [b], 54 [b]	64-QAM [b]				
	5.47 - 5.725	11		6, 9 [b]	BPSK			1000	
				12, 18 [b]	QPSK				
				24, 36 [b]	16-QAM				
				48b), 54b)	64-QAM [b]				
IEEE 802.11n	2.4 - 2.4835	8 x 20 MHz 4 x 40 MHz	20 40	150 (1 stream) 300 (2 streams) 450 (3 streams) 600 (4 streams)	BPSK QPSK ⋮ 64-QAM	4 x 4 MIMO OFDM 128 subcarriers (Δf = 312.5 kHz)	CSMA/CA / TDMA/TDD	100	70 - 250
	5.15 - 5.35 [a]	19 x 20 MHz 9 x 40 MHz						Indoors 200	
	5.47 - 5.725							1000	
IEEE 802.11ac (Gigabit WLAN)	5.15 - 5.25 [a] 5.25 - 5.35 [a] [c]	2 x 80 MHz 1 x 160 MHz	20 40 80 160 (optional)	867 (1 stream) 1,733 (2 streams) 2,600 (3 streams) 3,467 (4 streams) 6,933 (8 streams)	BPSK QPSK ⋮ 256-QAM	8 x 8 MIMO OFDM 512 subcarriers (Δf = 312.5 kHz)	CSMA/CA / TDMA/TDD	Indoors 200	40 - 120
	5.47 - 5.725 [c]							1000	
IEEE 802.11ax	2.4 - 2.4835	8 x 20 MHz 4 x 40 MHz	20 40 80 160	1,201 (1 stream) 2,402 (2 streams) 3,603 (3 streams) 4,803 (4 streams) 6,005 (5 streams) 7,205 (6 streams) 8,406 (7 streams)	BPSK QPSK ⋮ 1024-QAM	8 x 8 MIMO UL/DL OFDM 2048 subcarriers (Δf = 78.125 kHz)	OFDMA	100	40 - 120
	5.15 - 5.25 [a] 5.25 - 5.35 [a] [c]	2 x 80 MHz 1 x 160 MHz						Indoors 200	
	5.47 - 5.725 [c]							1000	
	5.945-6.425	24 x 20 MHz						25	

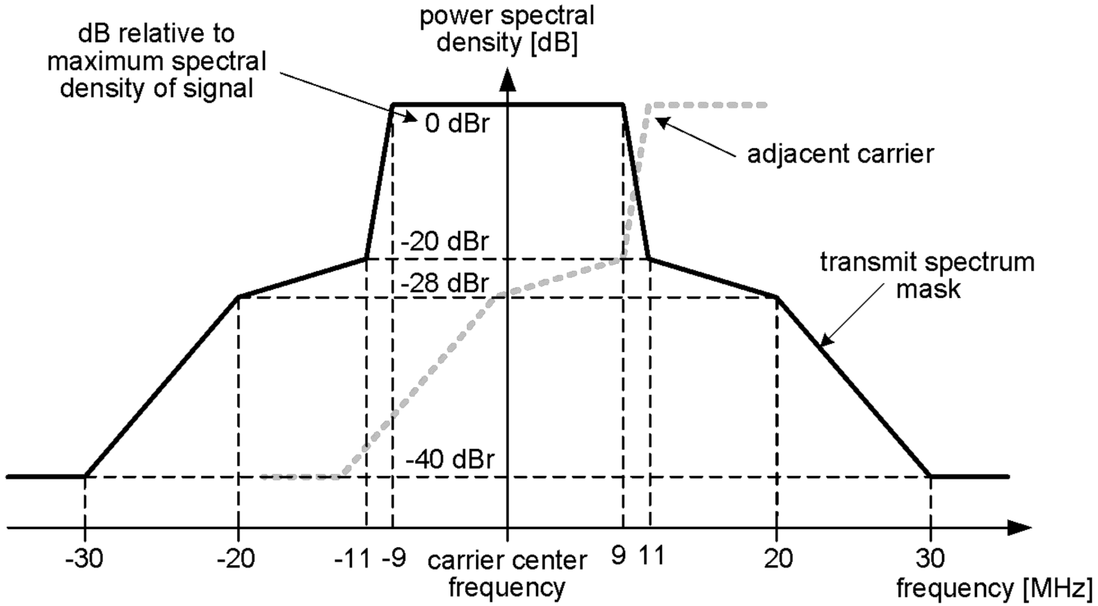
WLAN air interfaces (3/3)

Standard	Frequency range (GHz)	Number of channels	Bandwidth (MHz)	PHY Datarate (/s)	Modulation	Spreading	Channel access	max. Transmit power (mW EiRP)	Range (m)
		12 x 40 MHz 6 x 80 MHz 3 x 160 MHz		9,607 (8 streams)				Indoors 200	
IEEE 802.11ad (Wigig)	57 - 66	4	1'830.5	385 - 4'620 (SC) 693 - 6'757 (OFDM)	SC: π/4-BPSK π/4-QPSK π/4-16-QAM Spread QPSK OFDM: QPSK 16-QAM 64-QAM	SC: 1'760 Msym/s OFDM: 355 act. subcarrier (Δf = 5.15625 MHz)	TDMA/LBT	1000	10
IEEE 802.11ah (HaLow)	863 - 868 MHz	5 (1 MHz) 2 (2 MHz)	1 2	up to 8'670	BPSK QPSK ⋮ 256-QAM	OFDM 64 subcarrier (Δf = 31.25 kHz)	CSMA/CA/ TDMA/TD	25 e.r.p.	<1000
LTE-LAA	5.15 - 5.35 5.47 - 5.725	10 x 20 MHz 12 x 20 MHz	20 20	max. 100.8	QPSK 16 QAM 64 QAM	OFDM (Δf=15kHz)	TDD / LBT	200	40-120

a) Indoors only permitted
b) Optional
c) *not permitted throughout Europe because of absence of TPC and DFS mitigation techniques (acc. to ERC/DEC(04)08, Decides 1– 6 and EN 301 893)*
d) overlapping

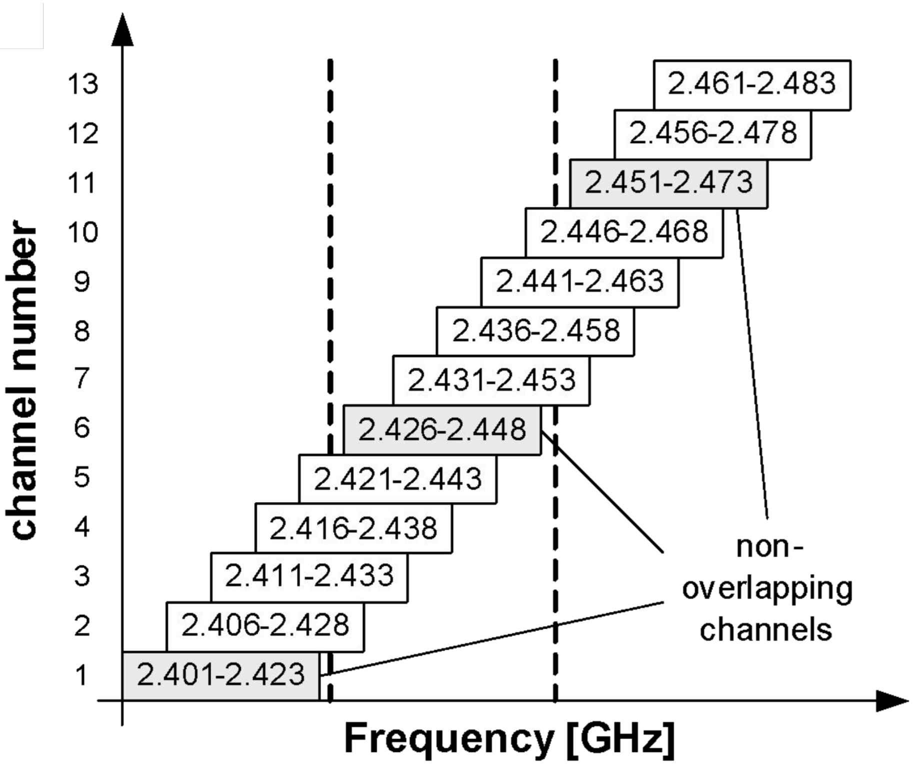
IEEE 802.11 Spectrum @ 2.4 GHz

Transmit spectrum mask of 802.11a: limiting transmission power in frequency range

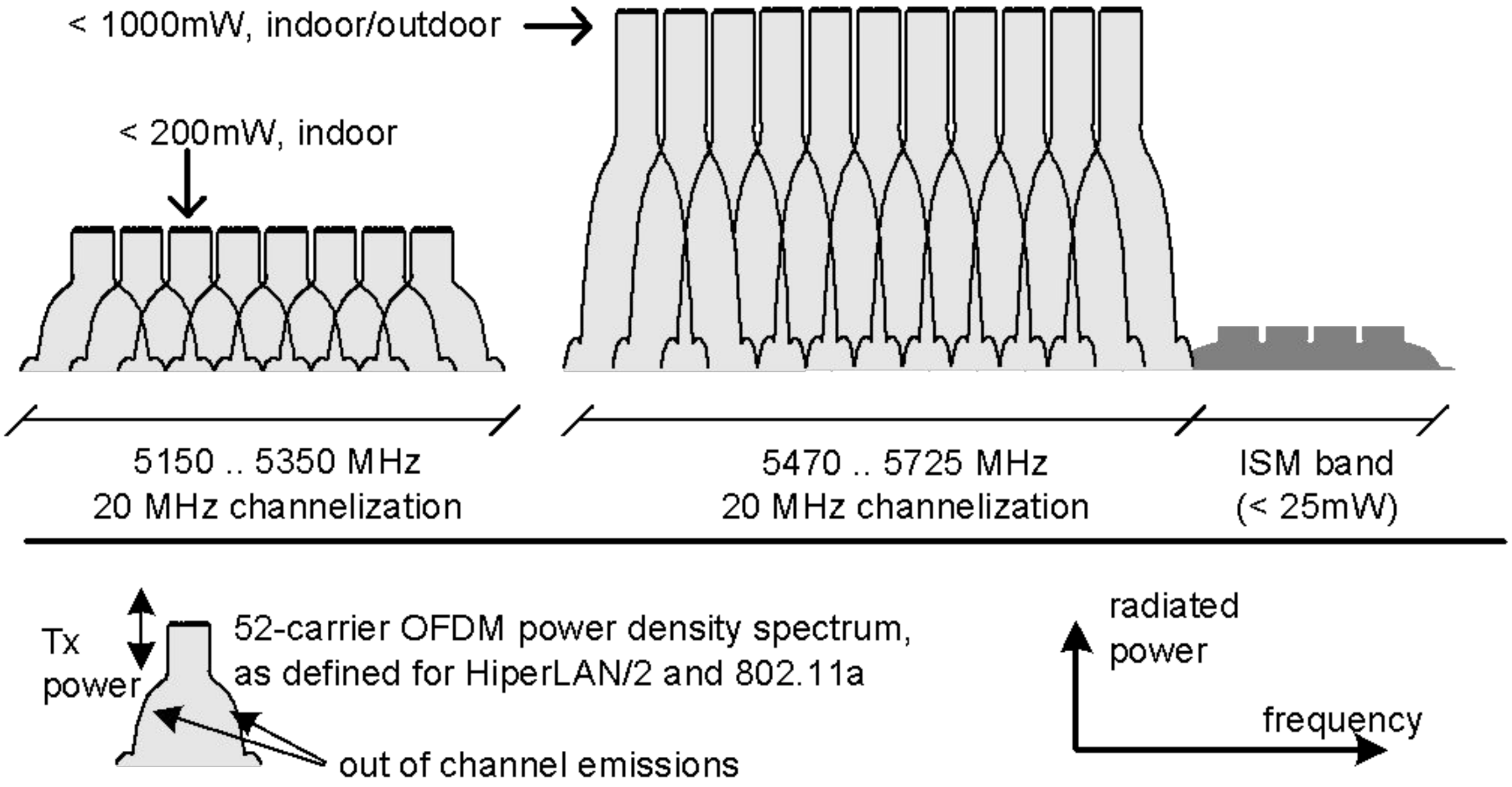


Adjacent channels interfere with each other

- Up to 13 channels, 3 are non-overlapping



IEEE 802.11 Spectrum @ 5 GHz



Operation @ Higher vs. Lower Frequencies

Advantages @ 2.4 GHz

- License-exempt (unlicensed) ISM band
- High device penetration and low device costs

Disadvantages @ 2.4 GHz

- Only 3 non-overlapping channels, heavily used even by dissimilar radio systems (e.g. Bluetooth, microwave ovens)

Advantages @ 5 GHz

- 19 non-overlapping channels → better interference situation, more capacity
- Higher transmission power (1W vs. 100mW)

Disadvantages @ 5 GHz

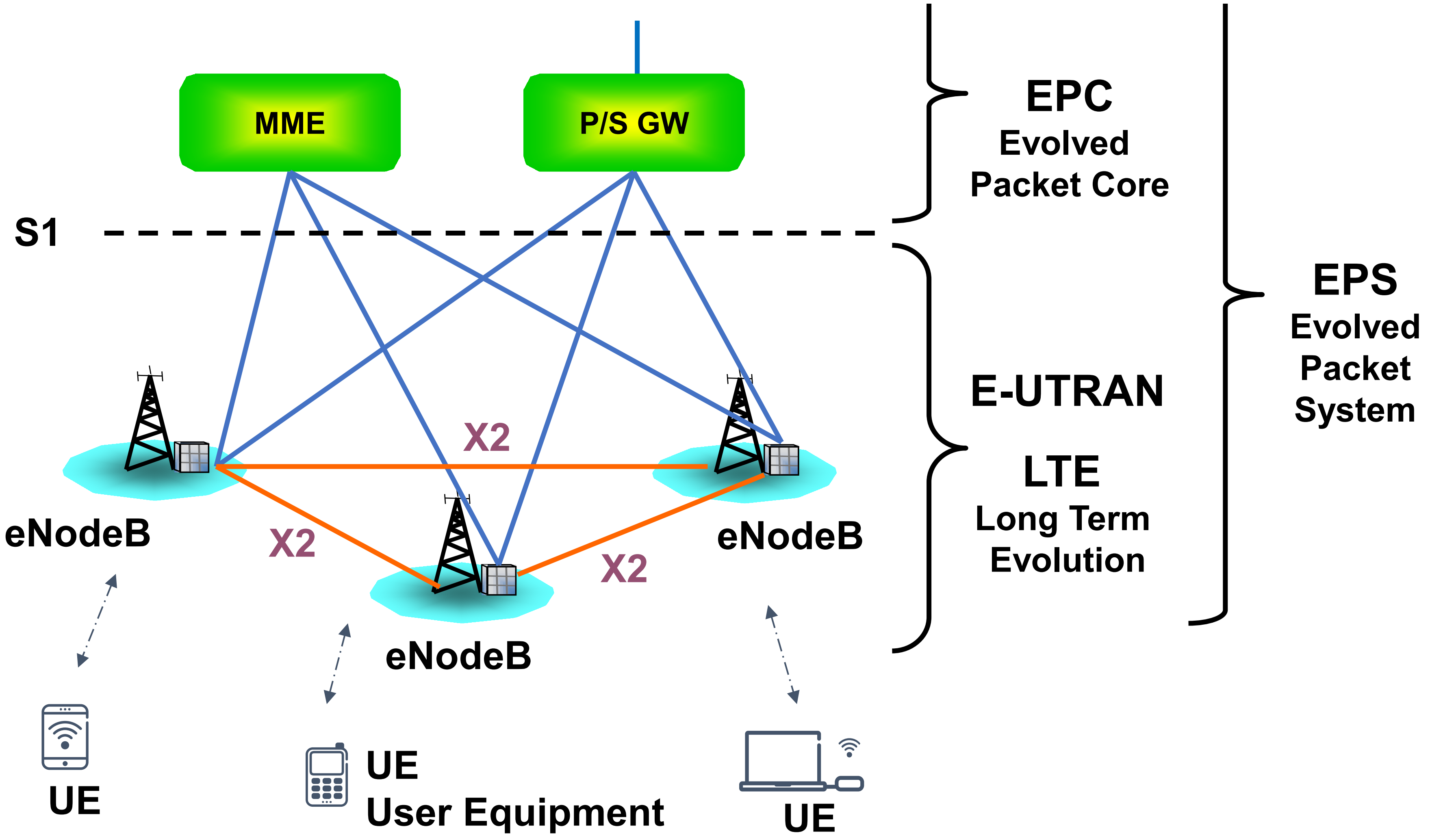
- Higher frequencies have higher path losses, reduced range → more dense deployment of APs is needed

Architecture des réseaux LTE & 5G

Sanne STIJVE

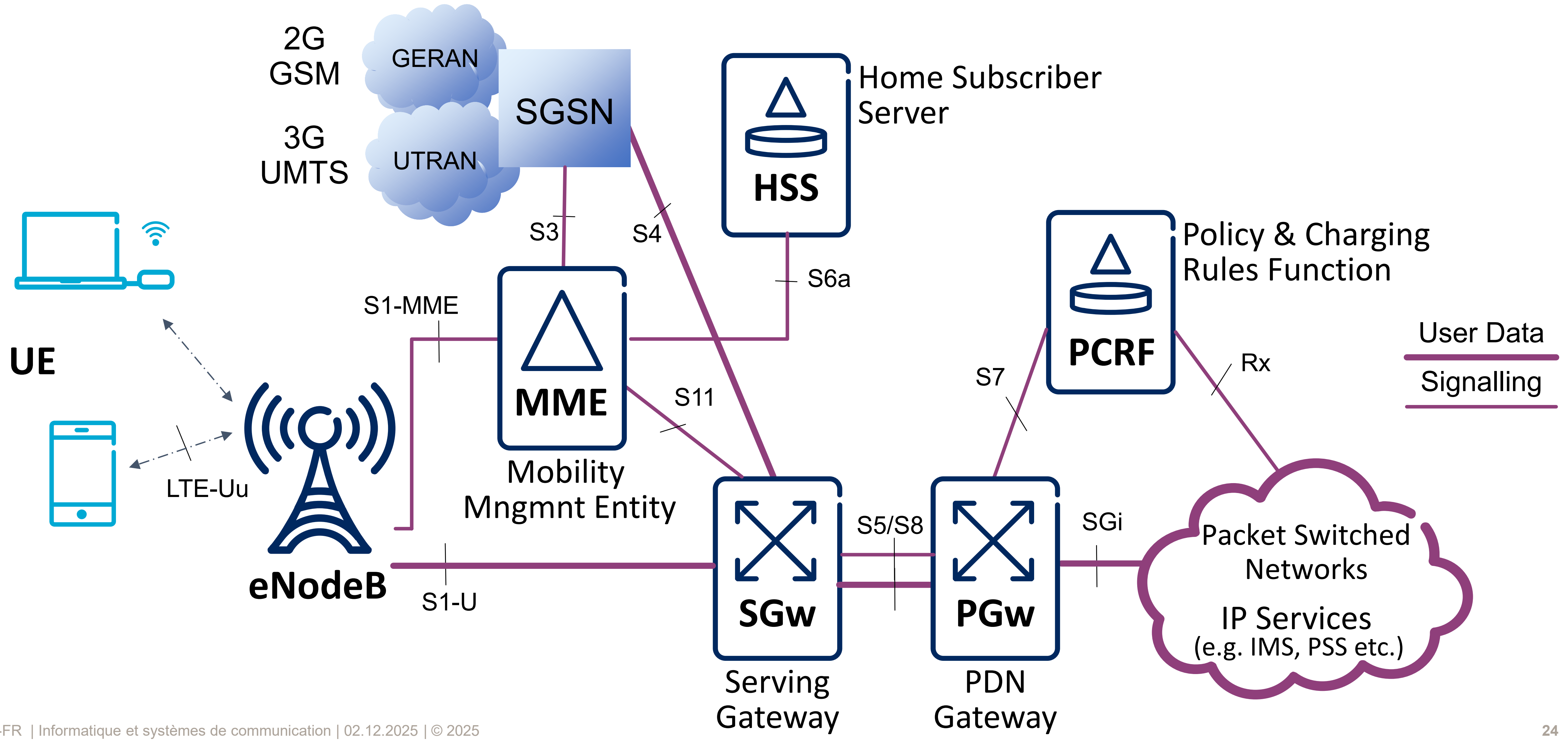
4G / LTE

LTE/EPC Architecture & Terminology



LTE/EPC Network Architecture

Plus: Network Management System (NMS, OSS)
Business Support System (BSS)



Source: Ericsson

Principles and explanations

- Clear separations of domains with defined interfaces
  - Independent evolution of User Equipment, Access, Core, Transport and Services
- Separation of Control Plane and User Plane

eNB, Evolved NodeB : Provides LTE Radio Interface

SGw, Serving Gateway : Local anchor for mobility

PGw, Packet Data network Gateway : Provides connectivity towards external Packet Data Networks. The PGw is responsible for supplying the IP address that is used by the UE

MME, Mobility Management Entity : Authentication and registrations; mobility management, security handling, bearer establishment, service connectivity

HSS, Home Subscriber Server : Manages user subscription information (evolution of HLR)

PCRF, Policy and Charging Rules Function : Handles policy control decisions and flow-based charging (QoS)

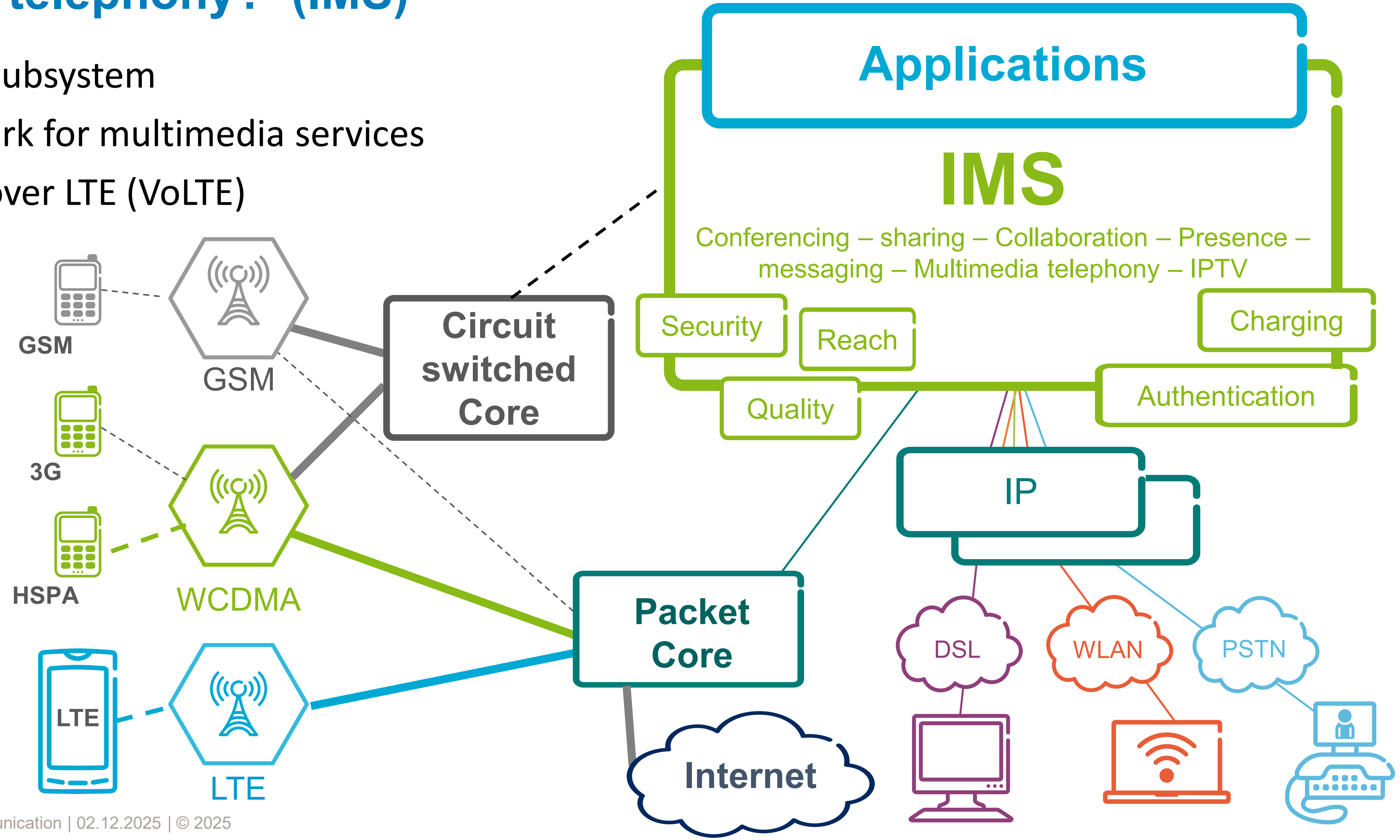
Source: Ericsson

What about telephony? (IMS)

IMS : IP Multimedia Subsystem

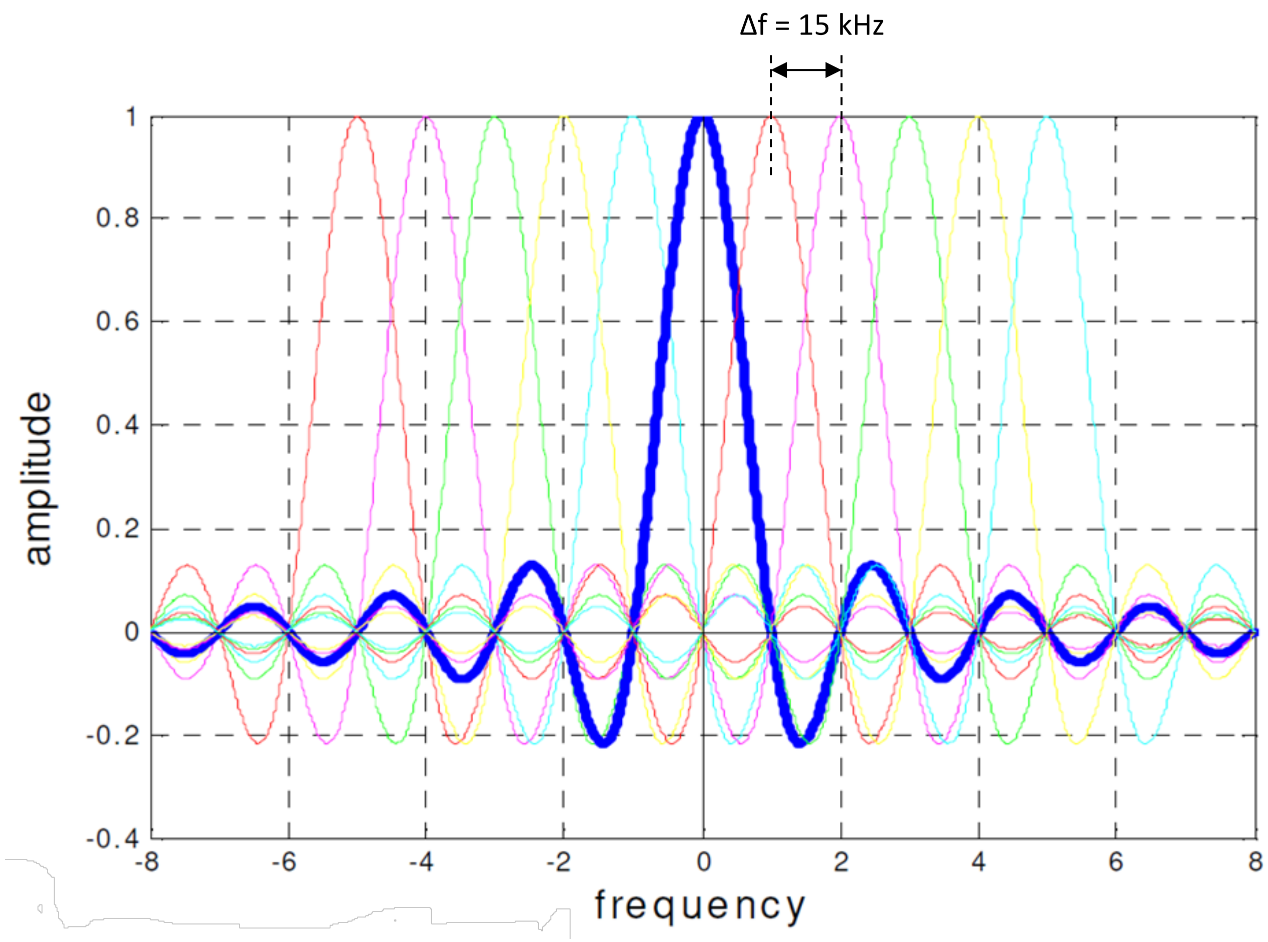
IMS is an all-IP network for multimedia services

Main driver is Voice over LTE (VoLTE)



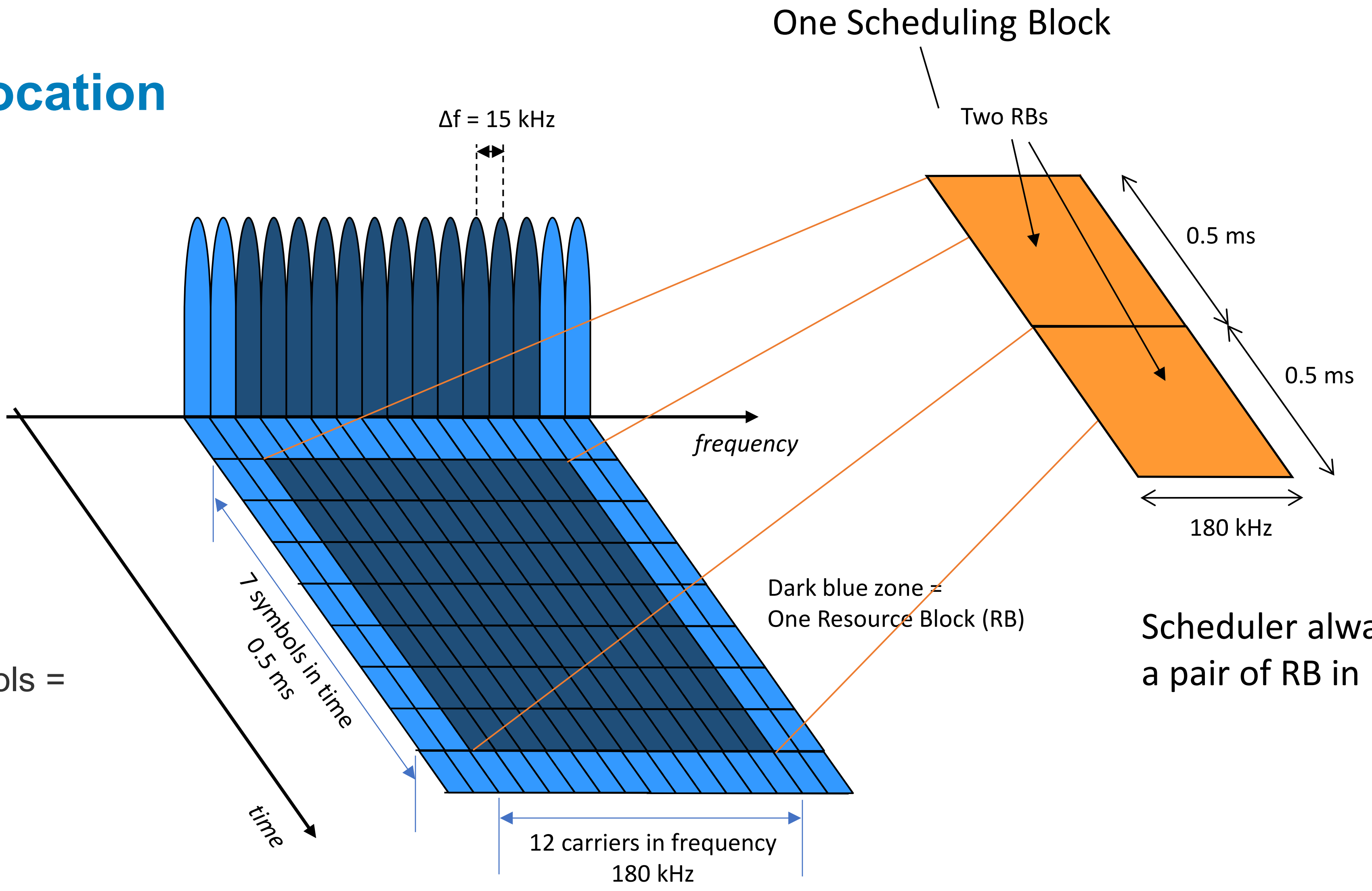
LTE Physical layer: Radio Access based on OFDM

- Orthogonal Frequency Division Multiplexing
  - OFDM commonly used today
- High spectral efficiency
  - Simple receiver design
  - Bandwidth divided into many tones
  - Tones in theory fully orthogonal
  - Frequency diversity
  - Suitable for MIMO
- Flexible bandwidth allocation, just scale number of tones
- Easily multiplexed while keeping users orthogonal



Sub carrier spacing in LTE: 15 kHz

Resource allocation

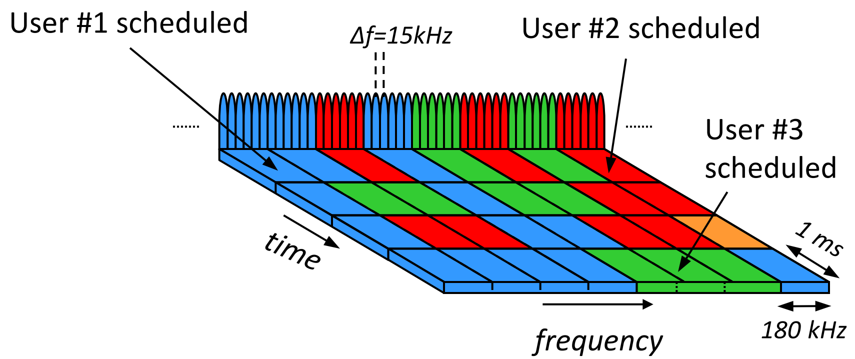


Scheduler always assigns a pair of RB in 1 ms TTI

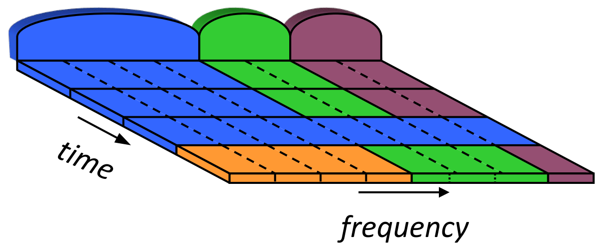
12 tones during 7 symbols = one resource block

LTE Physical Layer

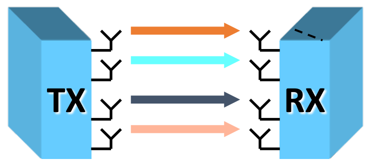
- Downlink: *Adaptive OFDM and OFDMA*
  - *Channel-dependent scheduling and link adaptation in time and frequency domain*



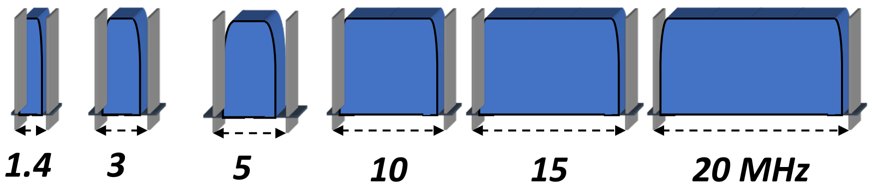
- Uplink: SC-FDMA with dynamic bandwidth (Pre-coded OFDM)
  - *Low PAPR ➡ Higher power efficiency*
  - *Reduced uplink interference (enables intra-cell orthogonality)*



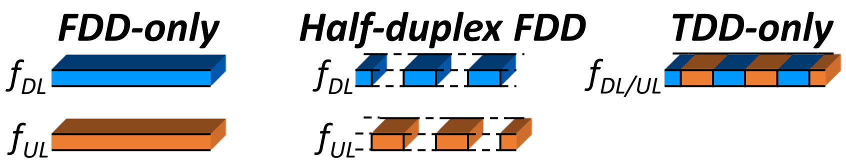
- Multi-Antennas, both RBS and terminal
  - *MIMO, antenna beams, TX- and RX diversity, interference rejection*
  - *High bit rates and high capacity*



- Flexible bandwidth
  - *Possible to deploy in 6 different bandwidths up to 20 MHz*



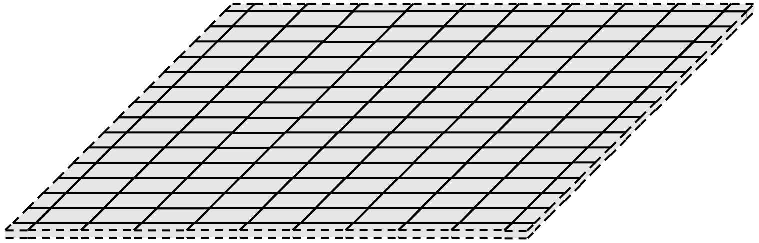
- Harmonized FDD and TDD concept
  - *Maximum commonality between FDD and TDD*
- Minimum UE capability: BW = 20 MHz



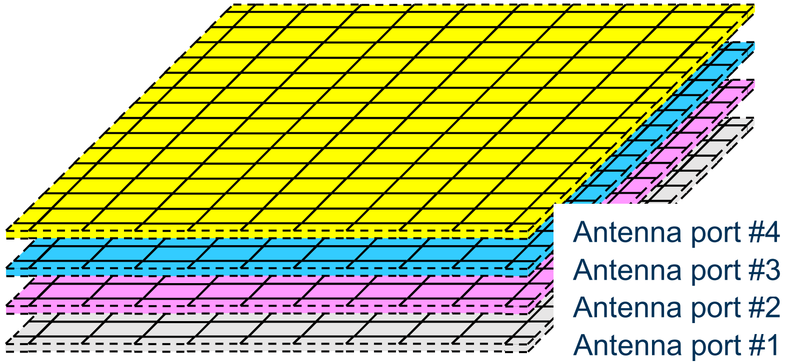
Source: Ericsson

Multi-antenna transmission

Single-antenna transmisson



Multi-antenna transmisson

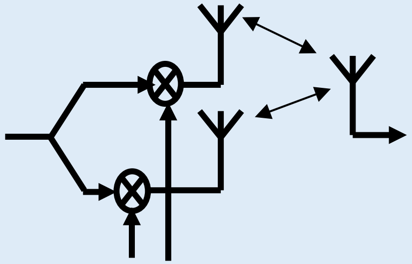


MISO or SIMO

Directivity

Antenna / Beamforming gain

Example



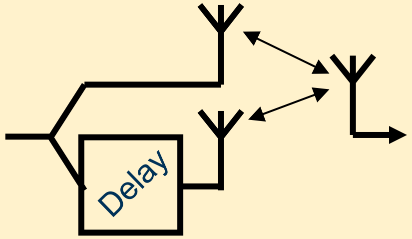
Transmit the signal in the best direction

MISO or SIMO

Diversity

"Reduce fading"

Example



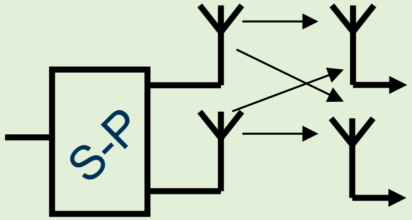
Transmit the signal in all directions

MIMO

Spatial Multiplexing

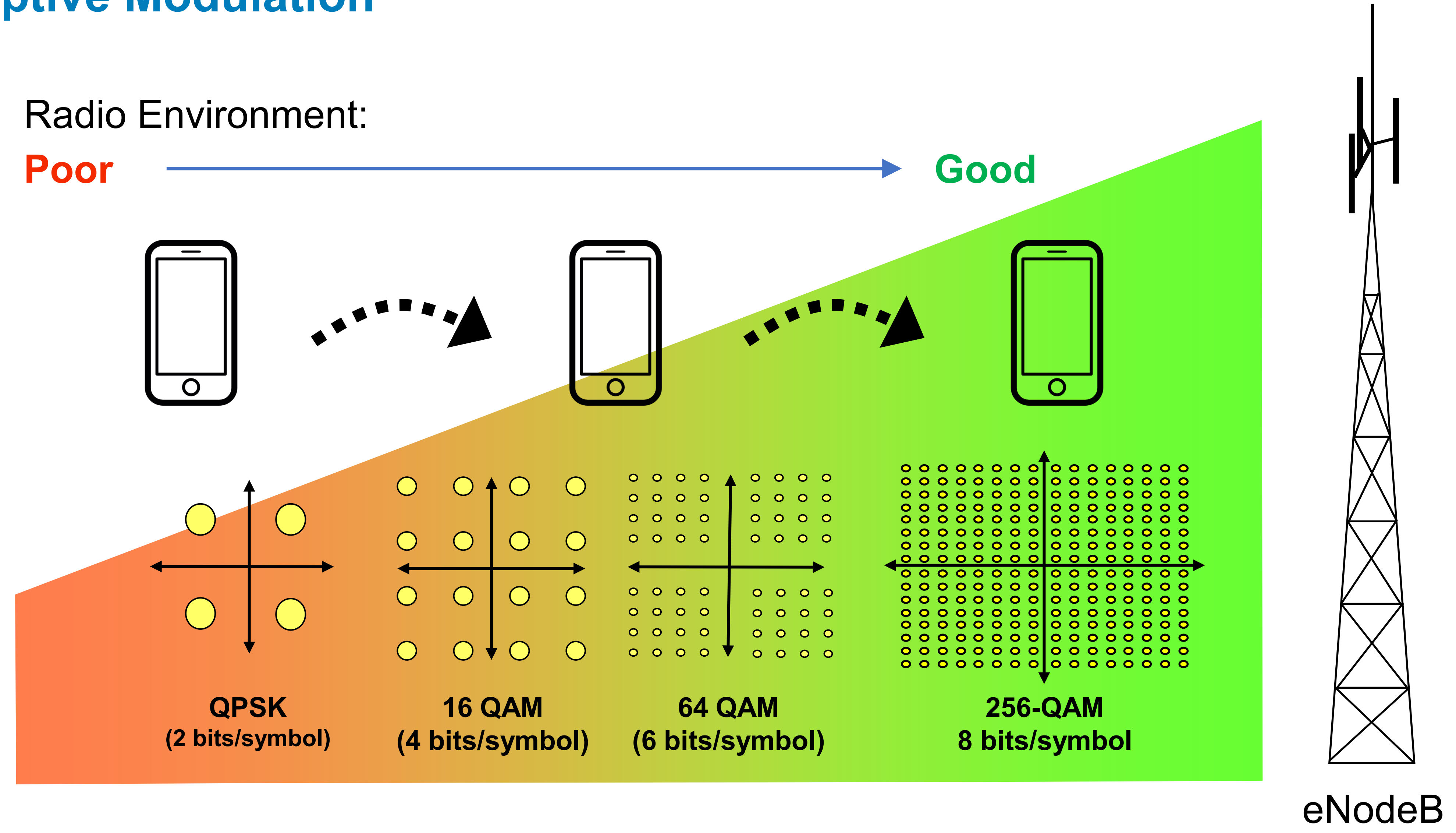
"Data Rate multiplication"

Example

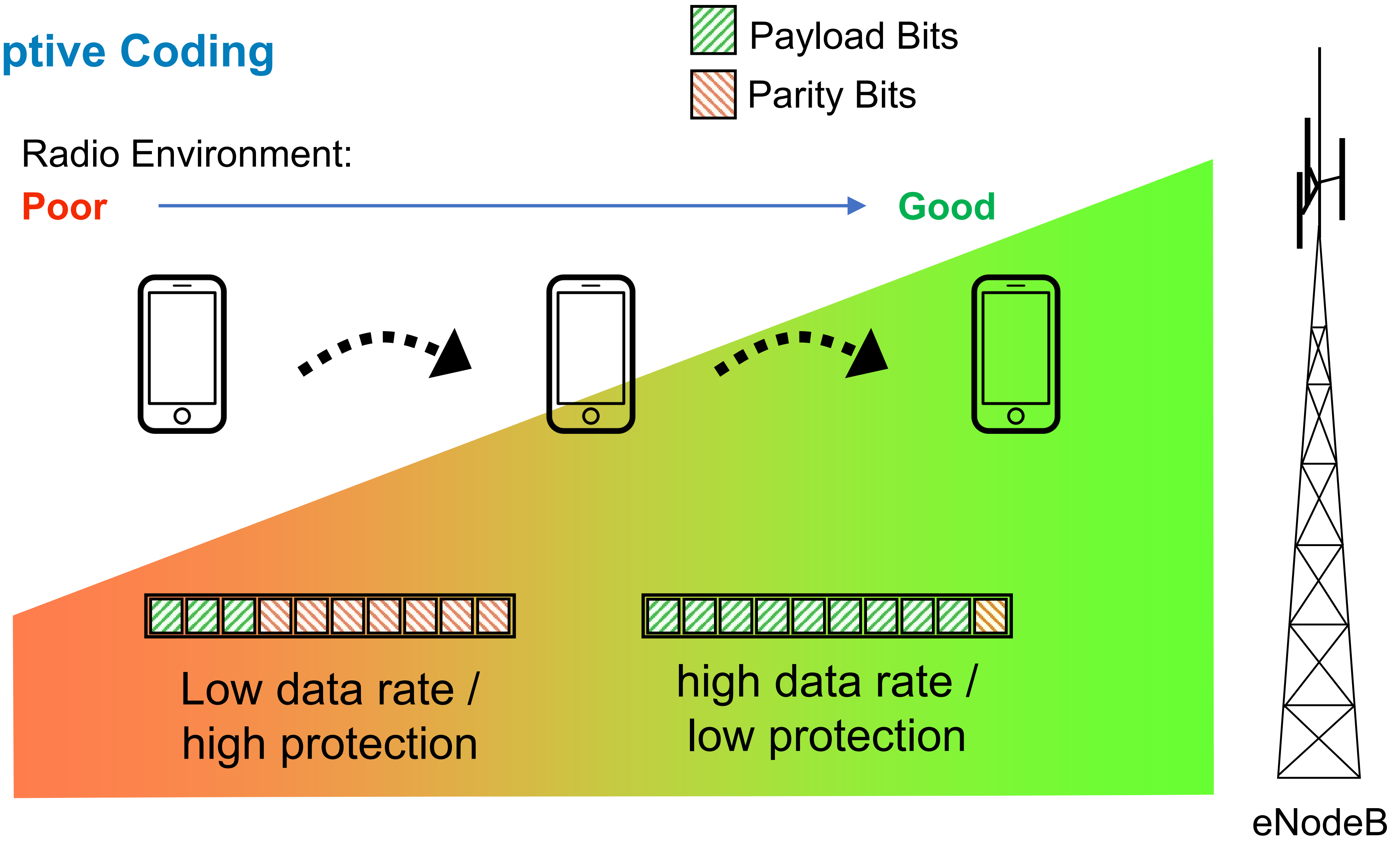


Transmit several signals in different directions

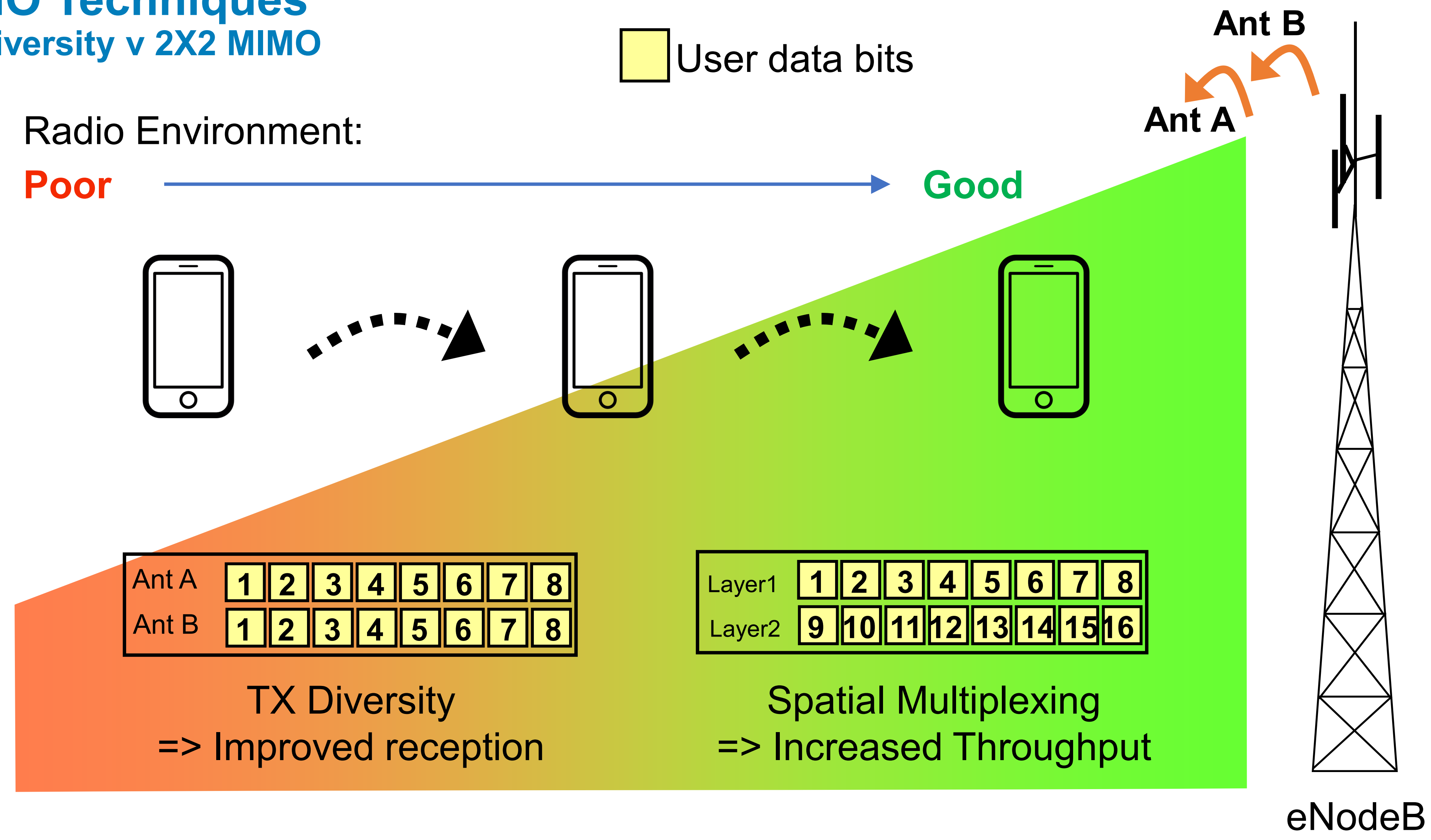
Adaptive Modulation



Adaptive Coding



MIMO Techniques
TX Diversity v 2X2 MIMO

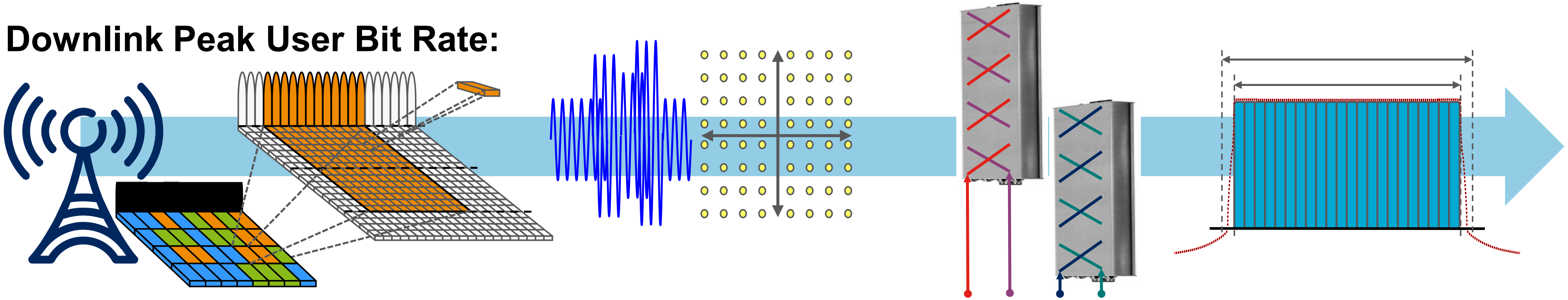


LTE UE Categories (not exhaustive)

<table>
<tr><th>Category</th><th>0</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th><th>10</th><th>11</th><th>12</th><th>13</th><th>14</th><th>15</th><th>16</th><th>17</th></tr>
<tr><th>DL Peak Rate</th><td>1</td><td>10</td><td>50</td><td>100</td><td>150</td><td>300</td><td>300</td><td>300</td><td>3000</td><td>450</td><td>450</td><td>600</td><td>600</td><td>390</td><td>3900</td><td>800</td><td>1000</td><td>25000</td></tr>
<tr><th>UL Peak Rate</th><td>1</td><td>5</td><td>25</td><td>50</td><td>50</td><td>75</td><td>50</td><td>100</td><td>1500</td><td>50</td><td>100</td><td>50</td><td>100</td><td>150</td><td>1500</td><td>*</td><td>*</td><td>*</td></tr>
<tr><th>Max DL mod</th><td colspan="11">64 QAM</td><td colspan="7">256 QAM</td></tr>
<tr><th>Max UL mod</th><td colspan="5">16 QAM</td><td>64 QAM</td><td colspan="2">16 QAM</td><td>64 QAM</td><td colspan="2">16 QAM</td><td colspan="7">64 QAM</td></tr>
<tr><th>Layers for spatial mux.</th><td>1</td><td>1</td><td colspan="3">2</td><td>4</td><td>2 or 4</td><td>2 or 4</td><td>8</td><td>2 or 4</td><td>2 or 4</td><td>2 or 4</td><td>2 or 4</td><td>2 or 4</td><td>8</td><td>2 or 4</td><td>2 or 4</td><td>8</td></tr>
<tr><th>3GPP Release</th><td>Rel. 12</td><td colspan="5">Rel. 8</td><td colspan="3">Rel. 10</td><td colspan="4">Rel. 11</td><td colspan="4">Rel. 12</td><td>Rel. 13</td></tr>
</table>

LTE Peak User Bit Rates

Downlink Peak User Bit Rate:



Approximately 25% signalling Overhead
=> 300 Mbps
150 Mbps 2X2 MIMO
75 Mbps Beam Forming

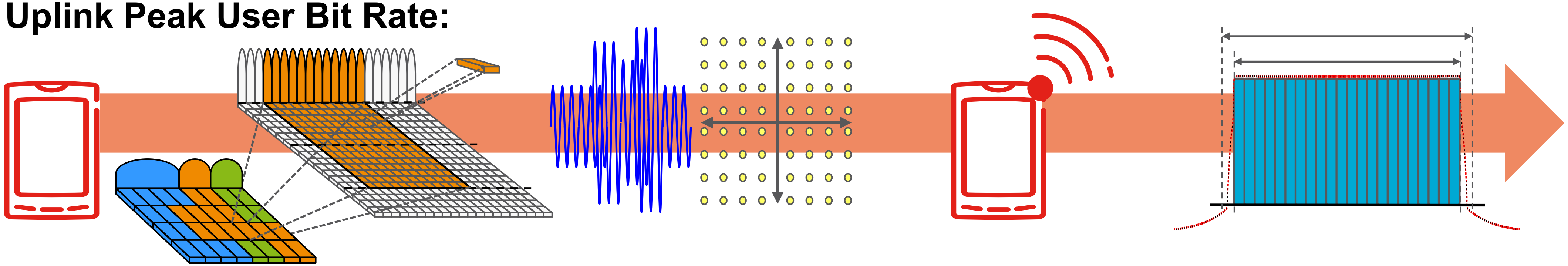
Each RB carries 168 symbols every 1 msec
=> 168,000 symbols/sec

Using 64 QAM each symbol carries 6 bits
=> 1 Mbps per RB

Using 4X4 MIMO transmission
=> 4 Mbps per RB

20 MHz Bandwidth supports 100 RBs
=> 400 Mbps

Uplink Peak User Bit Rate:



Approximately 25% signalling Overhead
=> 75 Mbps

Each RB carries 168 symbols every 1 msec
=> 168,000 symbols/sec

Using 64 QAM each symbol carries 6 bits
=> 1 Mbps per RB

Single Antenna transmission
=> 1 Mbps per RB

20 MHz Bandwidth supports 100 RBs
=> 100 Mbps

LTE Cell capacity

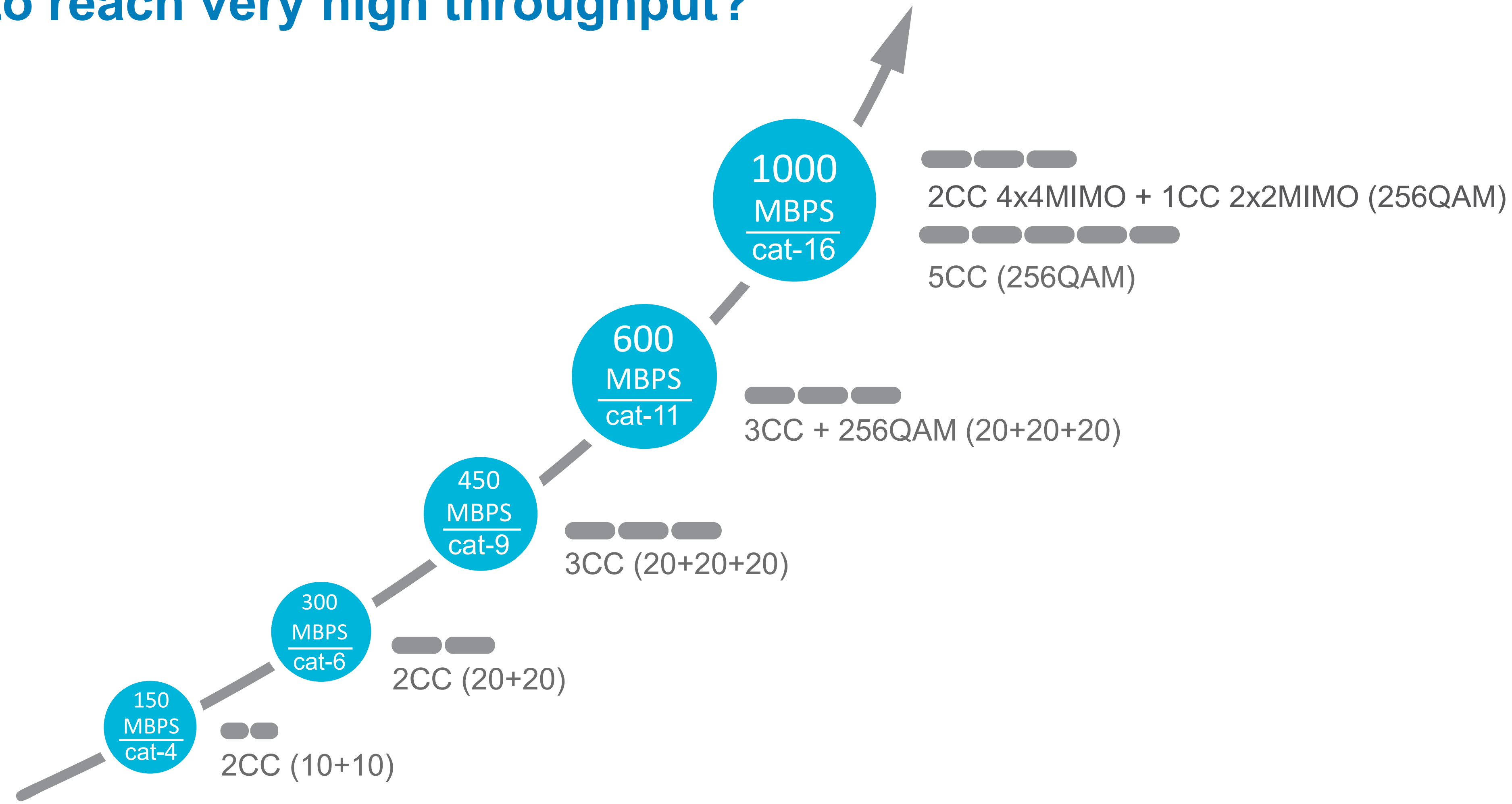
	3 MHz	5 MHz	10 MHz	20 MHz
Downlink with 2x2 MIMO	22 Mbit/s	37 Mbit/s	75 Mbit/s	150 Mbit/s
Uplink (no MIMO)	11 Mbit/s	18 Mbit/s	37 Mbit/s	75 Mbit/s

Cell throughput in relation with bandwidth of LTE FDD cell

Further increase of capacity:

- Add bandwidth (Carrier Aggregation)
- Use MIMO 4x4, 8x8 or massive MIMO (a 5G technology)
- Use advanced modulation (e.g. 256 QAM)

How to reach very high throughput?



Source: Ericsson

TDD configurations

TDD Configurations:

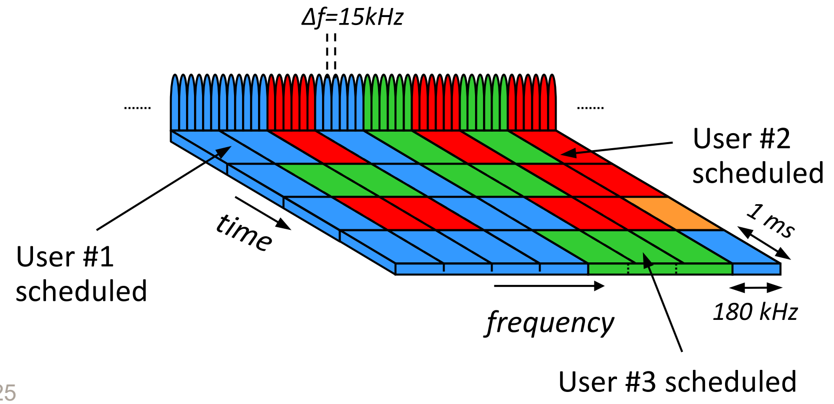
0	#0 ↓	↓ ↑	#2 ↑	#3 ↑	#4 ↑	#5 ↓	↓ ↑	#7 ↑	#8 ↑	#9 ↑
1	#0 ↓	↓ ↑	#2 ↑	#3 ↑	#4 ↓	#5 ↓	↓ ↑	#7 ↑	#8 ↑	#9 ↓
2	#0 ↓	↓ ↑	#2 ↑	#3 ↓	#4 ↓	#5 ↓	↓ ↑	#7 ↑	#8 ↓	#9 ↓
3	#0 ↓	↓ ↑	#2 ↑	#3 ↑	#4 ↑	#5 ↓	#6 ↓	#7 ↓	#8 ↓	#9 ↓
4	#0 ↓	↓ ↑	#2 ↑	#3 ↑	#4 ↓	#5 ↓	#6 ↓	#7 ↓	#8 ↓	#9 ↓
5	#0 ↓	↓ ↑	#2 ↑	#3 ↓	#4 ↓	#5 ↓	#6 ↓	#7 ↓	#8 ↓	#9 ↓
6	#0 ↓	↓ ↑	#2 ↑	#3 ↑	#4 ↑	#5 ↓	↓ ↑	#7 ↑	#8 ↑	#9 ↓

Scheduler - Exercice

Quels sont les inputs que le scheduler doit prendre en compte ?

Scheduler

Sur quoi le scheduler agit-il ? (quelles sont les décisions qu'il prend?)



5G
En comparaison avec la 4G

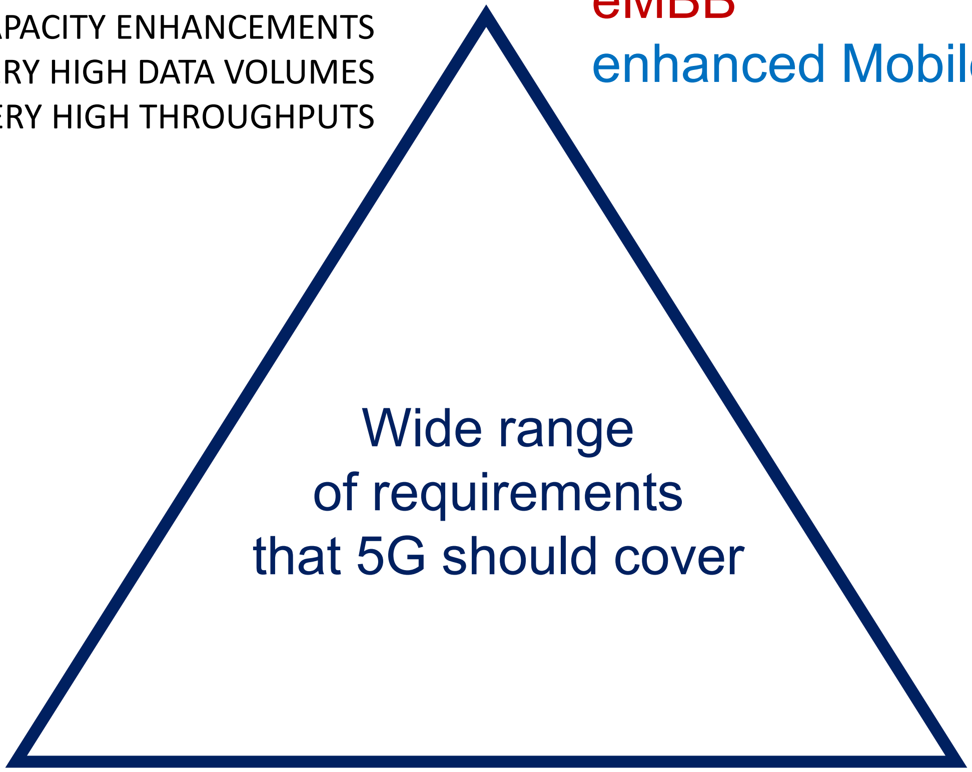
Et la 5G ?

- La 5G prend en charge une grande variété de nouvelles applications
- Le NW-Slicing permet de répondre aux différentes exigences sur le même réseau
- Le ‘LTE Evolution’ fait partie de 5G
- Le LTE constitue la base de la 5G par de nombreux aspects
- Les investissements dans LTE ne sont pas perdus

Wide range of requirements

CAPACITY ENHANCEMENTS
VERY HIGH DATA VOLUMES
VERY HIGH THROUGHPUTS

eMBB
enhanced Mobile Broadband



LOW COST, LOW ENERGY
SMALL DATA VOLUMES
MASSIVE NUMBERS
BETTER COVERAGE

ULTRA RELIABLE
VERY LOW LATENCY
VERY HIGH AVAILABILITY

mMTC
massive Machine-Type Communication

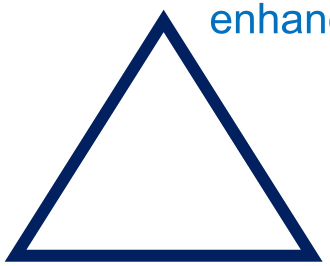
URLLC
Ultra-Reliable Low Latency Communication
(Time) Critical Communication

Exercice

- Pouvez-vous proposer quelques cas d'utilisation pour la 5G ?
  - Pensez à ce qui ne serait pas possible en 4G mais possible en 5G

- Classez vos cas d'usage suivant eMBB, mMTC et URLLC

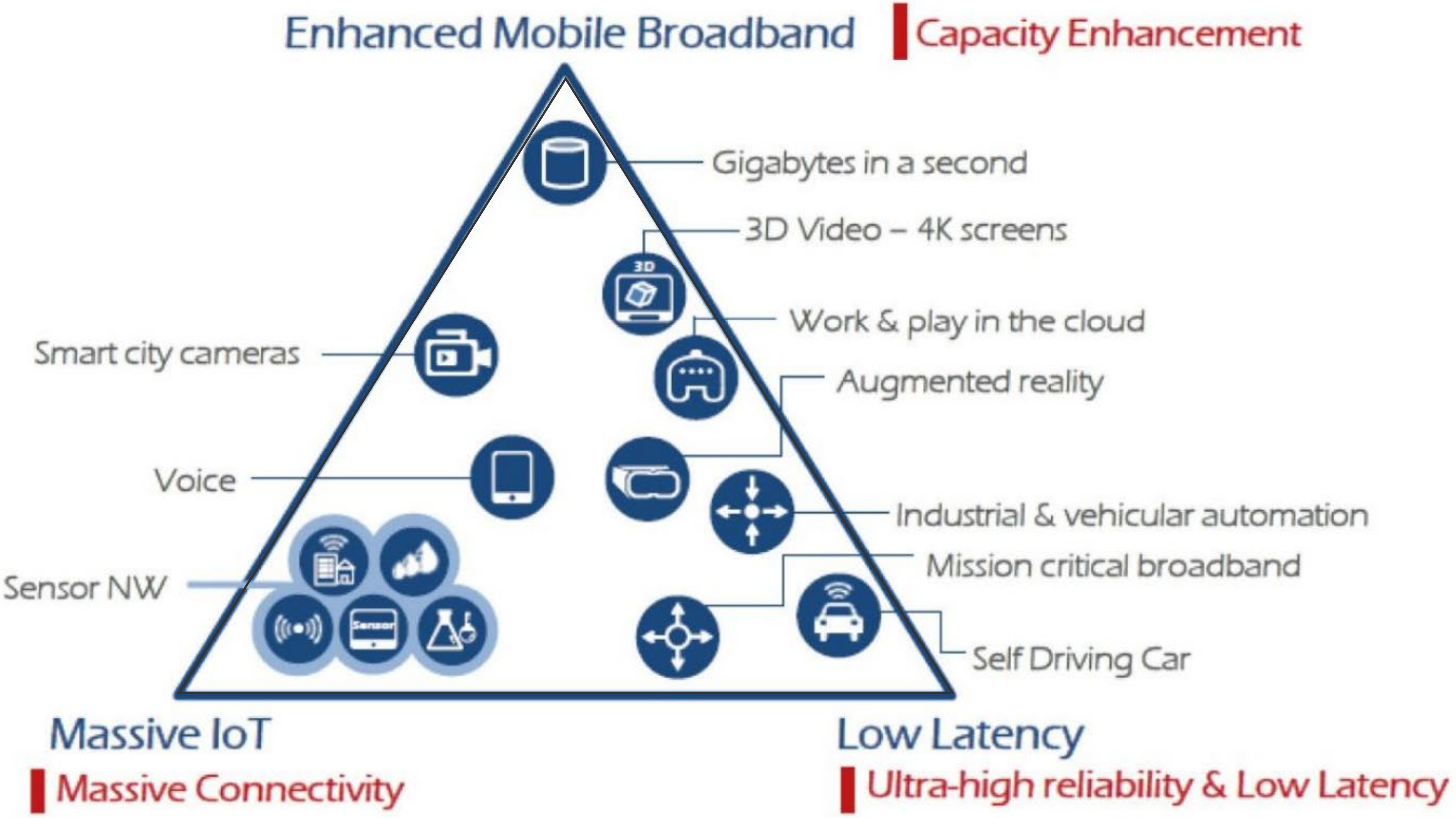
eMBB
enhanced Mobile Broadband



mMTC
massive Machine-Type Communication

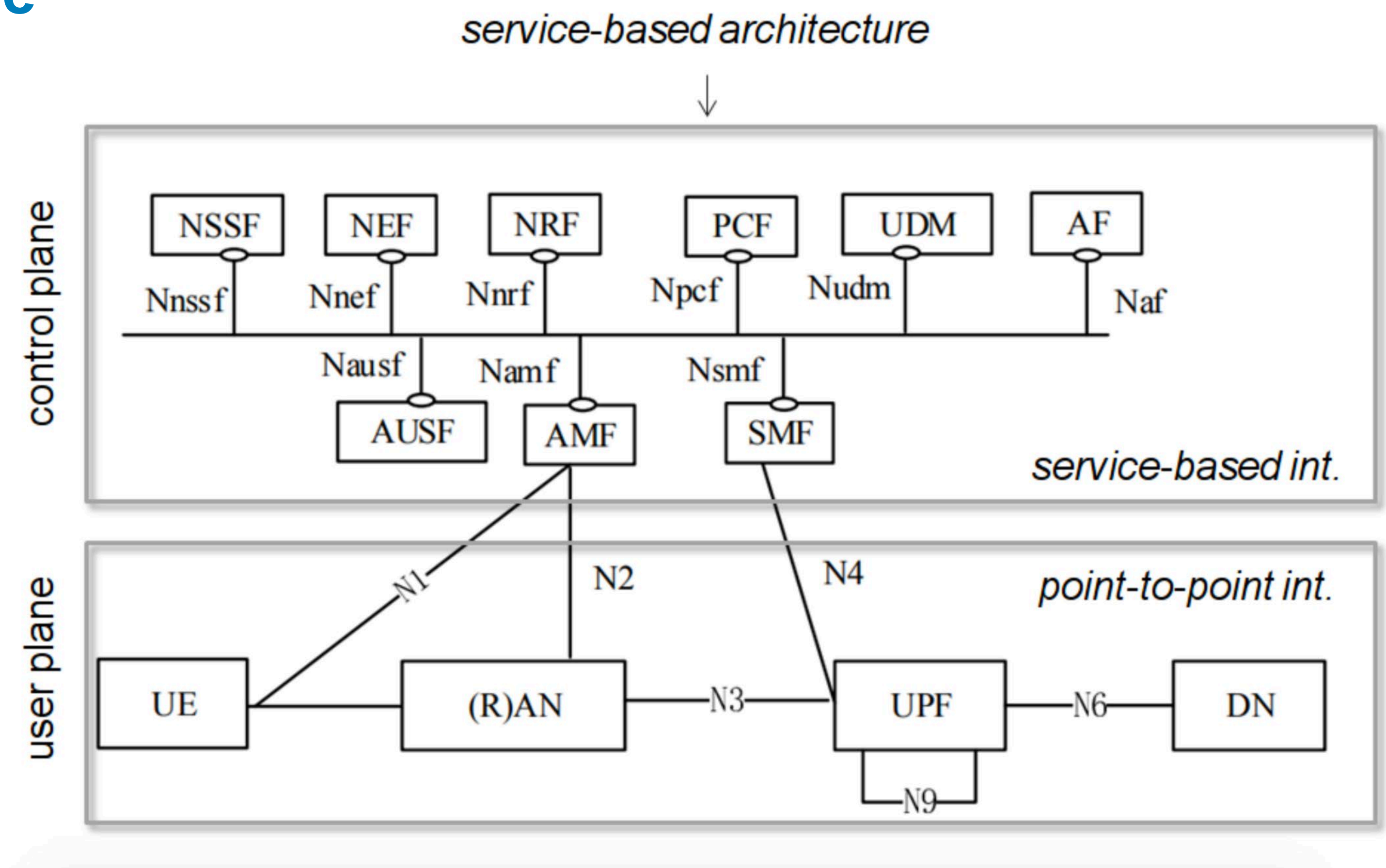
URLLC
Ultra-Reliable Low Latency Communication
(Time) Critical Communication

5G = eMBB, mMTC & URLLC



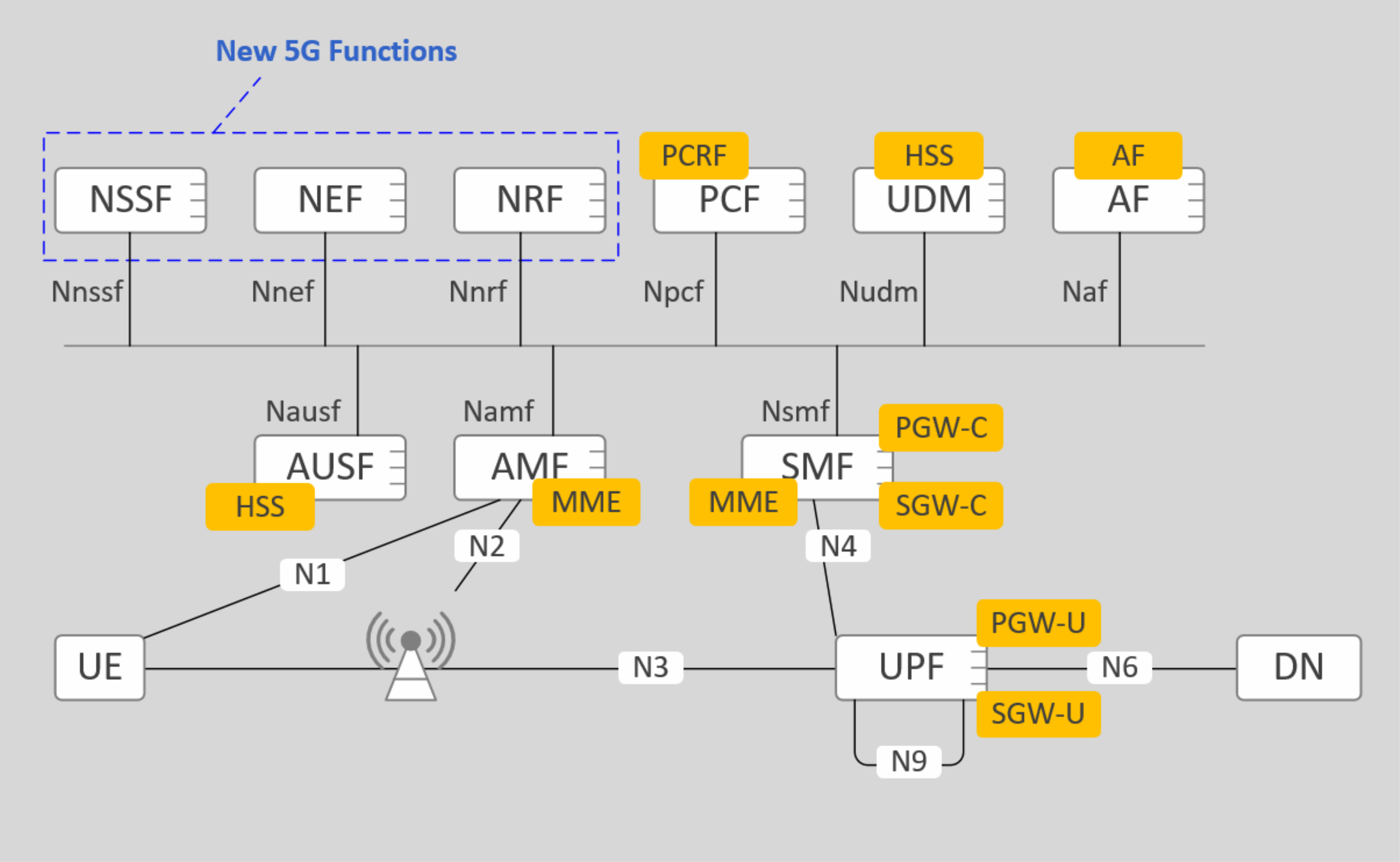
Source: ETRI graphic, from ITU-R IMT 2020 requirements

5G Architecture



The core functions are adapted for virtualization on NFVs, Network Functions Virtualization

5G Architecture with differences 4G-5G



4G EPC functions mapped to 5G core network functions

- **UE**: User Equipment
- **UPF**: User Plane Function
- **DN**: Data Network

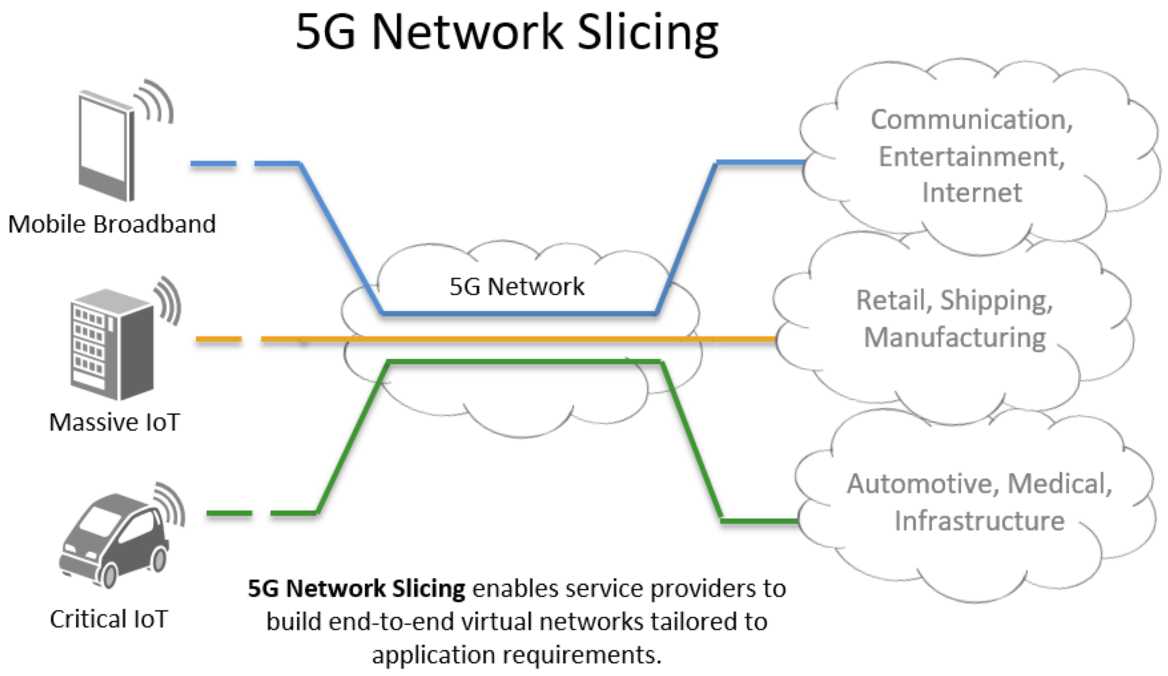
- **AUSF**: Authentication Server Function
- **AMF**: Access and Mobility Management Function
- **SMF**: Session Management Function

- **PCF**: Policy Control Function
- **UDM**: Unified Data Management
- **AF**: Application Function
- **NSSF**: Network Slice Selection Function
- **NEF**: Network Exposure Function
- **NRF**: NF Repository Function (NF = Network Function)

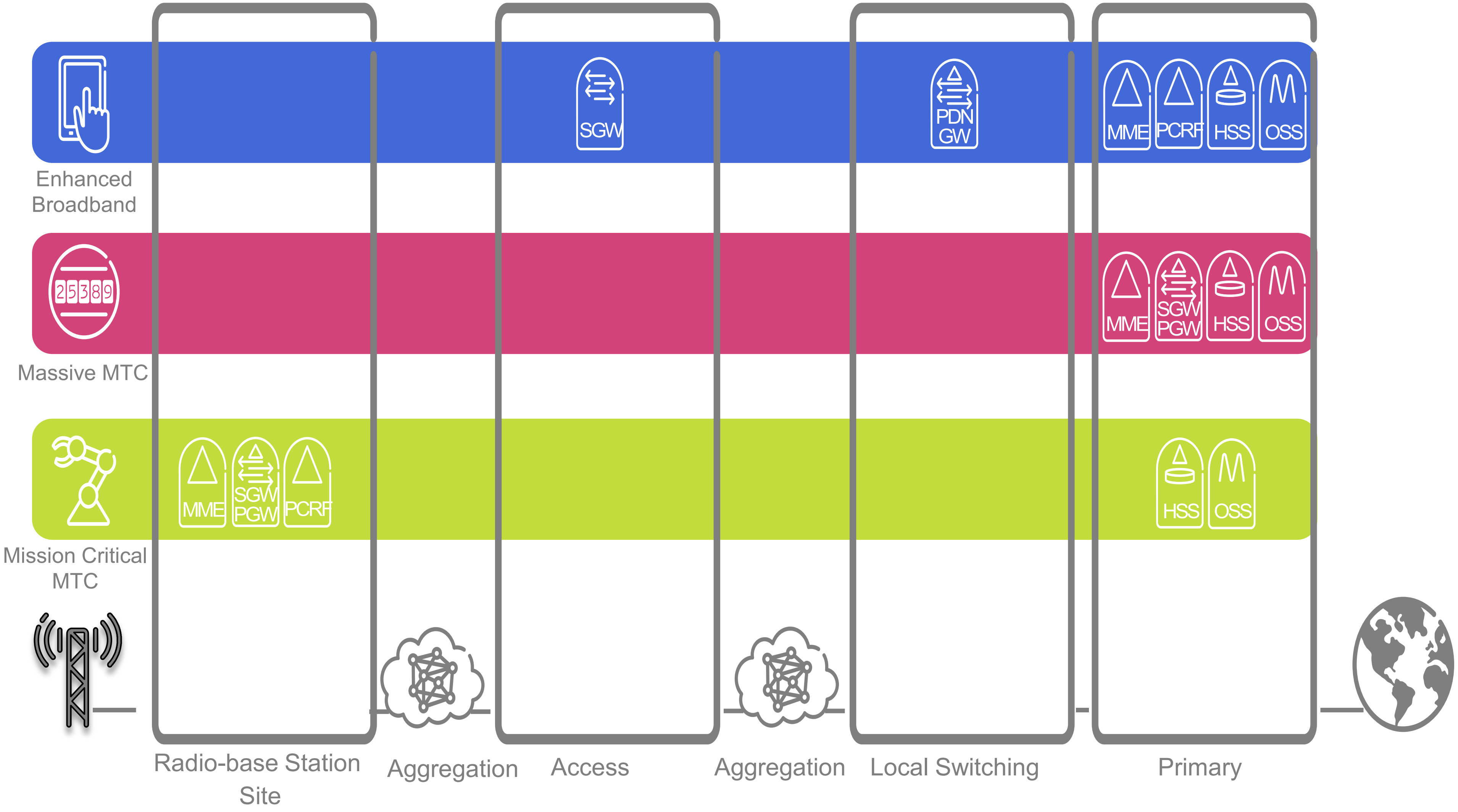
 Source: projet de Bachelor "5GLANE", J. Borgognon, 2019

Network Slicing

- Like «virtual networks»
- Network slicing is an inherent concept of the 5G Core
- Slices might be defined per service, per customer, per use case, etc.
- Flexible allocation of network functions
- Logical or physical isolation or sharing of hardware and/or spectrum
- Each slice can be configured differently
- Monitoring and performance can be done per slice



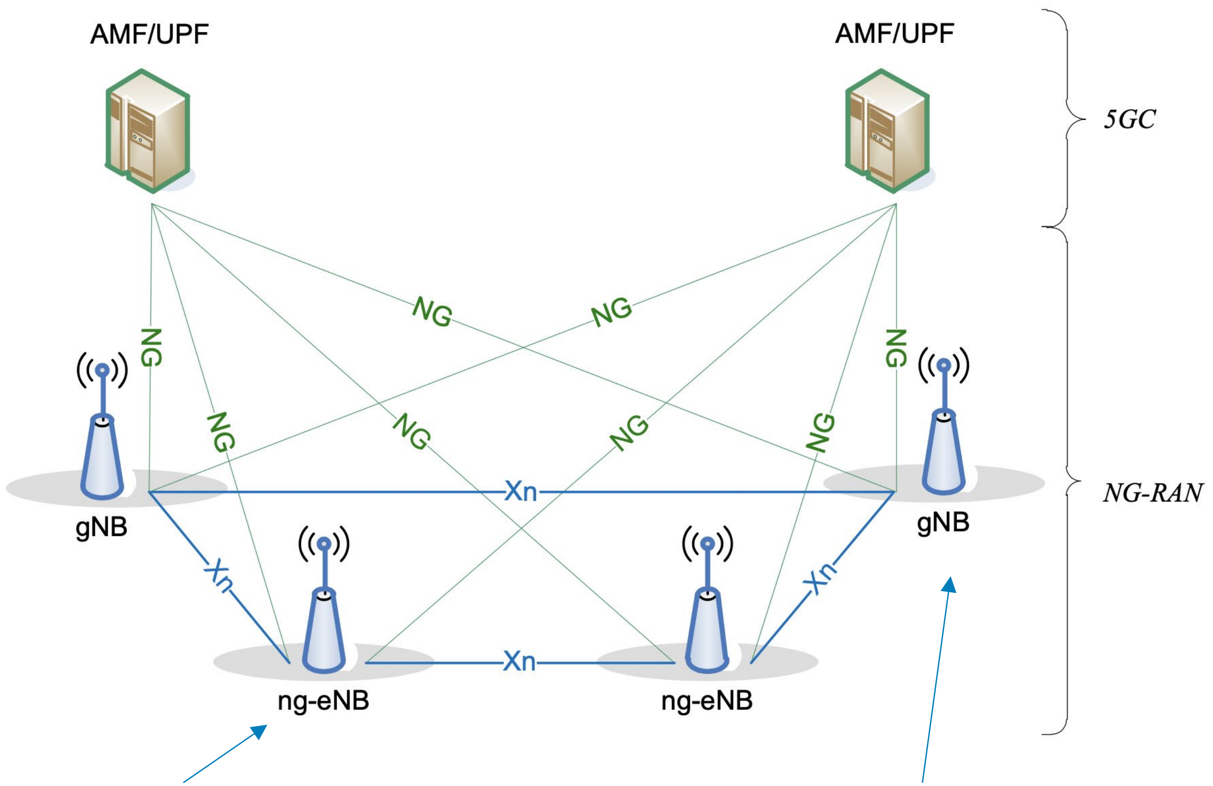
Network Slicing



Source: Ericsson

5G Radio Access

Tight interworking between Evolution of LTE & new 5G radio-access technology, NR

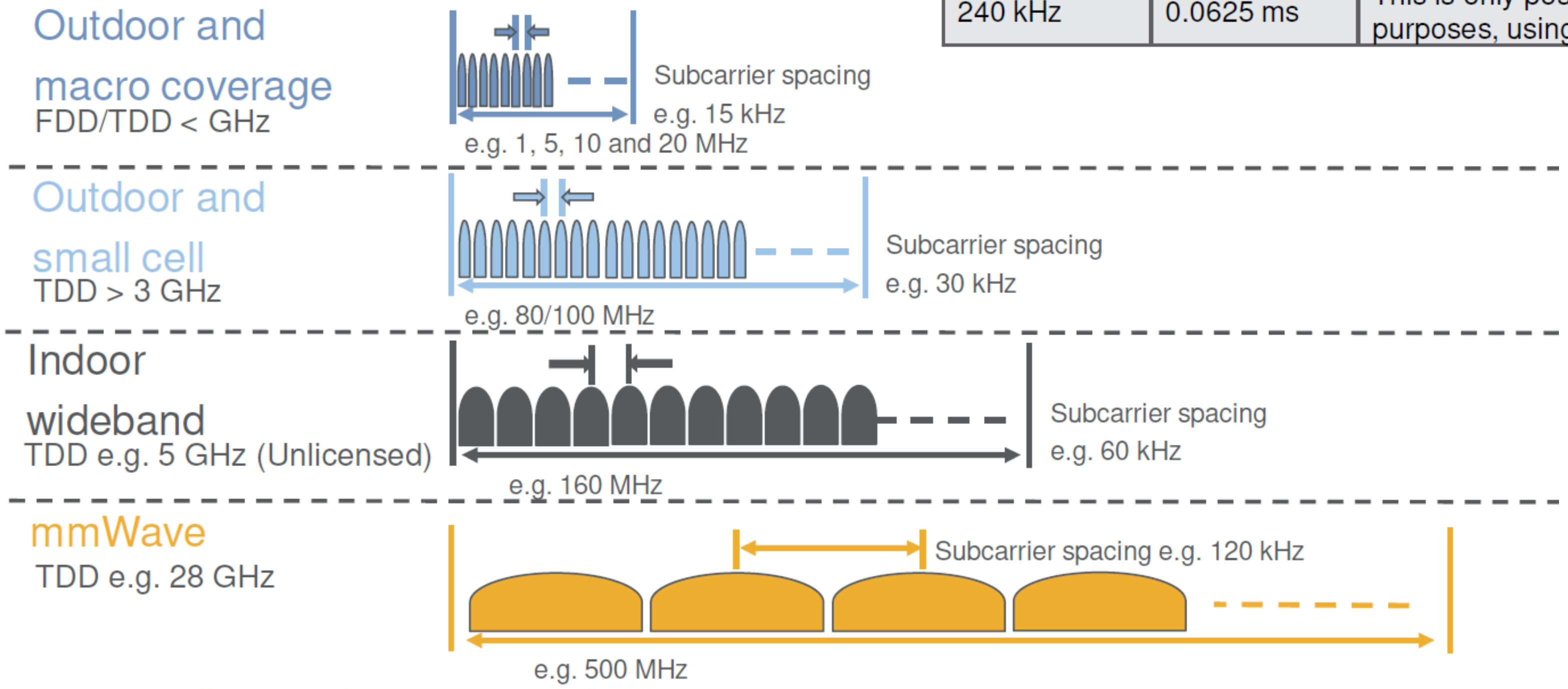


ng-eNB - LTE

gNB - 5G New Radio (NR)

5G NR: still OFDMA like LTE, but optimised

Sub-Carrier Spacing	Slot duration	Comment	Bands
15 kHz	1 ms	Same as LTE	FR1
30 kHz	0.5 ms		FR1
60 kHz	0.25 ms	Both normal Cyclic Prefix (CP) and extended CP may be used with 60 kHz sub-carrier spacing	FR1 and FR2
120 kHz	0.125 ms	This is the highest sub-carrier spacing for the path of data	FR2
240 kHz	0.0625 ms	This is only possible for search and measurement purposes, using the Synchronization Signal Block (SSB)	FR2



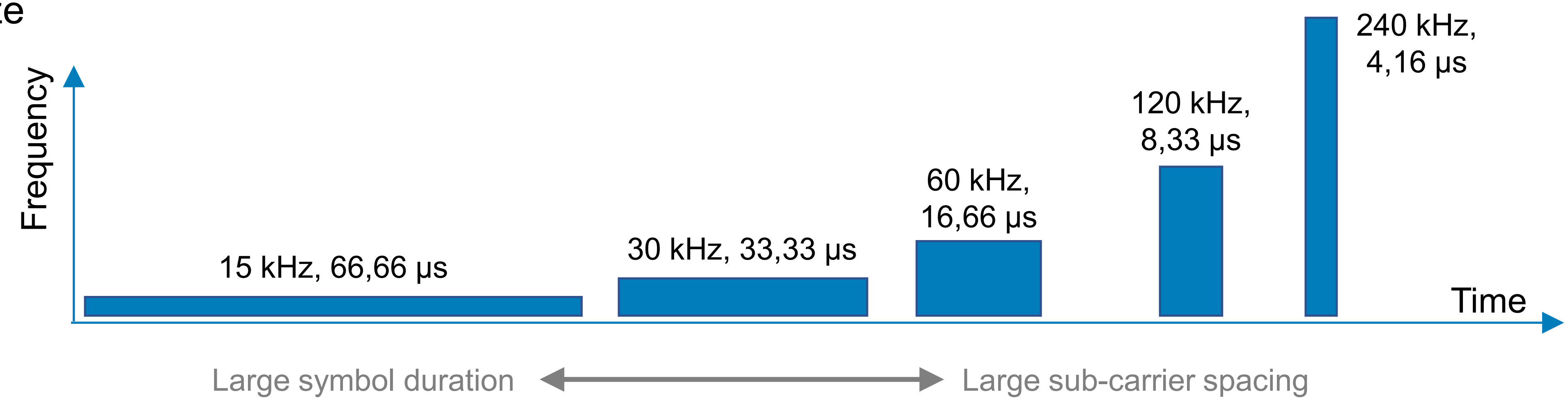
- FR 1 (Frequency Range 1): below ~ 7 GHz
- FR 2 (Frequency Range 2): between ~ 24 GHz and ~ 53 GHz (millimeter-wave)

Source: Qualcomm

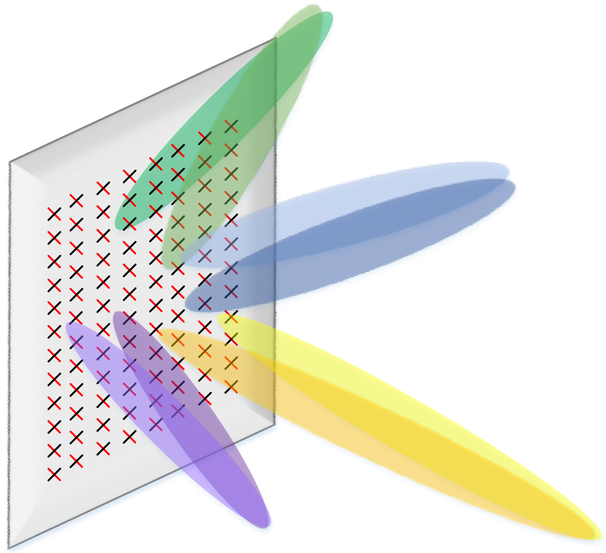
5G NR: still OFDMA like LTE, but optimised

Subcarrier spacing	Number of subcarriers per resource block	Resource block bandwidth	Number of OFDM symbols per slot	Slot duration	Number of slots in a 1 ms subframe
15 kHz	12	180 kHz	14	1 ms	1
30 kHz	12	360 kHz	14	0,5 ms	2
60 kHz	12	720 kHz	14	0,25 ms	4
120 kHz	12	1440 kHz	14	0,125 ms	8
240 kHz	12	2880 kHz	14	0,0625 ms	16

Symbol size



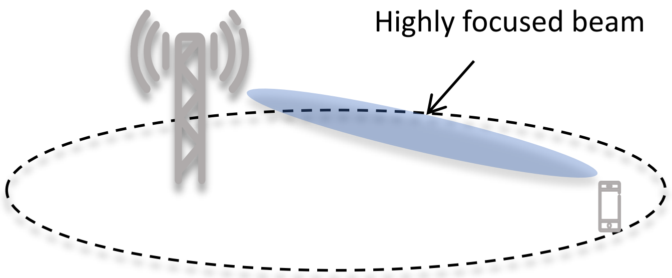
Massive MIMO



- **Many** sub-elements controllable from baseband
  - Substantially more than eight
  - Higher frequency keeps reasonable antenna size
- Beam **highly** focused due to the many sub-elements

Single-user MIMO

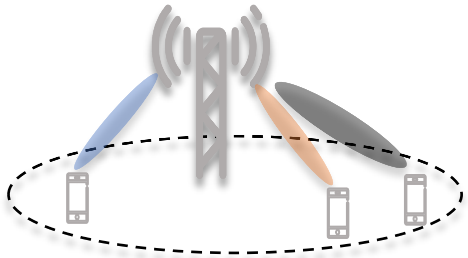
One user per time-frequency resource



Effective for coverage

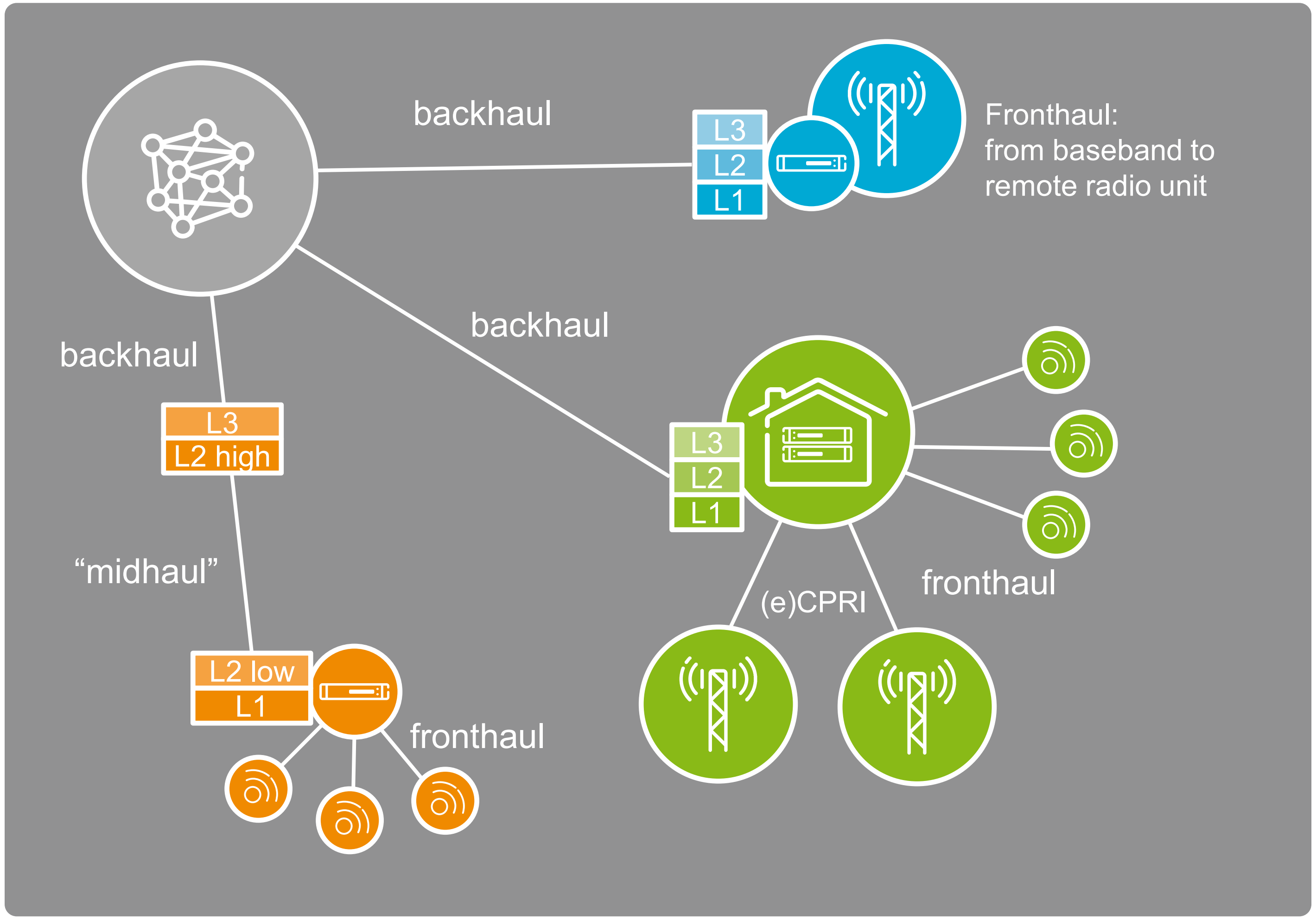
Multi-user MIMO

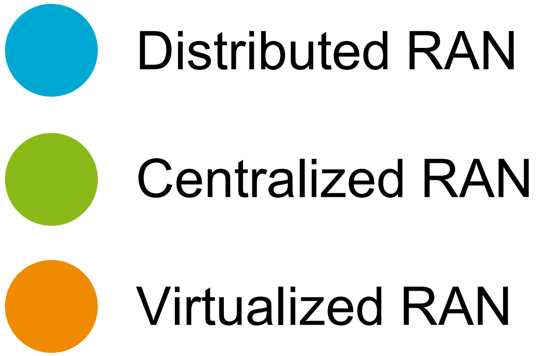
Multiple users on the same resource
User specific BF to spatially separate users



Effective for capacity

RAN Architectures - Flexible Architectures supporting many options

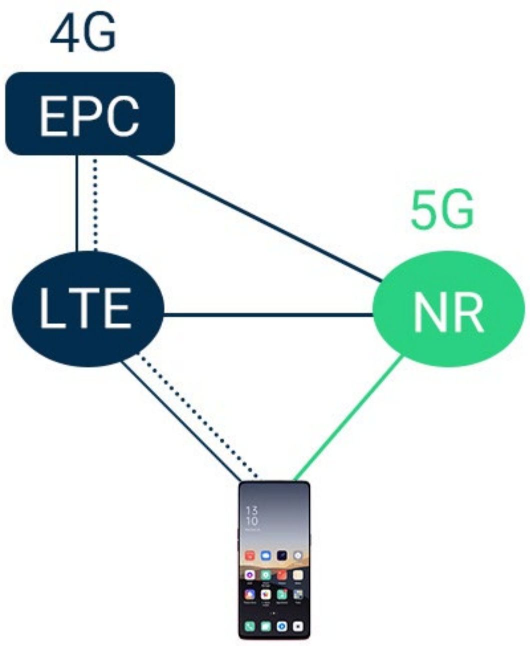




Source: Ericsson

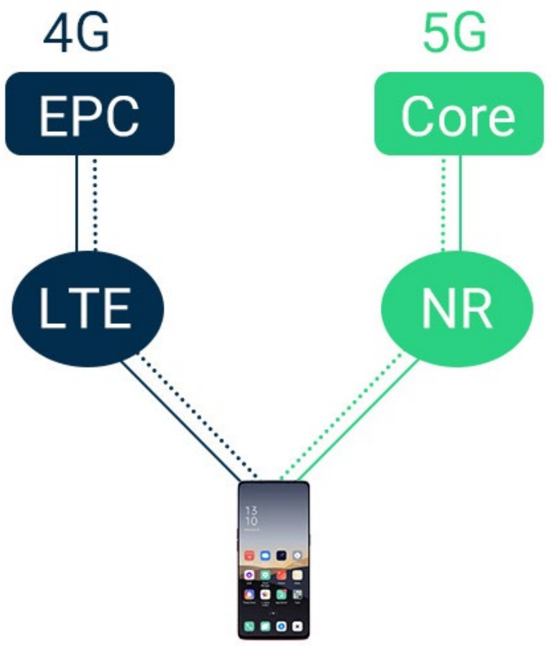
5G Deployment modes

Non Standalone Mode (NSA)



- NSA 5G uses a 4G LTE control plane to manage connectivity and user authorization.
- Introduced in 3GPP Rel.15 to allow for faster roll-out of 5G
- Allows also for dynamic spectrum sharing (DSS) between 4G LTE and 5G-NR.

Standalone Mode (SA)



- SA 5G uses a 5G core to manage connectivity and user authentication.
- Allows deployment without 4G/LTE

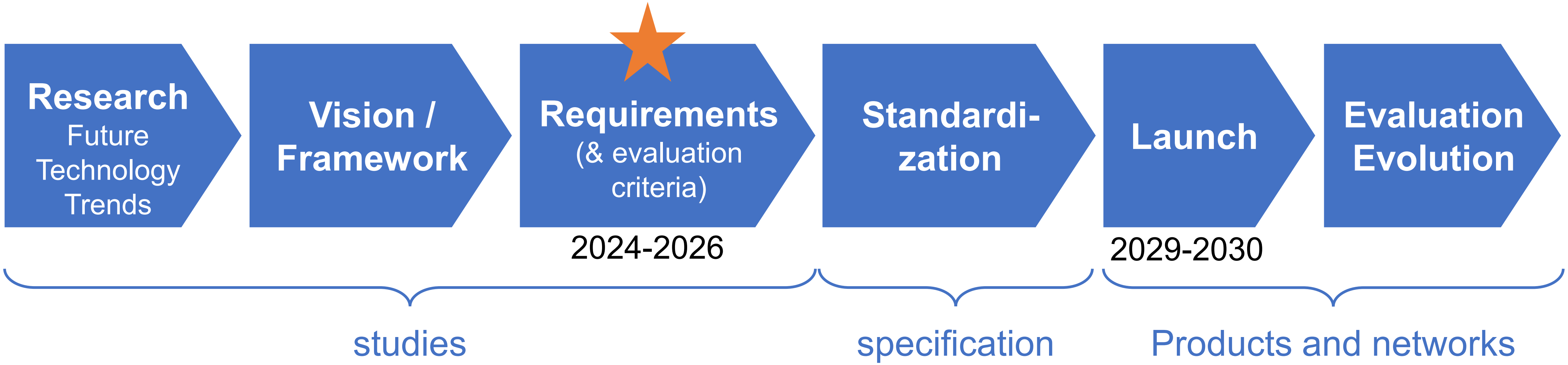
Control Plane Data Plane

Source: https://c.realme.com/in/post-details/1417760401533194240

6G

6G – Where are we?

Currently in the early stages of the standardization process



2024: workshop on IMT 2030 (i.e. 6G) use cases

- Different groups discussed their views on 6G/IMT2030 Use Cases (operators, verticals, regional alliances, suppliers, standardization bodies, ITU)

6G is expected to begin rolling out in the early 2030s

Note: things might change

6G – To do what?

Motivation and societal considerations

- Build an inclusive information society, contributing to the support of the United Nations' Sustainable Development Goals (SDGs).
- Expected to be an important enabler for achieving the following goals, among others:
    - Inclusivity
    - Ubiquitous connectivity
    - Sustainability
    - Innovation
    - Enhanced security and resilience
    - Standardization and interoperability
    - Interworking

Use cases & application trends

- Ubiquitous intelligence
- Ubiquitous computing
- Immersive multimedia and multi-sensory interactions
- Digital twin and virtual world
- Smart industrial applications ("Smart everything")
- Digital health and well-being
- Ubiquitous connectivity
- Integration of sensing and communication
- Sustainability

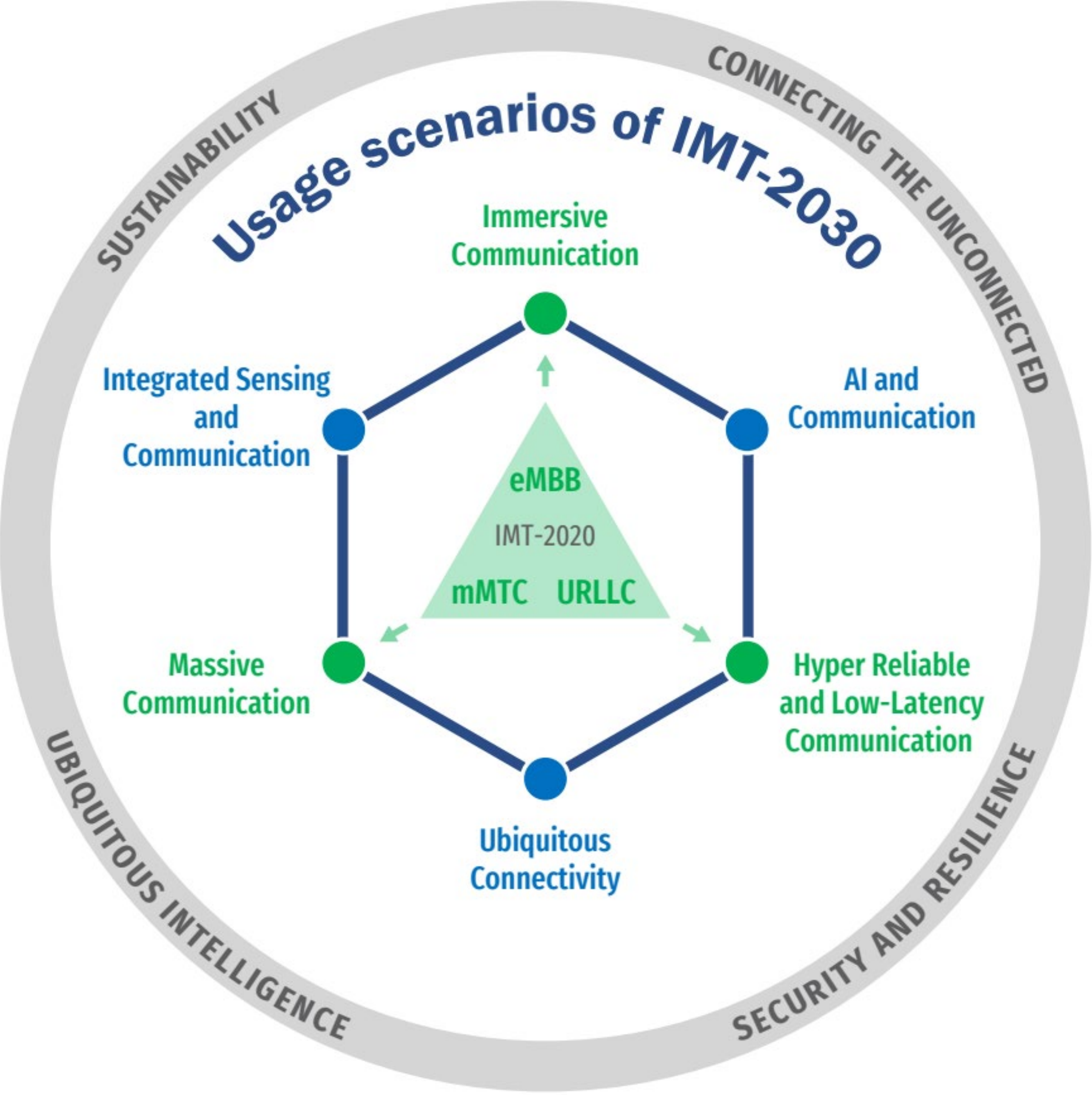
Support of Artificial Intelligence

Source: Recommendation ITU-R M.2160-0 (11/2023) "Framework and overall objectives of the future development of IMT for 2030 and beyond"

Overarching aspects and Usage scenarios of IMT-2030 (6G)

- **4 Overarching aspects**
  (Sustainability, Connecting the unconnected, Ubiquitous intelligence, Security & resilience)
  - Act as design principles commonly applicable to all usage scenarios

- **6 Usage scenarios:**
  - 3 are extensions from IMT-2020 (i.e. 5G)
    - eMBB → Immersive Communication
    - mMTC → Massive Communication
    - URLLC → HRLLC (Hyper Reliable & Low-Latency Communication)
  - 3 are new:
    - Ubiquitous Connectivity
    - AI and Communication
    - Integrated Sensing and Communication

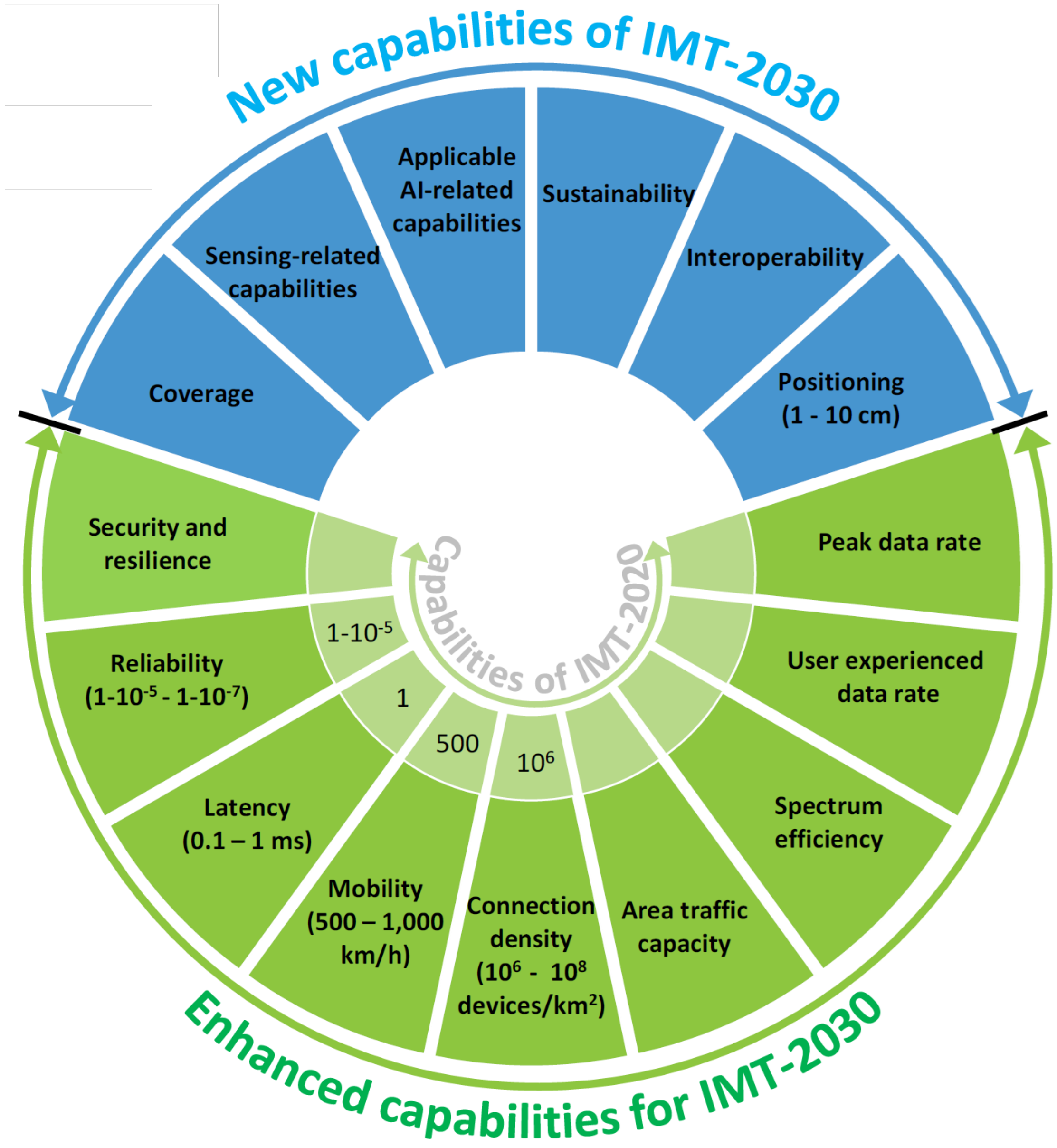


Source: Recommendation ITU-R M.2160-0 (11/2023) "Framework and overall objectives of the future development of IMT for 2030 and beyond"

Capabilities of IMT-2030 (6G)

- IMT-2030 (6G) is expected to provide enhanced capabilities compared to those described for IMT-2020 (5G), as well as new capabilities to support the expanded usage scenarios of IMT-2030.
- Each capability could have different relevance and applicability in the different usage scenarios.
- The range of values given for capabilities are estimated targets for research and investigation of IMT-2030.
- All values in the range have equal priority in research and investigation.

Note: targets and target values might change



Source: Recommendation ITU-R M.2160-0 (11/2023) "Framework and overall objectives of the future development of IMT for 2030 and beyond"

C'était:

Conception et exploitation de réseaux
Partie réseaux mobiles

Différents standards de réseaux mobiles

ainsi que:

Architecture des réseaux LTE & 5G