Air Interface Challenges and Solutions for future 6G Networks

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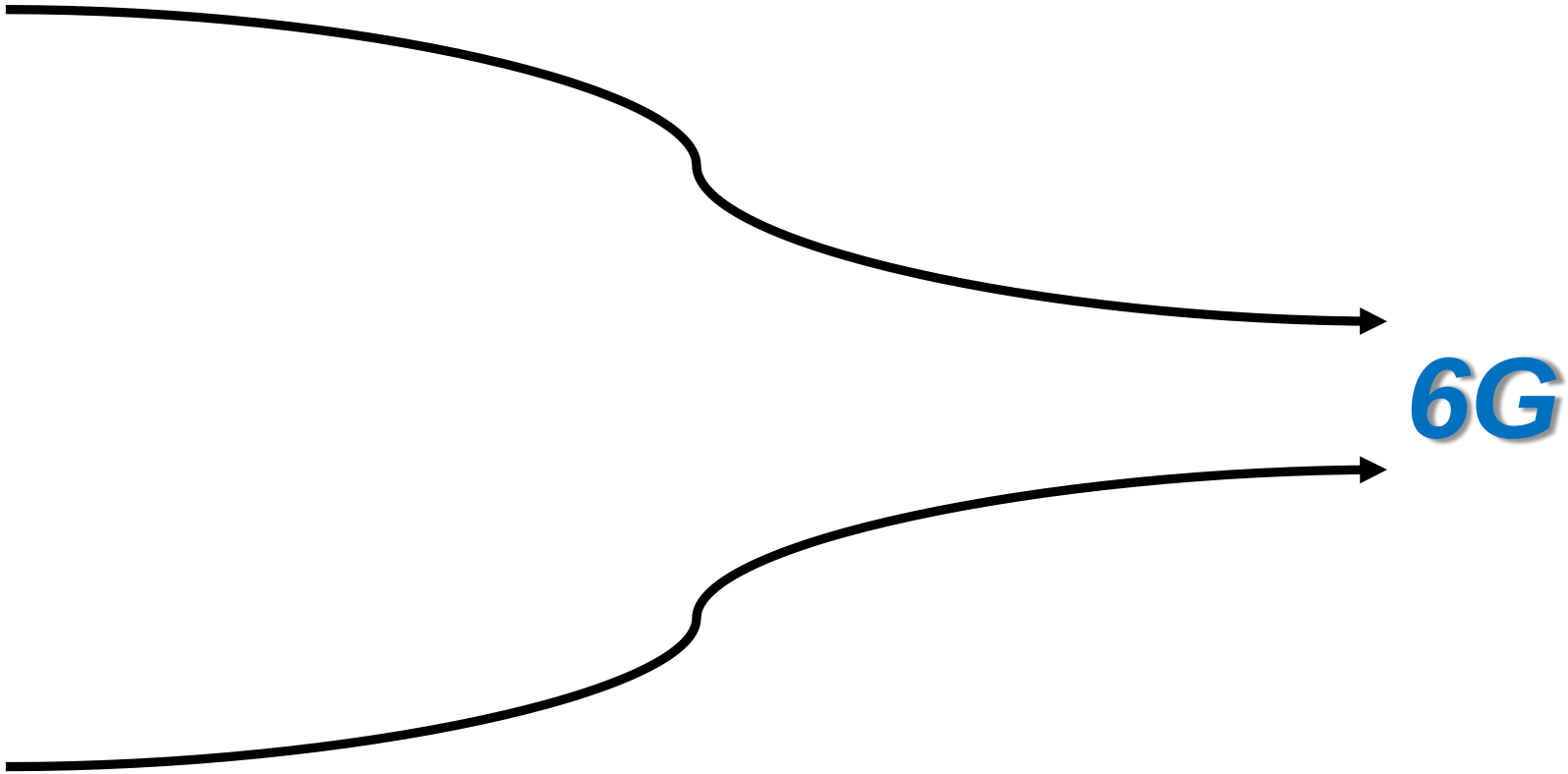
WHY WE NEED A NEW 'G'ENERATION ?

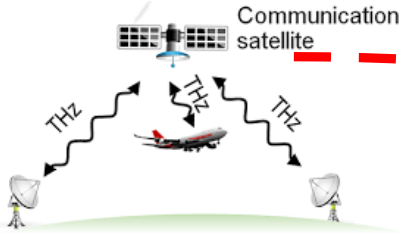
Technological breakthrough readiness

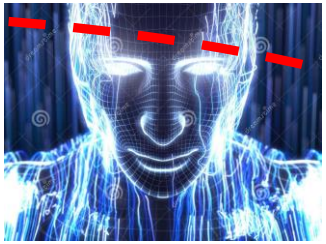


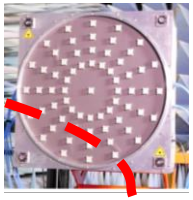
New services, Applications & use cases

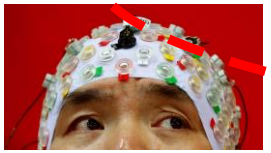
WHY WE NEED A NEW 'G'ENERATION ?

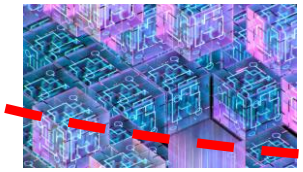
Technological breakthrough readiness

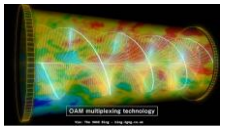




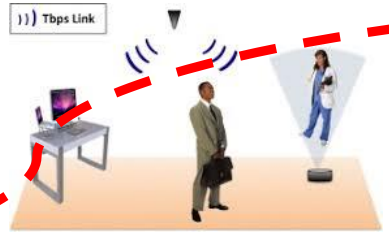








6G



New services, Applications & use cases

TWO EXAPLES OF 6G USE APPLICATIONS

5 Senses Interactive Hologram Technology

Interactive Haptic Communications

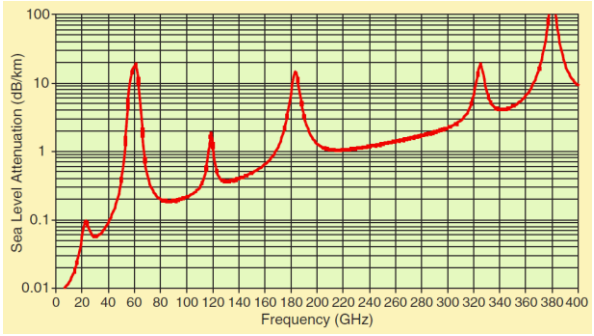
Low Latency (µs-ms)
Self-designing Joint C⁴ : Communication + Computing + Caching + Control
Ultra-high capacity (10*s* Tbps)
Deterministic (~~stochastic~~) network optimization

6G TRENDS

- **TREND 1: More bits, more spectrum**
- TREND 2: 3D Coverage and Spatial BW
- TREND 3: New Technologies (Meta materials, in memory computing, …)
- TREND 4: Ubiquitous Role of Antennas
- TREND 5: New Applications & New Service Classes
- TREND 6: Energy Free Communications (wireless recharging, …)
- TREND 7: C^3: Convergence of Communication, Computation & Caching
- **TREND 8: Ubiquitous support of AI**
- TREND 9: Breaking Big Data with Massive Smal Data
- TREND 10: …

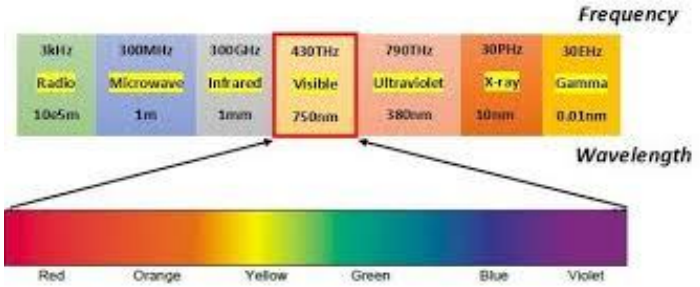
More bits, More Spectrum

Convergence of RF and Optical Wireless Networks

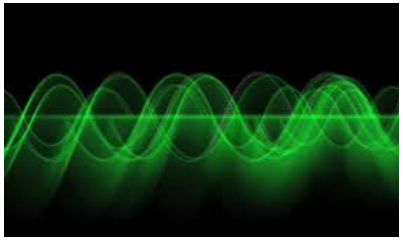


Radio waves paradigm

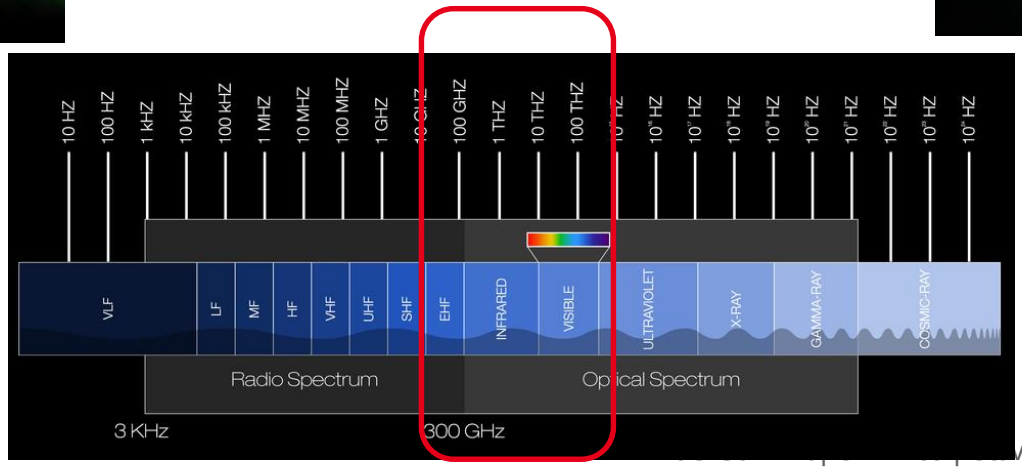
6G



Optical waves paradigm

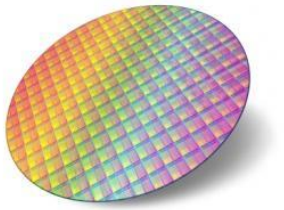


mmWave to µmWave

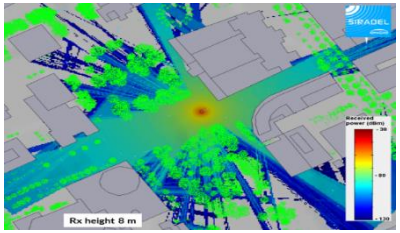


More bits, More Spectrum:
New challenges at different levels (not only radio!!)

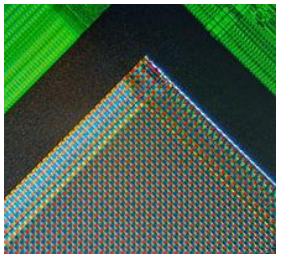
- **Technologies, CMOS integration**
  - Integration, power consumption and cost challenges

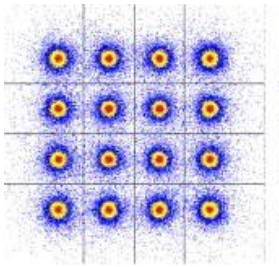


- **Channel model and propagation**
  - New propagation paradigm & blocking

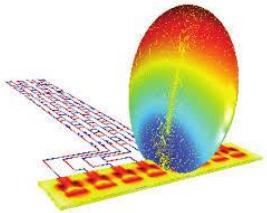


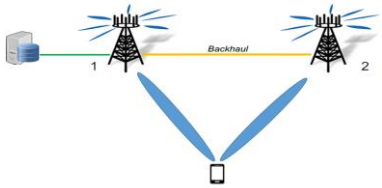
- **Transcriber architecture**
  - From RF receiver to *multispectral imager*

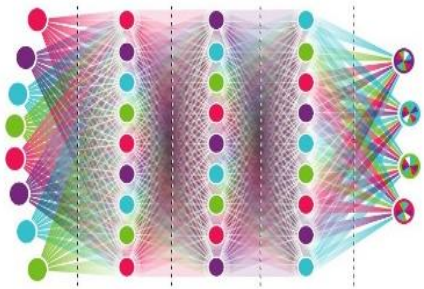




- **From 2D to 3D coverage:**
  - 3D adaptive connectivity
  - 3D spatial processing



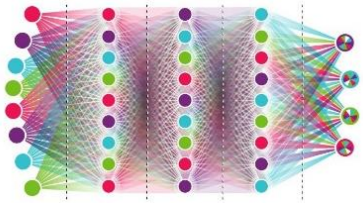




- **Adaptive 3D Multi-link Connectivity**

AI-BASED SOFTWARE-DEFINED AIR INTERFACE

In 6G many air interface parameters will be optimized for each user & IoT device



3D Localizatio

Context sensing

User behavior

Energy state

Rea

Need for real-time flexible adaptation with SW interfaces

5G → 6G >> x10^5 complexity increase

Software air interface

ectral imager

Sub 6GHz | mmWave | umWave

NOMA

2D | 3D

Adaptive Frame structure

Duplexing

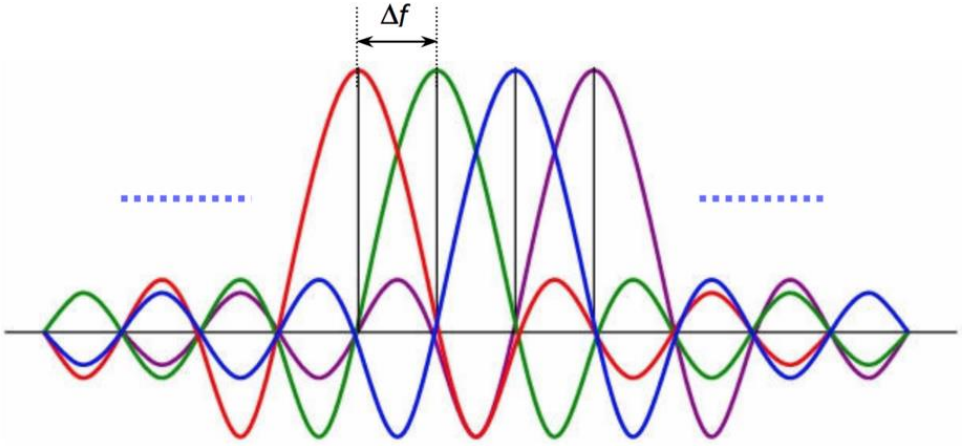
Adaptive Security

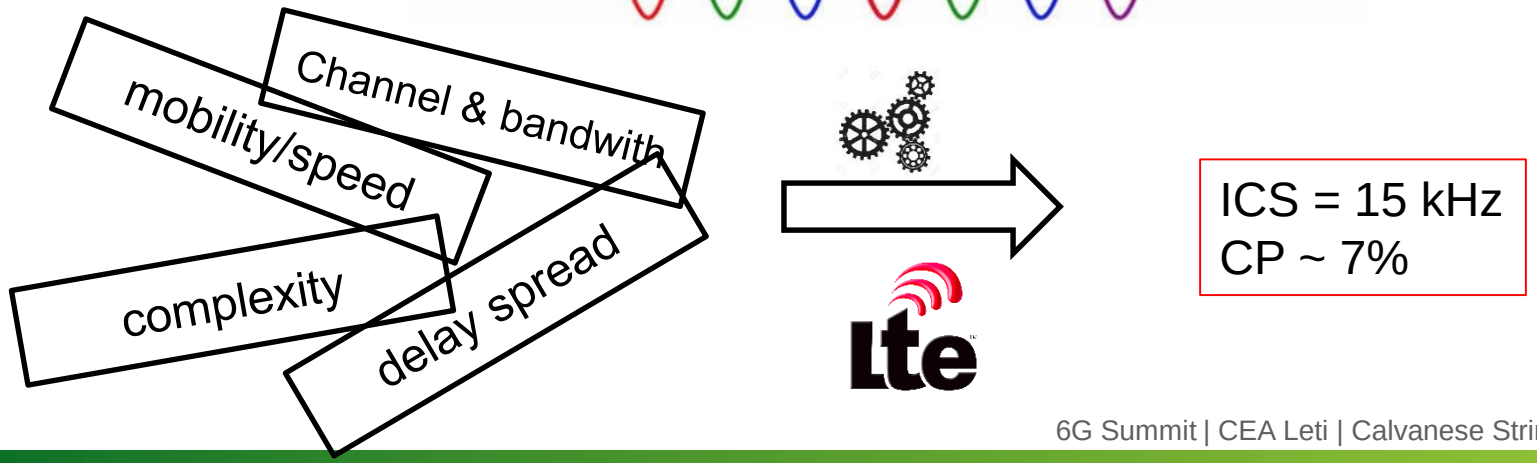
ment

eam alignment

Example of LTE Waveform numerology

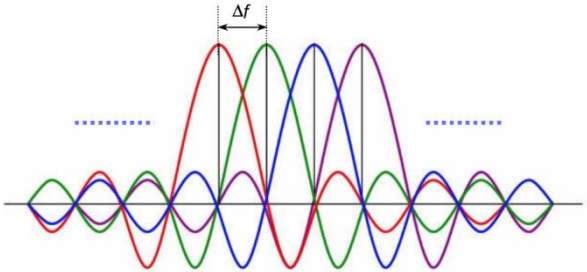
- **OFDM is characterized**
  - ICS: inter Carrier Spacing
  - Number of carriers
  - Cyclic prefix duration





ICS = 15 kHz
CP ~ 7%

Example of 5G Waveform numerology



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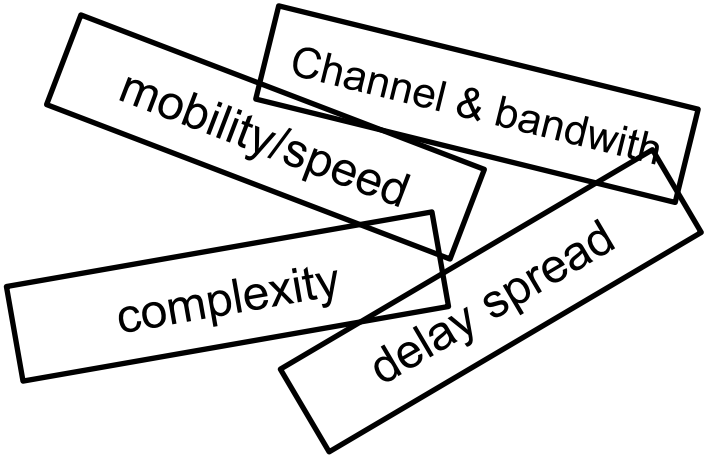


ICS = 2^u x 15 kHz
CP ~ 7%

5G

- Static configuration
- **When ICS ↑ then CP duration ↓**
- **Multi numerologies coexistence issue** [1][2]

[1] : D. Demmer, R. Gerzaguet, J.-B. Dore, and D. Le-Ruyet, "Analytical study of 5G NR eMBB co-existence," in 2018 25th International Conference on elecommunications (ICT), June 2018, pp. 186–190.
[2]: J. Y.-K. T. Levanen, M. Renfors, M. Valkama, and K. Pajukoski, "FFT-Domain Signal Processing for Spectrally-Enhanced CP-OFDM Waveforms in 5G New Radio," in Asilomar Conference on Signals, Systems, and Computers, 2018, Nov 2018

AI-BASED SOFTWARE-DEFINED Waveform numerology

(3D) Localization

Channel & bandwith

mobility/speed

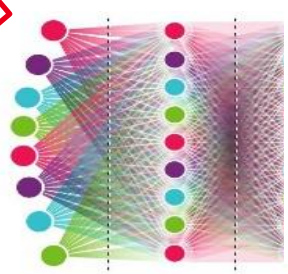
User habits

complexity

delay spread

...

...



UNDER INVESTIGATION

6G

ICS = X kHz
CP ~ Y %

- **Dynamic configuration**
- **Context aware ICS** and **CP** duration
- **Interference management** through **optimized waveforms**

WHY ARE WE TALKING ABOUT 6G?

- **Societal Use Cases** will changes
- **Technological breakthrough** will open new opportunities
- **Standards** are not compatible with future needs (3G PPP, ETSI, etc…)
- **Technology** is not mature or too costy (i.e. mmW at 140 GHz+, in memory computing, …)
- **Regulation** is not in favor yet (i.e. spectrum, drones, … for instance)
- **5G discussion** bodies has chosen different paths and priorities (Ex. VLC)
- The **need for such technology** is not here yet
- We just simply **do not how to do it now** (i.e. quantum computing)

Thank you!

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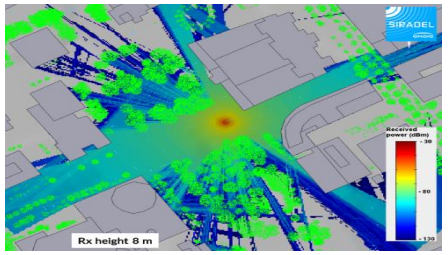
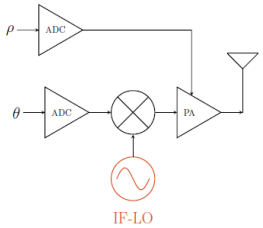
FOCUS 3 (2/2)

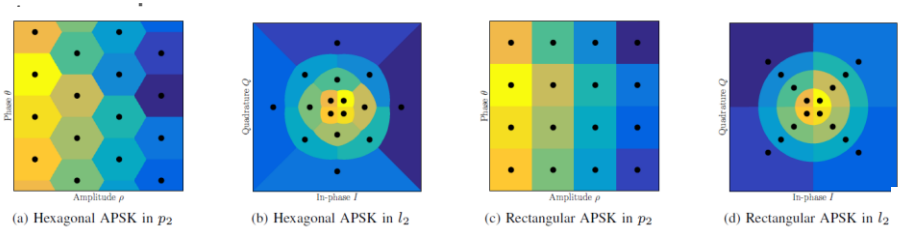
Research activities

- **Toward Tbps with THz channels**
  - Scenarios
    - Backhauling, Mesh networks, FWA
    - Kiosk application, offloading
    - WPAN, chip2chip, Wireless connector (USB.., farm server)

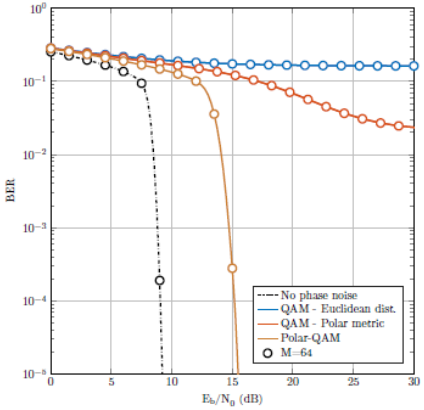


  - Research activities
    - Signal processing for « dirty RF » components

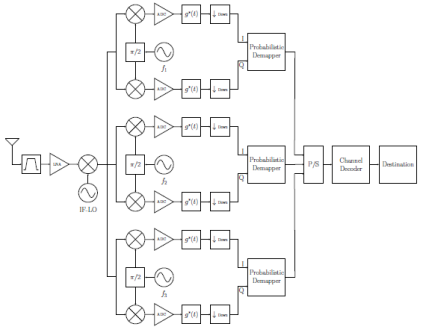




(a) Hexagonal APSK in p_2 (b) Hexagonal APSK in l_2 (c) Rectangular APSK in p_2 (d) Rectangular APSK in l_2

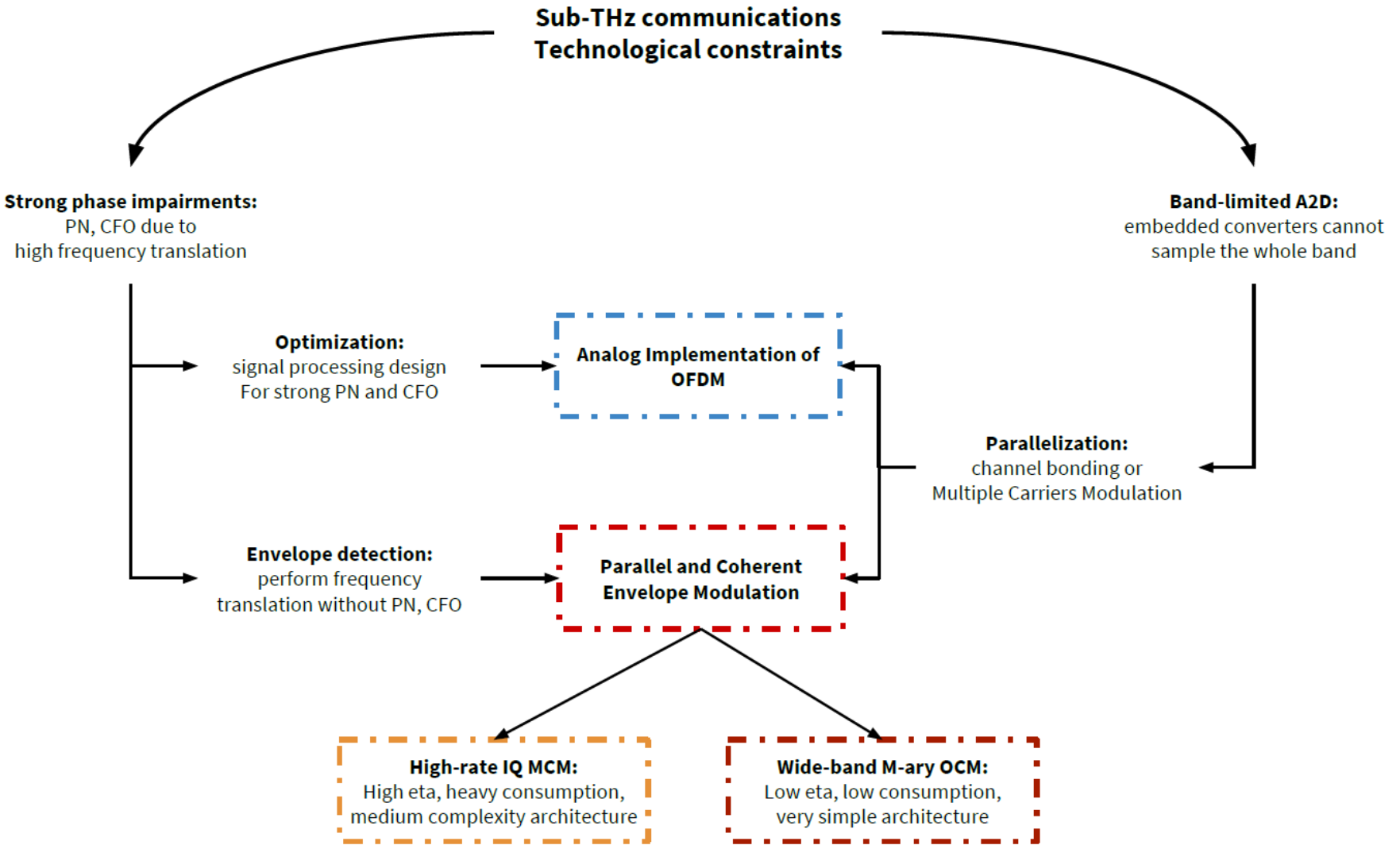


    - Joint RF transceiver and baseband design
      - Analog/digital partitioning, dedicated architecture



  - Dissemination
    - 8+ papers, 2+ patents

FOCUS 3 (2/2)


Sub-THz communications
Technological constraints
Strong phase impairments:
PN, CFO due to
high frequency translation
Band-limited A2D:
embedded converters cannot
sample the whole band
Optimization:
signal processing design
For strong PN and CFO
Analog Implementation of
OFDM
Parallelization:
channel bonding or
Multiple Carriers Modulation
Envelope detection:
perform frequency
translation without PN, CFO
Parallel and Coherent
Envelope Modulation
High-rate IQ MCM:
High eta, heavy consumption,
medium complexity architecture
Wide-band M-ary OCM:
Low eta, low consumption,
very simple architecture

SOME ASSUMPTIONS ON 6G

Artificial intelligence will dominate both in:

- **delivery area** - in the core and at the edges of the network(s)
- **fruition area** - devices like smartphones and things (super IoT)
- **application space**

Augmented Reality will become **pervasive**

- The technology support for it is still unclear (visual ambient, super contact lents, holograms, …)
- Smart materials might allow any surface to display information,
- ***holographic*** **projectors** might become available

Applications:

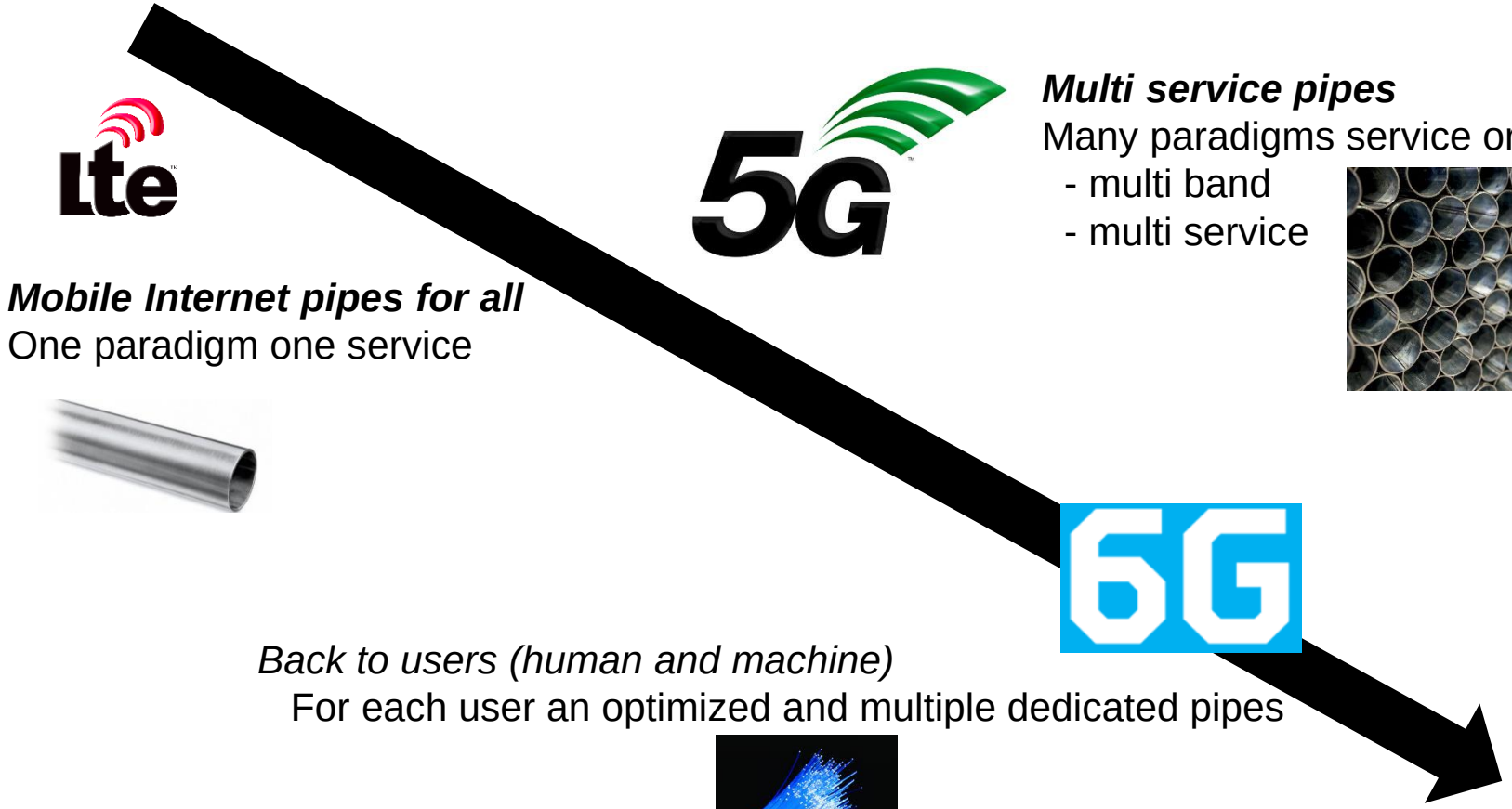
- Images created directly in the eyes (using electronic contact lenses, chip implant or brain implant (BCI). All of them are unlikely to be available, in the mass market before 2030)

Observations:

- it will be **cheaper to augment humans** to become able **to** receive and **visualize** bits **than augmenting** the **any ambient to display** them

6G vision (2/2)

- **More efficiency through local and distributed automized optimization**



Mobile Internet pipes for all
One paradigm one service

Multi service pipes
Many paradigms service oriented :
- multi band
- multi service

Back to users (human and machine)
For each user an optimized and multiple dedicated pipes