Strategic Research and Innovation Agenda Webinar
## 12,13th January 2023

OPTICAL NETWORKS

Raul Muñoz, CTTC

NetworldEurope Webinar, 12-13 January 2023, Virtual

INTRODUCTION

- Within the next decade, the world will achieve an even higher level of digitalization , thus improving our quality of life and boosting the industrial productivity.

- We will enter a new era in which hundreds of billions of things, humans, connected vehicles, robots, drones, etc. will generate Zettabytes of digital information.

- Smart optical connectivity will be the foundation of this new digital world: Always available, intrinsically secure, flexibly scalable and upgradable, and environmentally friendly.

- A programmable optical network infrastructure will be the nervous system that the digital society, industry, and economy will heavily rely upon as it has been proved during the recent pandemic.

- Delivering the required performance, resilience, and security levels, while satisfying cost, energy efficiency and technology constraints, presents a formidable research challenge for the next decade.
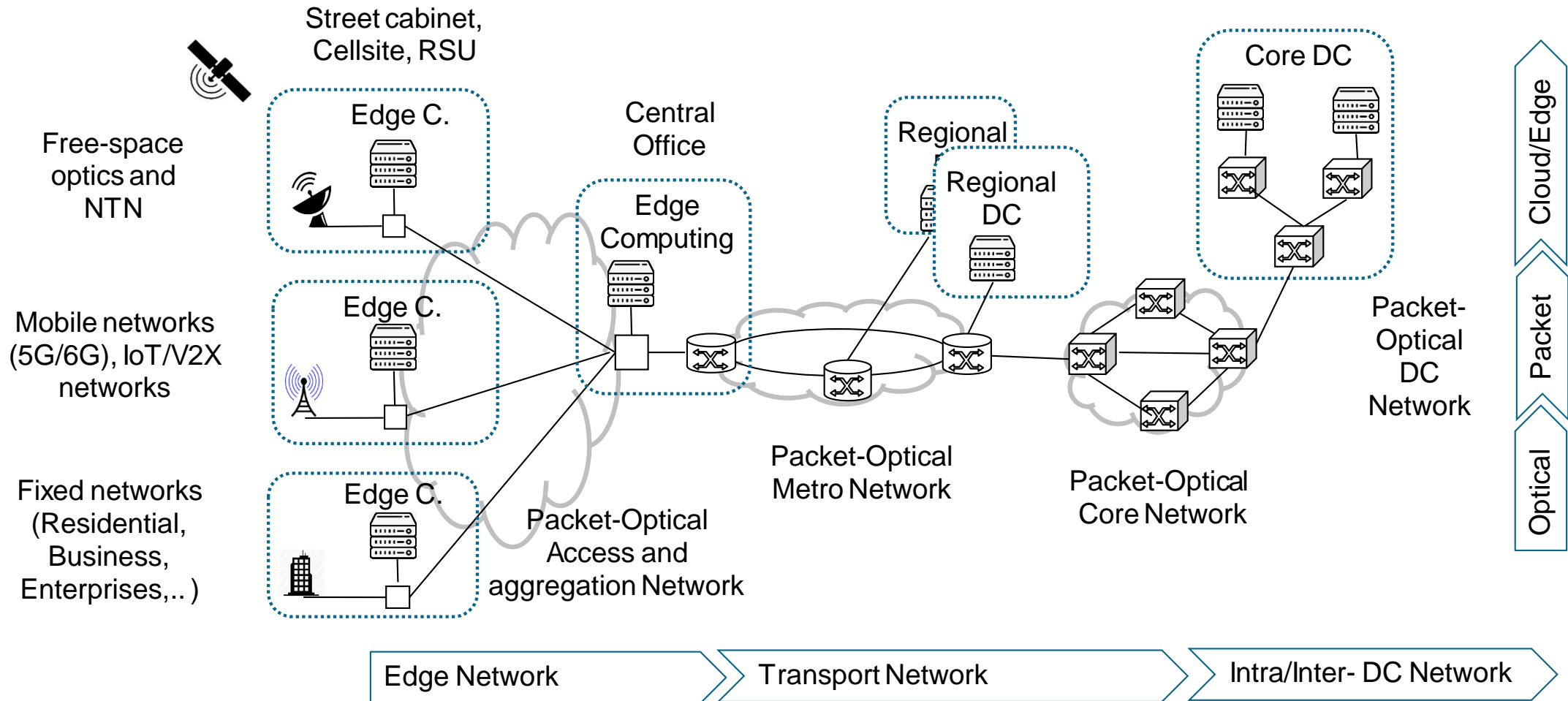
KEY PERFORMANCE INDICATORS

	Target KPI	Current	Short-term Evo	Mid-term Evo	Long-term Evo
		2022	~2025	~2028	~2031
Metro/Core	Spectrum[1]	5THz	10THz	20THz	50THz
	Port speed[2]	400Gb/s	1.6Tb/s	3.2Tb/s	6.4Tb/s
	Bandwidth[3]	<75GHz	<300GHz	<600GHz	<1200GHz
	Line capacity[4]	25Tb/s	100Tb/s	300Tb/s	1Pb/s
	Node capacity[5]	150Tb/s	600Tb/s	1.8Pb/s	6Pb/s
Access	PON speeds	25Gb/s	50Gb/s	100Gb/s	>200Gb/s
	User data rate[6] (consumer)	~500Mb/s	~1Gb/s	>2.5Gb/s	>5Gb/s
	User data rate[6] (business)	~5Gb/s	~10Gb/s	>25Gb/s	>50Gb/s
	Latency[7]	<1ms	<100µs	<10µs	<1µs
	Power consumption[8]	100% (baseline)	40%	30%	20%
	Service provisioning	Hour	Min	Second	Sub-second
	Network operations	Operator-controlled, reactive	Intent-based, proactive	Self-diagnosing	Self-optimizing

- Europe has been at the forefront of optical communications R&D for many years, from ground-breaking innovations such as new types of optical fibres, new erbium-doped amplifiers for WDM systems, and digital coherent optics for 100 Gb/s transponders, to global standards such as SDH and OTN.

- Seven out of the top 20 network operators are headquartered in Europe while five out of the 10 largest optical equipment manufacturers have major R&D centres in Europe.

- By revenue, they represent more than 50% of the global optical equipment market.

- Two of the largest component manufacturers have operations in Europe and more than a hundred SMEs and universities provide complementary innovation on network, system, or component levels.

- Optical technologies leverage a telecommunication infrastructure market of 350 billion EUR and impact more than 700,000 jobs in Europe.

THEMES

1. Sustainable capacity scaling (Editor: Sébastien Bigo, Nokia Bell Labs)

2. New switching paradigms (Editor: Colja Schubert, Fraunhofer HHI)

3. Deterministic networking (Editor: Jörg-Peter Elbers, ADVA Optical Networking)

4. Optical technologies for radio networks and systems (Editor: Fabio Cavaliere, Ericsson)

5. Optical network automation (Editor: Ramon Casellas, CTTC)

6. Security for mission critical services (Editor: Helmut Griesser, ADVA Network Security)

7. Ultra-high energy efficiency (Editor: Antonio Napoli, Infinera)

8. Optical integration 2.0 (Editor: Michael Eiselt, ADVA Network Security)

9. Optical access beyond FTTH - New theme! (Editor: Thomas Pfeiffer, Nokia Bell Labs Germany)

ACKNOWLEDGMENT TO CONTRIBUTORS

- Paul van Dijk, Lionix International

- Despoina Petousi, ADVA Optical Networking

- Martin Schell, HHI

- Benjamin Wohlfeil, ADVA Optical Networking

- Jose Capmany, iPronics

- Vittorio Curri, Politecnico di Torino

- Johannes Fischer, Fraunhofer, HHI

- Andrew Lord, BT

- Albert Rafel, BT

- Dimitra Simeonidou, University of Bristol,

- Tolga Tekin, Fraunhofer, IZM

- Ioannis Tomkos, University of Patras

- Yvan Pointurier, Huawei

- Filippo Cugini, CNIT

- David Hillerkuss, Huawei

- Luis Velasco, UPC

- Marco Ruffini, TCD

- Alexandros Stavdas, University of Peloponnese.

THEME 1: SUSTAINABLE CAPACITY SCALING

- Global data traffic in optical networks has been growing at a high and steady pace of x2 every 2-3 years over the past 15 years and there is no sign this will be slowing down.

- Hence networks need to urgently adapt, but not all segments will be equally affected.

- Projections of future traffic predict required data rates of 10 Tb/s line interfaces and over 1 Pb/s for optical fibre systems by 2025, while optical interconnect capacities are expected to be aligned with the Ethernet roadmap of line interface speeds (~6.4 Tbit/s in 2030).

- Networks also need to provide headroom for unexpected traffic increases, as observed in several EU member states during the health crisis of 2020-2022.

- Research topics:

    - i) Scaling to Petabit/s capacities in core and metro networks

    - ii) Next generation terabit/s transceivers.

THEME 2: NEW SWITCHING PARADIGMS

- New switching paradigms are needed to connect real-time programmable optical devices in distributed architectures.

- The steep learning curve in photonics integration will for example allow optical flow switching approaches, which were previously considered too costly and/or complex.

- This can pave the way to a new generation of switches with optimized mix between optical and electronic processing functions.

- They should be operating over multiple wavelength bands and spatial dimensions and have a smart network fabric relying on software programmability and slicing, addressing multiple protocol layers and network domains.

- Research topics:

  - Ultra-fast Multi-granular Switching Nodes,

  - Switching Architectures guided by Energy-Efficiency

THEME 3: DETERMINISTIC NETWORKING

- While today's Internet is built on a best-effort traffic paradigm, an increasing number of applications require reliable end-to-end transmission with guaranteed throughput and bounded latency.

- While mechanisms exist to control throughput, latency, jitter and packet loss in packet-optical networks, they often provide statistical QoS only and do not guarantee a deterministic network behavior.

- Available timing signals rarely offer the necessary accuracy and/or reliability to allow precise time synchronization for mission critical applications.

- Novel solutions are needed which trade-off performance improvements against scalability limitations and implementation complexity.

- Research topics:

    - i) Resilient solutions for high-precision, network-assisted timing distribution, ii) Reliable data & control plane solutions for deterministic network services, iii) Tools for service assurance in deterministic networks.

THEME 4: OPTICAL TECHNOLOGIES FOR RADIO NETWORKS AND SYSTEM

- The expected tenfold increase of traffic growth and the tight latency constraints dictated by new 6G services will require a substantial evolution not only of the RAN but also of the architecture and the technology of the underlying mobile transport network.

- Optics is an enabler for 6G not only as regards the new mobile transport network, but novel optical Interconnect technologies will play a key role in future advanced antenna systems, impacting their architectures.

- New advances in photonic integration open new opportunities to apply suitable combinations of optical, radiofrequency, and digital electronics to radio systems.

- These application macro-areas lead to a wide set of new challenges for optical technologies in radio access.

- Research topics:

    - i) Optical technologies for radio access networks, ii) High speed optical interconnects in radio systems, iii) Optically enabled radio functions.

THEME 5: OPTICAL NETWORK AUTOMATION

- Optical network automation is key to achieve operators' business goals and in supporting new complex services.

- Automation is critical in optical networks supporting increasing data rates given, for example, the complexity of modelling of physical impairments, or the large number of parameters and their interdependencies.

- AI/ML solutions in support of network operations should be further developed beyond policy- / expert- /rule- based systems.

- Control and orchestration architectures should become increasingly modular, leveraging the flexibility of deployment in hybrid clouds, while relying on open and standard data models, protocols, interfaces, and frameworks, including, for example, proven and mature open-source projects and initiatives.

- Research topics:

  - Network Telemetry and Optical Network Sensing, Control and Orchestration architectures for Network Automation, AI/ML in support of Network Operation, Reliability and Security of Control, Orchestration and Management, Optical Network Digital Twin.

THEME 6: SECURITY FOR MISSION CRITICAL SERVICES

- It is getting more important to better safeguard our network infrastructure against data leakage and unexpected service outages.

- The higher flexibility of optical networks, enabled through software-configurable network elements, also increases the vulnerability of such networks to various kinds of attacks and therefore security and resilience aspects need to be part of the concepts from the beginning, including the hardware and software layers of the network.

- More generally, the design of network equipment needs to employ modern security and reliability paradigms (security by design) and apply state-of-the-art software technology to foster efficient and secure implementation of increasingly complex network elements.

- Research topics:

  - Quantum-safe cryptography, Physical layer security, Network resilience, Intrusion detection and mitigation

THEME 7: ULTRA-HIGH ENERGY EFFICIENCY

- The focus on greener networks and processing systems, is becoming a top priority for our society.

- Currently the ICT sector accounts for 5-9% of electricity use and for around 3% of the global greenhouse emissions. The EC estimates that the ICT footprint could increase to 14% of global emissions by 2040.

- Hence, solutions are mandatory to make both, the power consumption and the footprint of the world-network infrastructures sustainable.

- As fibre optics and photonic devices are the key technologies underlying the worldwide telecommunication infrastructure, they will play a major role in reducing the total power consumption of the ICT.

- Research topics:

  - i) Simplified and fully configurable flexible E2E optical networks, ii) energy efficient transceivers,iii) energy-aware optical networks and components, iv) zero-electronic waste and scalable optical networks.

- The foundation for the development of cost- and energy-efficient systems with high reliability lies in the integration of multiple optical and electrical functionalities, as scaling down the number of high-speed interfaces will reduce the power consumption of the network components.

- At the same time, the performance of the components needs to be enhanced to support a wider spectral range for new optical bands and higher speeds for increased data rates per channel.

- These challenges require the investigation of novel material platforms and, ultimately, the combination of multiple platforms up to the manufacturing level

- Research topics:

  - Multi-band exploitation, High-capacity interfaces for spectrally and spatially multiplexed systems, New materials, Optical chip interconnects, Multi-platform manufacturing, Photonic-electronic integration, Reliability and repeatability.

THEME 9: OPTICAL ACCESS BEYOND FTTH

- The evolution of optical access technologies has so far been driven primarily by Fiber-to-the-Home (FTTH) network architectures and services.

- The future evolution of optical access technologies and architectures will bring about further increased system capacities, highly flexible system and network reconfiguration, integration of optical access and RAN, meshed and resilient network topologies, coexistence of best effort and deterministic traffic, secured transmission over complex architectures, and more.

- Optical access will use single- and multi-tenant business models, for vertical markets and industrial applications, for 5G and 6G mobile networks, and small intra-datacenter networks, taking advantage of their versatility of providing services in multipoint networks at the lowest possible cost while still meeting stringent QoS requirements.

- Research topics:

  - Increased capacities and flexible configuration of access transmission systems, Flexible real time and non-real time resource assignment, Redundant, meshed and flexible optical layer network architectures, Optical layer multi-tenancy in access networks.

THANK YOU FOR YOUR ATTENTION

networldeurope.eu