How we can achieve economic growth and global sustainability with optical transport evolution

- Future of Data Centers and Peering -

May 30th, 2024,

Masahisa Kawashima,

IOWN Technology Director, IOWN Development Office, NTT

Technology Working Group Chair, IOWN Global Forum

About Me: Masahisa Kawashima

IOWN Technology Director, IOWN Development Office,
R&D Planning Department, NTT Corporation

Technology WG Char, IOWN Global Forum

- System/Infrastructure Architect with Expertise in NW and IT
- Bridge Between Businesses and Technologies
- Strategy Thinker
- Past Achievements (just to mention major ones)
    - Video AI Inference Cloud, NTT East, 2022
    - "Master's ONE CloudWAN" , SD-WAN, NTT PC and Dimension Data Internet Solutions, 2017
    - Public Wi-Fi Service (Renewal), NTT West, 2013
    - NTT Open Source Software Center, NTT Holding, 2006

OUTLINE

How we can achieve economic growth and global sustainability with optical transport evolution
- Future of Data Centers and Peering -

1. Problem Statement: Data Center Moratorium
2. Why data centers are getting bigger and concentrated
3. Solution Proposal: Infrastructure Evolution with IOWN
4. Global collaboration at IOWN Global Forum
5. Q&A *I would humbly appreciate any feedback.*

Data Center Moratorium

Data Centers Consume Enormous Energy

	Power (W)	Power consumption (Wh/Year)	Ratio relative to general households
General households	1~6k	4M	x 1
Manufacturing factory (less than 100 people)	100k	1G	x 250
Manufacturing factory (More than 1,000 people)	1~10M	12~60G	x 3,000-15,000
Semiconductor factory	120M	1T※1	x 250,000
Hyper-scale data center	120M	1T※1	x 250,000
Data center (Worldwide)	-	315T	x 78,750,000

A 300MW class datacenters have appeared.

※1 : Estimated value for continuous use of 120MW.

※NTT Research: Calculated from the following literature, etc.
- https://www.env.go.jp/earth/ondanka/kateico2tokei/2017/result3/detail1/index.html
- http://www.cirje.e.u-tokyo.ac.jp/research/dp/2013/2013cj246.pdf
- https://esg.tsmc.com/download/file/2020-csr-report/english/pdf/e-all.pdf
- fy2018-pp-15.pdf (jst.go.jp)
- https://www.soumu.go.jp/main_sosiki/jichi_gyousei/daityo/jinkou_jinkoudoutai-setaisuu.html

AI Computing's Energy Consumption

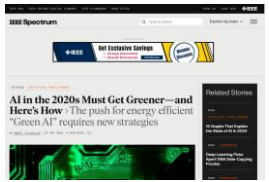
Consumption	CO_2e (lbs)
Air travel, 1 passenger, NY↔SF	1984
Human life, avg, 1 year	11,023
American life, avg, 1 year	36,156
Car, avg incl. fuel, 1 lifetime	126,000
Training one model (GPU)	
NLP pipeline (parsing, SRL)	39
w/ tuning & experimentation	78,468
Transformer (big)	192
w/ neural architecture search	626,155

Table 1: Estimated CO_2 emissions from training common NLP models, compared to familiar consumption.[1]

One Transformer Training's CO2 Emission
= 56.8 Humans' Annual CO2 Emission

Energy and Policy Considerations for Deep Learning in NLP, Emma Strubell, Anaya Ganesh, Andrew McCallum, Univ. Massachusetts Amhest, June, 2019

AI Workload Growth Rate

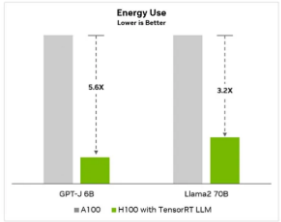


# of computations
x 30,000 in 6 years
= x 30 in 2 years

AI in the 2020s Must Get Greener and Here's How, Ameet Talwalkar, IEEE Spectrum, February 202, "

>>

Efficiency Improvement Rate



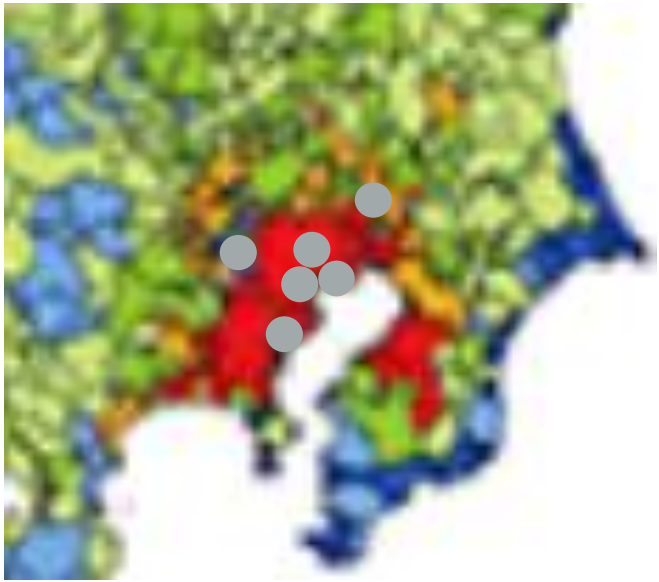
Computation
energy efficiency
x 3 to 6 in 2 years
(A100@2020 vs H100@2022)

Comparison of NVIDIA-A100, H100, and H200 for LLMs, Ayyuce Kizrak, Heartbeat

Data Centers are concentrated in Urban Areas

Urban Data Centers Increase CO2 Emission

Great Tokyo Metropolitan Area



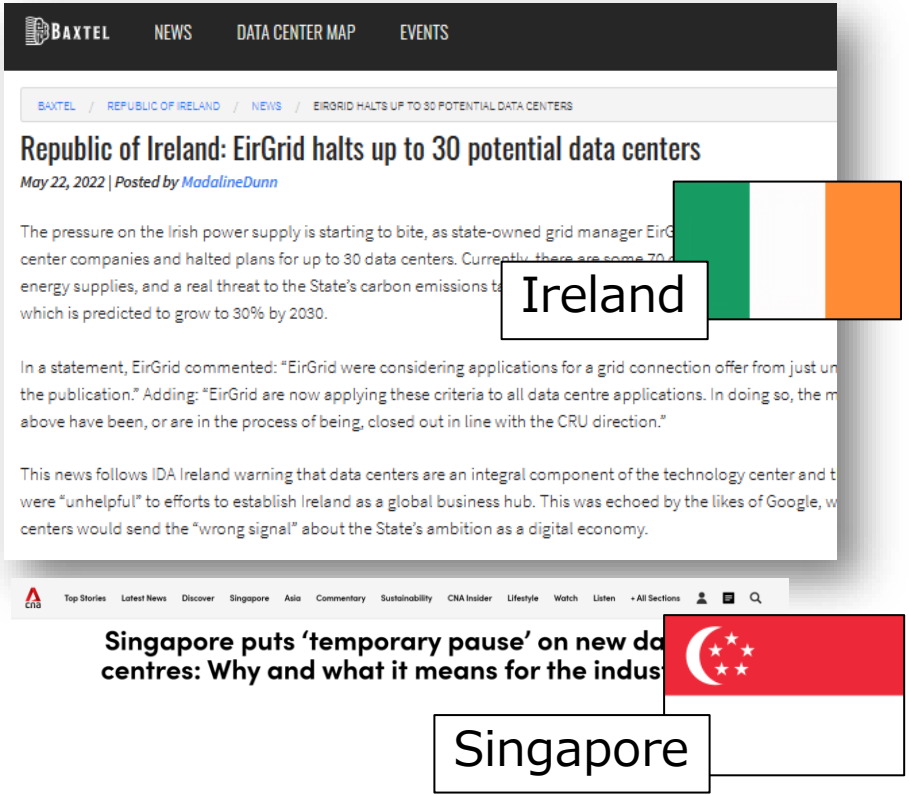
Energy Demand >> Renewable Energy Supply Potential

Energy Demand = Renewable Energy Supply Potential

Energy Demand << Renewable Energy Supply Potential

Data Center Concentration Area

Data Center Moratorium



https://baxtel.com/news/eirgrid-halts-up-to-30-potential-data-centers

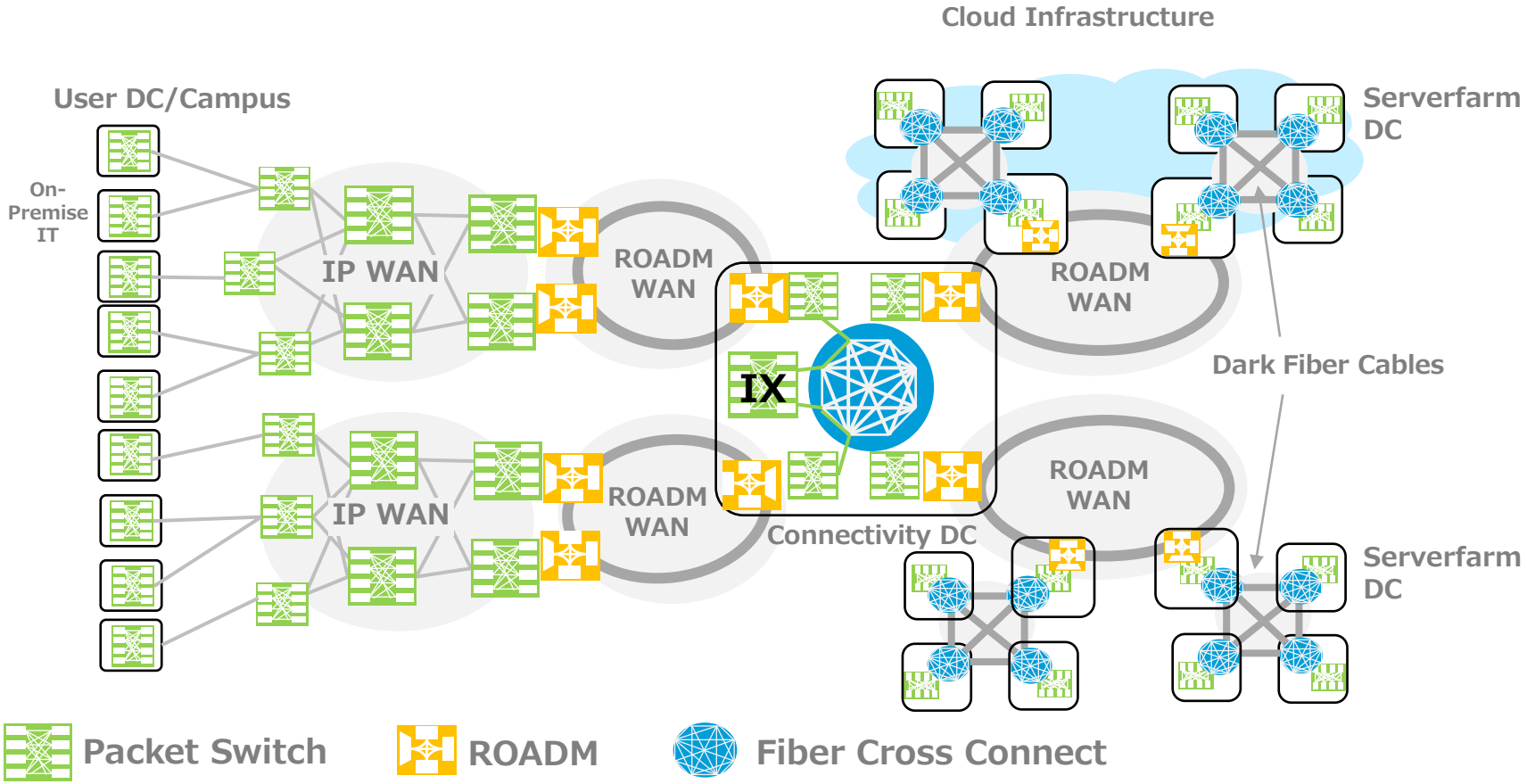
https://ctexaminer.com/2022/03/30/groton-town-council-votes-down-data-center-agreement/

https://www.datacenterdynamics.com/en/news/amsterdam-pauses-data-center-building/

https://www.channelnewsasia.com/business/new-data-centres-singapore-temporary-pause-climate-change-

Why data centers are getting larger and concentrated

Today's WAN



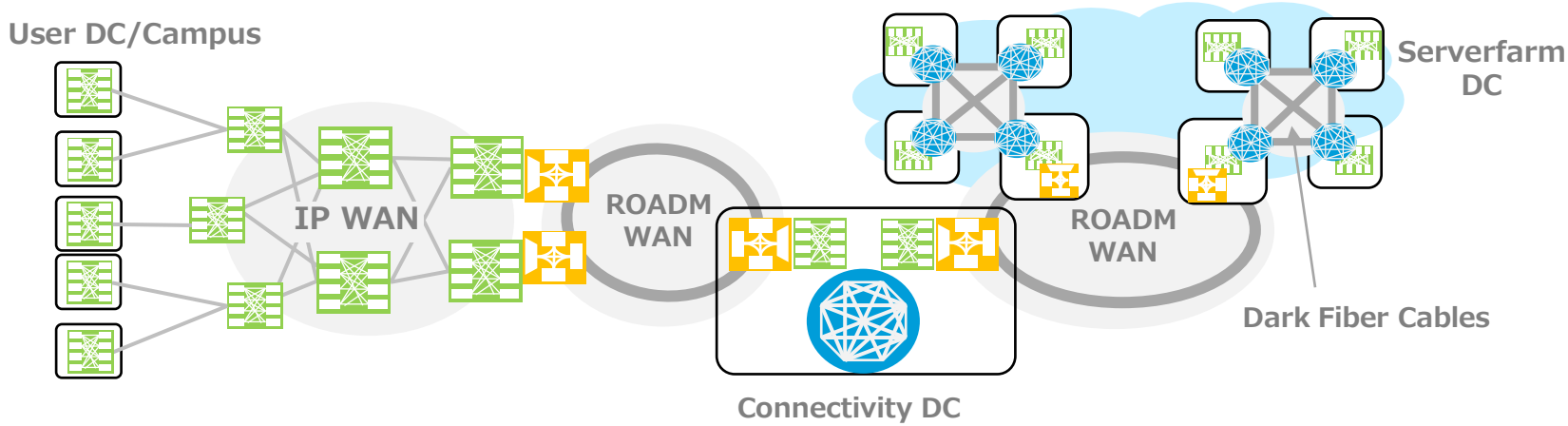
Communication Space and Computing Space

Communication Space

for human-human, huma-computer, **delay tolerant**

Computing Space

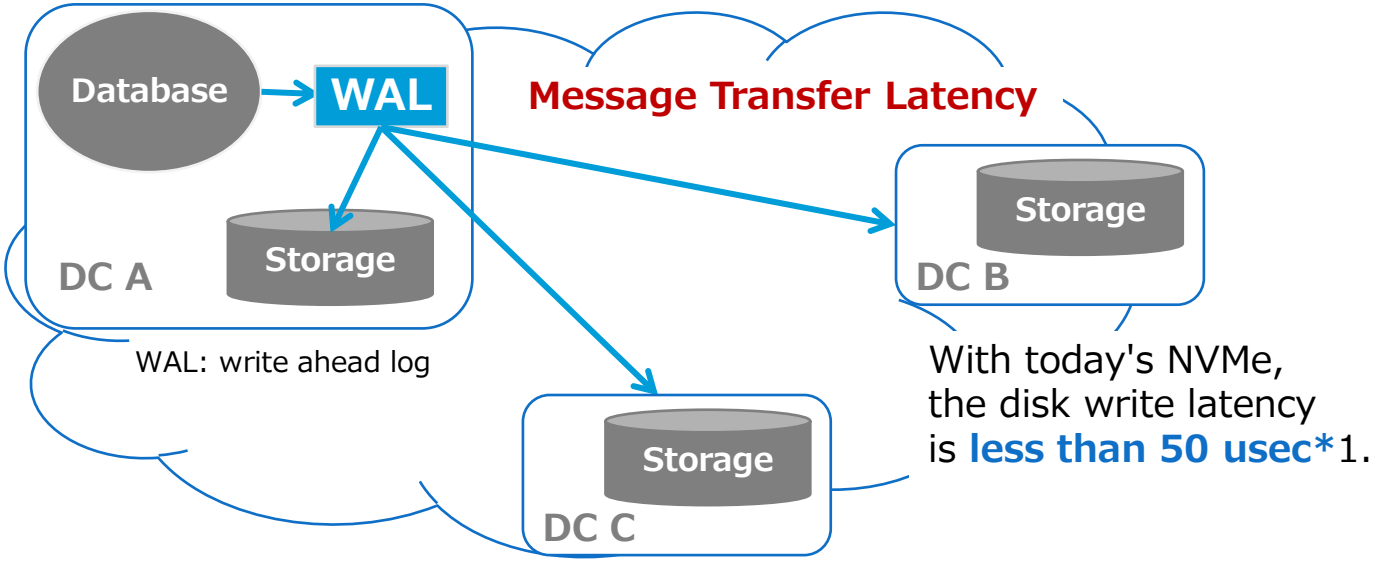
for computer-computer communication, **delay sensitive**



Packet Switch ROADM Fiber Cross Connect

Why Latency Matters

For example, if we want to build a **cloud-native database,**



The message transfer latency dominates the database performance.
Practically, it should be **less than 500 usec**.

reference: Amazon Aurora : Design Considerations For High Throughput Cloud-Native Relational Databases, SIGMOD '17
*1: Oracle Linux Blog, Measuring NVMe Latency, https://blogs.oracle.com/linux/post/measuring-nvme-latency

Latency Requirements For Computing Space

Use Case	Message Latency Requirements
Between AI/ML workers	tens of usecs
LAN storage sharing	a few hundred usecs
DB replication (synchronous)	a few to several hundred usecs
DB replication (asynchronous)	a few msecs
Between microservice applications	a few to several msecs

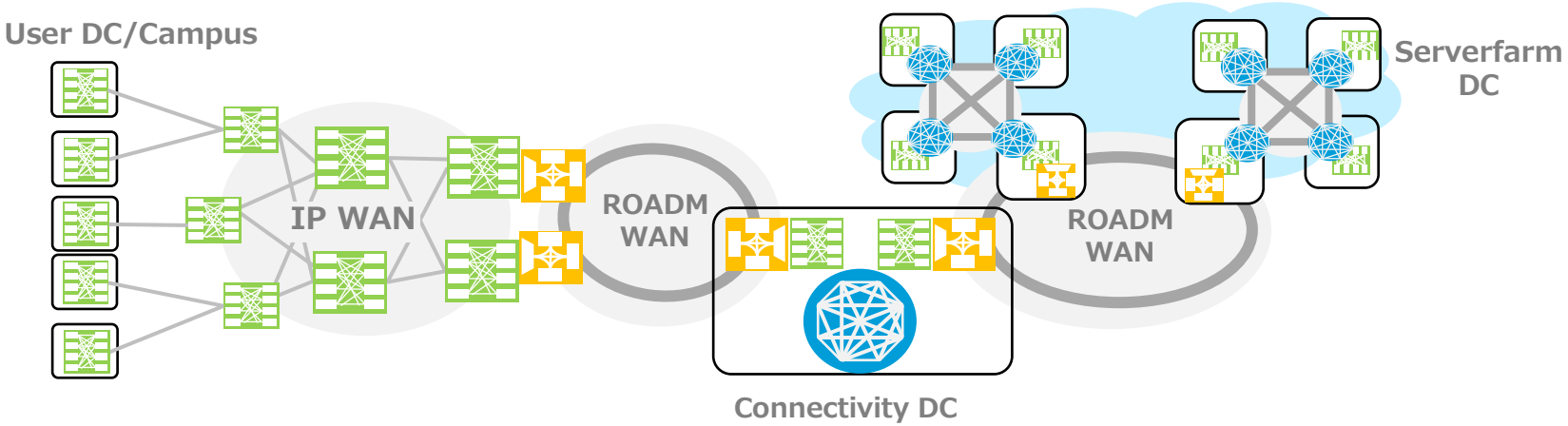
source: rough numbers based on my knowledge
(Please look for articles if you want to explore more)

NOTE: The above are the requirements on the **message** latency, NOT packet latency. With TCP/IP-based message transfer, the message latency is **a few times larger than the packet latency**.

Can distributed data centers form one computing space?

? joint ?? ⟵ Computing Space ⟶

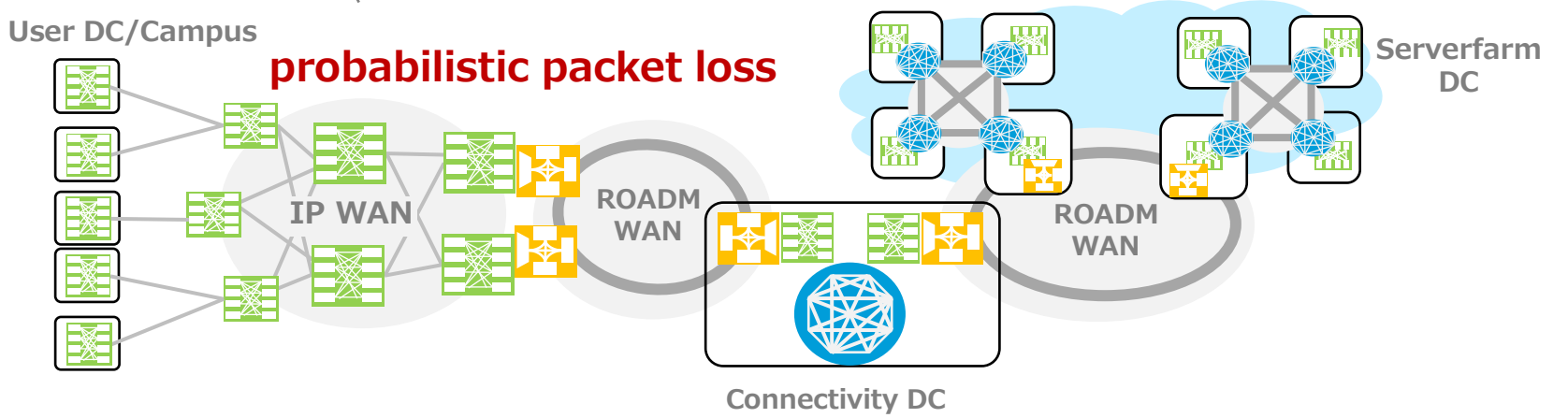
for computer-computer communication, **delay sensitive**



IP WAN's Limitation

too high message latency <------- ⟵ **Computing Space** ⟶

for computer-computer communication, **delay sensitive**

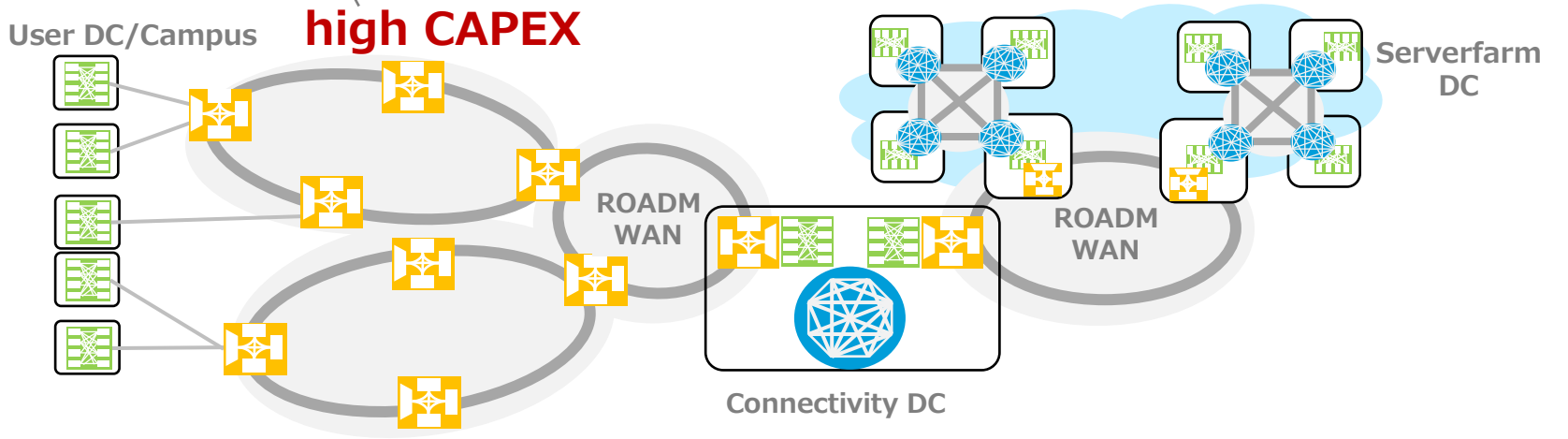


Packet Switch ROADM Fiber Cross Connect

ROADM's Limitation

too high connectivity cost <- - - - - - - - - - - - - - ⟵ **Computing Space** ⟶

for computer-computer communication, **delay sensitive**

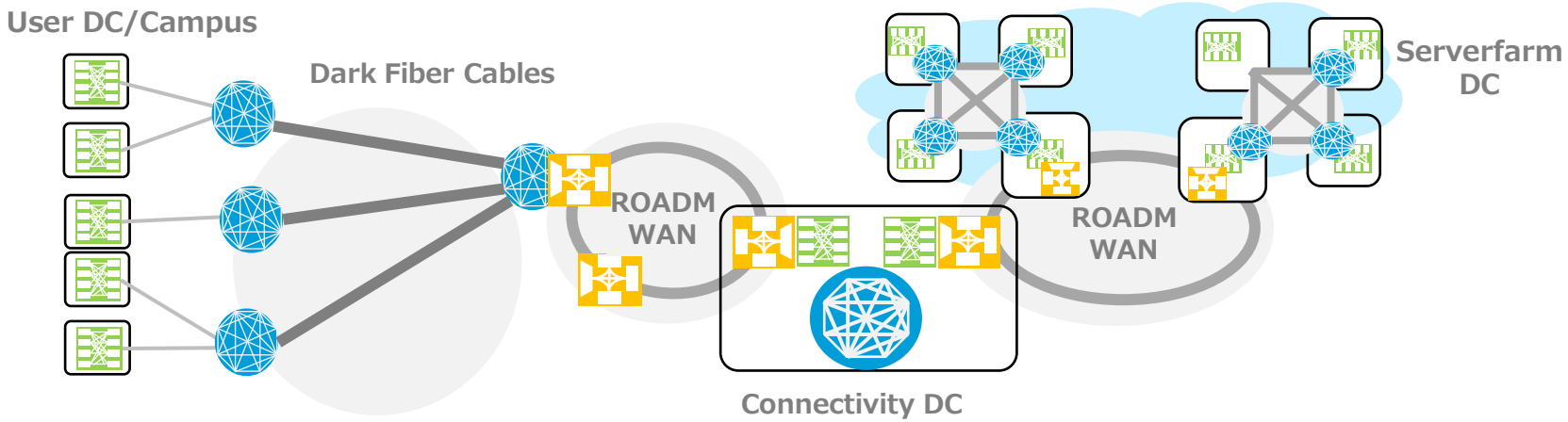


Dark Fiber's Limitation

lack of agility,
subject to fiber availability
inefficient fiber utilization

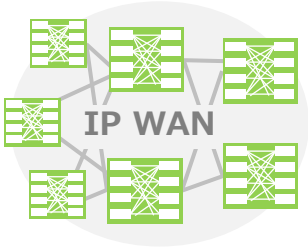
Computing Space

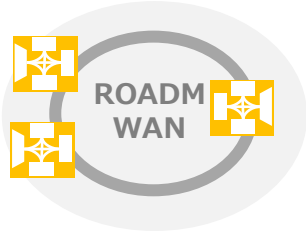
for computer-computer communication, **delay sensitive**

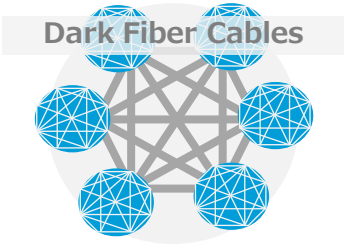


Packet Switch ROADM Fiber Cross Connect

Today's NW methods cannot support DC distribution







Distance Cost	**Low**	**Low**	**High**
Network Equipment Cost	**Low**	**High**	**Low**
Latency Requirements for Computing Space	**Difficult**	**YES**	**YES**

Infrastructure Evolution with IOWN

IOWN: Innovative Optical and Wireless Network

IOWN: Innovative Optical and Wireless Network

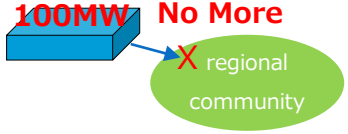
- Next Generation Infrastructure for Networking and Computing
- Leverages Optical Communication and Photonics Electronics Convergence Technologies
- Promotes Architectural Innovation as well as Device Evolution to eliminate today's issues

Arising Issues

Data Sovereignty or Cloud?

many legal restrictions

Data Center Moratorium



Latency

L4 **Flow Control, Resending**
Best Effort L3
Broadband, Low-Latency L2

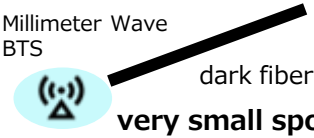
MEC CAPEX

Distribution to edges
→ **Split Loss**

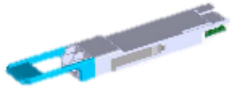
Unreliable Wireless Link

High-speed Link
→ Millimeter Wave Radio
→ **Unreliable**

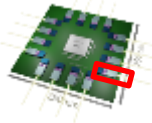
BTS Deployment Agility



Device Evolution



Optical Transceivers, Switches
Faster, Smaller



Photonics Electronics Convergence

+

Architectural Innovation

Networking

All-Photonic Network (APN)

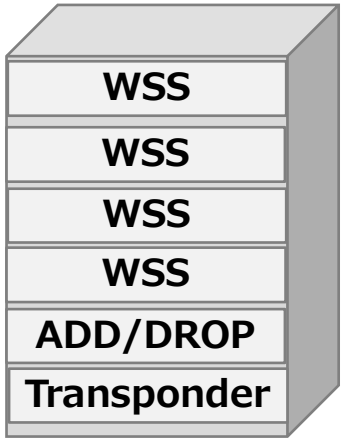
Computing

Disaggregated Computing

IOWN All-Photonic Network （APN）

NTT

Today's ROADM



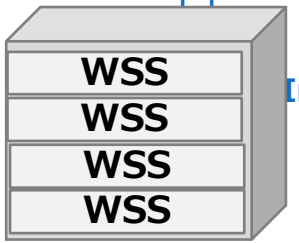
$$$$

Has become **composable**
but still an integrated system
with **high CAPEX**.

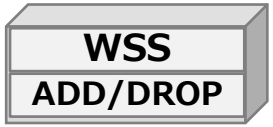
Disaggregate and Distribute with Open I/F

APN* Nodes
(Disaggregated ROADM)

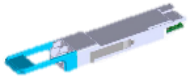
$$



APN-I (Interchange)



$ **APN-G (Gate)**



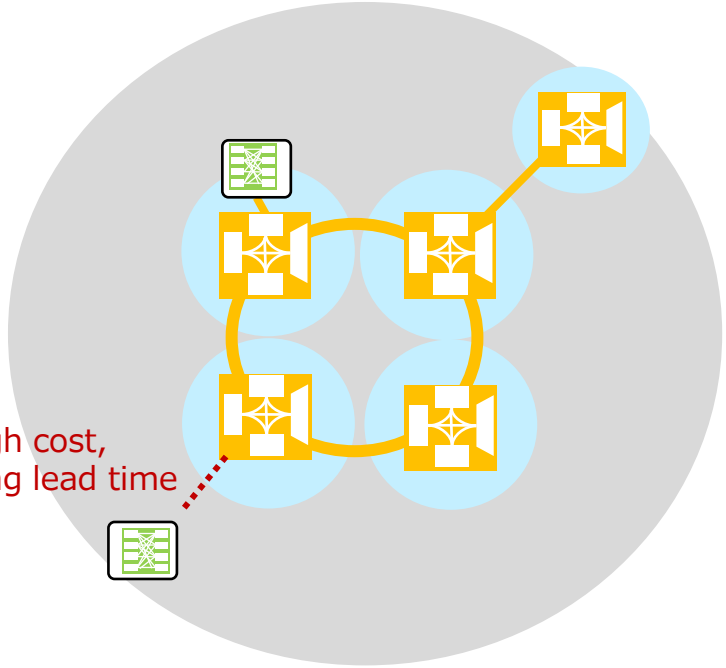
$ **APN-T (Transceiver)**

DWDM Pluggable Optics as a Transponder

*IOWN Global Forum, Open All-Photonic Network Functional Architecture Version 2.0
https://iowngf.org/wp-content/uploads/formidable/21/IOWN-GF-RD-Open_APN_Functional_Architecture-2.0.pdf

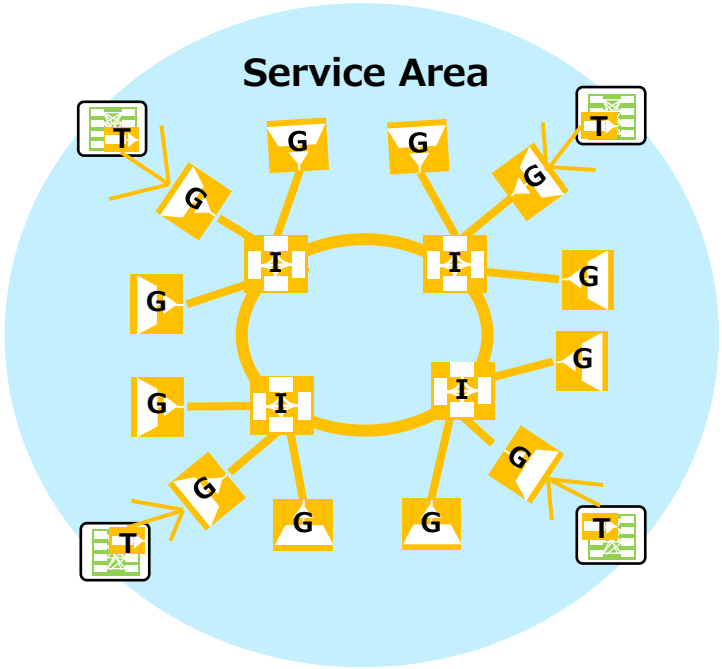
Low-Cost Area Expansion with APN

TODAY's ROADM WAN



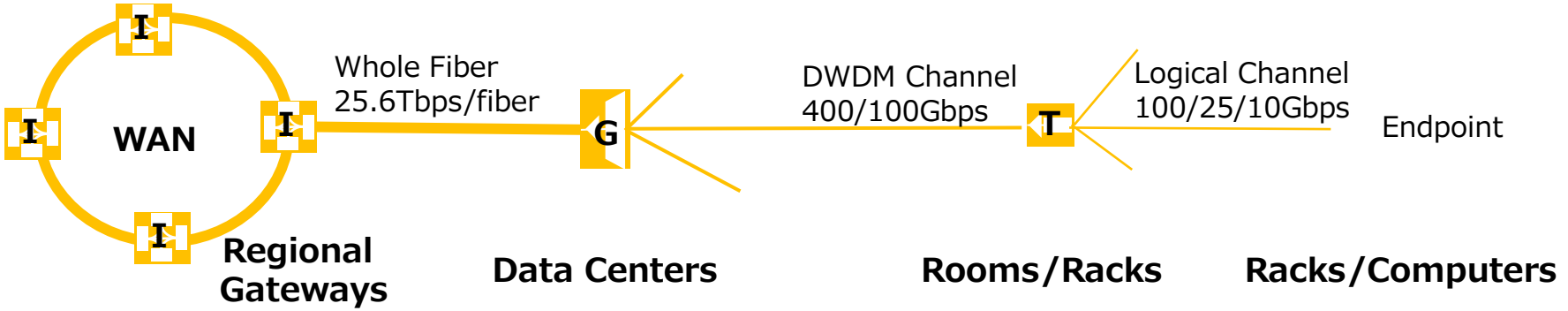
Limited Area Coverage

APN



Wide Area Coverage

Bandwidth Supply Chain with APN



Supply Chain Examples

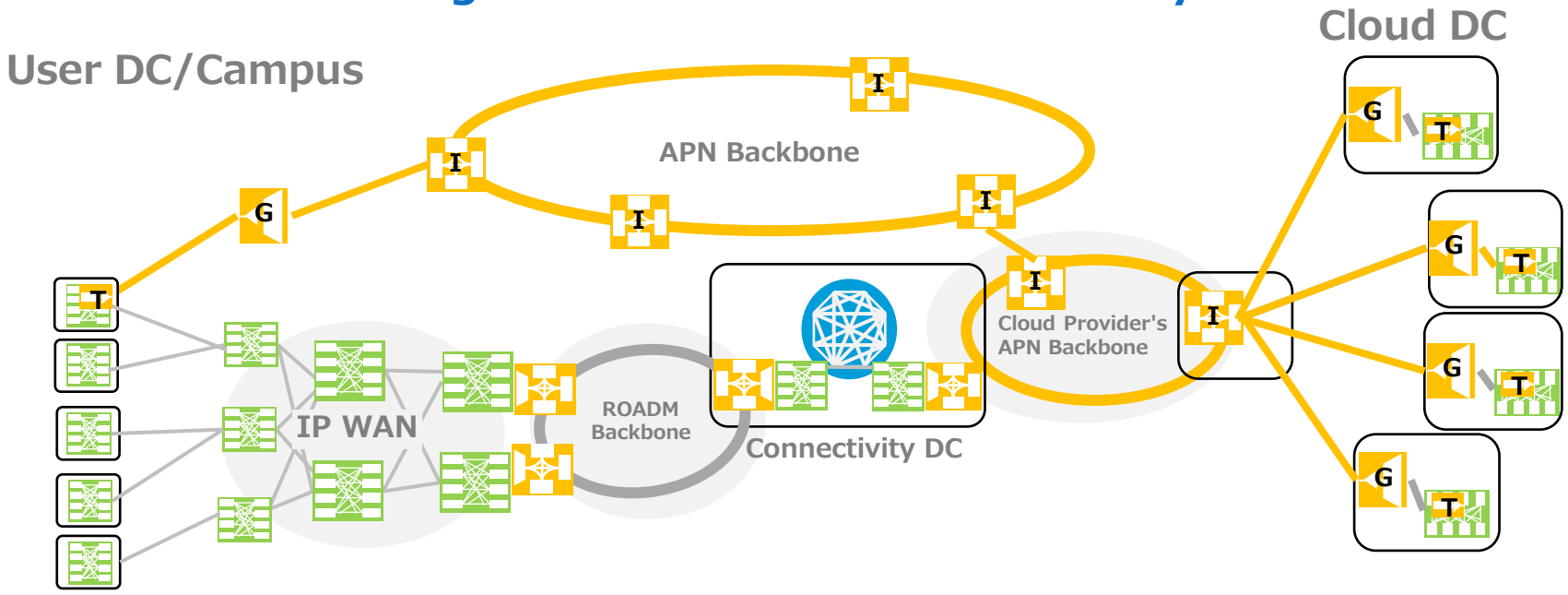
WAN Carrier — **WAN Carrier** — **IX/VPN Provider** — **Infrastructure User**

WAN Carrier — **IX/VPN Provider** — **Infrastructure User**

WAN Carrier — **DC Provider** — **Infrastructure User**

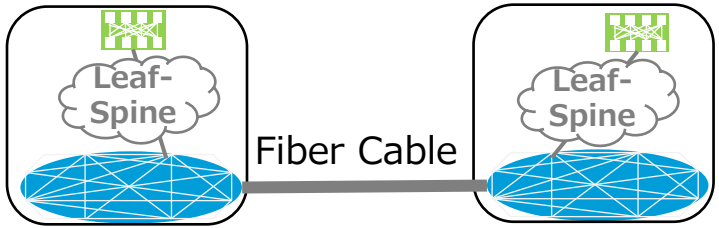
Evolved WAN with APN

IP and Optical Hybrid Networking with APN as a High-Bandwidth and Low-Latency Plane



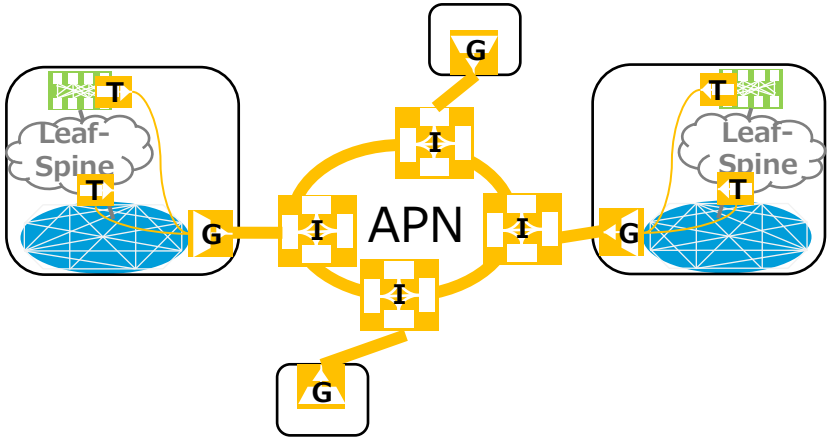
Future of Data Centers

Physical Interconnect with Cable Construction



- Long Lead Time, Fixed
- DC Provider Oriented (Siloed)
- Effective only when the inter-DC traffic is very large, e.g., several tens of Tbps

Software-Defined Interconnect



- On-Demand.
- DC User Oriented. Forms "Internet of Data Centers"
- Bandwidth Granularity, i.e., 400Gbps

Proof-of-Concept in US and UK

NTT

NTT

Contact JAPANESE ENGLISH

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TOP / Press Release / Successful demonstration of long-distance data center connections in the United Kingdom and the United States

April 12, 2024

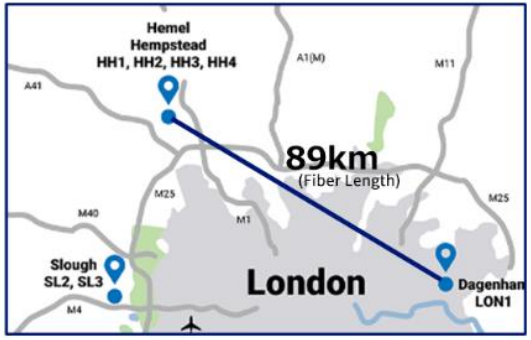
NTT Corporation

Successful demonstration of long-distance data center connections in the United Kingdom and the United States

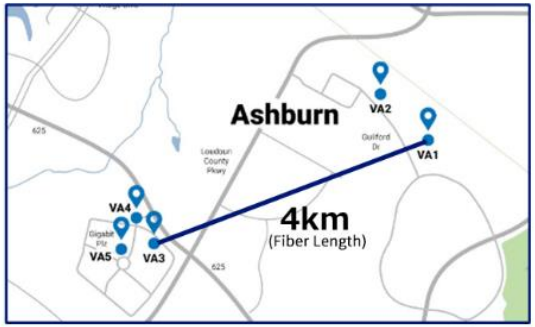
IOWN APN connects data centers approximately100 km apart to confirm a low delay communications of less than 1 millisecond and its applicability of distributed real-time AI analysis

Tokyo — April 11, 2024 — NTT Corporation (NTT) and NTT DATA Group Corporation (NTT DATA) have demonstrated IOWN APN[1] connections between NTT Group data centers in the United States and the United Kingdom. Two data centers near100 km apart in U.K. communicates via IOWN APN connection, and record a low delay of 1 millisecond or less, and realize a similar good performance in U.S. It makes multiple data centers functional as an integrated IT infrastructure logically equivalent to a single data center, and we demonstrated its applicability to distributed real-time AI analysis and the financial sector. We plan to conduct business

■ Hemel Hempstead/Dagenham (U.K.)



■ Ashburn (U.S.)



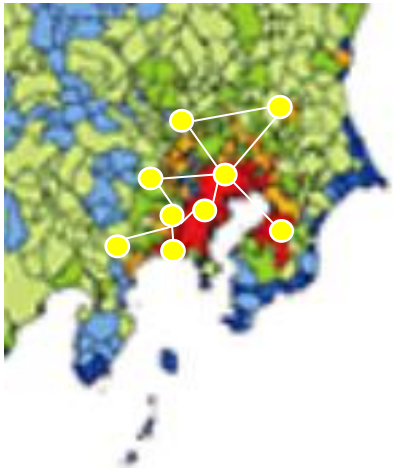
IOWN APN

Data Center De-centralization with IOWN APN

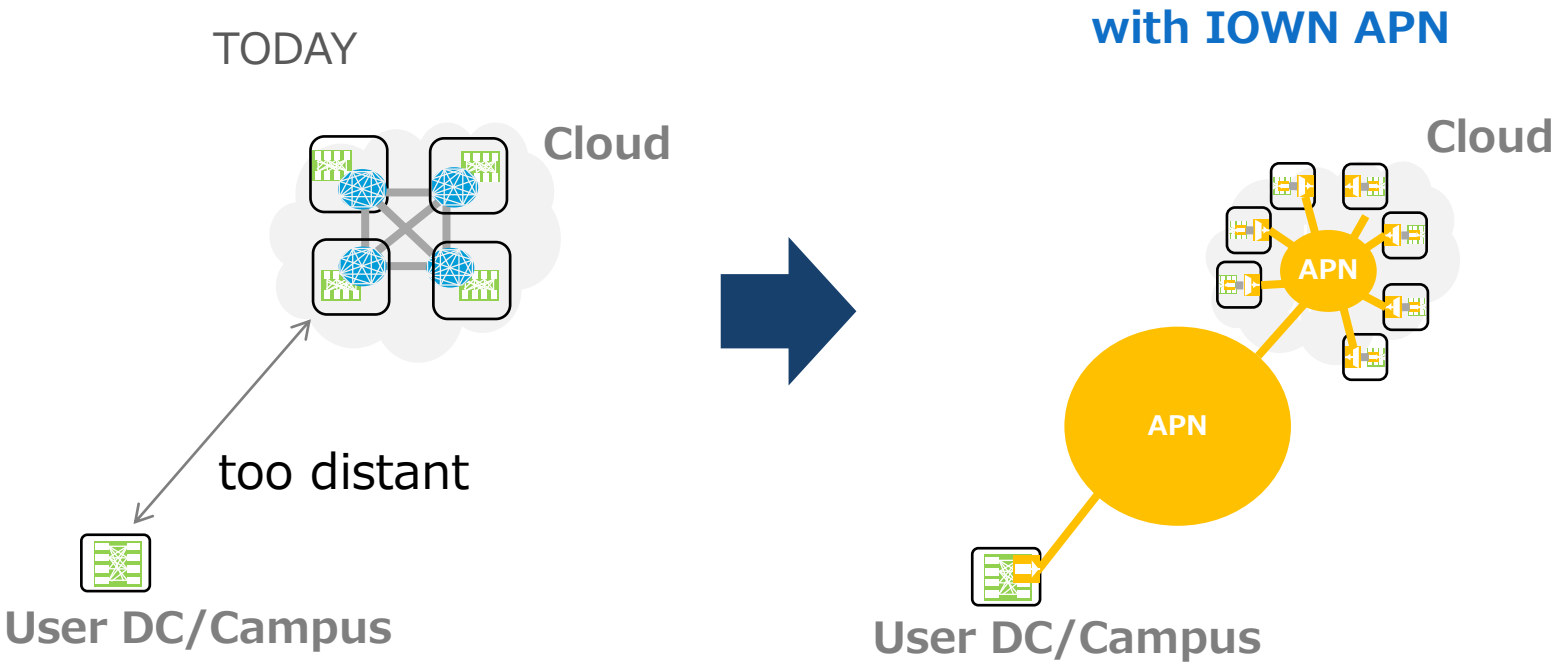
Data center de-centralization makes
data centers operable with **locally available renewable** energy

TODAY

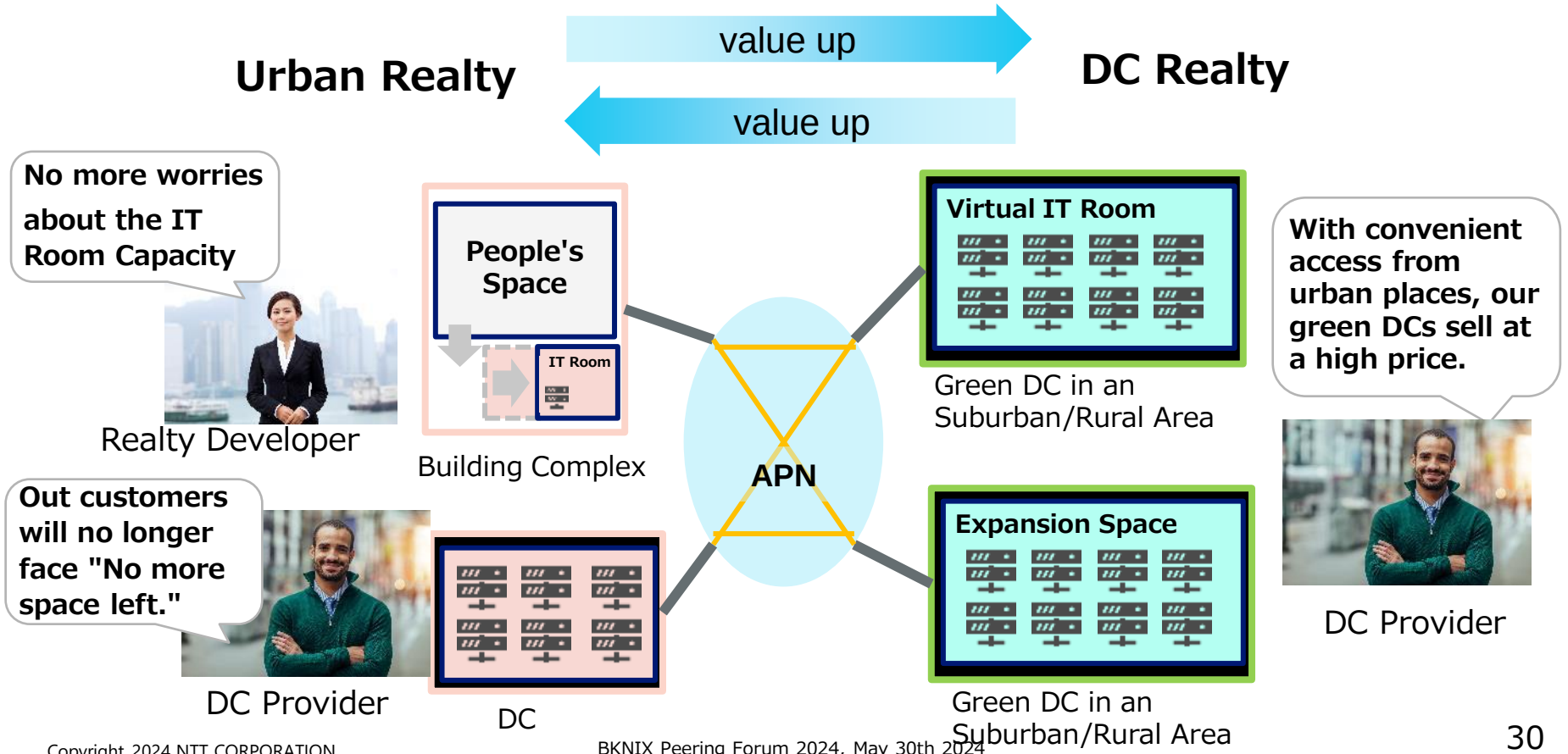
with IOWN APN



Edge-Cloud Convergence

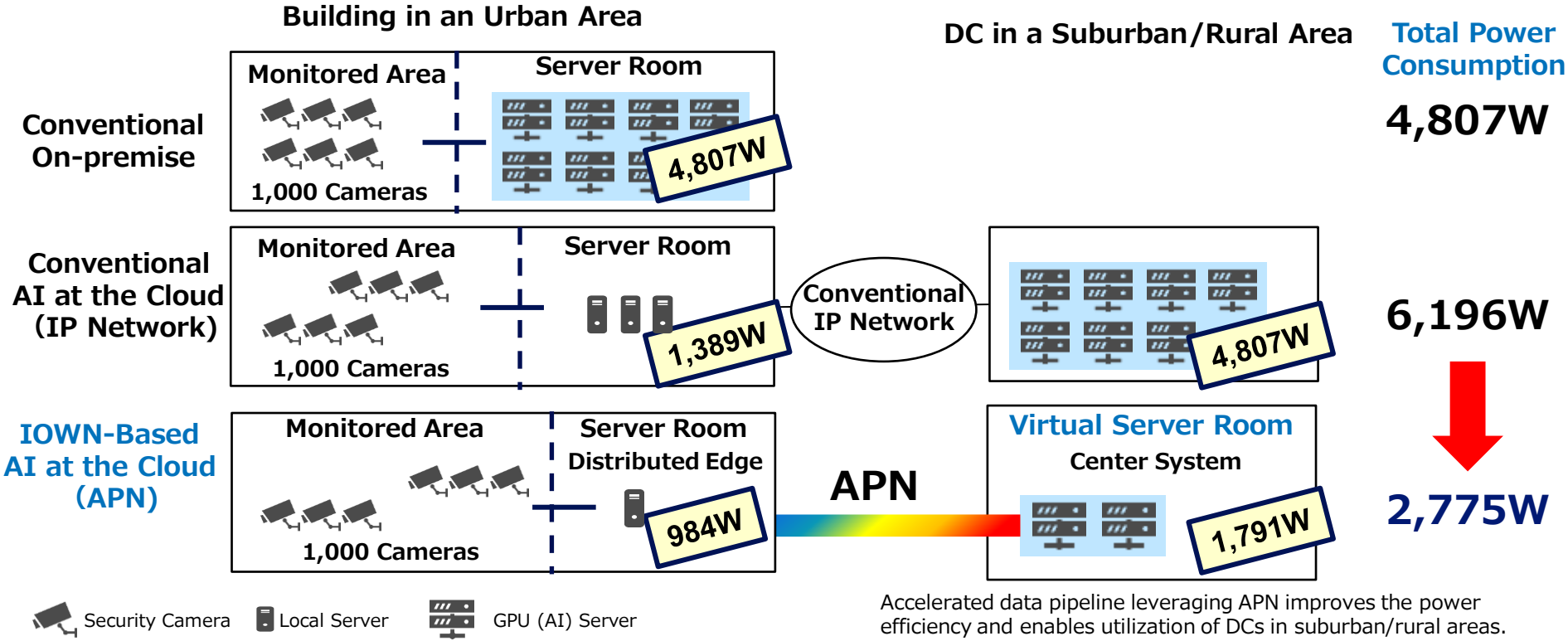


Business Model: Dual Realty Value-Up with APN



Offloading Urban AI Workload with APN

Joint solution with NTT, RedHat, Fujitsu, and nvidia

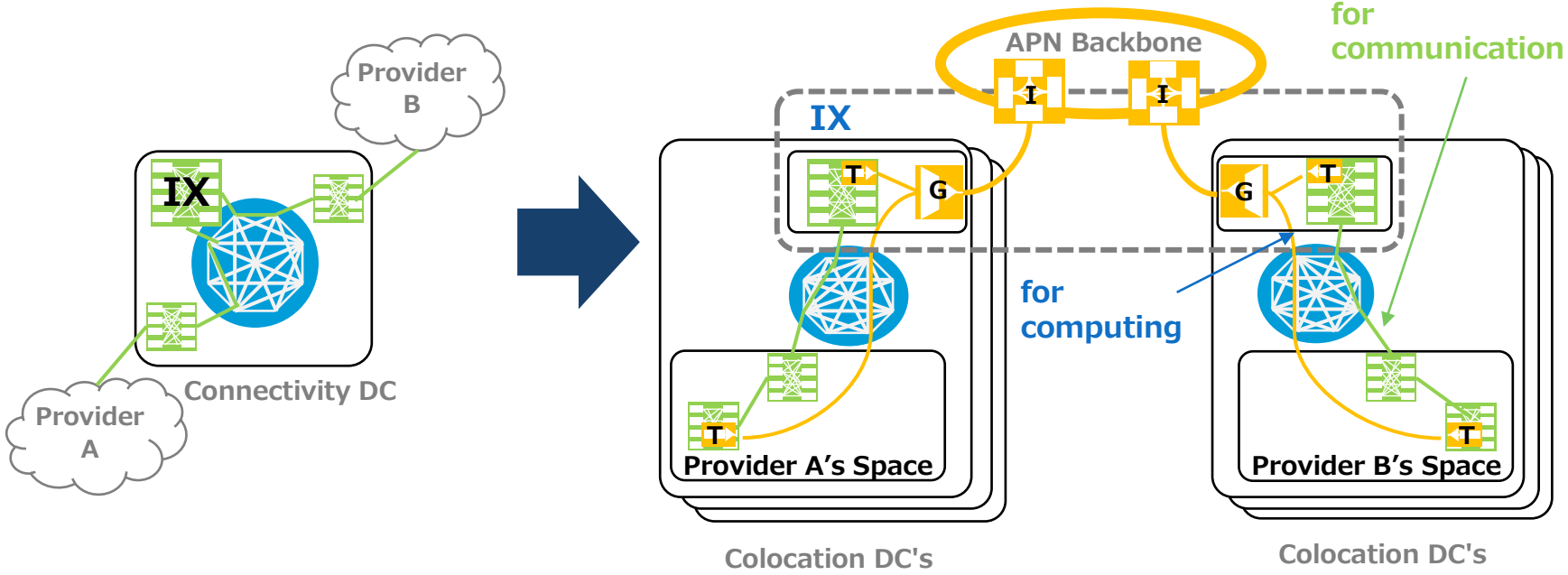


Accelerated data pipeline leveraging APN improves the power efficiency and enables utilization of DCs in suburban/rural areas.

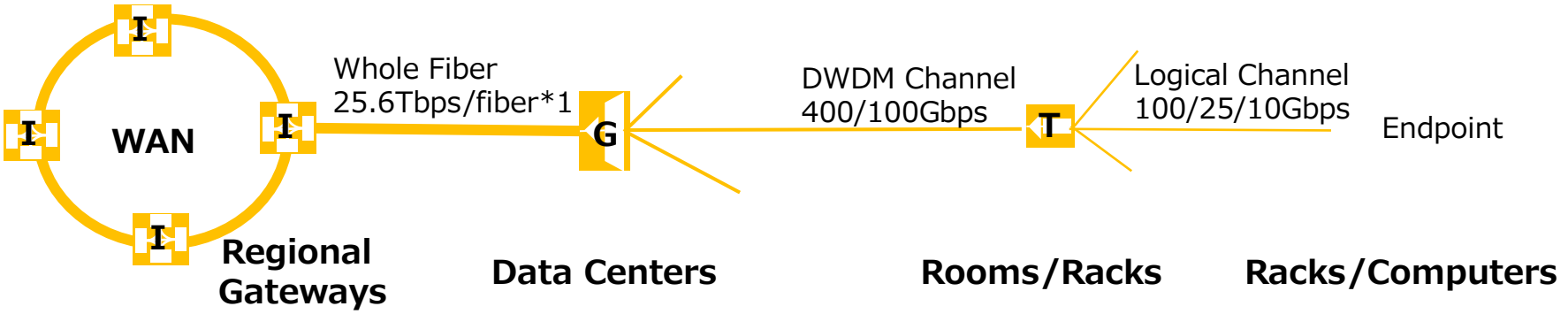
Future of Peering and IX

- Place-based Peering
- IX for Communication

- **Network-based, Location-Free** Peering
- IX for Communication and **Computing**



Bandwidth Supply Chain with APN



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WAN Carrier — **DC Provider** — **Infrastructure User**

*1: with C-band, 400Gbps/75GHz Ch x 64ch

Global Collaboration at IOWN Global Forum

IOWN GLOBAL FORUM ™

IOWN Global Forum

- IOWN: Innovative Optical and Wireless Network
- Established in January, 2020
- Global non-profit organization

Develop reference architecture, frameworks, specifications for the next generation **communication and computing infrastructures** that leverage the evolution of **optical communication** and **photonics-electronics convergence** technologies.

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Global 5G and Networks Lead & Senior Managing Director, Cloud First, Accenture

Chris Wright

Chief Technology Officer and Senior Vice President of Global Engineering, Red Hat, Inc.

IOWN GLOBAL FORUM™

IOWN Global Forum (Established in Jan. 2020)

NTT

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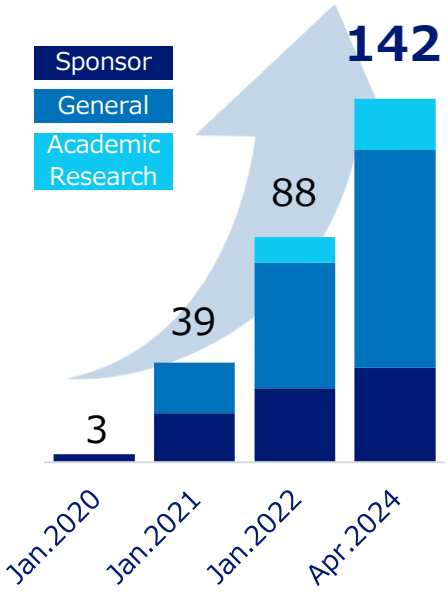


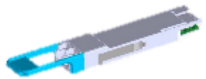
Why We Need IOWN Global Forum

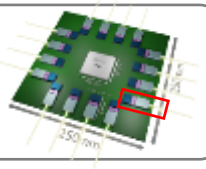
Because we need a new initiative for **infrastructure-level innovation**.

New Business Model

New Infrastructure Architecture

New Device



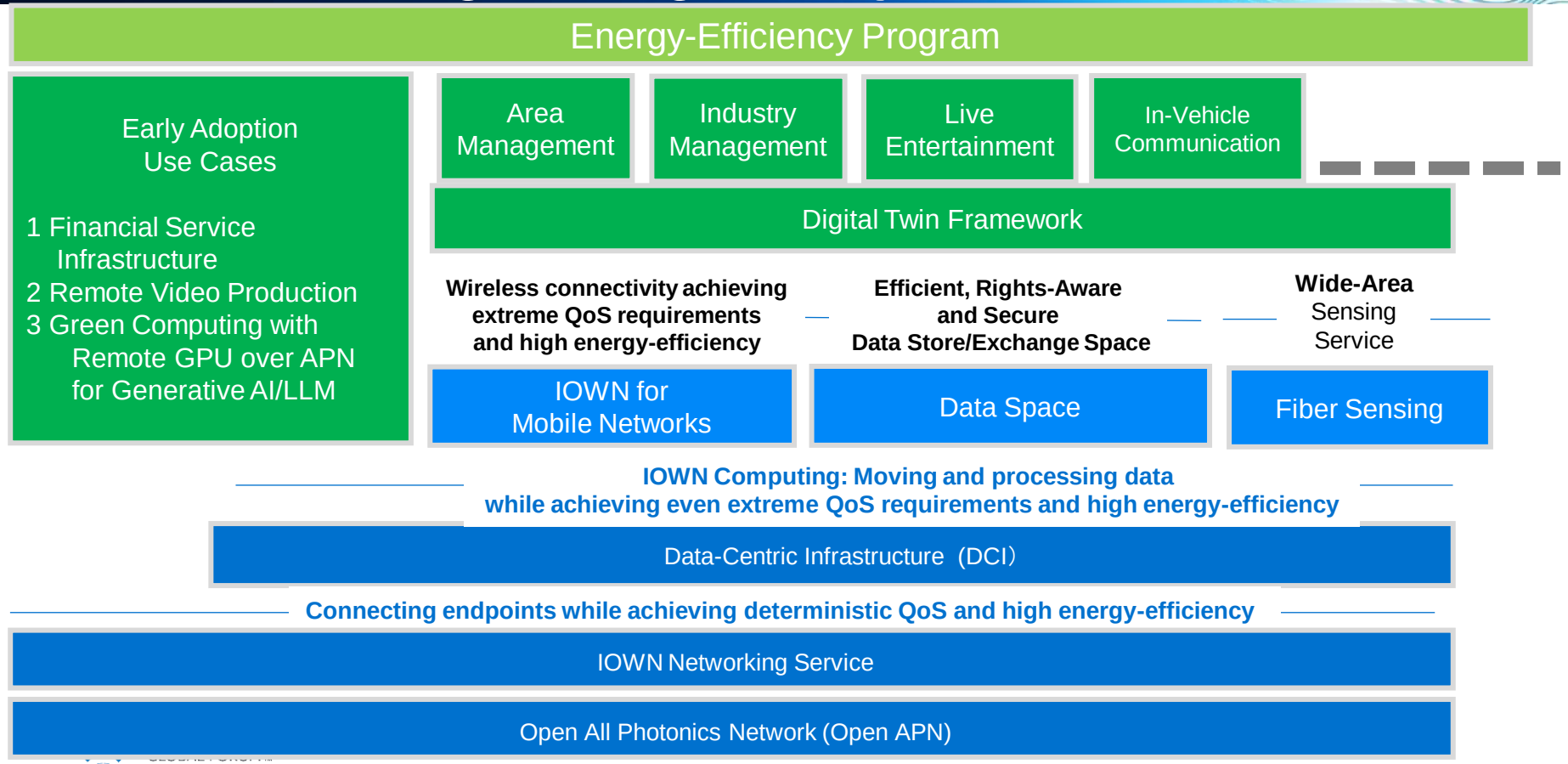


Full-Stack Re-engineering

To be developed collaboratively at IOWN Global Forum

IOWN GLOBAL FORUM™

IOWN Global Forum's Full-Stack Re-engineering Activity

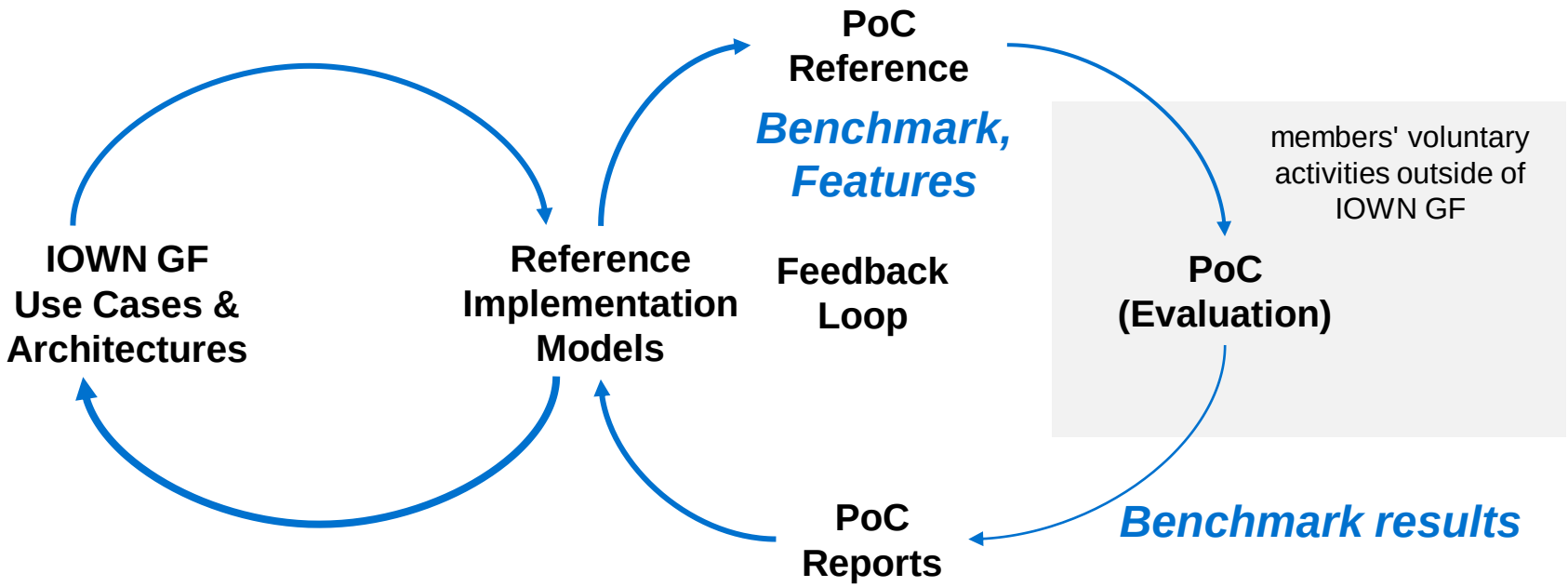


Early Adoption Use Cases

- **Financial** Service Infrastructure
  - CAPEX/OPEX Reduction for **DR/BCP**
  - **Agility** for Digital Service Development
- Remote **Video Production**
  - Reduction of **Production Staff Deployment Cost**
  - Production System **TCO Saving with Sharing**
- **AI Factory**
  - **Energy and TCO Saving** with **GPU Sharing**
  - Maintained **Data Confidentiality and Auditability**
- **5G/6G** Mobile Network
  - **RAN Energy and TCO** Saving with **Flexible Sharing** and **30km-Scale Cloudification**

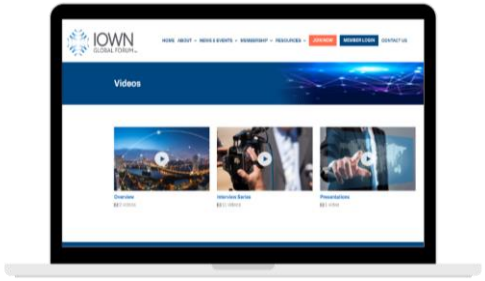
Benchmark-Driven and Energy-Conscious Technology Development with PoC

Develop truly viable and practically operable solutions through iterative technology development



Energy-Efficiency Program

Stay Connected with IOWN Global Forum



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Summary

- Data Center Moratorium
- Issue with Today's WAN
  - Cannot support wide DC distribution
- Infrastructure Evolution with IOWN
  - All-Photonic Network (APN): Disaggregate ROADM and distribute the components
  - Evolved WAN : IP/Optical Hybrid with APN as a High-Bandwidth and Low-Latency Plane
  - Future of Data Centers: Software-Defined, User-Oriented Interconnect.
  - Future of Peering: Network-based, Location-Free. IX for Communication and Computing
- Global collaboration at IOWN Global Forum

Thank you