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

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

Dong Wang | China Mobile Research Institute

Sep 28, 2025

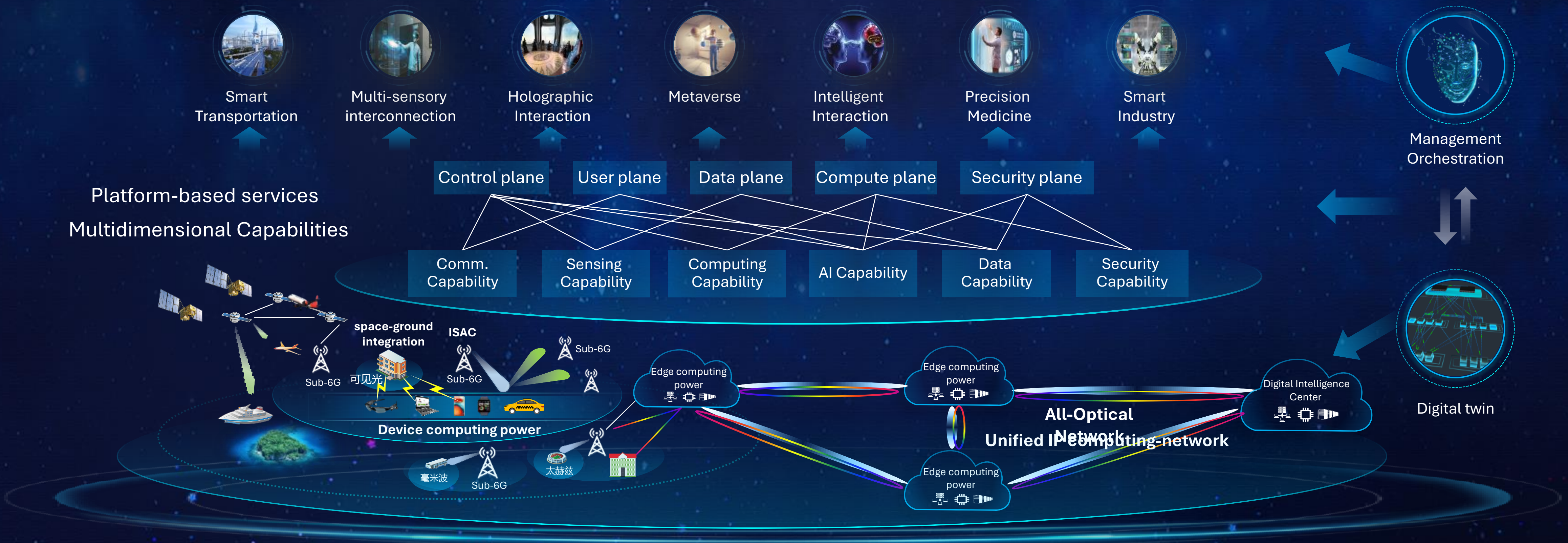
Contents

01

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

6G Overview

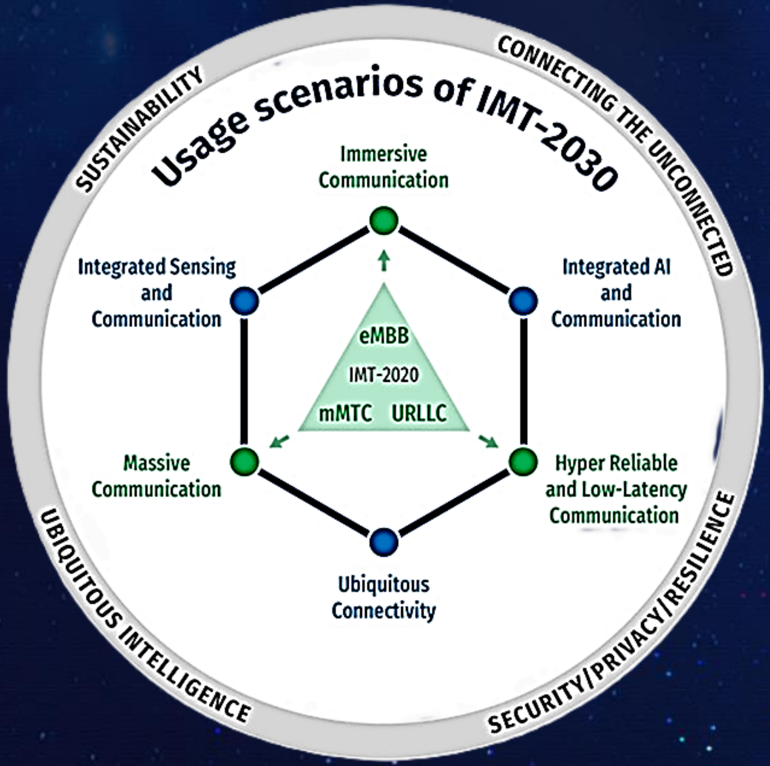
6G is a next-generation of mobile information network that integrates communication, sensing, computing and AI, and will provide seamless coverage across space-air-ground.



Enhanced Communication | Integrated AI and Communication | Integrated Sensing and Communication | Integrated 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

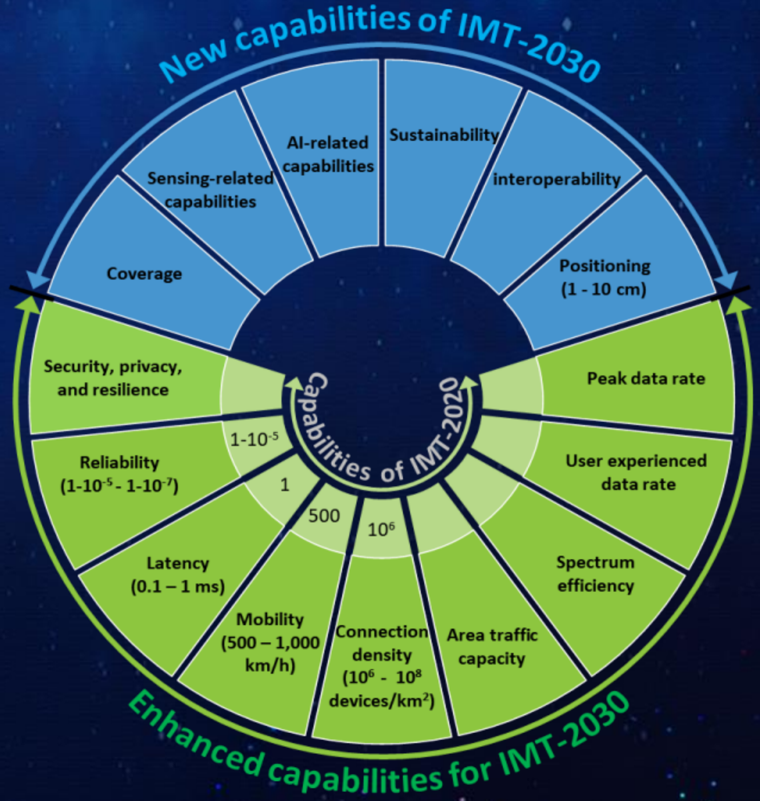


The typical scenarios

- **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

ECOC2025 | 中国移动 China Mobile

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

Fronthaul Requirement Changes

700MHz	2.6GHz	4.9GHz	6-7GHz	mmW(26GHz)
@30M	@160M	@160M	@1.2G	@2-2.75G

Base station density increases by **~10 times**

Spectrum resources increase by **~10 times**

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

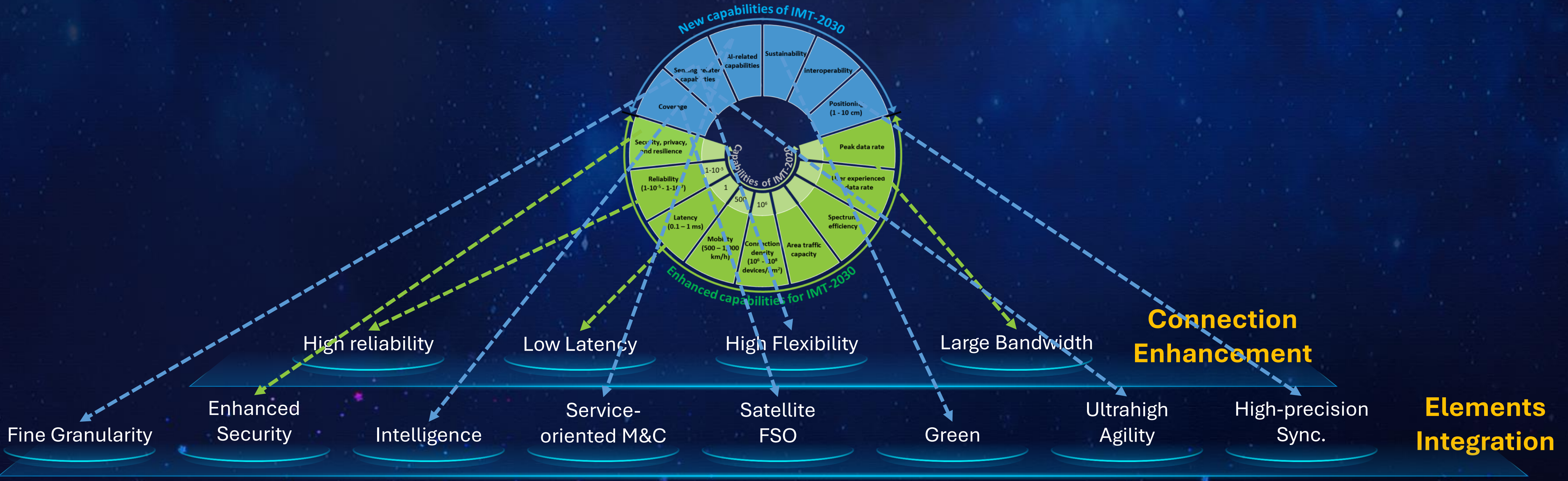
single frame multi-bursting | ad-hoc register windows

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.



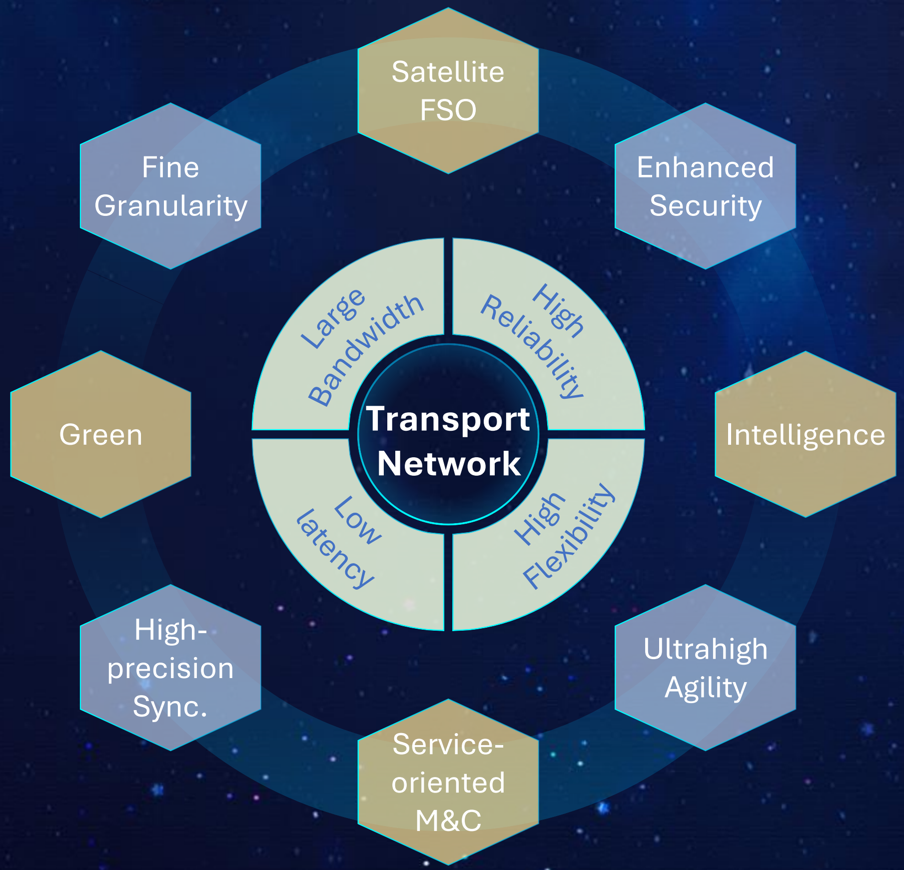
Connection Enhancement:
New technological innovations greatly enhance connectivity

+

Elements Integration:
The integration of new elements forms new capabilities

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"



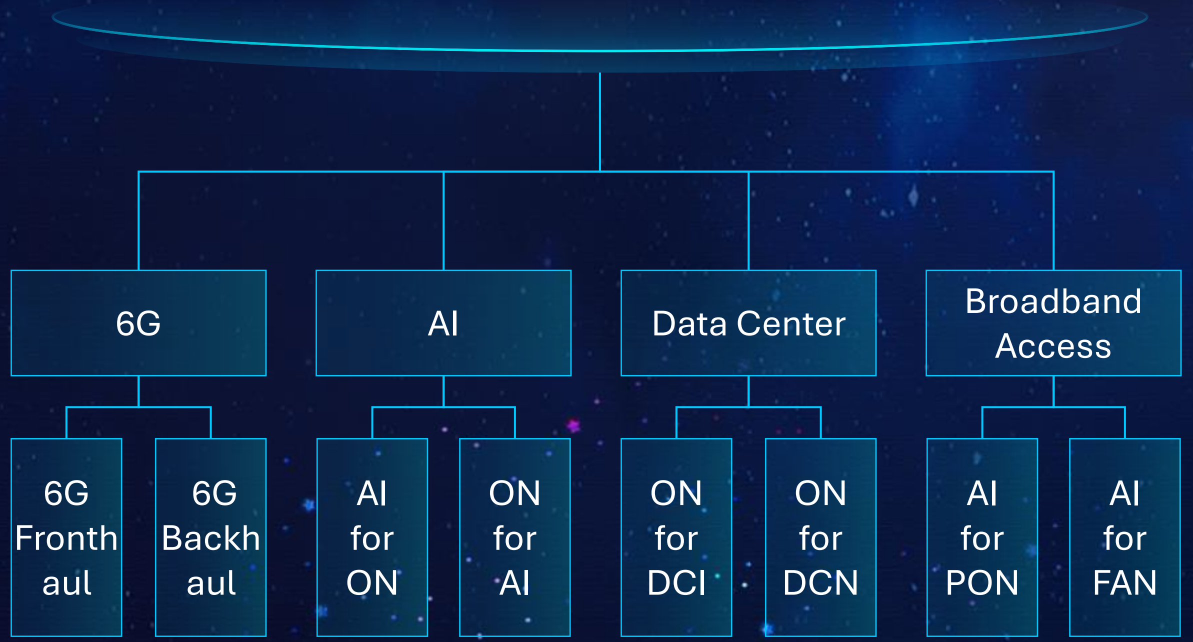
Capabilities

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

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

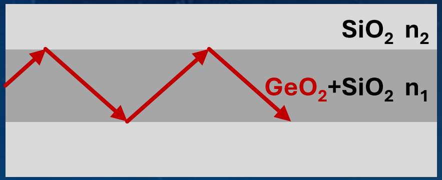
Hollow-core Fibers' Role in 6G Transport and China Mobile's Practice

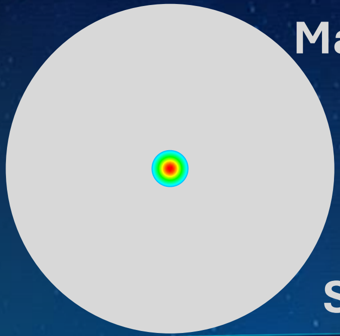
AR-HCFs suit 6G transport network requirements

Solid-core Single-mode Fiber

Material

TIR-based waveguiding





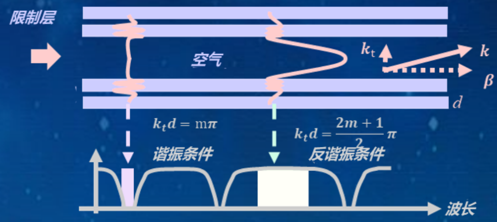
Silica

Antiresonant Hollow-core Fiber

Structure

Gas

Antiresonant reflection guiding



Ultra-low latency	Ultra-low Thermal-Sensitivity	Ultra-low Backscattering	Ultra-low loss	Ultra-low nonlinearity	Ultra-wide spectrum
Saving latency >30% Near the speed of light in vacuum	**Reducing 20x** About ~2ps/km/K	**Reducing ~28dB** About -100dB/km1	**<0.1dB/km** Breaking the Silica Loss Limit	**Reducing ~1000x** Dense Silica → Rarefied Gas	**Broadening >10x** Theoretical Coverage of Near-Infrared Band
Latency-Sens. Appl. AI Large Models	**Latency-Sens. Appl.** High-res. Synchronization	**Directional Dimension** Same-wavelength BiDi	**Determining Performance** Long Spans	**Breaking Nonlinearity Limit** Low Complexity, High SNR	**Free Band Choice** 1um、O/E/S/C/L/U、2um

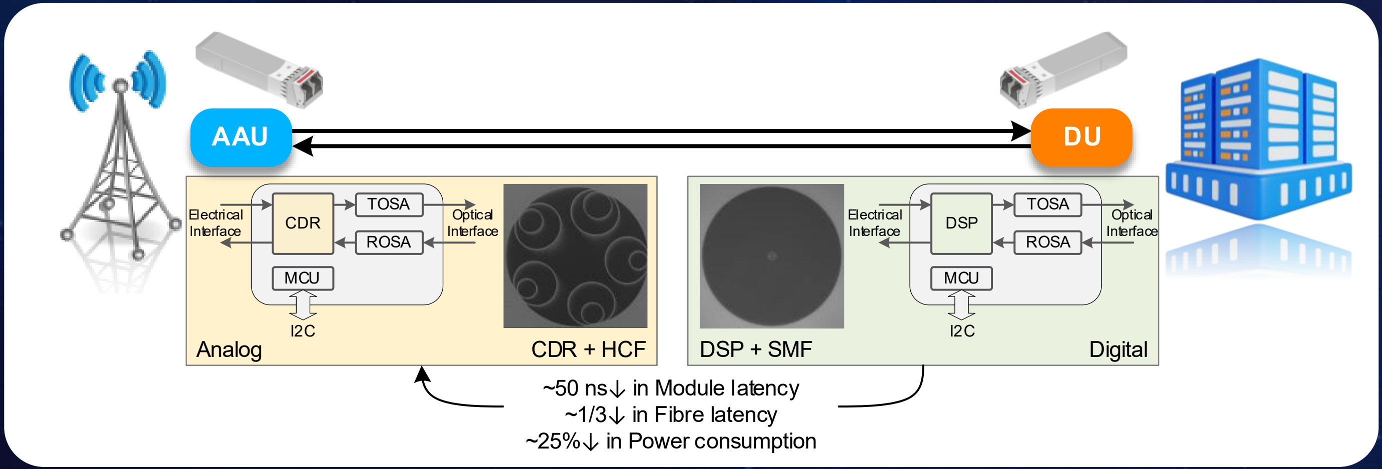
Low Latency | High-precision Sync. | Large Bandwidth | Enhanced Security

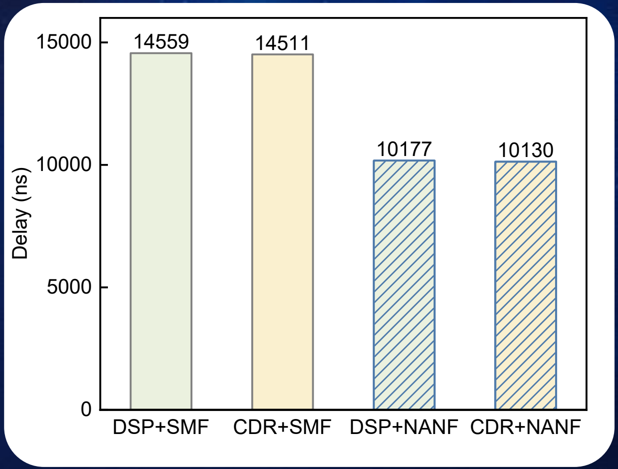
6G transport network requirements

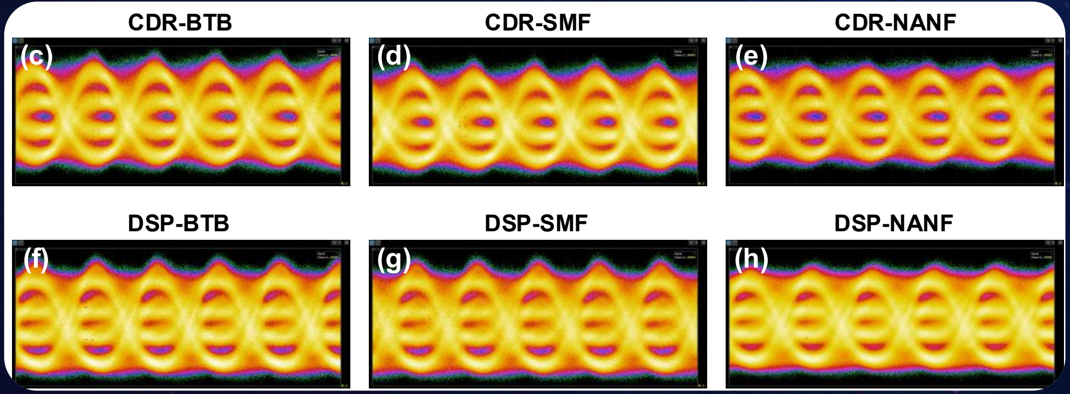
Low footprint/low latency frontthaul over AR-HCF

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.





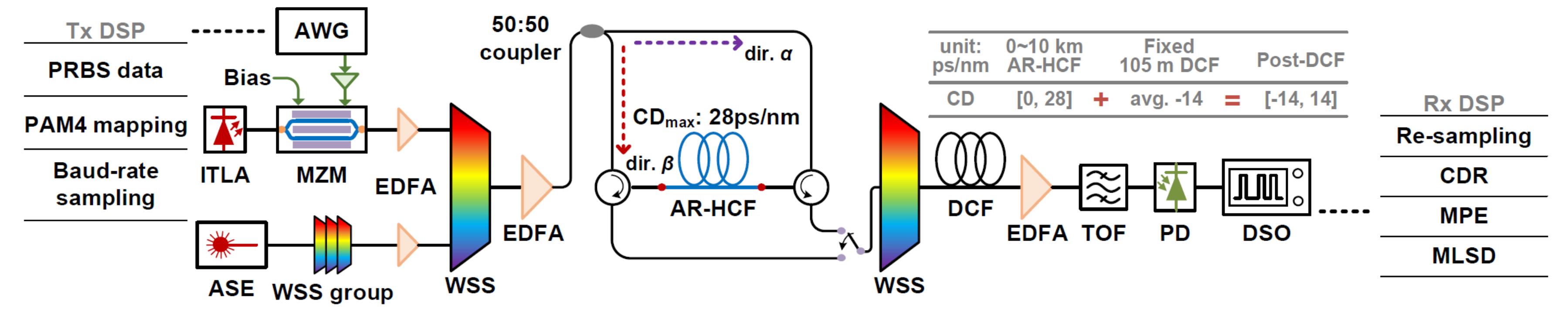


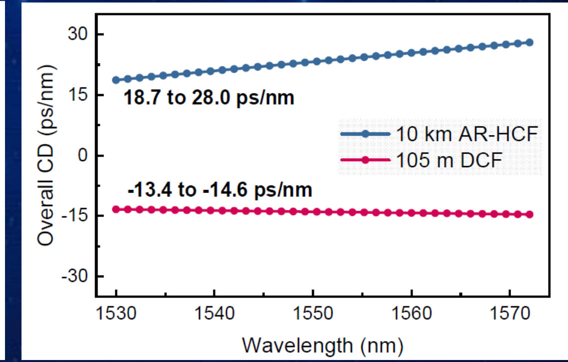
- **Optical module latency**: ~98% reduction by replacing DSP with CDR
- **Fiber latency**: ~30.2% reduction by HCF
- **Power consumption**: 24.99% (1.709 W → 1.282 W) reduction by replacing DSP with CDR

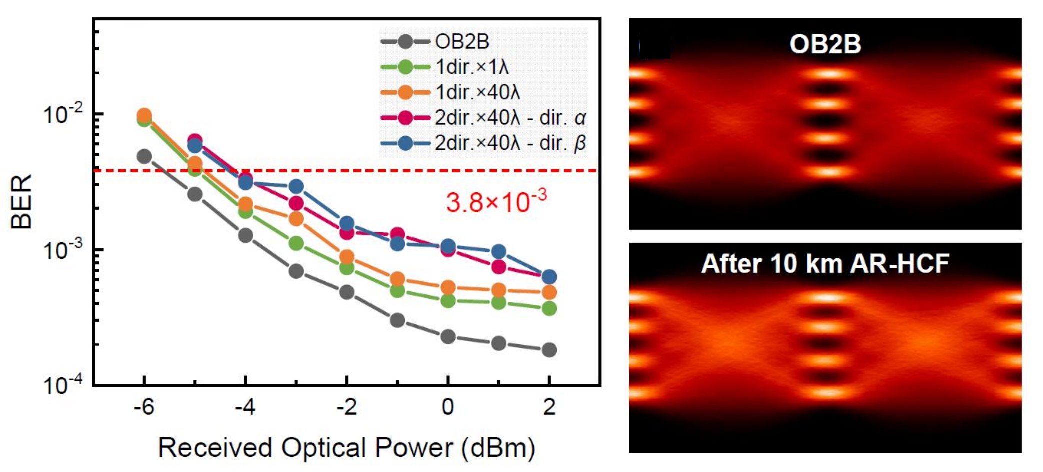
* Dawei Ge et al., ECOC 2024, W2A.113.

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

* Mingqing Zuo et al., ECOC 2025, O-SC7-08.3.

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.

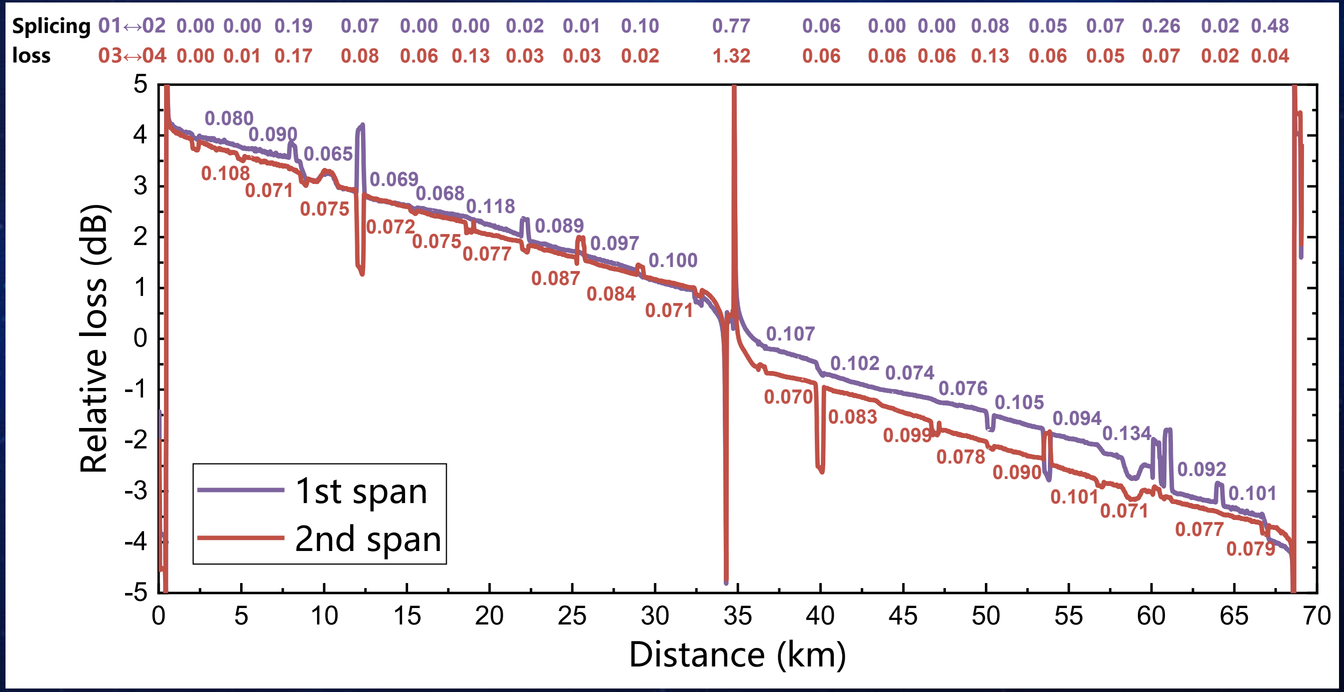
Source: D. Ge et al., OFC 2025, M1F.3.

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. CO_2 absorption： **0.263 → 0.078dB/km**

Standardization progress

China Communications Standards Association

ITU-T SG15/Q5 & Q6

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.

Thank you