Fujitsu All Photonic Network Vision
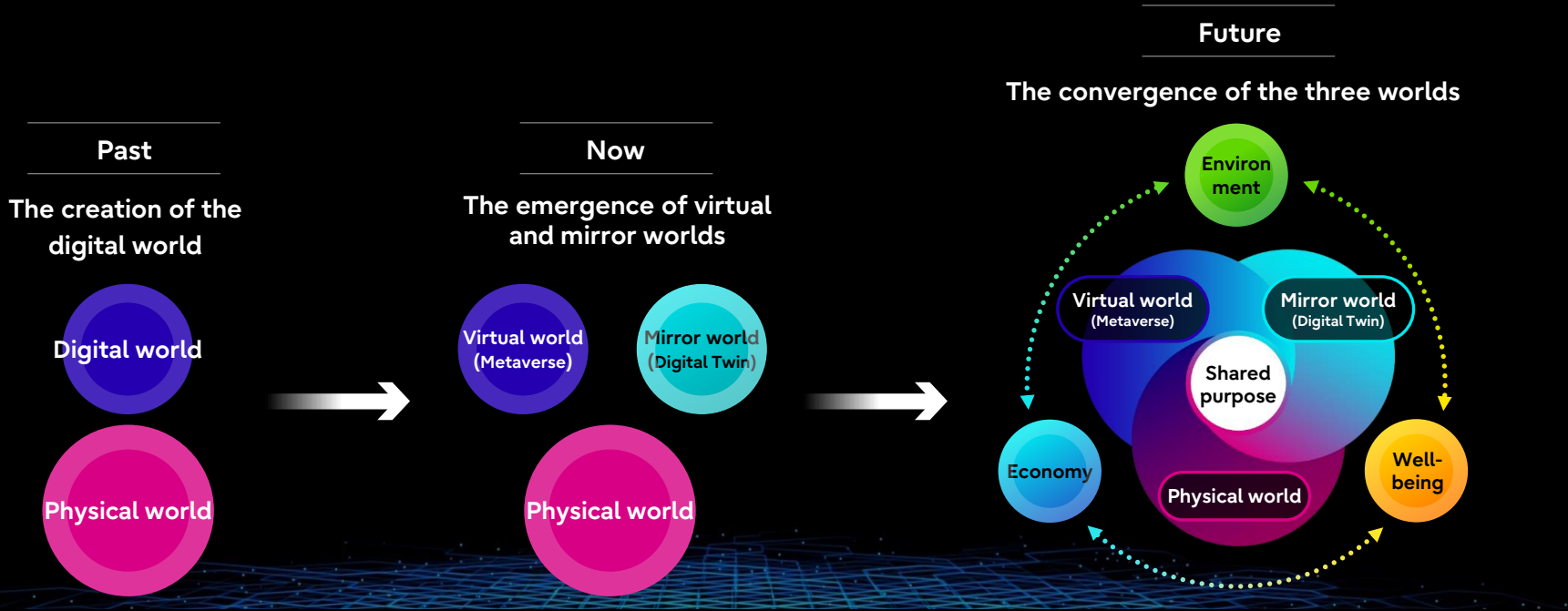
FUJITSU

Our purpose

Make the world more
sustainable by building trust
in society through innovation.

A borderless world

Future

The convergence of the three worlds

Environ ment

Virtual world (Metaverse)

Mirror world (Digital Twin)

Shared purpose

Economy

Physical world

Well-being

Past

The creation of the digital world

Digital world

Physical world

Now

The emergence of virtual and mirror worlds

Virtual world (Metaverse)

Mirror world (Digital Twin)

Physical world

- The virtual world can enable more inclusive experiences for everyone

- The mirror world has the potential to enhance the resilience of our physical world.

- The physical, virtual and mirror worlds will gradually merge. This will create a seamless, borderless world.

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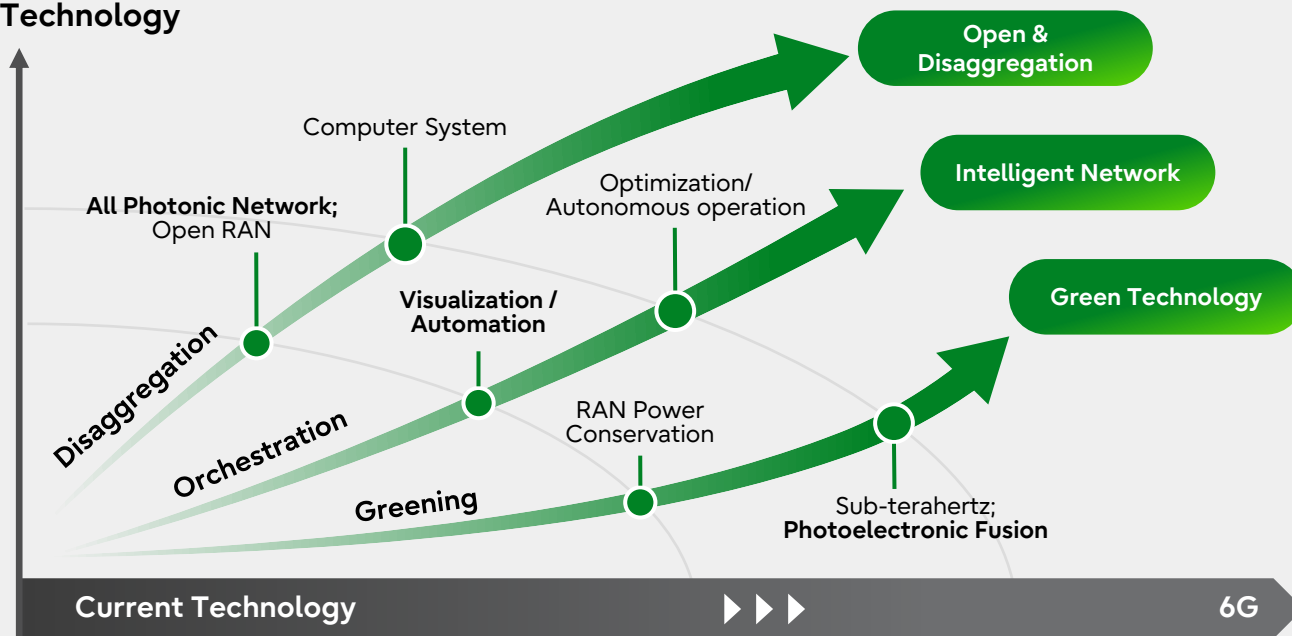# Network Architecture and Platforms
All Photonic Network

Technology Trends for Realizing a borderless world

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- **Deploying end-to-end fully virtualized cloud-native networks throughout the world**

Evolution of Technology

Open & Disaggregation

Computer System

Intelligent Network

All Photonic Network; Open RAN

Optimization/ Autonomous operation

Green Technology

Visualization / Automation

Disaggregation

RAN Power Conservation

Orchestration

Sub-terahertz; **Photoelectronic Fusion**

Greening

Current Technology ▶ ▶ ▶ **6G**

Open & Disaggregation

All Photonic Network, Mobile Base Stations (Open RAN), Computer System

Intelligent Network

Network Visualization, Automation & Optimization, AI/Machine Learning

Green Technology

Sub-terahertz, **Photoelectronic Fusion**, liquid-cooling Technology

All Photonic Network (APN) Concept

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End to end direct optical path

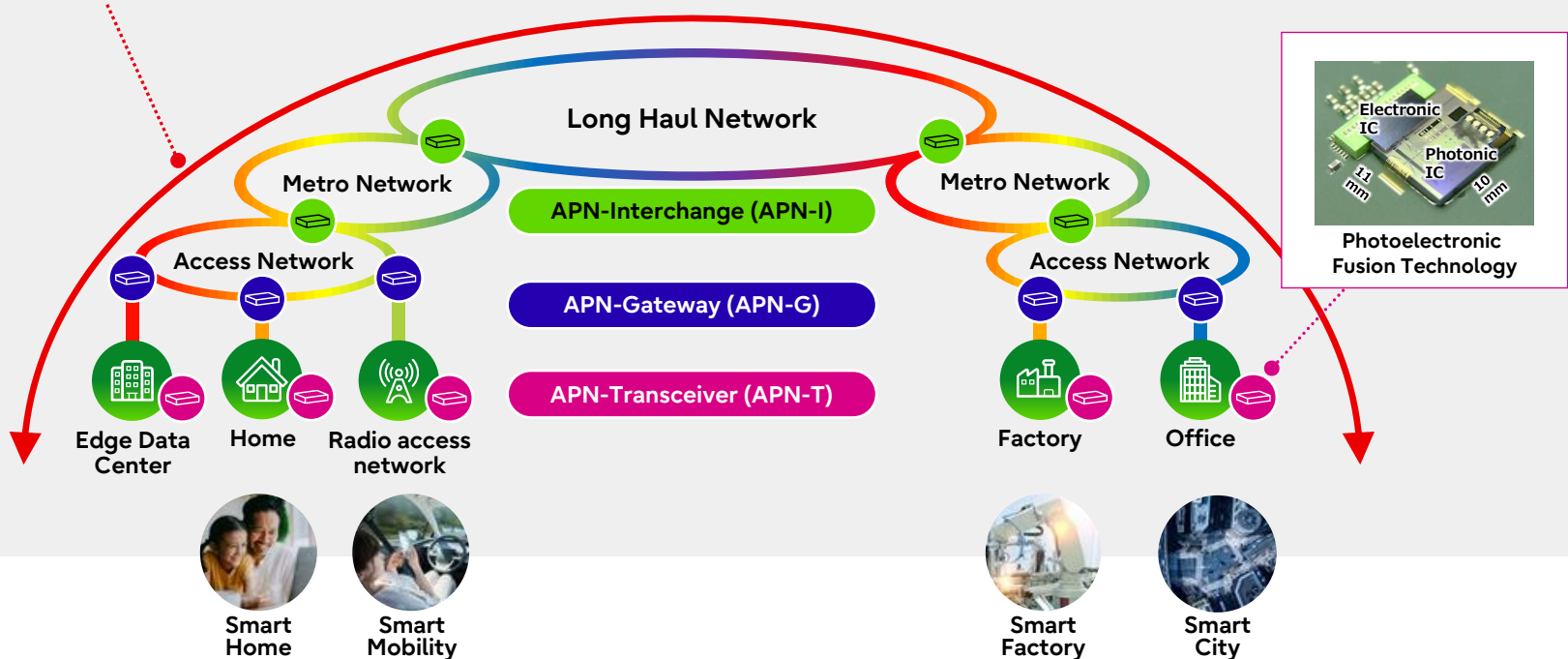🔋 **Lower Power Consumption**

⟫⟫⟫ **Higher Transmission Capacity**

⏱ **Lower end-to-end Latency**

End to end direct optical path connection for **lower power consumption, higher Transmission capacity and Lower end-to-end latency** by APN nodes (APN-T/G/I) without intermediate electrical router and switch nodes
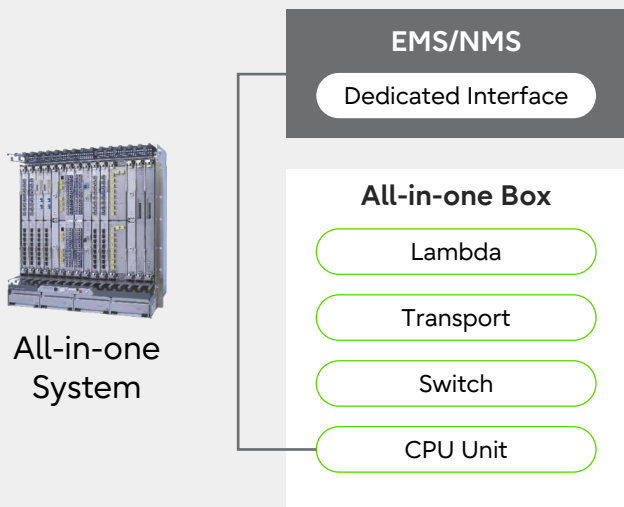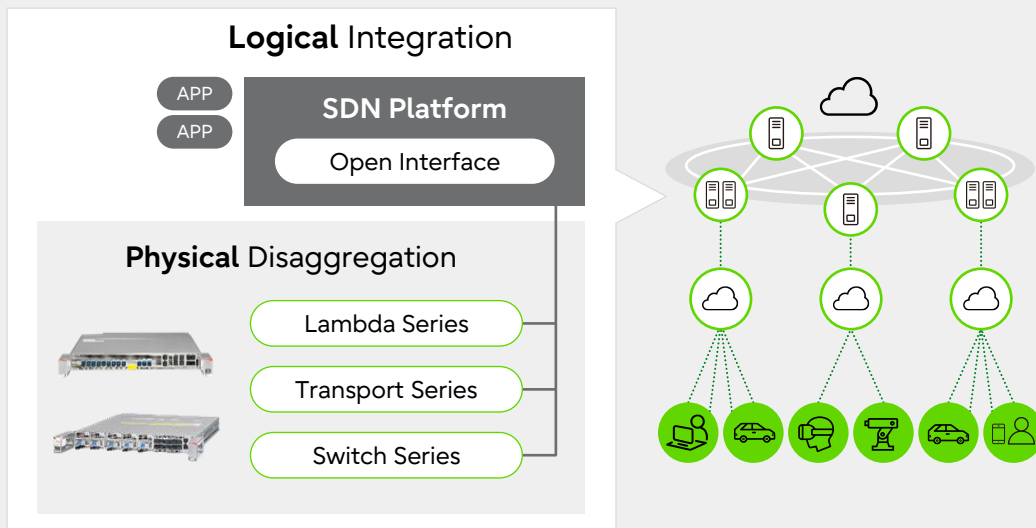

Long Haul Network

Metro Network

Access Network

APN-Interchange (APN-I)

APN-Gateway (APN-G)

APN-Transceiver (APN-T)

Edge Data Center

Home

Radio access network

Metro Network

Access Network

Factory

Office

Electronic IC

Photonic IC

11 mm

10 mm

Photoelectronic Fusion Technology

Smart Home

Smart Mobility

Smart Factory

Smart City

Open APN: Optical Transport System

- **Transitioning from a conventional all-in-one-box type system to a disaggregated system**
  - **SDN control allows for optimal, rapid network building**
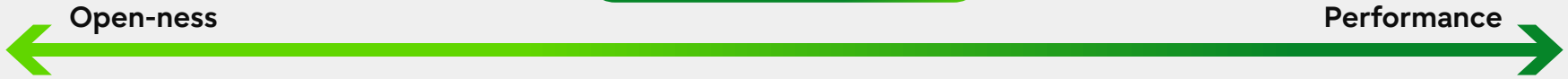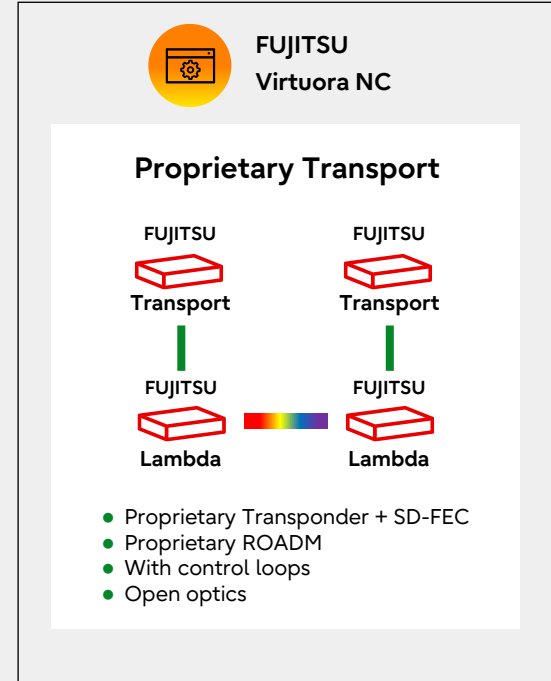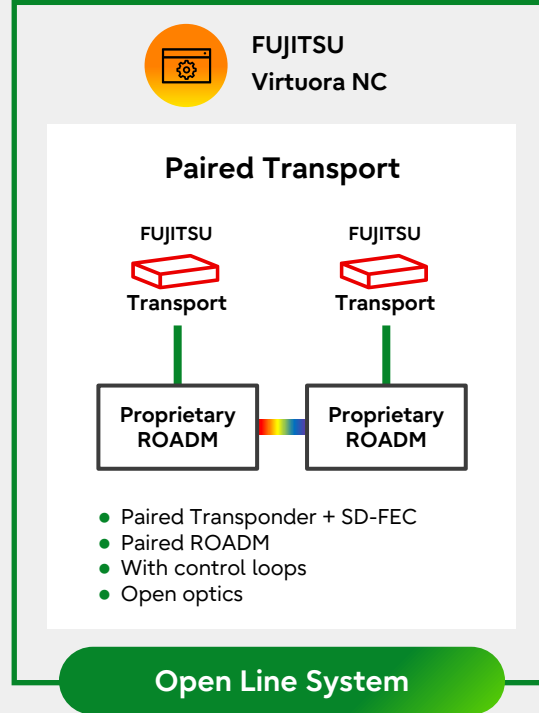 - **Optimized power consumption across the network**
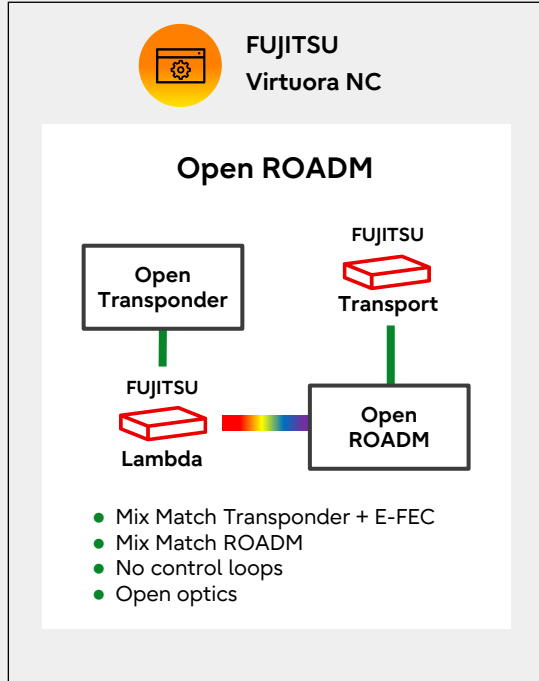

Conventional System

Open Disaggregated System

All-in-one System

EMS/NMS

Dedicated Interface

All-in-one Box

Lambda

Transport

Switch

CPU Unit

Logical Integration

APP

APP

SDN Platform

Open Interface

Physical Disaggregation

Lambda Series

Transport Series

Switch Series

Open APN: Open Line System (OLS)

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FUJITSU Virtuora NC

Open ROADM

FUJITSU
Transport

Open Transponder

FUJITSU
Lambda

Open ROADM

- Mix Match Transponder + E-FEC
- Mix Match ROADM
- No control loops
- Open optics

FUJITSU Virtuora NC

Paired Transport

FUJITSU
Transport

FUJITSU
Transport

Proprietary ROADM

Proprietary ROADM

- Paired Transponder + SD-FEC
- Paired ROADM
- With control loops
- Open optics

Open Line System

FUJITSU Virtuora NC

Proprietary Transport

FUJITSU
Transport

FUJITSU
Transport

FUJITSU
Lambda

FUJITSU
Lambda

- Proprietary Transponder + SD-FEC
- Proprietary ROADM
- With control loops
- Open optics

Open-ness

Performance
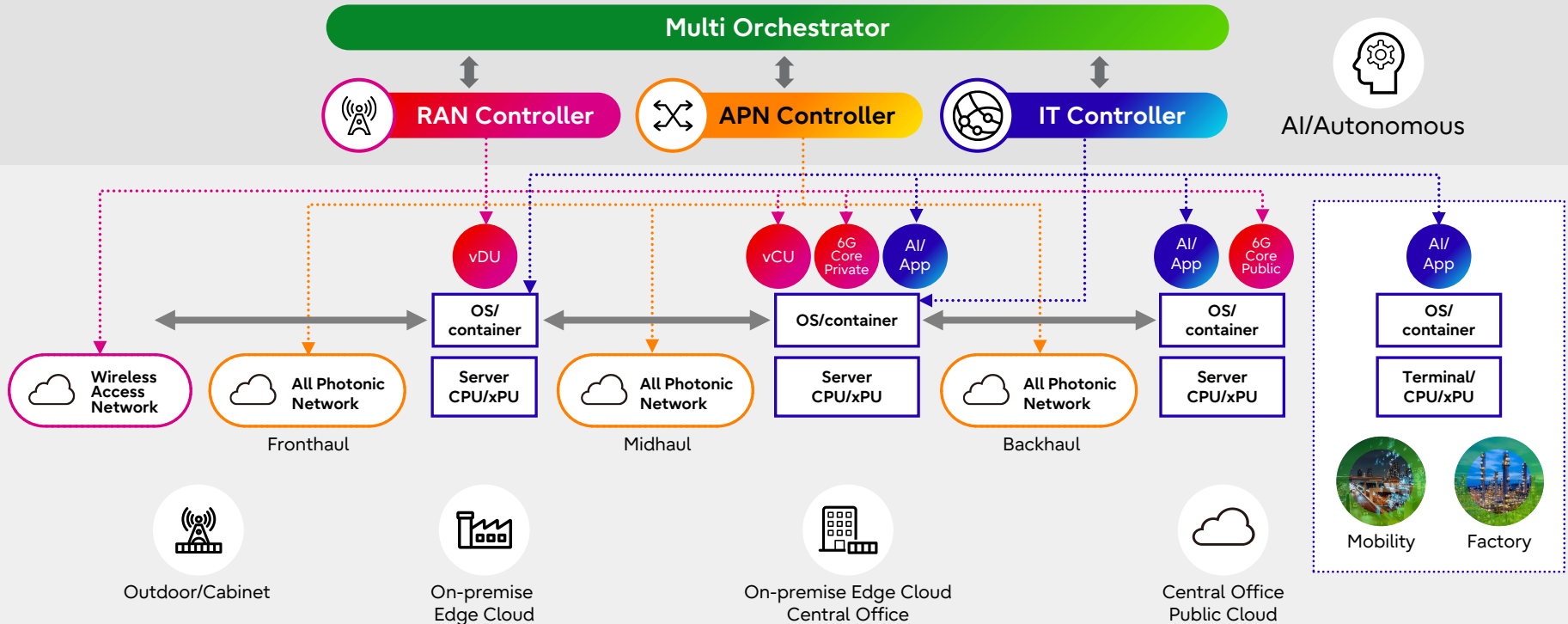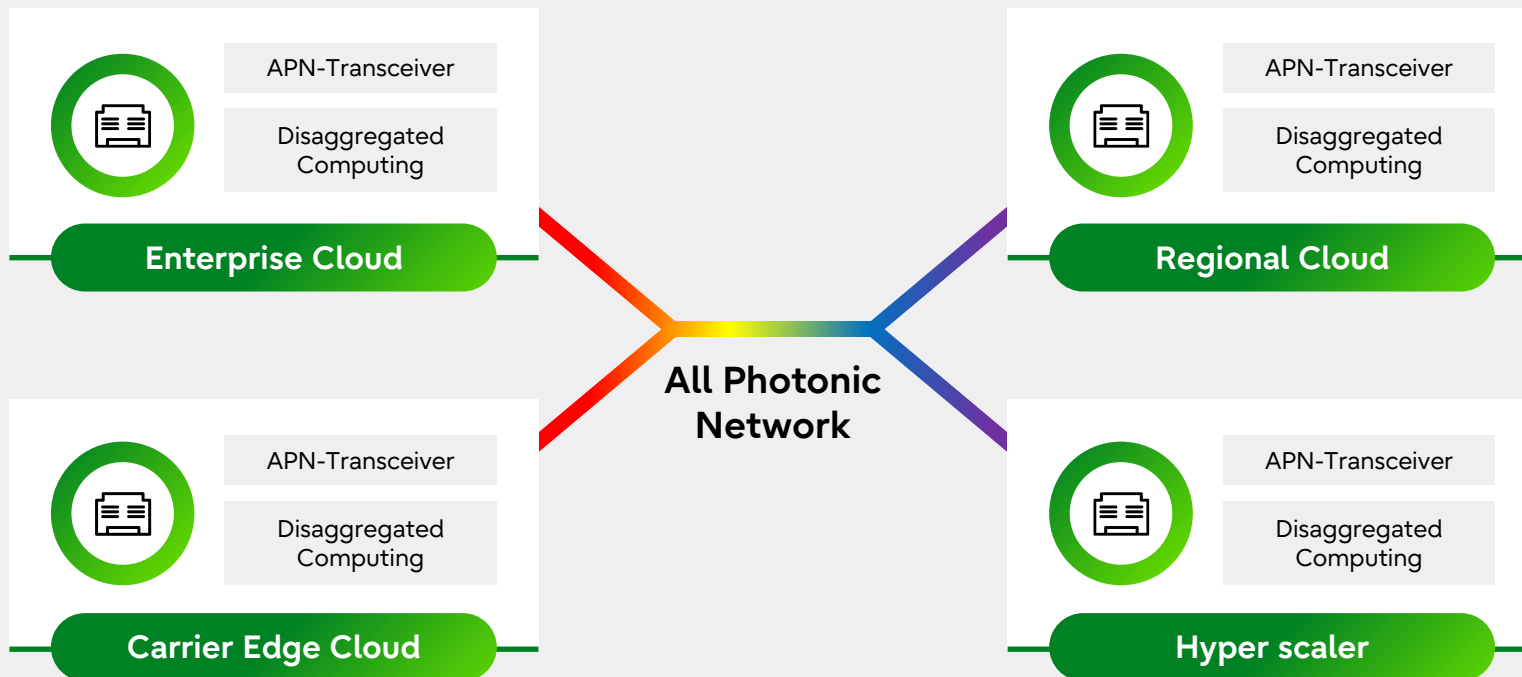
APN Interconnections by Multi Orchestrator

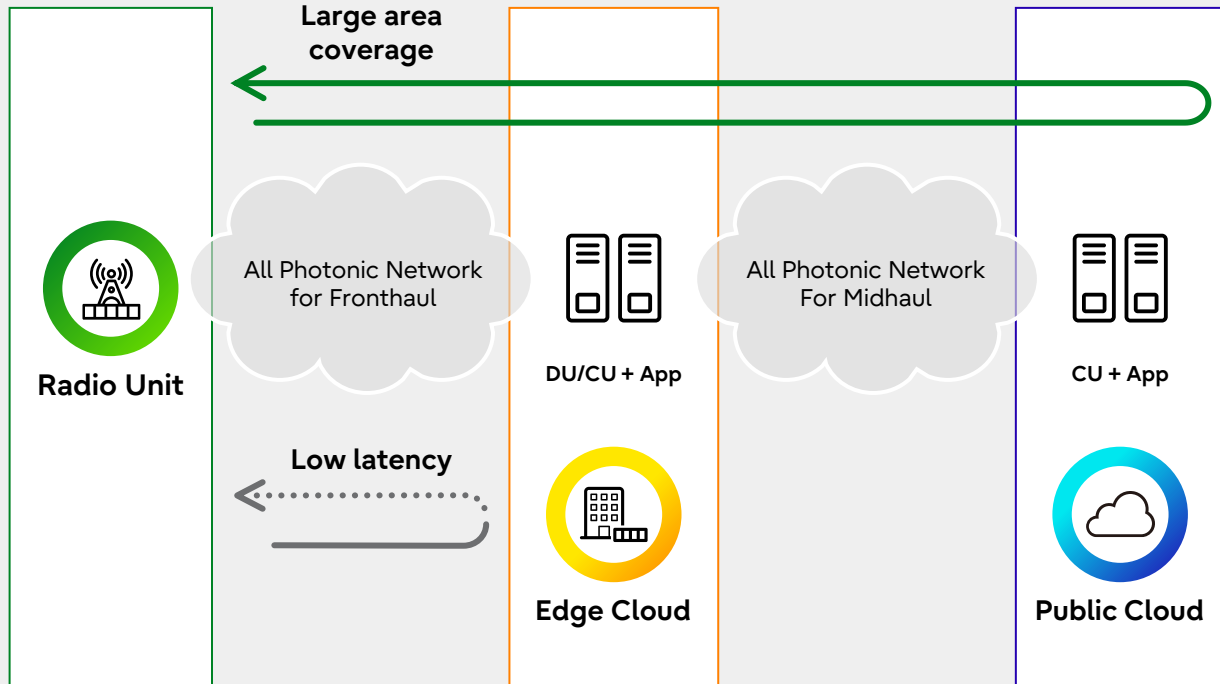**Data centric infrastructure for various type of data processing by all photonic network interconnection of function dedicated node**

APN in Long haul/Metro Domain

- **Metro/Nation-wide Distributed Data Center interconnection by APN for resilient DC services**

APN in Access/xhaul Domain

Use Case

Sensor/IoT

Large area coverage

All Photonic Network for Fronthaul

All Photonic Network For Midhaul

Radio Unit

DU/CU + App

CU + App

Low latency

Edge Cloud

Public Cloud

Wide Frequency range from MHz to Sub-THz

APN in Data Center/Computing Domain

Cloud A

Cloud B

Cloud C

APN-T for Data Center Interconnection

Photonic Smart NIC*

Accelerator

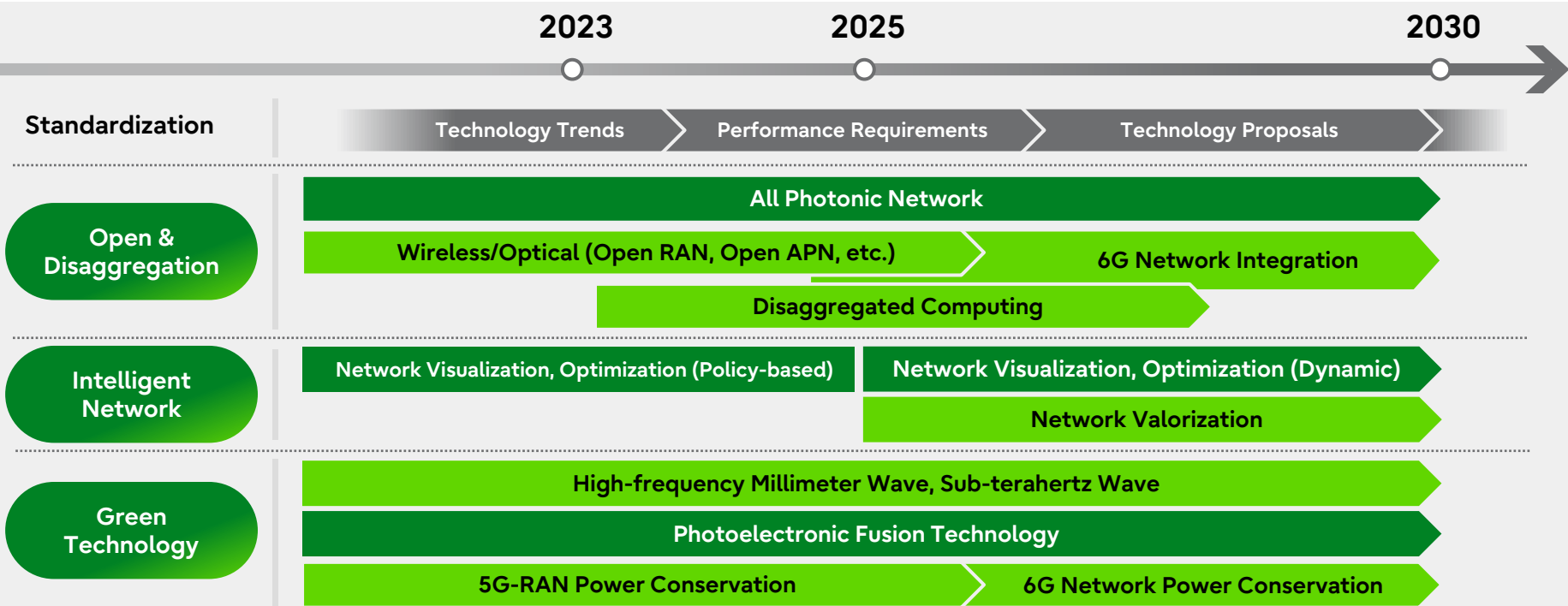CPU

Memory

Storage

Intra Data Center
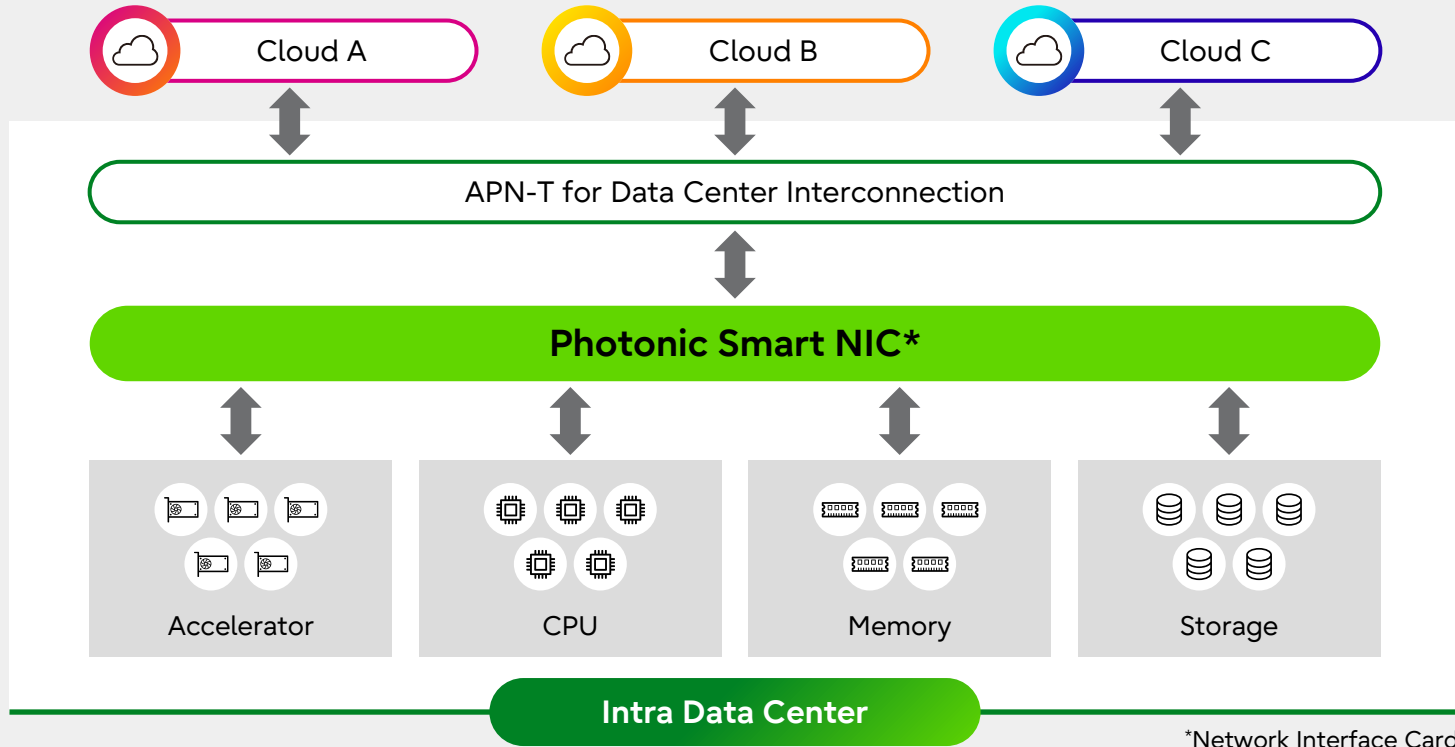
*Network Interface Card

Connecting the borderless world with APN

Fujitsu is developing future network technologies to create seamless experiences and a sustainable future

	2023	2025	2030

Standardization
- Technology Trends
- Performance Requirements
- Technology Proposals

Open & Disaggregation
- All Photonic Network
- Wireless/Optical (Open RAN, Open APN, etc.)
- 6G Network Integration
- Disaggregated Computing

Intelligent Network
- Network Visualization, Optimization (Policy-based)
- Network Visualization, Optimization (Dynamic)
- Network Valorization

Green Technology
- High-frequency Millimeter Wave, Sub-terahertz Wave
- Photoelectronic Fusion Technology
- 5G-RAN Power Conservation
- 6G Network Power Conservation

Note: The above is based on Fujitsu's current projections and is subject to change without notice.

Enabling technologies and Fujitsu Products

Fujitsu's Product Overview

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| APN-C | APN Controller | APN-I | APN Interchange | APN-G | APN Gateway | APN-T | APN Transceiver |

SDN Controller APN-C

Virtuora Network Management
Virtuora Planning & Design
Virtuora Network Controller

OTN Apps   WDM Apps   Packet Apps   DCI Apps

LAMBDA APN-I/G

L100/L600	: 9 port ROADM on Blade
L130	: 32 port ROADM on Blade
L110/L120	: CD Add/Drop Base Blade, C-band
L610/L620	: CD Add/Drop Base Blade, L-band
L140/L220	: CDC Add/Drop Base Blade
L160/L810	: Backward Raman Blade
L200/L680	: Compact ILA Blade
L310/L320	: Point-to-Point Line System, C-band
L900	: Next Generation ROADM
L910/L920	: Next Generation ILA

TRANSPORT APN-T

T300/T500	: 200G Transponder
T310/T510	: 200G Muxponder
T700	: 400G Transponder/Muxponder
T900	: 1.2T Transponder/Muxponder
T600	: 600Gbps Flex Muxponder for DCI
T950	: 1.2T Transponder/Muxponder for DCI

SWITCH APN-T

S100	: 1.2Tbps Ethernet Switch
S800	: 400G TSN Switch
S900	: 120Gbps Access Switch

COMMS INTEGRATOR(CI)

C20x : 36 port Communications Integrator Rack Manager

HOUSING

6 Blade Housing
Power Distributor

Multi-Functional Programmable Blades Optimized for SDN

APN T/G/I nodes : 1FINITY Ultra Optical System

- **New Optical Transport platform achieves top-level long-distance transmission capacity of 1.2Tbps**

- **Incorporate the latest technologies**
  - A digital signal processor (DSP) LSI using latest semiconductor processes
  - Liquid cooling delivers 2x the cooling capacity
  - C+L ROADM architecture able to handle multiple wavelength bands in one product
  - Forward Raman amplification

- **60% reduction in CO2 emissions**

- **Support for AI/ML automation to optimize performance**

More is less . . .

More wavelengths per fiber

More capacity or reach per wavelength

Less effort to install, operation, and maintain

Less power consumed per bit

The ideal balance of cost, capacity and reach – simplified

1FINITY L900 terabit-optimized OLS

- C+L band in one device ensures high reliability
- Using optical backboards to reduce cable connections during initial construction
- Forward Raman amplification increase maximum transmission
- Max transmission capacity 76.8Tbps, Max 16degree

1FINITY T900/T950 extreme-performance transponder

- High Baud Rate and Compensation Technology Realize High OSNR and Long-Distance transmission
- Space saving and low power consumption by liquid cooling technology
- Max transmission capacity 1.2Tbps/Lambda, 14.4Tbps/blade

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APN Terminal node : Latency Engineering Solution

OTN terminal product overcoming distance constraints

⚠️ **Network challenges between geographically distant sites**

- Physical latency during optical fiber propagation due to distance difference
- Transmission latency caused by passing through the devices
- Latency caused by variations in network quality

✅ **Transmission-time Visualization and adjustment** — Measure the latency in the NW between sites on a path-by-path basis to visualize and adjust the latency difference in transmission time.

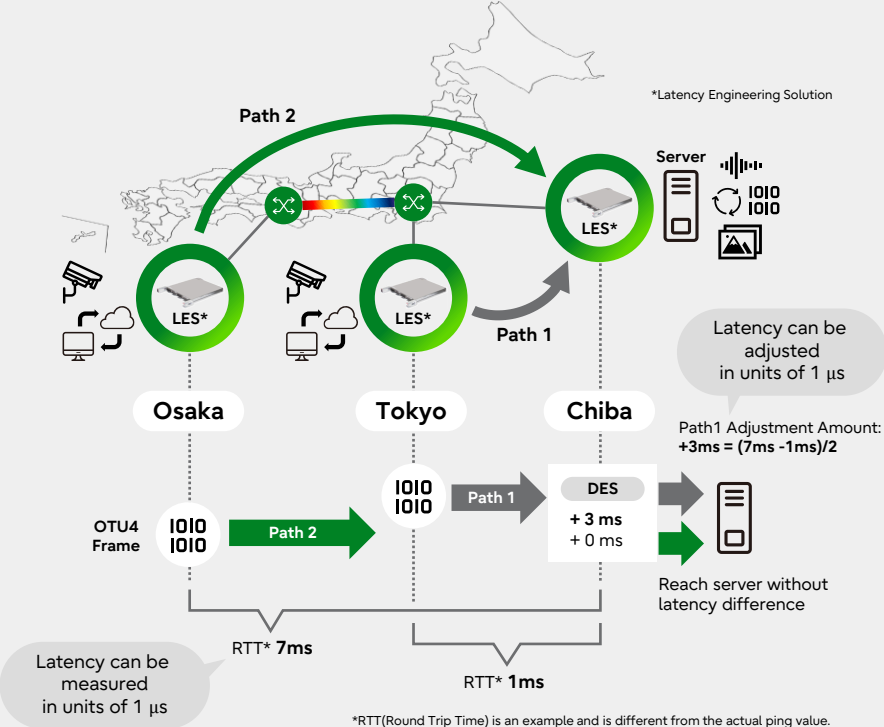✅ **Low power consumption and large-capacity communication** — Low power and high capacity optical transmission (OTU4) as terminal equipment for All Photonic Network

Achieve a fair, high-quality and sustainable communications infrastructure

Achieve a sustainable network by maintaining fair network quality among sites

➡️ A range of services that transcend space and do not require movement
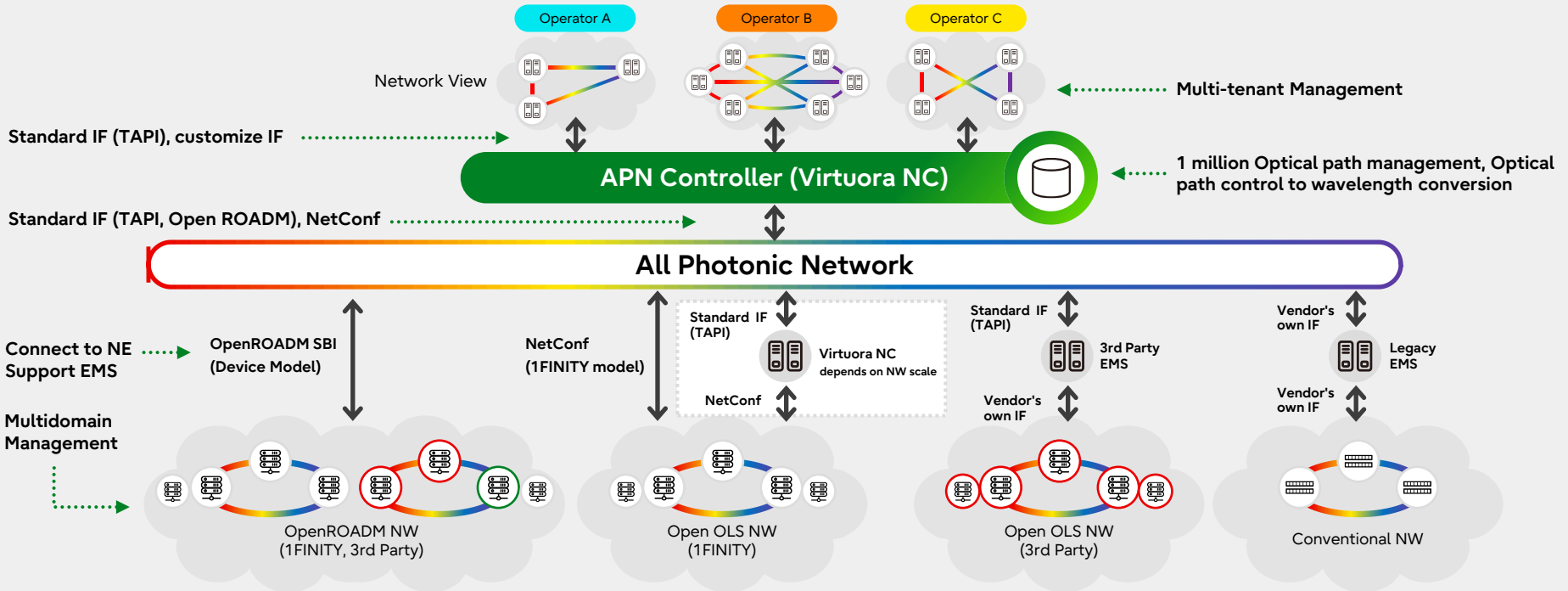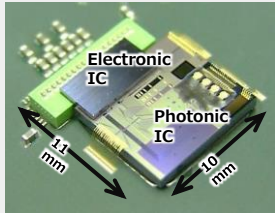
Example of Point to Point Network configuration

Service applications examples:
Multi-site video broadcasting, telemedicine, and e-SPORTS

*Latency Engineering Solution

Path 2

Path 1

Server

LES*

LES*

LES*

Osaka   **Tokyo**   **Chiba**

Latency can be adjusted in units of 1 μs

Path1 Adjustment Amount:
+3ms = (7ms -1ms)/2

OTU4 Frame

Path 2   Path 1   DES
+ 3 ms
+ 0 ms

Reach server without latency difference

RTT* **7ms**

RTT* **1ms**

Latency can be measured in units of 1 μs

*RTT(Round Trip Time) is an example and is different from the actual ping value.

APN Controller : Virtuora NC

- **On-demand optical path control :** An optical path can be controlled on demand and a fixed optical path can be set between arbitrary terminals
- **Domain Controller Management :** Integrated management of multi-vendor networks with end-to-end, containing a domain controller (EMS) terminating vendor IF
- **Multi-tenant Management :** Supports network view management for multiple operators to provide services on the same network


Operator A

Operator B

Operator C

Network View

Multi-tenant Management

Standard IF (TAPI), customize IF

APN Controller (Virtuora NC)

1 million Optical path management, Optical path control to wavelength conversion

Standard IF (TAPI, Open ROADM), NetConf

All Photonic Network

Connect to NE Support EMS

OpenROADM SBI (Device Model)

NetConf (1FINITY model)

Standard IF (TAPI)

Virtuora NC depends on NW scale

NetConf

Standard IF (TAPI)

3rd Party EMS

Vendor's own IF

Legacy EMS

Vendor's own IF

Vendor's own IF

Multidomain Management

OpenROADM NW (1FINITY, 3rd Party)

Open OLS NW (1FINITY)

Open OLS NW (3rd Party)

Conventional NW

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Fujitsu's Advanced Photonics Research for APN

Scalable transceivers

- Integrated photonics
- DSP algorithm
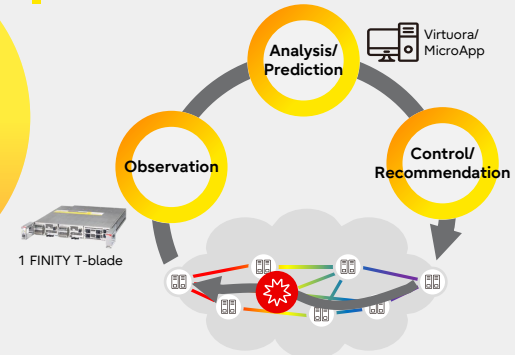- MCM (DSP, Electrical/Optical device) integration

Ultra-wideband optical transmission

- Multi-band transmission
- Node architecture
- Optical signal processing
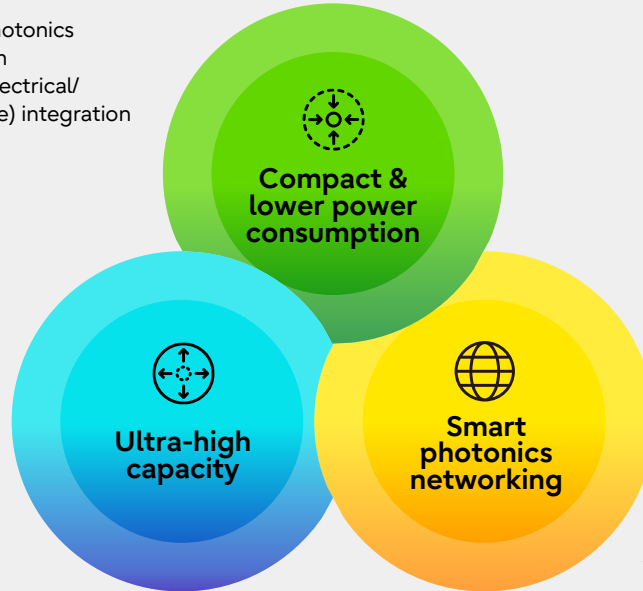
Optical network automation & Optical NW digital twin

- Photonics tomography
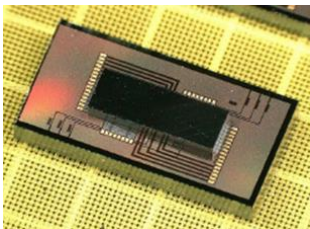- Flexible/Adaptive optical system architecture

Compact & lower power consumption

Ultra-high capacity

Smart photonics networking

Virtuora/MicroApp

Analysis/Prediction

Observation

Control/Recommendation

1 FINITY T-blade
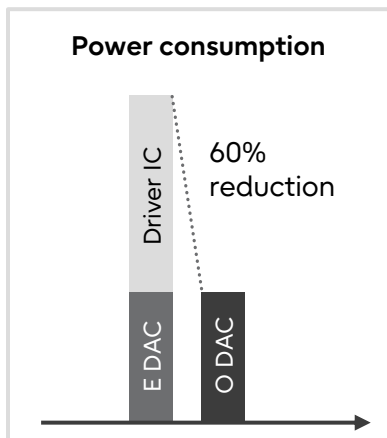
Scalable transceivers

In optical transmission and computing – reduced power consumption and improved data transfer

Photoelectronic Fusion Device

Compactness and high energy efficiency is achieved by implementing optical and electrical processing in the same package
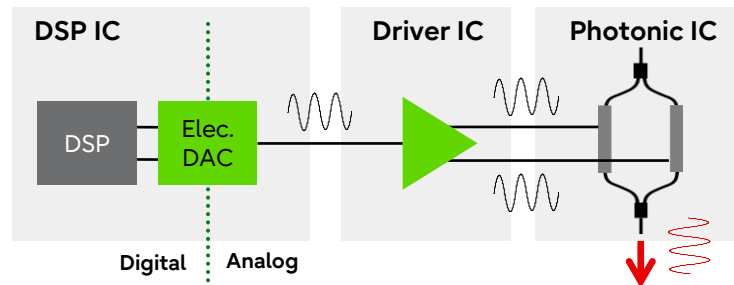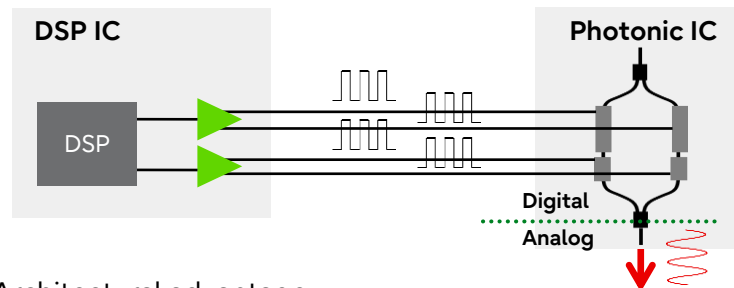
Si photonics chip
2.75 x 4.0 mm

Power consumption

Driver IC

60% reduction

E DAC

O DAC

FUJITSU

Conventional architecture

DSP IC

DSP

Elec. DAC

Driver IC

Photonic IC

Digital | Analog

Optical DAC architecture

DSP IC

DSP

Photonic IC

Digital

Analog

Architectural advantage:
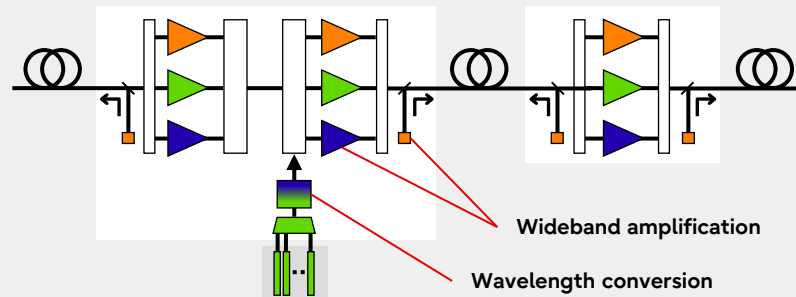Eliminates high-speed analog driver amplifier

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Ultra-wideband transmission (Beyond C+L)

- **Ultra-wideband optical transmission node to expand the operating wavelength band**

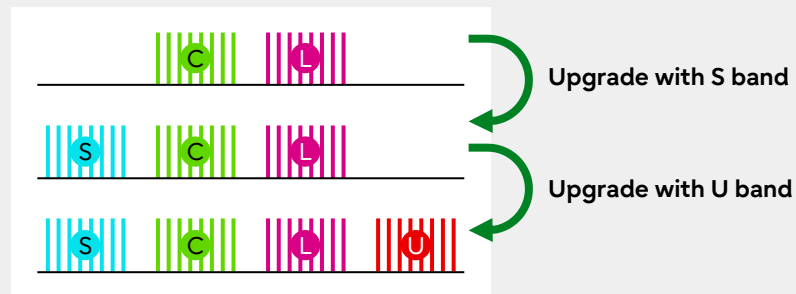- **Enable to connect multi-band network for direct optical path**

- Fujitsu has unique and novel **ultra-wideband system concept using wavelength conversion technology** and introduce the concept into the node through a collaboration with partners

  - Convert the WDM signals to any wavelength bands
  - No need to develop the new transponders for S band or U band

Example of ultra-wideband node configuration

Wideband amplification

Wavelength conversion

Wavelength conversion (example of upgrade)

Upgrade with S band

Upgrade with U band

Photonics Tomography
End-to-end photonic network monitoring

Network controller

Data Collection

Analysis Optimization

Recommend Control

| TRANSPONDER | ROADM | ILA | ROADM | TRANSPONDER |

OTDR ⋯⋯ OTDR OTDR ⋯⋯ OTDR

ASE ⋯⋯⋯⋯⋯⋯⋯⋯⋯ ASE

DGE ⋯⋯ DGE ⋯⋯ DGE

DSP ⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯ DSP

Physical layer Monitoring at NE

Telemetry/control data transfer and sharing by OSC

Optical Network Digital Twin

Design and Management Applications / Algorithms

run "what-if" scenarios

Operating conditions

ms speed

Signal quality of optical signals

Optical Network Digital Twin
Optical Network Modeling Function

streaming & on-demand

Telemetry

NMS, Controller

Tomography

Alarms

- Alien wave design (OLS Designer App)
- SOP Localization
- RWA, protection, restoration
- Network optimization
- Root-cause analysis
- Failure localization
- Margin-aware alarms
- Adaptive SLAs, ...

- Instrumentation control
- Data validation, screening
- Model selection/evolution
- Database of history

▲ Digital world   **Potentially Perfect, Automated**

▼ Physical world   **Inherently Fragile and Manual**

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Fujitsu Collaboration

FUJITSU

Open Optical/Radio Network

cbrs	IOWN GLOBAL FORUM	MEF
Open air interface	Open RAN	Open ROADM
O-RAN	OREX	TELECOM INFRA PROJECT

Open Software Platform

ONAP	ONF
OPEN DAYLIGHT	Warrior
LINUX Foundation	

Standards development organization/Certification, Academic community

ARIB	ETSI	3GPP	IEEE	ITU	OIF	OPTICA	TTC

Industry Affiliations

atis	Beyond 5G promotion consortium	cca	CIAJ	Ethernet Alliance
National Rural Electric Cooperative Association		Next G alliance		Next generation Mobile Network
NTCA	SCTE	TechTitans	TIA	tmforum	UTC

Thank you