# 6G-NTN: A Cognitive Service-Centric Paradigm for Next-Generation Networking

Speaker: Franco Davoli

3rd Visions for Future Communications Summit 24th-25th November, Lisbon (Portugal).

# Contributors

- This content has been prepared in the context of NetworldEurope Satellite Communications Working Group.

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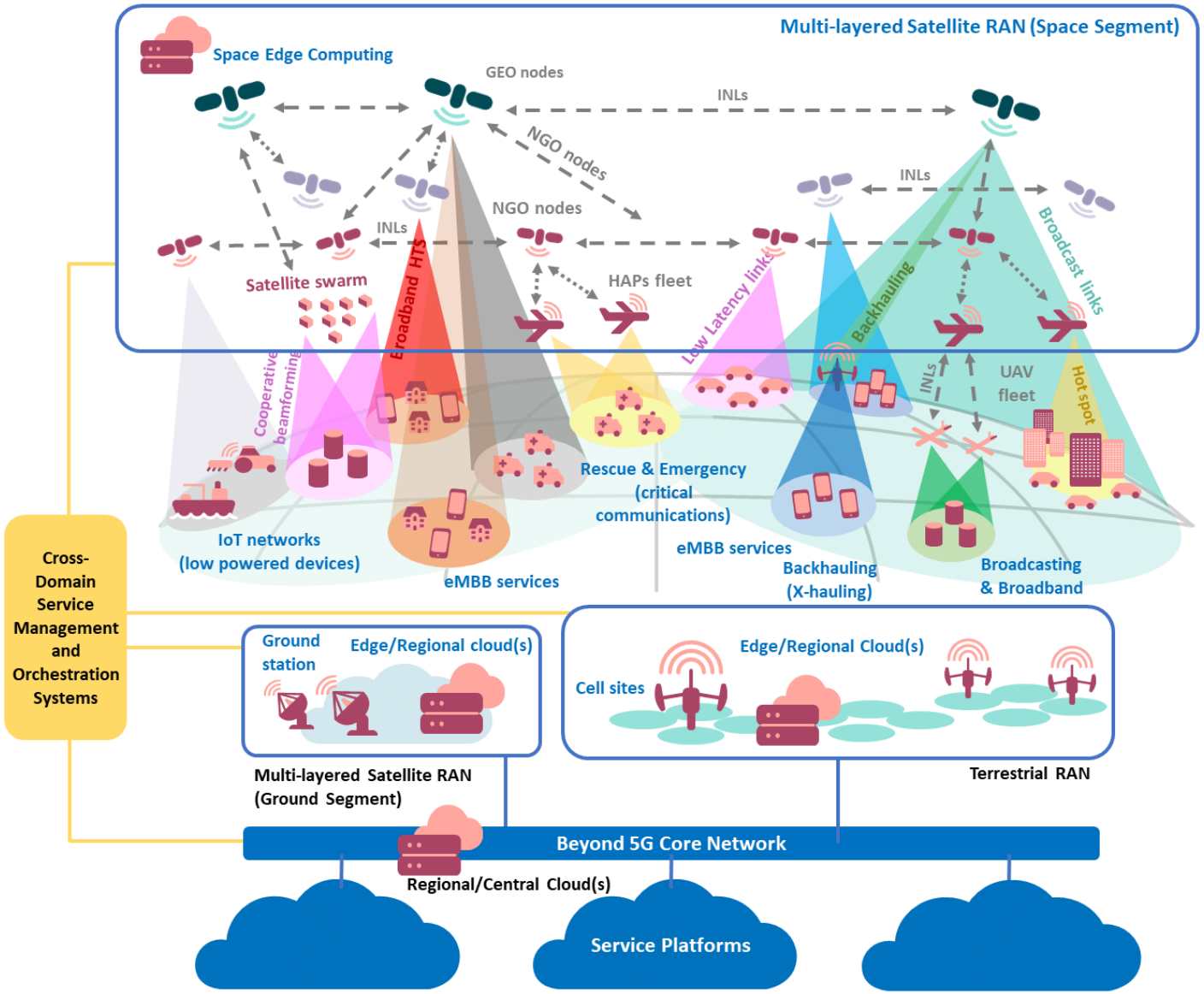
# 6G-NTN in a Nutshell

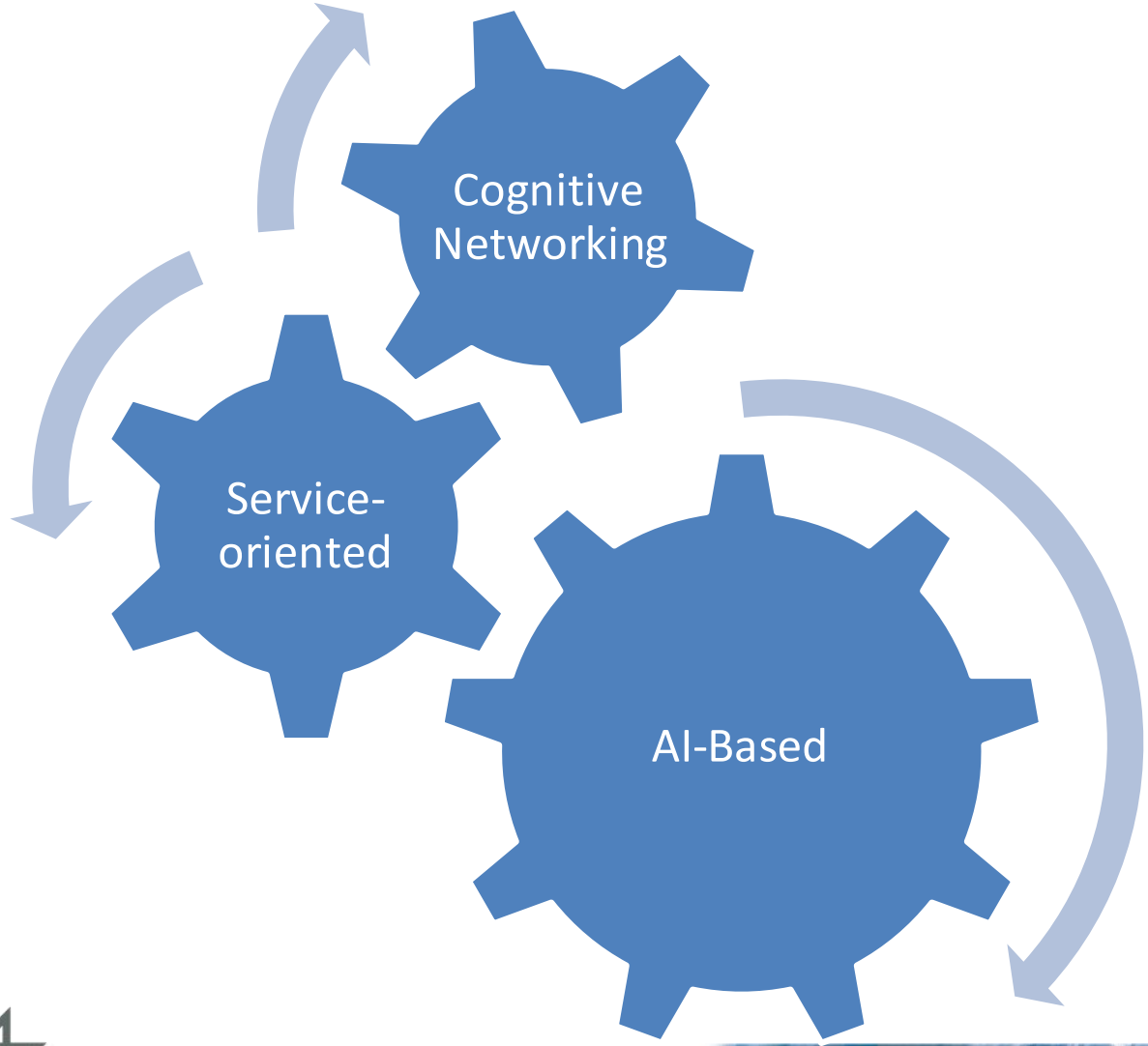



**Multidimensional**
**Multi-layered**
**Unified**

**Achieved by means of**

- **Unified and distributed-orchestration platform**
- **Full interoperability of the space segment to the integrated terrestrial wireless-wired network**
- **Full exploitation of the peculiarities of the space segment**

# Control/Management Planes in 6G-NTN: Gluing Everything




- Future space networks to become cognitive by observing and acting autonomously
- Full automation of network management and configuration tasks,
- Service-based networking (e.g., routing, forwarding, caching)
- Intent-based Networking on ground and space networks

# Main Building Blocks

- **Service centric networking**
  - Optimal placement and coordination of service function chains among different elements of the space and ground segments
- **Orchestration of space networks as an integrated part of the 6G system**
  - Exploitation of Function-as-a-Service paradigms supported by AI techniques to correlate NTN-6G context data with network operations and achieve effective network orchestration
- **Cloud continuum**
  - Exploitation of space assets placed in different interconnected flying systems will be an added value to guarantee diversified and QoS-proof access to distributed computing and storage resources across the whole 6G network.
- **Dynamic end-to-end network slicing and resource allocation**
  - Effective service provisioning techniques across all protocol layers in order to enable a service assurance in multi-layer multi-orbit scenarios by means of AI-based complex dynamic control strategies
- **Distributed AI techniques**
  - Applied throughout the entire 6G-NTN network architecture to guarantee a flexible and effective service provisioning under the operational constraints imposed by the heterogeneity of NTN-6G network elements.

# Main Directions for Effective Networking Operations in 6G-NTN

- Seamless Convergence of terrestrial and non terrestrial networks to boost 6G deployments
- Cognitive- and Intent-based Networking across heterogeneous networks
- Cloud services exploiting multi-orbit multi-layer assets
- Conception of satellite as a service to extend IaaS paradigms in space
- Integration of AI-as-a Service to allow for flexible and autonomous network operations

# Take-Home Message

*Seamless convergence between TN and NTN subsystems as key objective to increase the competitive value of the whole EU industry in the path towards 6G.*

# 6G NTN: A Flexible and Unified Air-Interface for the New Space Economy

Speaker: Miguel Ángel Vázquez, Senior Reseacher (Centre Tecnològic de Telecomunicacions de Catalunya)

3rd Visions for Future Communications Summit 24th-25th November, Lisbon (Portugal).

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  - Thomas Heyn (FhG-IIS).
  - Xavier Artiga, Joan Bas (CTTC).


CTTC

# 5G NTN Landscape

- Great success of incorporating space technologies in 5G NR (TR 38.821, TR 36.763)
  - Consolidated channel models and scenarios including GEO/NGEO.
  - CU/DU space splitting.
  - MAC enhancements for dealing with long delays.
  - Control plane data mobility aspects in LEO.
  - NB-IoT
- Studies will continue in future releases.

# 6G NTN in the New Space Economy

- Space economy is predicted to have a major leap in the next years.
- According to Morgan Stanley the space economy will increase from 350B$ in 2016 to 1Trillion$ in 2040.
- This huge gain is based on new applications
  - Space tourism.
  - Earth observation.
  - Space debris mitigation.
  - and, of course, satellite internet.
- Goal: 6G NTN should not only consider the convergence of the space component in terrestrial networks, but to embrace all aspects of the new space economy.

# Higher frequency bands

- The demand of more bandwidth entails the utilization of higher frequency bands.
- All players in the LEO race have applied spectrum allocation in EHF (Q/V,W).
- Is 5G NR ready for this new deployment?
  - Efforts in channel modelling are needed.
  - Thousands of satellite beams are expected, beam management shall scale accordingly.
  - Very high user bandwidth.
  - Spectrum co-existence.


FCC Authorizes Boeing V-Band LEO Broadband Constellation

By Rachel Jewett | November 3, 2021

# Regenerative payloads

**Xilinx launches 20nm space-grade FPGA for satellite and space applications**

First to enable machine learning inference together with unlimited on-orbit reconfiguration for real time on-board-processing in space; delivers full radiation tolerance spanning all orbits.

- Compared to current approaches, detect and ‘regenerate’ the Earth signal in the satellite leads to low CAPEX (number of gateways) by means of increasing the overall spectral efficiency.
- Space-borne transceivers (space grade hardware) shall tackle very high bandwidth signals (> 2 GHz) with limited capabilities compared to terrestrial equipment.
- Is there any air-interface aspect that could alleviate space segment processing requirements?

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# Data-driven RAN

- In initial 3GPP studies CU/DU split for NTN is confirmed to have no shortcomings.
- Open RAN approach to space systems shall be revisited:
  - Missions are addressed independently, there is no current multi-mission(orbit) controllers.
  - What are the benefits of RAN functional split between space and ground?
    - Example: MCS selection performed at the space segment could yield into a tremendous throughput gain compared to ground solution.
  - NTN RAN optimization shall be based in data traces and shift from the current 'model-based' approach to a 'data-driven' one.

# Sensing and Communications

- Multi-purpose satellite missions considering not only communications but other applications.
- Waveform design for both communications and
  - Radar: importance for space situational awareness, detecting space debris.
  - Position and navigation: high SNR communication signal could be employed for certain positioning applications (in addition to GNSS).
  - Timing is also critical for ground segment high capacity systems.
  - Earth observation applications.

# Conclusions

- New Space will have a huge impact in European economy in the next years.
- 6G NTN air interface is instrumental for this development.
- 6G NTN shall be suitable for
  - PNT.
  - Space-ground functional split with regenerative payloads.
  - Space debris mitigation.
  - Next LEO race.


# Sustainable IoT with Light-based IoT (LIoT) and Beyond

Prof. Marcos Katz
Centre for Wireless Communications
University of Oulu
Finland

**Vision of Future Communications Summit**
24th and 25th November 2021
Lisbon, Portugal

Flagship

# Towards a Sustainable Internet of Things (IoT)

## Sustainable IoT

- **Converged infrastructure** able to provide multiple services.
- **Energy-autonomous** IoT nodes
- **Efficient use of resources** (energy, spectrum, other physical resources)
- **Minimum environmental impact**

- Sustainability is multidimensional
- Being energy efficient is just one aspect
- Sustainability
  - Design phase
  - Implementation phase
  - Operation phase
  - End-of-life phase
- One of the key challenges is to create a **sustainable IoT concept**.
  - IoT nodes
  - Infrastructure

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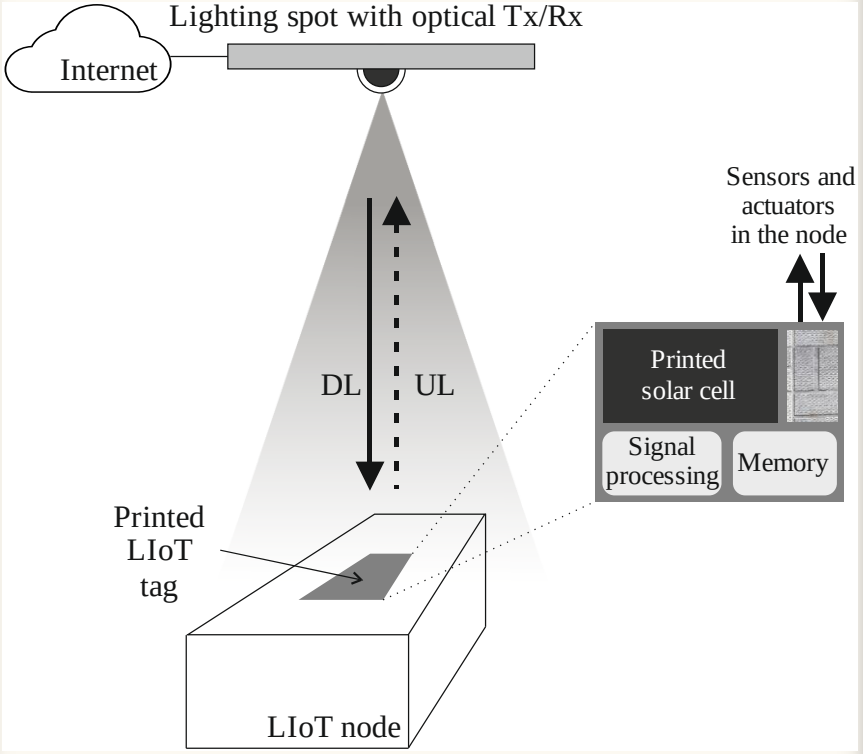
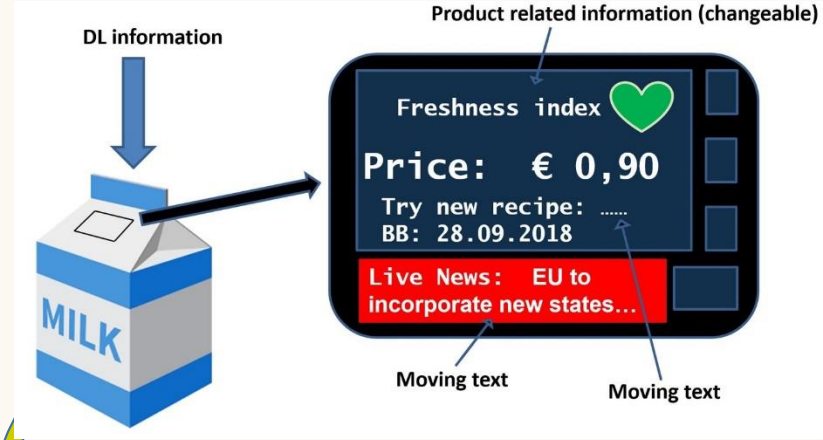
# Light-based IoT (LIoT)

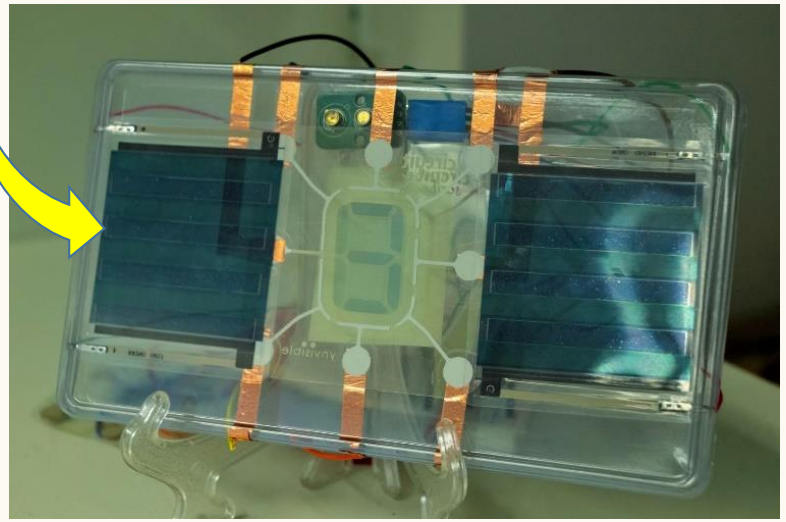



Light based IoT concept

- **Light based IoT (LIoT)**
- Light is used to a) power up an IoT node and b) send information wirelessly
  - Lighting infrastructure works as the AP
- **Expose and Connect** concept
- The **energy-autonomous** LIoT node can be attached to virtually any object
  - Energy harvesting from light is efficient
- Low-cost, environmentally sustainable IoT solution suitable for multiple use cases/applications

# VLC and Printed Electronics: A Happy Marriage



- Printed electronics (PE) provide a unique base to develop highly promising VLC solutions

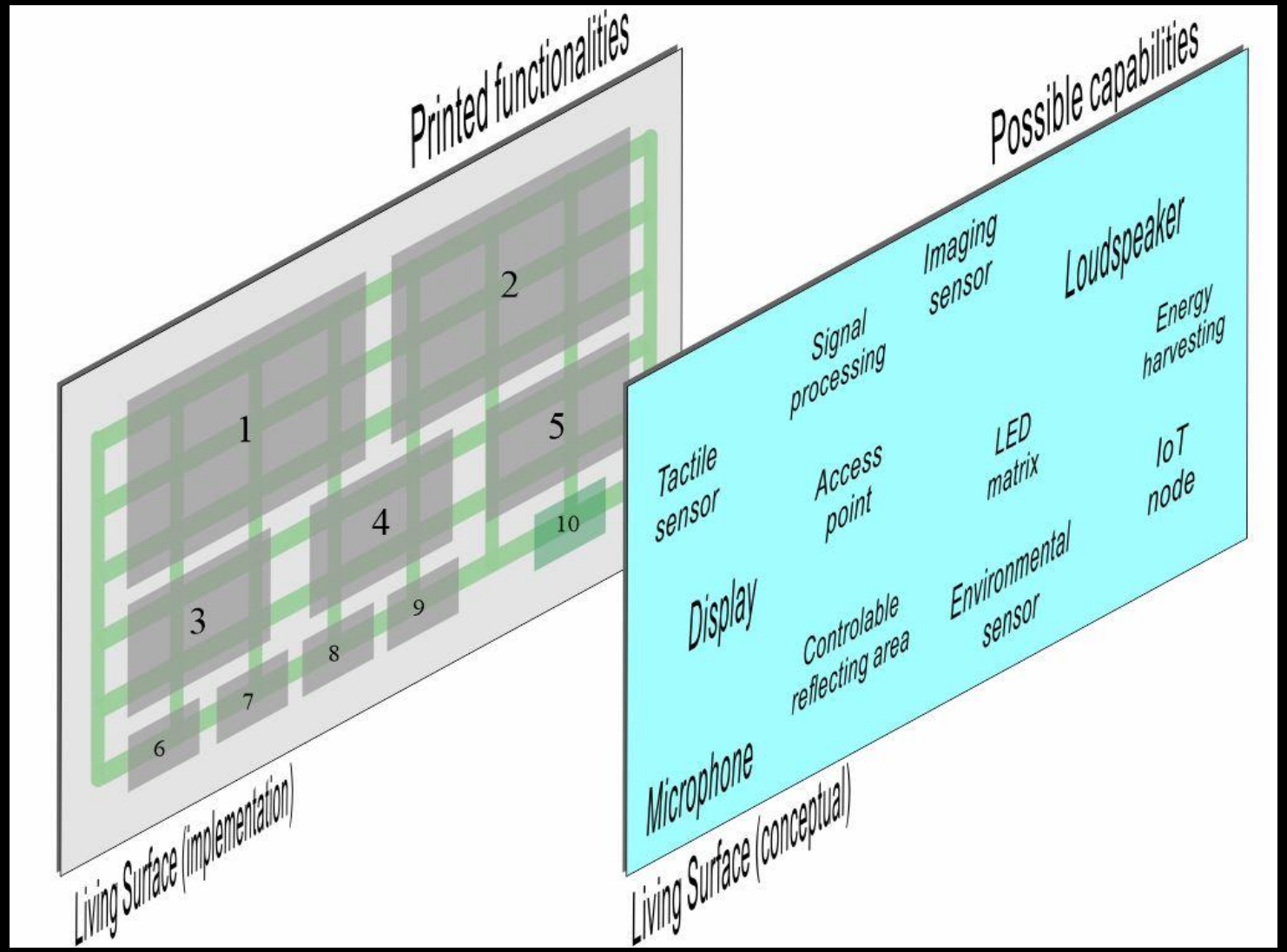
- Active and passive components can be printed, e.g., conducting wires, resistors, capacitors, coils, transistors, displays, optical components, etc.

- PE allows printing components and eventually complete functionalities/systems on a substrate (paper, film, etc.)

-> **Towards a fully printed LIoT node**

-> Minimizing the environmental impact

# **Beyond LIoT:** Living Surfaces

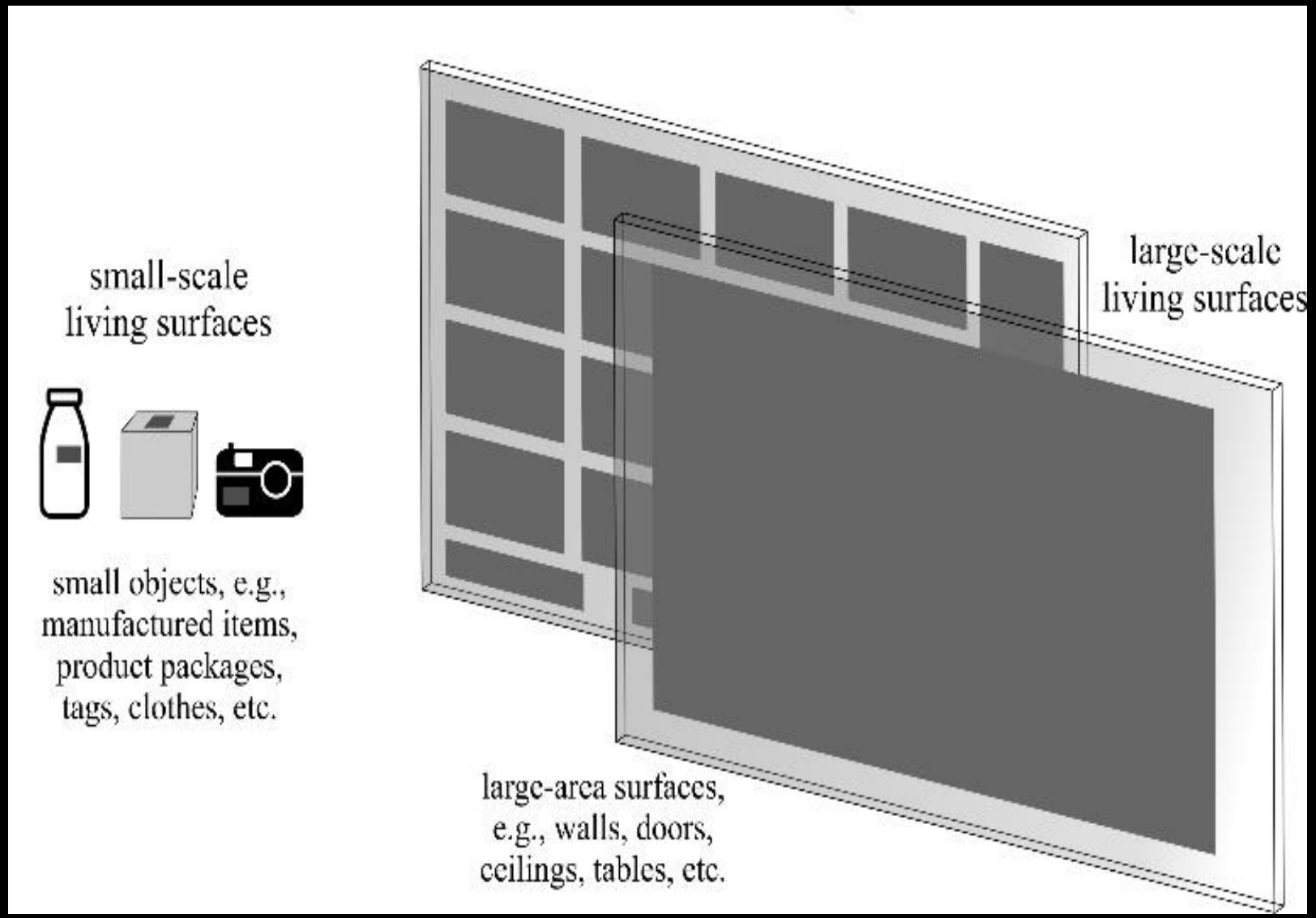



Any surface, small or large, could become an active **Living Surface** when empowered by a number of key integrated functionalities including wireless connectivity as well as sensorial, actuatorial and processing capabilities.

a. Fixed connections and functionalities

b. Reconfigurable: Large-

# Beyond LIoT: Living Surfaces




A **living surface** is a self-powered area containing a number of networking, processing and sensing functionalities implemented using printed electronics technology

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# VISION: THE SURFACE REVOLUTION

Both concepts, **LIoT** and its extension, **Living Surfaces**, have great potential to create a **sustainable, flexible** and **scalable** way to **communicate** and **interact.**

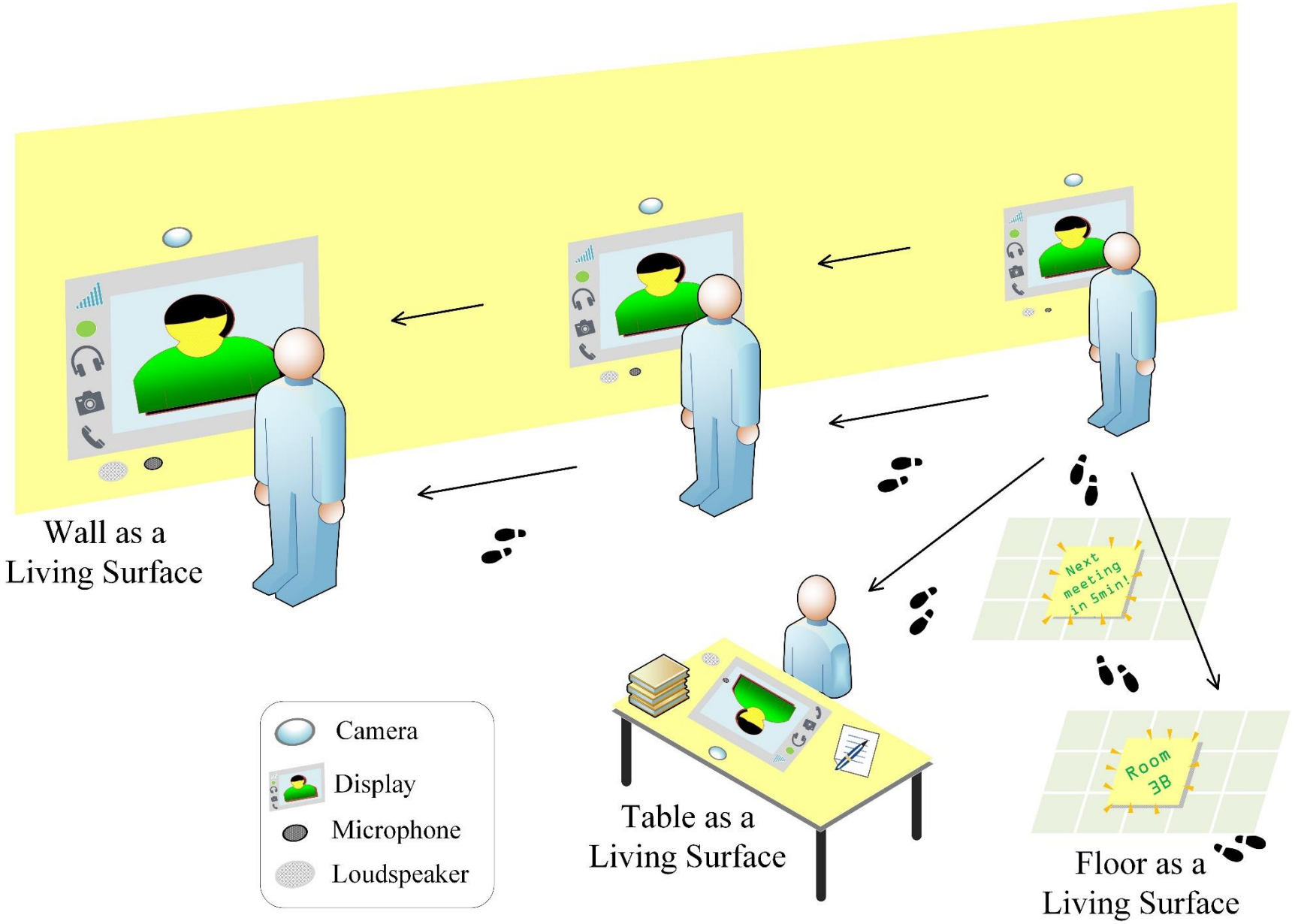
- **Fully printed** LIoT node
- **Fully sustainable** LIoT implementation, e.g., biodegradable electronics
- Developing a ”**1 cent**” LIoT node
- From **printed LIoT** to **Living Surfaces**
  - Any surface to become active, working as an intermediary between people and its **sorrounding environment and connecting them to the world**

# Beyond LIoT: Living Surfaces

Living surfaces interacting with users

- Functionalities may follow the user

- A mobile device may not necessarily be as we know it today, but it could be integrated into and



# Quantum Communication Technologies

**Claudio Cicconetti**

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# Computing & communication: classical vs. quantum

| Classical | Quantum |
|---|---|
| Bit → 0 or 1 | Qubit → $\alpha\|0\rangle + \beta\|1\rangle$ (*superposition*) |
| Bits can be copied | Qubits cannot be copied (*no-cloning theorem*) |
| Each bit is independent from any other | Qubits can be entangled (*nonlocal behaviour*) |
| Bits can be transferred / amplified / stored in buffers | Qubits can be teleported (original copy is destroyed) |
| Bits degrade with distance during transfer | Same! |
| Bits can be stored for indefinite time | Qubits degrade (**fast**) over time |

# How to use the quantum properties?

- Superposition + entanglement

  → **Quantum advantage / supremacy**

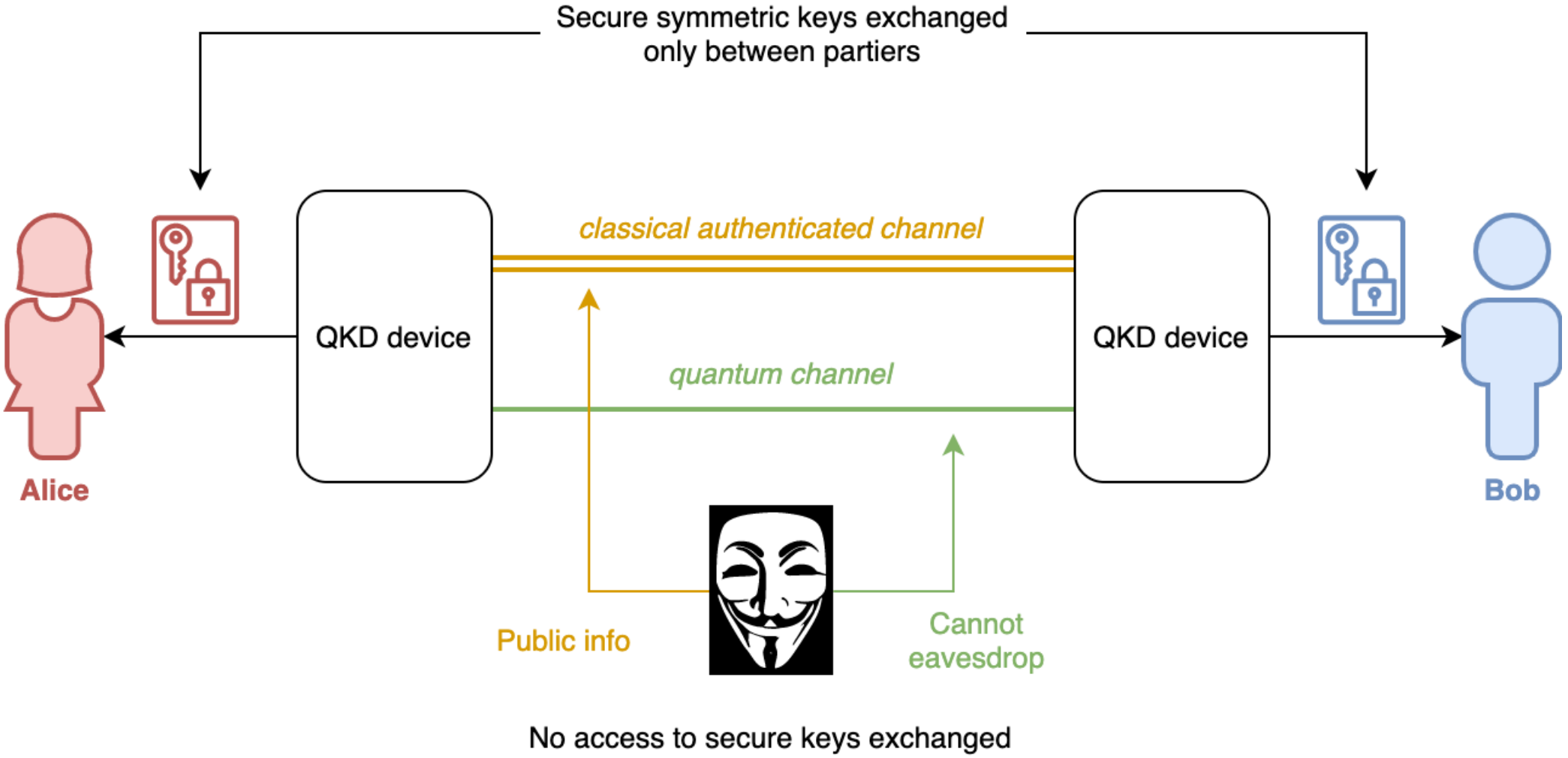
  We are currently in the Noisy Intermediate-Scale Quantum (NISQ) era

- No-cloning theorem + nonlocal behaviour

  → **Device independent protocols**

  Notable example: Quantum Key Distribution (QKD) → see next slide

# Quantum Key Distribution

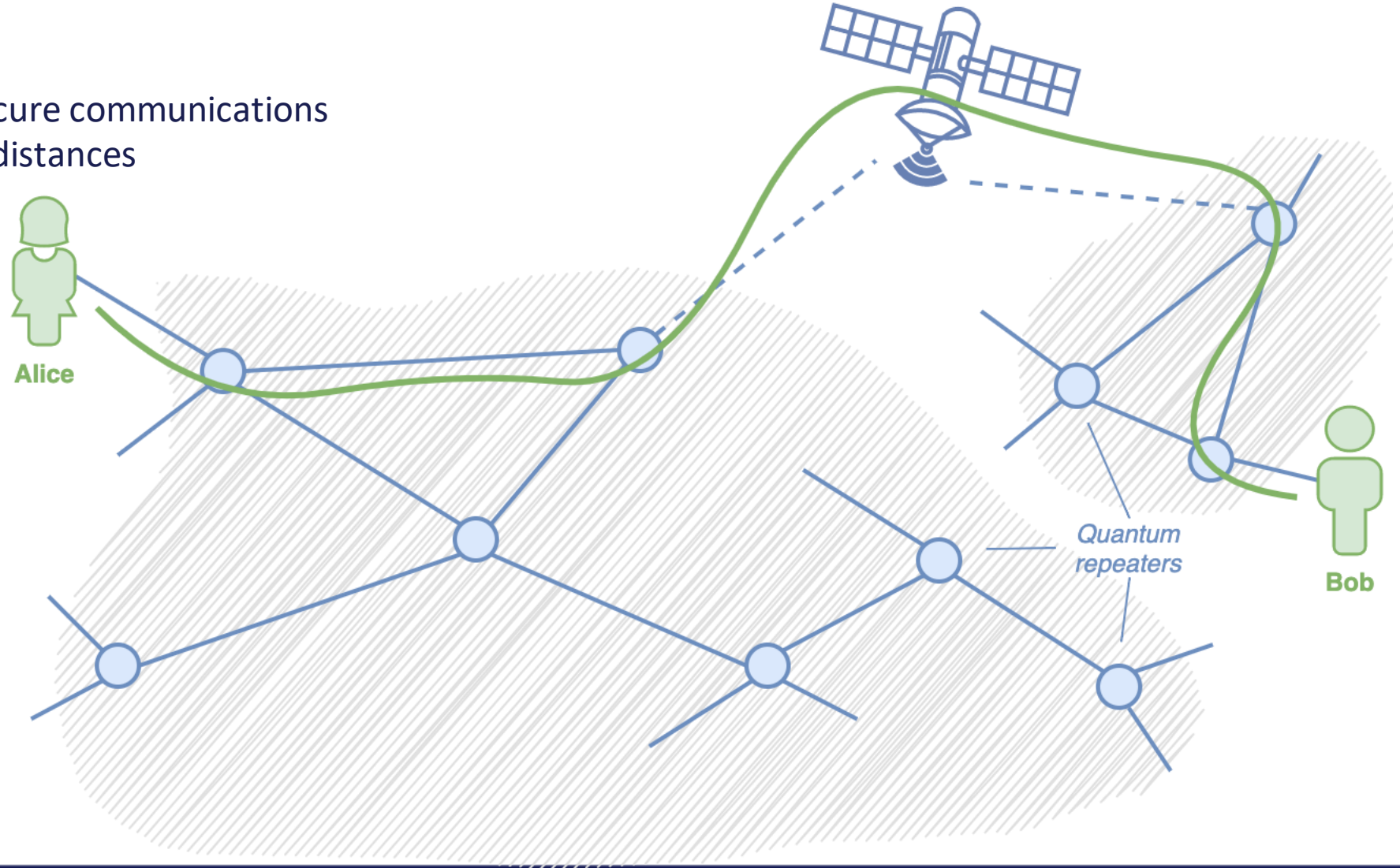


# Research areas

1. **PHY-layer technologies**
   - More efficient and resilient quantum entanglement and transportation
2. **Integration of classical & quantum network devices**
   - Re-design of security perimeters
   - Impact on cloud-native architectures
   - What about mobile networks / 6G?
3. **Quantum Internet**
   - New network architectures to fully exploit the quantum advantages
   - New control / management plane protocols
4. **Quantum computing *for* classical networks**
   - Quantum Machine Learning for better resource optimization / management
5. **Realistic use case and applications**
   - Societal, technological, and economic interest in the medium-/long-term

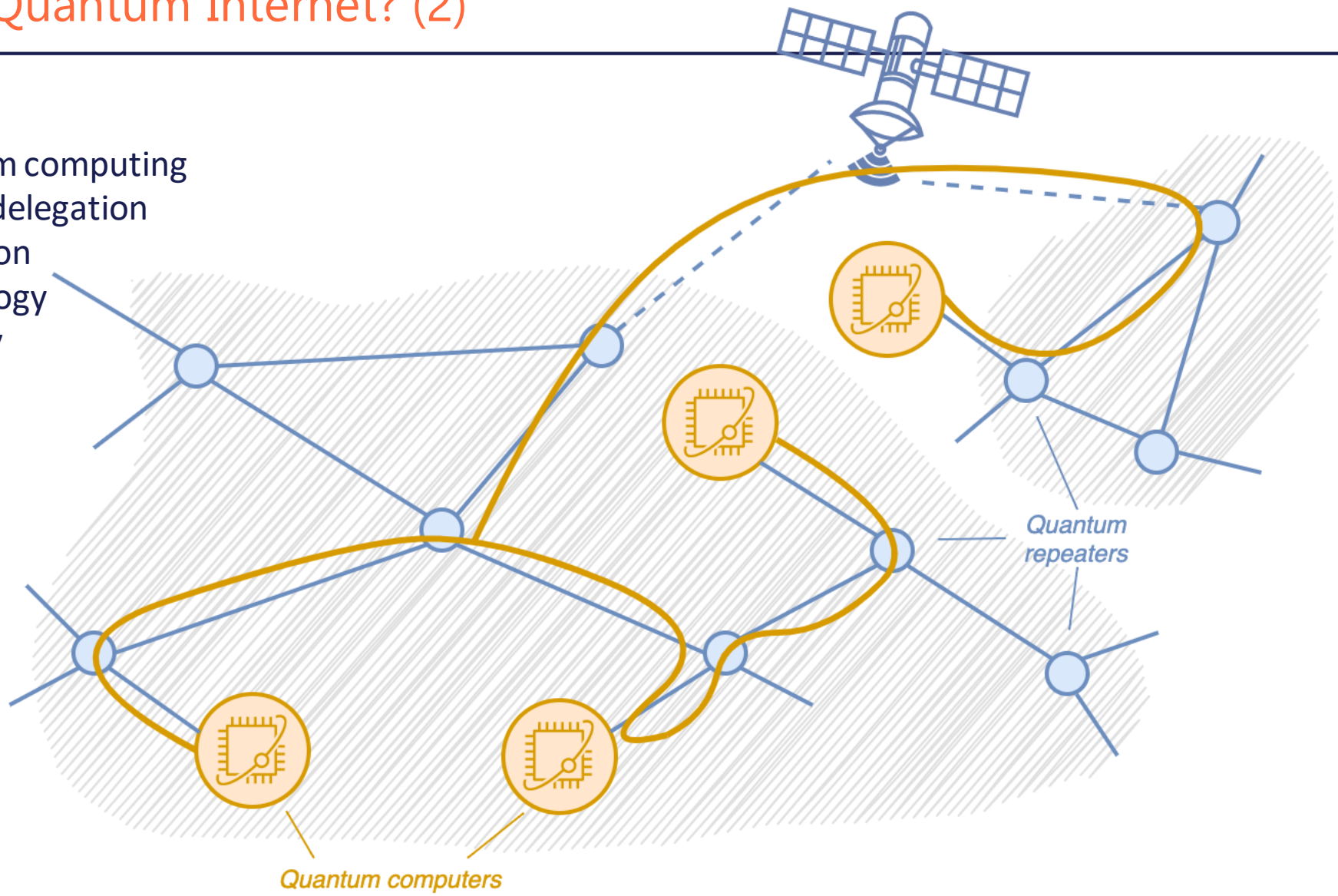
# Why a Quantum Internet? (1)

Application:
Unconditionally secure communications
over geographical distances



# Why a Quantum Internet? (2)

Applications:
Distributed quantum computing
Blind computation delegation
Clock synchronisation
Sensing and metrology
Quantum chemistry



# The current international landscape

- Standardisation bodies

  **ETSI** → Industry Study Group on QKD

  **ITU-T** → Focus Group on Quantum Information Technology for Networks

  **IRTF** → Quantum Internet Research Group

- Industry alliances

  **GSMA** → Released in March 2021 a white paper on "Quantum Computing, Networking and Security"

- EU initiatives

  **Quantum Flagship**

  **QuantERA** (ERA-NET programme)

  **EuroQCI**

**Foundational aspects**

**Oriented to infrastructures**

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Some relevant papers:


L. Hanzo et al. "Wireless Myths, Realities, and Futures: From 3G/4G to Optical and Quantum Wireless." Proc. of the IEEE 100, 2012.

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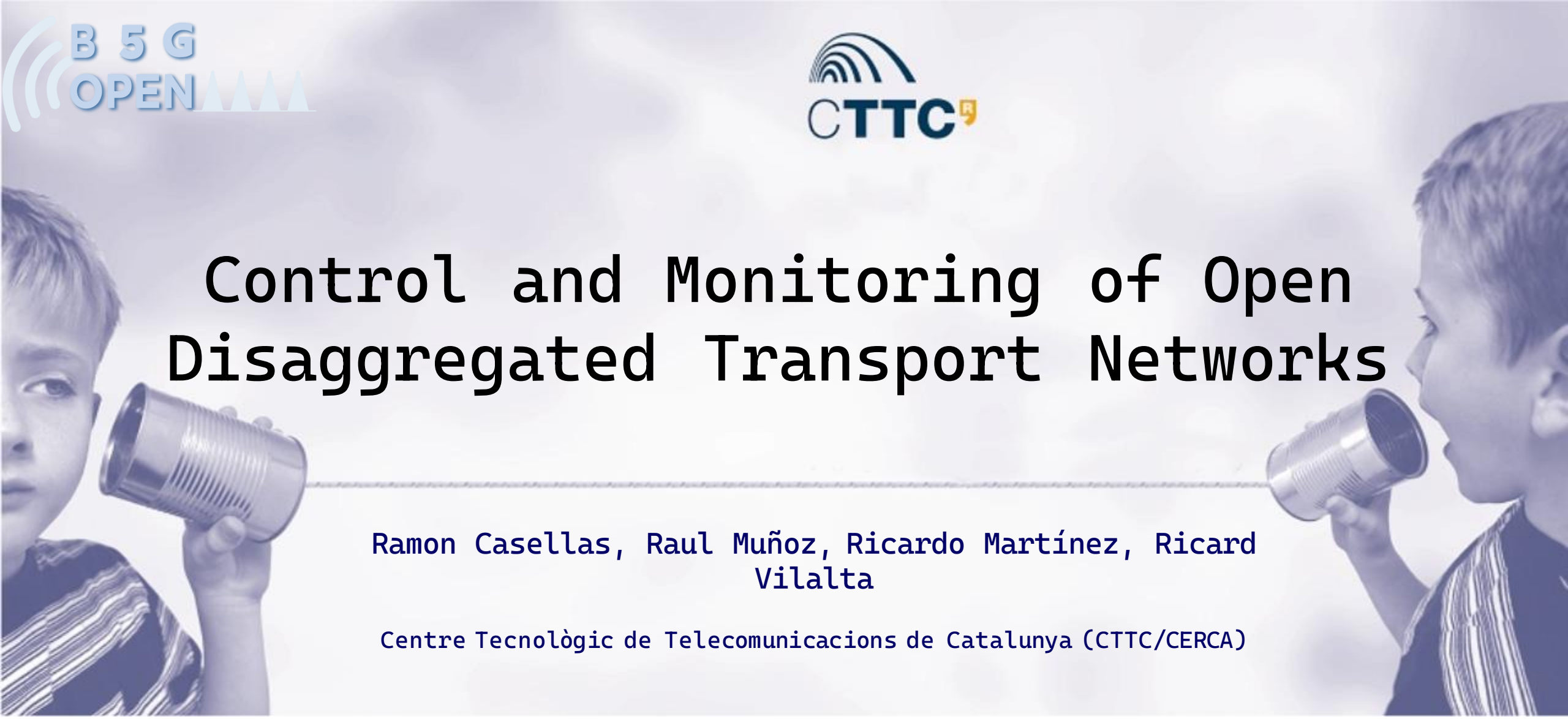


# Control and Monitoring of Open Disaggregated Transport Networks

Ramon Casellas, Raul Muñoz, Ricardo Martínez, Ricard Vilalta

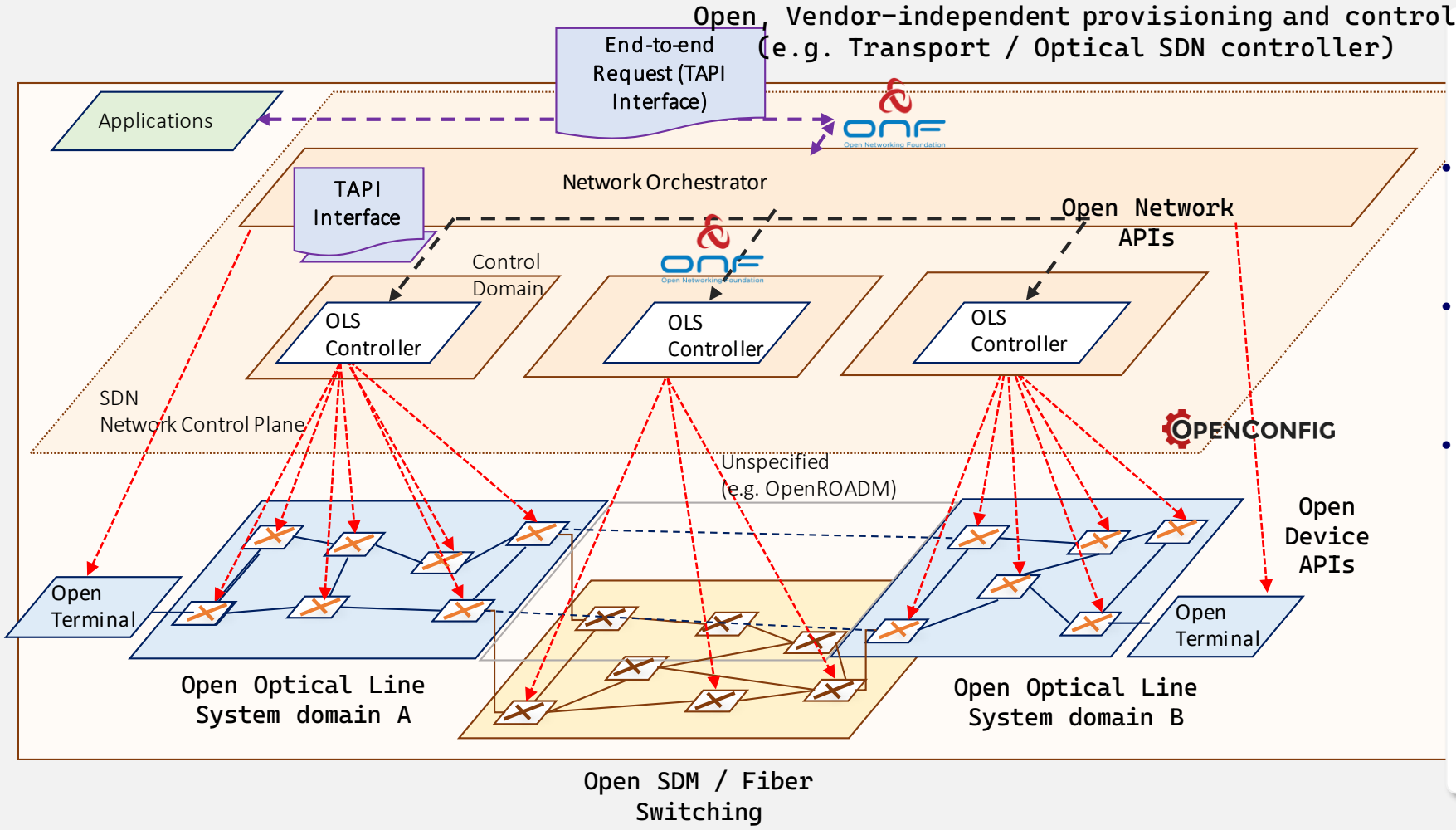
Centre Tecnològic de Telecomunicacions de Catalunya (CTTC/CERCA)

Visions of Future Communication Summit, Lisbon, 24-25 Nov 2021

# What to research? Starting point

- Optical (Transport) Networks no longer (just a) point-to-point technology
  - Towards Meshed networks with high dynamicity, increased device programmability
  - Optical Networks no longer “quasi-statically managed”
- Technical evolutions:
  - From “an optical channel” (fixed grid, fixed client rates) to “management of spectrum services”
  - Increasing data rates 100G, 200G, 400G, 800G – coherent transmission
  - Multiple “circuit switching” technologies: wavelength, waveband, frequency slot, SDM core/mode, fibers..
- Challenges
  - Dynamic provisioning and Efficient path computation with dynamic (heterogeneous) resource allocation
  - Address the effect of physical layer impairments (incl. optical monitoring and

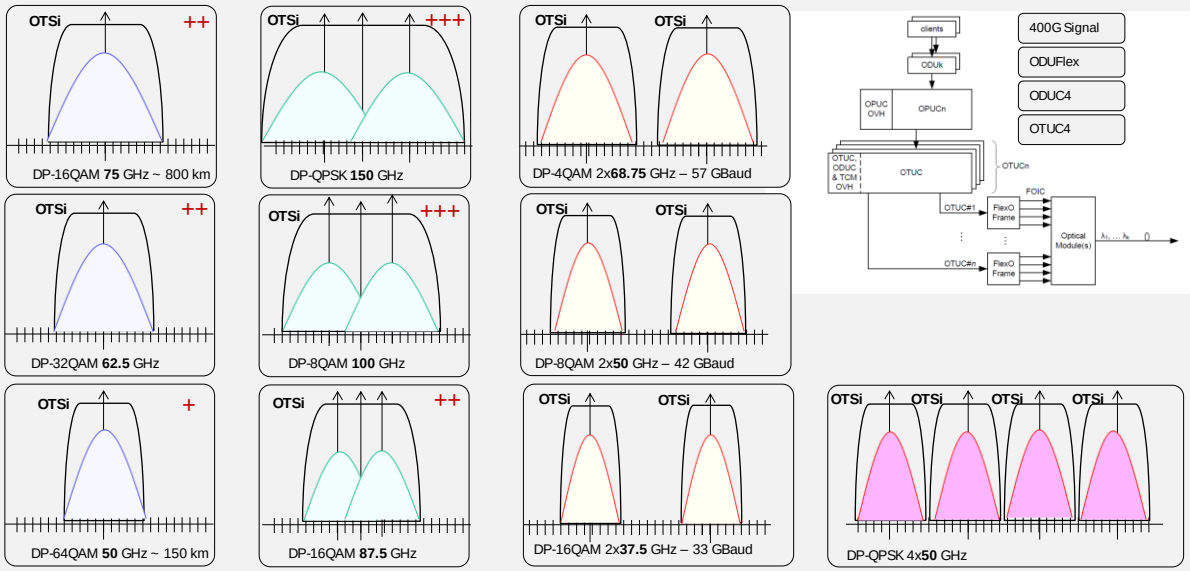
# Why is It Important? Optical Disaggregation (cf. TIP, ONF)




## Optical Disaggregation

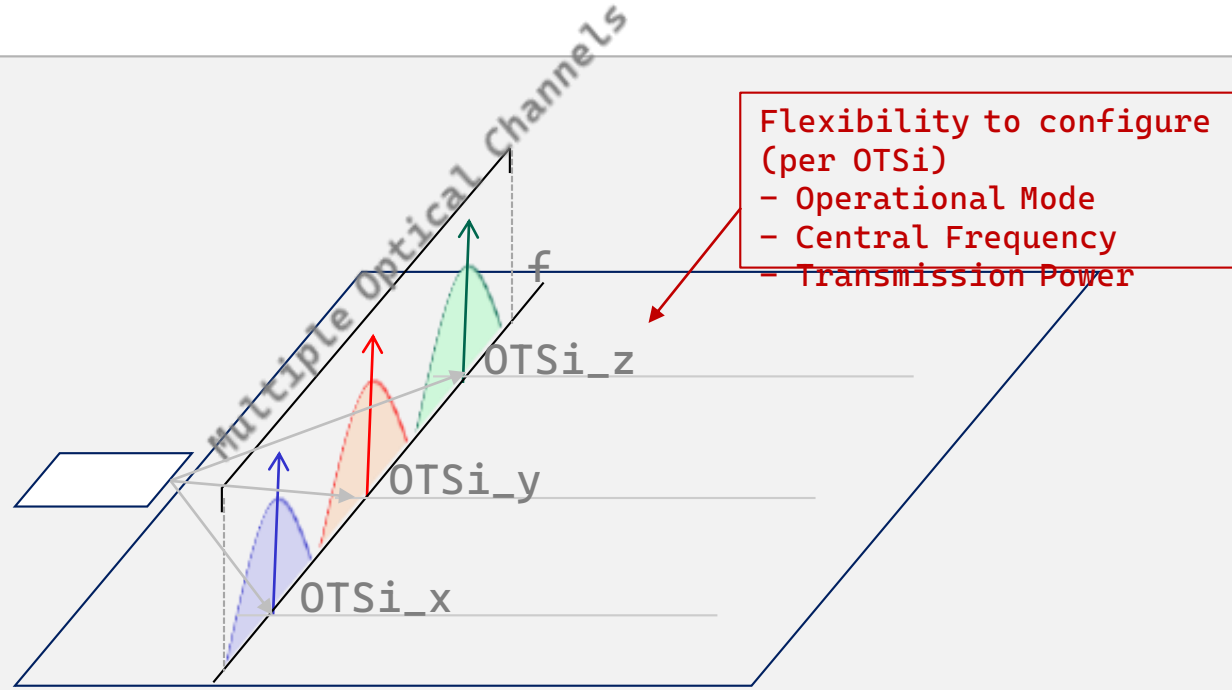
- Optical Disaggregation
  - Modular network element architecture
  - Interoperability through standard inte
- Full (component – level) disaggregation
  - The transport system is disaggregated,
  - Optical network elements by different
- Partial Disaggregation
  - Optical Terminals (OTs) and
  - Open Optical Line Systems (OLS)
  - OT lifecycle is shorter than the OLS' (e.g., coherent innovation)
  - OT most of the cost of the WDM network.

# B100G implications: Open Terminal Support of OTSiA

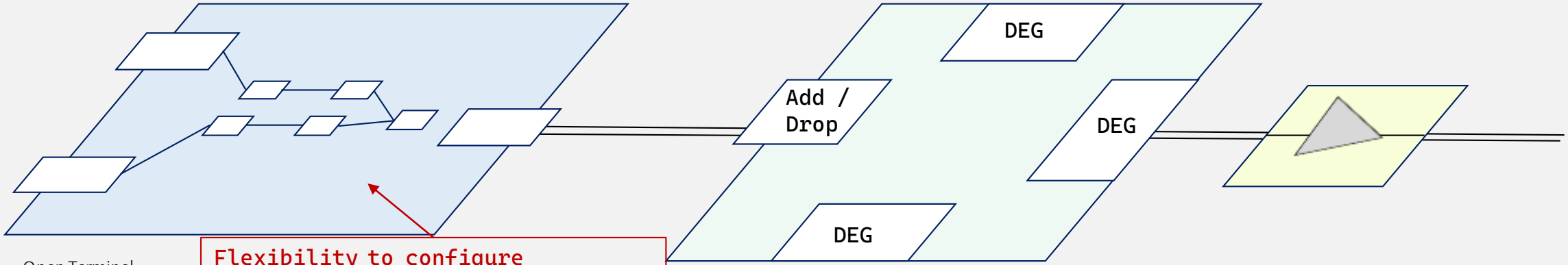









Flexibility to configure (per OTSi)
- Operational Mode
- Central Frequency
- Transmission Power




Flexibility to configure
- Logical Channels (e.g., OTN framing)
- Logical Channel Association(s)
- Different States

Open Terminal
OpenConfig enabled

# SDN Control Multiband and SDM sys.: Drivers and motivation

- Multi-band systems and band division multiplexing (BDM):
  - Extend optical spectrum used by wavelength division multiplexing (WDM) to the entire set of available low-loss bands (U, L, C, S and O) in standard single-mode fibers (SSMFs)
  - Potentially needs upgrades on the transceivers, optical amplifiers and ROADMs. Worth it?

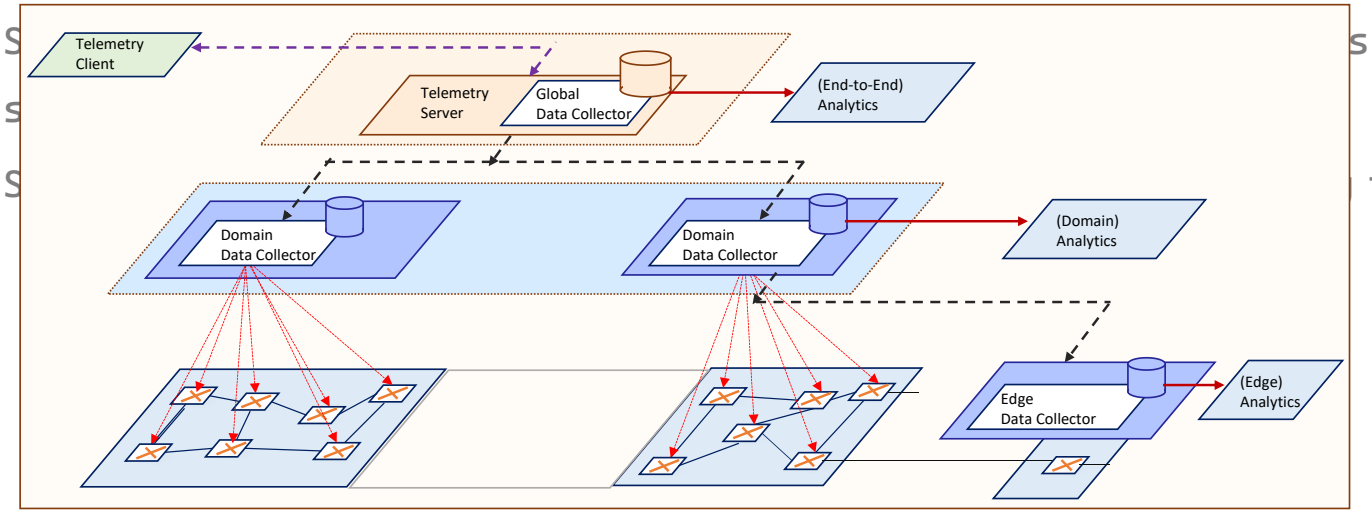
- Space division multiplexing (SDM) transmission to exploit the spectral and the spatial dimension of the fiber (i.e., frequencies, cores and modes):
  - SDM super-channels, by exploiting multicore fibers (MCF), multimode fibers (MMF), combining cores and modes in few-mode multicore fibers (FM-MCFs), or by deploying bundle of SSMFs
  - SDM switching for providing spatial paths beyond point-to-point transmission.

# What to research? Physical Impairments & QoT Validation

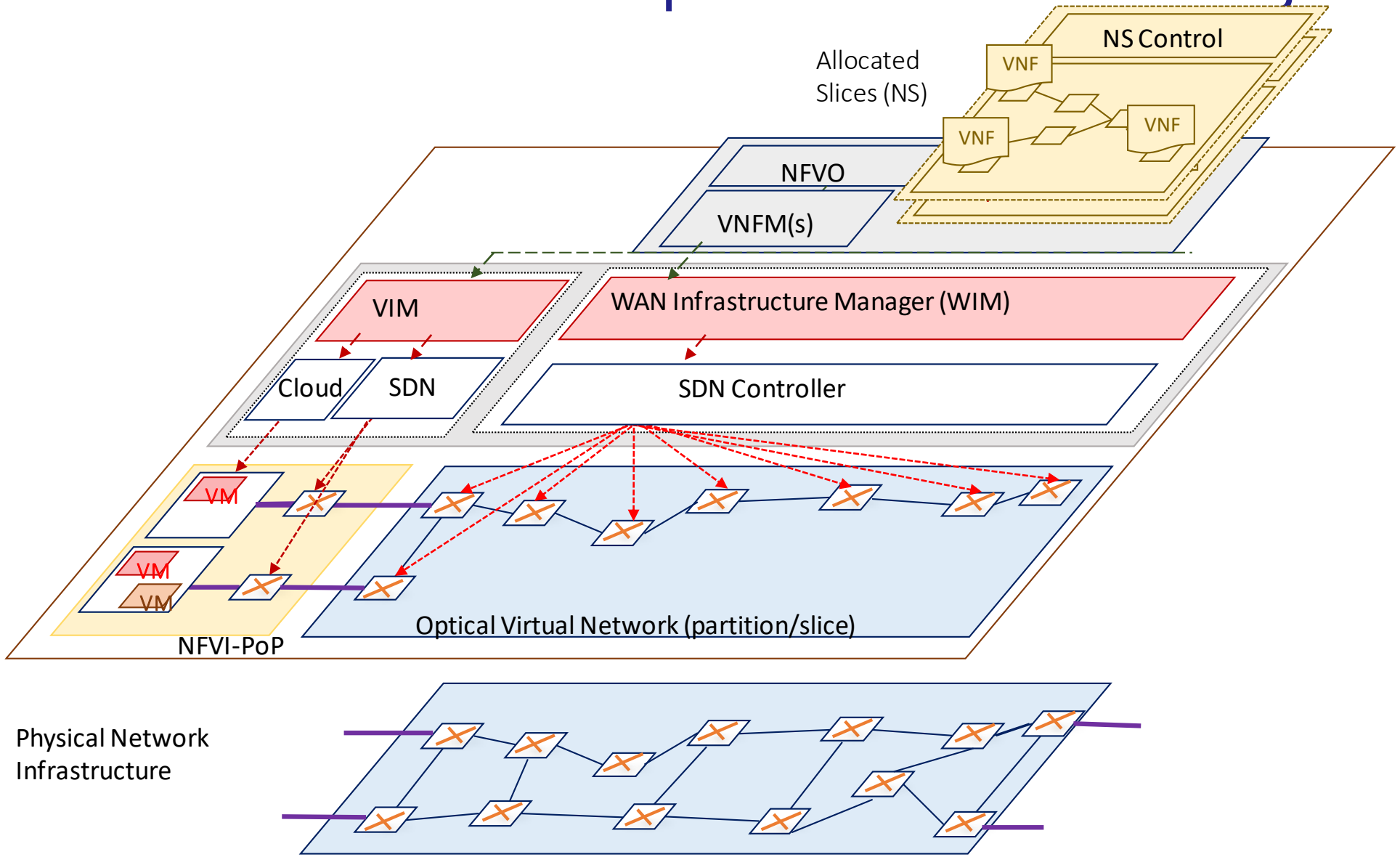
- At high rates 400G with Wide Band systems and MCF, accounting for PLI is critical
- Threats: Lack of common, standard and open data models
  - Complex problems & Limited innovation in terms of physical impairment modeling.
  - Current systems need to interop with heterogeneous monitoring info sources.
  - Proprietary and costly simulation tools difficult to interop or integrate.
- Opportunities : Combine system modeling and real-time monitoring
  - Open-Source planning and computation tools are becoming available: Net2plan, GNPy,…
  - Currently, active development in IETF CCAMP/TEAS working group, ONF T-API,…
- Challenges: Modeling in terms of
  - Open Terminals *operational modes*
  - Attributes of network elements and fibers (SSMF) etc.
- Increasing role of optical network telemetry

# Optical Monitoring and Telemetry: Crucial for network health

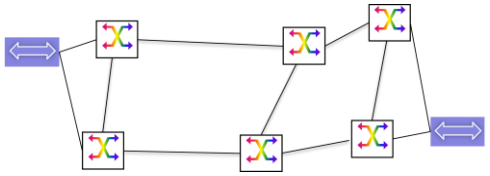
- Issues: Heterogeneity in terms of data sources, protocols and data models
  - Huge integration effort, Optical Monitoring in disaggregated networks is challenging
- Evolutions towards applications related to data-science, machine-learning, autonomous operation…
  - From “monitoring” to “monitoring + streaming telemetry” → Pull (Polling) vs Push
- What is needed?
  - Adopt “model-driven telemetry”. Develop telemetry architectures, Data models, Efficient Protocols, and Applications
  - S… …second; Full or partial s…
  - S… …too many clients; Robustnes…

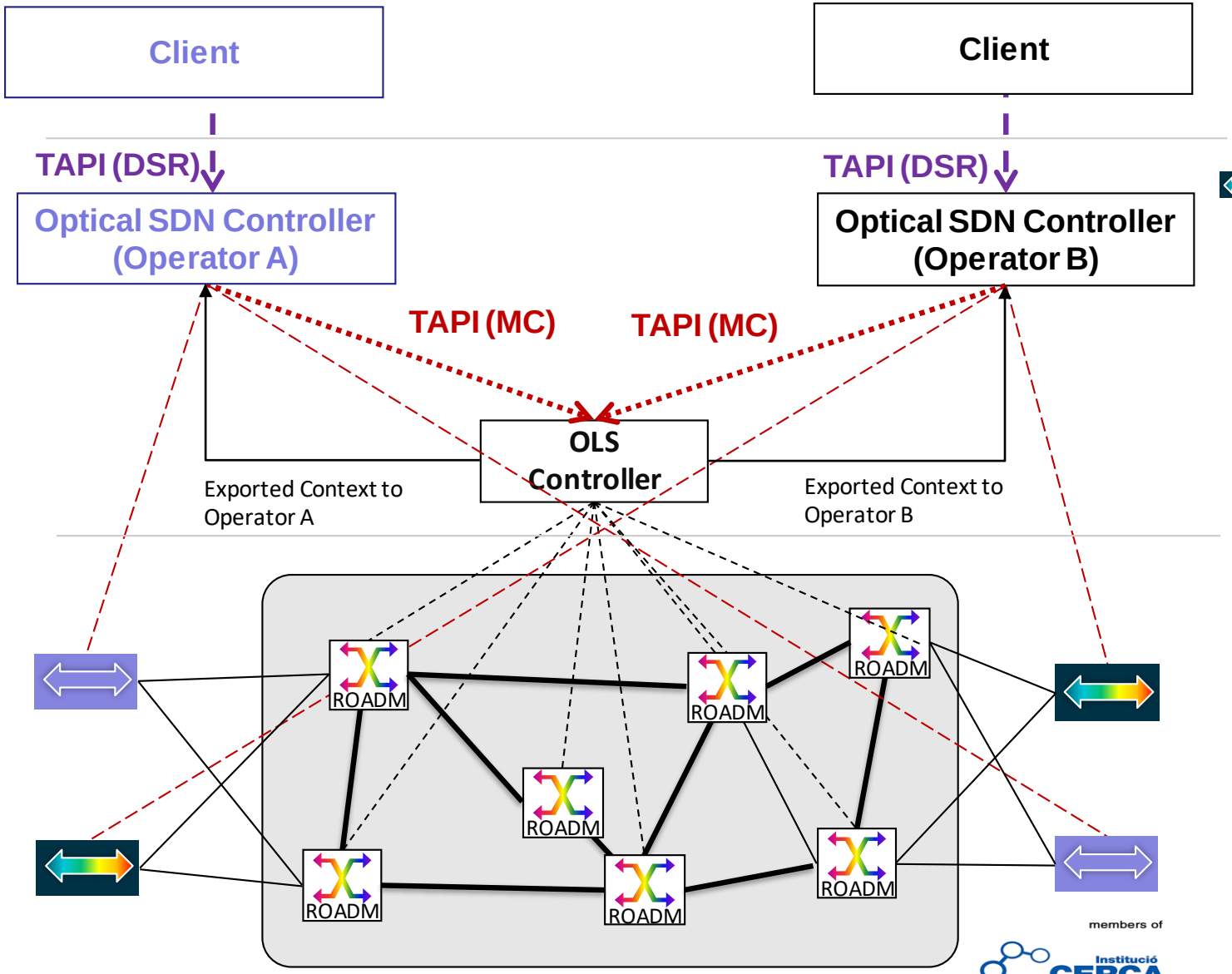


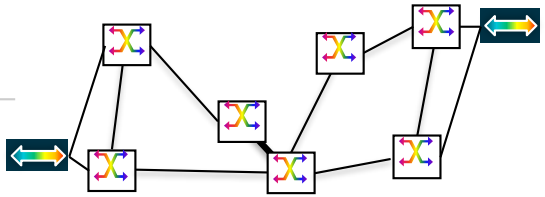
# What to Research? Transport Network Slicing



# Why is it important? Spectrum Services



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