On the way to the Tactile Internet

25th International Symposium on Wireless Personal Multimedia Communications

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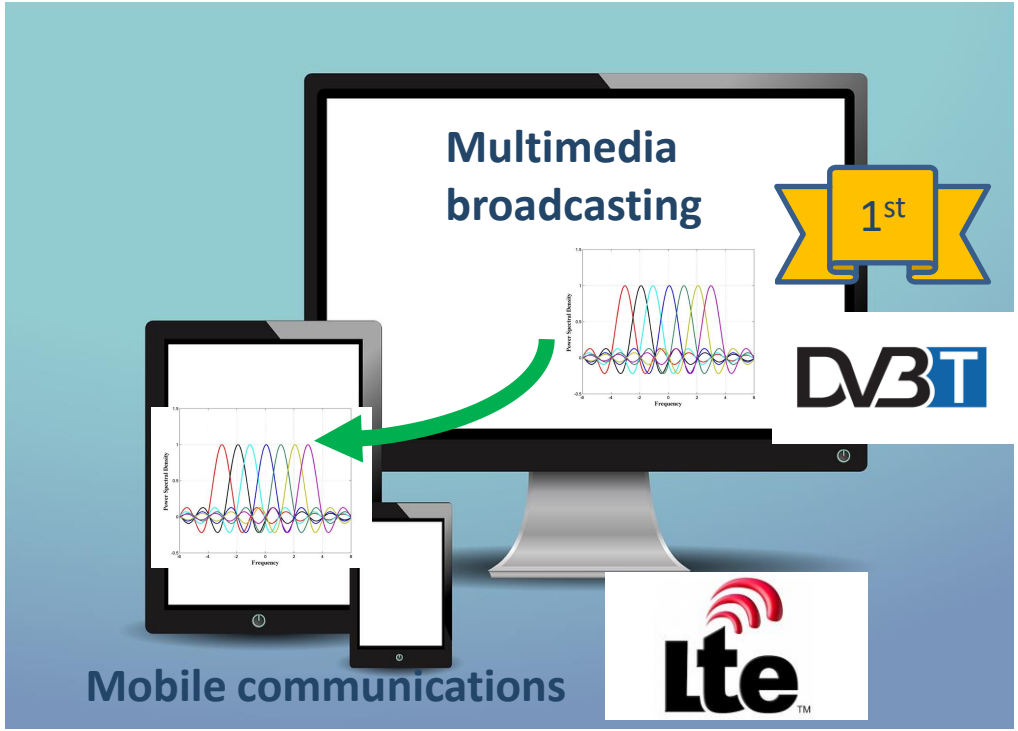
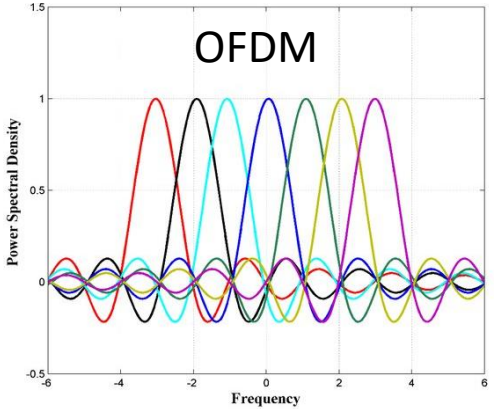
Before we start …

Initially two disjoint services and networks



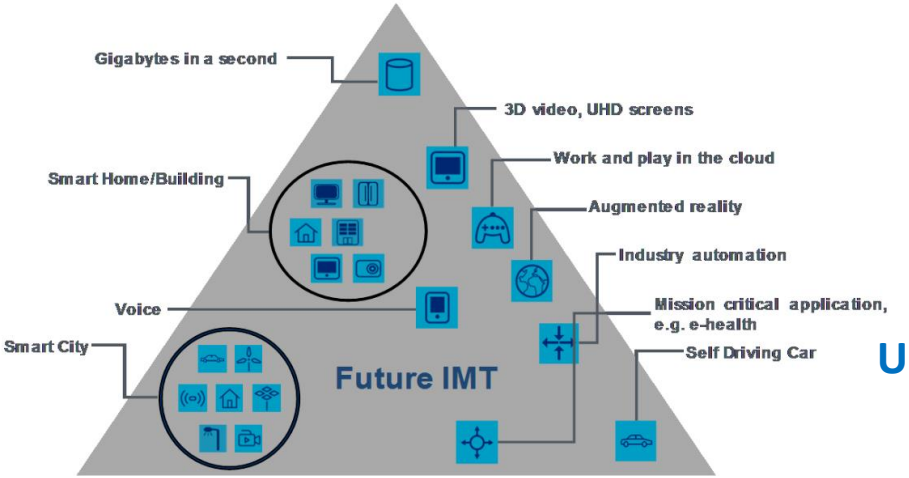


- Channel effects
- Synchronization
- Phase noise
- PAPR
- …

5G New Radio - a substantial leap forward

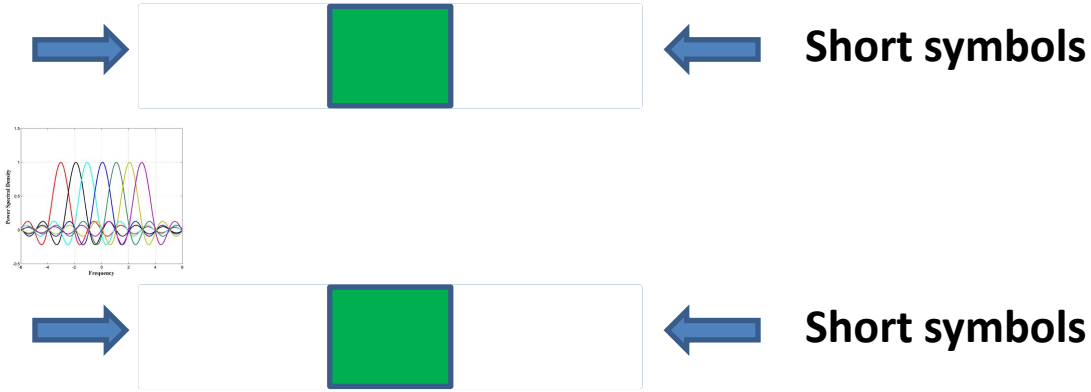
Enhanced mobile broadband

Massive machine-type communications



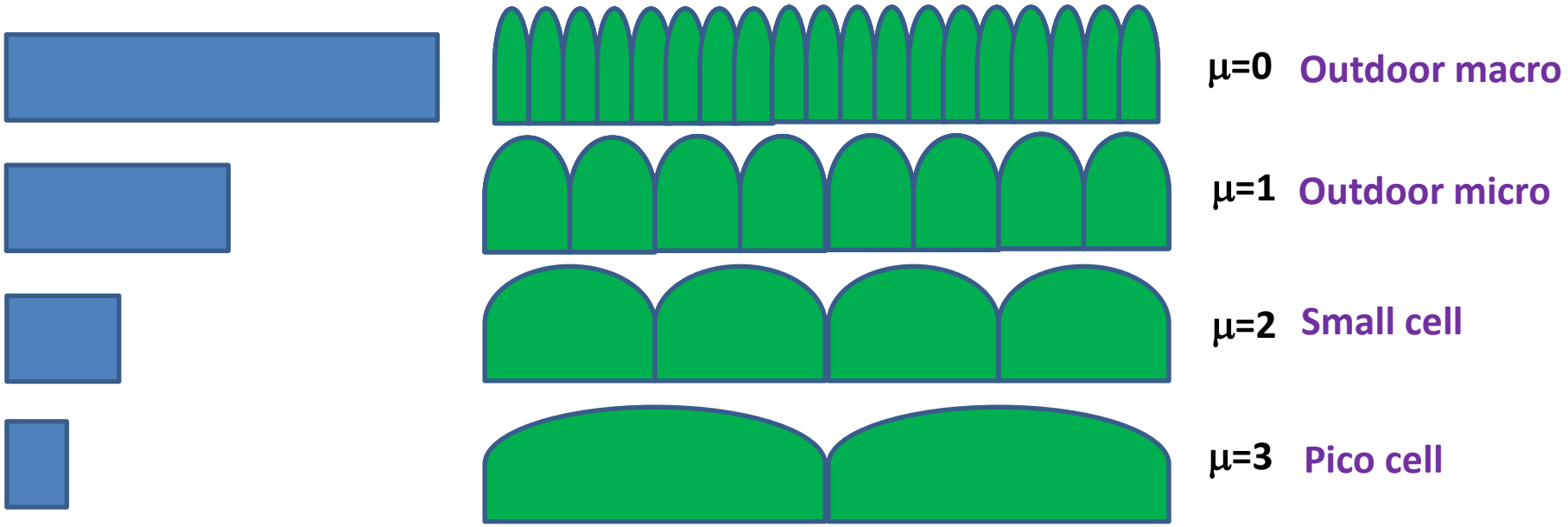
Ultra-reliable low latency communications

Adapting the signal to different scenarios



- However, OFDM duration in LTE is adapted to the maximum expected multipath

5G NR - OFDM numerology

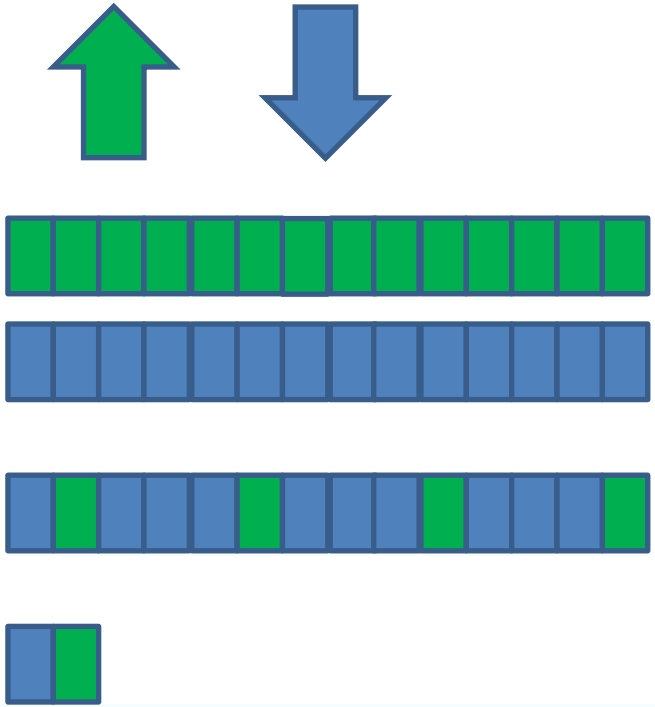


OFDM symbol duration **OFDM sub-carrier spacing**

We can adapt the numerology according to the mobility / multipath
What about latency?

Flexible slot formats

- Latency depends on two-way communication (UL and DL)
- In LTE if a slot is defined as UL or DL, all OFDM symbols in the slot must be configured as DL or UL
- In 5G NR the OFDM symbols in each slot can be configured in several ways (more than 50 format configurations!)
- Also “mini-slots” are available for very fast scheduling



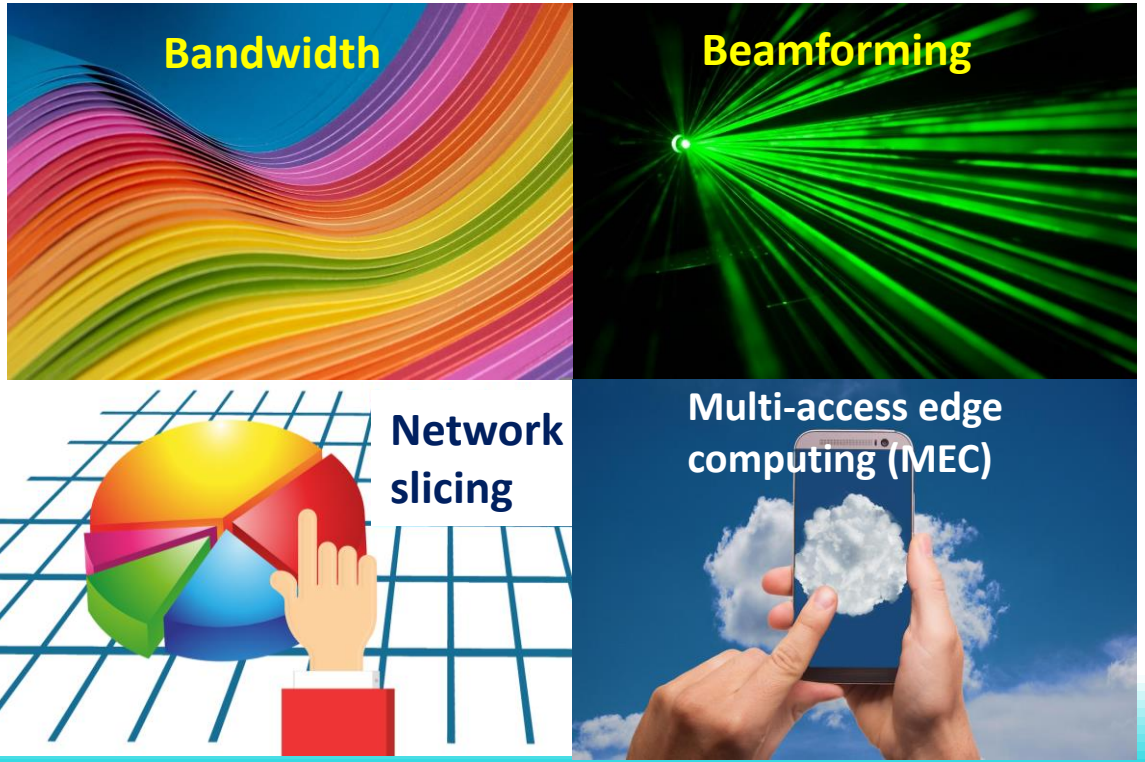
Shorter symbols in higher frequencies

- Higher frequency means:
  - Shorter distances due to high path loss
  - Need of beamforming gain

Reduced multipath

mmWaves in 5G NR

Now we can afford personalized (unicast) delivery – key enablers



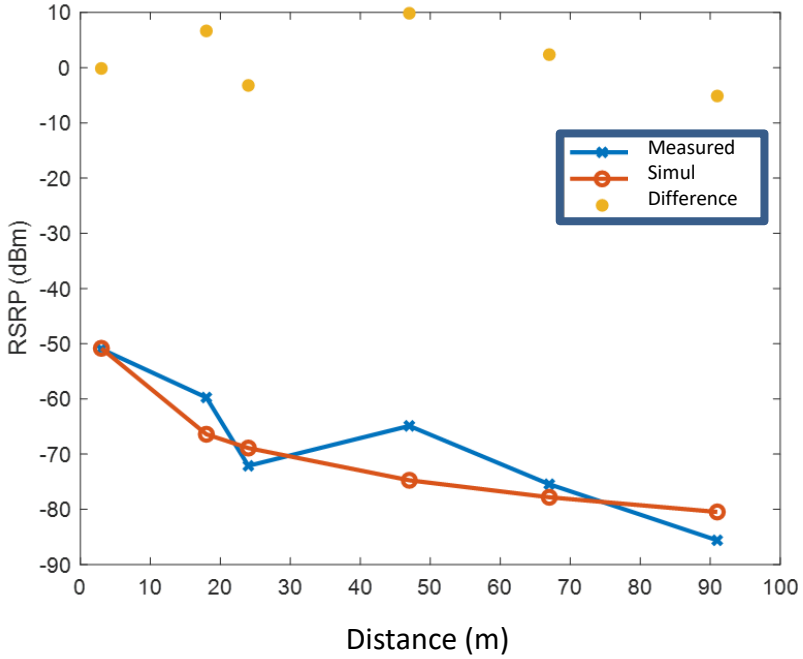
An example – AMATISTA project

- **Immersive music therapy based on virtual reality in a nursing home**
- **Using 5G NR at mmWaves**
  - Simulator to understand best MCS, numerology, beamforming configurations
  - Validation with measurements
  - Immersive music therapy application

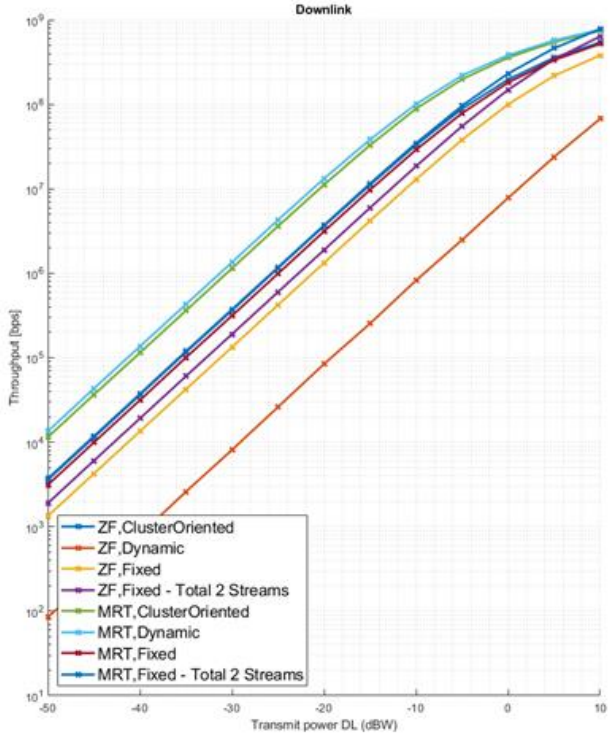
An example – AMATISTA project

- **Immersive music therapy based on virtual reality in a nursing home**

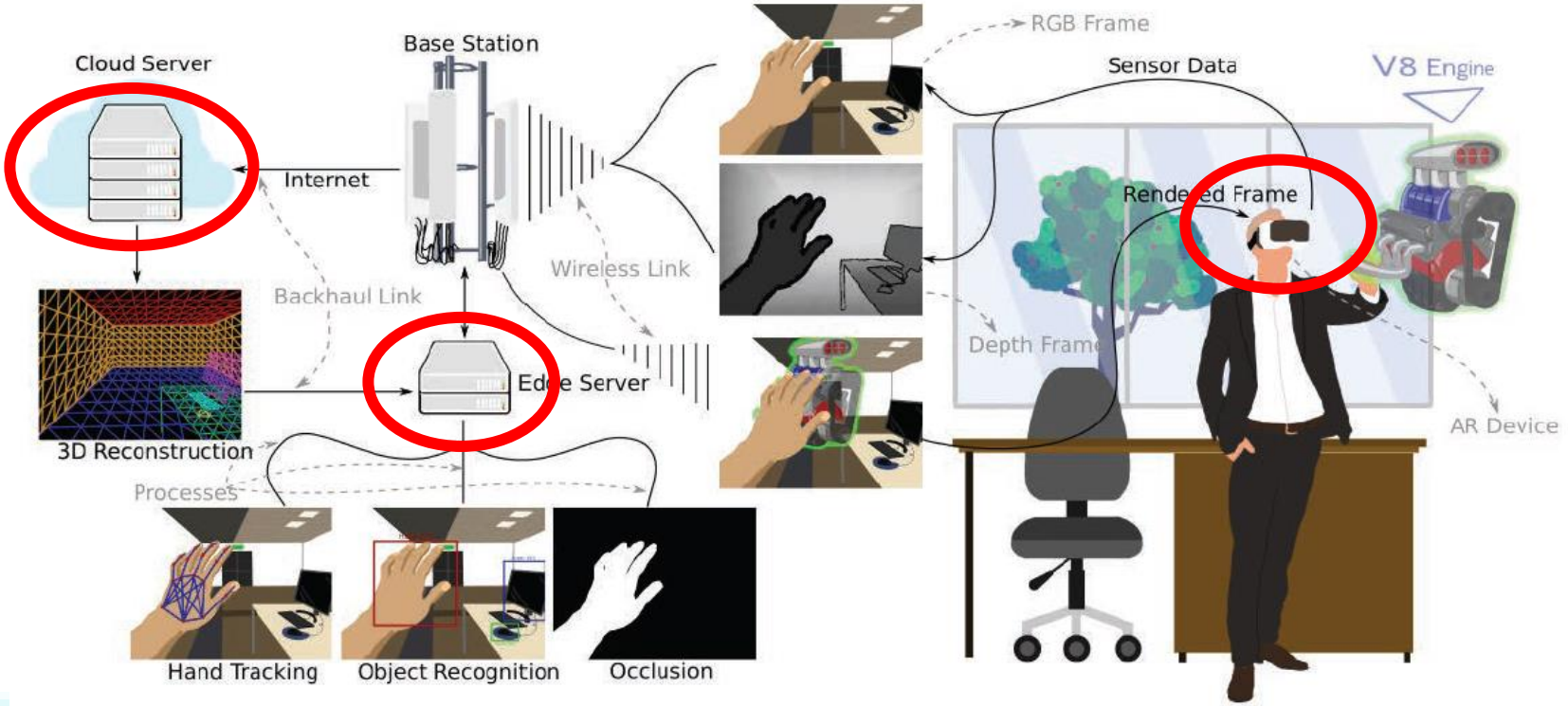
Validating the simulator



Analyzing new possibilities

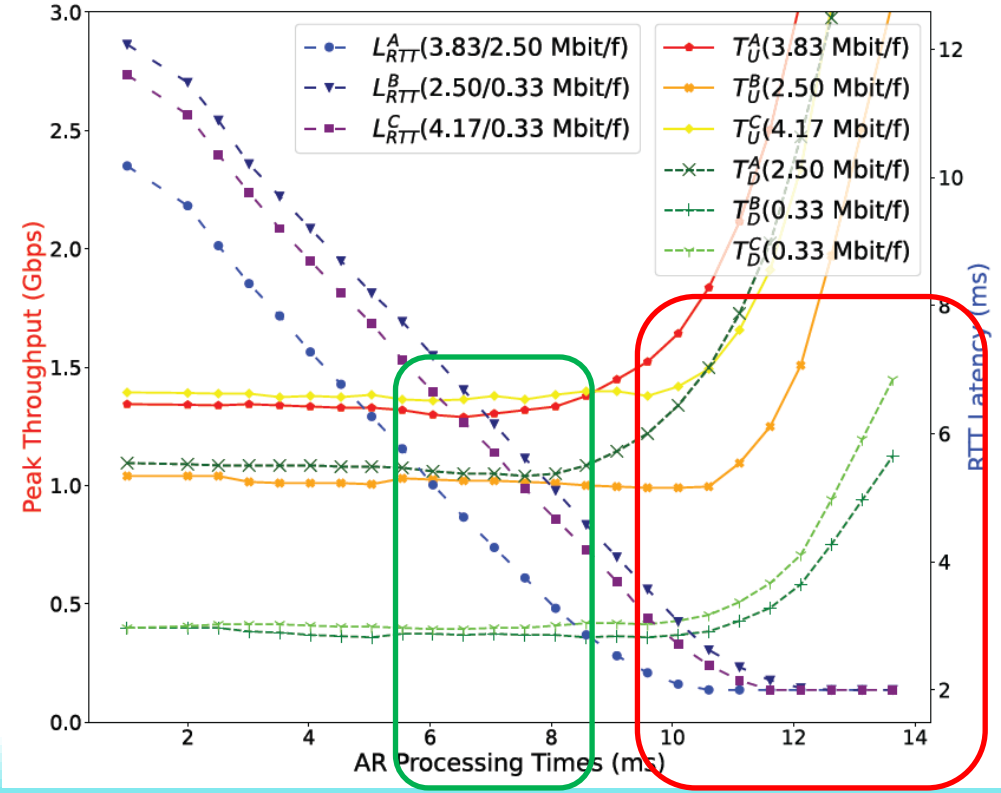


Where shall we do the processing? (offloading)



Requirements for different offloading options

- use case A: Full offloading
- use case B: Object detection and segmentation offloading
- use case C: Occlusion handling offloading

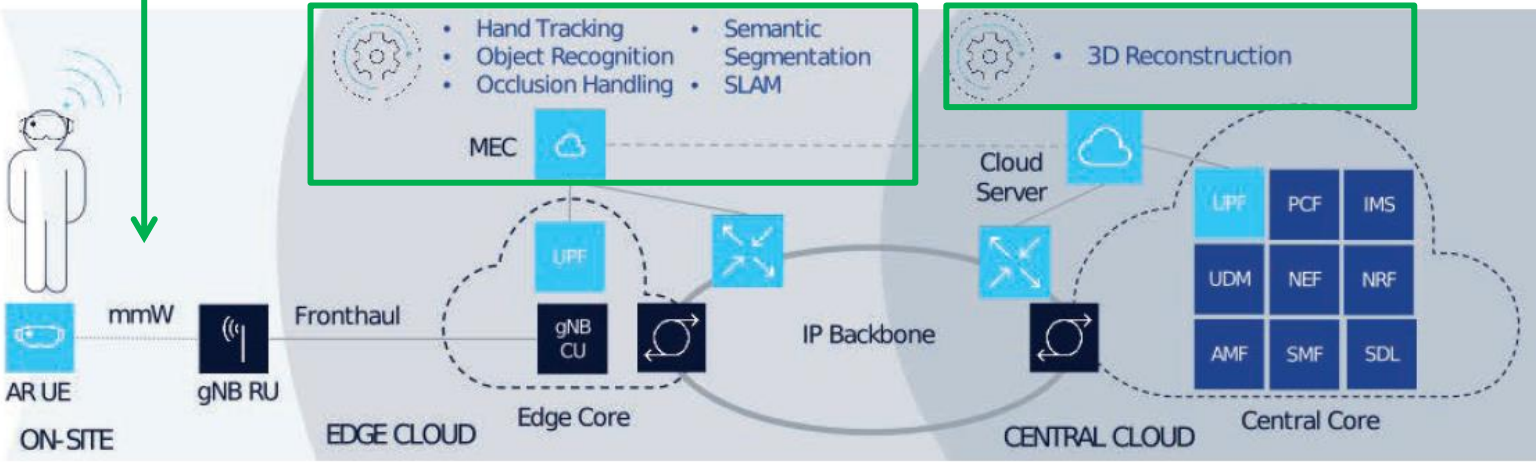


1 Gbps and 4 msec

Very demanding for the radio interface

Proposed architecture

- TDD configurations 34 to 42 and 50 to 55 (prioritize the uplink)
- Subcarrier spacing of 120 kHz (numerology 3) and a bandwidth of 400 MHz
- High frequency bands: mmWave
- Network slice with RAN resources properly reserved



What if …

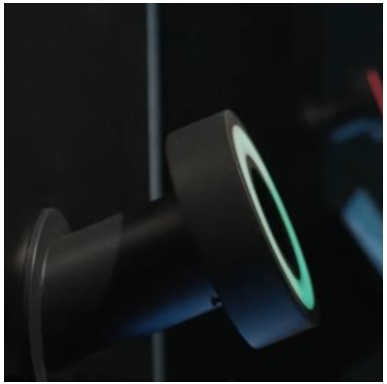
El Oído *(Hearing)*

The Essence of a Painting.
An Olfactory Exhibition
(10 fragances)

El Olfato *(Smell)*

El Tacto *(Touch)*

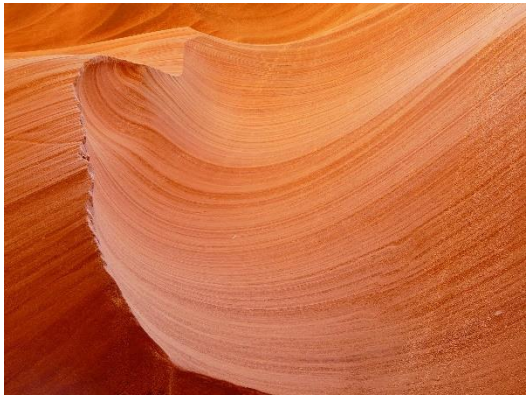
La Vista *(Sight)*



El Gusto *(Taste)*

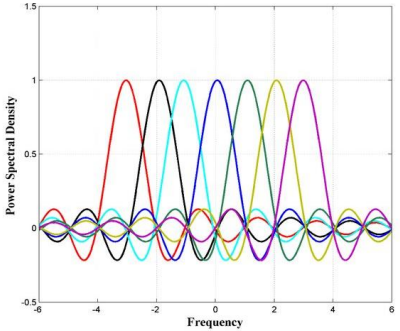
The 5 senses painted by Bruhegel and Rubens (El Prado Museum)

Towards an internet of the senses

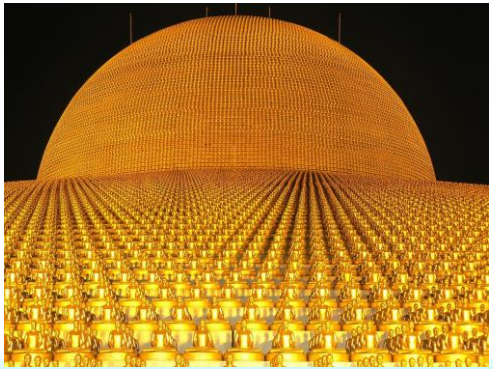


THz

VLC



New waveforms



Ultra-massive MIMO

RIS

Towards an internet of the senses

Liquid antennas

https://agarcia.webs.tsc.uc3m.es/experiments-with-liquid-antenna/

Javier Otero Martínez, Javier Rodríguez Rodríguez, Yuanjun Shen, Kin-Fai Tong, Kai-Kit Wong, Ana García Armada, “Towards Liquid Reconfigurable Antenna Arrays for Wireless Communications”, IEEE Communications Magazine, in press.

Towards an internet of the senses

ICAS

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Work is underway

- The Society of Motion Picture & Television Engineers (SMPTE) has defined the ST 2100-1, "**Definition and Representation of Haptic-Tactile Essence for Broadcast Production Applications**", June 2017.
- The IEEE 1918.1 "**Tactile Internet**" Standards Working Group considers the **Live Haptic-Enabled Broadcast** use case.

Thank you

Projects: LTE Xtreme, AMATISTA, TeamUp5G, TERESA, IRENE-EARTH

GOBIERNO DE ESPAÑA
VICEPRESIDENCIA TERCERA DEL GOBIERNO
MINISTERIO DE ASUNTOS ECONÓMICOS Y TRANSFORMACIÓN DIGITAL

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Pictures and images from:

- ITU-R M.2083-0 (09/2015): IMT Vision – Framework and overall objectives of the future development of IMT for 2020 and beyond
- https://www.museodelprado.es/
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