ALLEGRO: Next Generation Ultra-Low Energy and Highly Secure Optical Networks

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ALLEGRO - General Information

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- Coordinator: Fraunhofer IZM, DE
- URL: www.allegro-he.eu

ALLEGRO Consortium

1	COO	**Fraunhofer**	FRAUNHOFER GESELLSCHAFT ZUR FORDERUNG DER ANGEWANDTEN FORSCHUNG EV	DE
		IZM	Fraunhofer Institute for Reliability and Microintegration (IZM)	
		HHI	Fraunhofer Institute for Telecommunications, Heinrich Hertz Institute (HHI)	
2	BEN	**AUTH**	ARISTOTELIO PANEPISTIMIO THESSALONIKIS	EL
3	BEN	**INF-G**	CORIANT R&D GMBH	DE
4	BEN	**ICCS**	INSTITUTE OF COMMUNICATION AND COMPUTER SYSTEMS	EL
5	BEN	**INF-P**	INFINERA UNIPESSOAL LDA	PT
6	BEN	**IPR**	IPRONICS PROGRAMMABLE PHOTONICS SL	ES
7	BEN	**NVIDIA**	MELLANOX TECHNOLOGIES LTD - MLNX	IL
8	BEN	**COS**	COSMOTE KINITES TILEPIKOINONIES MONOPROSOPI AE	EL
9	BEN	**TUE**	TECHNISCHE UNIVERSITEIT EINDHOVEN	NL
10	BEN	**TEI**	ERICSSON TELECOMUNICAZIONI SPA	IT
11	BEN	**TIM**	TELECOM ITALIA SPA	IT
12	BEN	**CNIT**	CONSORZIO NAZIONALE INTERUNIVERSITARIO PER LE TELECOMUNICAZIONI	IT
13	BEN	**CTTC**	CENTRE TECNOLOGIC DE TELECOMUNICACIONS DE CATALUNYA	ES
14	BEN	**LINKS**	FONDAZIONE LINKS - LEADING INNOVATION & KNOWLEDGE FOR SOCIETY	IT
15	BEN	**TID**	TELEFONICA INVESTIGACION Y DESARROLLO SA	ES
16	BEN	**UPC**	UNIVERSITAT POLITECNICA DE CATALUNYA	ES
17	BEN	**POLITO**	POLITECNICO DI TORINO	IT
18	BEN	**EUL**	EULAMBIA ADVANCED TECHNOLOGIES MONOPROSOPI ETAIRIA PERIORISMENIS EFTHINIS	EL
19	BEN	**ELIG**	E-LIGHTHOUSE NETWORK SOLUTIONS SL	ES
20	BEN	**SIC**	SECURE-IC SAS	FR
21	AP	**ETHZ**	EIDGENOESSISCHE TECHNISCHE HOCHSCHULE ZUERICH	CH
22	AP	**IDQ**	ID QUANTIQUE SA	CH
23	AP	**UOB**	UNIVERSITY OF BRISTOL	UK

ALLEGRO Concept

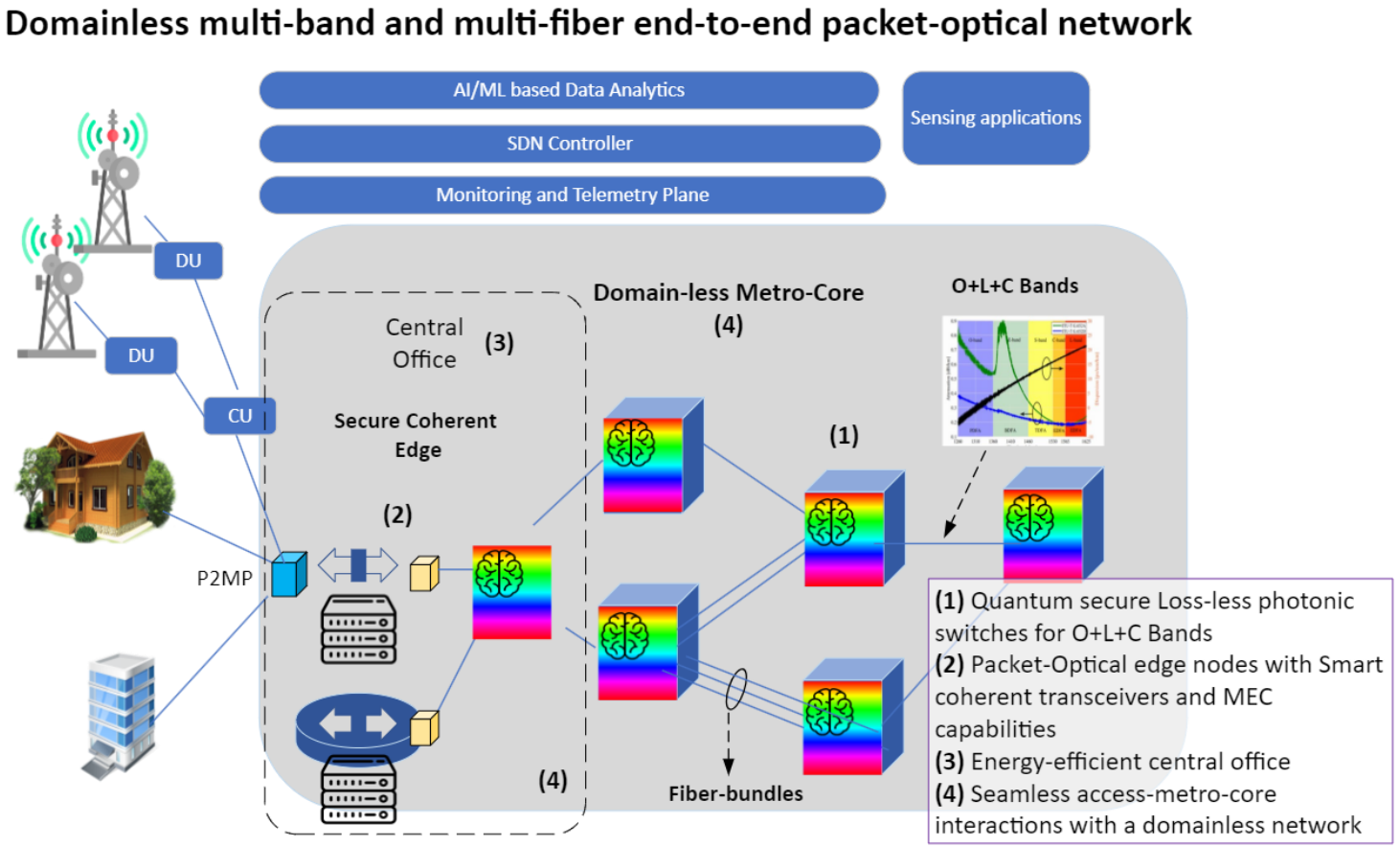
ALLEGRO targets designing, prototyping, and demonstrating a novel end-to-end (E2E) solution for next-generation optical networks.

ALLEGRO integrates packet-optical transport architecture satisfying four key pillars for next-generation telecommunication systems:

- Ultra-high-capacity from access to the core;
- Considerable reduction of power consumption and cost;
- Autonomous network control management exploiting artificial intelligence / machine learning (AI/ML) for ultra-high-capacity multi-domain optical systems; and
- Secure and reliable optical transmission.

ALLEGRO Objective 1

Architecture and design of an AI/ML empowered **ultra-high capacity** and **energy efficient** all-optical solution spanning from access to core with native **ultra-high security** and reliability.



ALLEGRO's domainless quantum-secure multi-band and multi-fibre end-to-end all-optical network.

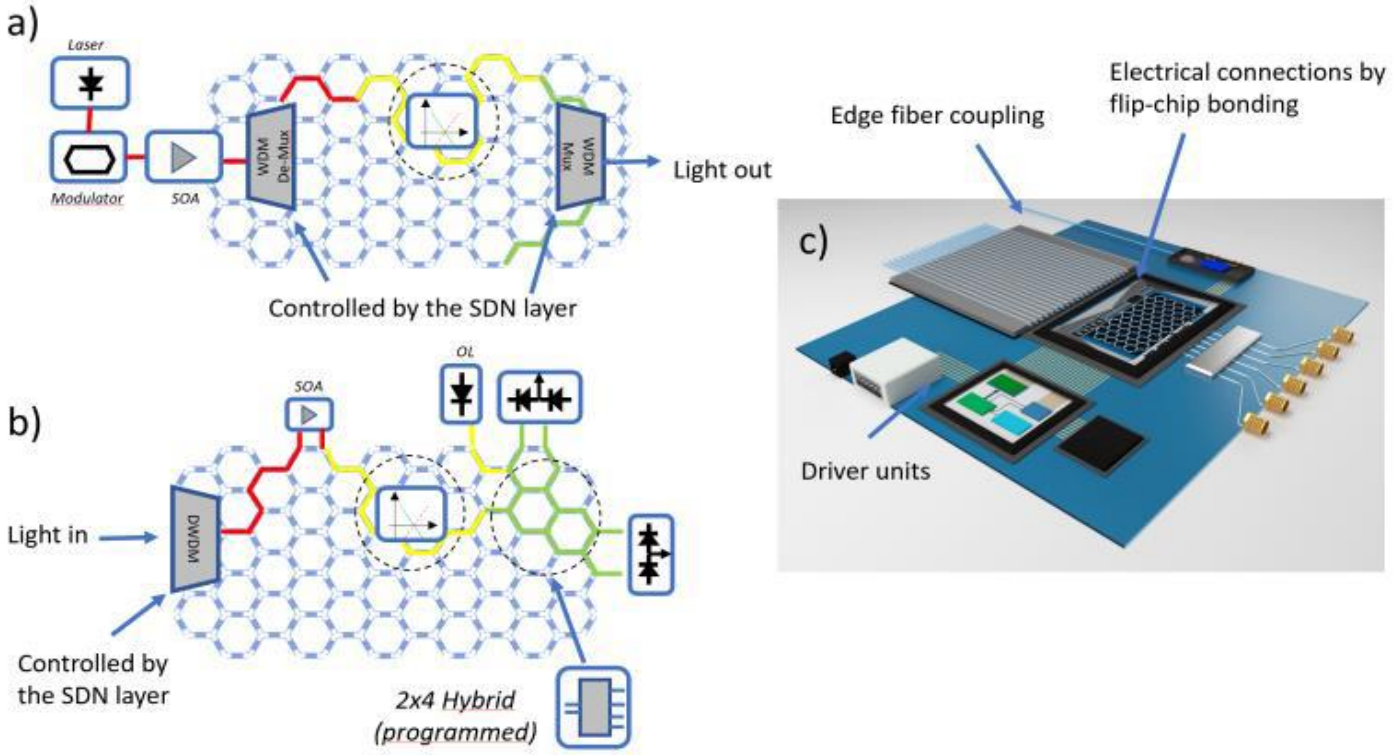
ALLEGRO Objective 1 KPIs

- Energy efficient (> 25% energy savings) all-optical network for beyond 5G and 6G;
- Fast (< 100 ms) deployment and reconfiguration of disaggregated network functions;
- > 2x reduction of OEO (Optical-Electrical-Optical) components in E2E network;
- Reduce operational costs (> 25%) by improved control plane and autonomous decision making;
- Provide E2E security able to support > 90% of services.

ALLEGRO Objective 2

Design, fabricate, package, and test novel smart transceivers.

The devices will comprise programmable photonic integrated circuits (PICs) containing 64 input/output (I/O) ports, able to connect up to 64 transmitter and receiver subsystems, allowing a total data rate of 32 Tb/s and wavelength routing.



Schematic representation of the smart transceiver developed in ALLEGRO.

a) Transmitter; concept of operation in the configurable mesh for a single laser and modulator.

b) Receiver; concept of operation in the configurable mesh for one wavelength after the DWDM.

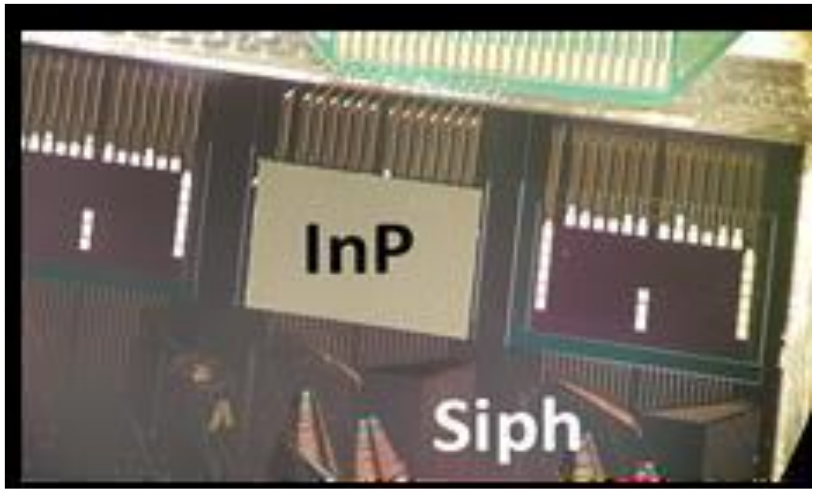
c) Packaging of the device including optical and electrical interfaces.

ALLEGRO Objective 2 KPIs

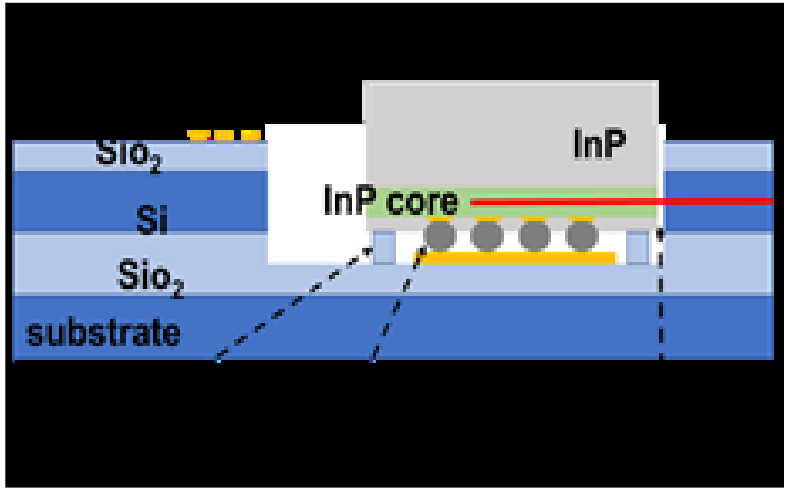
- 1 Tb/s transmitter: dual-polarisation plasmonic IQ modulators with Vπ = 1 V, 125 GBd 16 quadrature amplitude modulation (QAM) per polarisation, and electrical amplifier-less operation;
- 1 Tb/s receiver: dual-polarisation plasmonic balanced photodetectors with a responsivity of 0.5 A/W, 125 GBd 16QAM reception per polarisation using an optical hybrid;
- Photonic channel processing (filtering, dispersion compensation, balanced detection mismatch compensation: bandwidth granularity 1 GHz, channel separation 100 MHz, up to 64 independent frequency channels (subcarriers (SCs));
- 2x4 Hybrid: Power division precision < 0.05 dB, phase shift precision < 0.1 rad.

ALLEGRO Objective 3

Investigate and realize novel fast and lossless hybrid photonic switches with on-chip amplification operating in the O, C and L bands for datacom network architecture providing transparent switching operation to eliminate OEO conversions (and thus a lot of expensive transceivers and the associated cables).



Photograph of hybrid integrated 1x8 switch



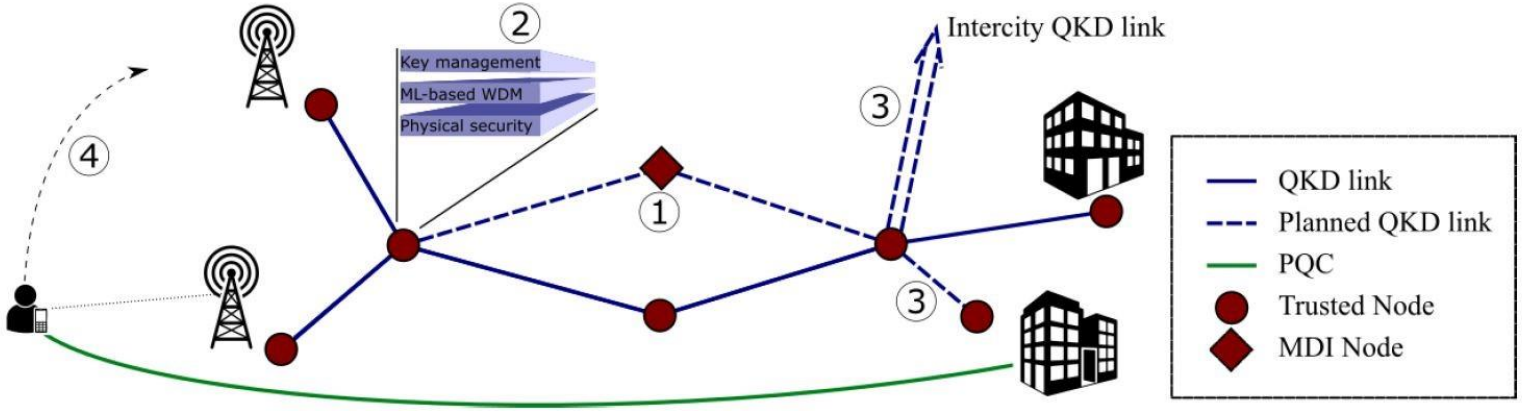
Hybrid integration via flip-chip bonding

ALLEGRO Objective 3 KPIs

- Programmable multiband optical switches operating in the O, C and L bands with multifunctional capability (switching, broadcasting and multicasting);
- Low power consumption of < 8W for the 16×16 O-band optical switch and less than 0.5 W for the 32x32 C- and L-band optical switches;
- Switching time of < 20 ns for the O-band switch (Edge-DC) and sub-ms for the C- and L-band switches;
- Loss-less operation by co-integration of on-chip amplifiers.

ALLEGRO Objective 4

Design and develop an advanced secure data plane network for the “quantum era”.



The following methods are pursued by ALLEGRO to achieve Objective 4:

(1) QKD (Quantum Key Distribution) protocols (e.g., MDI, QKD) for increased security and higher performance;

(2) physical security present in every node by QKD, PUFs (Physically Unclonable Functions) for authentication, QDT (Quantum Detector Tomography) methods for security and performance improvements; ML-based multiplexing for optimized integration of QKD in real-world OTNs (Optical Transport Networks); local KM to build up a scalable QKD network;

(3) flexible hybrid solutions that dynamically build in new QKD links (locally and globally) in the security architecture and that

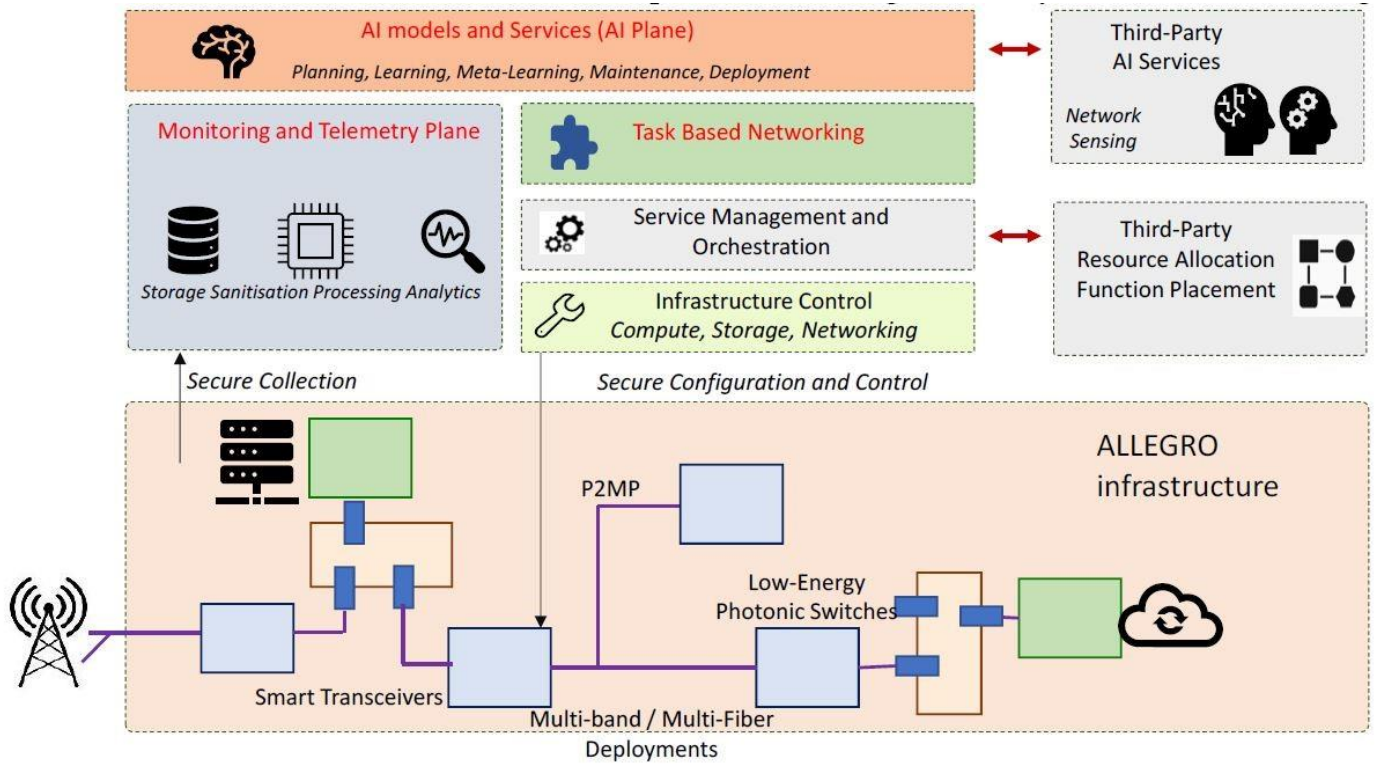
(4) automatically adapt the key relaying when a mobile users move.

ALLEGRO Objective 4 KPIs

- Multiplexing of QKD link next to classical channels with a total power of at least 1 dBm;
- Demonstration of E2E hybrid solution based on elaborated security use cases;
- Development of PUF devices with interchangeable random physical tokens, capable to support at least 50.000 challenge response pairs per token and key length of at least 2048 bit;
- Reduction of > 50% in quantum bit error rate (QBER) and increase of > x2 in secret key exchange rate under stable state of polarization (SOP) conditions, and accuracy of > 90% for eavesdropping detection by using QDT;
- Protocol-agnostic system with user dynamically changing between at least two QKD protocols.

ALLEGRO Objective 5

Design and development of a **secure and reliable control, monitoring and orchestration system for low energy and low latency** multi-band optical networks and services with AI/ML assisted network operation.



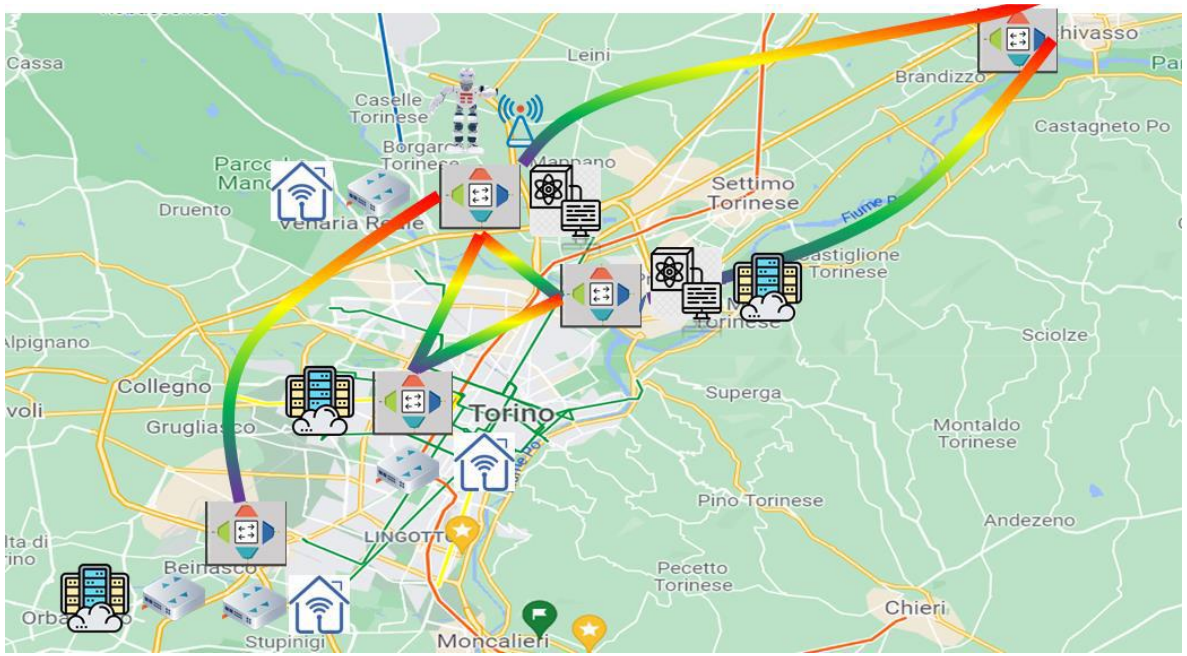
Overall architecture of the control, orchestration, and monitoring system of ALLEGRO

ALLEGRO Objective 5 KPIs

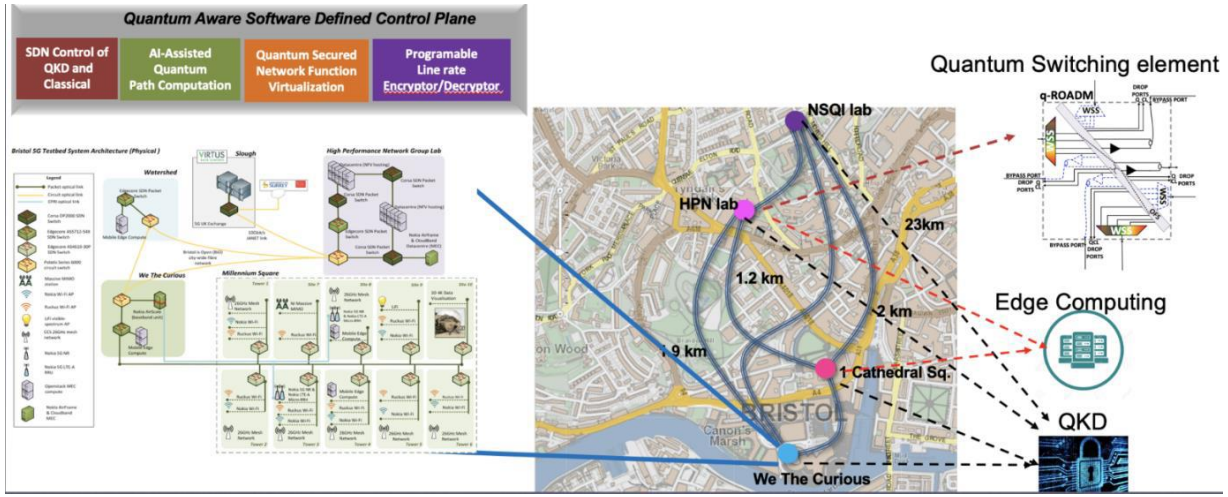
- E2E network provisioning in a sub-second level considering control plane latency of only ~ 100 ms;
- Device local control loop, including data collection, analysis and decision making in < 10 ms;
- Polynomial complexity algorithms, improve baseline and state-of-the-art algorithms for resource allocation and dynamic function placement targeting low power consumption, low latency and jitter (~10 μs) operation;
- Autonomous operation to reduce OPEX > 25% as compared to manual operation due to statistical multiplexing of the highly dynamic traffic and required service assurance;
- High resolution vibration and stress sensing using metro / radio access network (RAN) infrastructure with high locomotion resolution (< 1m) and wide sensing range (>10 km) for intrusion detection and prevention.

ALLEGRO Objective 6

Realization of E2E demonstrators



Torino cluster: geographical pictorial layout



UoB testbed for showcasing quantum secure 5G utilising a dynamic optical network and installed fibre in the city

ALLEGRO Objective 6 KPIs

- Demonstrate an integrated prototype of the ALLEGRO architecture that satisfies the security, latency, operational and energy efficiency KPIs identified in the other objectives;

- Achieve up to 50% reduction of the power consumption by optimizing CAPEX investments at the boundary between the metro and access network thank to smart multi-band P2MP transceivers and switches and by efficiently operating the network thanks to AI/ML techniques;

- Multi-service E2E validation of a multi-protocol agnostic security layer.

ALLEGRO Objective 7

Reinforce EU leadership and influence industry to adopt ALLEGRO principles through standardization, communication and dissemination activities.

COSMOTE's role in ALLEGRO

- COSMOTE leads the task of **defining the architecture** of the project's proposed technology and contributes to the **use cases definition**.
- COSMOTE will also participate in the **assessment of the new technology**, as well as to the **dissemination and exploitation of the project's in**novations.
- **COSMOTE's IoT platform will be available to be used in the project demos**, especially in the Torino cluster.

Thank you!

COSMOTE - Mobile Telecommunications S.A.

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