NETWORLD EUROPE

CCSA

Emerging Scenarios and New Technology Trends of Optical Communications

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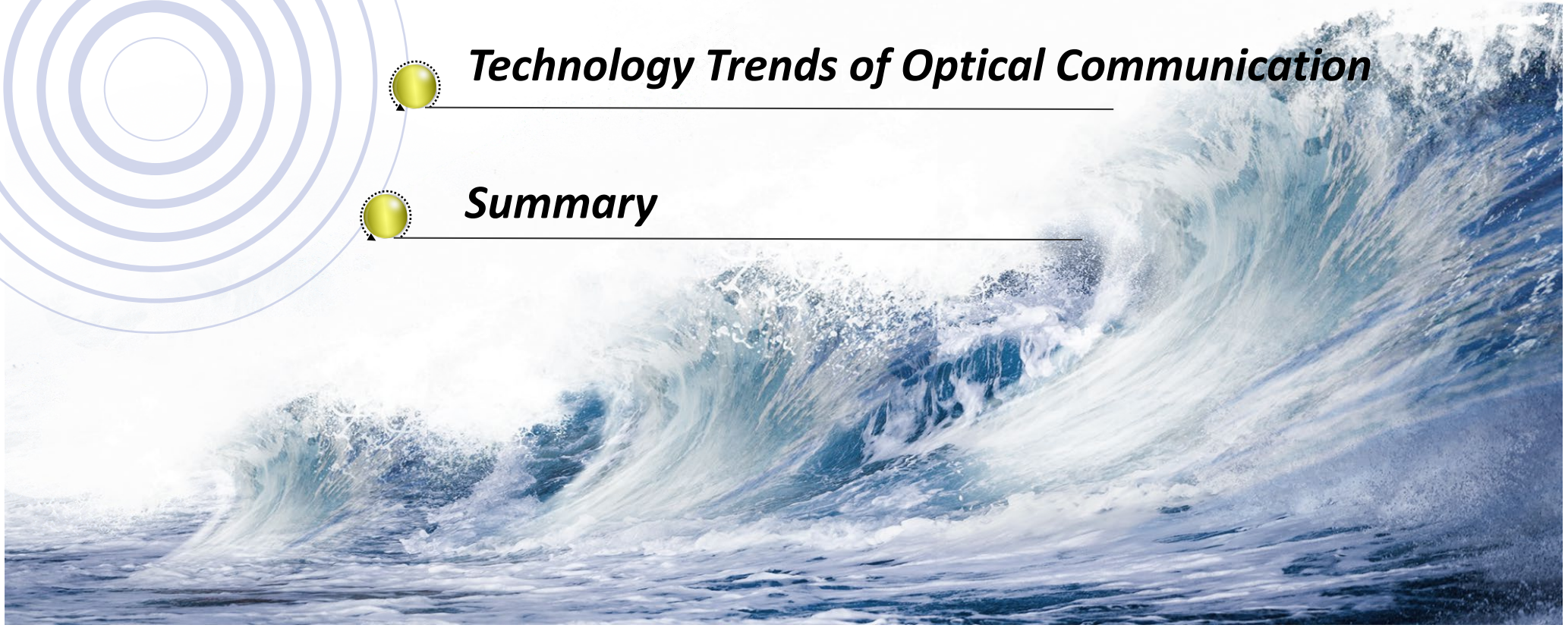
Beijing 15:00 – 18:30, CEST 09:00 – 12:30
Sept. 21st, 2023 Shanghai

Agenda

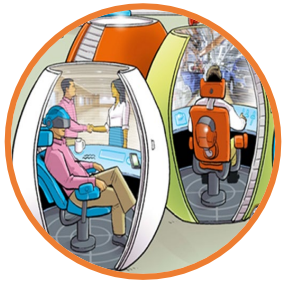
- *Overview of Emerging Scenarios*
- *Technology Trends of Optical Communication*
- *Summary*



Digital Technologies Pave the Way for Intelligent Society

New Vision

8K/16K/AR&VR/
Naked-eye 3D



Human-centered
Immersive experience

New Computing

AI big model
General-Purpose AI

Ubiquitous
Cognitive intelligence

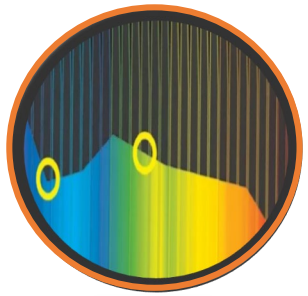
New Communications

6G Wireless network
F6G fixed network

Super broadband
Smart & massive connections

New Sensing

Full-band sensing
Bionic sensing



Feel everything even beyond
human nature

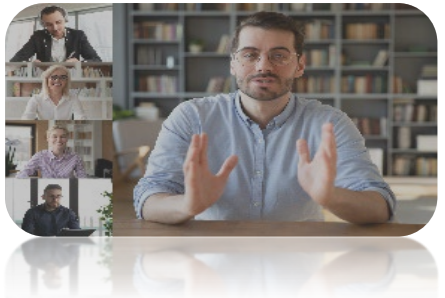
Agricultural Society → **First industrial revolution** (mechanization) → **Second industrial revolution** (Electrification) → **Industrial Society** → **Third industrial revolution** (Informatization) → **Fourth industrial revolution** (Digitalization) → **Digital Society** → **Fifth industrial revolution** (Intelligence) → **Intelligent Society**

Emerging Scenarios Drive the Evolution of Intelligent Society

Smart Computing

Smart Home

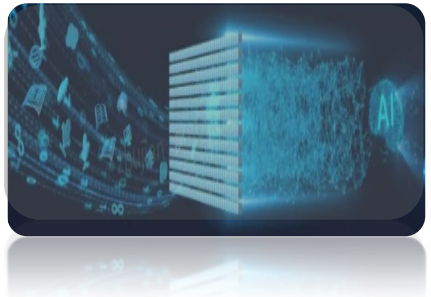
Smart Campus



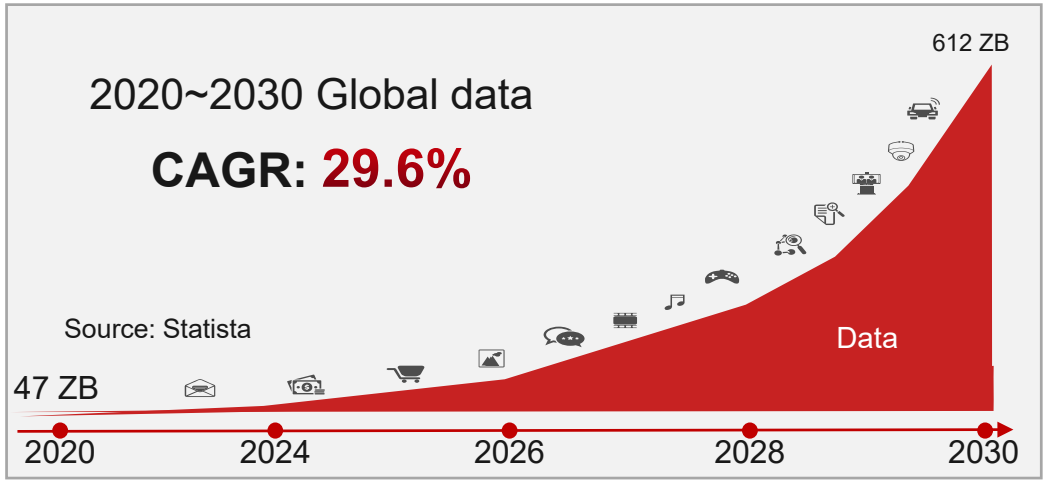
Smart Industry

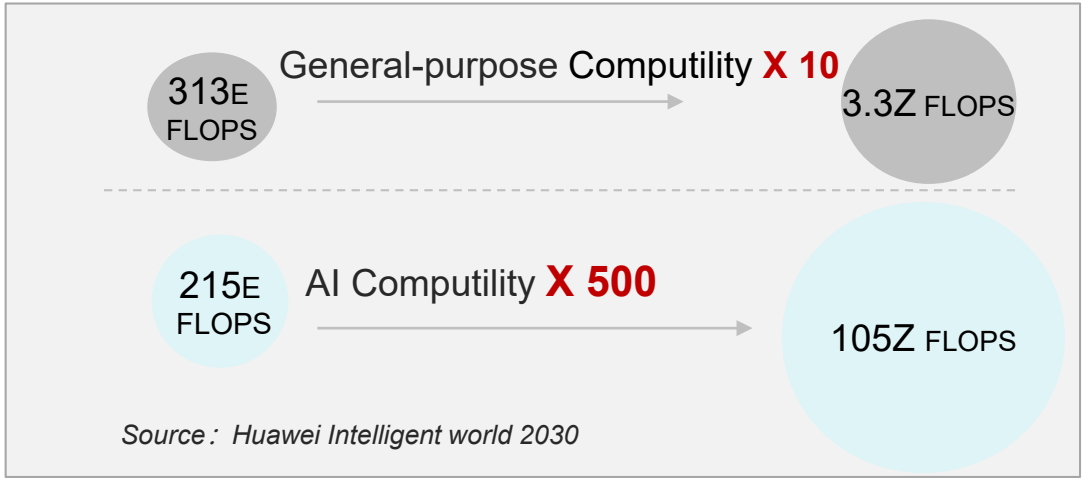
Smart City

Smart Network



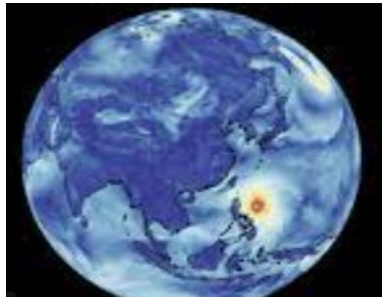
Smart Computing: Data and Computility Dramatically Exploded





Chat-GPT

Realtime climate forecast



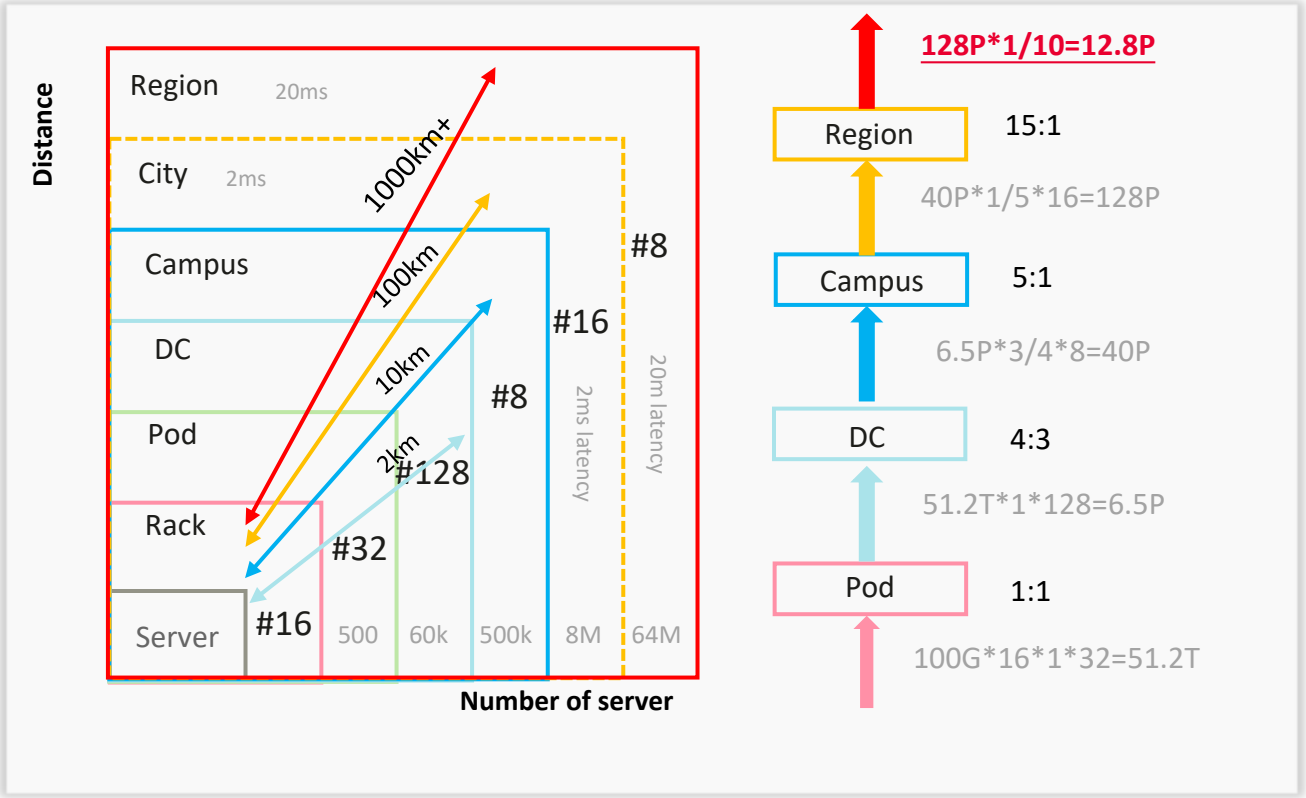
Medical simulation

3D vide rendering

- More and more applications such as Chat-GPT, real-time climate forecast, Medical simulation require huge data and computility, bring ~30% data increase (YoY).
- AI computility dramatically increase 500 times within next 10 years.

Smart Computing: High-speed & Flexible Optical Transport Network is the Key

Traffic forecast for Chinese backbone DC@2030



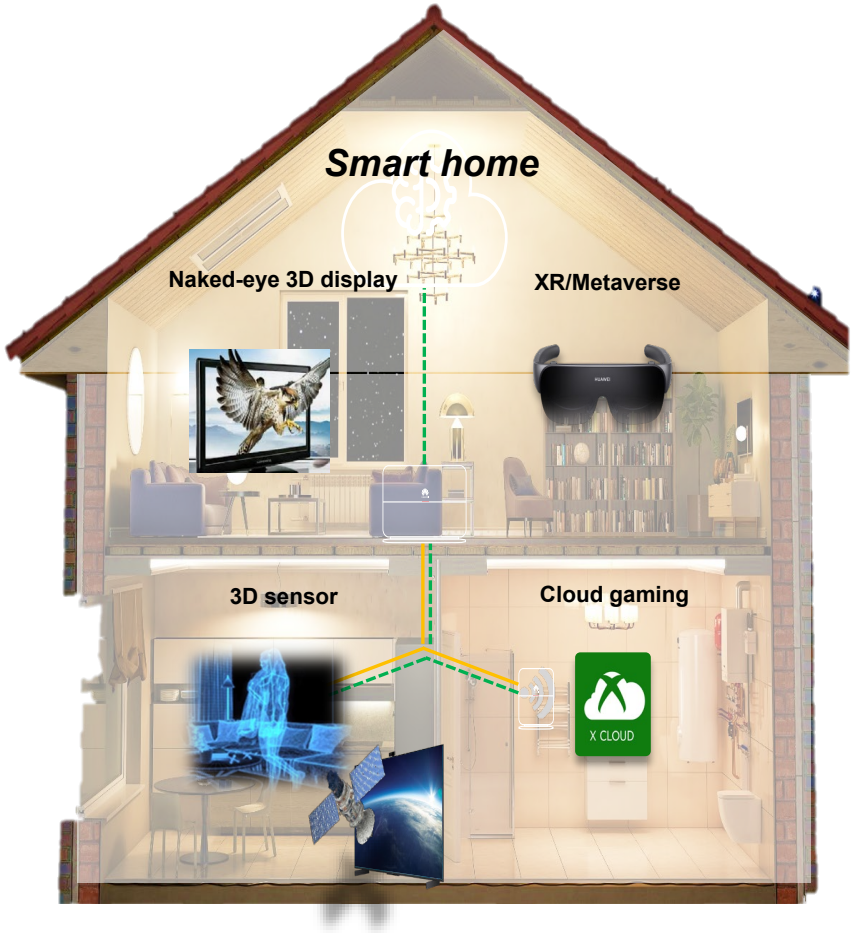
Key Requirements for transport network

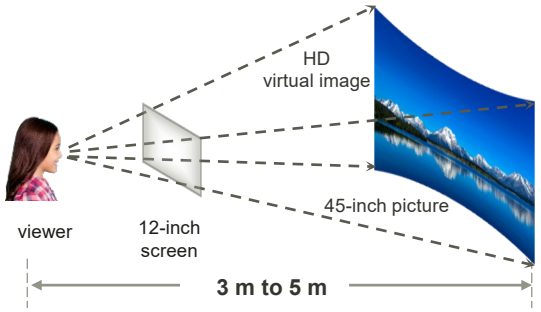
- **Port rate：800G~1.6T/CH**
- **Capacity：~100T**
- **OXC：100D+**
- **OXC compacity：10P+bit**
- **Seconds-level building up connections（task-oriented）**

☐ An example of Chinese backbone DC, 12.8 Pbit/s data demand for transmission, which has a high requirement for transmission network.

【eg. channel computing resources from the east to the west(20230】

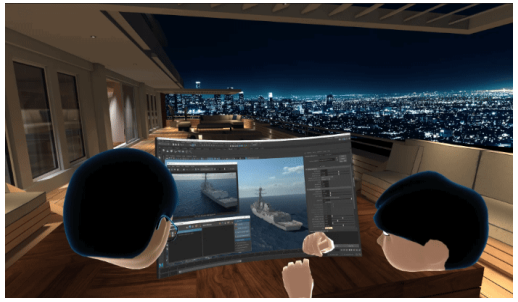
Smart Home: Online Education, Entertainment and Health Care





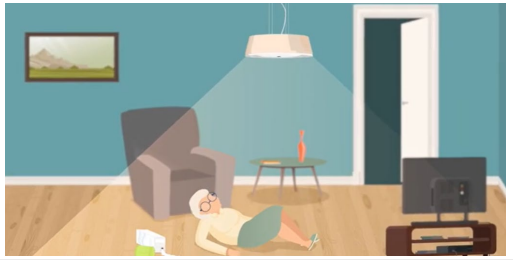
Online Education

- Far-view display for eye health
- AI-assistant learning



Entertainment

- 4K→8K→3D for TV & Film
- 3D video for communication



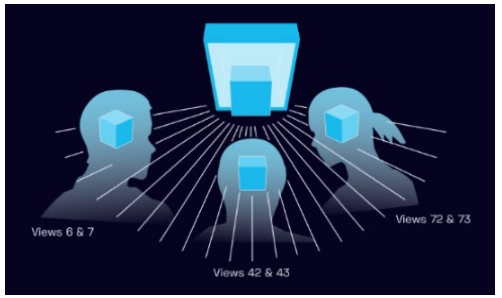
Health Care

- Posture recognition (fall) and calling for help automatically
- Monitoring of heart rate, breath, snoring, out of bed

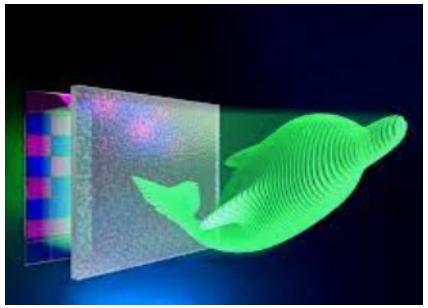
Smart Home: High Capacity and Low-latency Required

2020:4K→8K

2025: Naked-eye 3D



2030: Holographic 3D



Index	8K	Multiview 3D(9 views)	Holographic(10 layers)
Resolution	7680 x 4320	7680 x 4320	7680 x 4320
Frame rate	100/120	100/120	100/120
Bit depth	10/12bit	10/12bit	TBD
Gamut	BT.2020	BT.2020	TBD
Data rate	120Mbps	>1Gbps	>10Gbps
Latency	<10ms	<5ms	<1ms

Best effort	**GPON**	**10G-PON**	**50G-PON**
Best	**10G-PON**	**50-GPON**	**Beyond 50G-PON**

- To enable better QoE, higher data rate up to 10Gb/s and lower latency boundary down to 1ms are indispensable.

Ref: BBF TR-126

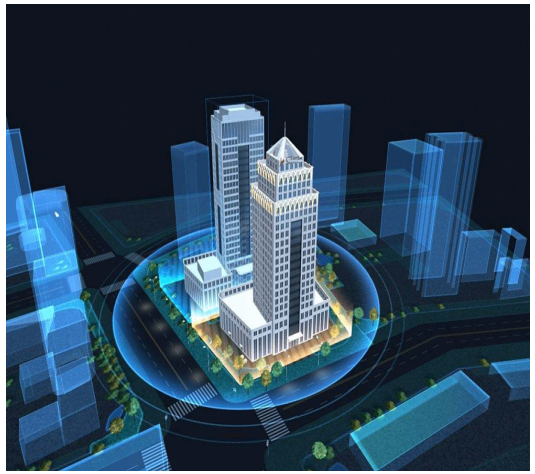
Smart Campus： AR/VR for Smart Office & School & Hospital

① Smart Office

- XR for multi-screen surrounding (meeting/minute/Message/…)
- Super Mobility: 1000inch screen

② Smart Conference

- 3D Camera and display to a ‘real’ face-to-face meeting



③ Smart School

- **Multimedia classroom:** 8K/16K Electronic whiteboard and digital courseware; Multi-views naked-eye 3D
- **Smart Audio-visual Classroom:** AR/VR simulation

④ Smart Hospital

- Real-Time 3D CT Reading
- Remote diagnosis and treatment

Smart Campus: Ultra-low Latency is the Intrinsic Characteristic for AR/VR

Latency Calculation for AR/VR

头旋转速度 / 时延	60°/s		80°/s		100°/s	
30ms	1.8°	54p	2.7°	81p	3.0°	90p
20ms	1.2°	36p	1.6°	48p	2.0°	60p
15ms	0.9°	27p	1.2°	36p	1.5°	45p
10ms	0.6°	18p	0.8°	24p	1.0°	30p
7ms	25.2’	12.6p	33.6’	16.8p	**42’**	21p

Requirement for AR/VR

Services	**Less interactive**		**Intense Interactive**
Applications	4K 3D	8K-2D	3D-VR game
Frame	30~60 fps	30~60	90/120 fps
Data-rate	79~158 Mbps	114~228	316 /421 Mpbs
E2E latency	<20ms		**≤7 ms (best)**

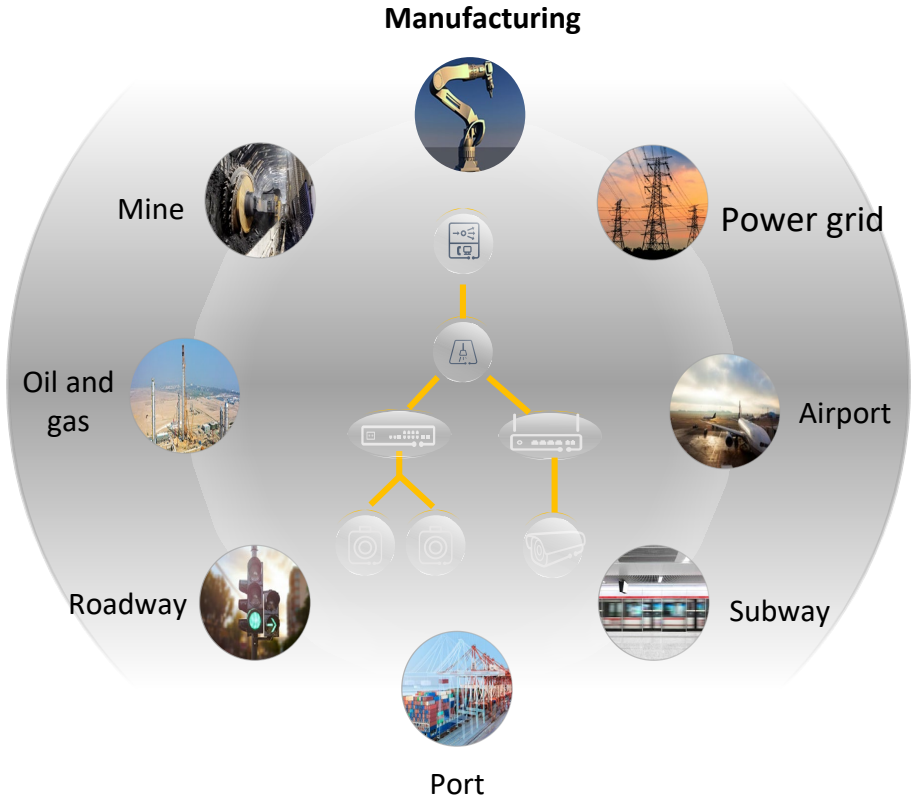
E2E Latency = Tracking latency + Rendering latency + Network Latency

8~10 ms | 1~2 ms | 1~2 ms

- To have better experience, 42’ angle tolerance is required. Considering the fast head moving 100°/s, 10ms E2E latency is required.
- AR/VR needs 10ms for best experience, but it has not yet been achieved (Vision Pro is 12ms).
- Every part needs to contribute to reduce the latency, thus ultra-low latency (us-level) network is required.

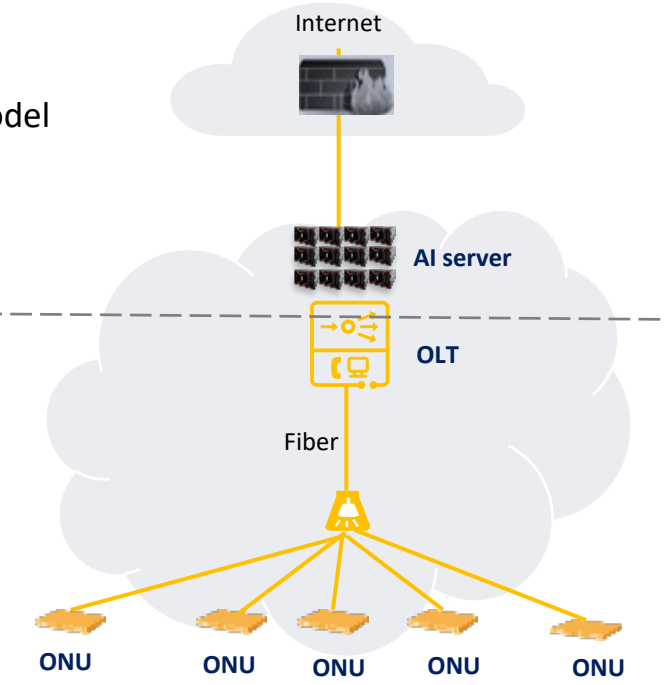
Ref. Michael Abrash, Oculus CTO

Smart Industry: Optical Infrastructure for Production Network



AI-processing&Control

- Industry oriented large-sized model
- Fast Edge computing
- Multi-domain coordination

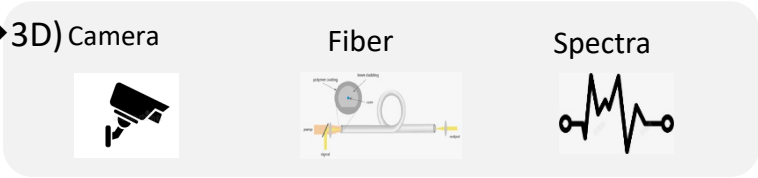


Optical Network

- Low latency (1~2ms)
- High speed uplink （1G~10G）
- Deterministic low jitter （50us）
- Reliability & Security

Optical Sensing

- Camera for vision (2K→4K→8K→3D)
- Fiber for stress/Vibration
- Spectra for substance detection



- Every walk of life is approaching digitalization to improve the efficiency and reduce the operation cost
- Optical infrastructure play an important role, such as Optical sensing as a foundation and high-speed optical network as a deterministic pipeline

Smart City: Fiber/Camera/Spectra for City Digitalization and Security

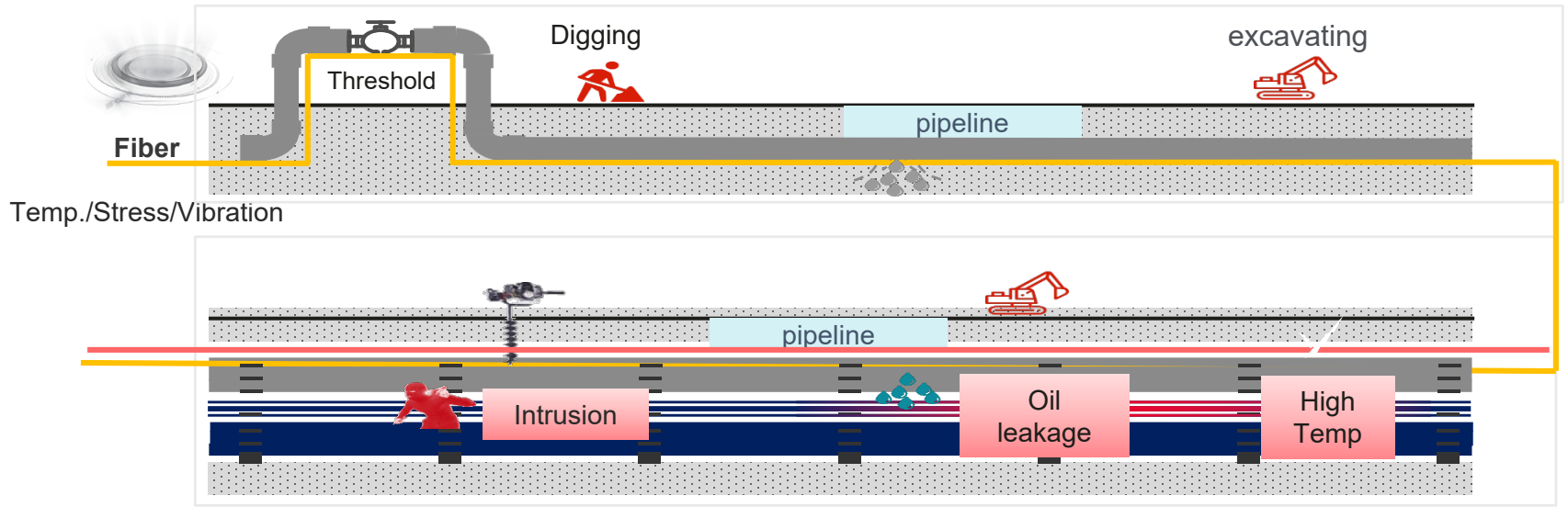
Oil Pipes Monitoring	Disaster Prediction	City Security	Water Monitoring	Gas Monitoring
structural safety Temp./Stress/Vibration	Earthquake/ Landslide Warning	Intrusion identification	Drinking water safety	Explosive & Hazardous gas
Fiber	**Fiber**	**Camera**	**Spectra**	**Spectra**

Real-time sensing

- Temp <1°C, Stress <1με, Freq >5KHz
- Resolution<1m
- Detection distance >100km

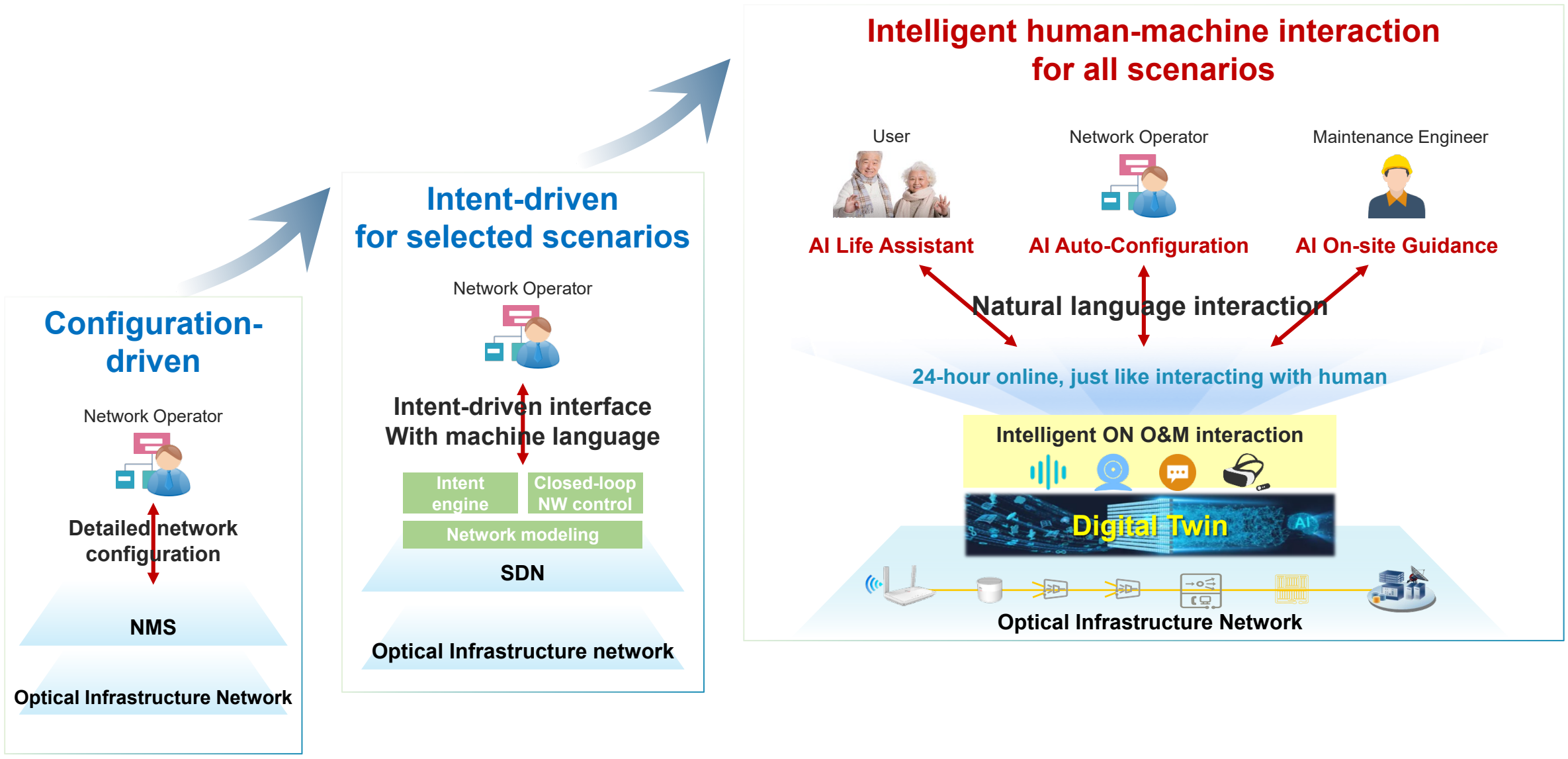
Events Detection with AI

- Multi-parameters AI training & process
- Big Model self-learning

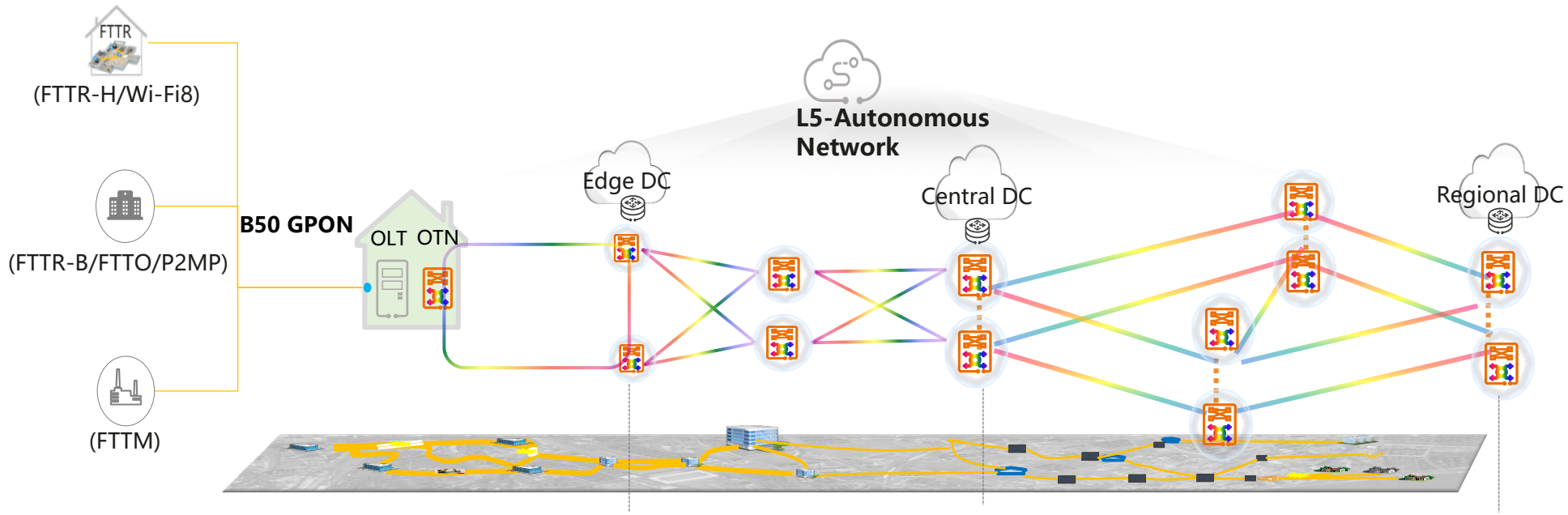


- Multi-dimension sensing system enables city digitalization and protect the city, such as Oil pipelines monitoring, earthquake forecast, perimeter security, water and gas monitoring…
- An example of Oil Pipes monitoring is shown, the events of Digging, excavation, intrusion and leakage can be recognized with the help of fiber sensor and AI process.

Smart Network: Intelligent Human-Machine Interaction for O&M



Potential Technologies to Support Emerging Scenarios



High-speed transport Network

800G/1.6T optical module

C+L+S optical spectrum

Access& on-premises network

Beyond-50G PON

NG-FTTR+Wi-Fi8

L5 Autonomous Network

Sophisticated Optical Knowledge System

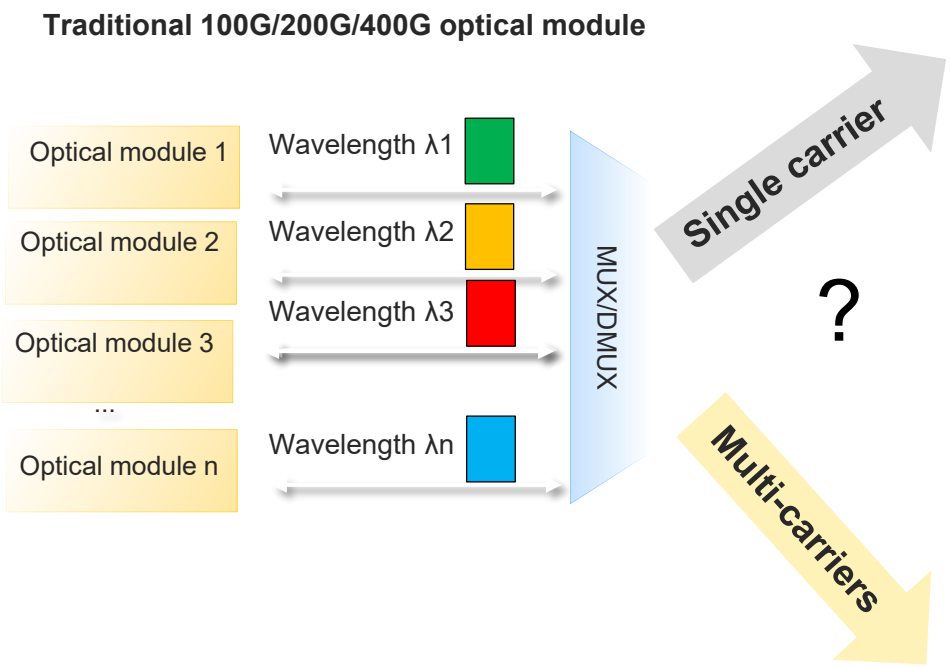
Intent-driven Nature Language Processing

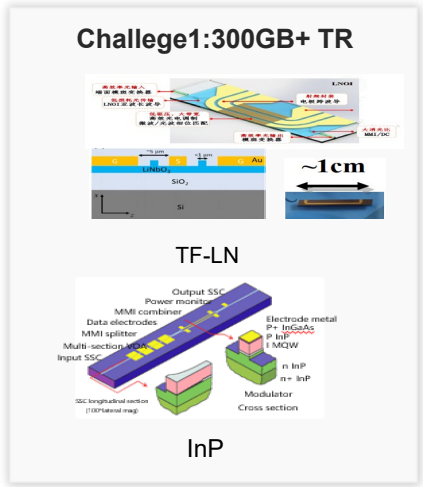
The Evolution of Optical Coherent Transmission Network (for Long-haul 2000km+)

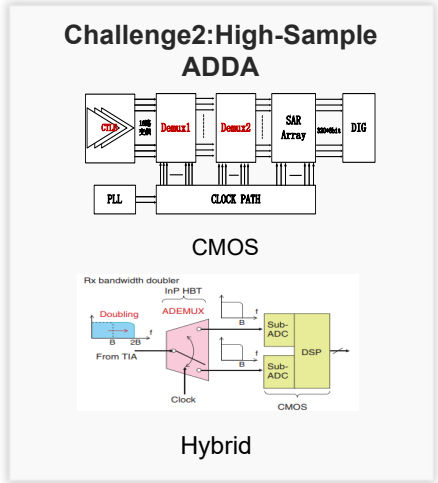
Rate/Port	**100G**	**200G**	**400G**	**800G~1.6T**
Commercial Deployment	**201x-2018**	**2019-2022**	**2023-2027**	**2028-**
Capacity/fiber	**8T**	**16T**	**32T**	**64T+** ?
Spectrum Grid	50GHz	75GHz	150GHz	300GHz+
Spectrum bandwidth(80CH)	4000GHz	6000GHz	12000GHz	12000GHz+
Bandwidth (Optical components)	C4T	C6T	C6T ⊕ L6T	C6T ⊕ L6T ⊕ S/Uband

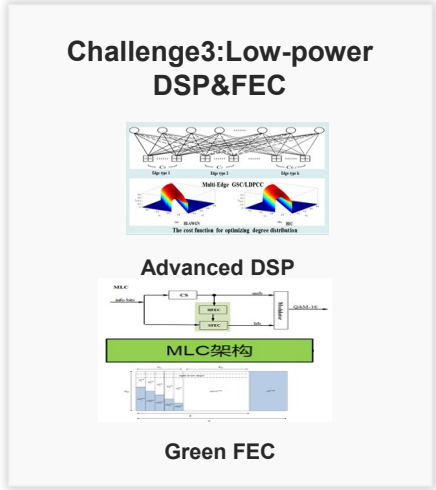
- Fiber is precious resource, we need to maximum the capacity
- Data rate of optical module and spectrum bandwidth of optical layer are key enabler for capacity evolution

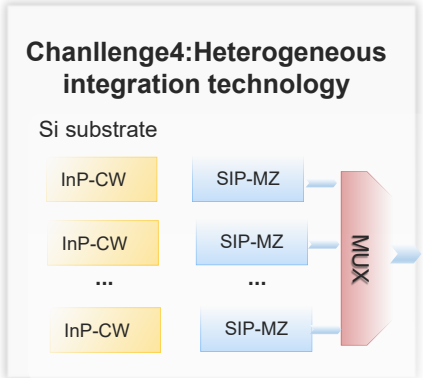
1. Transmission: Challenges for 800G/1.6T Optical Module

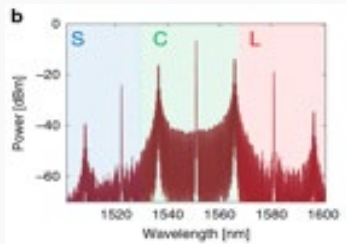


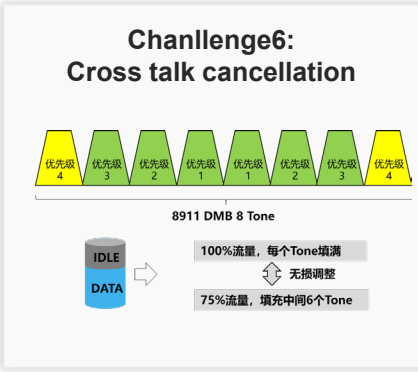








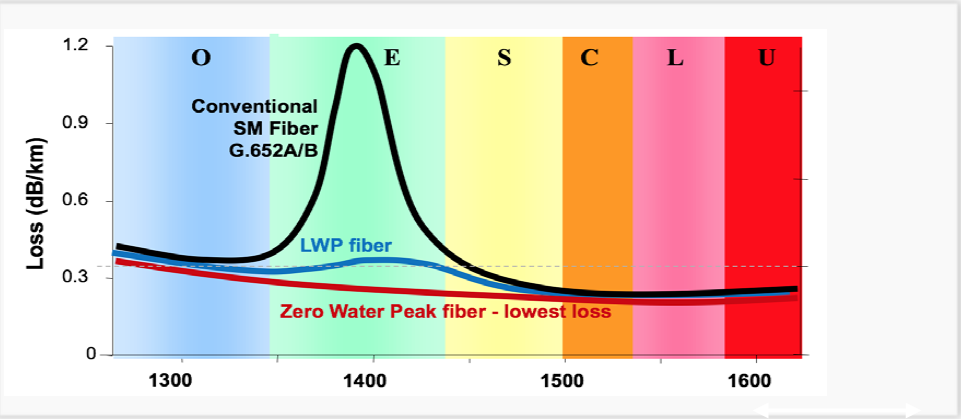




- 100G/200G/400G are achieved by single carrier with the bandwidth increase of optical and electrical components, but it is harder for 800G/1.6T.
- Two potential solutions are researched, one is high-speed single carrier and the other is Multi-carrier.
- The challenges for single carrier includes 300GB+ TR, ~400GSa/s AD/DA and low-power DSP&FEC; The challenges for Multicarrier are heterogeneous integration, multi-wavelength laser and cross-talk cancellation.

2. Transmission: Challenges for Expand the Spectrum

C+L spectrum vs. available spectrum (500 THz)



Extend the full-spectrum boundary

Expand available spectrum

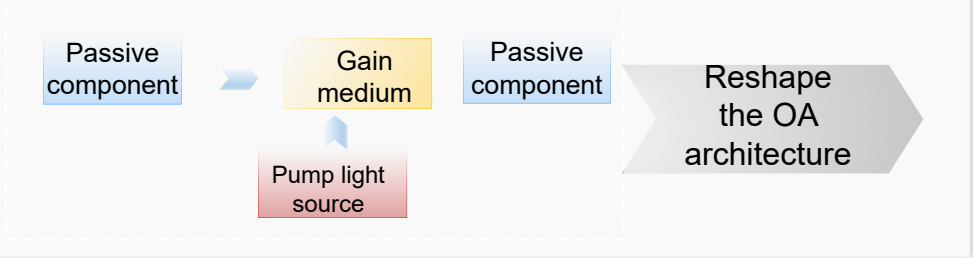
by 2–4 times

C: 6T

C+L: 12T

C+L+S+U/E?

The (EDFA) architecture was proposed in the 1980s, with a 3 dB NF(noise figure) limit.



Breaking the quantum noise limit

Strive to decrease NF to be less than or close to

3 dB

New architecture

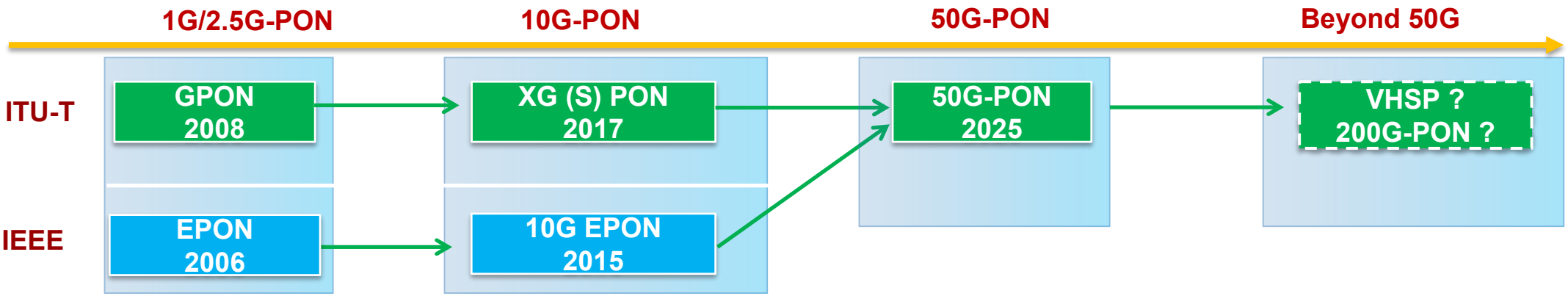
?

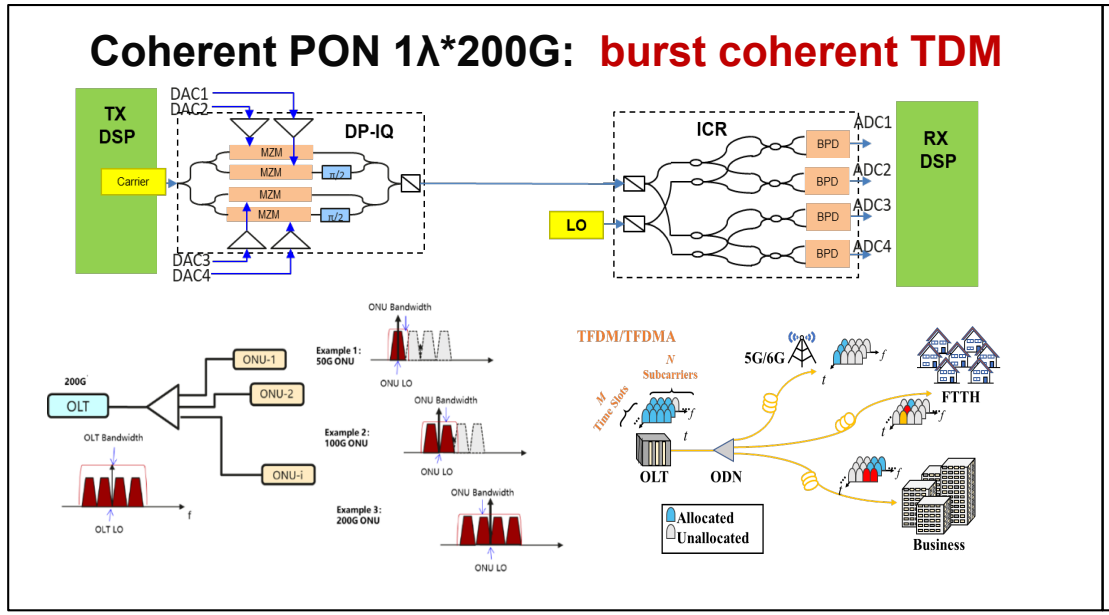
PSA

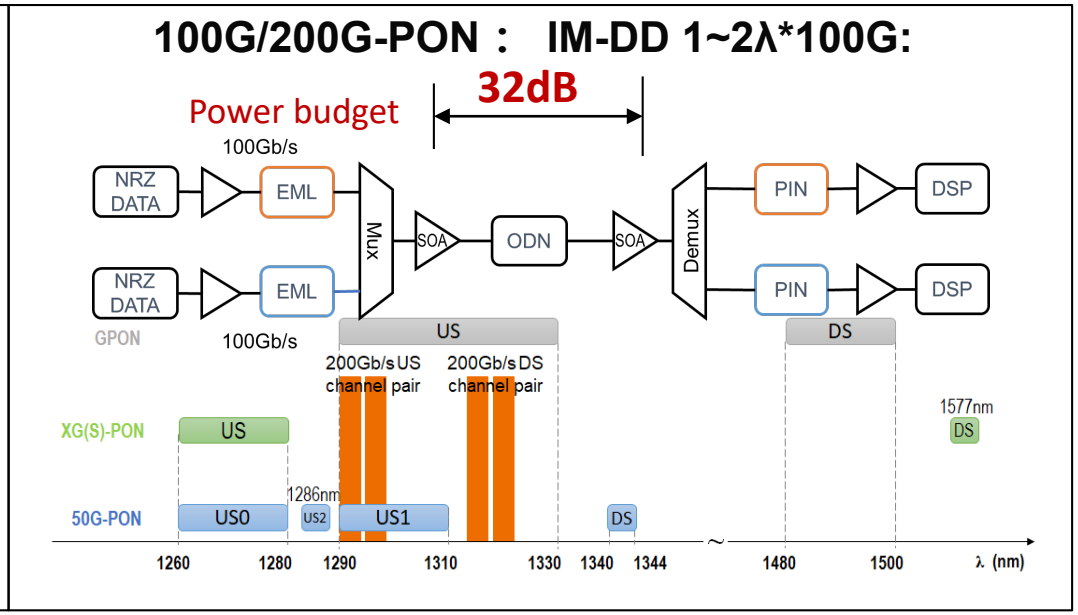
...

- C+L band has been occupied, S or U band should be considered to expand the spectrum, which may increase 2~4 times, the key challenge are: 1) reduce the fiber loss to <0.2dB/km; 2) S/U band optical amplifier and other components.
- EDFA has 3dB theoretical limitation, how to break through it is a important topic to research, which will improve the whole transmission system.

3. Access: Challenges for Beyond 50G PON



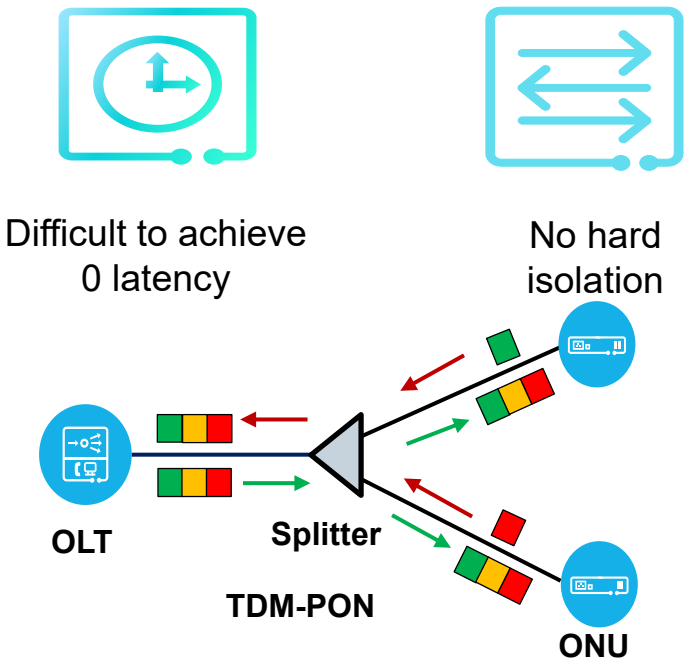




- What will be the next generation beyond 50G-PON? What are the applications and requirements of the B50G?
- What technologies will B50G need to adopt, to meet the ever-increasing bandwidth and latency requirements and also support smooth evolution from existing ODNs? Coherent or IM-DD? Single wavelength or multiple wavelength?

4. Access: Challenges for Low-latency and Premium PON

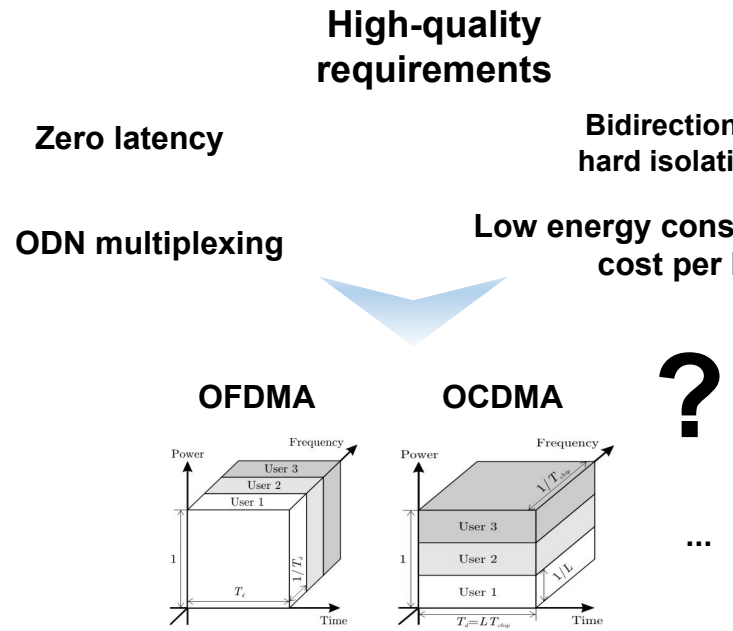
Challenges



TDM/TDMA:

- Inherent Latency caused by DBA
- Every ONU receive all the optical signal data, no isolation and may have rogue issue
- High bandwidth requirement on ONU optics

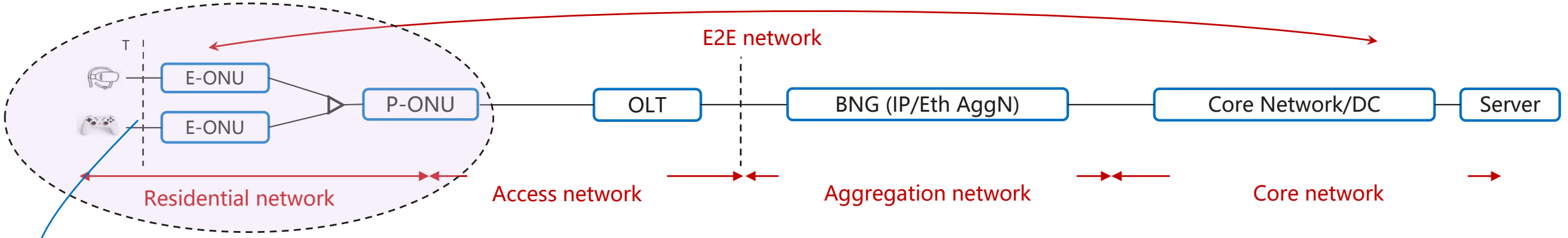
Premium P2MP optical access architecture



OFDMA/OCDMA:

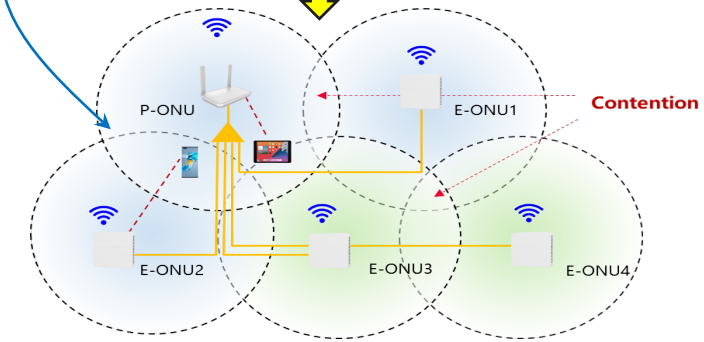
- Zero latency can be achieved as no TDM
- Every user can have dedicated subcarriers/codes, hard isolation and no rogue behavior
- Challenges: how to achieve high power budget, cost-effective and high utilize efficiency

5. On-premises Network： NG-FTTR + Wi-Fi8 Coordination

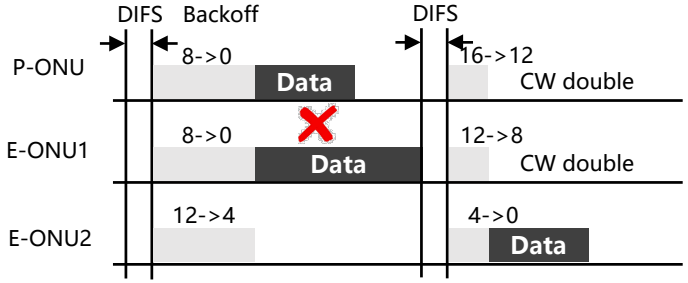


Wi-Fi link

QoE Bottleneck

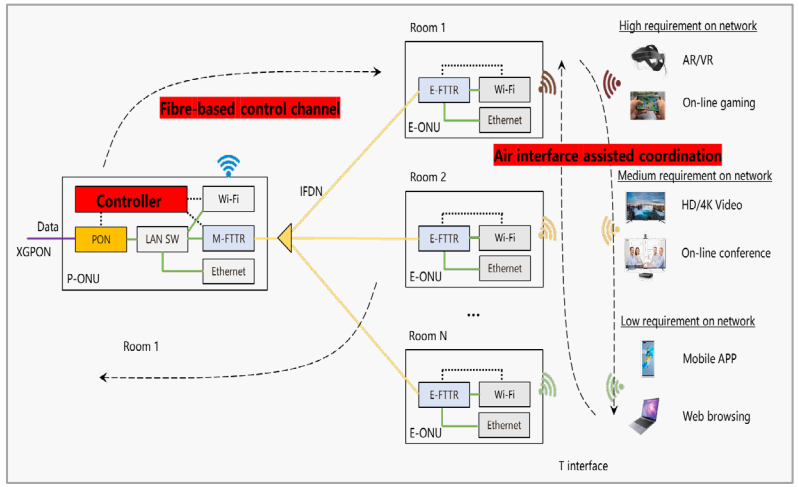


Wi-Fi CSMA collision



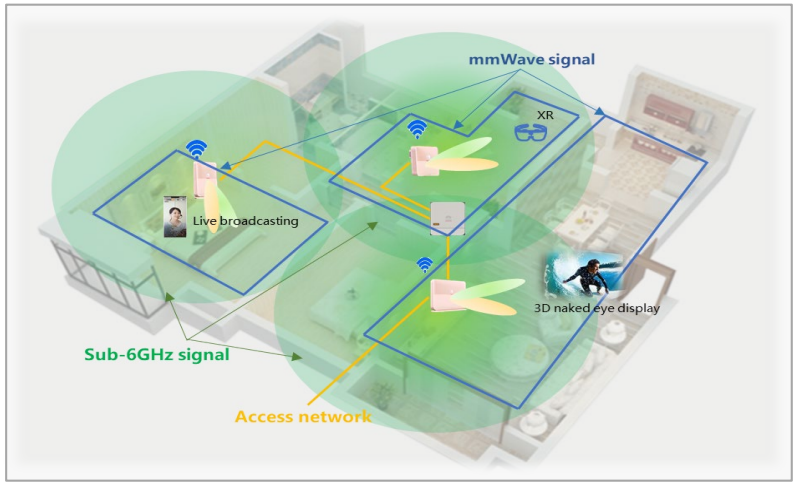
Unstable connection with large variation of latency

Challenges of UHR (potential solution 1)



- Need to design real-time control mechanism
- Low-cost & high speed short-range fibre link
- Interference mitigation scheme & algorithm
- Legacy STA compliance issues

Challenges of IMMW (potential solution 2)

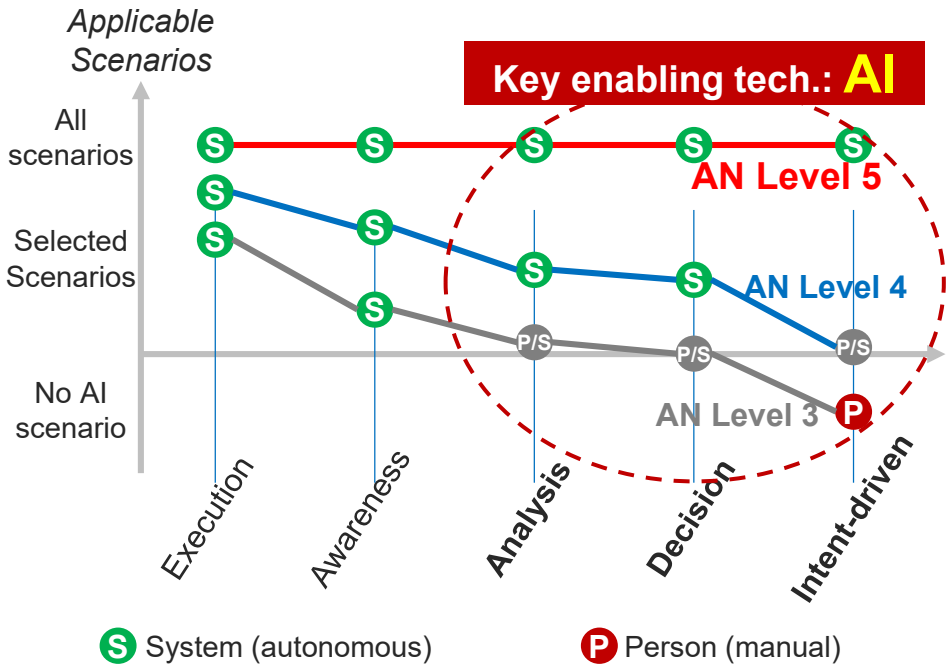


- New & simplified air interface design
- Overcome LOS issues without significant loss
- Coordination between sub_6G & mmWave
- Easy beamforming & tracking mechanism

HUAWEI

6. Autonomous Network Level 5 based on Ubiquitous AI

Autonomous Networks evolution

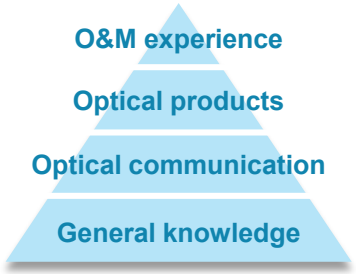


Note: AN levels defined by TM Forum IG1218

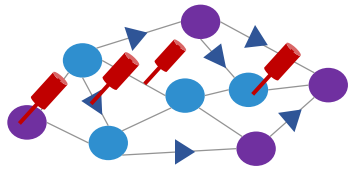
Autonomous Levels	L0: Manual Operation & Maintenance	L1: Assisted Operation & Maintenance	L2: Partial Autonomous Networks	L3: Conditional Autonomous Networks	L4: High Autonomous Networks	L5: Full Autonomous Networks
Execution	P	P/S	S	S	S	S
Awareness	P	P/S	P/S	S	S	S
Analysis	P	P	P/S	P/S	S	S
Decision	P	P	P	P/S	S	S
Intent/ Experience	P	P	P	P	P/S	S
Applicability	N/A	Select scenarios				All scenarios

Key challenges and tech. for AN Level 5

Sophisticated optical knowledge system



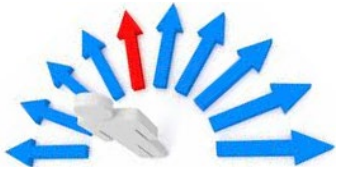
- ms-level optical info collection
- NE level data (pre-) processing



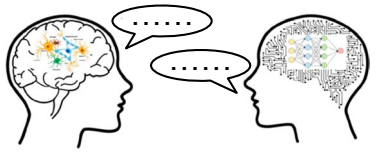
1. How to learn optical knowledge
2. How to know NW status
3. What operators /users want
4. How to configure

Optical Network O&M

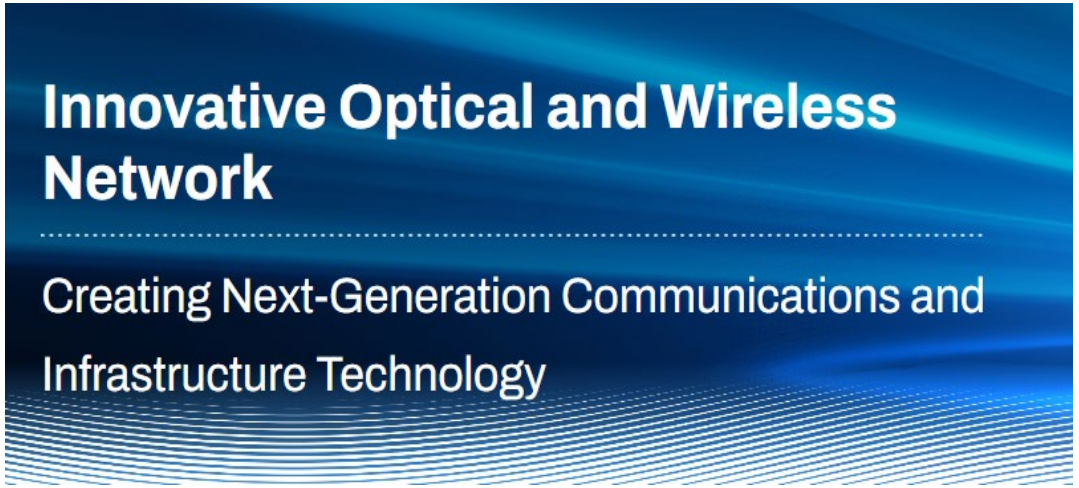
- Interpretable AI de making
- Auto network configuration



- Intent driven
- Nature Language Processing

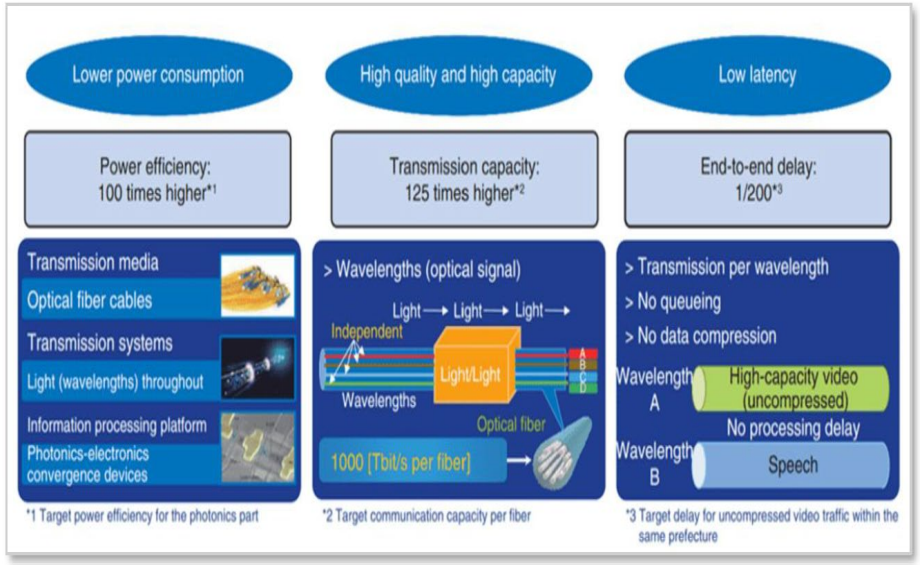


IOWN Has Similar Technical Vision for NG All-photonic Network



NTT intel SONY

Members: 3(2019)→30(Now)→100+(2030)

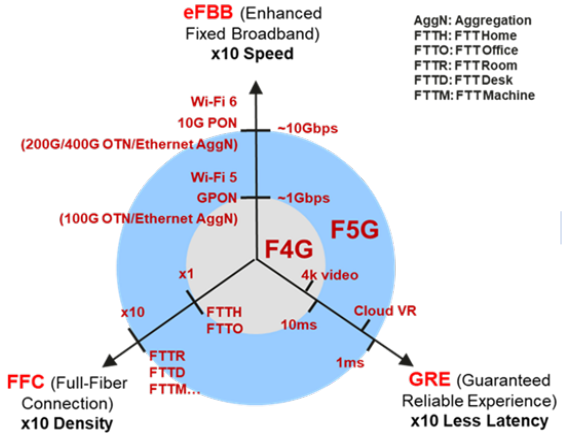


- IOWN was founded by NTT, intel & Sony, aiming at to define the requirement of NG all-optical network.
- They proposed some KPI: low power by 100x; higher capacity by 125x; low latency by 200x.

Summary: European and Chinese Academy & Industry work together for F6G

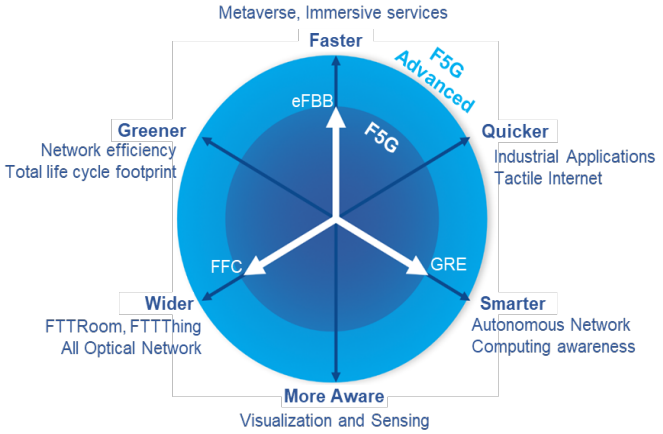
2020~2025

F5G



2025~2030

F5G Advanced



2030~

F6G

- 1.6/3.2T
- 200G PON
- NG FTTR+Wi-Fi8
- E2E slice
- L5 AN
- .....

- ETSI has defined the F5G (2020) and F5G-Advanced (2023)
- F5G Advanced is under standardization
- F6G Vision and white paper have been released by the Academy


谢谢！
Thank you!