Optical network evolution oriented at computing force network and metaverse

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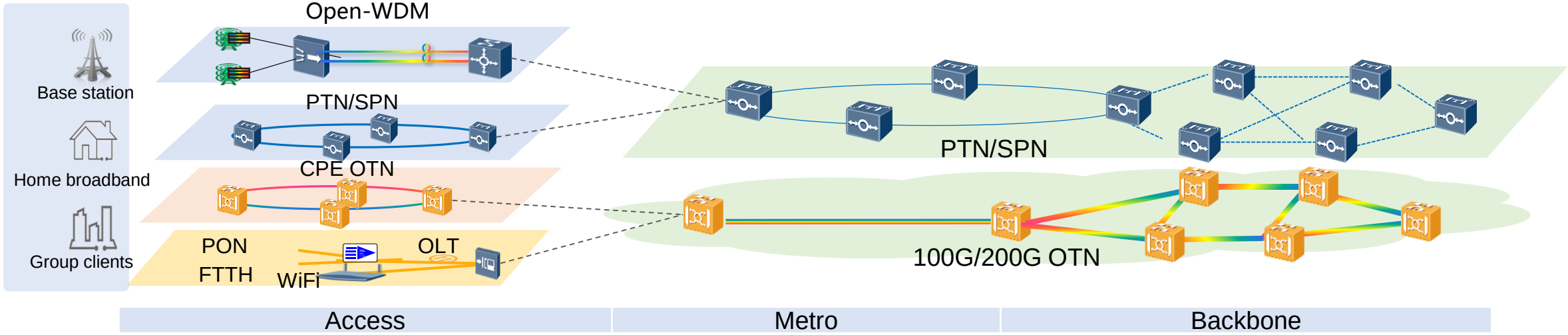
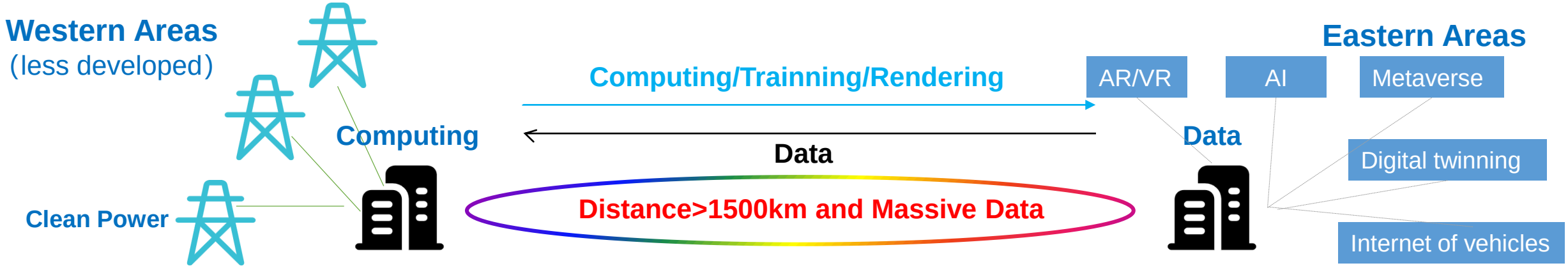
Overview of China Mobile Network

5G	Fixed broadband	Backbone
1,000,000 Base stations 520,000,000 5G users Backhaul: 400,000 SPN Fronthaul: 10G Grey interface-> 25G Open WDM	258,000,000 FTTH subscribers 200Mbps+: >70%, 1Gbps: >10% 10G PON capable OLT: >90%	OTN OTU: >660T (mainly 100G/200G) Optical cable >400,000 kilometers (G.652D->G.654E)



Computing Force Network（CFN） Introduce Challenges and Opportunitys to Optical Networks

- **Users and applications（AR/VR, AI, Metaverse etc） are located in the China Eastern areas, and we want to use abundant clean power in the West. So we started the strategy "Channel Computing Resources from East to West" to save electricity power transmission costs from the east to west.**
- **In order to improve service experiences, eastern area also has ubiquitous computing requirements,such as internet of vehicles, and requires flexible and efficient access methods.**
- **In conclusion, new services, such as Metaverse, AI and internet of vehicles, are driving the development of optical networks.**



Channel Computing Resources from East to West

- ✓ **Capacity：** 100G is not enough, 400G/800G is necessary
- ✓ **Latency：** Backbones: <20ms, Province/region: <5ms, City: <1ms

Ubiquitous Computing Requirements

- ✓ **Service flexibility：** not limited by any geographical scope
- ✓ **Latency**: determined low latency and uninterrupted computing
- ✓ **Security：** data within the park/campus

- Establishing a large capacity and ultra-low latency backbone network(400G) is the KEY to achieve the goal of CFN.
- Flexible and efficient optical access(eg. 5G, PON, SPN, OSU) is required to improve experiences and meet the demands of ubiquitous computing.

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Considerations on Key Implementation Technologies of 400G

- **In the scenario of "Channel Computing Resources from East to West" , there is a transmission demand of more than 1500 kilometers. Because of the sensitivity to delay and cost, it is hoped that the 400G un-electriccal repeated distance will reach 1500 kilometers**
- **In China, the selection of 400G modulation technology(16QAM, 16QAM-PCS, QPSK) is a hot topic, HOW about abroad?**

What we have done in 400G last years

- ✓ **2019**: 400G 16QAM @67GBd with 75GHz grid successfully reached **600km with OSNR margin over 5 dB** on our G.654.E link , reported in ECOC 2019[1].
- ✓ **2021** : 400G 16QAM-PCS @~91GBd using both single-carrier and sub-carrier techniques with 100GHz grid successfully transmitted over **1333km G.654.E with OSNR margin >7dB**.

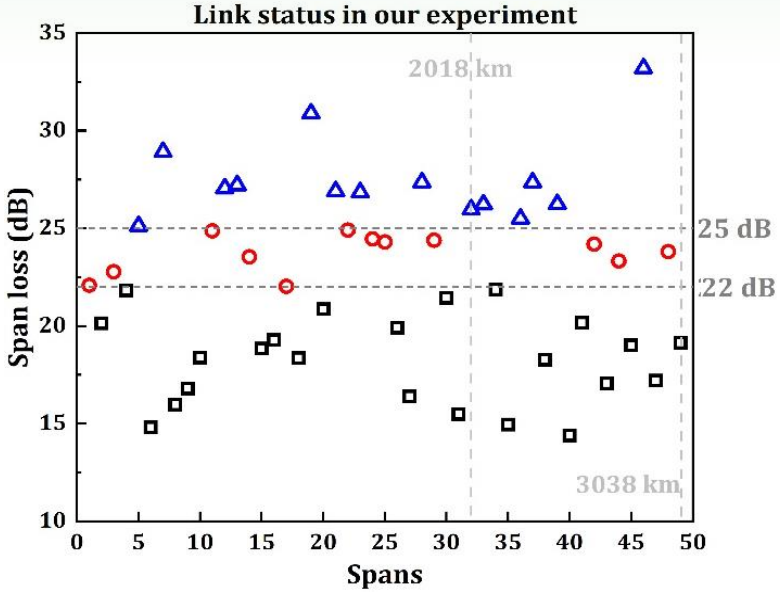
	2019	2021	
Field trail Distance	603 km @G.654.E	1077 km @G.652.D	1333 km @G.654.E
Modulation format	~67GBd 16QAM	~91GBd 16QAM-PCS	
BTB OSNR	20.2 dB	16.8~17 dB	
Channel spacing	75 GHz	100 GHz	
Launch power	4.5 dBm	4 dBm	4.72 dBm
Amplifier	EDFA	EDFA	EDFA
OSNR margin	5.13 dB	5.99 dB	7.02 dB

- 400G 16QAM-PCS @~91GBd transmission performance(1077 km@G.652.D and 1333 km@G.654.E) can not meet the requirements of"Channel Computing Resources from East to West".
- It needs new technology to support transmission of more than 1500 kilometers in G.652.D, so QPSK technology begins to emerge

●Dong Wang, et al., "FIELD TRIAL OF REAL-TIME SINGLE-CARRIER AND DUAL-CARRIER 400G TERRESTRIAL LONG-HAUL TRANSMISSION OVER G.654.E FIBER", ***ECOC 2019, W.1.A***, 2019.
●Dong Wang, et al., "Ultra-Low-Loss and Large-Effective-Area Fiber for 100 Gbit/s and Beyond 100 Gbit/S Coherent Long-Haul Terrestrial Transmission Systems", ***Scientific Reports***, 9(17162), 2019.

Latest Progress of 400G QPSK Performance Testing

Comparison of 400G QPSK/16QAM-PCS for the first time and 3038km 400G QPSK quasi real-time exploration verification for the first time were completed, both tests are tunder the current network link settings.



The maximum transmission distance of the link is 3038km for 49 spans, and the proportion of spans greater than 25dB exceeds 28%. The maximum span attenuation is 33.2dB, and the average span loss is 22.24 dB.

Transmission performance comparison			
	2018km G.652.D		3038km G.652.D
Modulation format	~91 GBd 16QAM-PCS	120GBd QPSK	120GBd QPSK
Implementation	Commercial module	External DSP, Other components are commercially ready	
BTB OSNR	**16.8 dB**	**16.43 dB**	
Launch power	5 dBm	5.5 dBm	7 dBm
Raman counts	8		25
Raman gain	10~12 dB		
OSNR margin	**2.56 dB**	**4.15 dB**	**3. 43 dB**
OSNR penalty	2 dB	0.97 dB	-

- QPSK has more 1dB advantages in OSNR margin and penalty than 16QAM-PCS, and its overall performance advantage is **more than 2dB** after 2018km transmission. **QPSK is a better choice**, which is expected to start implementation in our network **next year**.
- Components including laser, modulator and detecor are the key factor for 400G QPSK， It is necessary to promote the realization of high-speed modulator **supporting 130G baud rate**

Current 800G Research Progress

800G represents the development direction of next generation transmission, which is still in the early stage of research

- 90GBd based 64QAM-PCS single carrier 800G, G.654.E+hybrid amplification, **1000km+** transmission (ECOC 2021)
- 64QAM-PCS 800G based on 95GBd, using G.654.E+pure Raman amplification, can achieve **2018km** transmission (ECOC 2022)

	2021	2022
Distance	1122 km	2018 km
Modulation format	90.5GBd 64QAM-PCS(single-carrier)	95GBd 64QAM-PCS(sub-carrier multiplexing)
Launch power	0.33 dBm	2.31 dBm
Average pre-FEC BER after transmission	3.05E-2	1.53E-02
Average OSNR after transmission	30.79 dB	28.44 dB

- Further research on single-carrier and sub-carrier multiplexing is necessary for 800G.
- Combining 400G research results and sharing 130G high baud rate modulation industry to promote the development of 800G
- The 400G long-haul transmission will be based on the C6T+L6T optical layer. To achieve better performance based the same optical layer, higher baud rate(eg. 130G) and lower-order modulation formats(eg. 16QAM) are in need for 800G

- Han Li, et al., “Real-time Demonstration of 12-λ×800-Gb/s Single-carrier 90.5-GBd DP-64QAM-PCS Coherent Transmission over 1122-km Ultra-low-loss G.654.E Fiber”, ***ECOC 2021, We3C1.5.***
- Dawei Ge, et al., “Real-time 10-λ×800-Gb/s SCM 95-GBd DP-64QAM-PCS Transmission over 2018-km G.654.E Fibre with Pure BDRA”, ***ECOC 2022, Tu1A.1.***

Summary

To satisfy the new requirements of computing force networks and metaverse development, build an OXC-based all-optical network for computing force networks

400G is the next generation optical transmission, while QPSK is the main trend

For accessing ubiquitous computing force, it's necessary to evolve to SD-AN, realize agile access through SD-WAN, PON, OSU, SPN and other heterogeneous modes based on SDN.

If there is any question, please feel free to contact us by e-mail.

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Thank you

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