ITU workshop on “The Evolution of Transport and Access Networks to Support IMT 2030/6G”, 7 July, 2024

6G Transport Requirements and Technologies

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Contents

中国移动
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01

6G Prospects：New Generation-oriented Information Service Network

Ubiquitous 5G Network Empowers ToC and ToB Business

- **eMBB**: 5G supports diverse services, and now **short videos** account for **70% total traffic**. Users Dataflow of Usage (DOU) is nearly **18 GB/month**, and **40%** users consumes over **30GB/month**.
- **mMTC**: Towards full-scenario, 5G supports connection densities of up to **1 million devices/km²**.
- **uRLLC**: Targeting low latency and high reliability for 5G vertical industry, **300,000 VPN customers** over 5G has been deployed, **edge computing applications account for 60%** and **network slicing account for 10%**.

ToC: Upgrade Experience

5G Split Ratio

>60%

Dataflow of Usage

ToB: Empower Verticals

Edge Computing 60% + **Network Slicing 10%**

300,000 VPN customers


5G+ industry
>6948


5G+ electric power
> 547

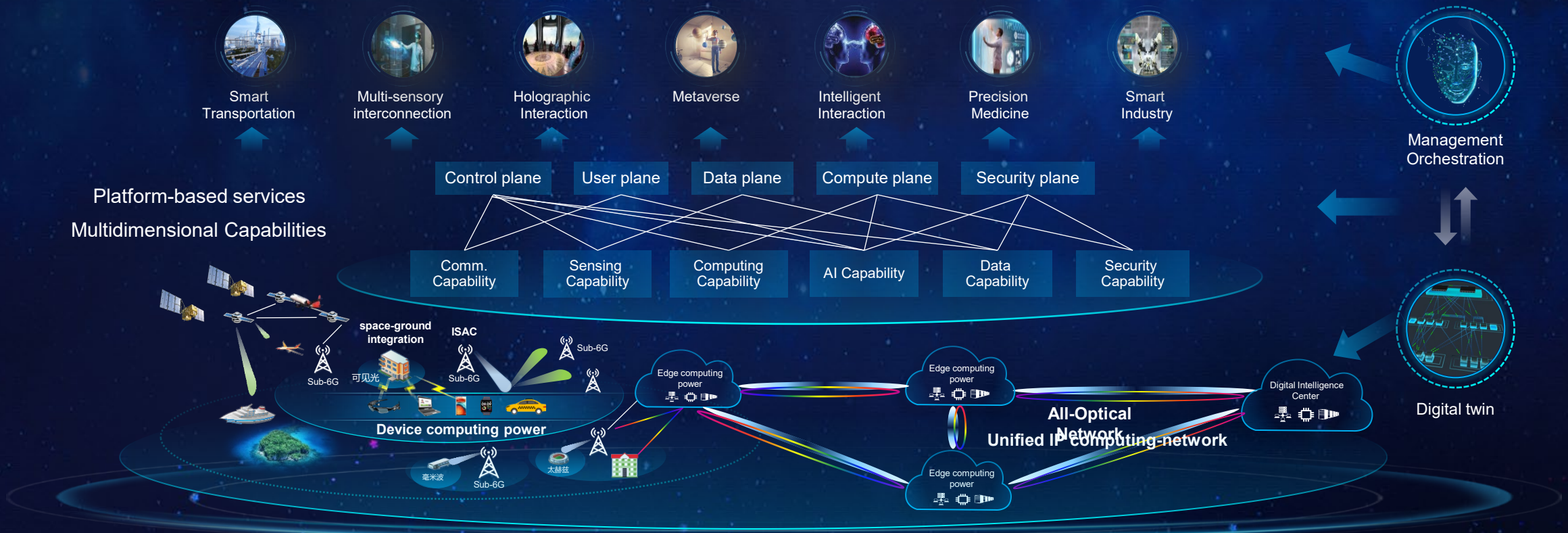

5G+ hospital
>2149


5G+ mining
>614

Notes: Data from CMCC

6G Overview

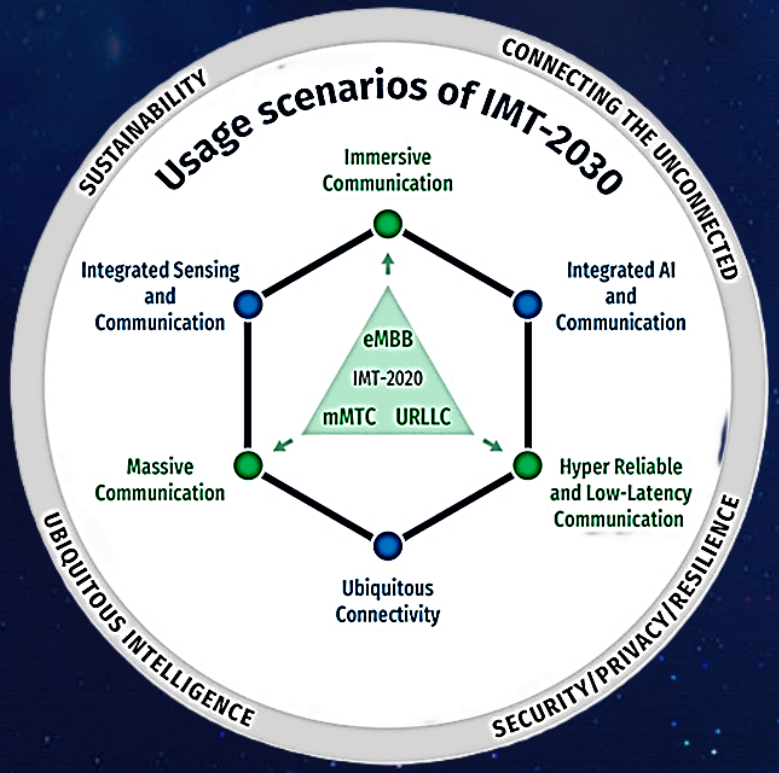
6G is a next-generation of mobile information network that integrates communication, sensing, computing and AI, and will provide seamless coverage across space-air-ground.



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

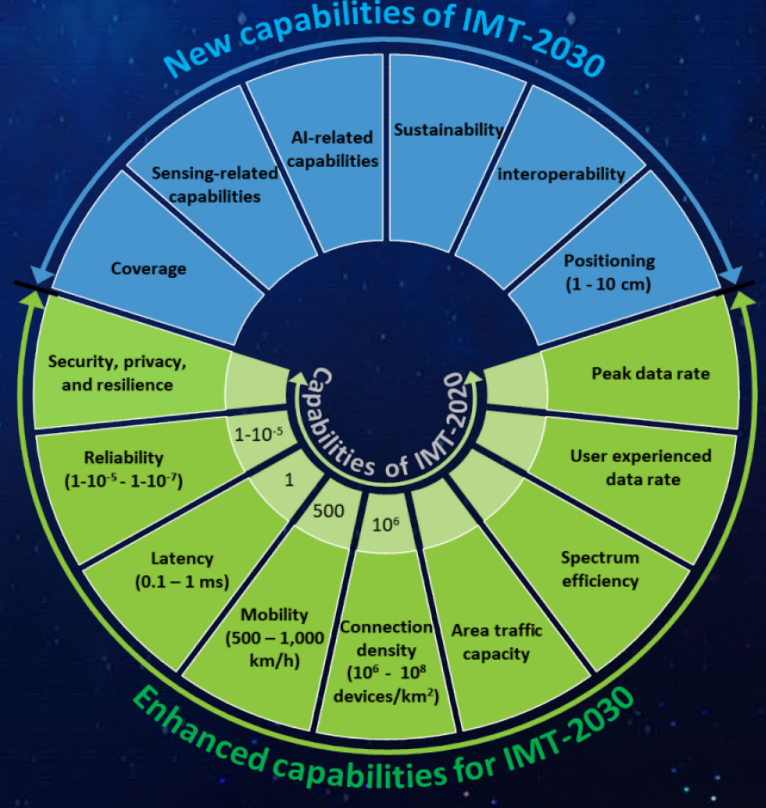


The typical scenarios

- **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



02

6G's New Demands for Transport and Outlooks of Key Technologies

What is 6G?

Opinion 1: 6G is a **multi-band merged network** combining high, medium, and low frequencies. The low-frequency supports continuous coverage, while high frequencies support large traffic in hotspot areas.

Opinion 2: 6G is **integration of communication and sensing**, where communication and sensing share frequency resources, mutually empowering each other to achieve more efficient transmission and sensing.

Opinion 3: In 5G, CP and UPF are separated, with CP centralized and UPF deployed on demand. 6G CN will evolve towards **distributed autonomy**, where the Small Cloud Unit, integrating both UPF and CP, will be widely deployed.

Opinion 4: 6G features **ubiquitous intelligence**. RAN, TN, and CN will evolve from independently introducing AI as needed towards E2E AI models, for cross-domain/network integrated platform services.

Opinion 5: 6G is **integration of terrestrial network and NTN**. The terrestrial network remains the primary carrier of services, while the NTN is the complement and enhancement based on the terrestrial network.

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.

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

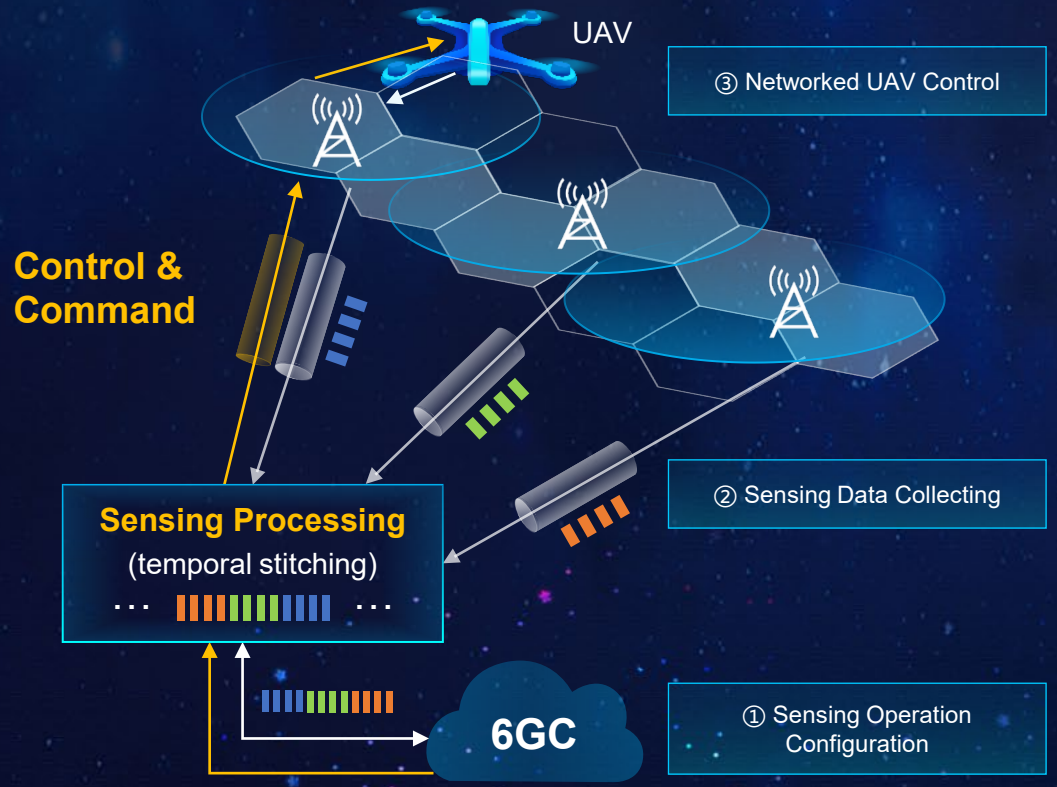
single frame multi-bursting | ad-hoc register windows

Network Slicing Capability

oDSP for Dispersion Compensation

Integrated Sensing and Communication Influent Backhaul Transport

Integrated sensing and communication features different signal processing and transport.
Cooperative transmission of sensing data from multiple base stations & control signals.



Ref: 3GPP TR 22.837

Sensing Data Alignment

Spatial Collaboration:
data aligned from different BS

Temporal Collaboration:
timestamp-based data stitching

Control Signal Alignment

Networked Control:
multi-UAV control through 6G

Control Collaboration:
alignment of multi-UAV control

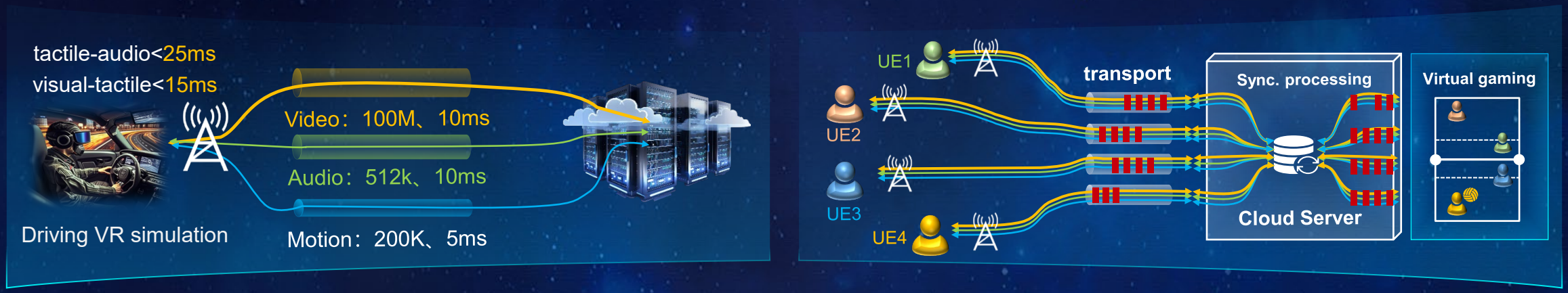
Multimodal Transport

low latency & deterministic high precision time sync.

security hard isolation

TSN may be a potential technology for alignment

VR is More Than Multimedia, Multilayer Forwarding & Alignment



VR is More Than Multimedia

Ultimate VR experience		Flow differentiation			Diverse QoS flows with high sync. req.				
Strong interaction eMBB+URLLC	**Multi-sensory** visual、audio、tactile	**Video** 5QI-89, 90	**Motion** 5QI-87, 88	**Audio** **5QI-7**	**Video** 100M 10ms	<15ms	**Motion** 512K 10ms	<25ms	**Audio** 200K 5ms

data flows of VR service mapping to different 5QI (3GPP TS23.501)

3GPP TR 22.847 KPI

Multilayer Forwarding & Alignment： new interface and uniform coodination control

Flow differentiation & different tunnels	Alignment between different flows inside a session
L3 forwarding+L1 hard isolation	Alignment of different base stations

6G Centralized + Distributed CN Architecture Brings New Challenges

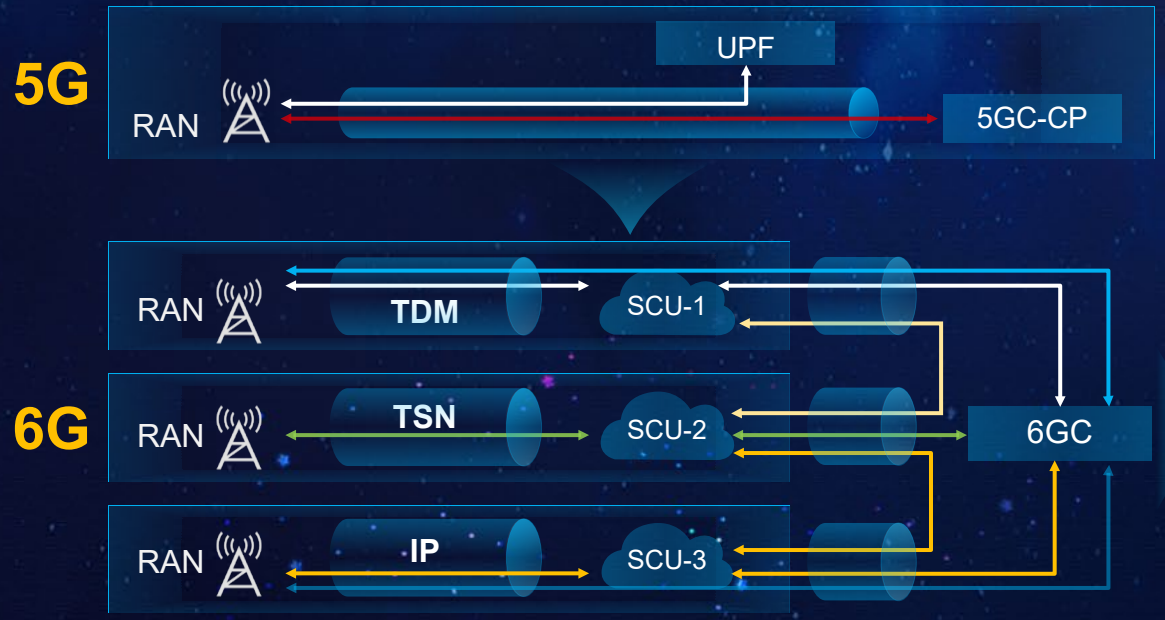
6G service: high customization, diversity, dynamics; 6G network: distributed plug&play SCU

Challenges to transport network: multi-modal customization, L1~L3 flexible connections

5G CN Architecture

CP separated from UPF

Static connections between RAN and CN



ITU-T Y.IMT2020-DCN

6G: Centralized + Distributed CN Architecture

SCU: CP+UPF, Plug and play

Dynamic relationship between RAN and CN

Deep Customization | **Safety Isolation** | **Regional Partition**

1、Diverse Traffic Directions

- RAN to SCU, RAN to 6GC, SCU to SCU, SCU to 6GC

2、Multi-Modal Customization Transport

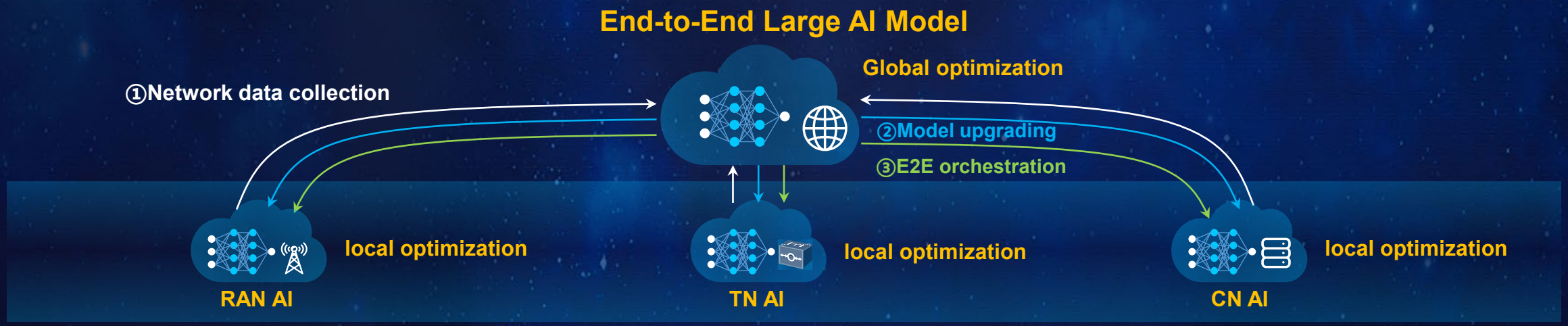
- PKT & TDM connection, TSN: for deep customization req.

3、High Flexibility of Connections

- Time flexibility: Plug&Play
- Spatial flexibility: Reconfigurable topo, dynamic flow direction

6G E2E AI Collaboration

Towards 6G AI-based network optimization, a centralized and distributed collaborative management and control architecture is required for implementing a E2E large AI model covering RAN, TN, and CN.



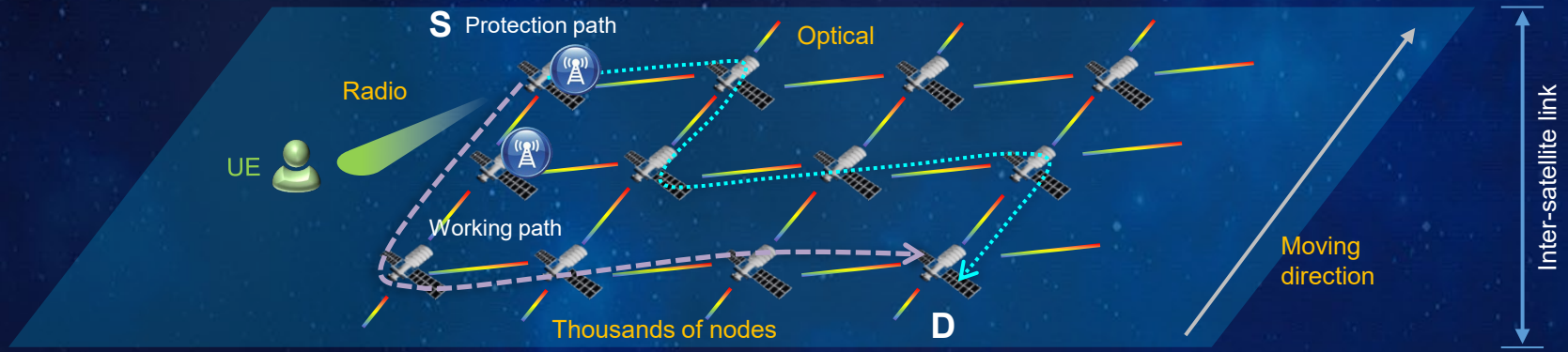
AI-based cross-domain distributed collaboration, expanding of management and control

Intra-domain real-time collaboration	Cross-Domain Centralized Orchestration and Scheduling	Multi-Dimensional Resource Coordination and Control
Intra-domain distributed collaboration for real-time intelligent computing	Large AI model orchestrates and schedules resources in each domain	Collaboration of network, computing, and data resources

AI-based collaborative management and control are more complex, requiring the control plane to support quick adjustment of multi-dimensional resources.

6G Satellite Optical Transport Network Technology

Towards 6G space-air-ground integration, it is essential to explore the inter-satellite optical-layer networking architecture and key technologies that accommodate the highly dynamic satellite network topology.



Is Optical-Layer Networking Necessary for Inter-Satellite Communication?

Few Satellites - IP + P2P Communication is Enough
few satellites, few IGP domains, no network oscillation

Thousands of Satellites – Optical-layer Networking
IP network always in rerouting state, low link utilization

What is the Most Suitable Transport Technology for Inter-Satellite Optical-Layer Networking?

Technologies Suitable for Periodic Changes in Connections
Rapid optical-layer connections, insulates the IP layer from topology changes.

High-speed Inter-Satellite Optical Communication
10Gbps→100Gbps→400Gbps

Inter-Satellite Optical Transport Network is within the scope of SG15 and is highly recommended.

Improved Time Synchronization Accuracy for 6G

6G basic services, inter-station collaboration, positioning services, and precise delay measurement services require extremely high time synchronization accuracy, reaching up to tens of nanoseconds.

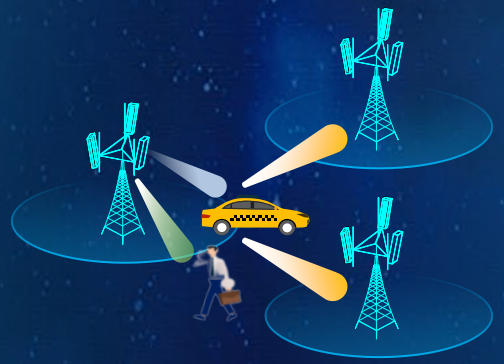
6G Basic Service

Space-Air-Ground & ISAC

Physical resources competition

Ultra-short frames , Time sync: ±1.5us

Inter-station Collaboration

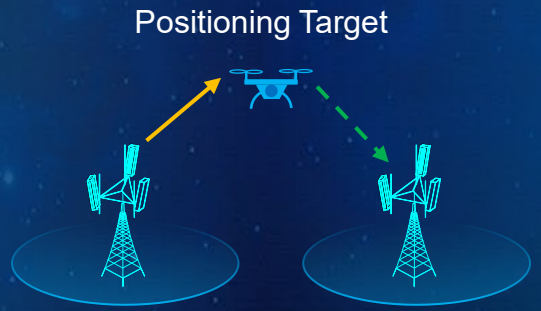


Cross-site, cross-frequency CA

High-band continuous CA: ±65ns

Low-band: ±130ns

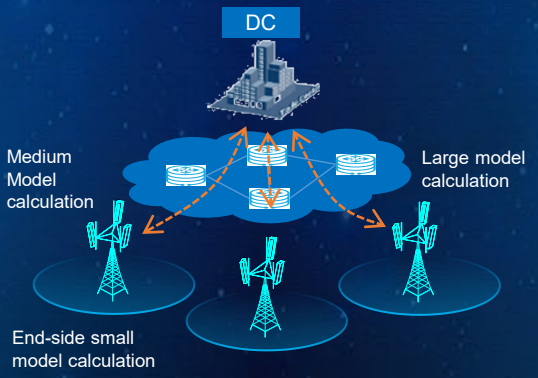
Positioning Service



Positioning

1m accuracy requires air-interface relative sync <3ns

Precise Delay Measurement



Precise delay measurement

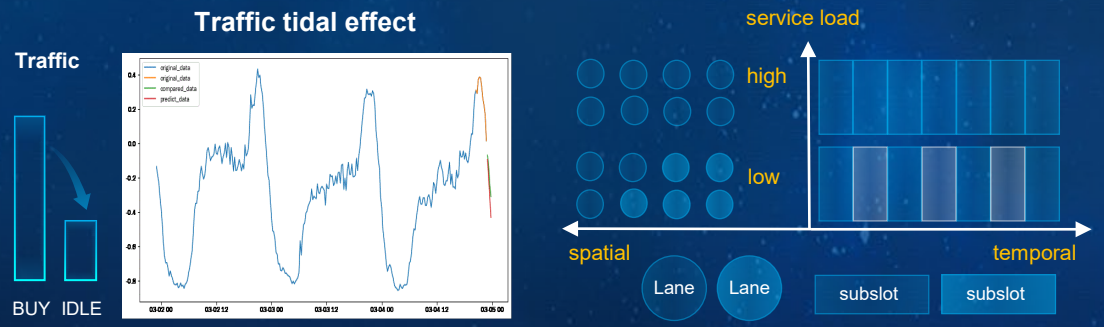
high-deterministic data exchange

E2E sync: <±100ns

Green and Energy-Efficient 6G Transport Network

6G transport network will introduce green design concepts through technological innovations at optoelectronic physical layer, packet scheduling layer, and networking layer to maximize network resource utilization efficiency.

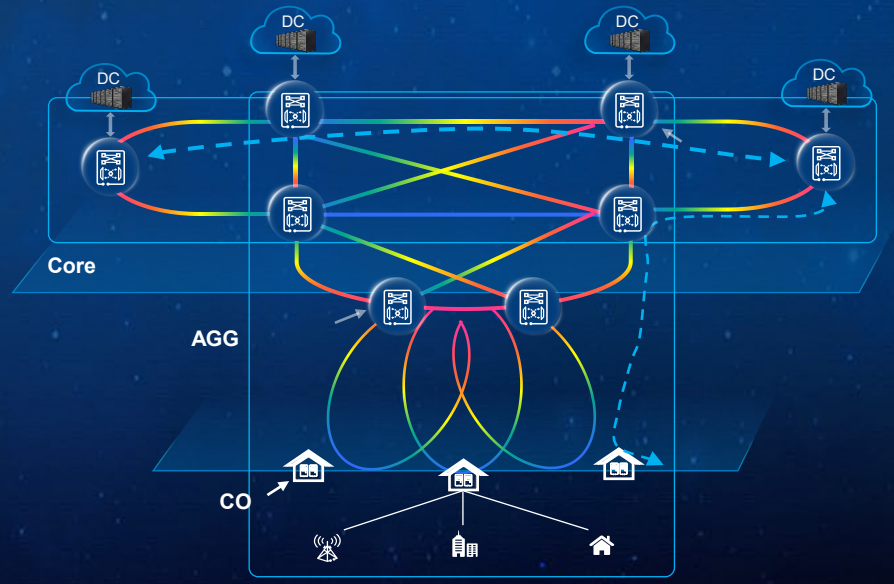
Dynamic Balancing to Address Tidal Effects



6G ultra-high bandwidth→increased traffic PAPR, enhanced variability, and substantial resource redundancy

- **Dynamic balancing and scheduling:** idle ports/cards dormancy
- **Physically spatial-temporal energy-saving:** flexible frame design

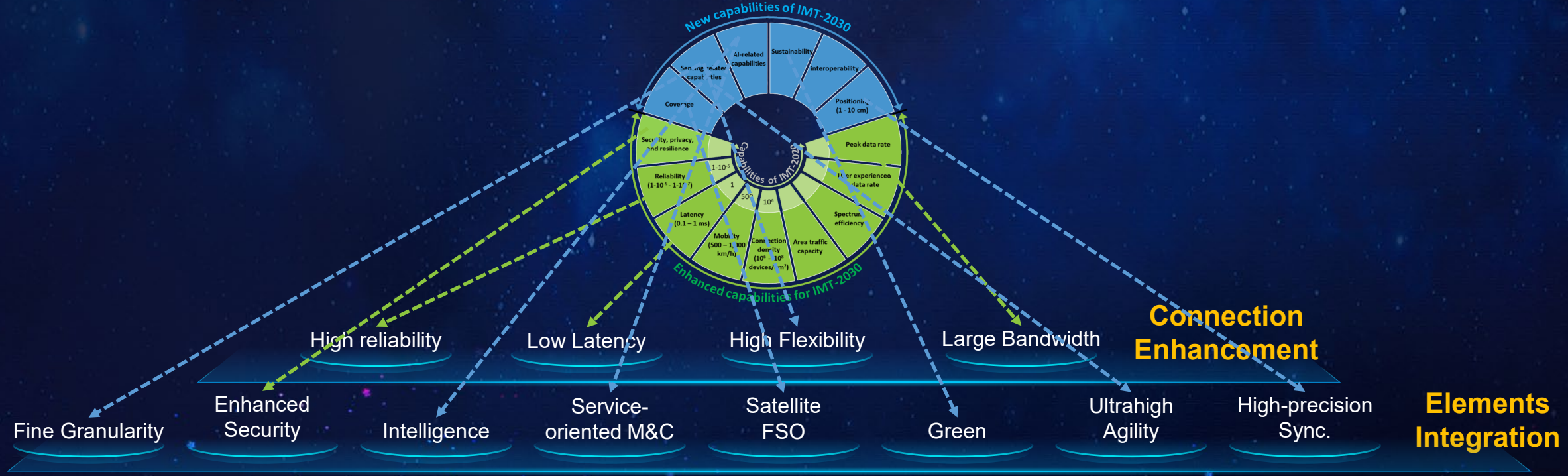
Resource sharing for Green Networking



- **Network pooling:** resource sharing in network architecture.

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.



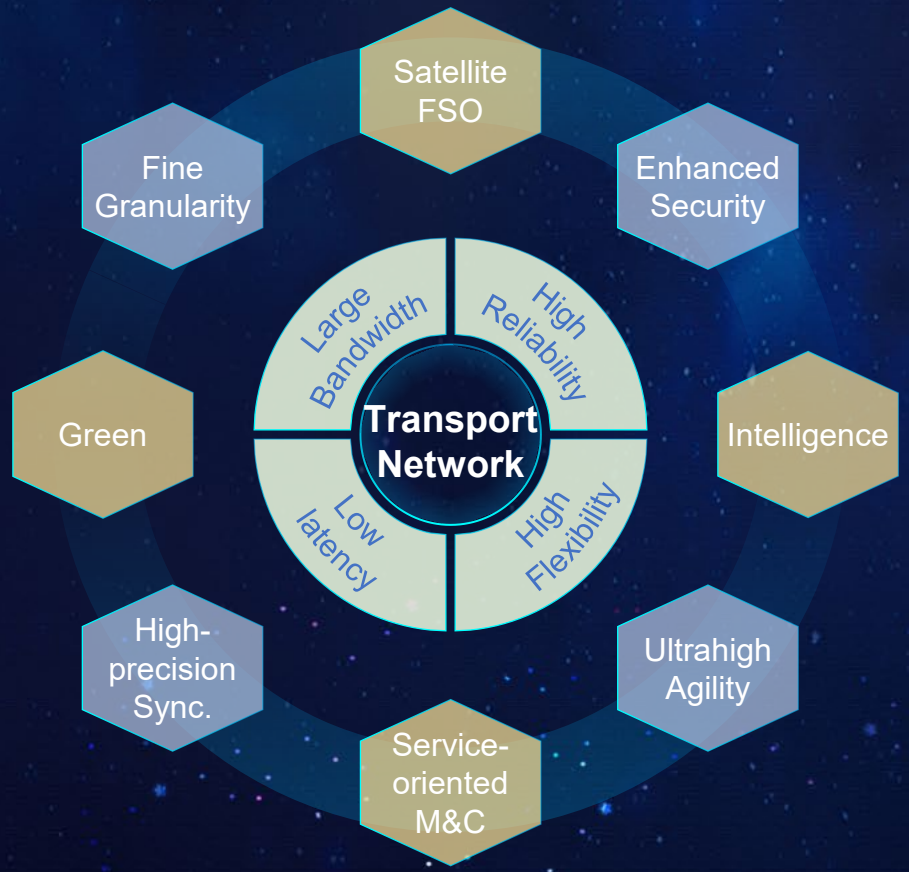
Connection Enhancement:
New technological innovations greatly enhance connectivity

+

Elements Integration:
The integration of new elements forms new capabilities

KPIs 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
	Metro access: 100G
	Metro aggregation: 400G
	Metro 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 $1\text{-}10^{-6}$ ~ $1\text{-}10^{-7}$
	Transmission Reliability $1\text{-}10^{-7}$

Suggestions on ITU-T SG15 Future Works for IMT2030/6G and Beyond

IOT2030 (International Optical Telecommunications towards 2030)

PON femto	Fronthaul (FH)	Backhaul (BH), Metro Network	Satellite Optical Transport	Sync.	AI E2E M&C Architecture	Green
Q2	Q6	Q11, Q12	Q12, Q6, Q11,Q13,Q14	Q13	Q12, Q14	Q6, Q11, Q12, Q14

- SG15 should lead the FH, BH, Femto access, Synchronization, Satellite Optical Transport etc. for IMT2030/6G.
- A Focus Group for “International Optical Telecommunications towards 2030 (IOT2030)” may facilitate the 6G requirement definition, alignment of different technologies in different questions within SG15, and cooperation between ITU-T SG15 and other SDOs such as 3GPP, IETF, IEEE, CCSA, and ETSI etc.
- Collaboration within the entire ecosystem including industrial and academic partners, as well as publication of high-impact technical papers in ITU, OFC and ECOC etc., will be beneficial to our society.

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Thank you!