一般社団法人　電子情報通信学会
THE INSTITUTE OF ELECTRONICS,
INFORMATION AND COMMUNICATION ENGINEERS

信学技報
IEICE Technical Report
CS2021-46(2021-09)

An Approach to Large-scale Disaster-Resilient Optical Networks with Openness and Disaggregation

Sugang Xu[1], Kiyo Ishii[2], Noboru Yoshikane[3], Sifat Ferdousi[4], Masaki Shiraiwa[1], Yusuke Hirota[1], Takehiro Tsuritani[3], Massimo Tornatore[4,5], Yoshinari Awaji[1], Naoya Wada[1], Shu Namiki[2], and Biswanath Mukherjee[4,6]

1. National Institute of Information and Communications Technology (NICT), Nukui-Kitamachi Koganei, Tokyo 184-8795, Japan
2. National Institute of Advanced In-dustrial Science and Technology (AIST), Tsukuba 305-8568, Japan
3. KDDI Research, Inc., 2-1-15 Ohara Fujimino-shi, Saitama 356-8502, Japan
4. University of California, Davis, USA
5. Politecnico di Milano, Italy
6. Institute for Broadband Research and Innovation (IBRI) at Soochow University, P. R. China

E-mail: [1]{xsg, shiraiwa, hirota.yusuke, yossy, wada}@nict.go.jp, [2]{kiyo-ishii, shu.namiki}@aist.go.jp, [3]{yoshikane, tsuri}@kddi-research.jp, [4]{sferdousi, mtornatore, bmukherjee}@ucdavis.edu

Abstract

Novel open and disaggregated optical-networking technologies promise to enhance multi-vendor interoperability thanks to their open interfaces in both data-plane and control/management-plane. From the viewpoint of disaster resilience in optical networks, such interoperability will significantly improve the flexibility in product selection with regard to replacing damaged subsystems with products of different vendors. We investigate an approach to enhance resilience of future optical networks with two dimensions: openness and disaggregation. We report our studies on the control and optical performance monitoring/telemetry of optical networks with this approach and show the experimental results in disaster recovery scenario.

.

Keywords Open, Disaggregation, Integration, Control, OPM, Telemetry, Disaster recovery.

This article is a technical report without peer review, and its polished and/or extended version may be published elsewhere.
Copyright ©2021 by IEICE

An Approach to Large-scale Disaster-Resilient Optical Networks with Openness and Disaggregation

Sugang Xu[1], Kiyo Ishii[2], Noboru Yoshikane[3], Sifat Ferdousi[4], Masaki Shiraiwa[1], Yusuke Hirota[1], Takehiro Tsuritani[3], Massimo Tornatore[4,5], Yoshinari Awaji[1], Naoya Wada[1], Shu Namiki[2], and Biswanath Mukherjee[4,6]

[1]NICT, [2]AIST, [3]KDDI Research Inc. [4] UC Davis, USA, [5]Politecnico di Milano, Italy , [6]IBRI, China

1

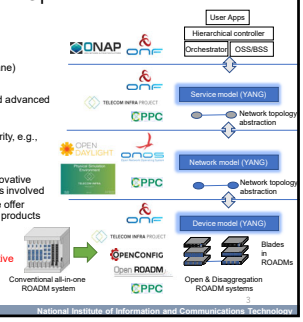
Outline

- Background and motivations
  - Why are openness and disaggregation beneficial to enhance resilience of optical networks?
- Research activities in disaster-resilient optical networks with openness and disaggregation
  - **Part-1:** Integration and control of diverse optical subsystems
    - Diverse blade integration and unified control of disaggregate/legacy ROADMs
  - **Part-2:** Optical performance monitoring (OPM) and robust telemetry
    - Offer robust OPM/Telemetry in post-disaster recovery with open APIs and data models
- Summary

2

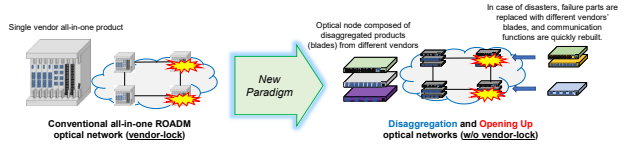
An Open Approach to Meet Carriers' Requirements — SDN + Open + Hardware Disaggregation in Optical Networks

- Break vendor-lock, decreasing CAPEX (D-Plane)
  - Be able to mix and match best-in-class platform
- Automated reconfiguration and API to Apps, decreasing OPEX (C/M-plane)
  - Be able to achieve SDN-based multi-layer automated control
- Timely utilization of the new system/subsystems based on the latest and advanced technologies
  - Decouple the entire optical system and replace the short life-cycle subsystems to better-fit the technology evolution and market maturity, e.g., TPND
- Accelerate innovation (both carriers and vendors)
  - Empower carriers to leverage new architectures and offer new innovative services, thanks to the open architecture and more App developers involved
  - Also, offer subsystem vendors incentives on innovations, therefore offer system integrators more choices to cost-efficiently customize their products meeting carriers' needs
- Enhance the resiliency of optical networks
  - Easy to offer and flexibly integrate more interoperable and alternative resources for early disaster recovery



3

Why are openness and disaggregation beneficial? (from the resilience perspective)



High risk of resource shortage in Emergency recovery

- Emergency recovery might be hard due to the shortage of the vendor's products.
- Further exacerbated during large-scale disasters.

Broadly available interoperable resource

- Simply replace the damaged part (blades) with new blades.
- Broadly available blades supply from different vendors, qualitatively reduced the risk of resource shortage in all-in-one single optical network
- Enable swift recreation of lost communication functions.

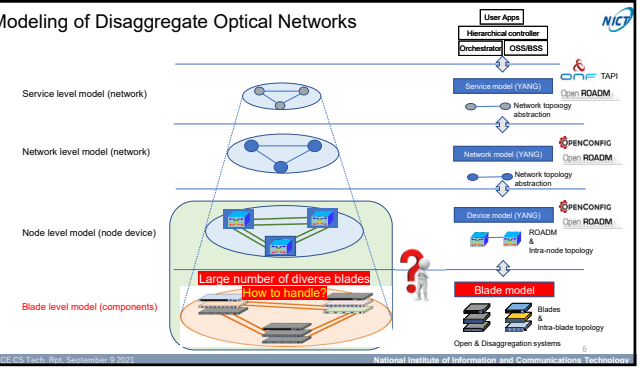
4

Outline

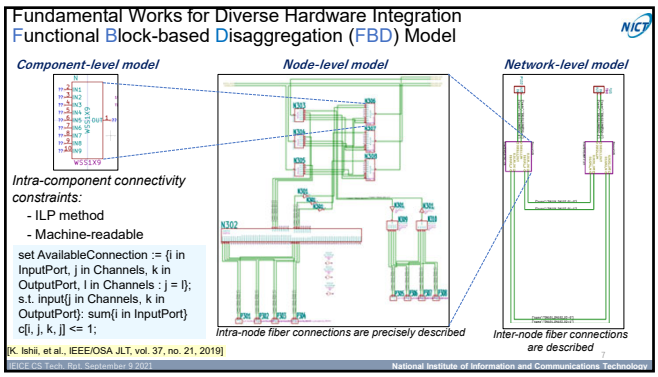
- Background and motivations
  - Why are openness and disaggregation beneficial to enhance resilience of optical networks?
- Research activities in disaster-resilient optical networks with openness and disaggregation
  - **Part-1:** Integration and control of diverse optical subsystems
    - Diverse blade integration and unified control of disaggregate/legacy ROADMs
  - **Part-2:** Optical performance monitoring (OPM) and robust telemetry
    - Offer robust OPM/Telemetry in post-disaster recovery with open APIs and data models
- Summary

5

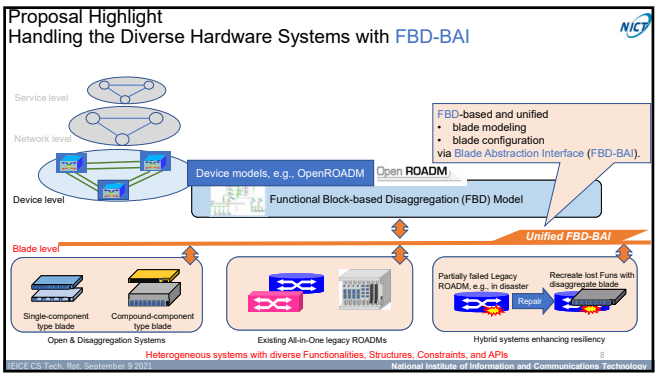
Modeling of Disaggregate Optical Networks



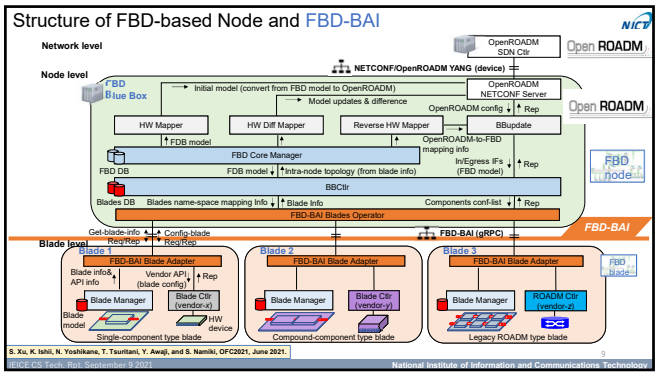
6


Fundamental Works for Diverse Hardware Integration
Functional Block-based Disaggregation (FBD) Model
Component-level model
Node-level model
Network-level model
Intra-component connectivity constraints:
- ILP method
- Machine-readable
set AvailableConnection := {i in InputPort, j in Channels, k in OutputPort, l in Channels : j = l};
s.t. input{j in Channels, k in OutputPort}: sum{i in InputPort} c[i, j, k, j] <= 1;
[K. Ishii, et al., IEEE/OSA JLT, vol. 37, no. 21, 2019]
Intra-node fiber connections are precisely described
Inter-node fiber connections are described
IEICE CS Tech. Rpt. September 9 2021
National Institute of Information and Communications Technology

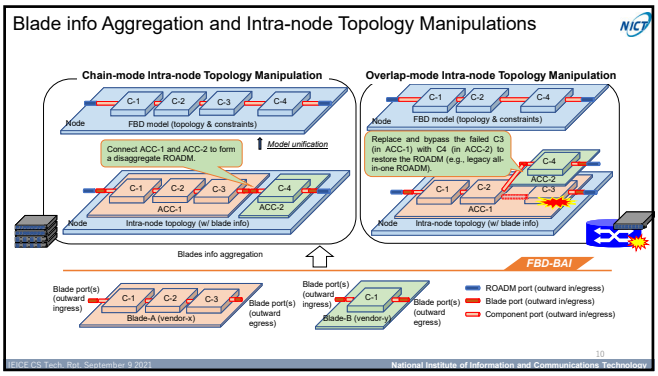
7


Proposal Highlight
Handling the Diverse Hardware Systems with FBD-BAI
Service level
Network level
Device level
Device models, e.g., OpenROADM
Open ROADM
Functional Block-based Disaggregation (FBD) Model
FBD-based and unified
• blade modeling
• blade configuration
via Blade Abstraction Interface (FBD-BAI).
Unified FBD-BAI
Blade level
Single-component type blade
Compound-component type blade
Open & Disaggregation Systems
Existing All-in-One legacy ROADMs
Partially failed Legacy ROADM, e.g., in disaster
Repair
Recreate lost Funs with disaggregate blade
Hybrid systems enhancing resiliency
Heterogeneous systems with diverse Functionalities, Structures, Constraints, and APIs
IEICE CS Tech. Rpt. September 9 2021
National Institute of Information and Communications Technology

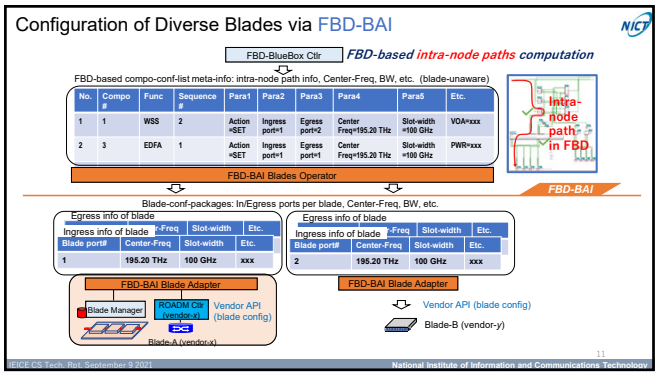
8


Structure of FBD-based Node and FBD-BAI
Network level
Node level
Blade level
OpenROADM SDN Ctlr
Open ROADM
NETCONF/OpenROADM YANG (device)
FBD Blue Box
OpenROADM NETCONF Server
Initial model (convert from FBD model to OpenROADM)
Model updates & difference
OpenROADM config
Rep
HW Mapper
HW Diff Mapper
Reverse HW Mapper
BBupdate
FDB model
OpenROADM-to-FBD mapping info
FBD Core Manager
In/Egress IFs (FBD model)
FBD DB
FDB model
Intra-node topology (from blade info)
BBCtlr
Blades DB
Blades name-space mapping Info
Blade Info
Components conf-list
FBD-BAI Blades Operator
FBD node
FBD-BAI
Get-blade-info
Req/Rep
Config-blade
FBD-BAI (gRPC)
Blade 1
Blade 2
Blade 3
FBD-BAI Blade Adapter
Blade info& API info
Vendor API (blade config)
Blade Manager
Blade Ctlr (vendor-x)
Blade Ctlr (vendor-y)
ROADM Ctlr (vendor-z)
Blade model
HW device
Single-component type blade
Compound-component type blade
Legacy ROADM type blade
FBD Blade
S. Xu, K. Ishii, N. Yoshikane, T. Tsuritani, Y. Awaji, and S. Namiki, OFC2021, June 2021.
IEICE CS Tech. Rpt. September 9 2021
National Institute of Information and Communications Technology

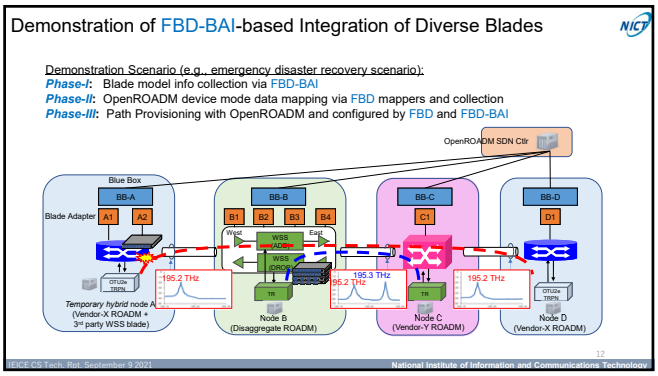
9


Blade info Aggregation and Intra-node Topology Manipulations
Chain-mode Intra-node Topology Manipulation
Overlap-mode Intra-node Topology Manipulation
Node
FBD model (topology & constraints)
Model unification
Connect ACC-1 and ACC-2 to form a disaggregate ROADM.
Replace and bypass the failed C3 (in ACC-1) with C4 (in ACC-2) to restore the ROADM (e.g., legacy all-in-one ROADM).
ACC-1
ACC-2
Intra-node topology (w/ blade info)
Blades info aggregation
FBD-BAI
Blade port(s) (outward ingress)
Blade port(s) (outward egress)
Blade-A (vendor-x)
Blade-B (vendor-y)
ROADM port (outward in/egress)
Blade port (outward in/egress)
Component port (outward in/egress)
IEICE CS Tech. Rpt. September 9 2021
National Institute of Information and Communications Technology

10


Configuration of Diverse Blades via FBD-BAI
FBD-BlueBox Ctlr
FBD-based intra-node paths computation
FBD-based compo-conf-list meta-info: intra-node path info, Center-Freq, BW, etc. (blade-unaware)
Intra-node path in FBD
FBD-BAI Blades Operator
FBD-BAI
Blade-conf-packages: In/Egress ports per blade, Center-Freq, BW, etc.
Egress info of blade
Ingress info of blade
FBD-BAI Blade Adapter
Blade Manager
ROADM Ctlr (vendor-x)
Vendor API (blade config)
Blade-A (vendor-x)
Blade-B (vendor-y)
IEICE CS Tech. Rpt. September 9 2021
National Institute of Information and Communications Technology

11


Demonstration of FBD-BAI-based Integration of Diverse Blades
Demonstration Scenario (e.g., emergency disaster recovery scenario):
Phase-I: Blade model info collection via FBD-BAI
Phase-II: OpenROADM device mode data mapping via FBD mappers and collection
Phase-III: Path Provisioning with OpenROADM and configured by FBD and FBD-BAI
OpenROADM SDN Ctlr
Blue Box
Blade Adapter
BB-A
BB-B
BB-C
BB-D
Temporary hybrid node A (Vendor-X ROADM + 3rd party WSS blade)
Node B (Disaggregate ROADM)
Node C (Vendor-Y ROADM)
Node D (Vendor-X ROADM)
195.2 THz
195.3 THz
IEICE CS Tech. Rpt. September 9 2021
National Institute of Information and Communications Technology

12

Three-phase Demo Clip (C-Plane)

Demonstration of *FBD-BAI*-based Integration of Diverse Blades

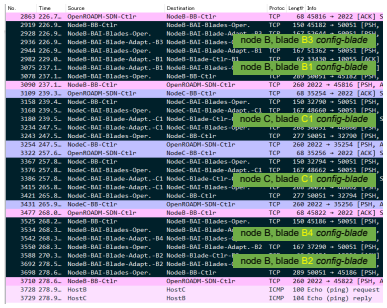
Phase-I: Blade model info collection
Phase-II: OpenROADM device mode data collection
Phase-III: Path Provisioning with OpenROADM and configured by FBD and FBD-BAI

13

Selected Messages via WireShark in Phase-III Demonstration

Phase-III via OpenROADM FBD, FBD-BAI

For the second lightpath <B, C>



14

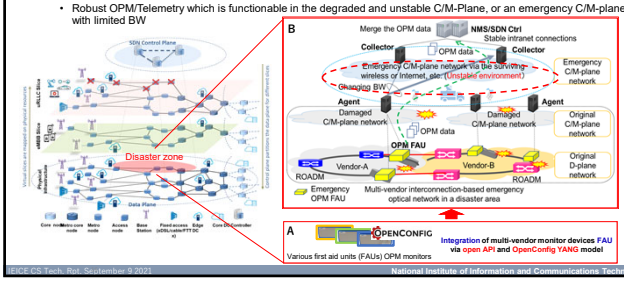
Outline

- Background and motivations
  - Why are openness and disaggregation beneficial to enhance resilience of optical networks?
- Research activities in disaster-resilient optical networks with openness and disaggregation
  - **Part-1:** Integration and control of diverse optical subsystems
    - Diverse blade integration and unified control of disaggregate/legacy ROADMs
  - **Part-2:** Optical performance monitoring (OPM) and robust telemetry
    - Offer **robust OPM/Telemetry** in post-disaster recovery with open APIs and data models
- Summary

15

Overview: Offer Robust OPM/Telemetry in Post-disaster Recovery

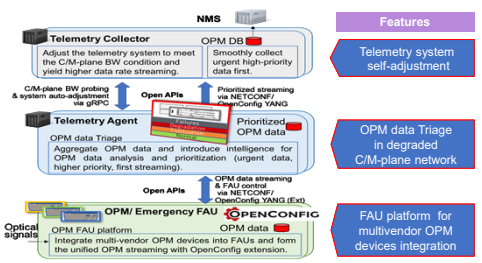
- A. How to integrate multi-vendor OPM devices to quickly recreate lost OPM/Telemetry in case of disaster recovery?
  - Integration of multi-vendor monitor devices-based first-aid-unit (FAU) via open API and OpenConfig YANG model
- B. How to achieve Robust OPM/Telemetry in case of disaster recovery?
  - Robust OPM/Telemetry which is functionable in the degraded and unstable C/M-Plane, or an emergency C/M-plane with limited BW



16

Emergency FAU integration via Open API/Data-model and Robust OPM/Telemetry under C/M-plane Constraint

Open and Robust OPM/Telemetry functionable under C/M-plane BW constraint



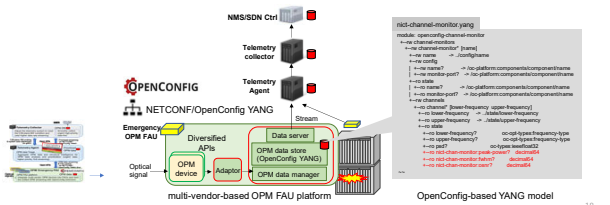
Features
Telemetry system self-adjustment
OPM data Triage in degraded C/M-plane network
FAU platform for multivendor OPM devices integration

S. Xu, Y. Hirota, M. Shiraiwa, M. Tornatore, S. Ferdousi, Y. Awaji, N. Wada, and B. Mukherjee, IEEE/OSA JLT, Jan. 2020.

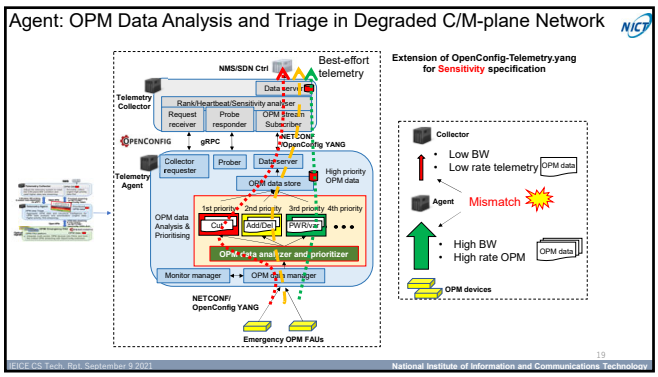
17

Multi-vendor OPM FAUs Integration via OpenConfig

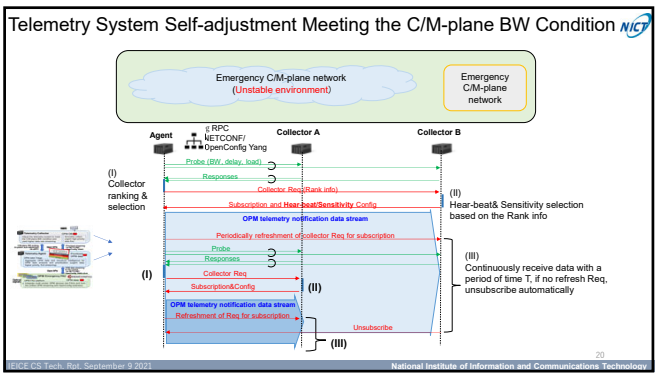
- We can use OPM FAU to replace the damaged OPM components and recreate the lost OPM functionality as early as possible
- Multi-vendors OPM devices integration with an open architecture
  - Introduce OPM device adaptor to deal with the diversified APIs
  - Adopt NETCONF and OpenConfig YANG data model



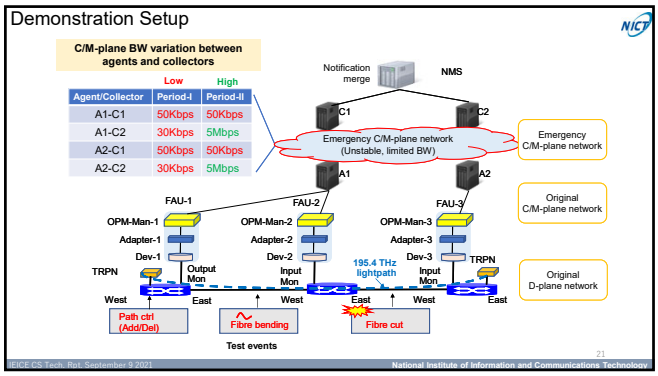
18



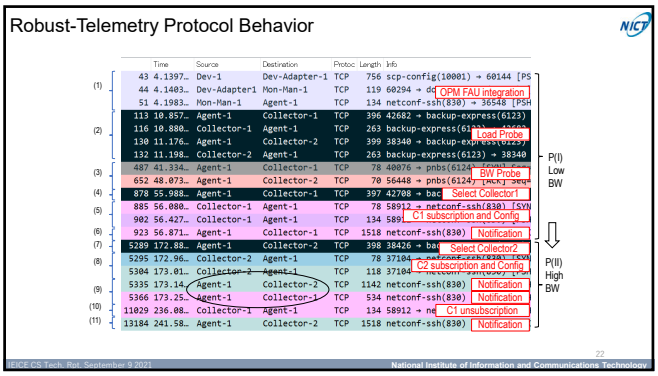
19



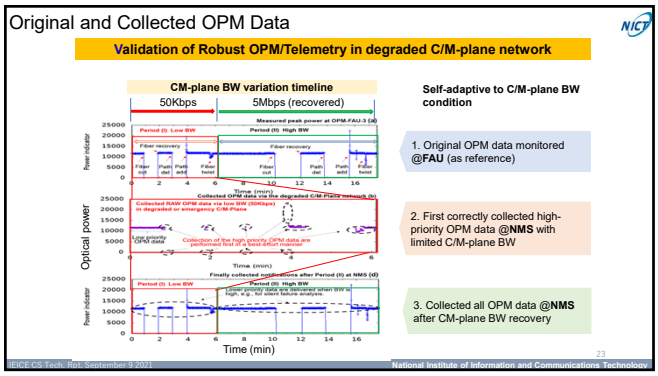
20



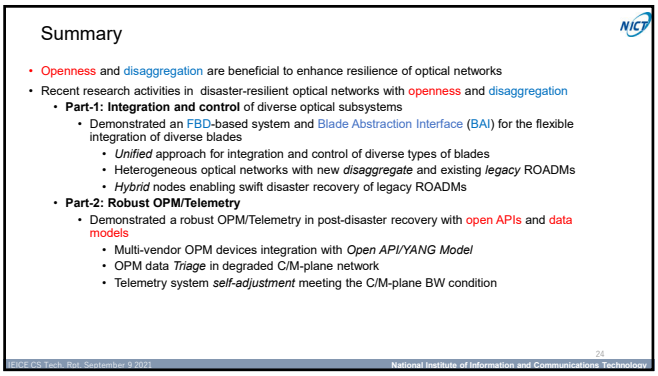
21



22



23



24

Thank you very much!

Acknowledgement

The work in Part-1 was supported in part by JSPS KAKENHI JP19H02164
& Ministry of Internal Affairs and Communications grant number JP MI00316.

The work in Part-2 was supported in part by US-Japan JUNO2 project: NSF Grant no. 1818972.

The authors thank Mr. Toshiyuki Shimizu and Mr. Weping Ren for their valuable helps.