IMT Atlantique
Bretagne-Pays de la Loire
École Mines-Télécom

Lab-STICC

STIC AmSud

5G IN 5 MINUTES

RAMONaaS Summer School
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Brest, France

Luiz ANET NETO
luiz.anetneto@imt-atlantique.fr

MOBILE STACK IN A NUTSHELL

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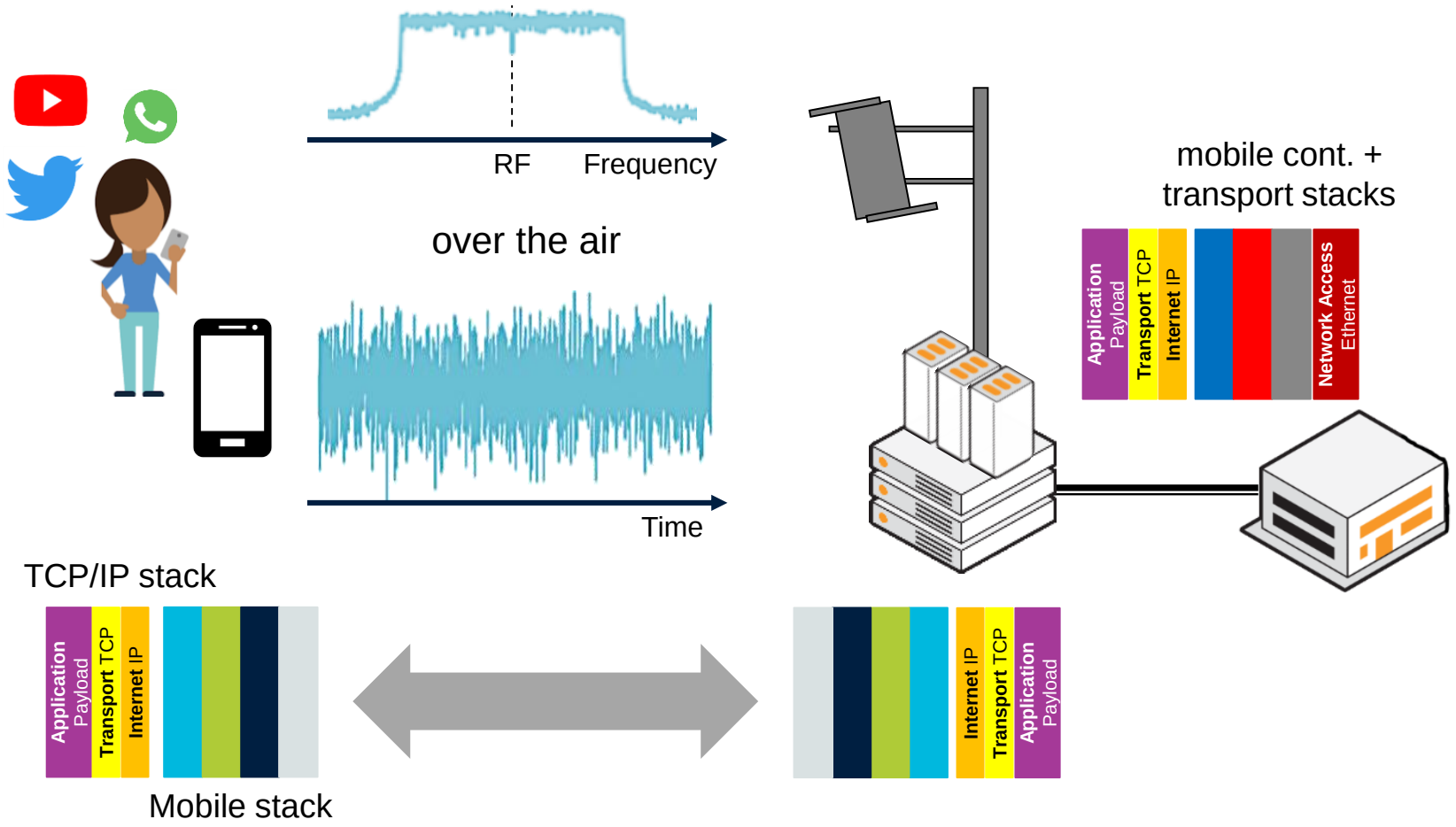
RAN STACK IN A NUTSHELL

How a Mobile Signal is Created

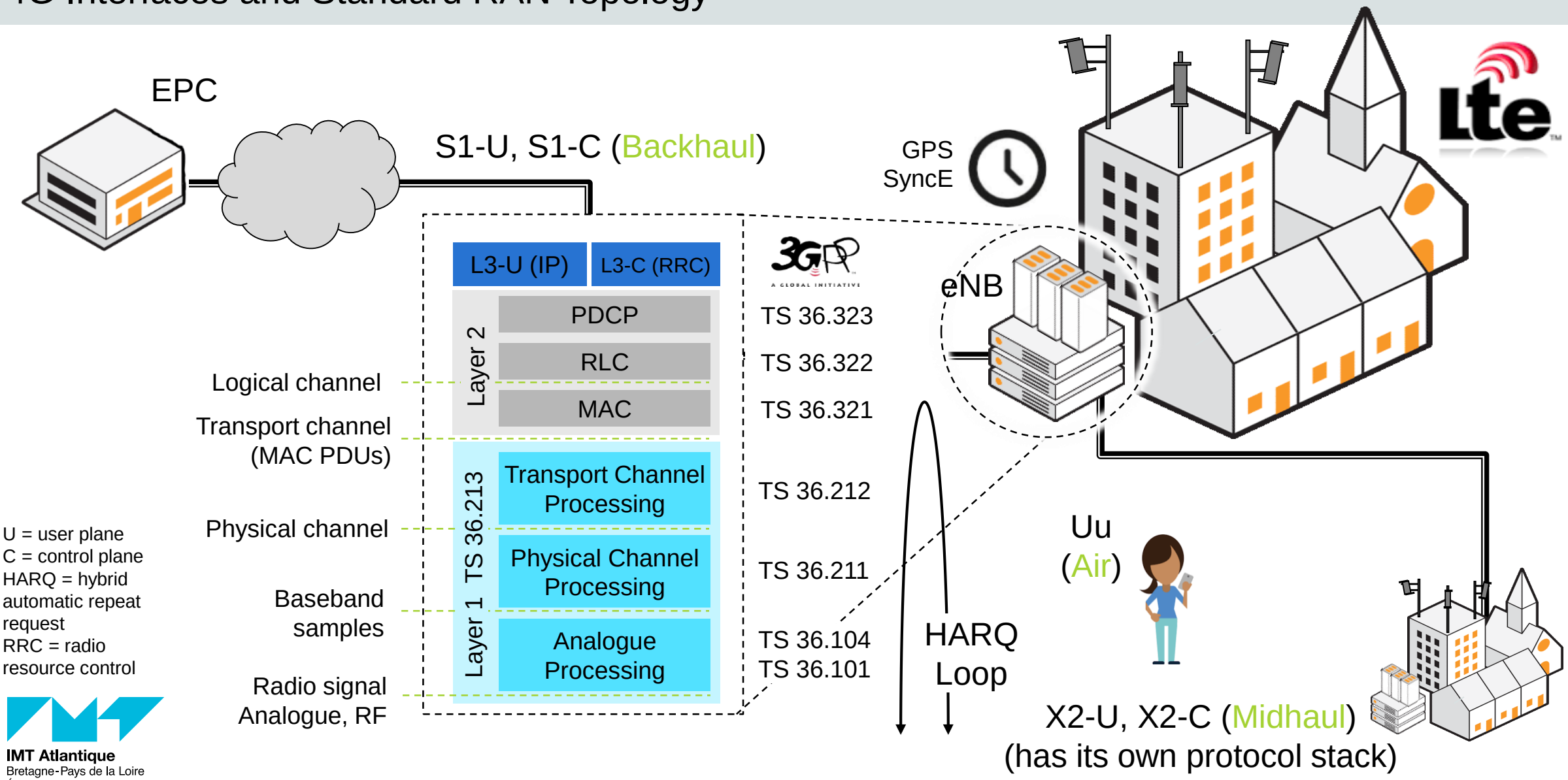
This class is about optical networking

- Of course, we'll not focus on the mobile procedures here
- But it is crucial that we understand certain aspects of it so that we can measure the impact of mobile traffic over fiber networks
- I hope you'll see why by the end of the class



RAN STACK IN A NUTSHELL

4G Interfaces and Standard RAN Topology



U = user plane
C = control plane
HARQ = hybrid automatic repeat request
RRC = radio resource control

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RAN STACK IN A NUTSHELL

A Closer Look into the Mobile Stack

Prior to the RAN machine (EPC)

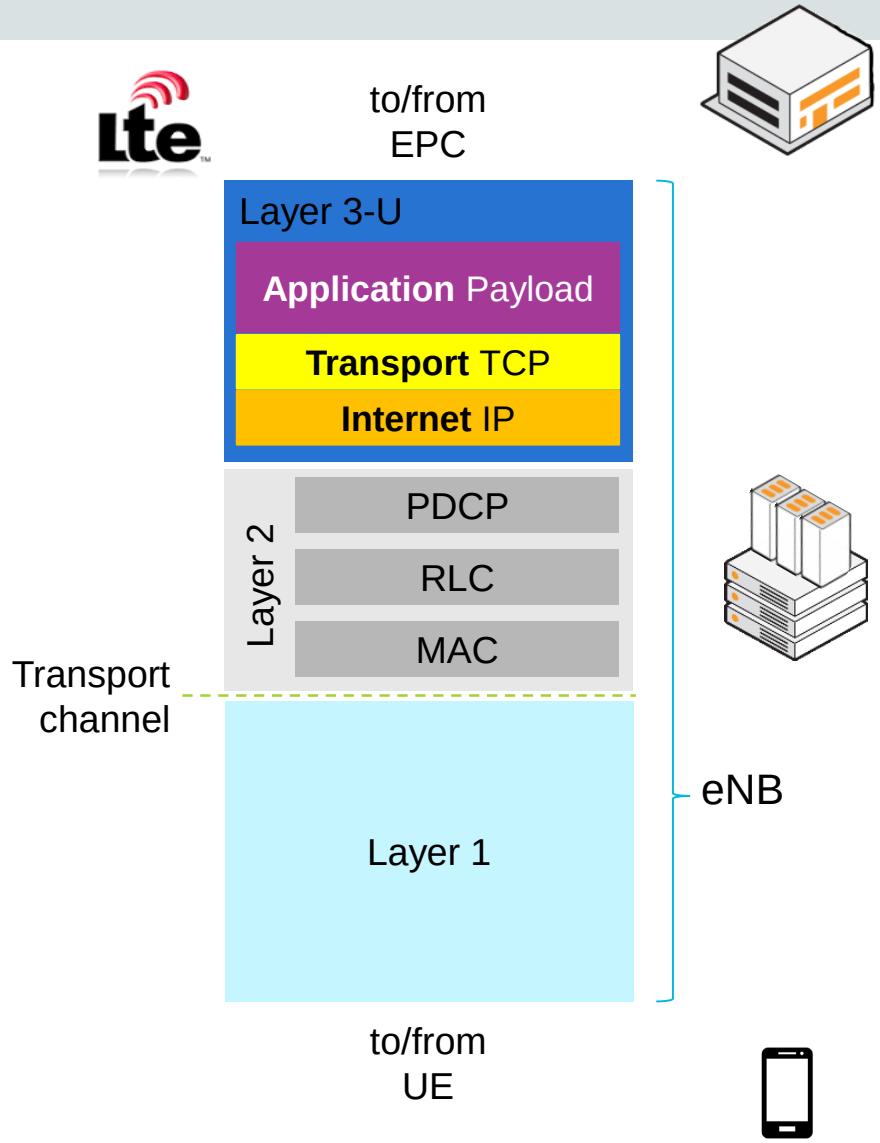
- Packets routing/forwarding inside the mobile network, mobility control (handovers), bridge to exterior networks, etc
- GTP (General Packet Radio Service Tunnelling Protocol), additional layer to homogenise processing of all types of packets
- Stacking/unstacking layers

LAYER 3

- User plane (IP) + control plane packets

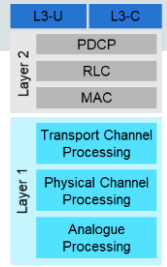
LAYER 2

- Packet Data Convergence Protocol (PDCP)
  - Header compression, cyphering, integrity protection (during handovers), etc
- Radio Link Control (RLC)
  - Logical categorization of U/C planes, sequencing of blocks (HARQ), concatenation and segmentation, repetition
- Medium Access Control (MAC)
  - MUX/DEMUX, prioritization, hybrid automatic repeat request (ARQ + FEC), PHY scheduler (resource allocation), etc



RAN STACK IN A NUTSHELL

A Closer Look into the Mobile Stack



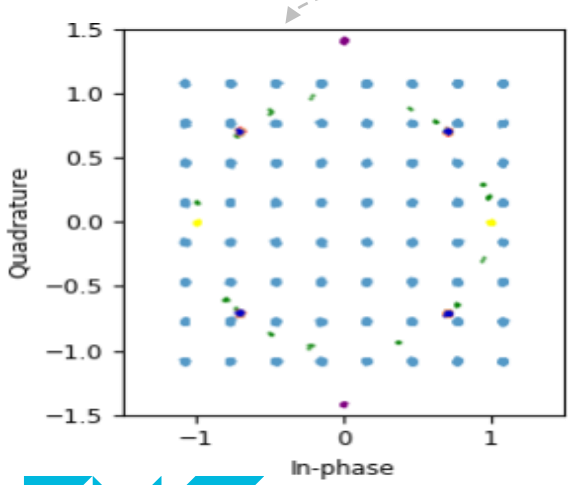
LAYER 1

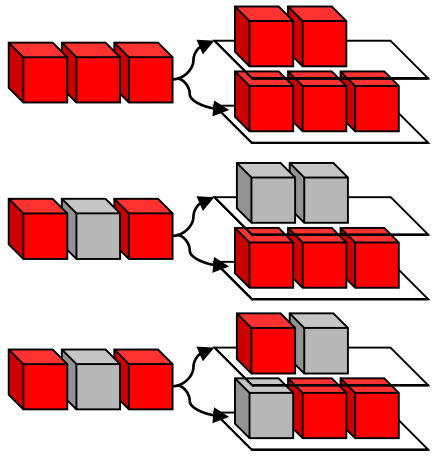
Downlink | Code words | IQ symbols | IQ symbols per antenna port | Time x freq. symbol grids | Complex valued, Baseband time samples

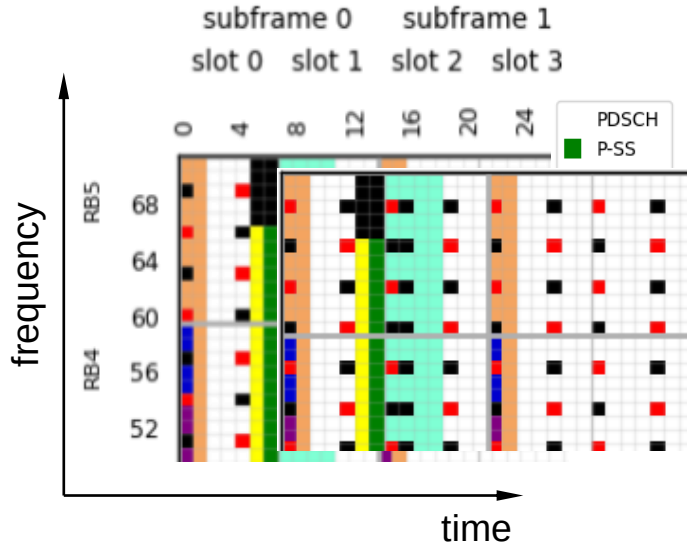
Transport Channel Processing (FEC)

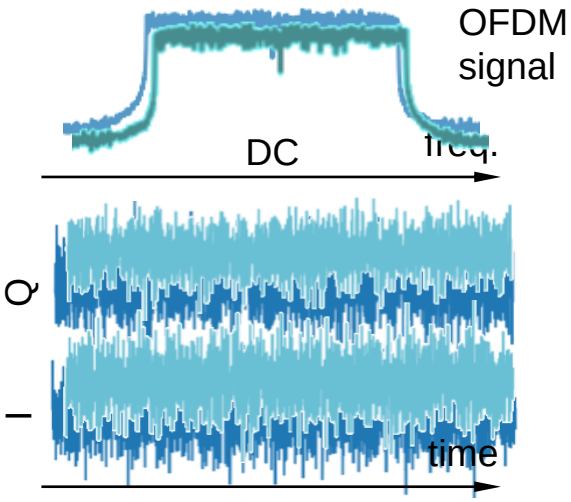
Physical Channel Processing: Scram-bling | Mod. | Layer mapping | Pre-coding | Resource element mapping | iFFT | Cyclic Prefix

Analogue Process. (DAC, RF, amplification)









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THE PATH TOWARDS 5G

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The wireless revolution

- From the 1980's, one new generation every ~8-10 years
- Generation: worldwide adoption and deployment
- 1G: Analog communications with bulky and battery-inefficient terminals
- 2G: Digital implementations and short message service (SMS) functionalities
- 3G: First mobile Internet access
- 4G: Network dominated by data-centric usages in 4G
- 5G: Increased channel capacity & unprecedented usages of the mobile network

Left: M. Cooper Motorola's 1G DynaTAC (1 kg, 3500 USD, ~35 min. tallk time). Right: Motorola's foldable Razr 5G (190 g, 1500 USD, ~8h talk time)

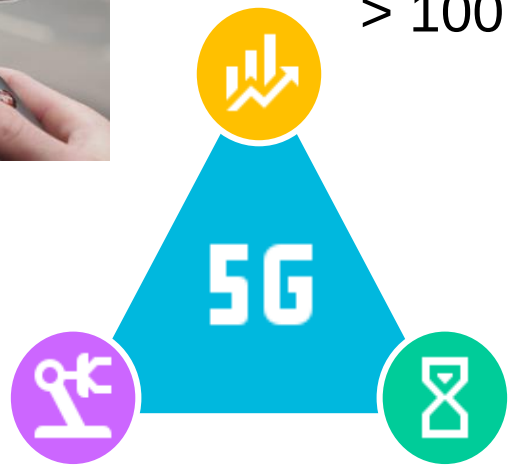
THE PATH TOWARDS 5G

The 5G Triangle

eMBB: enhanced mobile broadband
mMTC: massive machine type communications
URLLC: ultra-reliable low-latency communication

eMBB 1 - 10 Gb/s
> 100 Mb/s/device

Carte SIM pour M2M et IOT - Things Mobile - couverture mondiale, réseau multi-opérateur GSM/2G/3G/4G LTE, sans coûts fixes, sans échéance avec...
14
15,00€



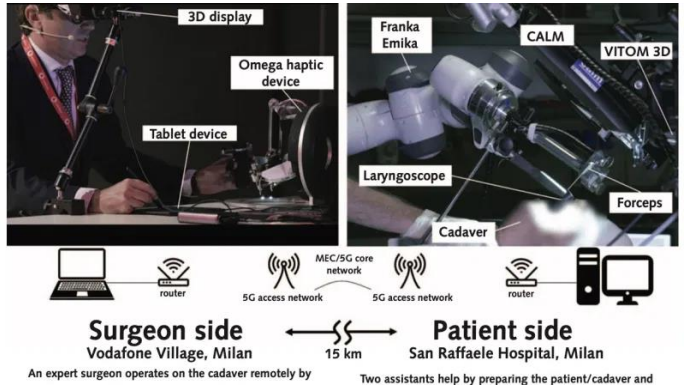
mMTC

1M/km²

URLLC

1-10 ms E2E
99,999%

Robotic tele microsurgery performed on a cadaver patient's vocal cords using a 5G network (Annals of Internal Medicine, 06/20)



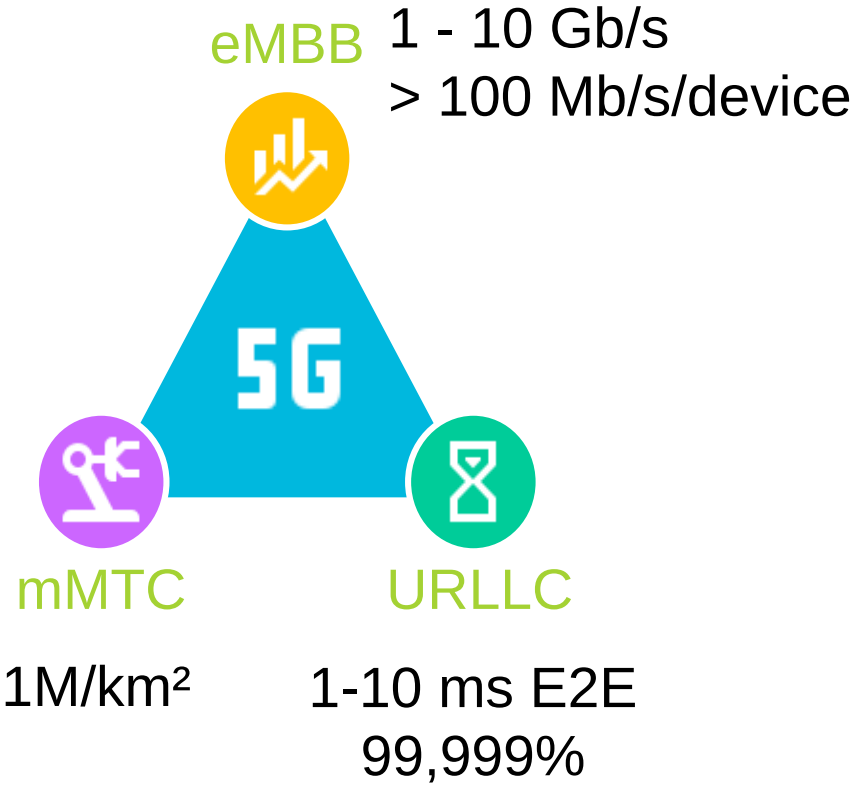
THE PATH TOWARDS 5G

The 5G Triangle

As always, evolution will take place gradually

- First, increase capacity of conventional broadband (EMBB)
  - Use 4G network but with increased bandwidths of 5G radio (non stand alone 5G - NSA)
- Bring fully autonomous 5G and slowly migrate legacy systems
  - 5G core and radio
  - Stand alone (SA) 5G
- Prepare network and deploy new services
  - URLLC, mMTC

As expected, the optical transport networks must be prepared for all those phases



Different requirements

- Bandwidth, latency, jitter, availability, reliability, positioning precision, number of devices
- Not mutually excluding
- Colorful palette of services, situations, traffic volumes and end-user devices.

3GPP TS 22.261
3GPP TS 22.104
* NGMN 5G White Paper

Scenario	Experienced bit-rate per user, downlink (uplink)	Area traffic capacity, downlink (uplink)	Overall user density	Active user density
Urban	50 (25) Mbit/s	100 (50) Gbit/s/km^2	10000/km^2	2000/km^2
Rural	50 (25) Mbit/s	1 (0.5) Gbit/s/km^2	100/km^2	20/km^2
Indoor hotspot	1 (0.5) Gbit/s	15 (2) Tbit/s/km^2	250000/km^2	[*]
Crowd broadband	25 (50) Mbit/s	3.75 (7.5) Tbit/s/km^2	500000/km^2	150000/km^2
Dense urban	300 (50) Mbit/s	750 (125) Gbit/s/km^2	25000/km^2	2500/km^2

Different requirements

- Bandwidth, latency, jitter, availability, reliability, positioning precision, number of devices
- Not mutually excluding
- Colorful palette of services, situations, traffic volumes and end-user devices.

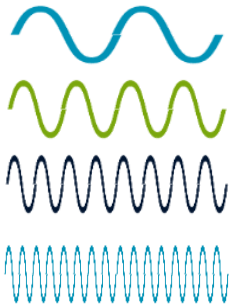
3GPP TS 22.261
3GPP TS 22.104

Use-case	Target availability (%)	Mean time between failures	End-to-end latency	Experienced bit-rate
Sensors for process and asset monitoring	99.99	≥ 1 week	< 100 ms	≤ 2 Mbit/s
Cooperative carrying of a large piece by robots	99.9999 to 99.999999	10 years	< 2.5 ms	2.5 Mbit/s
Robotic aided surgery with haptic feedback	> 99.999999	> 10 years	< 2 ms	2-16 Mbit/s

THE PATH TOWARDS 5G
Technological Enablers

5G New Radio (NR)

New carriers
sub-6GHz and mmW



@700 MHz FDD

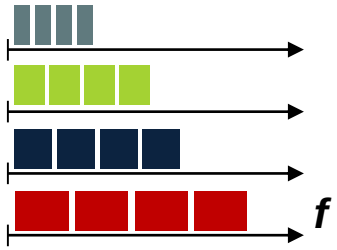
@3.6 GHz TDD

@26GHz
>2GHz, TDD

@>26GHz

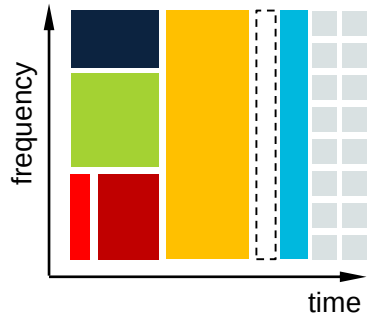
+ 800, 900, 1800, 2100, 2600 GHz

Up to 16 CA and
Up to 400 MHz CC

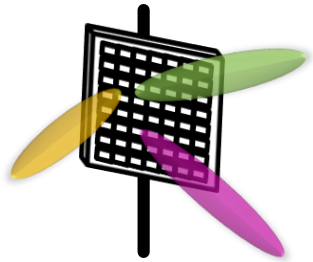


CA: carrier aggregation
CC: component carrier

Scalable & multiplexed
numerology



mMIMO (beam
forming, steering,
multiplexing)



mMIMO: massive
multiple inputs
multiple outputs

5G key-points

New latency and bit-rate constraints	**New functional splits**	**Slicing**
NFV & SDN	**Ethernet everywhere**	**Synchronization**