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Deterministic Full-Fibre Service Network for F5G and Beyond

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Bordeaux, France

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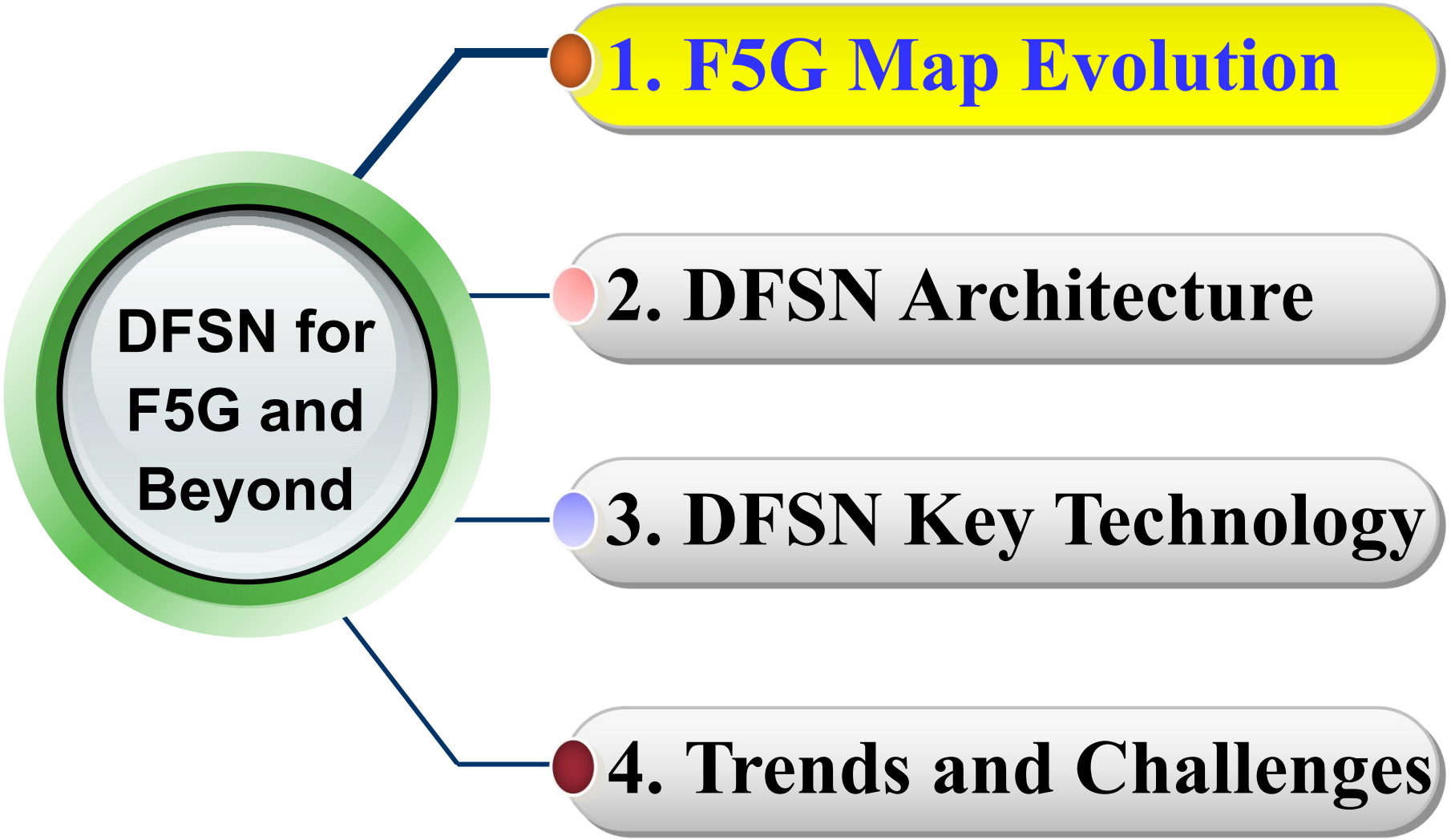
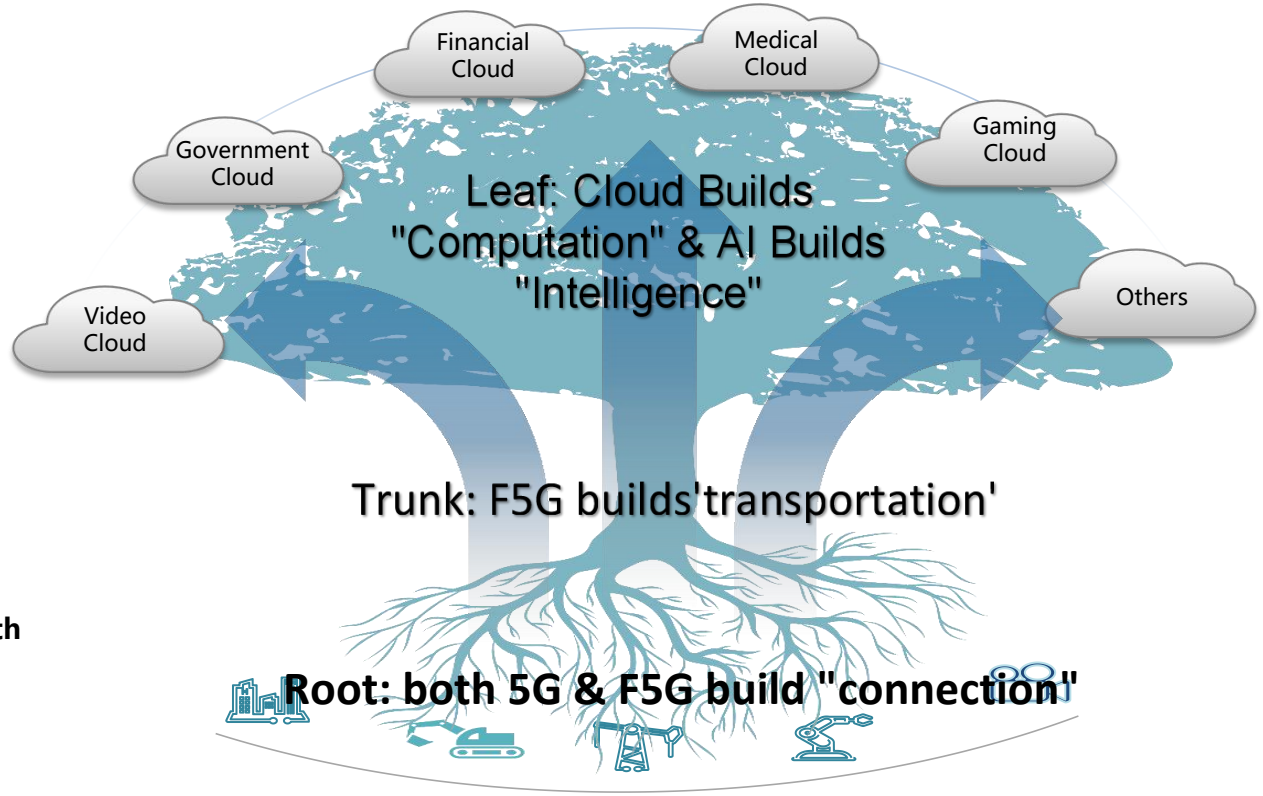
Outline


DFSN for F5G and Beyond
1. F5G Map Evolution
2. DFSN Architecture
3. DFSN Key Technology
4. Trends and Challenges

F5G+5G: The Foundation for Global Information Infrastructure

F5G+5G build "Connection + Transportation" to foster the Intelligence and Computing Capability



5G in the Air

Wireless to Everything

eMBB: 300 Mbit/s to 1 Gbit/s

mMTC: 1 million connections/km2

URLLC: millisecond-level experience

F5G on the Ground

Fiber to Everywhere

eFBB: 1 Gbit/s to Tbit/s-level bandwidth

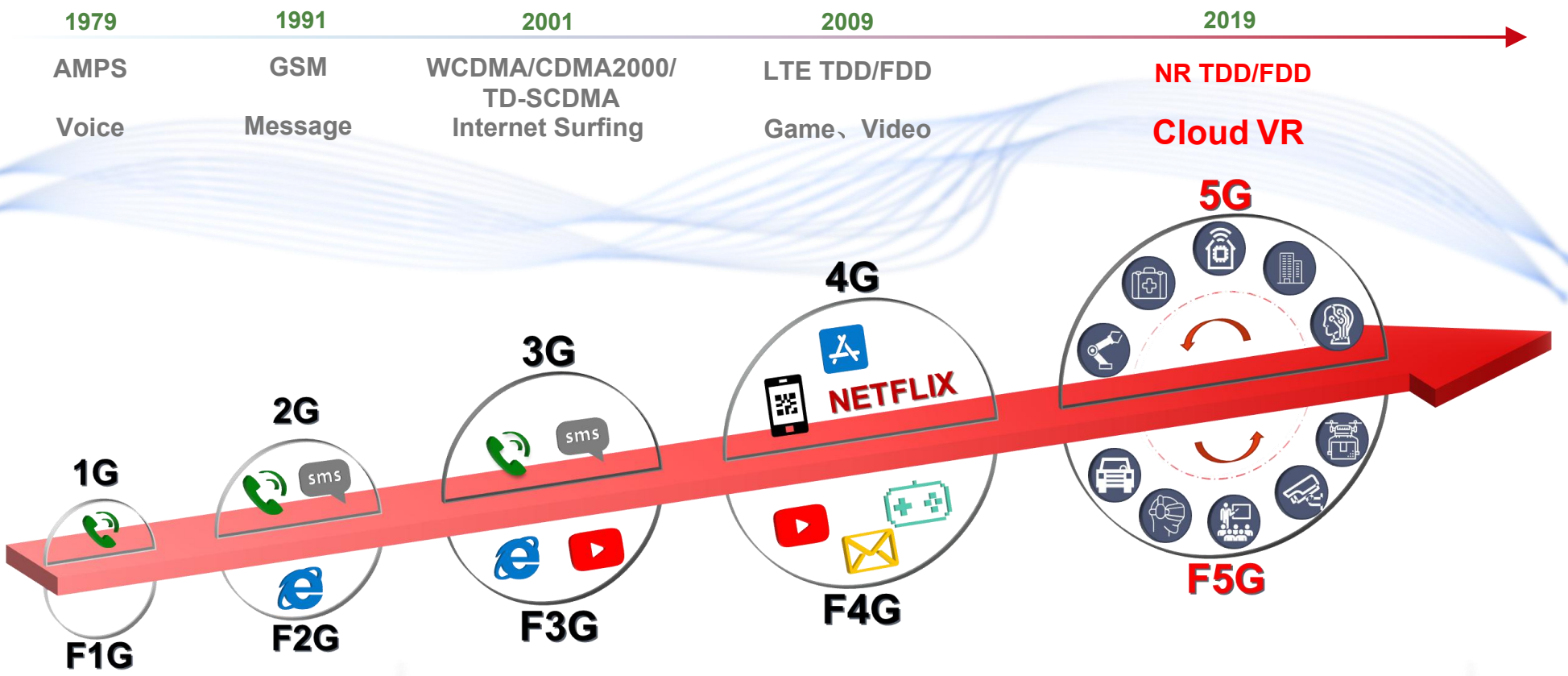
FFC: 100,000 connections/km2

GRE: microsecond-level experience

$$(\text{Connection density, N})^2 \times \text{Calculation accuracy} \propto \text{Digital economy strength}$$

Metcalfe's Law: Digital economy Values increase with increase with N^2

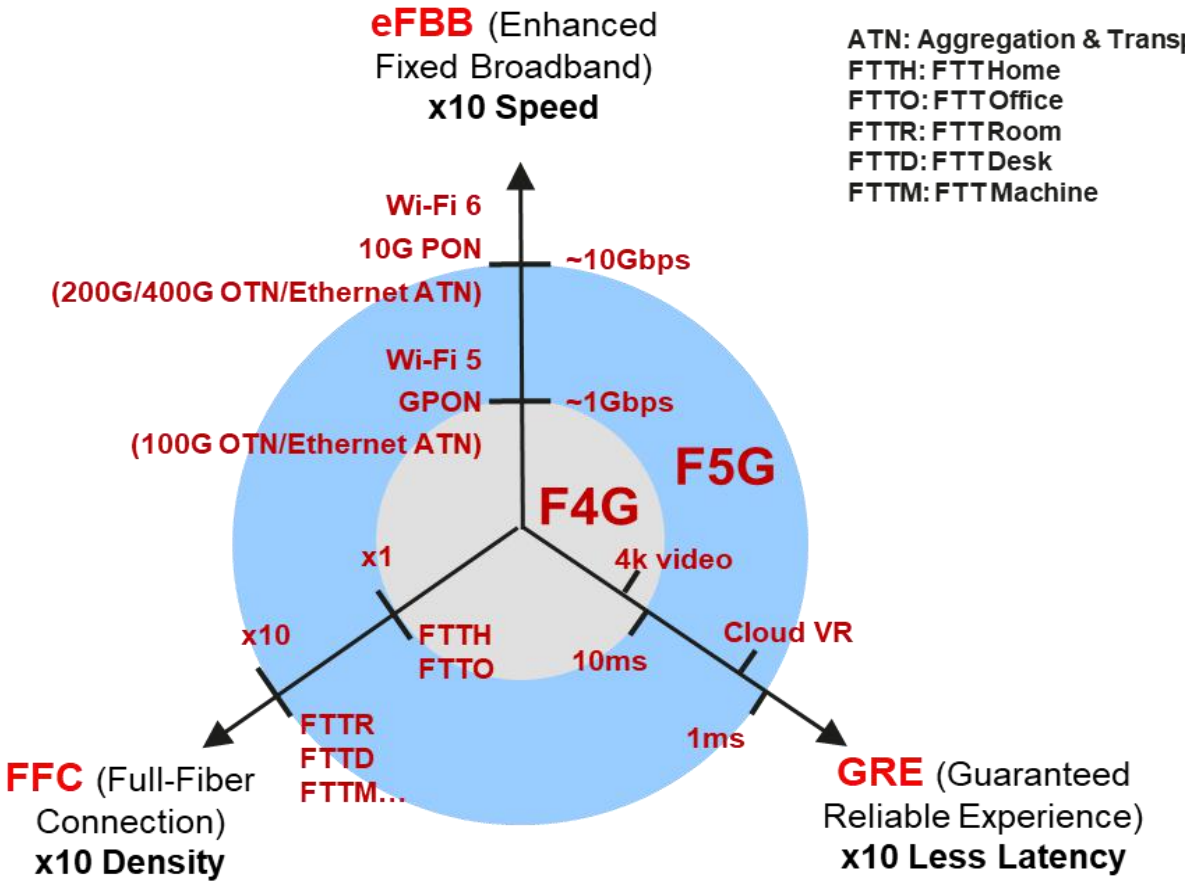
F5G+5G: Evolution



F5G builds a Deterministic Full-Fibre Service Network (DFSN)

eFBB (enhanced Fixed Broadband)

- Wifi-6、10GPON、200G/400G OTN
- Symmetrical gigabit broadband upstream and downstream
- Connect the last 10m bottleneck of gigabit connection with WI-FI6 technology
- The bandwidth of the aggregation network is constantly improved



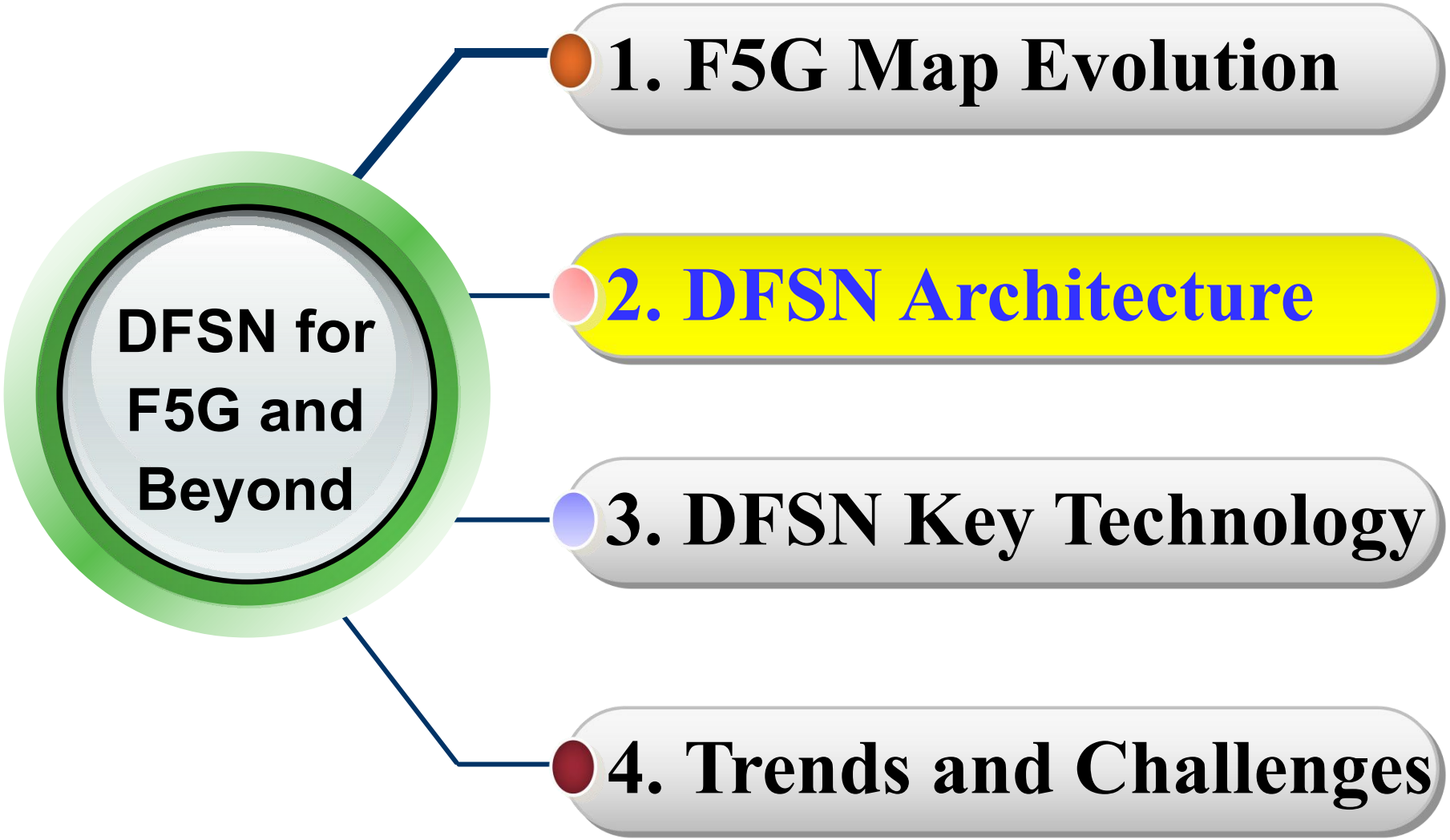
GRE (Guaranteed Reliable Experience)

- 4K video、Cloud VR
- The network side supports zero packet loss and microsecond delay
- The terminal reduces Wi-Fi delay
- Improves users' experience of watching 4K video and interactive games

FFC (Full Fibre Connection)

- FTTR、FTTD、FTTM
- Full coverage fiber optic infrastructure
- support ubiquitous connectivity

Outline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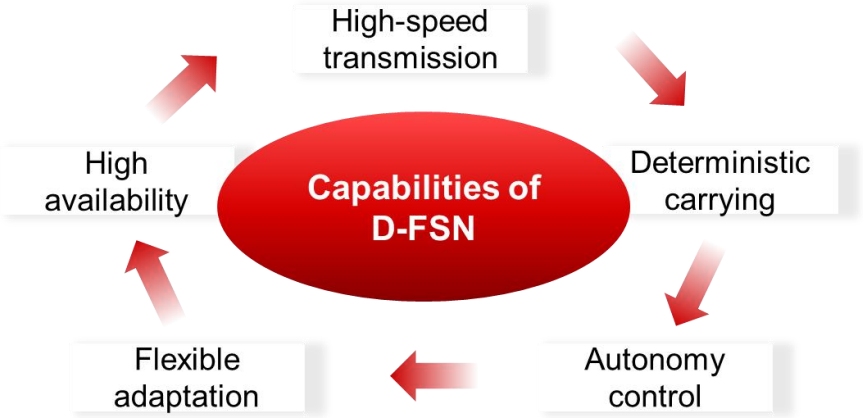
Design principles of DFSN architecture



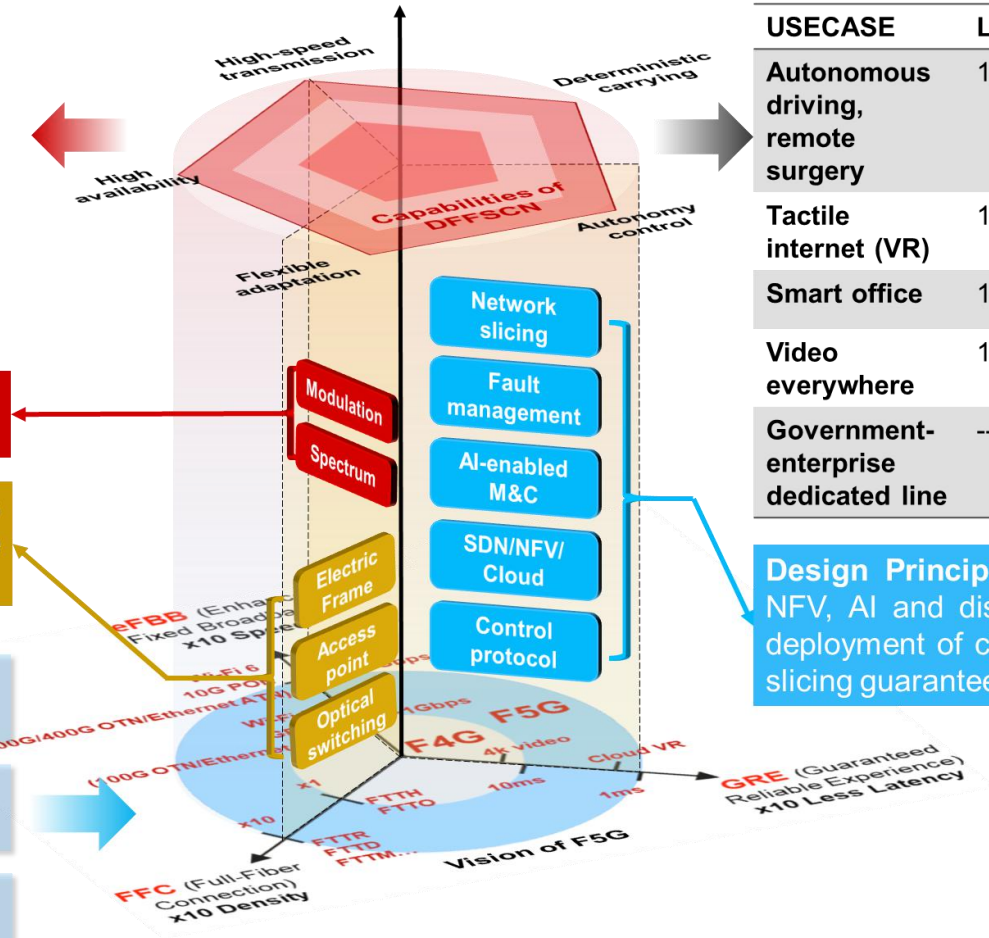
Design Principle: Further improve the optical transmission capacity and speed

Design Principle: Design multi-service network access points and an electrical layer frame structure to realize service awareness and further improve the optical switching capacity.

Vision of F5G (ETSI ISG F5G)

- eFBB (x10 Speed)
- FFC (x10 Density)
- GRE (x10 Less Latency)

Key enablement of D-FSN

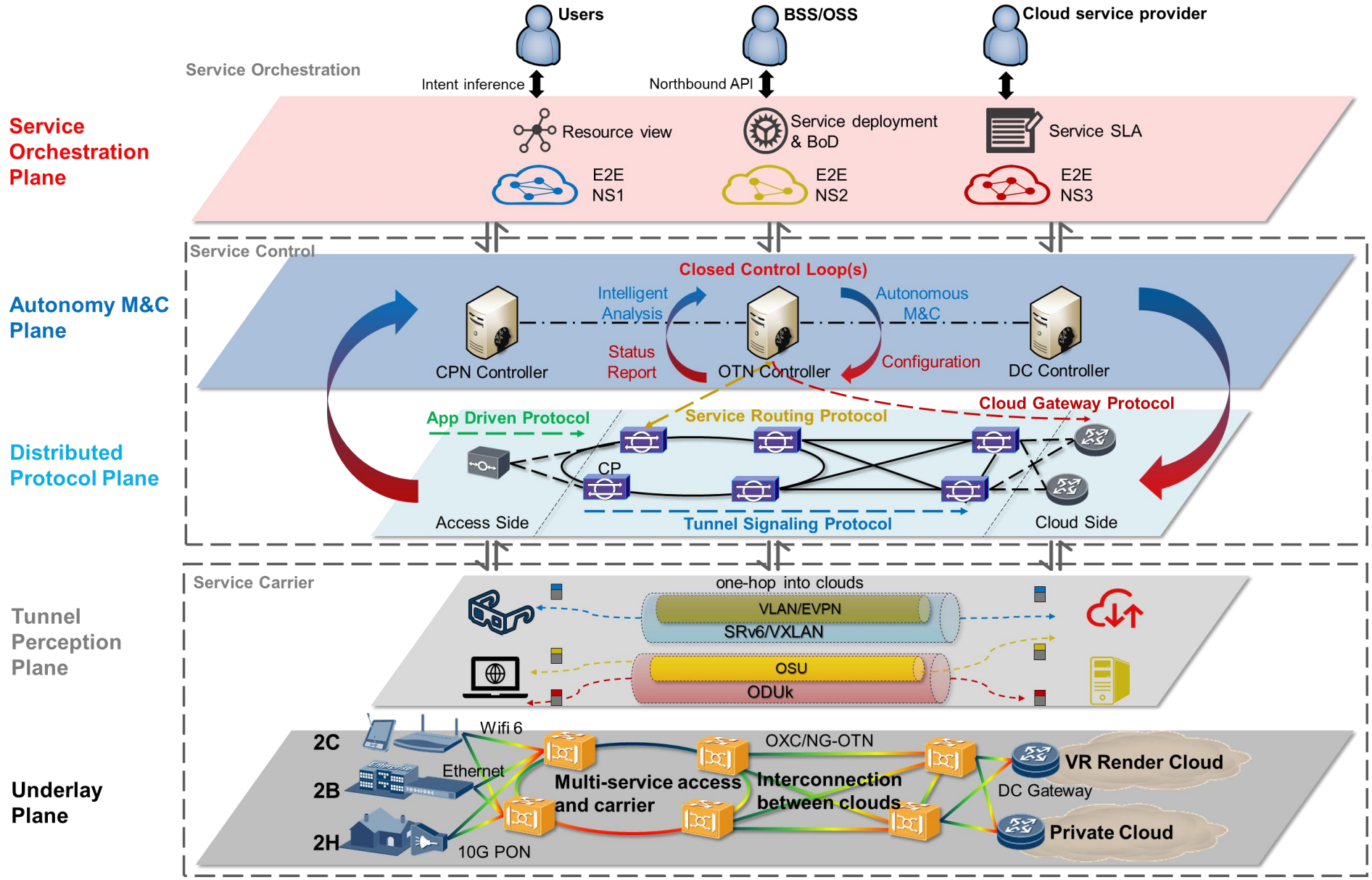


Deterministic requirements of services in F5G era

USECASE	LATENCY	BANDWIDTH	RELIABILITY	SAFETY
Autonomous driving, remote surgery	1ms	50k-10Mbps	99.9999%	High
Tactile internet (VR)	1ms	50Mbps	------	------
Smart office	10ms	>1Gbps	99.999%	High
Video everywhere	10ms	>200M	------	------
Government-enterprise dedicated line	------	20M-1G	99.999%	High

Design Principle: Give full play to the advantages of SDN, NFV, AI and distributed control protocols to realize the rapid deployment of cloud services. Fault management and network slicing guarantee deterministic transmission of services.

DFSN architecture



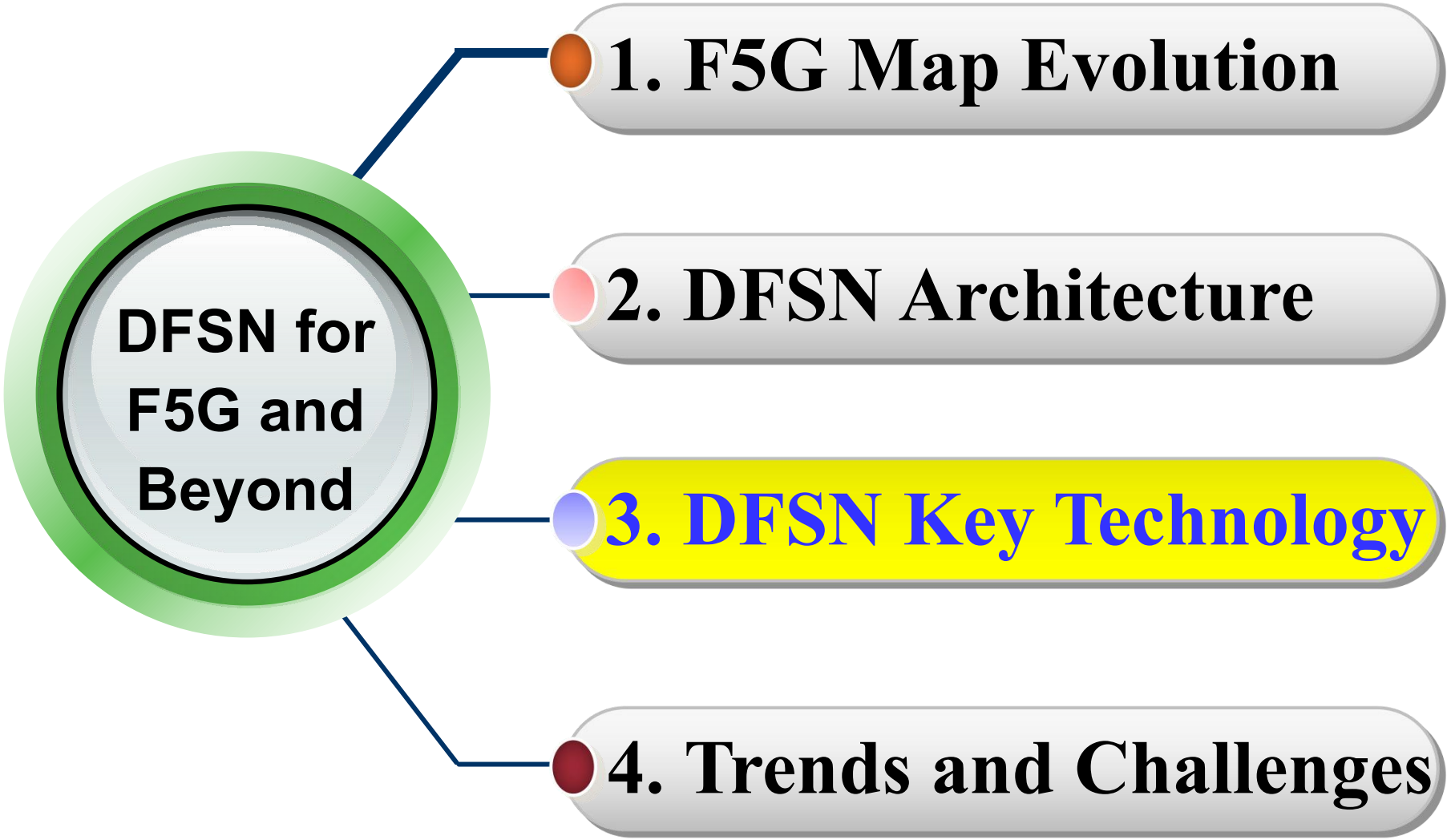
Three Structures

- Service carrier (Transmission equipment)
- Service control (Controller)
- Service Orchestration (Orchestrator)

Five Planes

- **Underlay Plane**
  2C/2B/2H、 Unified Optical Access Point、OXC/NG-OTN 、Multi-Cloud
- **Tunnel Perception Plane**
  ODUk/OSU、SRv6
  One-hop into clouds
- **Distributed Protocol Plane**
  App Driven、Service Routing 、Tunnel Signaling、Cloud Gateway Protocols
- **Aturonomy M&C Plane**
  Closed Control Loops、AI、Open & Programmable
- **Service Orchestration Plane**
  E2E Network Slice、Intent API

Outline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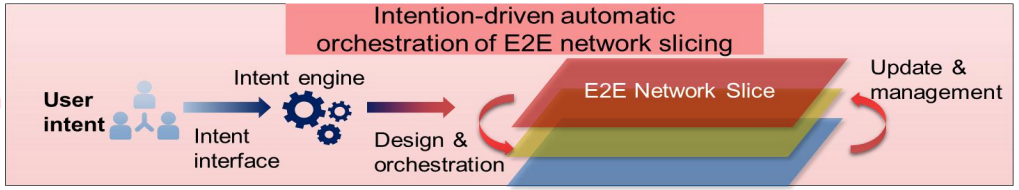
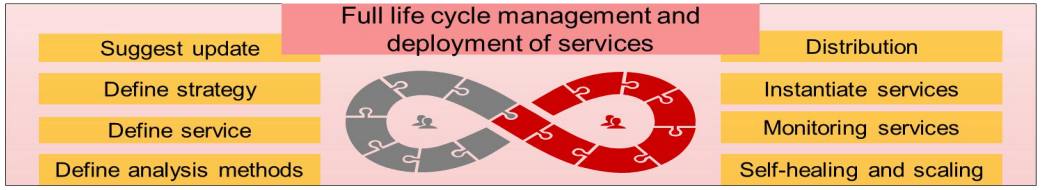
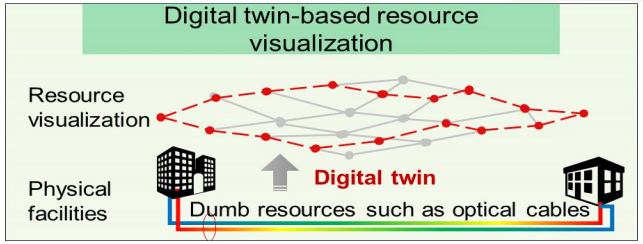
DFSN technology map overview

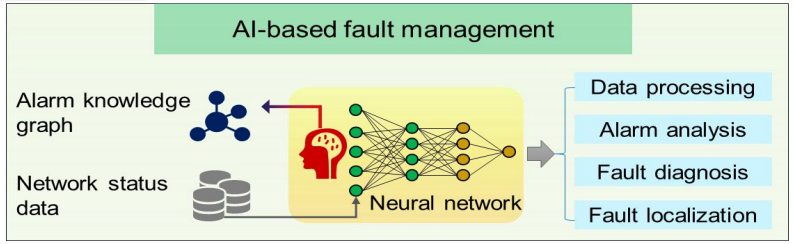
Service Orchestration Plane

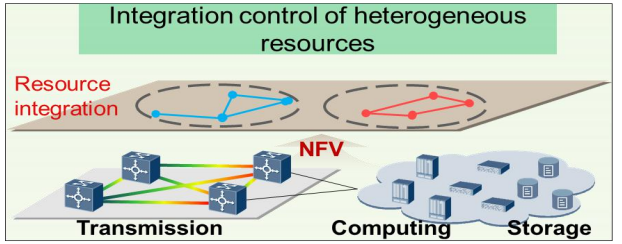




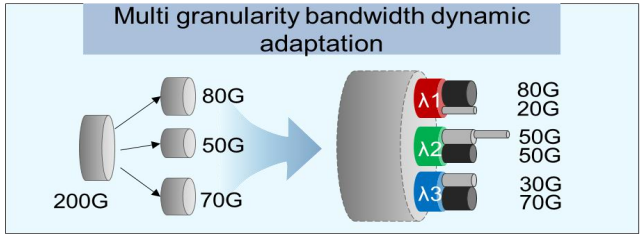
Autonomy M&C Plane

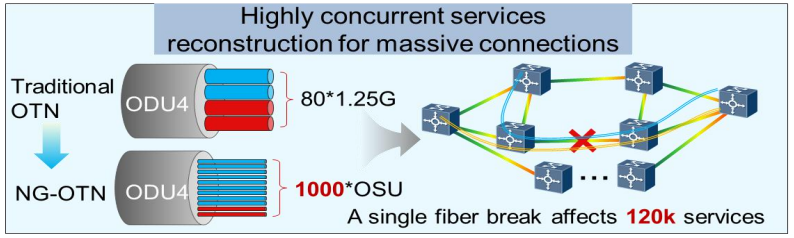


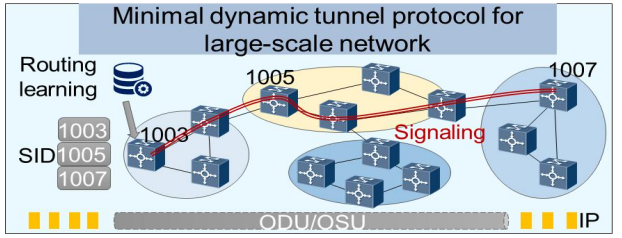




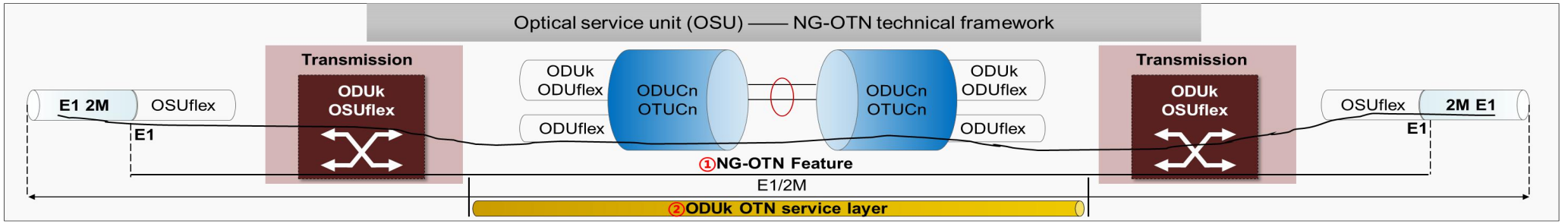
Distributed Protocol Plane



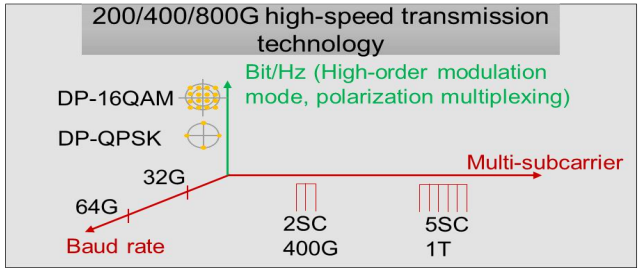


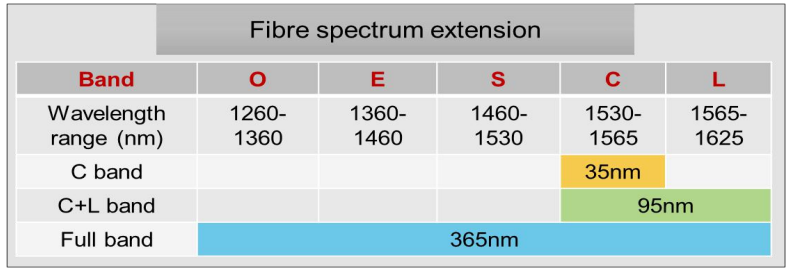


Tunnel Perception Plane

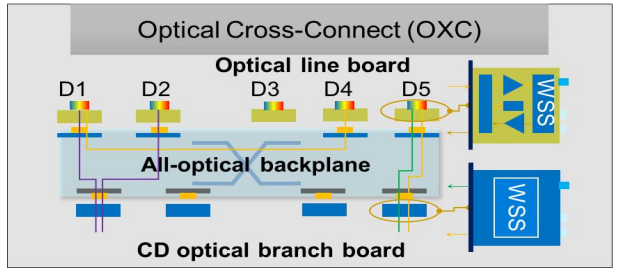


Underlay Plane





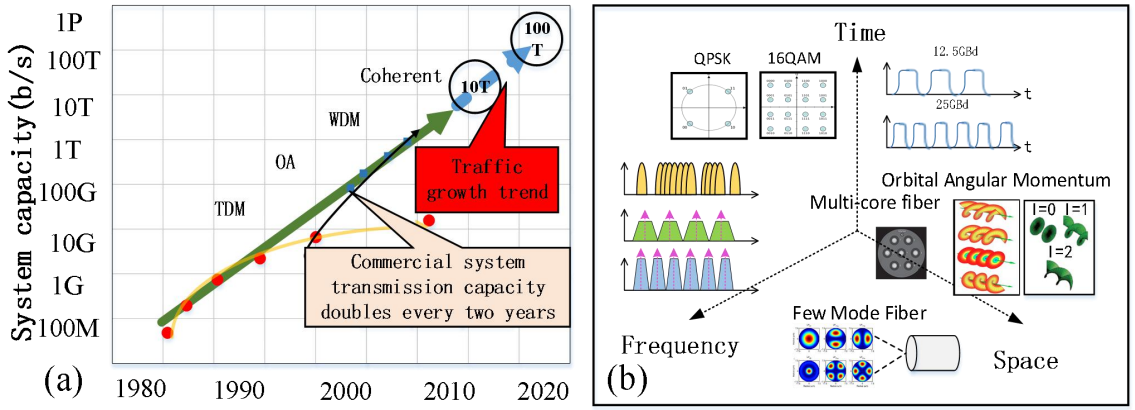
Band	O	E	S	C	L
Wavelength range (nm)	1260-1360	1360-1460	1460-1530	1530-1565	1565-1625
C band				35nm	
C+L band				95nm	
Full band	365nm				



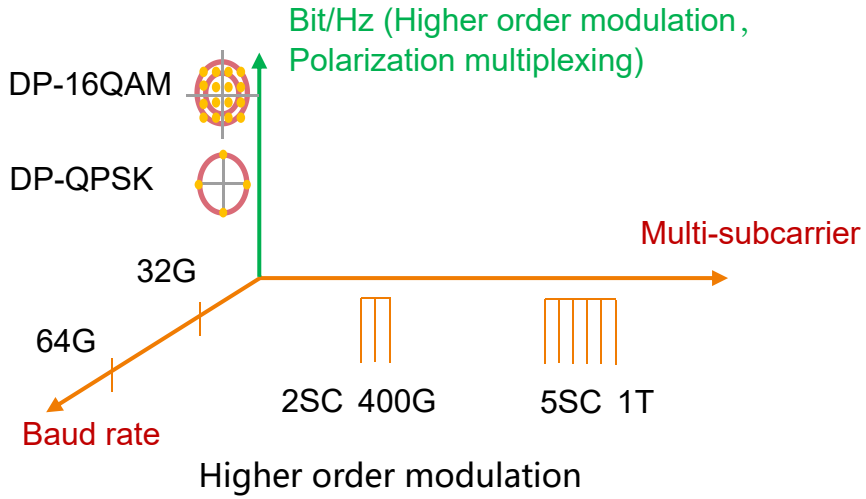
Key technology in the Underlay Plane (1)

- **200/400/800G High-speed transmission technology**

Type	Number of carriers	System capacity	Channel interval	Transmission distance
2*200G PM-QPSK	2	12.8T	62.5GHz	1500km
2*200G PM-8QAM	2	16/12.8T	50/62.5GHz	700/900km
2*200G PM-16QAM	2	21/16T	37.5/50GHz	400/600km
1*400G PM-16QAM	1	21T	75GHz	300km
1*400G PM-32QAM	1	25.6T	62.5GHz	200km
1*400G PM-64QAM	1	32T	50GHz	100km
800G ?	-	-	-	-



Multi-dimensional multiplexing with photoelectric cooperative features

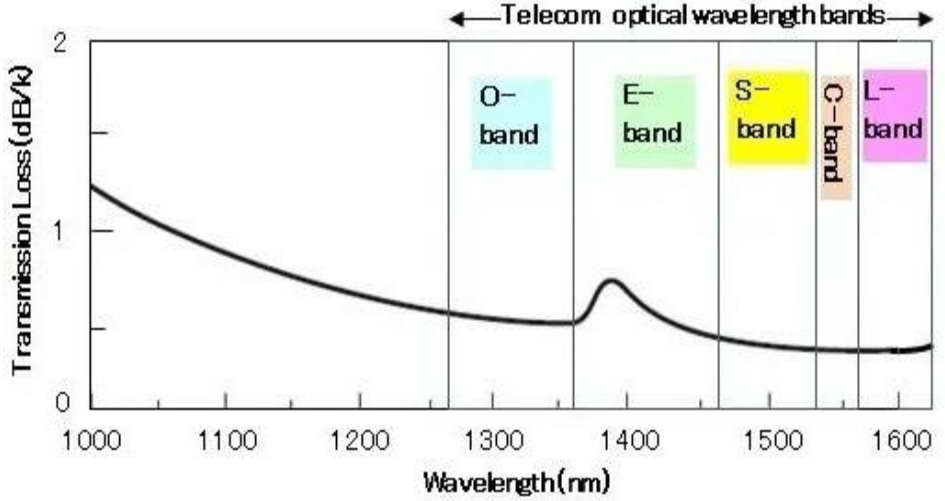


Higher order modulation

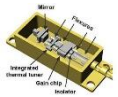
- On the basis of 100G, further increase the network capacity, and reduce the cost and power consumption of optical transmission per bit.
- The main methods include increasing the line baud rate, using high-order modulation and multiple sub-carriers.
- Resource mining from the three dimensions of time, space and frequency and realize the integrated scheduling of multi-dimensional resources and the photoelectric coordinated adaptation with services.

Key technology in the Underlay Plane (2)

Fibre spectrum extension



Extension C-Tunable Laser



- New optical grating
- Extended C stable light signal

Extension C-WSS

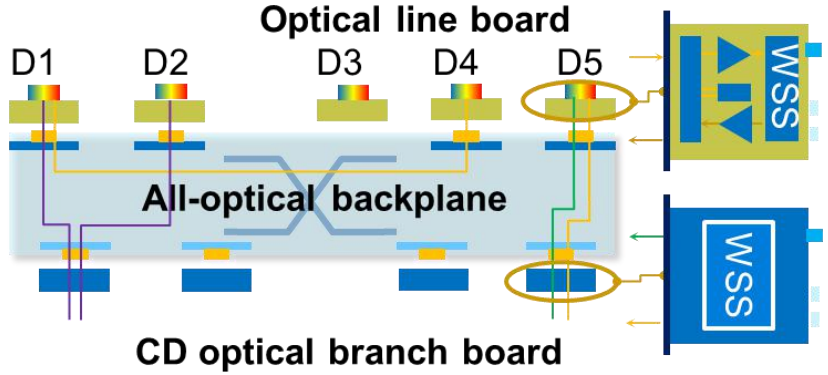
- New LCOS
- Extended C WSS

Extension C-OA

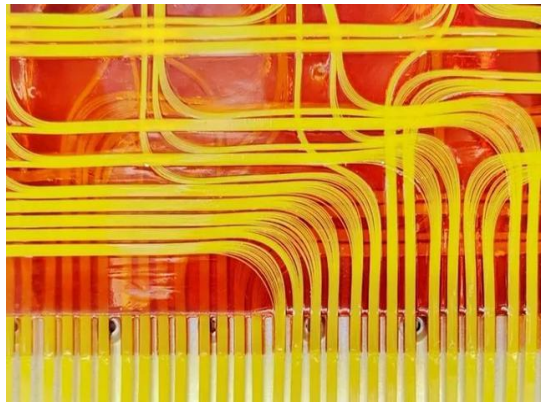
- New EDFA
- Full spectrum high gain low NF

- **Extended C band:** Extend the conventional C band 4THz to 6THz.
- **C+L band:** On the basis of C-band/extended C-band, further extending L-band is equivalent to doubling the capacity of C-band.
- **Optical device expansion:** spectrum expansion of end-to-end optical devices such as lasers, optical amplifiers, WSS, splitting and multiplexing.

Optical Cross-Connect (OXC)



OXC

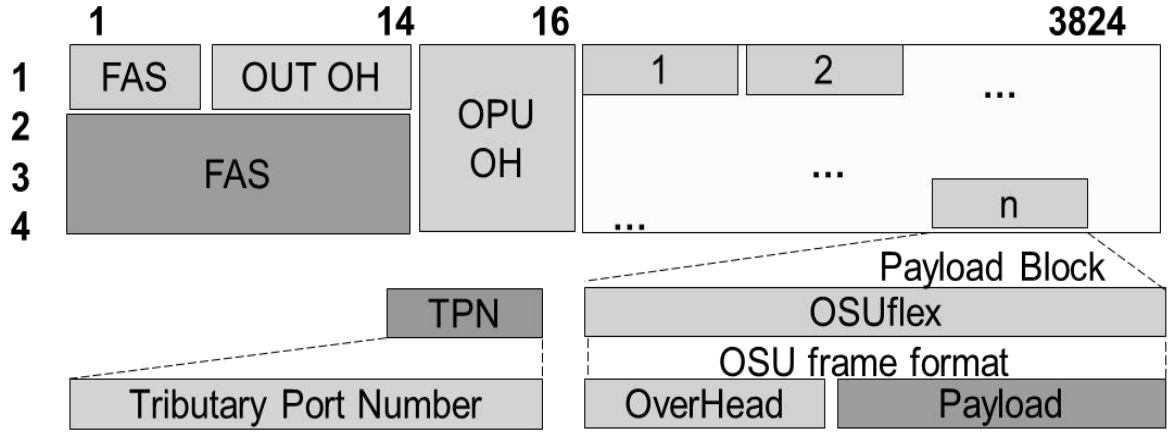


All-optical backplane

- The optical backplane realizes Mesh interconnection between boards, flexible scheduling
- Up to 32 dimensions of scheduling, and Pbit/s-level wavelength scheduling.
- Save 75% of the computer room space and 40% of the power supply.

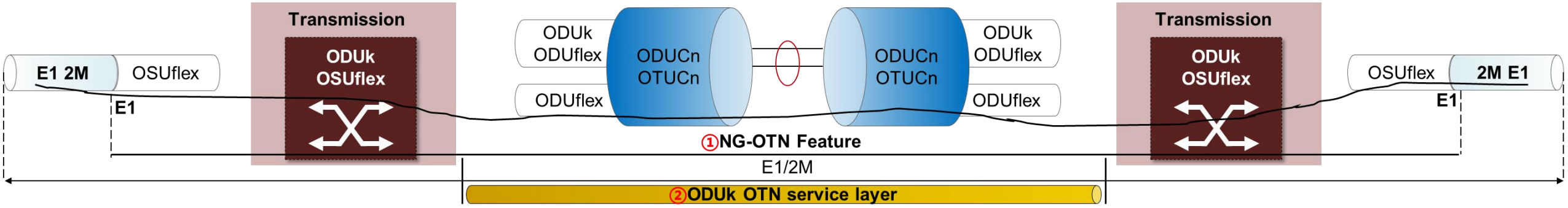
Key technology in the Tunnel Perception Plane

- **OSU-OTN is the best carrier technology for high-quality applications**



Optical Service Unit (OSU) frame structure

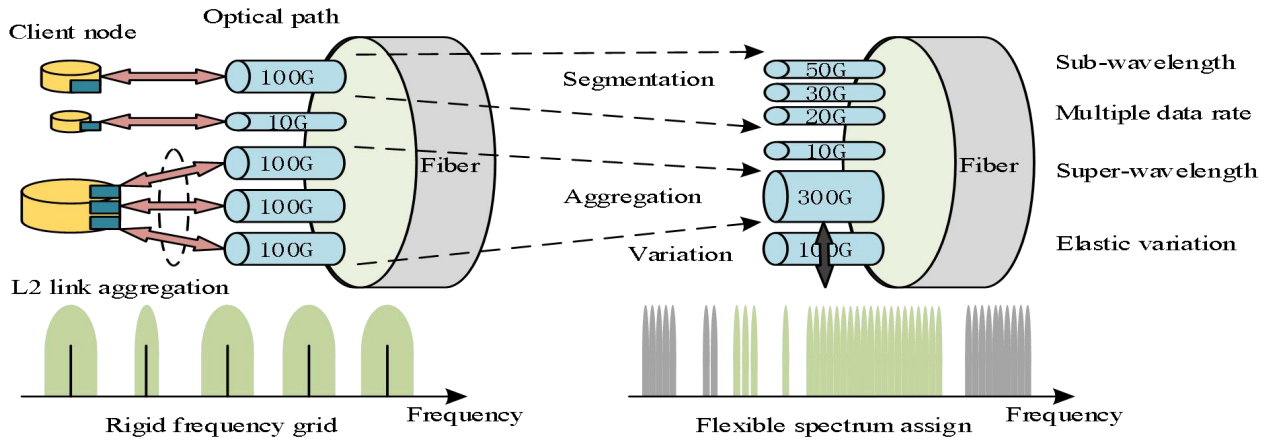
- OSU-based OTN can carry multi-granular client-side service access from **2Mb/s to 100Gb/s**
- Provide stable, low-latency, flexible, adjustable and controllable capabilities
- The best carrier technology for **high-quality cloud-network convergence applications**



OSU-based E2E transmission architecture

Key technology in the Distributed Protocol Plane (1)

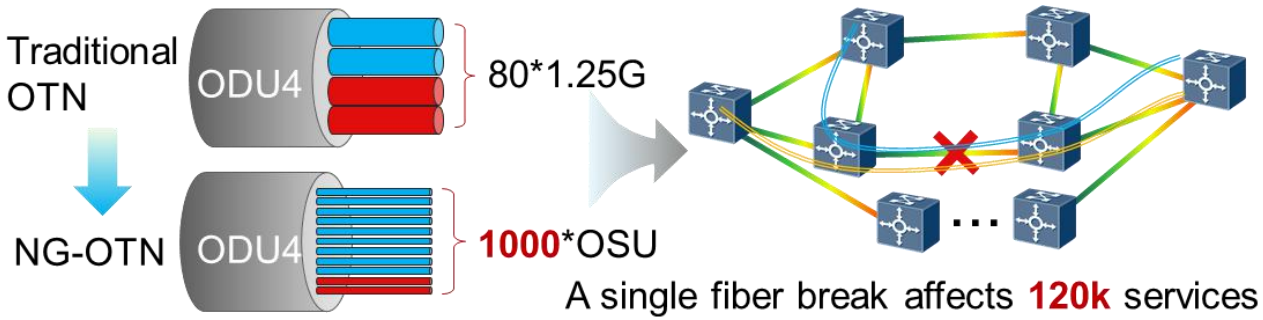
- **Multi-granularity bandwidth dynamic adaptation**



Problem: The small granularity of OSU brings about effective management and allocation of spectrum resources.

Solution: Design a dynamic pipeline adaptation and adjustment mechanism/protocol. Adjust the pipeline bandwidth (OSU) quickly and flexibly according to business requirements to ensure the agile and flexible pipeline provision of DFSN. N

- **Reconstruction of high-concurrency services with massive connection**

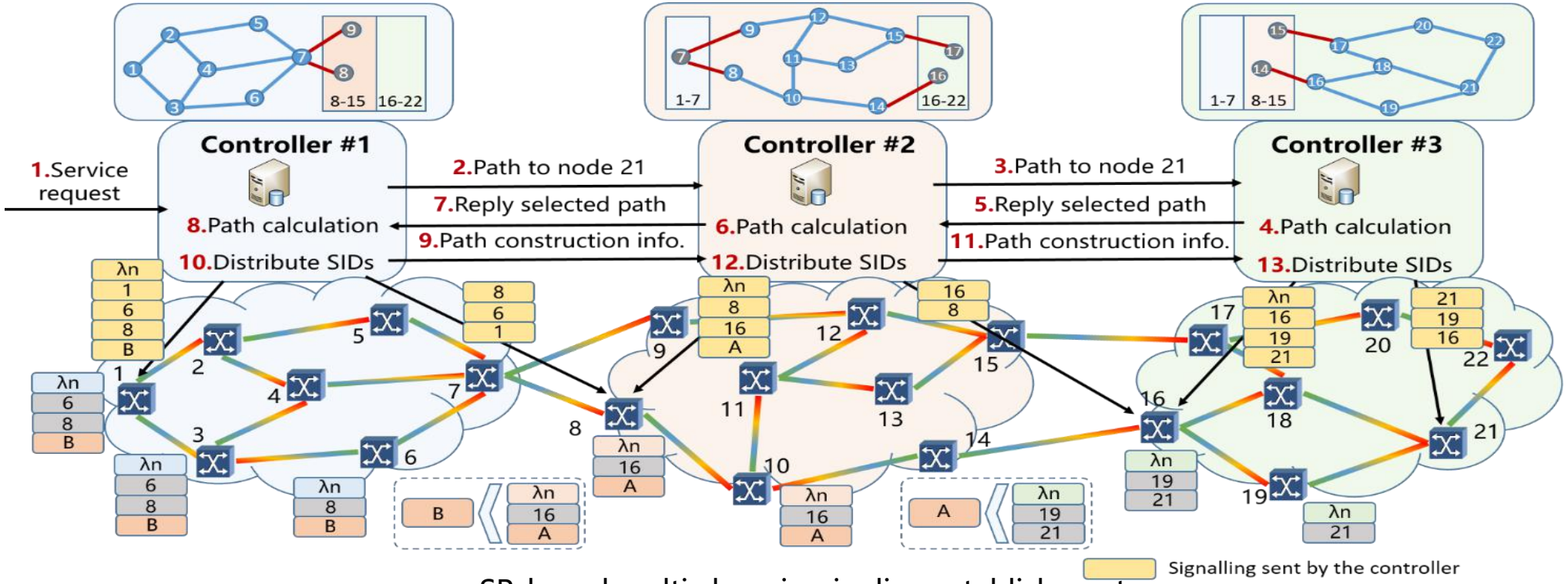


Problem: A single optical fiber carries a large number of services, and the number of connections affected by a single fiber break increases, resulting in a decrease in user service quality.

Solution: Set up a protection path for the business, and quickly switch when the connection fails. When hardware resources remain unchanged, ensure that the performance of multi-service concurrent reconstruction is similar to that of single-service reconstruction.

Key technology in the Distributed Protocol Plane (2)

- **Minimalist dynamic pipeline protocol in large-scale networks**



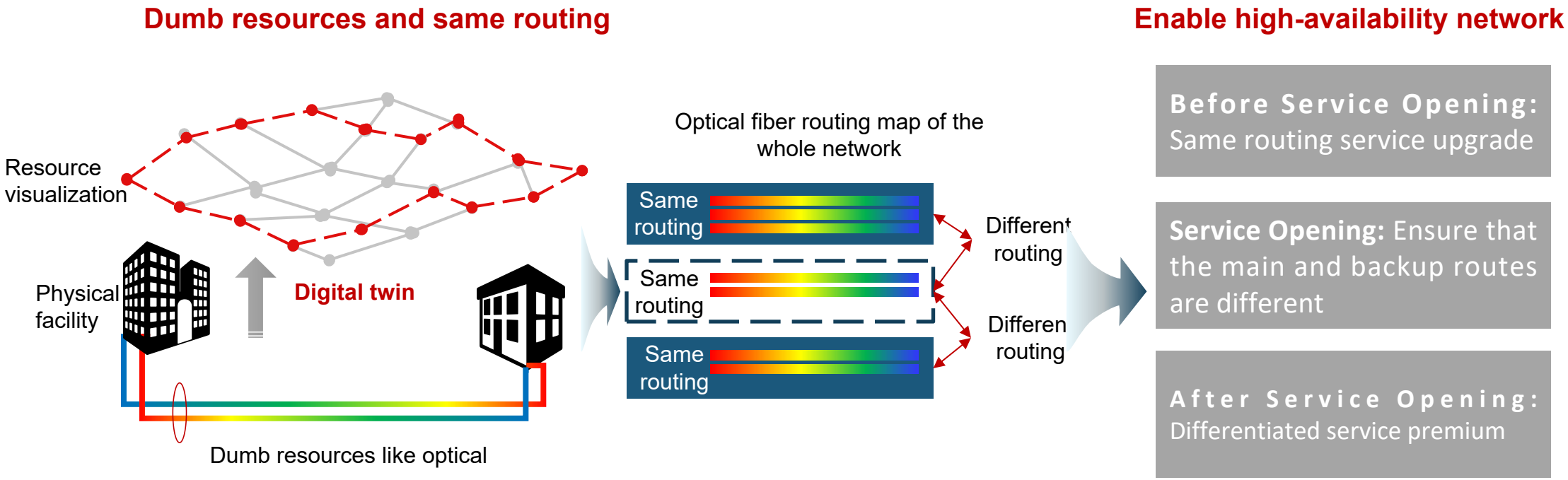
SR-based multi-domain pipeline establishment

Problem: In the scenario of F5G large-scale networks, how to realize the rapid issuance of cross-domain optical path establishment signaling under the premise of ensuring inter-domain privacy?

Solution: Drawing on the extension of Segment Routing (SR), combining the ideas of SDN and SR, realizing sub-domain management and centralized distributed control, and realizing the rapid issuance of cross-domain road construction signaling in multi-domain scenarios.

Key technology in the Autonomy M&C Plane (1)

- **Resource visualization based on digital twins**

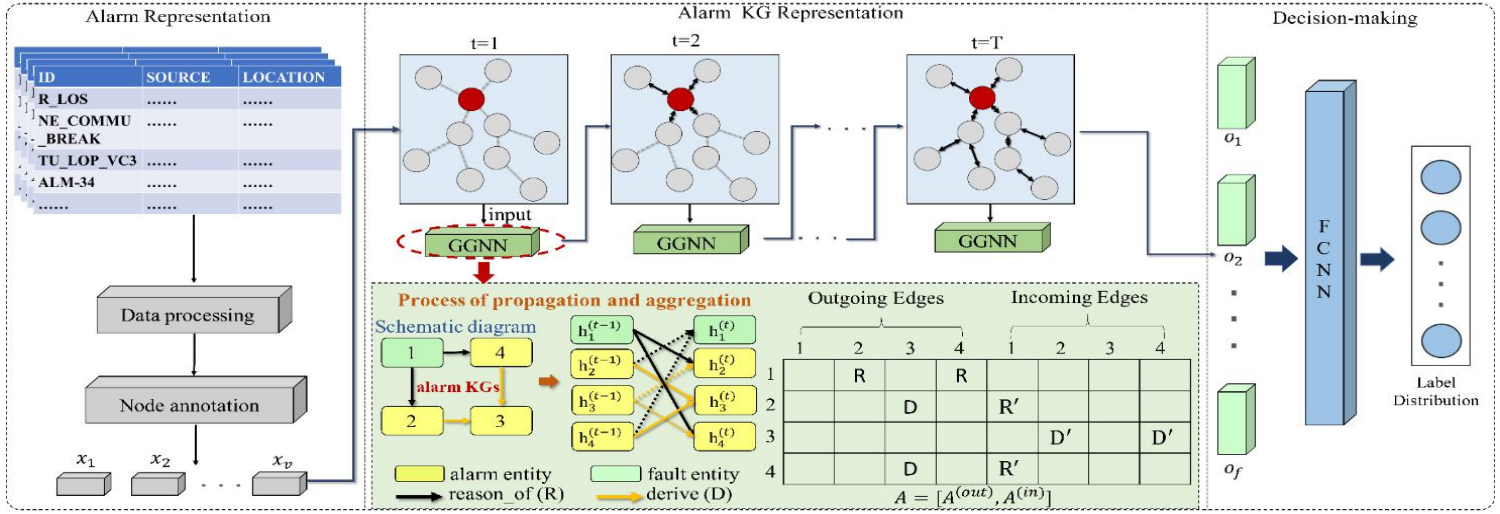


Problem: How to realize the visibility and management of the potential bandwidth resources of optical fiber dumb resources? How to realize the decoupling of optical cable physical resources and business logic network and provide multiple routing mutually exclusive choices for services to meet the main and backup, even recovery path selection?

Solution: The optical network is an analog network. The digital twin of the optical network is to build a mirrored digital network on the physical network, which can reflect the status of network resources and the running status of services in real time, thereby effectively supporting resource visibility and health protection.

Key technology in the Autonomy M&C Plane (2)

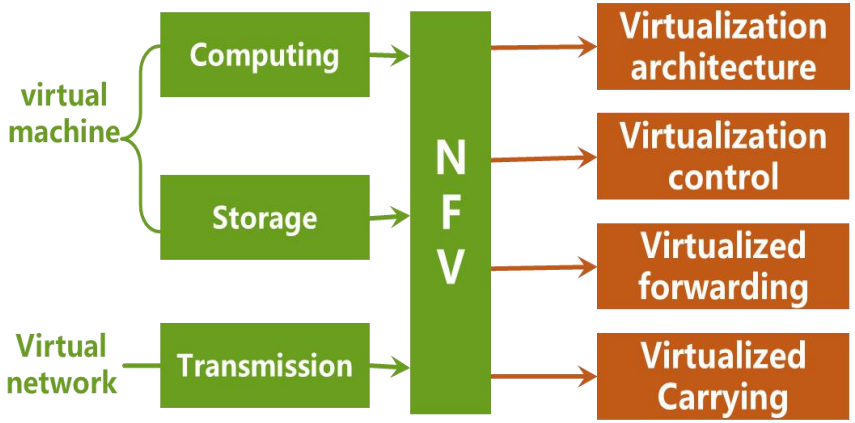
- **AI-based network fault management**

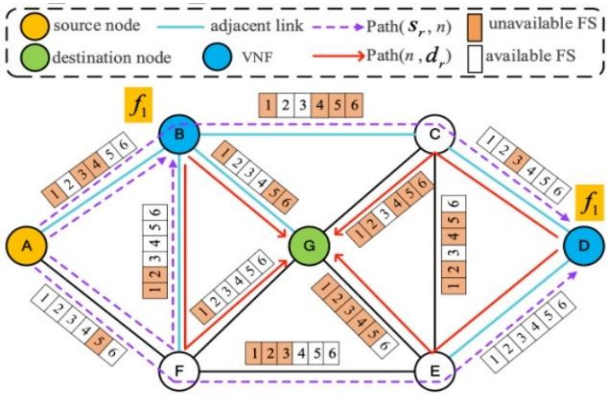


Problem: It is necessary to build a complete AI algorithm to realize the cleaning, analysis, fault diagnosis and localization process of network alarm data to ensure the deterministic and highly reliable transmission of services.

Solution: Use the knowledge graph to construct an alarm knowledge set, and use AI reasoning technology such as graph neural network to simulate the decision-making behavior of learning operation.

- **Convergence control of computing, storage and transmission resources**



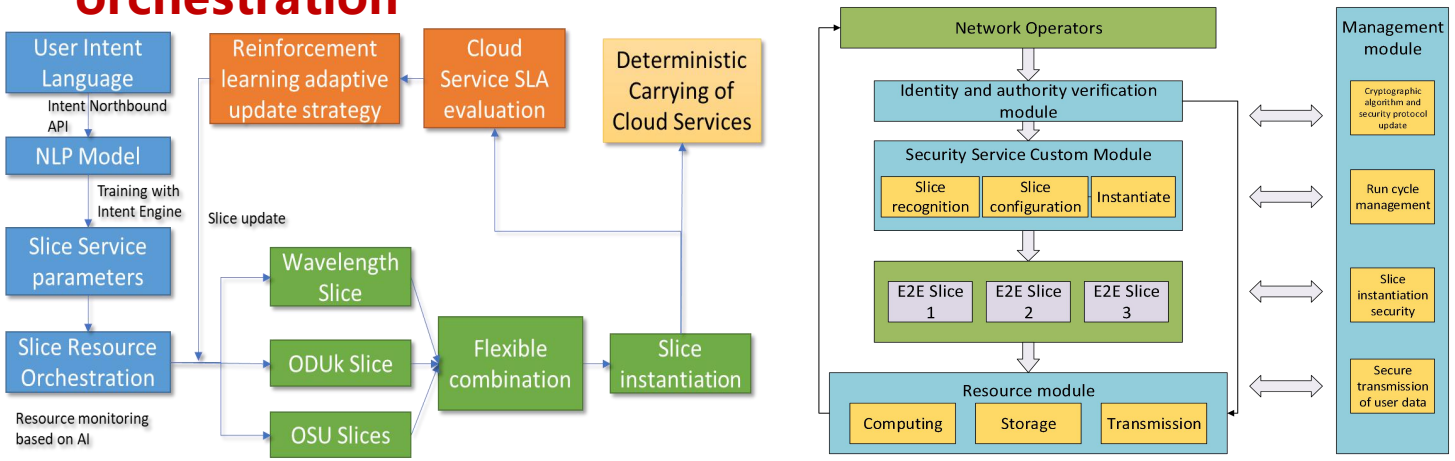


Problem: The segmented management of various cloud computing platforms makes collaborative control of network computing and transmission resources difficult, and it is difficult for intelligent scheduling and optimal deployment of network resources.

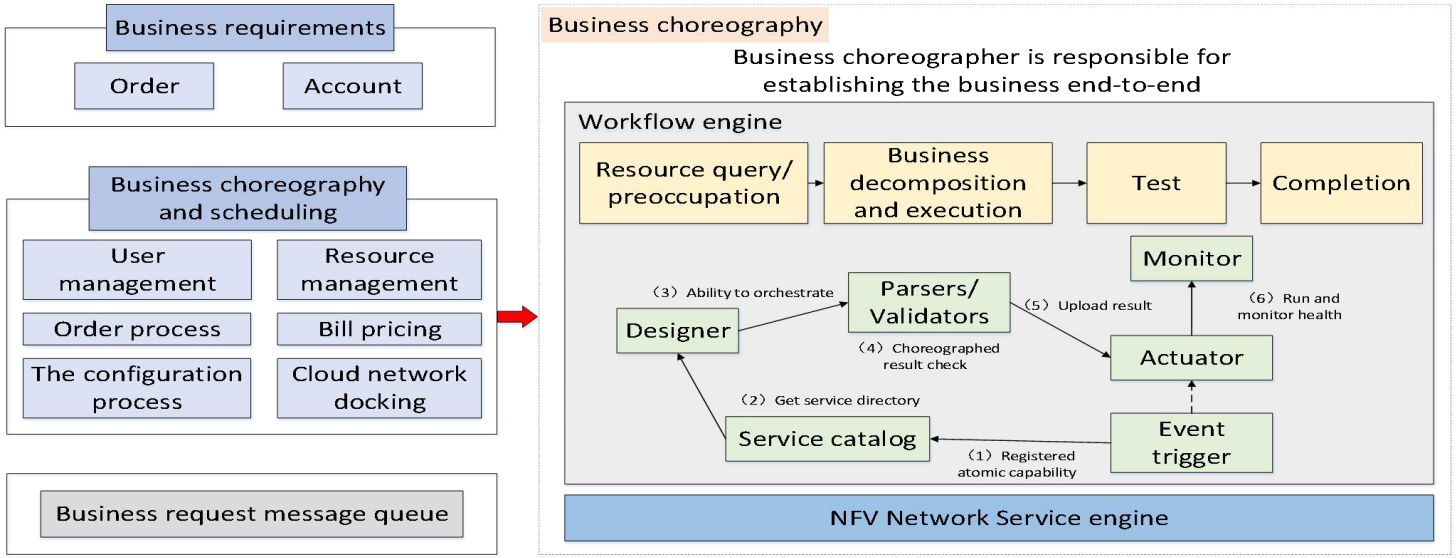
Solution: The mechanism of multi-dimensional network resource virtualization and unified measurement methods, explore a network resource collaborative control solution oriented to resource integration

Key technology in the Service Orchestration Plane

- **Intention-driven end-to-end network slicing automated orchestration**



- **Service life cycle management**



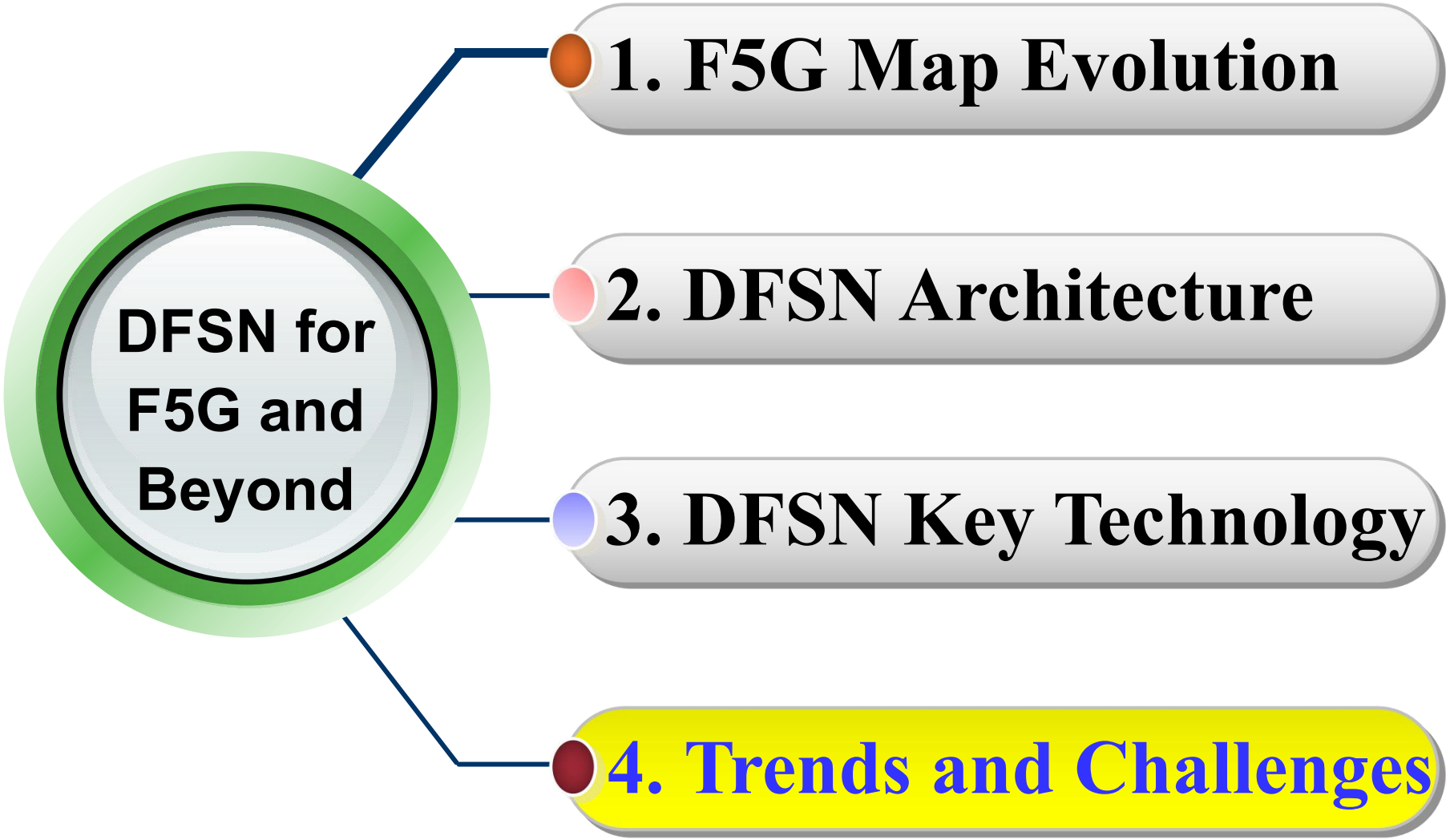
Problem: The segmented management of various cloud computing platforms makes collaborative control of network computing and transmission resources difficult, and it is difficult to achieve intelligent scheduling and optimal deployment of network resources.

Solution: Research the mechanism of multi-dimensional network resource virtualization and unified measurement methods based on network slicing, and explore the collaborative control scheme of network resources oriented to resource integration.

Problem: 5G base stations rely on fixed networks and cannot achieve end-to-end deployment of services on their own.

Solution: It is necessary to call down the controller and network equipment to obtain the entire network topology, and present all the equipment status and network, so as to complete the rapid end-to-end deployment of services.

Outline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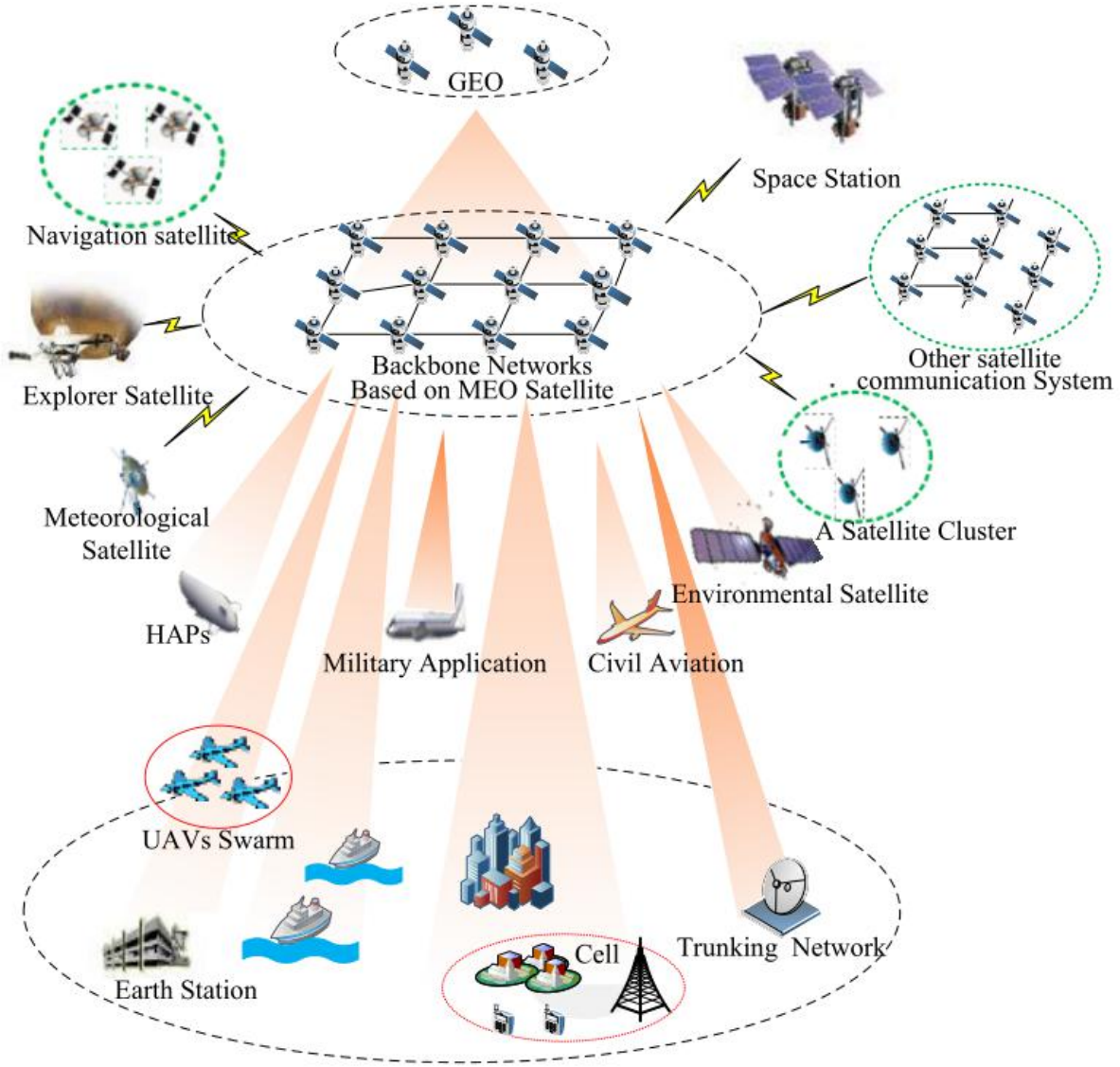
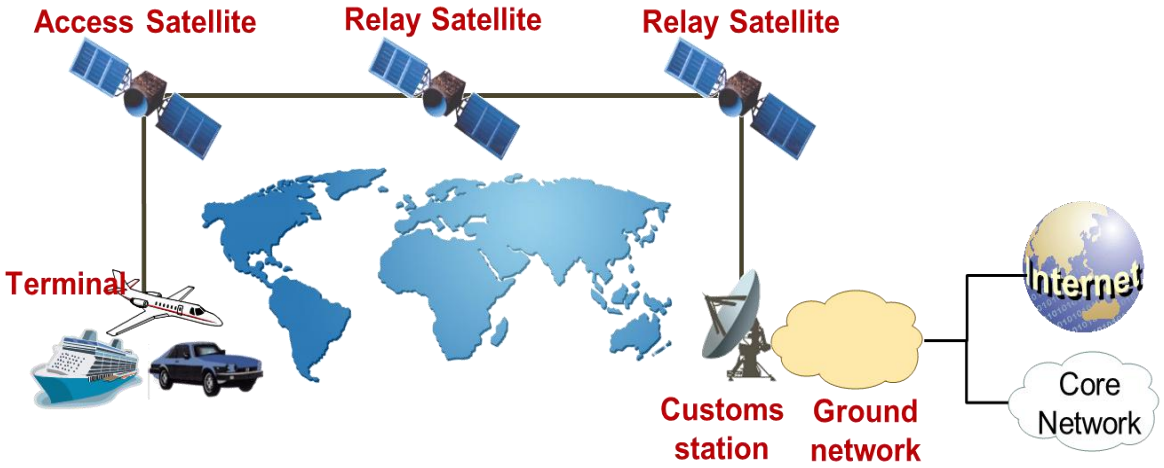
F6G：From” Fibre to Everywhere” To ” Optics to Everything”

	F4G	F5G	F6G
Service Objects	Enrich people's life through communication Fiber to Home	Optical connections enable various industries widening connections and enhancing user experience Fiber to Everywhere (Room/Bussiness/Cell site/…) (Machine/WiFi AP…)	Optical Connection Physics and Virtual Worlds Optic to everything
Scenario	FBB	eFBB、GRE、FFC	eFBB、GRE、FOC
Typical Application	4K video Online Game VOBB	VR video、Game POL 5G Backhaul 3D VR shopping Industrial Optical Network WiFi6 backhaul	holographic communication BCI communication Remote precision surgery
		 	
	2010~	2020~	2026~

- **eFBB**(enhencedFBB)
- **GRE**(Guaranted Reliable Experience)
- **FFC**(Fully Fiber Connected)
- **FOC**(Full Optical connected)

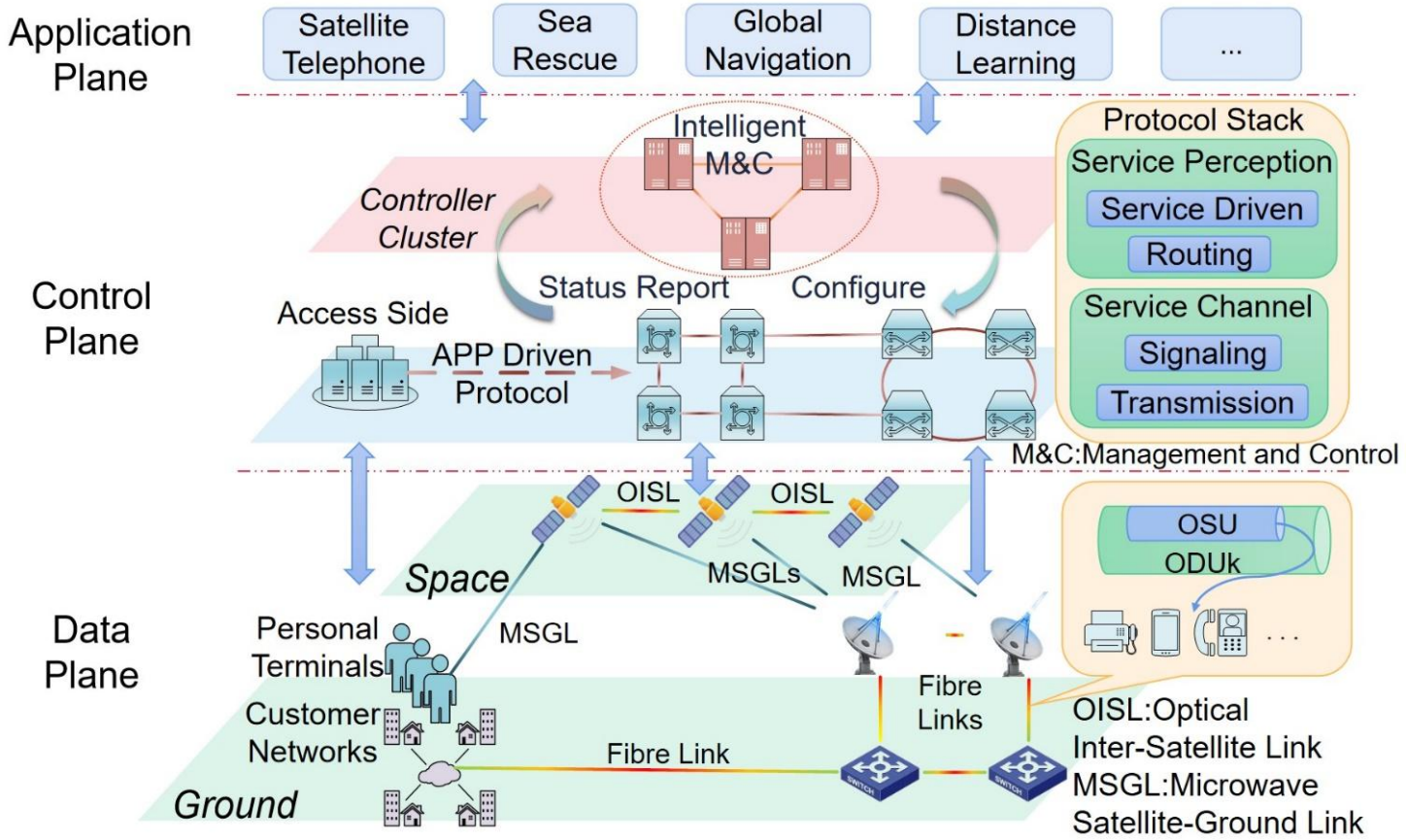
Satellite Laser Communication





- **Sky-ground integration:** satellite laser, floating platform , terrestrial network all-optical network, OTN, and ASON
- **Requirements:** 10 Gbit/s to 100 Gbit/s, long distance (1000 km to 10000 km), dynamic tracking, and Doppler redshift compensation

All Optical Service Networks for Integration of Space and Ground



Key Technology

- **Network Planning Automation Technology**
- **Centralized and Distributed Cooperation Control Model**
- **Routing Technology of Directional Forwarding**
- **Segment Distributed Signaling Technology**
- **Machine Learning based Traffic Planning Strategy**

Thank You!

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