

Workshop 15: Is hollow-core fiber ready for 6G? - Technologies and Standards

6G Transport Requirements and Its Progress Based on AR-HCF

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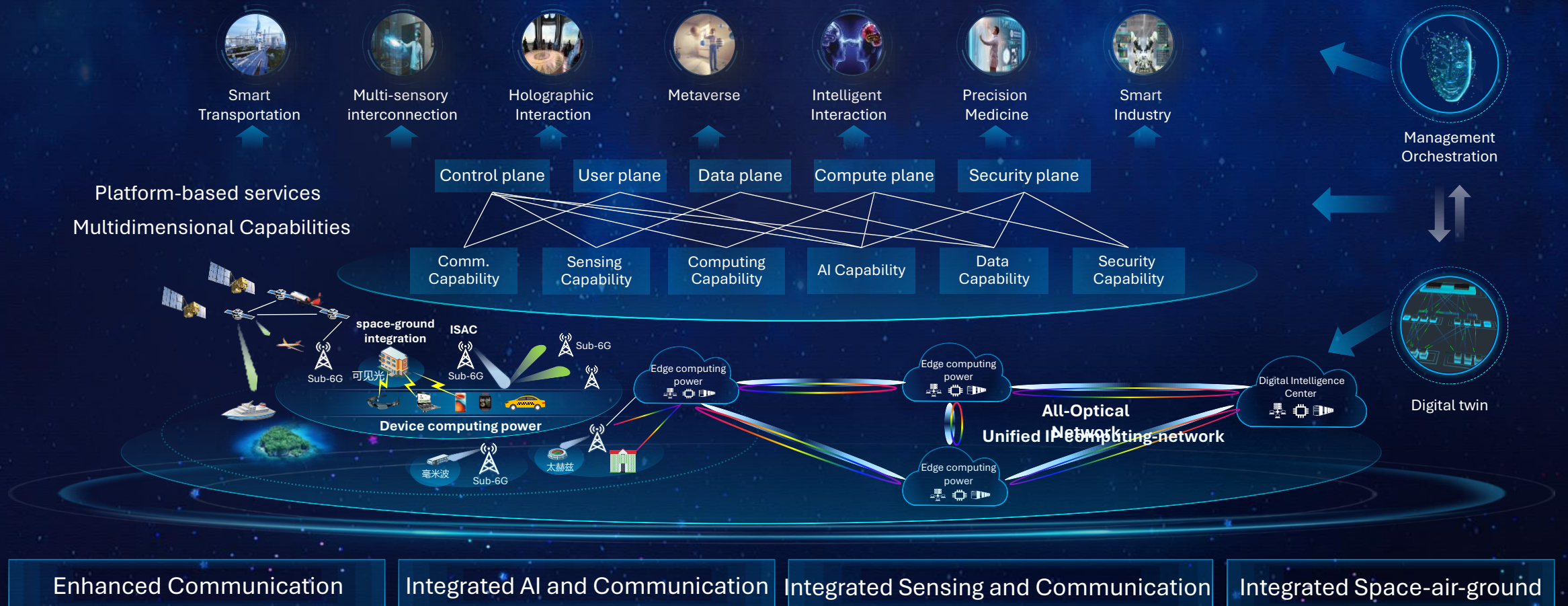
**Hollow-core Fibers' Role in 6G Transport and
China Mobile's Practice**

01

6G Prospects, New Demands for Transport and Outlooks of Key Technologies

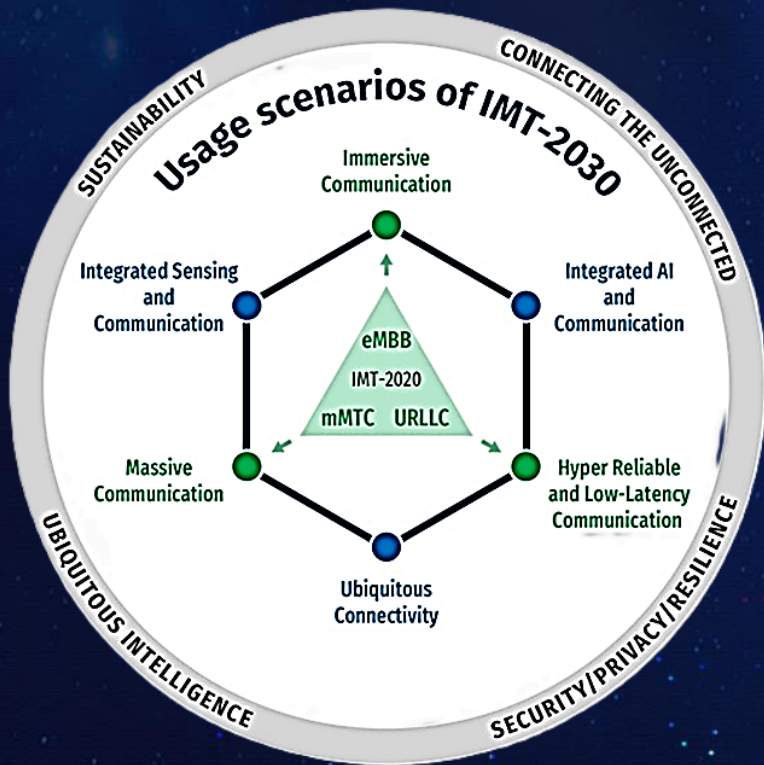
6G Overview

6G is a next-generation of mobile information network that integrates communication, sensing, computing and AI, and will provide seamless coverage across space-air-ground.



ITU-R Clarifies 6G Usage Scenarios and Capabilities

6G network will act as a platform to comprehensively enable capabilities such as AI, sensing, computing, etc, and the network will transform from communication services to information services

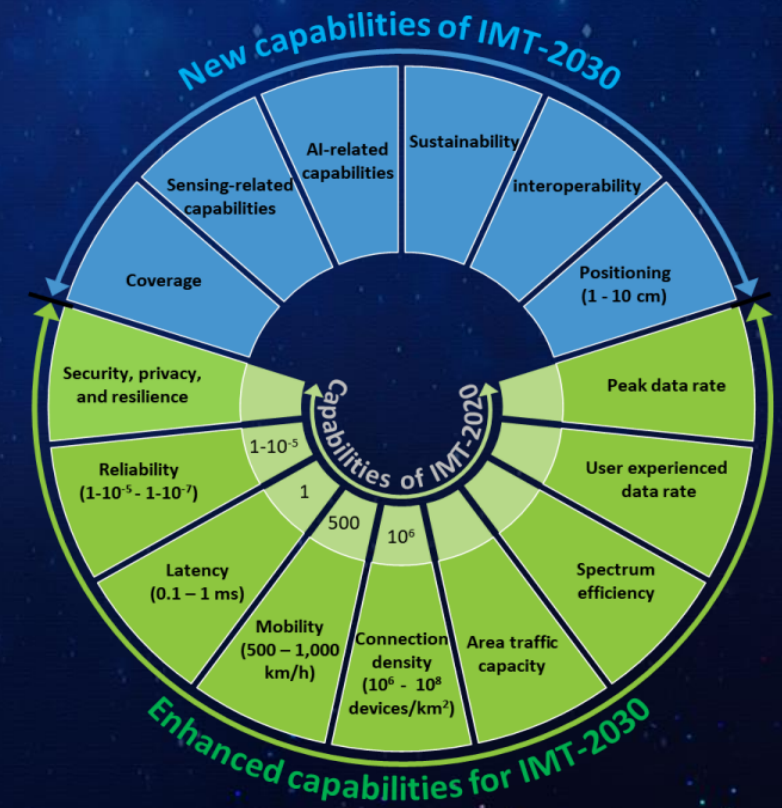


The typical scenarios

- **Performance immersion:** 3 major scenarios enhancement
- **Elements integration:** AI, sensing
- **Coverage globalization:** space-air-ground

The technical KPI

- **6G new capabilities expansion:** coverage, sensing, AI, etc
- **5G capabilities enhancement:** reliability, latency, spectrum efficiency, data rate, etc



6G Fronthaul Network Confronts Unprecedented Challenges

Higher 6G frequency bands and denser sites require a large number of high-speed fronthaul connections, posing great challenges to fronthaul networking and technologies.



For 6G fronthaul, eCPRI interface is expected to be around 100Gbps.

Dispersion tolerance of 100G fronthaul reduces to 1/16 compared with 25G, becoming the major challenge.

O-band or C-band?

100+ GBd NRZ or 56 GBd PAM4?

CWDM, MWDM, LWDM or DWDM?

1

O-band is cost effective due to low dispersion and reusing of short distance optics

2

oDSP become necessary mainly for dispersion compensation

3

PAM4 is preferred than NRZ provided available performance due to cost advantages

4

CWDM/MWDM may still dominate the fronthaul market for cost advantages

5

Management and control become more important as the C-RAN scale increases, and the semi-active architecture is more attractive.

Evolution of 6G Backhaul Network Technologies



Mobile Backhaul

Rate enhancement necessitates **optical module** capable of transmitting over metro distances of 10km/40km

BIDI optical module is mandatory because 1588 for time synchronization is still need

Denser base stations and tens of thousands of nodes of 6G brings challenges to IP connection

Femto Access

Low latency, the largest challenge of 50G PON for 6G Femto

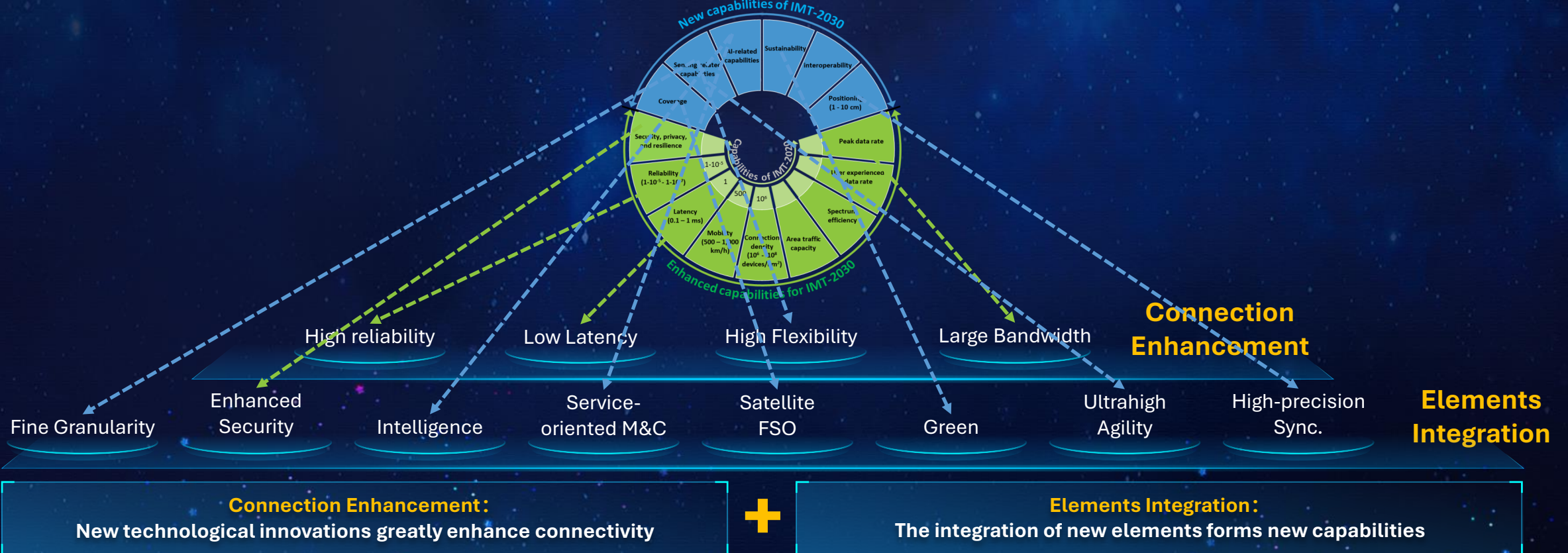
single frame multi-bursting | ad-hoc register windows

Network Slicing Capability

oDSP for Dispersion Compensation

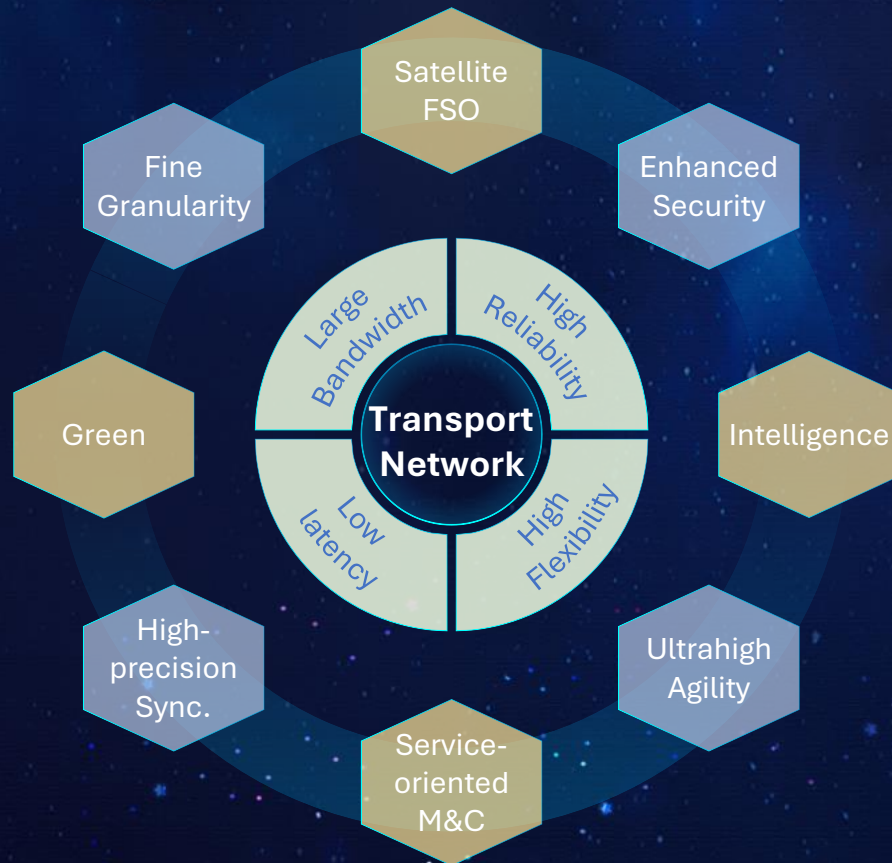
Mapping 6G Capabilities to 6G Transport Technologies

The upgrade of 6G scenarios and capabilities requires enhancing connection capabilities and integrating several new elements into the transport network, driving the transformation of network capabilities from mere connection to advanced functionalities.



6G Requires Multi-dimensional Improvement of 6G Transport

6G “Connect to Intelligence” motivates 6G transport network “Intelligent Connection” evolution, building multi-dimensional abilities of “Beyond Connection”



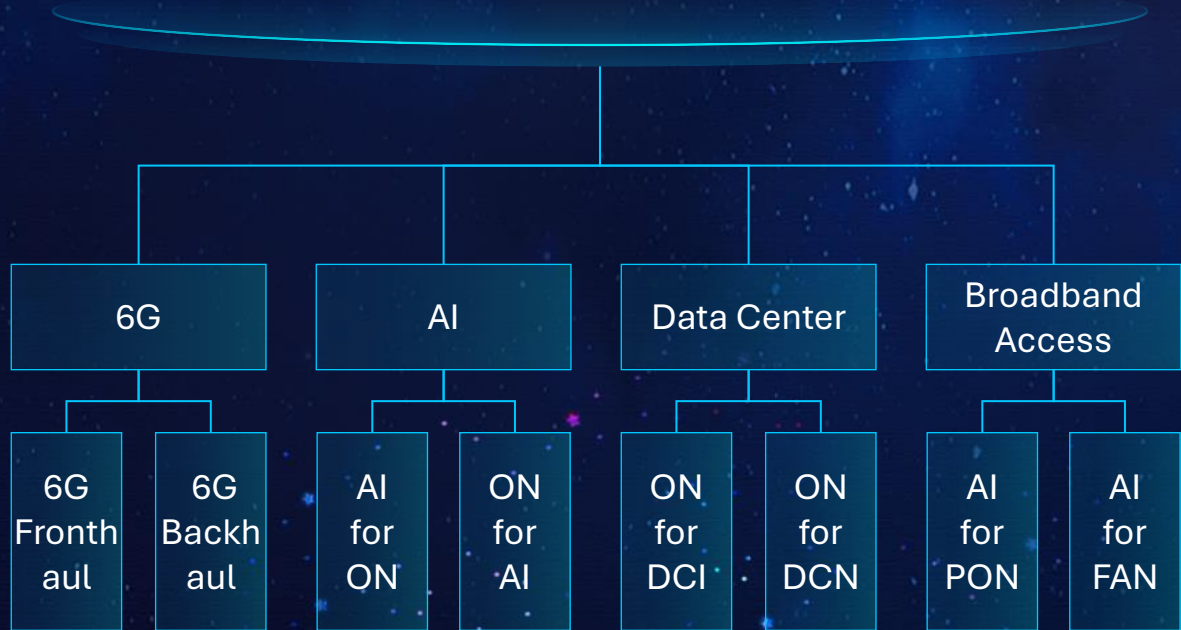
Capabilities

Large Bandwidth	Single station peak data rate $\times 10$
	Fronthaul data rate 100G
	Access: 200G
	Aggregation: 400G
Low Latency	Core: 1.6T
	Cross Station Coordination $\sim 100\mu\text{s}$
	Femto Latency Requirements $\sim 300\mu\text{s}$
High Flexibility	Backhaul Latency Requirements $\sim \text{ms}$
	Connection Setup $\sim \text{minute}$
	Connection Density $\times 10 \sim 100$
High Reliability	Air Interface Reliability $1 \sim 10^{-6} \sim 1 \sim 10^{-7}$
	Transmission Reliability $1 \sim 10^{-7}$

ITU-T SG15 has started ION2030 work item

Referring to IMT2030 discussed in the field of mobile networks, ITU-T SG15 has started the ION2030 work item including four major scenarios of 6G transport、 AI、 data center and broadband access

International Optical Network for 2030 and beyond




- 2026.7** • Formally release the ION2030 technical report and guide subsequent standard development
- 2025.10** • Draft of ION2030 technical report will be completed based on broad inputs
- 2025.03** • ITU-T SG15 agreed to start ION2030 work item for next-generation optical network
- 2024.07** • China Mobile demonstrated the 6G transport network concept in ITU-T for the first time

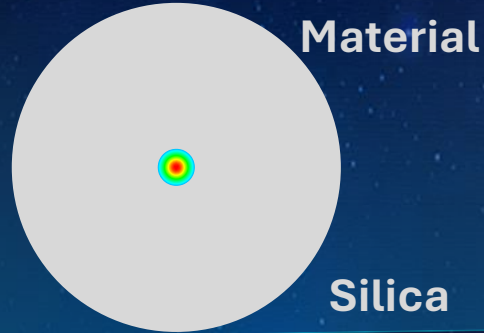
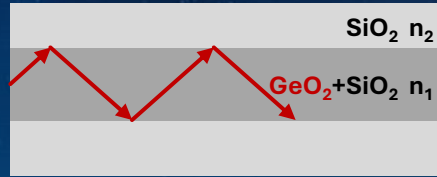
02

**Hollow-core Fibers' Role in 6G Transport and
China Mobile's Practice**

AR-HCFs suit 6G transport network requirements

Solid-core Single-mode Fiber

TIR-based waveguiding



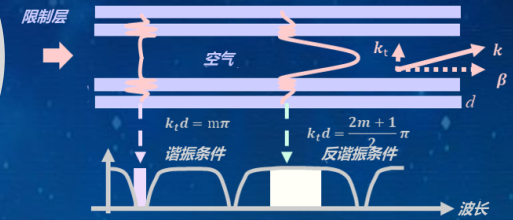
Antiresonant Hollow-core Fiber

Structure



Gas

Antiresonant reflection guiding



Ultra-low latency

Saving latency >30%

Near the speed of light in vacuum

Latency-Sens. Appl.

AI Large Models

Ultra-low Thermal-Sensitivity

Reducing 20x

About ~2ps/km/K

Latency-Sens. Appl.

High-res. Synchronization

Ultra-low Backscattering

Reducing ~28dB

About -100dB/km1

Directional Dimension

Same-wavelength BiDi

Ultra-low loss

<0.1dB/km

Breaking the Silica Loss Limit

Determining Performance

Long Spans

Ultra-low nonlinearity

Reducing ~1000x

Dense Silica → Rarefied Gas

Breaking Nonlinearity Limit

Low Complexity, High SNR

Ultra-wide spectrum

Broadening >10x

Theoretical Coverage of Near-Infrared Band

Free Band Choice

1um、O/E/S/C/L/U、2um

Low Latency

High-precision Sync.

Large Bandwidth

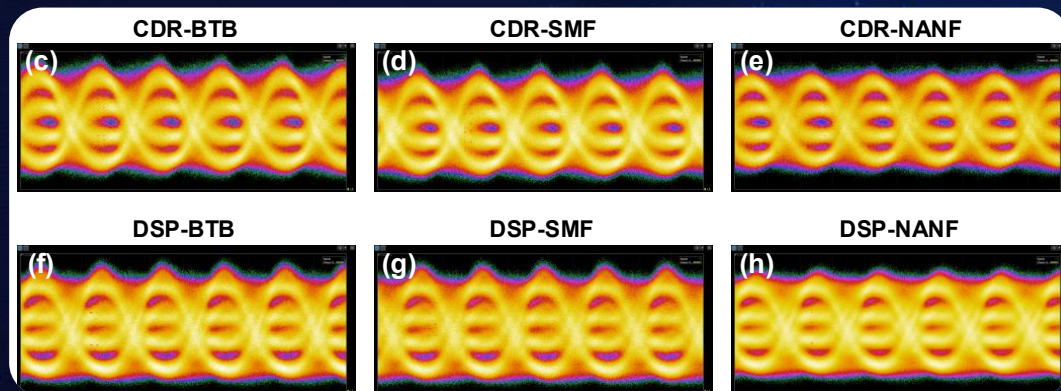
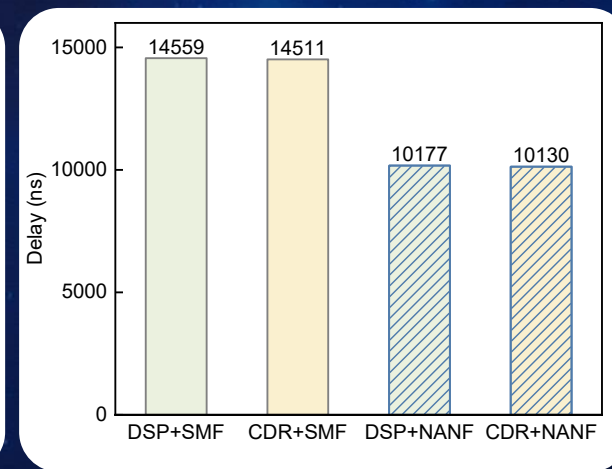
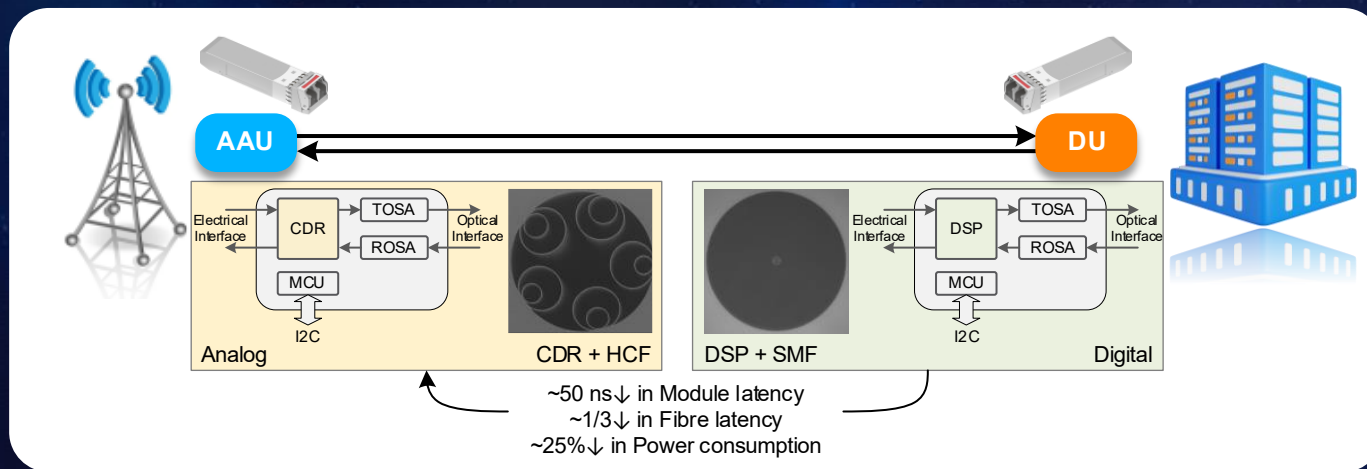
Enhanced Security

6G transport network requirements

Low footprint/low latency fronthaul over AR-HCF

AR-HCF helps to reduce both fiber and module latency by pairing with CDR-based fronthaul modules

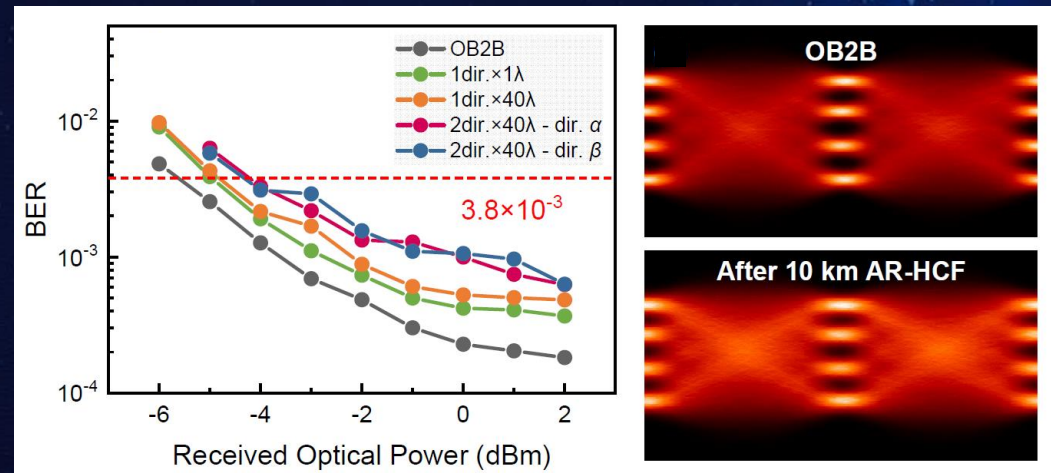
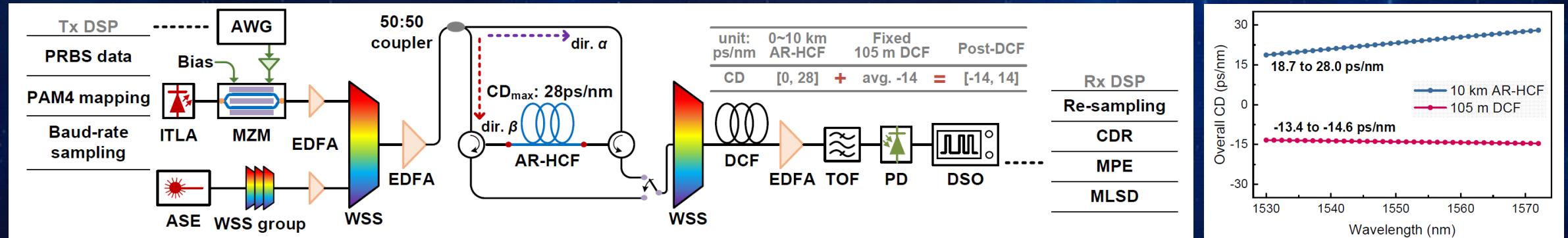
Pure channel characteristics of AR-HCF suits for low latency fronthaul.



- **Optical module latency:** ~98% reduction by replacing DSP with CDR
- **Fiber latency:** ~30.2% reduction by HCF
- **Power consumption:** 24.99% (1.709 W → 1.282 W) reduction by replacing DSP with CDR

Large capacity DWDM fronthaul over AR-HCF

For large capacity DWDM fronthaul over SMF, FWM is the main risk because of nonlinearity and low CD, AR-HCF helps to mitigating nonlinearity while non-negligible CD becomes the major problem.



- **DCF**: to keep CD values of **fronthaul link (0~10km)** between **±14ps/nm/km**, falling into DSP compensation ability
- **Same Wavelength BiDi**: increase capacity by **2x without noticeable penalty**
- **Overall capacity**: 2dir.×40λ×224 Gb/s = **16.7 Tb/s**, **~55x** larger capacity than current commercial WDM fronthaul
- **Transmission distance**: 10km

AR-HCF can also be used in backhaul scenario

Multiple field trials have been carried out in 2024 over the length of 10~42.7km, typical backhaul distance
 AR-HCF cables have normally running applications for ~ 12 months, showing great stability.

Field trial evolution in 2024 in China



Source: D. Ge et al., OFC 2025, W1C.4.



Source: D. Ge et al., OFC 2025, M1F.3.

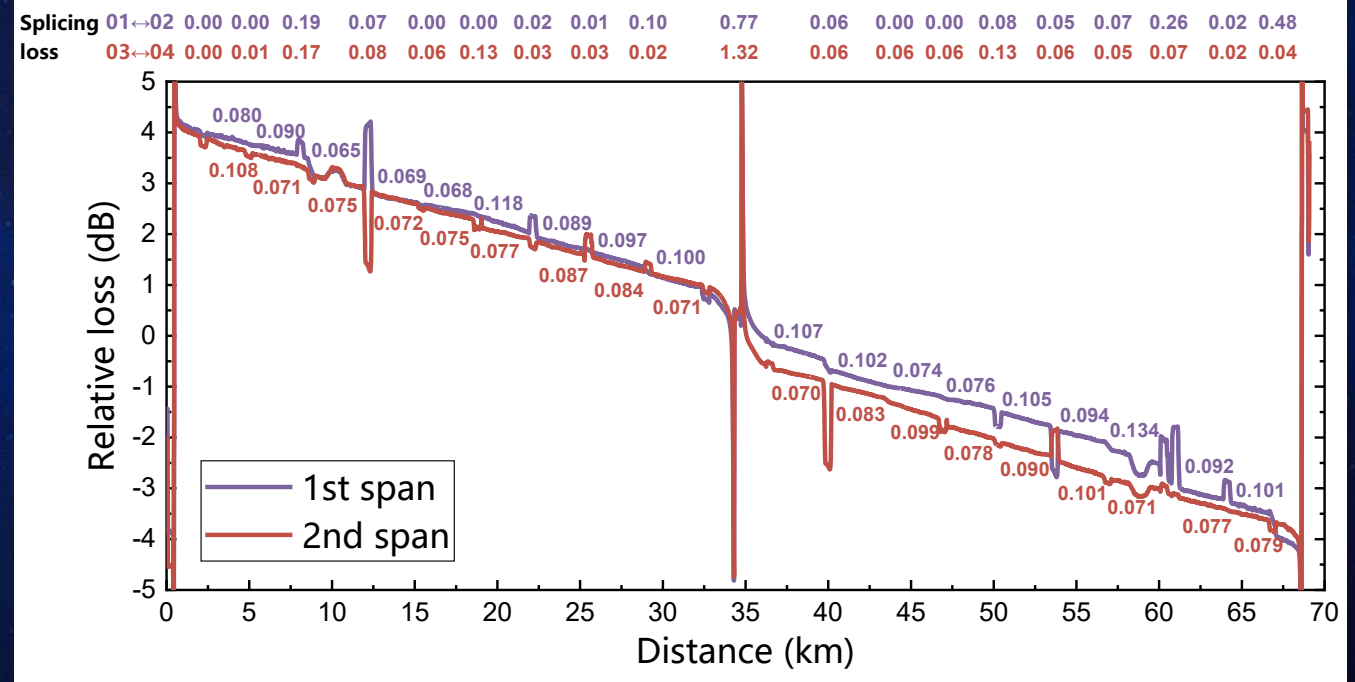


Source: D. Ge et al., OECC 2025, MC3-1.

First AR-HCF commercial deployment in China

In July 2025, China Mobile deployed the first commercial AR-HCF cable link between Shenzhen stock exchange market and Hongkong stock exchange market for stock trading.

First commercial deployment in China



- Average deployed fiber loss: **0.085 dB/km**
- Average splicing loss: **0.07dB/point**
- Max. CO₂ absorption: **0.263 → 0.078dB/km**

Standardization progress

China Communications Standards Association

ITU-T SG15/Q5 & Q6

中国通信标准化协会
CCSA
课题编号: 2023R33

空芯光纤技术研究

2024年10月

中国通信标准化协会
CCSA
课题编号: 2023R24

基于空芯光纤的超高速光传输技术研究

2024年08月

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SG15-C0455¹
STUDY GROUP 15
CONTRIBUTION¹

Source:^{1,2} China Mobile Communications Corporation; China Academy of Information Communications Technology; China Telecommunications Corporation; Yangtze Optical Fibre and Cable Joint Stock Limited Company; TKH Group NV; Viavi Solutions^{1,2}

Title:¹ Proposal for a New Technical Report on Hollow-core Fibres and Corresponding Transmission Technologies^{1,2}

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Abstract:^{1,2} This contribution briefly describes the progress of hollow-core fibres and corresponding transmission technologies in recent years both in academic and industry. Commercial deployments have been started in North America, China and Europe. It is proposed that a work item should be started to write a new technical report on hollow-core fibres and corresponding transmission technologies in Q5/15 and Q6/15.^{1,2}

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STUDY GROUP 15
CONTRIBUTION¹

Source:^{1,2} China Mobile Communications Corporation^{1,2}

Title:^{1,2} Discussion on categories of hollow-core fibres^{1,2}

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Abstract:^{1,2} This contribution briefly discusses the categories of hollow-core fibres. It is proposed that among all these categories, anti-resonant hollow-core fibres (AR-HCFs) may be the preferred one in optical communications.^{1,2}

1 Introduction:^{1,2}
Since 2023, several contributions related to hollow-core fibres (HCFs) have been submitted to Q5 and Q6. These contributions have provided information on the development of HCFs and introduced basic concepts. C0825 (Nov. 2023) [1] shared key performances and trial progresses about HCFs. C0022 (Mar. 2025) [2] showed the feasibility of AR-HCFs, and proposed to establish a new TR. WD06-09 (June 2025) [3] showed the feasibility of optical transmission systems based on AR-HCFs, proposing that Q6 should further collaborate with Q5 to start technical discussions on AR-HCFs, optical transmission systems based on AR-HCFs, and applications. WD05-14R1 (July 2025) [4] shared various measurement results on HCFs. Growing attentions have been paid to HCF by Q5&Q6 experts from operators, manufacturers and institutes, and new entities and expert joins the Questions for the topic. However, there are several kinds of HCFs, whether or not they should be all included in future discussion is a predominant question.^{1,2}

2 Discussion:^{1,2}
Since the first report of air-guidance in optical fibre in 1999 by P. Russell et al., there are two main categories of HCFs. One is hollow-core photonic bandgap fibre (HC-PBGF), and the other one is anti-resonant hollow-core fibre (AR-HCF).^{1,2}

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STUDY GROUP 15
CONTRIBUTION¹

Source:^{1,2} China Mobile Communications Corporation^{1,2}

Title:^{1,2} AR-HCF and its role in ultra-wide band transmission systems^{1,2}

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Abstract:^{1,2} This contribution briefly introduces the enhancement of AR-HCF in UWB transmissions, with comprehensive comparison with UWB based on SMPs.^{1,2}

1 Introduction:^{1,2}
At the plenary meeting in March, 2025, there was a contribution [1] submitted to Q5/15 proposing to start standardization activities on anti-resonant hollow-core fibres (AR-HCFs) with drafting a Technical Report. Q5/15 agreed to invite further information on hollow-core fiber technologies to consider the possibility of a new technical report in Q5 [2]. In June, 2025, China Mobile et al. also submitted a contribution to Q6/15 about the feasibility of optical transmission systems based on AR-HCFs, proposing that Q6 should further collaborate with Q5 to start technical discussions on AR-HCF, optical transmission systems based on AR-HCF, and its applications. In the meeting report of Q6 interim meeting [3], it was agreed that a joint meeting will be held during the October 2025 plenary meeting specifically addressing HCF and related transmission systems. We can see that both HCFs and corresponding transmission systems have been rapidly discussed in Q5&Q6.^{1,2}
As we all know that AR-HCFs have many advantages: lower losses (<0.1dB/km at the lowest point) than conventional solid-core fibres, ultra-low nonlinearity (3-4 order of magnitude decrease), ultra-wide transmission window (>60THz), low chromatic dispersion (about 2-5 ps/nm.km in transmission windows), and minimum latency (over 10% reduction). In this contribution, we would like to discuss the aspect of ultra-wide transmission window, showcasing the role of AR-HCF in ultra-wide band (UWB) transmissions.^{1,2}

2 Discussion:^{1,2}
UWB optical transmission systems appear as a promising solution to enhance capacity within the existing optical fibre infrastructure by maximizing WDM transmission in single-mode fibres (SMFs) [4]. This strategy extends the conventional C-band to super C-band [5], C-L-bands, add

Technical report of hollow-core fiber

Technical report of optical transmission techniques based on hollow-core fiber

Contributions to Q5/Q6 in October 2025

Welcome to join us in contribution to ITU-T for AR-HCF and its transmission system's technical research!

Conclusions

- ✓ **6G requires low latency, large bandwidth, high precision sync. and enhanced security, which are great matches for AR-HCF to meet with compared to SMF.**
- ✓ **AR-HCF is technically ready, but massive industrial manufacturing and standardization are still major challenges for its future utilization.**



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Thank you

