

European Technology Platform Networkworld Europe

Workshop on Future Optical Networks

POST-EVENT DETAILED REPORT

Jointly Organized by



September 21st, 2023



Event Overview

Objective

The event aimed to provide an open information space to share current and future views about the future optical networks, and how this theme is being addressed by different stakeholders, sharing the valuable experiences and practices of Europe and China. Two different discussion panels are organized, discussing current and future network operator's implementations, as well as new advances in optical technology that can be applied in access and transport networks. Ultimately, the workshop will contribute to identifying future optical innovation challenges that are being posed by the ever-increasing bandwidth demanded in optical infrastructure for the benefit of our society.

Information on the event will be made public afterwards.

- **Location: Hybrid (Online and Onsite Shanghai)**
- **Date: 21/09/2023**
- **Duration: 3H30 hours**
- **Number of registrations: 108**
- **Maximum number of simultaneous attendees: 58**
- **Event Post-Report drafted by:**
Fatma Marzouk and José Cabaça, with contributions from Networld Europe and CCSA organization teams.

Agenda

Workshop	Future Optical Networks Workshop - NetworldEurope & CCSA	
Date	Sept. 21st Beijing 15:00 – 18:30, CEST 9:00 – 12:30	
Agenda	Talk Title	Speakers
09:00-09:20	Opening speech and introduction	Rui Luis Aguiar Network Europe, Steering board chair Wen, Ku CCSA Board Chair
Panel 1		
09:20-09:50	Optical Network Challenges and Evolution in the Computing Era Optical networks: From past challenges to future opportunities	Tang, Xiongyan VP and Chief Scientist of China Unicom Research Institute Jorg-Peter Elbers VP Advanced Technology, Standards & IPR, ADTRAN
09:50-10:20	New Use Cases and New Technology Trends in Optical Communications The future of optical access network (FTTx)	Zhang fatai IETF CCAMP WG Co-Chair, ITU-T SG15 Vice Chair, CCSA TC6 Vice Chair, Optical Standards & Patents Department Director in Huawei Philippe Chanclou Innovation head of Fixed Access Networks, Orange
10:20-11:00	Current Situation & Challenges / New Use Cases & Tech Trend Q&A - Speakers + Panel Guest Carlos Bouça Head Of Fixed Access Network, Altice	
11:00-11:20	Break	
Panel 2		
11:20-11:50	Progress and Prospects of Optical Network Technologies and Standards in China Evolution towards the 6th generation fixed network (F6G): Research challenges and standard roadmap	Zhang haiyi Director of Institute of Technology and Standards CAICT, Head of 5G Transport WG of IMT-2020 (5G) Promotion Group, Deputy leader of TC6 WG1 and ST7 WG1 of CCSA Raul Munoz Research Director, Head of Packet Optical Networks and Services at CTTC
11:50-12:20	Standard & Next Step Industry Development Q&A - Speakers + Wang, Xuemin VP of Huawei European Research Institute	
12:20-12:30	Closing words	Rui Luis Aguiar Network Europe, Steering board chair Wen, Ku CCSA Board Chair

Program Summary

Opening Speech and introduction

Rui L. Aguiar (Networld Europe, Steering Board Chair/ University of Aveiro)

Prof. Rui Aguiar welcomed the speakers and the participants, and in particular CCSA and Mr. Wen Ku for the onsite organization of the event in China. Prof. Rui Aguiar make some remarks on the administrative aspects of the event namely the availability support of multi-language interpretation, both to onsite and online attendees (English or Chinese). Prof. Rui Aguiar concluded his opening speech by noting the very good curricula of the event speakers and thanking them for their availability.

Wen Ku (Secretary-General, CCSA)

Mr. Wen Ku welcomed the participants on behalf of CCSA and that it is a pleasure for him and CCSA to co-host with Networld Europe the event in China. Mr. Wen Ku affirmed that since the beginning of the introduction of fiber optics until now it has become the foundation for the society communications network. China has over 590 million fiber optical subscribers by July 2023 and is making huge investments in the optical communications networks, expecting that by 2030 every home in China has gigabit connections. It is expected that by 2030 6G will be in its commercial phase, with higher bandwidth requirements and lower latency, for applications like metaverse and virtual reality that will gradually become popular and this will be only possible using optical network. Mr. Wen Ku pointed out that technical innovation is the foundation of optical network development in the near future and there are 4 aspects that will drive that innovation, first the use of all spectrum bands in fiber optic, second is ever increasing need for higher communication rates, third is all optical network deployment with optical switching capabilities and fourth is the autonomous optical networks.

Mr. Wen Ku expects future cooperation between standardization organizations for joint development, meeting the requirements of the emerging digital industry, and be able to define the future optical network technology. CCSA's General- Secretary is very pleased to see the participation of industry executives, experts, operators, and scholars as we are discussing the future of optical networks that are making the foundation for the digital world and as we continue to innovate and make breakthroughs, he hopes that we can discuss the scenarios, trends and directions in optical networks wishing a great success to this event.

Session 1 Discussion

Presenter: *Xiongyan Tang (VP and Chief Scientist of China Unicom Research Institute)*

Mr. Xiongyan Tang started his presentation by introducing the theme of computing power as the new productive force in the digital economy era, and then he introduces the "East Data West Computing" project that will improve the computing service capability in China. To achieve this an efficient optical network infrastructure is needed and thus in May 2022 China Unicom released the all-optical network infrastructure for the F5.5G computing era. Mr. Xiongyan Tang presented the main technical directions of all-optical networks (all-optical access network, all-optical access metro and all-optical backbone) namely the aspects regarding ultra high-speed (achieving 400Gbps and 800Gbps in the near future), large capacity (using space division multiplexing) and long-distance transmission (deployment of new G.654.E optical fibers) as well as intelligent networks (e.g., ROADM and OXC) and efficient bearer networks (OSU technology used to carry multiple services from 10Mbps to 100Gbps). An evolution in optical transmission bit rate from 2003 to 2023 was given, where we clearly see the increase from 10Gbps in 2003 to 400Gbps in 2023 and with higher bit rate of 800Gbps coming in the next 3 to 5 years for long-haul applications to introduced in China backbone network. Apart from investing in higher bit rates we should also work on the integration of optical computing and storage networks to meet the demand

for higher computing power. Another topic in which China Unicom is working, together with Huawei, is the use of WDM as an enabler for low-cost metropolitan area optical network. This can be done using a multi dimension matrix based MxN ROADM achieving also optimal TCO as ROADM can reduce space and power consumption by 50%. Concerning the optical access network, China Unicom is working on the 50G PON and the computing power enhancement in PON. As 50G PON is becoming an international standard it will also be addressed in China to enable the AI, VR and metaverse on the home applications. Another direction is FTTR + Q-band WiFi, that we are developing with Huawei, this will enable the deployment of millimeter wave WiFi at home. Since we will not have interference in the house divisions so we can have good coverage.

The speaker concluded his presentation with a summary of the most relevant topics:

- 1- All-optical backbone: High-capacity all-optical network ensures computing power scheduling (800G).
- 2- All-optical access: Ubiquitous high speed optical access enables all-optical cloud/computing access.
- 3- Optical network and computing synergy enhance awareness of computing power and application in transport and access network, and realizes efficient collaboration of network and computing resources.

Presenter: *Joerg-Peter Elbers (VP Advanced Technology, Standards & IPR, ADTRAN)*

Mr. JP Elbers started his presentation showing the importance of fiber optics interconnecting continents and making possible communications worldwide between enterprises and people through the use of internet. The speaker then referred the main aspects of fiber optics evolution since the 70s (with the invention of the low-loss fiber) until the present days (where we have ROADM, coherent transceivers and DWDM making possible huge amounts of data transmission in the fiber). Next, and quoting Peter Drucker “You cannot predict the future, but you can create it” he elaborates on predictions for the future. Especially in terms of capacity where we see in service providers networks 25% CAGR, which means we need 10 times the capacity in 10 years, and if we think about content providers capacity we will need in terms of compute-to-compute networks 50% CAGR, which means we need increased capacity around 60 times in 10 years.

Mr. JP Elbers continued by showing the optical network architecture where we could see the:

- Access&Aggregation network (which comprises 10Ks of nodes with up to 10km distance between them),
- Metro/regional network (which comprises 100s of nodes with up to 100km distance between them) and
- National backbone network (which comprises 10s of nodes with up to 1000km distance between them).

Next, he elaborates on the Core and Access&Aggregation networks evolution main KPIs and what is expected until 2030, namely in what concerns to Port Speed, Fiber spectrum, Line capacity and Node capacity in the Core network and Uplink speed, PON speed and Data rate in the Access&Aggregation network. Another relevant aspect is that 80% of network costs are related to OPEX and as networks become more and more complex this drives the need for network automation. Thus, the introduction of NetDevOps will help the operators in the network lifecycle management, from the initial planning to the operation, maintenance and using AI/ML to provide the human operator a kind of virtual network assistant that will take a lot of the routine tasks and make sure the network is always operating in a stable way. Network resilience is also paramount to the correct functioning of optical networks, so we need to have network protection against failures, natural disasters, and attacks. The use of OTDR is very important in the correct location of fiber cuts as well as efficiently monitoring the infrastructure to be able to detect anomalies in a preventive way so that these anomalies can be solved before an alarm occurs.

Mr. JP Elbers concludes his presentation by pointing out that sustainability and energy efficiency are also crucial in today's networks. Although Data Centers are the major contributors for the energy consumption, we can see in Networks around 6% to 8% growth in energy consumption per year, so we need to have a holistic view in order to work out solutions that can reduce the energy consumption.

Presenter: Zhang Fatai (IETF CCAMP WG Co-Chair, ITU-T SG15 Vice Chair, CCSA TC6 Vice Chair, Optical Standards & Patents Department Director in Huawei)

Mr. Zhang Fatai started by describing the Digital Technologies that pave the way for an Intelligent Society, in the fields of Vision (8K, 16K, AR&VR, Naked-eye 3D), Computing (AI big model, General-purpose AI), Communications (6G wireless network, F6G network), Sensing (Full-band sensing, Bionic sensing) and also the emerging scenarios like Smart Computing, Smart Home, Smart Campus, Smart Industry, Smart City, Smart network.

- In Smart Computing we can see/expect CAGR of around 30% from 2020 to 2030 in Data Computing and in AI computility we expect 500 times growth in the same period.
- In Smart Home we expect online Education with AI-assistant learning, Entertainment with 4k/8K and holographic 3D video communication, Health Care with posture recognition (fall) and automatic call for help as well as heart rate, breath, snoring monitoring.
- In Smart Campus the usage of AR/VR will drive the smart office, smart conference, smart school, and smart hospital scenarios. For these scenarios latency is very important as AR/VR needs around 10ms maximum to a better experience (E2E latency = Tracking latency+Rendering latency+Network latency).
- In Smart Industry we need 3 key areas AI-processing and Control, Optical Network, and Optical Sensing.
- In Smart City we can use fiber/camera/spectra to achieve a better city digitalization and security by monitoring oil pipes, gas, water, as well as city security, and disaster predictions.
- In Smart Networks we can expect an evolution from Configuration-driven to Intent-driven for selected scenarios and ultimately to Intelligent human-machine interaction for all scenarios.

To address these emerging scenarios, we need technologies that can efficiently deal with all the aspects related to latency, bandwidth, etc. However, as we continue to evolve our networks (lowering latency and increasing bandwidth) we will face several challenges:

- In transport networks we will need 800G/1,6T optical modules which can be done using high-speed single carrier or multi-carrier but the challenges are high sampling (400GSa/s) AD/DA and low-power DSP&FEC, the heterogenous integration, multi-wavelength laser and cross-talk cancellation. Also, fiber is a valuable resource, and we need to expand the optical spectrum to S and U bands but the challenges are reducing fiber loss to less than 0.2db/Km and the use of S/U band optical amplifiers.
- In the access networks we need 50G PON and beyond but what technologies will B50G PON adopt to meet the ever-increasing bandwidth and latency requirements? We can use OFDMA/OCDMA but the challenges are how to achieve high power budget and how to make it cost-effective.
- For L5 Autonomous networks we still have a long way to walk as we are now in L2 or L3 in terms of autonomous networks. The challenges are 1-how to learn optical knowledge, 2-how to know network status (collecting network element data (pre)processing) ,3-what operators/users want (intent driven/nature language processing), 4-how to configure (auto network configuration)

Mr. Zhang Fatai concludes his speech presenting the IOWN (Innovative Optical and Wireless Network) initiative and its main proposed KPIs which are lower the power by 100 times, higher transmission capacity by 125 times and lower latency by 200 times.

Presenter: Philippe Chancelou (Innovation head of Fixed Access Networks, Orange)

Mr. Philippe Chancelou presentation focused on the FTTH Access Network. He started with the FTTH plant investments where we could see that FTTH CAPEX is about 10% in active network equipment's (OLT and ONT), 40% in civil work and 60% in the passive infrastructure (ducts, splitters, fiber cables, ...). In terms of PON optical budget the most used are class B+ and class C+, with 28dB and 32dB respectively, available as optical budget attenuation in the passive optical infrastructure. Class C+ is being introduced when we need to reach clients that

are more distant from the OLT and when we want to introduce a greater splitting ratio. Then he elaborates on the PON evolution, starting with the G-PON (2.5Gbps), then XGS-PON (10Gbps) and HS-PON (50Gbps) that are the next to be introduced in the PON. All these flavors co-exist in the same passive infrastructure thus allowing their fast introduction. Mr. Philippe Chanclou pointed out that in the first GPON deployments, between 2006 and 2015, the OLT and ONT must be from the same vendor but from 2015 onwards, and thanks to standardization, the interoperability between active equipment's became a reality thus allowing network operators to implement their PON networks more efficiently. Orange group has a certification and qualification program, the certification follows the BBF.247 which is mandatory, and the qualification is comprised by a set of tests to verify that the OLT-ONU interworking is according to the Orange group engineering rules. With this Certification and Qualification procedure Orange ensures that the new equipment introduced in the network is fully interoperable and compatible with existing ones.

Another important aspect is the introduction of SDN in the PON network as currently we have several OLT managers, since each vendor equipment has its own OLT manager using as interface for communication SNMP or CLI. With SDN we can have an OLT SDN controller that communicates via modern interfaces (Netconf/Yang, IPFIX, gRPC) with all the OLTs installed in the network.

Next, Mr. Philippe Chanclou elaborates on the new backplane approaches to have higher switching capabilities, decrease the power consumption between the line cards and uplink card, with the introduction of a photonic backplane (OCTAPUS project which is funded by the European Commission). He also notes that the PON infrastructure is not only for FTTH but also for FTTCampus (enterprises, factories, ...) and saying that Orange has implemented since 2018 the use of passive optical LAN (POL) to buildings with more than 500 people.

Mr. Philippe Chanclou then concludes his speech saying that Orange is also studying the introduction of FTTRoom which is a cost-effective home network infrastructure, associating optical fiber and radio for a wireless end connectivity to very high bit rate services in the home. This FTTRoom solution uses two cascaded PONs, the first is the typical PON until the "home gateway" and the second is from the "home gateway" to every room. This new "home gateway" will be functioning as a "miniOLT" that allows the implementation of a home PON to every room and finally using high bit rate WiFi solution in each room.

Open Challenges from Panel Discussion 1 (Prof Rui Aguiar as moderator)

Speaker: Carlos Bouça (*Head Of Fixed Access Network, Altice*)

Mr. Carlos Bouça introduced the past and present situation on FTTH in Altice (Portugal). FTTH is 15 years old, from 2007 to present date and last week Altice launched the 10Gbps PON. He also refers that in Europe while Portugal, Spain and other countries have a very high FTTH fiber penetration others like Germany have low fiber penetration. For the future he thinks that we need FTTR and WiFi as the customer will require good bandwidth but also mobility. For him the big challenge for today is looking for FTTH as the universal fiber network to leverage all applications, these applications must be commercial realities. In F5G we have this expectation as we are putting in the same table R&D, Telcos, and commercials. Commercials are essential to push R&D as we cannot continuously be developing technologies and we don't have the monetization, we need to sell real solutions to customers.

Answering to the question "How to address deployment costs in low-density areas?" Carlos says that Corvo island in Azores, a very small island, is now fully covered with FTTH. For this to happen network operators need to have state aid in their network investments. The European union is giving some help on this matter across Europe involving all the actors from network operators to manufacturers.

Mr. Carlos Bouça also agrees that AI/ML and data analytics is very important for the network operator. Using telemetry to have access to all events happening in the network will be of paramount importance in the process of acting preventively before the failure occurs, also with self-healing and optimization network procedures.

Answering to the question “What do you think is the best idea that your company will deploy in the future in terms of commercial or business models?” Mr. Carlos Bouça says that his company, as an incumbent company, has a challenge that is to leave all legacy networks in order to put all investment into a single optical network.

Speaker: Zhang Fatai (*IETF CCAMP WG Co-Chair, ITU-T SG15 Vice Chair, CCSA TC6 Vice Chair, Optical Standards & Patents Department Director in Huawei*)

Mr. Zhang Fatai also refers that in China they are upgrading their FTTH network from G-PON to XGS-PON to provide better service experience for their customers. Also, for residential network investments are being made in new technologies like WiFi6 and WiFi7.

Answering to the question “How to share data adequate for AI/ML developments on the control plane?” Mr. Zhang Fatai says that IETF has been doing some research work in telemetry mechanisms and netconf/yang and standardize the interfaces to collect the data quickly and accurately specifically for the autonomous network. Regarding autonomous networks there are still a lot of challenges ahead of us, like for example how to implement the digital tools? how to use advanced AI algorithms for the centralized control plane?

Speaker: Philippe Chanclou (*Innovation head of Fixed Access Networks, Orange*)

Mr. Philippe Chanclou thinks that the uplink needs to be upgraded as we are offering a higher bite rate in the PON. He also refers that in Orange they are using PON to PON cards for backhauling scenarios. Another important aspect is the securitization of the uplink connection. Orange is now using in the uplink 4x10Gbps for the G-PON and 100Gbps for the XGS-PON. Of course, we needed to upgrade the Core in terms of bandwidth capacity as we moved from xDSL (DSLAMs) to fiber (OLTs) so the demand was very high in this transition. However, from G-PON to XGS-PON the investment in the core is not on the same scale as the jump in bandwidth usage is not so high.

Speaker: Joerg-Peter Elbers (*VP Advanced Technology, Standards & IPR, ADTRAN*)

Mr. JP Elbers says that in a typical European network operator the major contribution for the higher bandwidth volume in the metro and core networks belongs to business-to-business applications. He refers that typically the residential traffic is 20Tbps, the business traffic is 60Tbps and the mobile traffic is about 0.5Tbps. So, a lot of the money in the metro and core network is coming from the need of business customers. Another interesting aspect is the traffic pattern as residential and mobile traffic tends to be delivered to a few distribution centers the business traffic tends to be more distributed with approximately the same % of traffic that stays in the local area, regional and national areas. Another interesting question is when we will evolve to 50Gbps PON as this will demand extra capacity needs in the core, and what will China do in terms of the commercial introduction of 50GPON and what do they see as the primary drivers for its introduction.

Asked about what the main future business will be, Mr. JP Elbers answers saying that network operational simplicity and network automation will be the biggest driver for the future in the telco industry.

Session 2 Discussion

Presenter: Zhang Haiyi (*Director of Institute of Technology and Standards CAICT, Head of 5G Transport WG of IMT-2020 (5G) Promotion Group, Deputy leader of TC6 WG1 and ST7 WG1 of CCSA*)

Ms. Zhang Haiyi made his presentation on “Progress and prospects of optical network technologies and standards in China”. She started with a background and overview of optical networks as the cornerstone of communication networks, playing an important role in driving effective ICT investment, promoting information consumption, and empowering various industries transformation. Ms. Zhang Haiyi presented an overview of

China operator optical network starting with the optical transport network (highlighting the backbone and metro that will be 400G/800G in the near future), the optical access network (with the future introduction of 50GPON and FTTR). Concerning the physical infrastructure G.654E fiber is being introduced in the backbone as well as hollow core fiber. Regarding SDN there have been enhanced MCS function and standard north and south-bound interface (currently in L3 intelligent operation). As for AI/ML, big data and digital twin networks China is targeting L4 network intelligent operation by 2025.

Ms. Zhang Haiyi referred the main CCSA related technical committees for optical network as:

- TC6 – Transport Network and Access Network technical committee
 - WG1: Transport Network (correspondence with ITU-T SG15, IEEE802.3, OIF and IETF)
 - WG2: Access Network and Home Network (correspondence with ITU-T SG15, IEEE, ETSI, ANSI, etc)
 - WG3: Cables (correspondence with ITU-T SG15, IEC TC86/SC86A)
 - WG4: Optical Devices (correspondence with ITU-T SG15, IEC TC86/SC86B SC86C)
 - SWG: Special WG for participating ITU-T SG15 meeting and activities
- TC7 – Network Management and Operational Support technical committee
 - WG2: Transport, Access, and Hosted Network Management (correspondence with ITU-T SG2 and SG15, TMF)
- SP2 – 5G Network End-To-End Slice special project group
 - SP2 is a joint project group of TC3, TC5, TC6 and TC7 and specify SPN slicing interworking and SLA guarantee for 5G network.

Regarding the progress of optical network technologies Ms. Zhang Haiyi presented 5 topics:

- Transport network – 400G/800G is currently the hot topic in the backbone network. Several trials are in operation in 2023 regarding the 400G, with China Mobile deploying commercial 400G in the end of 2023. Slicing Packet Network (SPN) technology combined with the advantages of multi-layer transport technology, has been deployed on a large scale in fields such as 5G bearer and industry private network applications. SPN standardization is almost complete specially int CCSA TC6 WG1 Standards on SPN and CCSA SP2 Standards on SPN for 5G network slicing.
- Access network – Today in China there are around 587 million FTTH/O subscribers. Over 20 million OLT 10Gbps PON ports installed and with more than 128 million subscribers with more than 1Gbps downstream. The number of users with Gbps and above has been increased rapidly, with an annual growth rate more than 250%. Also, more than 99% of villages have fiber access. The 50G PON series standards for PON system requirements are already available and China is starting tests and field trials for the 50G PON. FTTR is the hottest topic in CCSA TC6/WG2. FTTR general requirements standards has been approved in April 2023 and we are expecting that the PHY and DLL standards be approved by 2024.
- Devices and modules – Standards have been approved specially CCSA TC6 WG4 Standards on 800Gbps optical devices. Now the focus is on Tbps and CPO/LPO research.
- New fibers – A new generation of optical fibers is emerging, from submarine cables, to multi-fibers optical cables, Space Division Multiplex fibers and Hollow Core fibers. These fiber characteristics are being standardized in CCSA TC6 WG3 (correspondence with ITU-T G.65X.X).
- Network management – The current level of optical network intelligent operation has reached L3+. In 2025, we expect that online AI and DT based simulation functions may be introduced, evolving towards L4. So, the hot topic is the integration of AI and DT.

Ms. Zhang Haiyi concluded his presentation with a set of important technologies that can accelerate the evolution of optical networks namely:

- 800Gbps and beyond in the Transport Network and the introduction of new large capacity fibers (O, S, C, E, L bands)

- All optical networks (OXCs and ROADMs)
- TDM and Packet Fusion Enhancement (OSU, SPN)
- End to End Network Slicing and SLA Assurance
- 50G PON and FTTR in the Access Network
- New devices and modules with high integration (LPO/CPO/Silic on photonic integration)
- Intelligent Network Management & Operating with AI and Digital Twin Networks

Presenter: Raul Munoz (*Research Director, Head of Packet Optical Networks and Services at CTTC*)

Mr. Raul Munoz presentation focused on the Evolution Towards the 6TH Generation Fixed Network (F6G): Research Challenges and Standard Roadmap. The speaker started by showing the vision of End-to-End fixed networks referring the need of having optical networks from the Access, Transport and Core network and the services supported in each of the networks. He then continued with a graphic showing the international internet bandwidth usage and the CAGR to shape what will be the requirements of the optical networks. The CAGR from 2008 to 2014 = 46%, from 2014 to 2018 = 30% and from 2018 to 2022 = 29% so we can see that the pace of the traffic growth is slowing down. The question is what will happen until the end of this decade? A slide was shown with the most representative services in the fixed networks from F1G to F6G. In terms of F5G we can see that the most relevant are virtual reality, augmented reality, and smart city with VR and AR being the ones that will have major impact in terms of traffic growth and for the F6G we expect digital twin, internet of senses and holograms to be the most relevant which will also have a huge impact in terms of traffic growth.

Mr. Raul Munoz then presented the NetworldEurope SRIA optical KPIs for the present (2022), short-term (2025), mid-term (2028) and long-term (2031) evolution. Just to give some examples of the table presented we can see that for:

- Metro/core network - the spectrum evolution in the present 5Thz, 10Thz (2025), 20THz (2028) and 50THz (2031); the optical port speed evolution in the present 400Gpbs, 1.6Tbps (2025), 3.2Tbps (2028) and 6.4Tbps (2031); in terms of line capacity evolution in the present 25Tpbs, 100Tpbs (2025), 300Tpbs (2028) and 1Ppbs (2031).
- Access network - the PON speed evolution in the present 25Gpbs, 50Gpbs (2025), 100Gpbs (2028) and >200Gpbs (2031); in terms of user data rate (consumer) in the present ~500Gpbs, ~1Gpbs (2025), ~2.5Gpbs (2028) and >5Gpbs (2031); in terms of latency in the present <1ms, <100µs (2025), <10µs (2028) and <1µs (2031).
- In terms of power consumption and taking the present as a baseline of 100%, 40% (2025), 30% (2028) and 20% (2031); in terms of service provisioning in the present hour, minute (2025), second (2028) and sub-second (2031); in terms of network operations latency in the present operator-controlled (reactive), intent-based (proactive) (2025), self-diagnosing (2028) and self-optimizing (2031).

Then, the speaker says that 6G will have a huge impact on Transport Networks and presents a slide with 3 scenarios:

- Fully distributed (Legacy) – where the connection between the cell site (RU+DU+CU) and the core central office (CN) is done via Backhaul (Split option 1).
- Partially distributed - where the connection between the cell site (RU+DU) and the regional central office (CU) is done via Midhaul (Split option 2) and the connection between the regional central office (CU) and the core central office (CN) is done via Backhaul (Split option 1).
- Centralized distributed – where the connection between the cell site (RU) and the access central office (DU) is done via Fronthaul (Split option 7-2), the connection between the access central office (DU) and the regional central office (CU) is done via Midhaul (Split option 2) and the connection between the regional central office (CU) and the core central office (CN) is done via Backhaul (Split option 1).

In terms of bit rate for the several split options we expect for:

- Split Option 1 – in 6G Basic 16Gbps/16Gbps (DL/UL) and in 6G Advanced 100Gbps/80Gbps (DL/UL).
- Split Option 2 – in 6G Basic 16.016Gbps/16.024Gbps (DL/UL) and in 6G Advanced 100.02Gbps/80.024Gbps (DL/UL).
- Split Option 7-2 – in 6G Basic 86.71Gbps/86.13Gbps (DL/UL) and in 6G Advanced 430.78Gbps/430.20Gbps (DL/UL).

Other relevant expected reference parameters for 6G are:

- Channel bandwidth – 400MHz-1GHz (DL/UL)
- Modulation – 256QAM-1024QAM (DL), 256QAM (UL)
- Number of MIMO layers – 8-16 (DL/UL)
- Number of antenna ports – 64-128 (DL/UL)
- Sampling rate – [4-10]*30.72Msamples/s (DL/UL)

Mr. Raul Munoz then presents the challenge of how can we increase the node throughput and link capacity? He presents 2 options. The first one is trying to increase the fiber spectrum utilization, especially in the O, E and S bands. The second option is to use Space Division Multiplexing (SDM) fibers, as mentioned before in other presentations. He continued by presenting the optical network research challenges identified in the NetworkEurope SRIA 2022 document:

- Sustainable capacity scaling (Editor: Nokia Bell Labs France)
 - i)Scaling to Petabit/s capacities in core and metro networks,
 - ii)Next generation terabit/s transceivers.
- New switching paradigms (Editor: Fraunhofer HHI)
 - i)Ultra-fast Multi-granular Switching Nodes,
 - ii)Switching Architectures guided by Energy-Efficiency
- Deterministic networking (Editor: ADVA Optical Networking)
 - 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.
- Optical technologies for radio networks and systems (Editor: Ericsson)
 - i)Optical technologies for radio access networks,
 - ii)High speed optical interconnects in radio systems,
 - iii)Optically enabled radio functions.
- Optical network automation (Editor: CTTC)
 - i)Network Telemetry and Optical Network Sensing,
 - ii)Control and Orchestration architectures for Network Automation,
 - iii)AI/ML in support of Network Operation,
 - iv)Reliability and Security of Control, Orchestration and Management, v) Optical Network Digital Twin.
- Security for mission critical services (Editor: ADVA Network Security)
 - i)Quantum-safe cryptography,
 - ii)Physical layer security,
 - iii)Network resilience,
 - iv)Intrusion detection and mitigation
- Ultra-high energy efficiency (Editor: Infinera)
 - 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.
- Optical integration 2.0 (Editor: ADVA Network Security)

- i) Multi-band exploitation,
 - ii) High-capacity interfaces for spectrally and spatially multiplexed systems,
 - iii) Optical chip interconnects,
 - iv) Multi-platform manufacturing,
 - v) Photonic-electronic integration,
 - vi) Reliability and repeatability.
- Optical access beyond FTTH (Editor: Nokia Bell Labs Germany)
 - i) Increased capacities and flexible configuration,
 - ii) Flexible real time and non-real time resource assignment, Redundant,
 - iii) Meshed and flexible optical layer network architectures,
 - iv) Optical layer multi-tenancy in access networks.

The speaker then concluded his presentation showing the evolution, within the ETSI Industry Specification Group (ISG), for Fifth Generation Fixed Network (F5G) (2020), F5G Advanced (2025) and F6G (2030). A figure with the evolution roadmap was presented with the several releases. Release 3 is now ongoing in WI21-F5G-Adv generation definition; WI20-F5G Adv Use Cases; WI1c-F5G Adv Requirements, Gap analysis, Landscape; WI1d-F5G-Adv Architecture; WI17-Testing Service Quality; WI18-OCN Architecture.

Finally, the speaker concluded his presentation with the main key figures of the ISG F5G in terms of number of Members & Participants, Standard Contributions, and Industry Development.

Open Challenges through Panel Discussion 2 (Mr. Jyrki Huusko as moderator)

Speaker: Wang, Xuemin (*VP of Huawei European Research Institute*)

Answering to the question What is your view of the major technical challenges when moving from F5G to F6G? Mr. Wang affirmed that optics is the main driver for fixed networks and for wireless networks will be WiFi and mobile generations. The standardization in China is very aligned with ITU, 3GPP, ETSI, IEEE, etc, and these organizations should work together to address the main challenges of the future technologies.

Mr Wang Xuemin says that quantum technology involves a lot of military applications and thus quite related with geographical topics. Specifically for quantum communication and quantum computing, we can say that quantum communication is more mature as for its coordination with optical networks and it is now in the process of industrial application but for commercial use it is a bit confidential and will take time to be implemented. For optical network and quantum communication in the future there will be a lot of opportunities for cooperation.

Speaker: Rui L. Aguiar (*Networld Europe, Steering Board Chair/ University of Aveiro*)

Prof. Rui Aguiar also gave his thoughts saying that we have 2 opposite trends that needs to be aligned, one trend is the expected increasing in bandwidth, the other trend is that we need lower costs. Sometimes we see incremental evolutions of the technologies and depending on the standardization body is the previous version plus plus. And careful should be taken as we cannot throw away the investments already done. On the other hand, and this can be seen clearly in mobile networks, occasionally we reach a point where we need to start discussing if the costs that we have for this incremental evolution do not reach a point where it's better to just say let's have a new generation. Prof Rui says he feels uncomfortable when hearing the vision of an all-optical network and we keep avoiding the discussion of the traffic patterns and the way the network should be optimized is very different from what it was before. The networks are becoming a Hub and Spoke network and we have not address this as our concept of the network, so maybe is time for us to reflect on how much less cost could we have if we look to the network from this point of view.

Speaker: Zhang Haiyi (*Director of Institute of Technology and Standards CAICT, Head of 5G Transport WG of IMT-2020 (5G) Promotion Group, Deputy leader of TC6 WG1 and ST7 WG1 of CCSA*)

Ms. Zhang Haiyi says that optical technology has been further integrated into IP technology. For some edge nodes we can think of the possibility of also further enhancing the sensing capability, and for core nodes we can leverage the potential of optical network in terms of large capacity and low latency and together with SDN and other technologies we can provide quite flexible access and transport networks.

Answering the question of how do you see the future and the impact of Quantum technology for the future optical networks, Ms. Zhang Haiyi says that quantum network will not conflict or replace optical network, the two will develop in parallel. In terms of the actual quantum information network, she says that right now in Europe and the USA there has been some research and there could be some small experiments and for the actual applications maybe they will be available in the next decade or even longer term.

Speaker: Raul Munoz (*Research Director, Head of Packet Optical Networks and Services at CTTC*)

Mr Raul Munoz says that in their case the optical layer will replace as much as possible the IP layer or the equivalent electrical switching layer. We cannot completely avoid the electrical layer, but we can with an autonomous and dynamic optical network perform a lot of switching there. The reason why is because is much more power consuming and thus more expensive to do the switching in the IP layer. We are now entering the era of programmable optical networks so we can dynamically modify parameters to make the network adaptive. Mr. Raul Munoz says that quantum and optical networks need to converge at some point. In order to deploy the quantum links that are required for specific applications the requirements that we may need are extremely high, and unless that we deploy a quantum network from the scratch for these specific applications it will be very difficult to deploy that technology. And that's something that is not feasible because it's very expensive. So, the question is can we manage a quantum network by using the optical network? For the future, at least in the short term we must be able to use the optical network to provide quantum links in order to deploy some specific applications. In this way we don't need to deploy a quantum network from scratch that would be parallel to the optical network infrastructure, so this is something that still needs a lot of research.

Closing Words

Prof Rui Aguiar is very pleased with the event, and he hopes that the audience and the online participants have enjoyed so much as he did. It is clear to him that optical networks are and will be essential for society in the future and we need to have a sort of balanced approach to their development, with a need to lower the costs and opening the usefulness of the network. Hopefully the society will create at least the market demand but there are also other aspects that we need to consider how to overcome like for instance the need to implement optical infrastructure in rural areas, how to address the new type of traffic patterns that we have, how to adapt and integrate an increasingly cloud oriented environment into the optical network, how to increase intelligence of the network to make it dynamic. So, there's a huge amount of work to develop in the next coming years. He concluded by thanking the webinar organization teams for all the effort and work preparing this event, as well as the speakers and panelists that contributed with their views and content.

Mr. Wen Ku also thanked the speakers, panelists, and participants onsite and online in the event and highlighted that optical networks are very important. He says that optical networks are the foundation for the information society and he has been promoting optical network because in many rural areas and also some urban areas copper infrastructure is quite broken and does not meet the requirements for a broadband infrastructure network. Copper network has a lot of limitations in terms of maintenance, interference, bandwidth, etc and with

the ever-increasing need for bandwidth and the reduced price of optical modems the optical network for the end user becomes a reality. Optical networks have been developing very rapidly in China and the future of communications will be with the optical foundation. So optical networks are very critical as we move into the future with an all-optical network and also applied in the datacenter to interconnect machines. Mr. Wen Ku refers to the fact that quantum networks by 2030 will not be able to compete with optical networks as quantum networks are in its early stage, maybe in 10 to 20 years we can start seeing some implementations of quantum networks.

China has the objective of implementing optical networks everywhere, including the rural areas, and we are willing to share our experiences and best practices with our friends in this field. One critical thing to lower the costs is to standardize the products, qualification and certification are key to ensure the quality and lower the operational costs. We hope to learn from each other and together we can bring this technology to the next level. He concluded by thanking again all the people involved in this event for their contributions as well as for the online and onsite participants.

Keynotes Summary

From the workshop session the following keynotes were consensual:

- **Technological innovation is the foundation of optical network development.** Looking forward to the future, the following four aspects need in-depth innovation research. First, new spectrum. Optical communication has been extended from C-band to L-band, and will in the future expand in the S, O, and E-bands. New optical fibers, including few-mode, multi-core, and air-core optical fibers, might be explored in data centers and submarine cable scenarios. The second is high rate. New optical devices and technologies, such as thin film materials, are used to achieve above 200G baud rate to meet increasing bandwidth requirements. The third is green all-optical switching, which supports all-optical grooming technologies with wider spectrum, more dimensions, and faster speed, meeting the requirements of large-capacity and low-power consumption applications on backbone networks and data centers. The fourth is the intelligent optical network, which intelligently identifies services, provides a super-large-scale network with over 10,000 nodes, and schedules millions of services to ensure service reliability and network robustness.
- Only with **uniform standards** can there be economies of scale and the optimal input-output ratio. The large-scale deployment of optical modems in China reduces the price from nearly 1000 yuan to 100-200 yuan, which is the foundation of China's optical network development. European experts believe that China accounts for about 30% of the global PON market. The deployment of 50G PON in China has a decisive impact on the global industry pace.
- **Optical network is the foundation for future network and service evolution.** Optical network evolution is the co-evolution of networks and technologies such as space networks, wireless networks, and IP.

And the following keynotes need to strengthen consensus later:

- Whether the **evolution and deployment of optical networks are driven by technologies or services**, and how to ensure that carriers can make profits. Driven by technologies, optical networks must be upgraded with 6G and Wi-Fi evolution. Unify standards, reduce costs, and cultivate services. Carriers can win and make profits in competitions. How carriers can make profits needs to be reviewed in detail, certainly by technology-driven, with certain risks.
- **F6G evolution route and details.**

Feedback after the session

Several formal and informal feedback was received after the session, from the participants globally. There was a large agreement on the feedback, with compliments on the quality of the webinar and its content.

