A vision of future networks

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Which societal stakes in the future?

- Energy efficiency and environmental responsibility
- Efficient industries and agriculture
- Efficient public services, cities and communities
- Security, privacy and sovereignty
- More quality time for individuals
- **Others that we cannot predict now**

4G and 5G have started to address these stakes…

…but we are just at the start of the path

Which usages… and level of investment?

Usages are driving the effective use of technology

Need to continue and expand the dialogue initiated for 5G with users of future networks to identify their needs (verticals, cities, communities, citizens)

5G will enable disruptive services, e.g.

- **Low Latency services: AR, VR, cloud services**
- **Networks cloudification: Slicing, edge cloud**

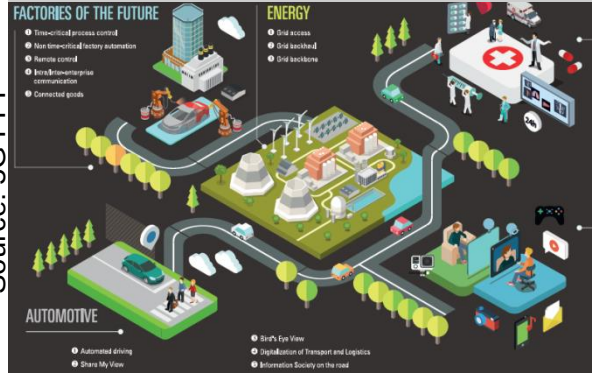
Get feedback from their user experience and adoption for meaningful long-term evolution plans

Network deployments are CAPEX-intensive, under a growing pressure for reducing them

Need for return on investment, or reduced CAPEX

Some networks evolutions are clear

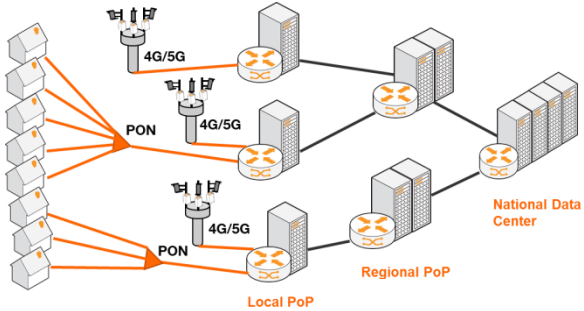
From essential to critical connectivity
need for trust, security and resilience



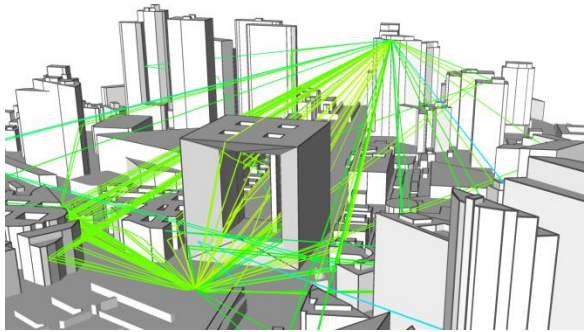
Source: 5G PPP

From pop. to ubiquitous coverage
calling for new deployment models

From communication to cloud infra
new business value propositions



Reaching EMF limits in some cities
need for EMF-aware technologies

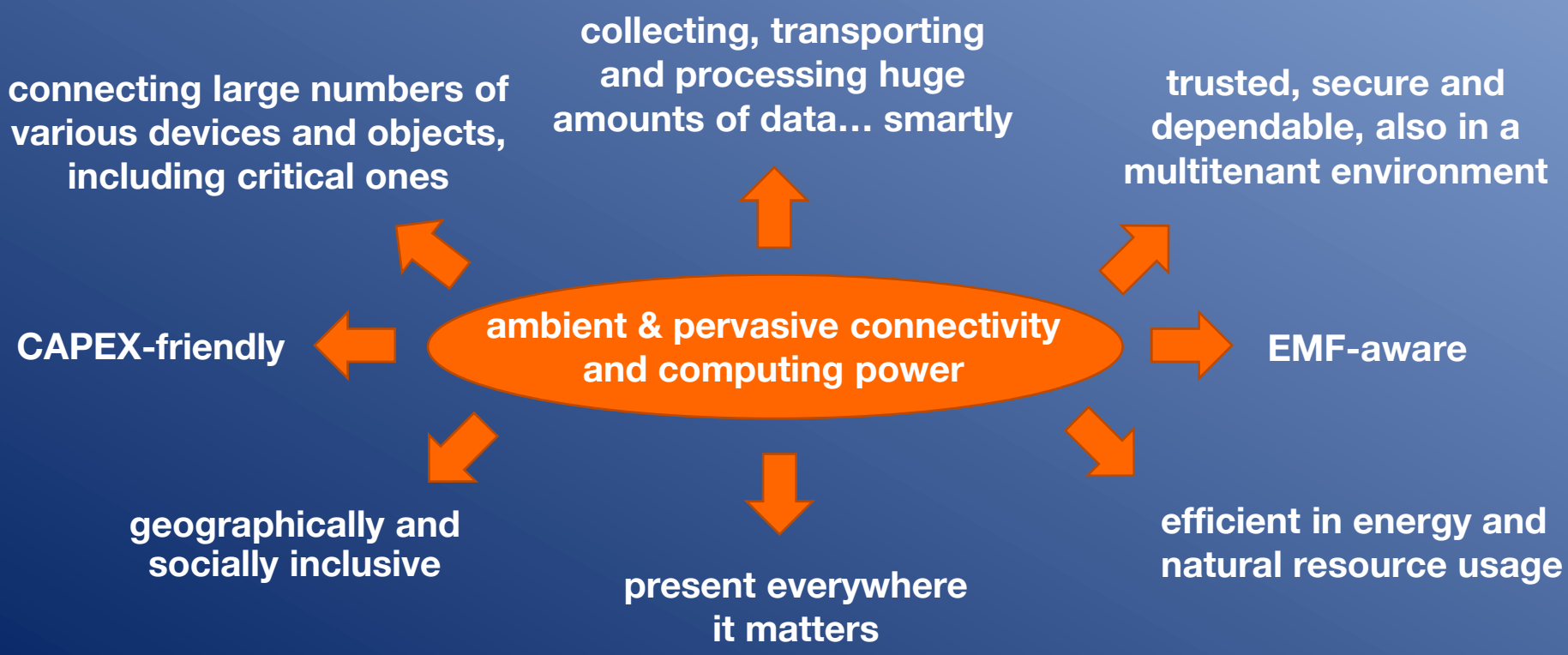


Intensive use of rare natural resource
need for energy efficiency & recycling

Source: Jeffrey Thompson | MPR News

From facilitator to socially mandatory
need to ease the basic Internet access

The future networks vision

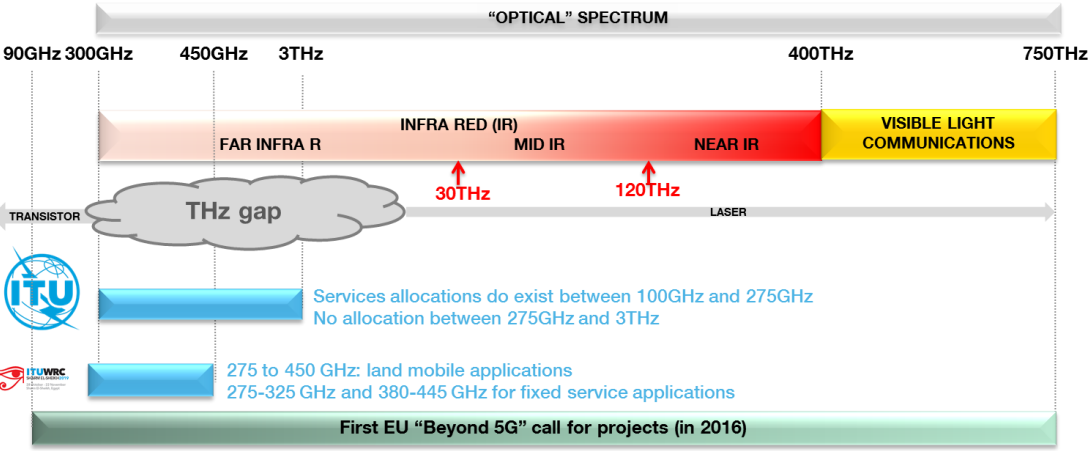


Examples of candidate techniques

- New spectrum bands (e.g. THz bands)
- Artificial Intelligence-optimised system, including physical layer
- Ambient backscattering: communication recycling the ambient waves
- Radar sensing / high-accuracy geolocation
- Distributed MIMO / spatial focusing
- Leveraging devices as network/cloud infrastructure elements, under operator control
- Interference management (Tx and Rx) for spectral efficiency in low bands
- Application-aware network/cloud and network/cloud-aware applications, under network supervision
- Unification of cloud and network infrastructures

THz spectrum

THz spectrum: in practice from ~100GHz to ~450GHz



6 EU-funded on-going projects investigate this topic (inc. one EU/Japan project) under the ICT-09-2017 H2020 Call "Networking research beyond 5G"

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Orange lead

THz spectrum offers large bandwidth and capacity but raises a number of challenges

Propagation

Absorption loss, Attenuation with distance, Blockage / Non Line of Sight situations…

– Propagation channel modelling required

Signal generation and baseband algorithms

e.g. FEC achievable throughputs?

Hardware implementation and related cost

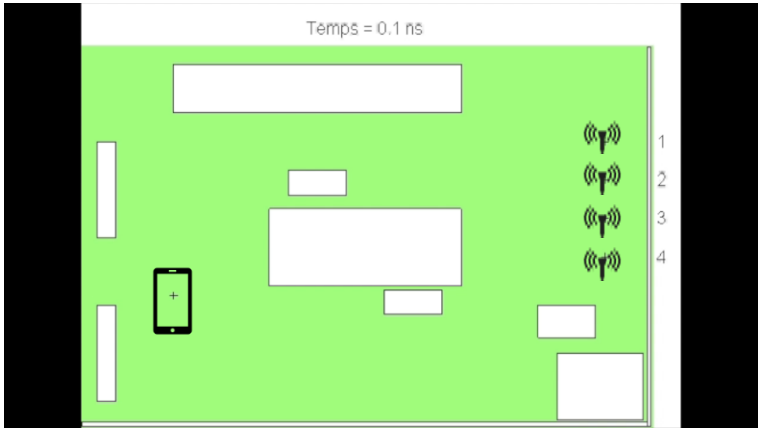
Which semiconductor technology / material in those bands (noise / gain / output power) ? Which maturity (inc. level of integration)? When? At which cost?

Antennas design?

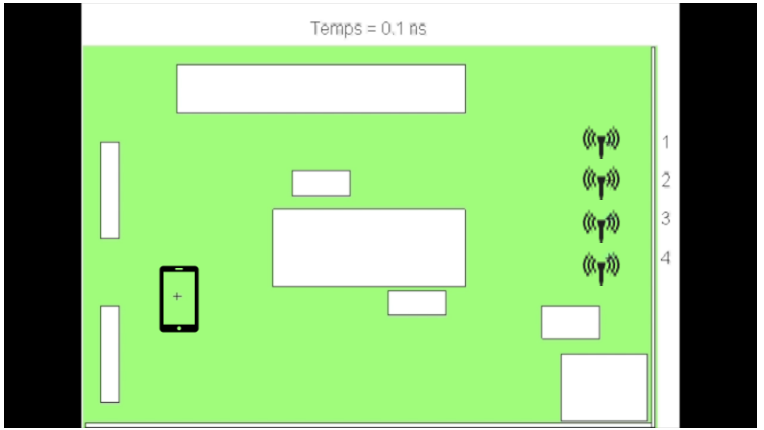
Spatial focusing for EMF-aware transmissions

Principle:

1. Learning phase: Mobile sends pilots, Base Station learns channel



2. Focusing phase: Base Station uses the measured channel, exploits uplink-downlink channel reciprocity and computes the beamformer

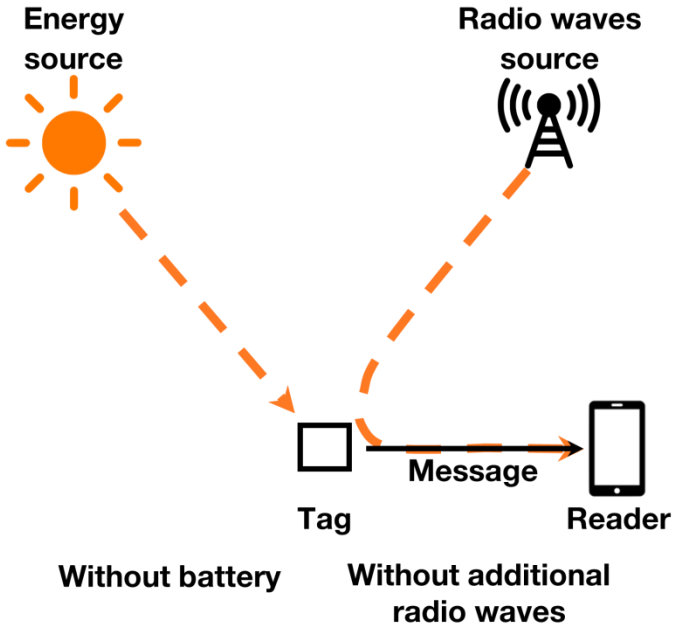


Several experiments:

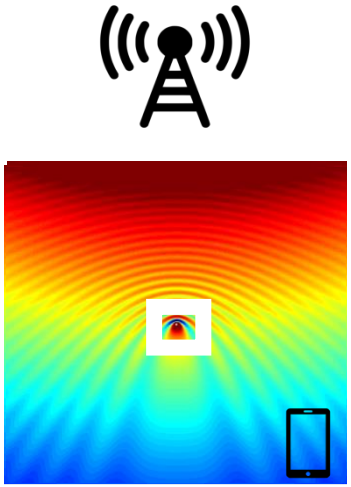
- **2018: Open Air Interface prototype (8 antennas elements) [1]**
- **2019: Channel measurements with Nokia Bell Labs 64 antenna elements massive MIMO test-bed [2]**

[1] D.-T. Phan-Huy et al, "Single-Carrier Spatial Modulation for the Internet of Things: Design and Performance Evaluation by Using Real Compact and Reconfigurable Antennas", IEEE access, Volume 7, 2019.
[2] D.-T. Phan-Huy, Stefan Wesemann, Philippe Sehier, 'How Wireless Dumb Devices Could Attain High Data Rates Thanks to Smart Massive MIMO Networks') accepted for presentation at the 23rd ITG Workshop on Smart Antennas, April 2019

Recycling ambient energy and radio waves



How does it work?



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K. Rachedi, D.-T. Phan-Huy, N. Selmene, A. Ourir, M. Gautier, A. Gati, A. Galindo-Serrano, R. Fara, J. de Rosny "Real-Time Ambient Backscatter Demonstration", accepted at *IEEE INFOCOM 2019*, Paris, 29 April-2 May

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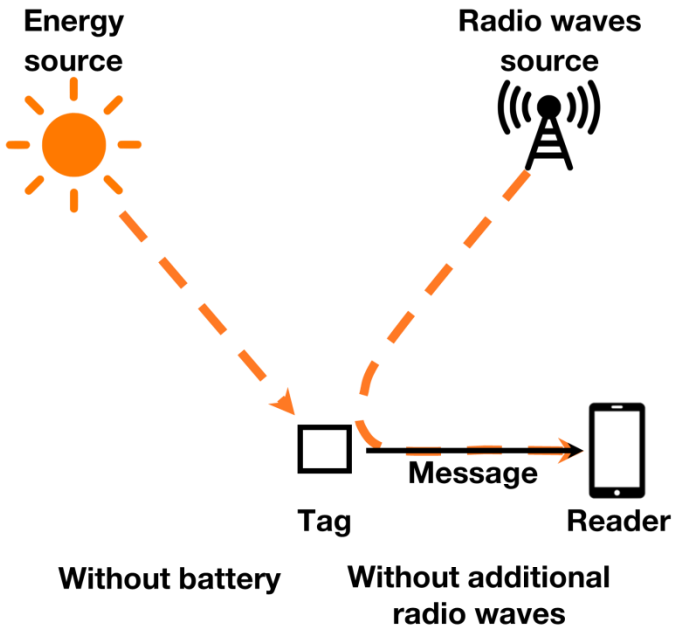
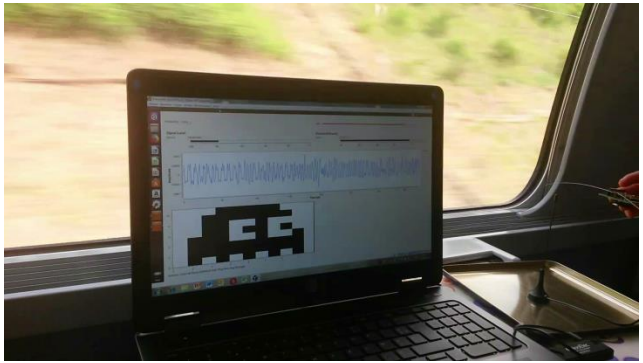


first prototype recycling TV and 4G waves



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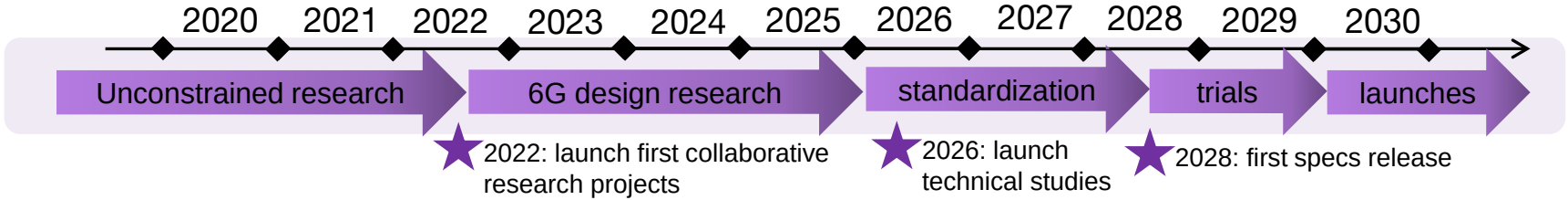
5G long-term evolution… or 6G?

- Upcoming techniques or disruptions may be integrated in 5G evolutions or in a 6G
  - 5G has been designed to be highly flexible and evolutive, what are the limits for integrating new techniques?
- Industrial plans for 6G should be made when we have reasonable confidence to define a meaningful technology from technical and business perspectives
  - Get feedback from 5G commercial operations first
  - Identify the practical needs and business cases beyond 5G possibilities in order to justify investments in a new technology
  - Make time for exploratory (unconstrained) research, and not to start too soon in order not to miss any new technology progress or disruption
- If we assume that 6G would deploy commercially in 2030, adopting the same planning as for 5G would lead us to the following high-level roadmap:



Take-aways

- Beyond performance aspects, research on future networks has to address
  - Trust and resilience, in multi-tenant environments
  - EMF-aware transmissions
  - Energy and natural resource usage efficiency
  - Digital inclusion

- Need to keep a balance between mid-term and long-tem research:
  - Still a lot of research needed to deliver the full 5G potential!

- 6G system-design industry considerations should not start before ~2025

- The exploding complexity of the networks multi-requirements optimisation calls for system-level research: research on isolated building blocks is not sufficient!
  - Computing power and open-source now allow us to test innovations in close to real-life environments at moderate cost – see http://www.pluginthefuture.eu/

Thank you