Keio University

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Keio Future Photonic Network Open Lab.

- Challenge of the next generation networking - with Hollow-Core Fibers -

https://pilab.jp/OpenLab/

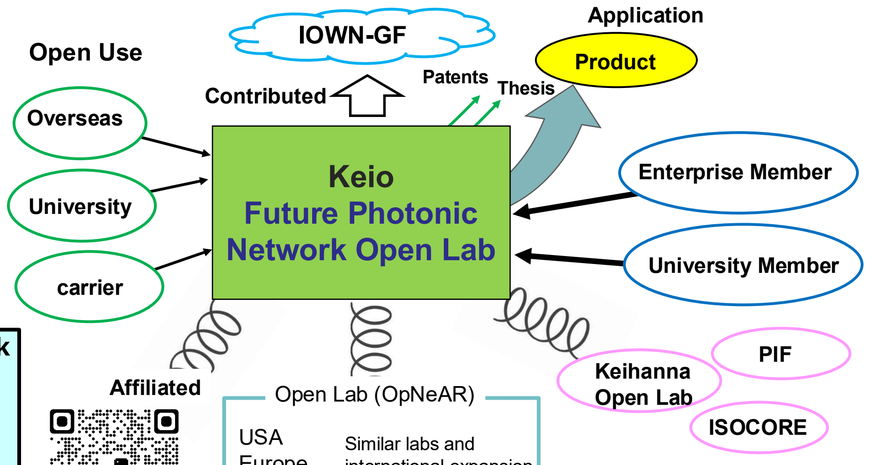
KEIO FUTURE OPTICAL NETWORK OPEN RESEARCH CENTER

OASys-PON Optical Access Network System

Keio Future Optical Network Open Research Center

Prof. Yamanaka Prof. Tsuda

Research Center Presidents



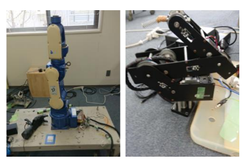
- Ultra Low-Latency Network and Applications
  - 400 Gbps Class Access NW
  - Over 1,000 branch PON
  - Analog Radio over Fiber NW
  - Autonomous Driving Vehicle (ADV)
  - Remote Control (RC) Robots
  - Local 5G campus

Open Lab. HP

HCF Campus Video

RC Vehicle

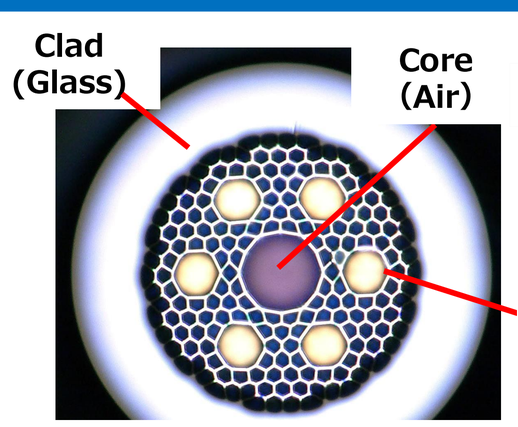
ADV



RC Robots

Hollow-Core Fiber (HCF)

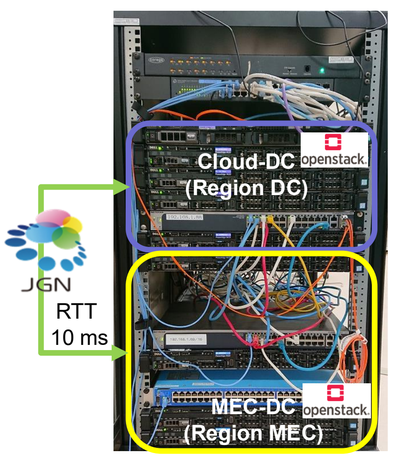
Single Mode Fiber (SMF)
- Total reflection due to the differenc in reflex index between core and cla



Lightera™

HCF (Photonic Band Gap Fiber type)
- Utilizing Bragg reflection in the photonic crystal structure -

- The core material is “Air”, not glass.
- Low-Latency (2/3 of glass core) ⇒ Suitable for Ultra Low Latency Apps.
- 1,000 times higher photodamage threshold than SMF ⇒ Suitable for high-power, multi-wavelength optical signal transmissions
- 1/1,000 low non-linearity coefficient than SMF ⇒ Suitable for high-power, analog transmissions
- Theoretically lower loss than glass

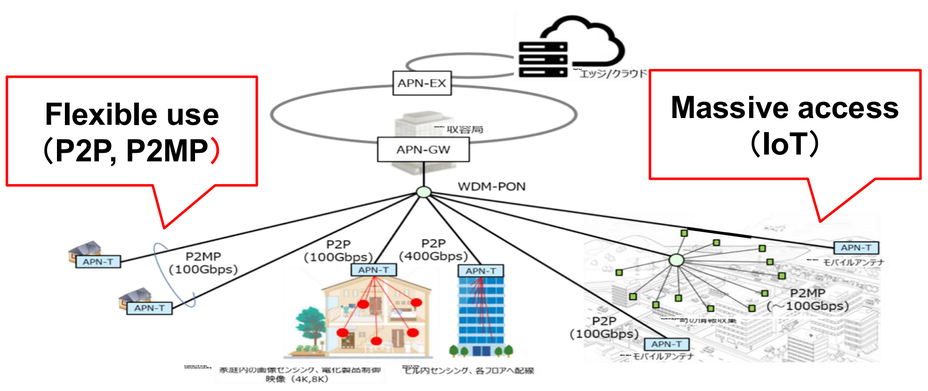


Mini DC

10G-EPON

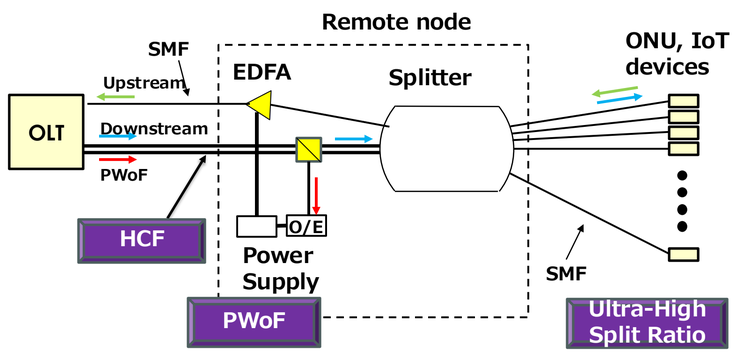
Local 5G Mobile Access System

Application of HCF to Access Systems

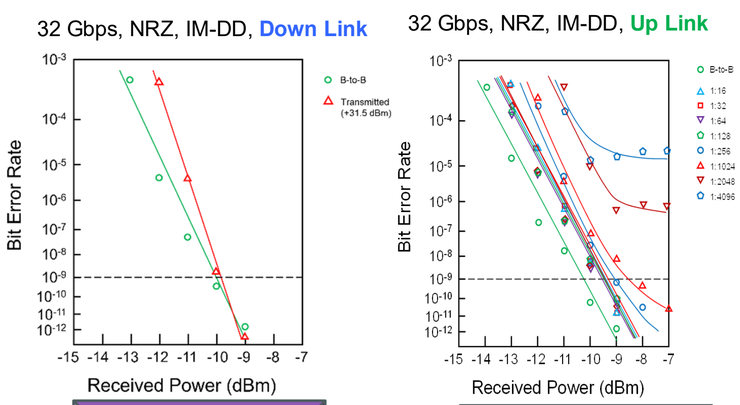


- **Ultra-High Splitting Ratio PON technology** utilizing **High power resistance**
- **Power over Fiber (PWoF) PON technology** utilizing **High power resistance**

Ultra-High Splitting Ratio PON Technology



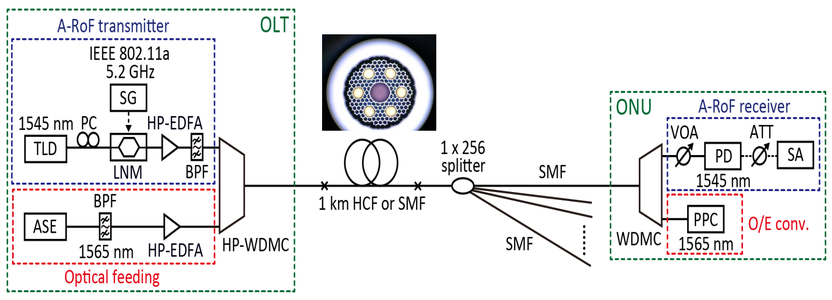
Configuration of the ultra-high splitting ratio PON



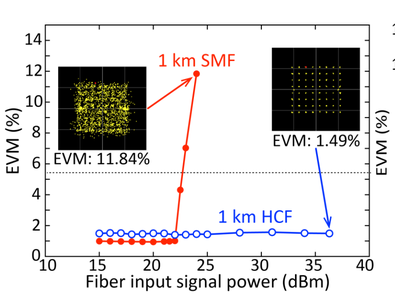
Experimental Results

High power transmission and increased number of branches using HCF

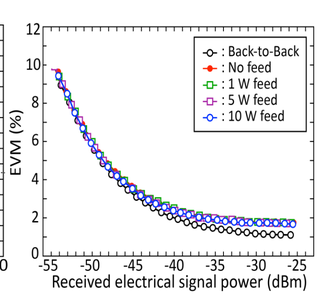
Power over Fiber (PWoF) PON Technology



256 branches WiFi (5.2 GHz) signal transmission with optical power feeding



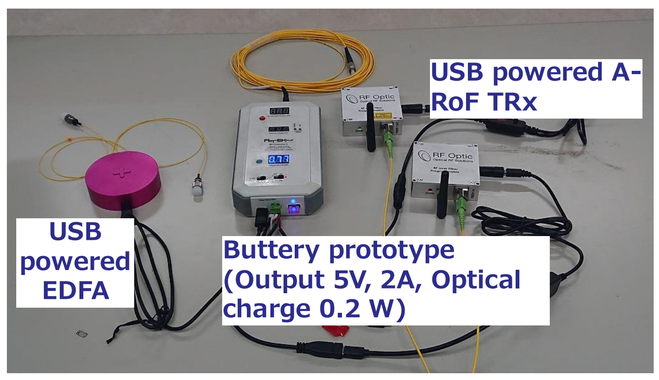
SMF vs. HCF after 1 km transmission



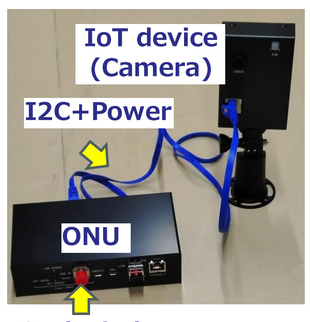
EVM vs. input feed light power

Simultaneous transmission of +40 dBm energy transmission light and RoF signal light over 1km fiber.

Applications of PWoF



Optically charged buttery prototype and expected power supplied devices (EDFA, A-RoF TRx)



Optical-charge Input

Active: 2.7 W
Sleep: 0.16 W

Full optically powered Deep Sleep ONU and IoT device

This work is supported by Ministry of Internal Affairs and Communications of Japan (JPMI00316) and JGN TB-A24002.

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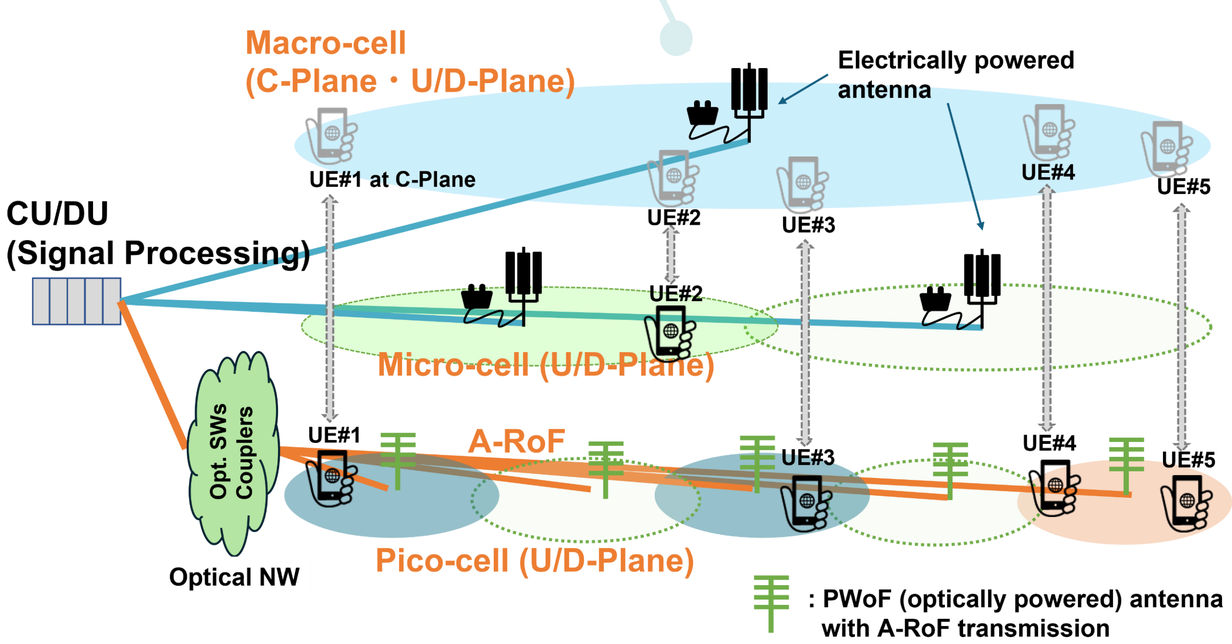
HART
High Power Analog Radio over Fiber Technology

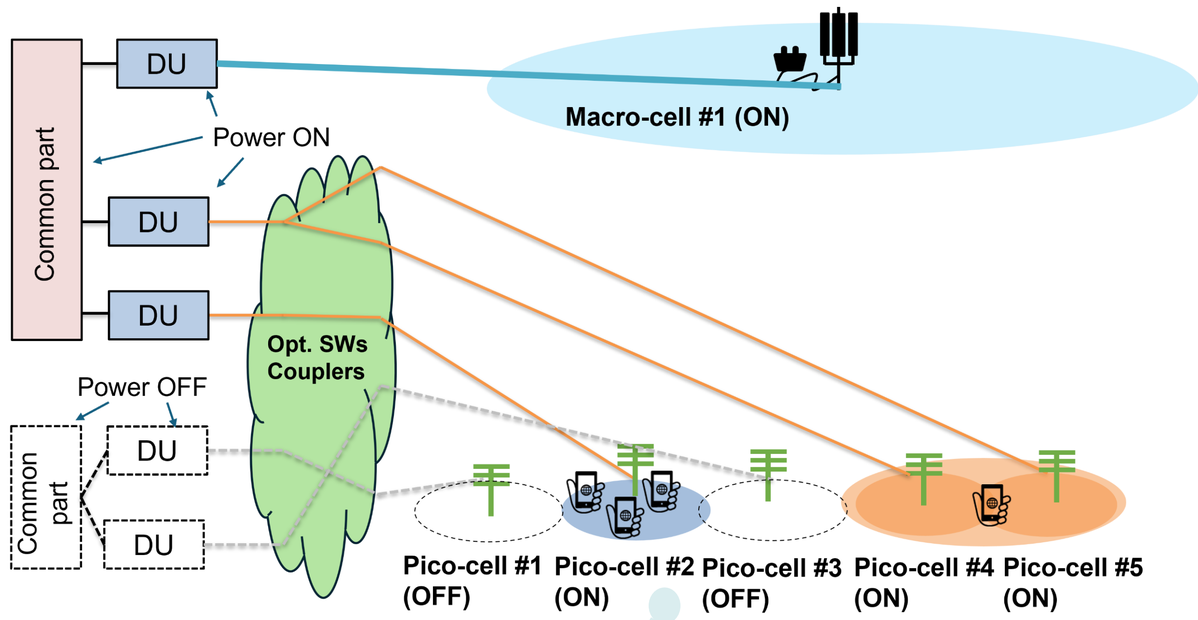
Analog Radio-over-Fiber based 5G smart mobile fronthaul networking testbed using Hollow-Core Fiber

Yamanaka Laboratory, Keio University, Japan

Power-saving B5G wireless base station system with "analog" radio over fiber technology using air-hole core (hollow-core) fibers

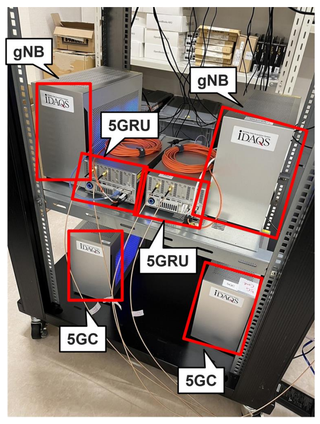
✓ **Proposal of Switched RoF as a New Mobile Fronthaul**
- **Insertion of Optical switch and Optical coupler between CU/DU and optical powered simple antennas**
- **Controlling Microcells based on UE location detection in Macrocell using Hierarchical cell structure**

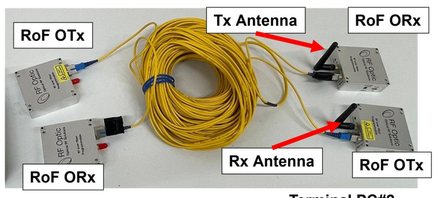


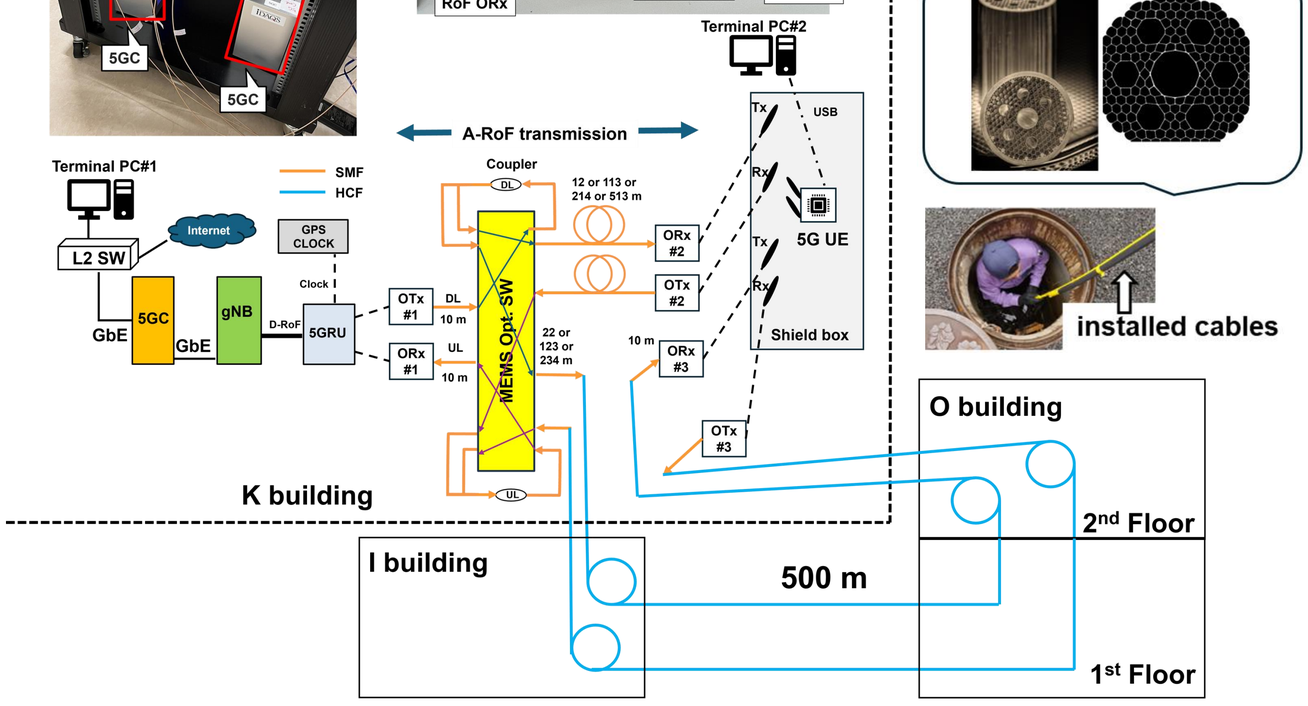


✓ **Details at the bottom of the hierarchy**
1. **Powering off empty cells**
2. **Using multicast connection in low-user-density areas**
3. **Using one-to-one connection in high-user-density areas**

Experiment of Analog Radio-over-Fiber Using Field-installed Hollow-Core Fiber Links



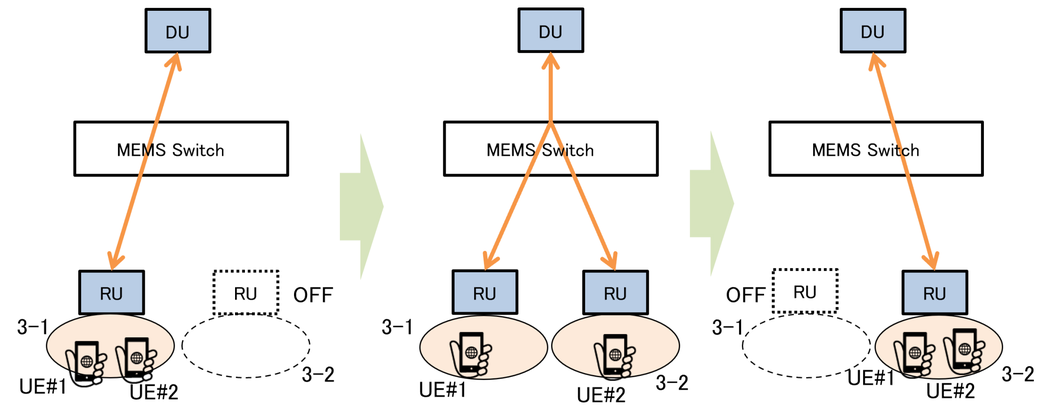




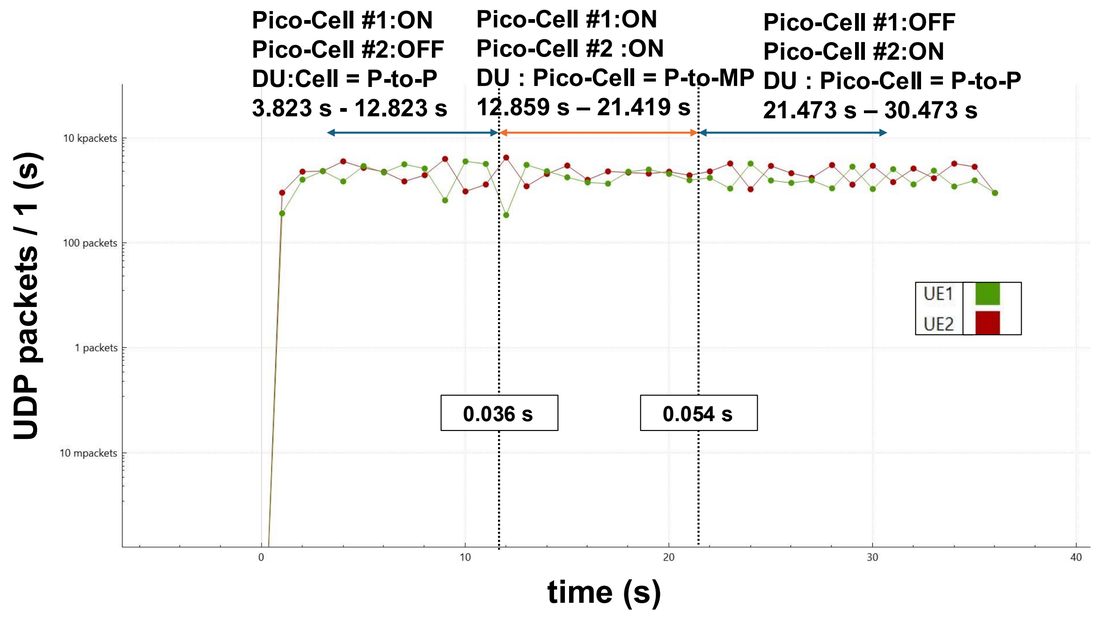
A Sub6 analog RoF based local 5G system using a field installed hollow-core photonic bandgap fiber is constructed.

Demonstration of Switched RoF with Energy-Efficient Cell Selection Optimization

Switching scenario



No throughput degradation after switching



This work was supported in part by the National Institute of Information and Communications Technology (NICT) (JPJ012368C07101). This research was conducted at the Keio Future Photonic Network Open Lab.

Keio University

R&D on Multi-band Metro-network architecture using terrific Multiple wavelength M^3 WaveNet

Yamanaka Laboratory, Keio University
Advanced Network Research Laboratories, NEC Corporation EpiPhotonics Corp.

Paradigm Shift in Metro Networks for "Direct Wavelength Connectivity"

Research goal: Develop innovative multiband massive WDM metro networks (M3) that provide "direct wavelength connectivity" among users.

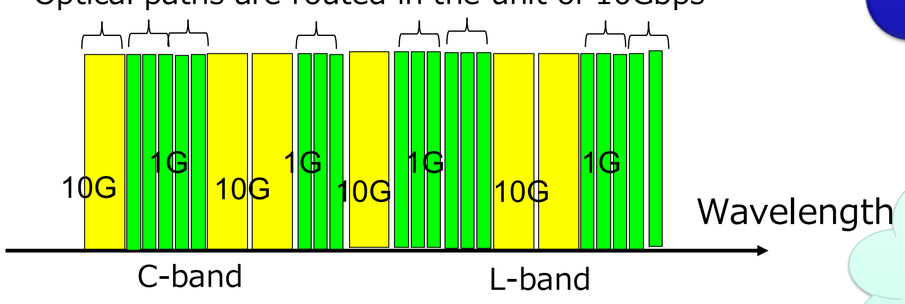
- Increase **current 10 channels** per fiber by more than 1,000 times to **several 1,000 channels**.
- Development of **cost-effective and energy-efficient WSS**
  - #1 : Power-efficient metro node architecture using programmable WSS (Keio University)
  - #2 : Highly efficient ROADM network configuration technologies for multi-band networks (NEC)
  - #3 : Ultra-High Channel Count Programable WSS (EpiPhotonics)

Basic concept of M^3 WaveNet

1Gbps * several paths → **10GHz grid**

Without using TDM, we use narrower-grid optical paths ⇒ **Ultra low latency and energy consumption**

Optical paths are routed in the unit of 10Gbps



Ultra fine-pitch and narrow band

By maximizing efficiency of wavelength utilization, we aim to achieve 1000+ channels (S/C/L-band)

#1 Power-efficient metro node architecture using programmable WSS

- Pursuit for cost efficiency and low energy consumption
- Expanding wavelength bands and improving flexibility

•200 channels per fiber (C+L)
•50% energy reduction
•50% improvement in wavelength utilization

#2 Highly efficient ROADM network configuration technologies for multi-band networks

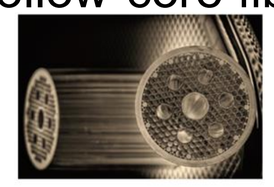
WSS
(internal production)

#3 Ultra-High Channel Count Programable WSS

- World's highest level fine-pitch resolution LCOS

LCOS

Hollow-core fiber



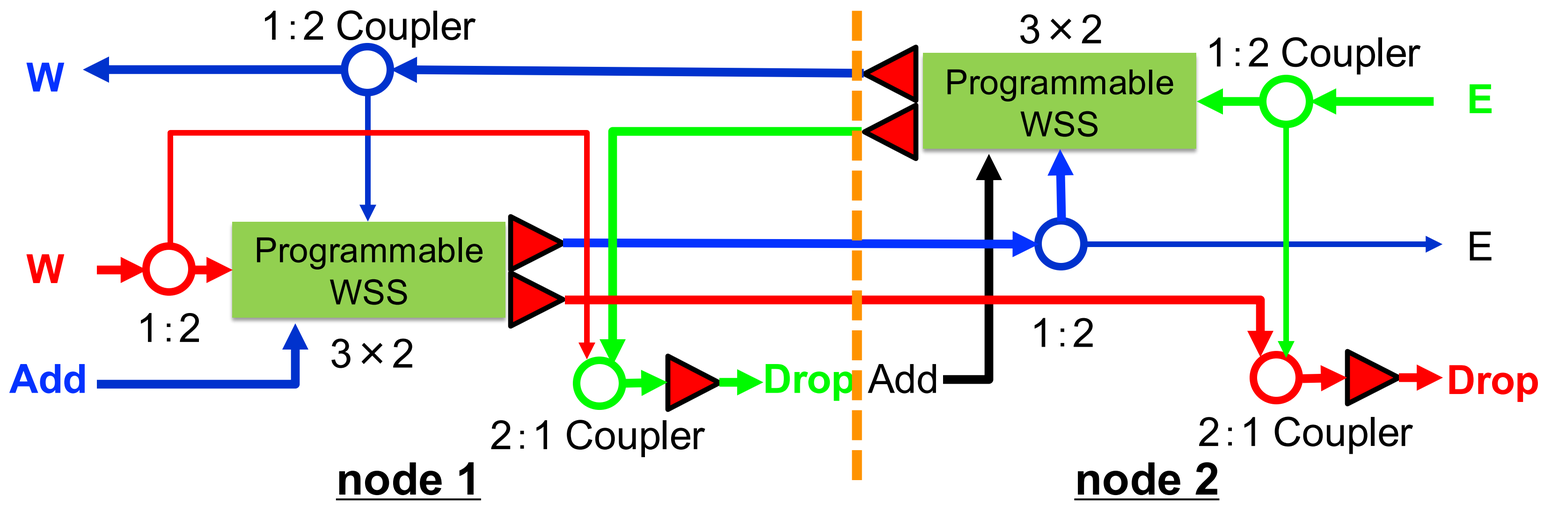
Solving Raman tilt through AI-based smart network control

World's first port configuration programmable WSS

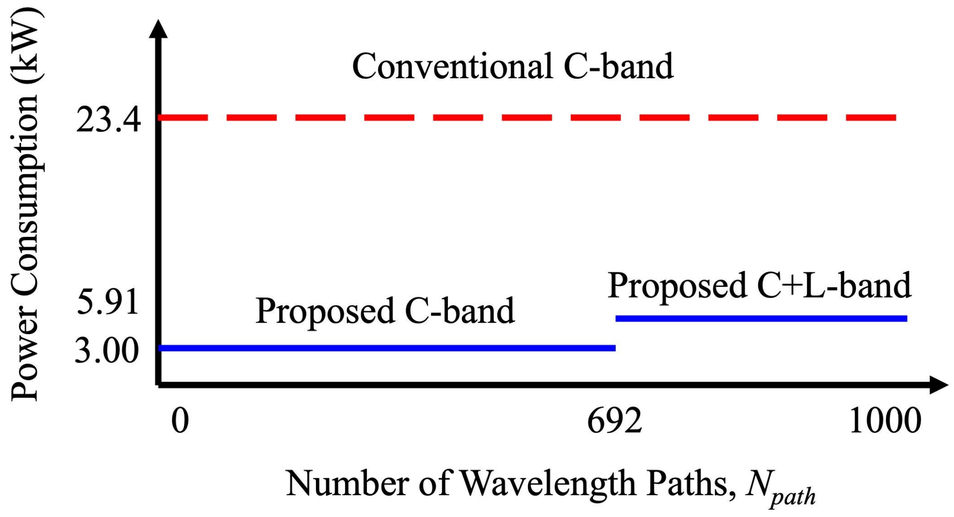
Power efficient metro node architecture using programmable WSS (Keio University)

- Node architecture suitable for metro networks based on Programmable WSS and passive devices
  ⇒ 75 % reduction of power consumption
  - **Low power consumption (less than 10W) programmable WSS is employed**
  - **Passive devices** are utilized to reduce the number of high-power WSSs and amplifiers

Proposed node architecture



Power consumption reduction effect



- **At each WSS of adjacent nodes, it is determined whether the signal should be dropped at the next node or bypassed, and the routing is branched via optical fibers accordingly**
- **By incorporating optical couplers, the number of WSSs and amplifiers can be reduced ⇒ Low power consumption**

These research results were obtained from the commissioned research (JPJ012368C08501)
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