2023 Japan-US Network Opportunity 3 (JUNO3)

# Project Title: Cloud-Carrier Cooperation for Efficient and Ultra-Reliable Programmable Backbone Networks

*Award Number: 2210384*

**Speakers:**
**Dr. Yusuke Hirota (NICT)**
**Dr. Sifat Ferdousi (UCDavis)**

**April 3, 2023**
**Principal Investigator Meeting**

UCDAVIS

NICT

# Project Team

- **PIs**
  - Biswanath Mukherjee; University of California, Davis; PI
  - Sifat Ferdousi; University of California, Davis; Co-PI
  - Yoshinari Awaji; NICT (Japan); Team leader (PI Japan side)
  - Yusuke Hirota; NICT (Japan); (Co-PI Japan side)

UCDAVIS Complementary expertise NICT

- Dr. Awaji has long-term R&D experience on optical resilient communication systems
- Dr. Hirota and Dr. Xu brings expertise in future network and optical network architecture
- Dr. Mukherjee has extensive research experience in optical network design and survivability
- Dr. Ferdousi has expertise in resiliency in cloud networks

- **International Collaborators**
  - Massimo Tornatore; Politecnico di Milano, Italy (*acted as UC Davis lead PI in JUNO2*)
  - Abhijit Mitra, IIIT-Delhi, India

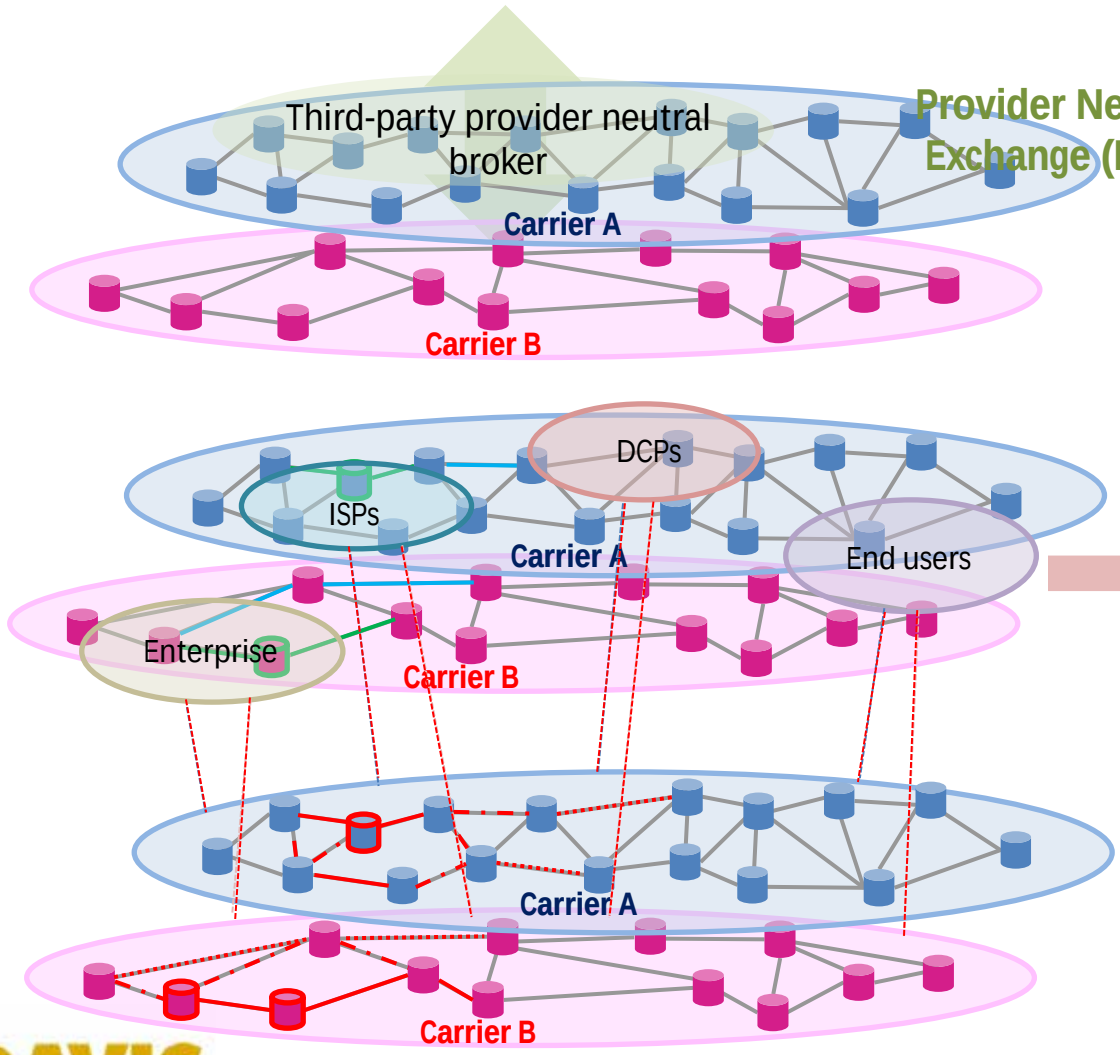
# Introduction

- In the light of 5G and beyond, the traditional cloud network architecture need to evolve to accommodate heterogeneous services with stringent ultra-reliability requirements – can be challenging for individual carrier/provider networks especially during *resource crunch*

- Innovative networking solutions such as ***cloud-carrier cooperation*** among multiple entities, aided by advanced network programmability, can allow need-based flexible resource sharing and reliable end-to-end communication within an integrated network-cloud ecosystem

  - Third-party entity
  - Data abstraction
  - Cooperation
  - …

# Why Cooperation?




**!POLICY!**

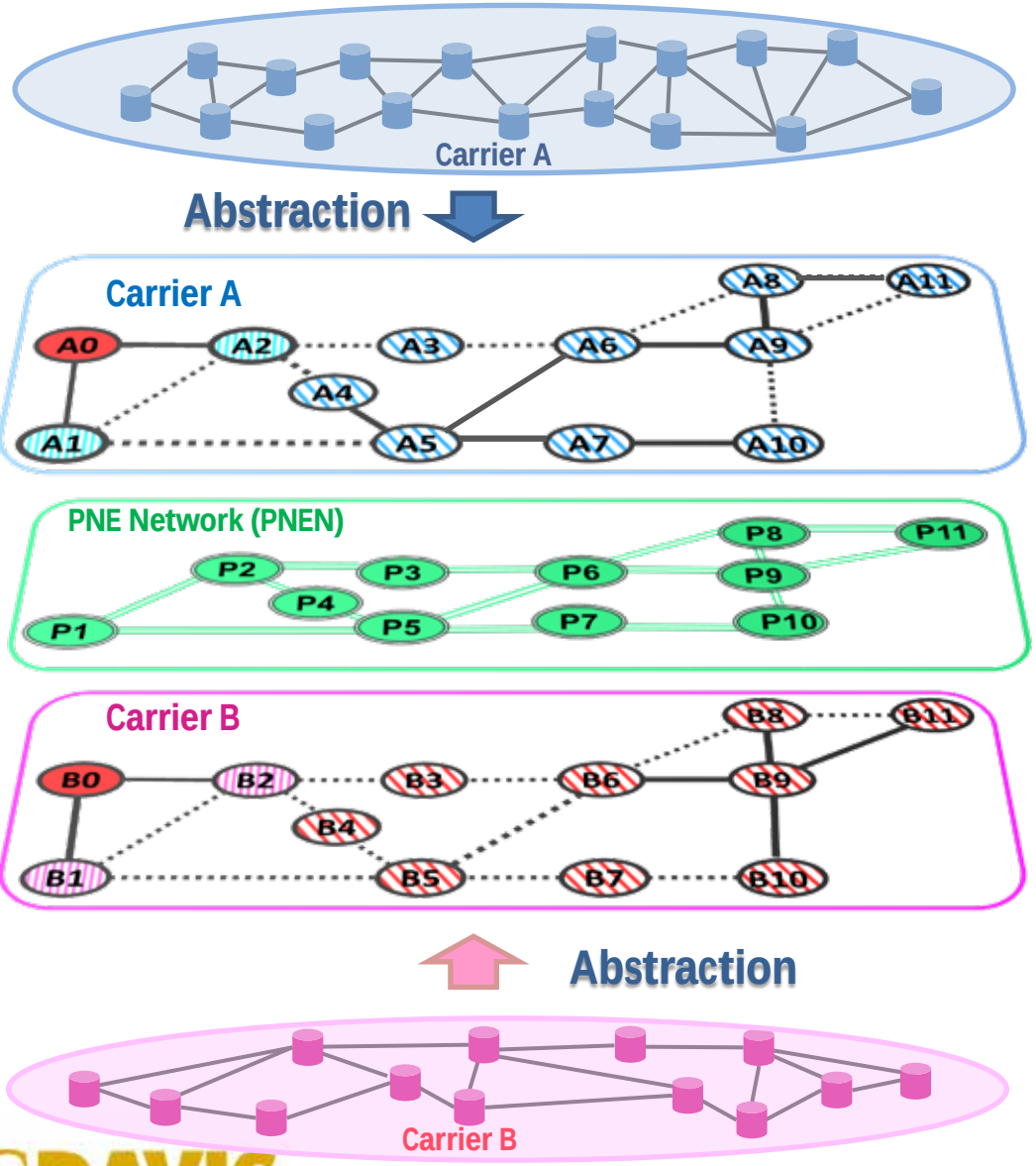
**Confidential Information**

Cooperation possible?

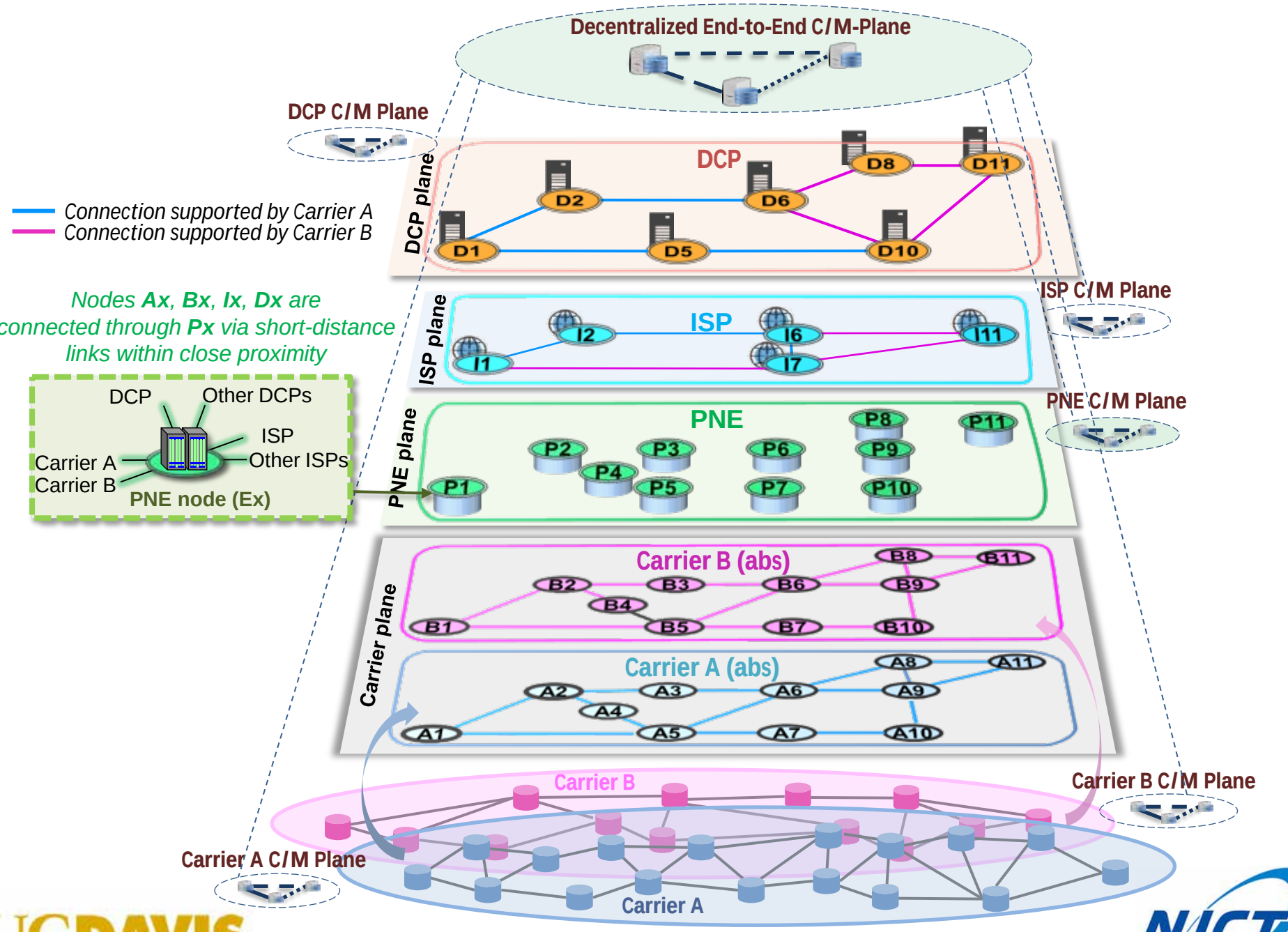
- Un-coordinated recovery planning
- Delayed service restoration
- Inefficient resource utilization

Resource sharing possible?

# Multi-Entity Ecosystem

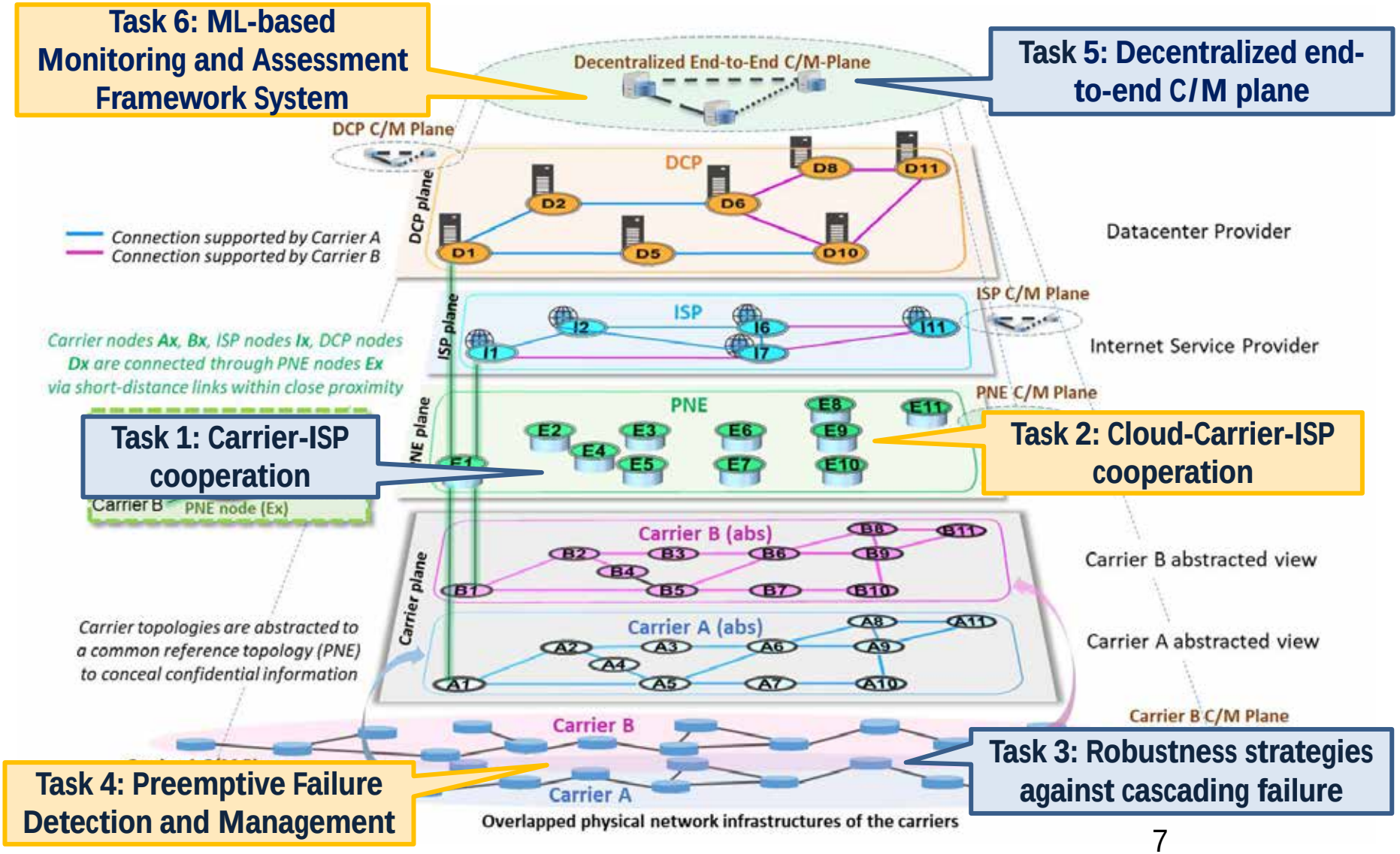



**Abstraction is key**




Overlapped physical network infrastructures of the carriers

# Project Overview



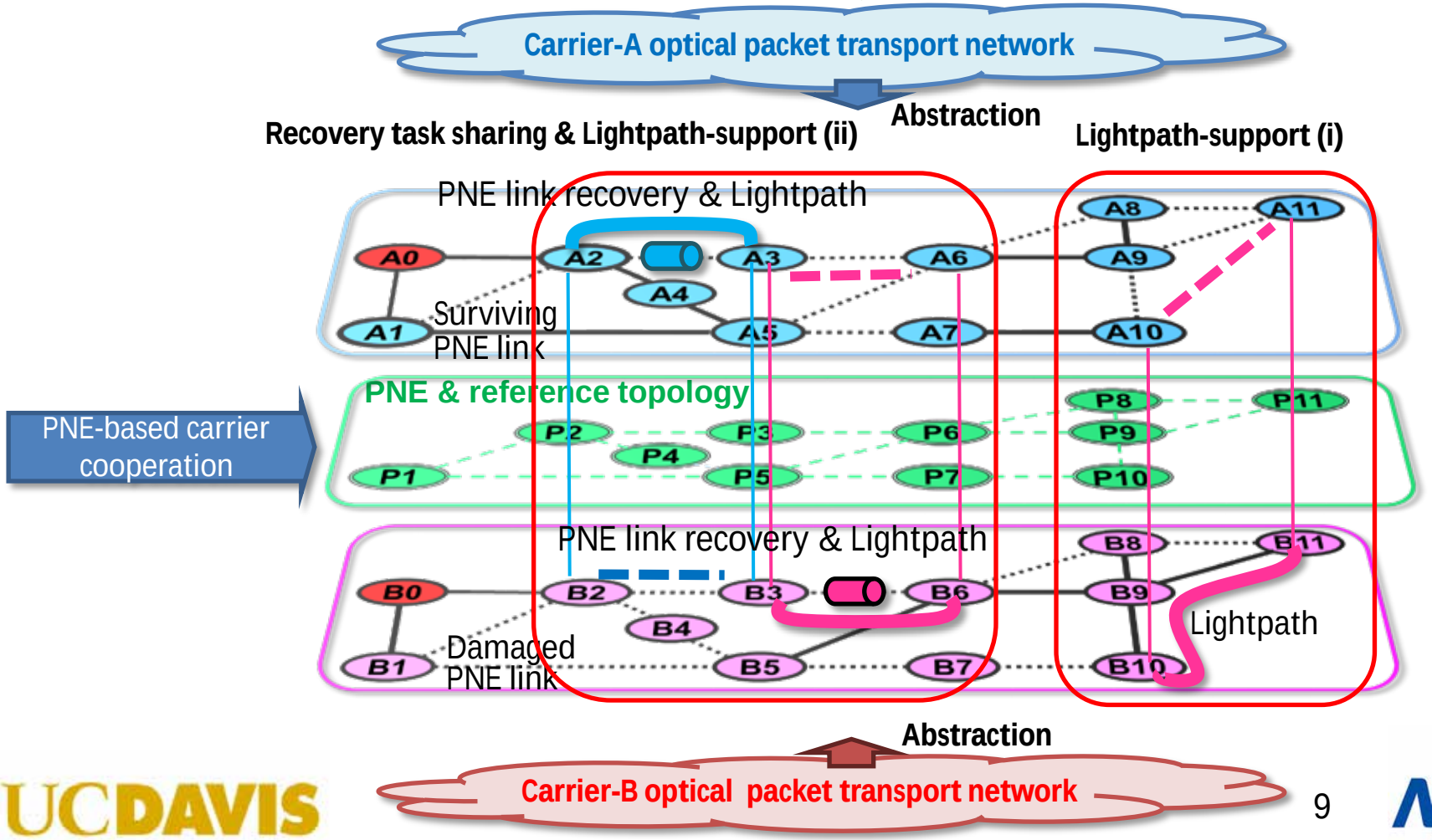
# Overall Topics

| Cloud-Carrier Cooperation | | | |
|---|---|---|---|
| ***Phase*** | Modeling phase | | Implementation phase |
| ***Theme*** | Planning<br>Cooperation framework | Preparedness<br>Failure management | Implementation<br>C/M plane design |
| ***Target*** | Efficient end-to-end service provisioning | Robust networks for reliable cooperation | Reliable C/M-plane to facilitate cooperation |
| ***NICT*** | Task 1<br>Carrier-ISP cooperation | Task 3<br>Robustness strategies against cascading failure | Task 5<br>Decentralized end-to-end C/M plane |
| ***UC Davis*** | Task 2<br>Cloud-Carrier-ISP cooperation | Task 4<br>Preemptive Failure Detection and Management | Task 6<br>ML-based Monitoring and Assessment Framework System |

# Task 1: Carrier-ISP cooperation

**Our interests (Modeling)**

- Detailed issues & constraints in Carrier cooperation
- Abstracted information which can facilitate cooperation
- Simple and efficient cooperation mechanisms



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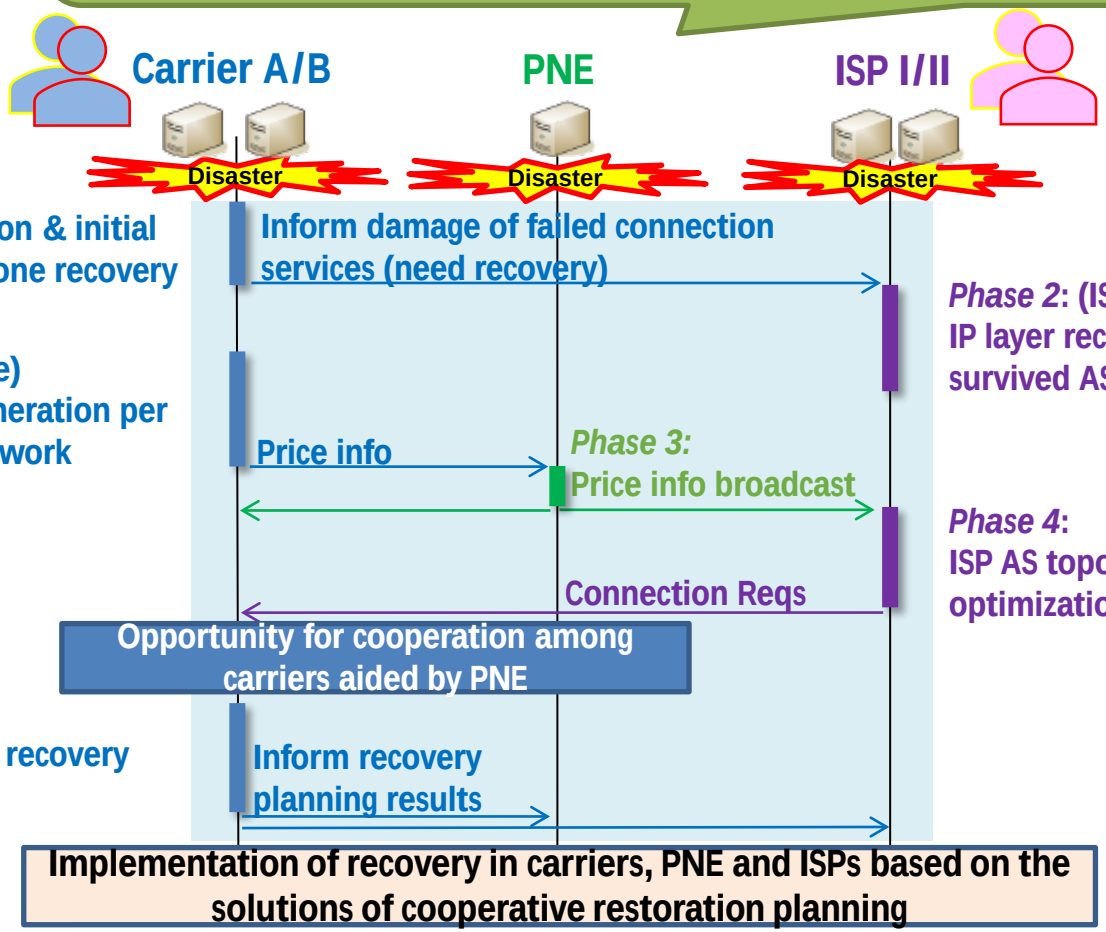



***Phase 1***:
Damage info collection & initial planning for standalone recovery

***Phase 2***: (Carrier-side)
Connection price generation per node pair in PNE network

***Phase 5***:
Reqs confirmation & recovery planning

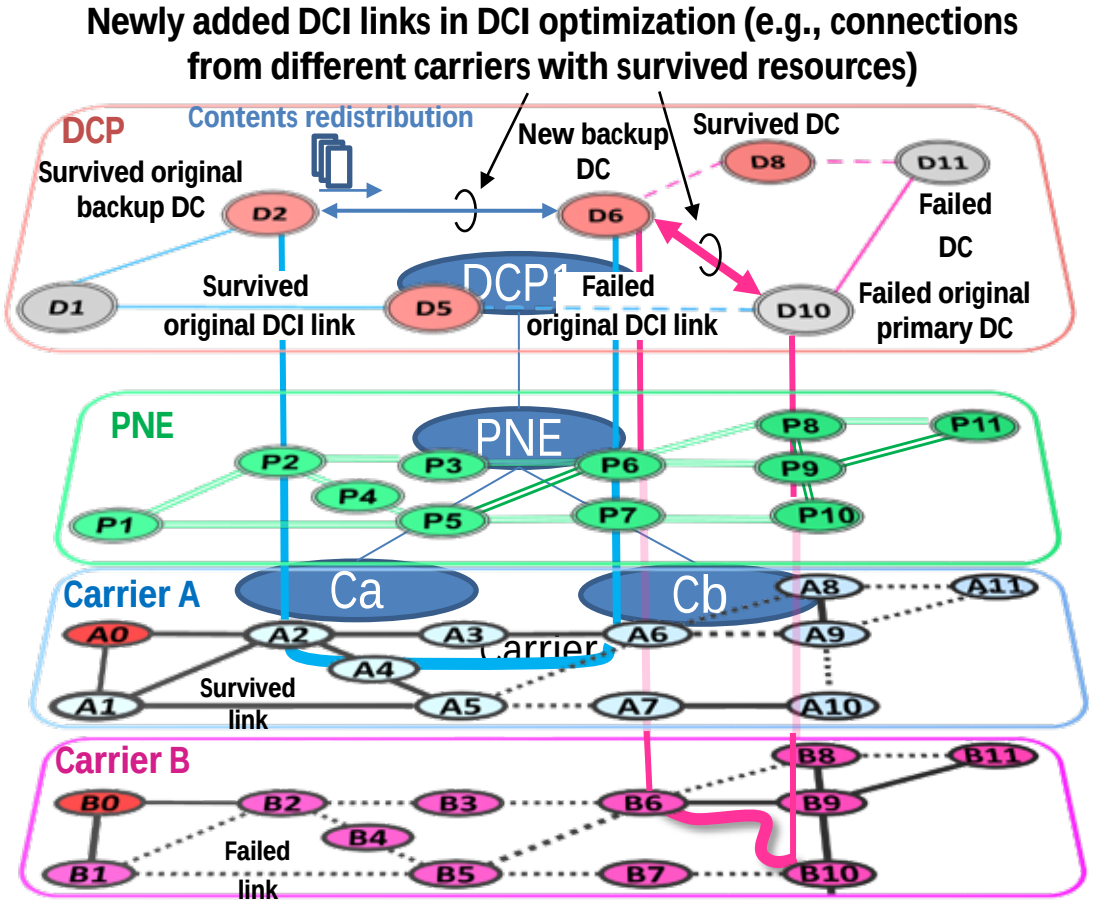
***Phase 2***: (ISP-side)
IP layer recovery with survived AS links

***Phase 4***:
ISP AS topology re-optimization

***Cooperative restoration planning***

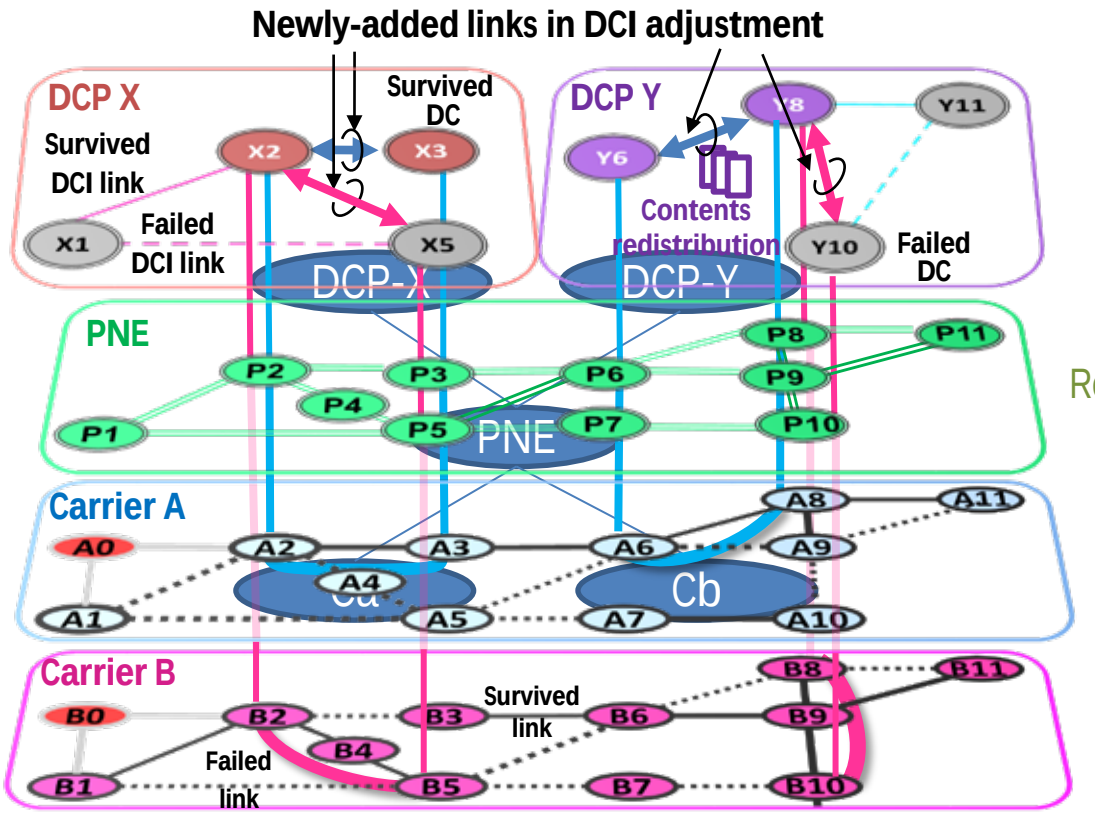
***Cooperative restoration implementation***

# Task 2: Cloud-Carrier Cooperation




**Maximize post-disaster cloud service restoration**

# Task 2: Cloud-Carrier Cooperation




Multiple DCPs compete for resources

⇩

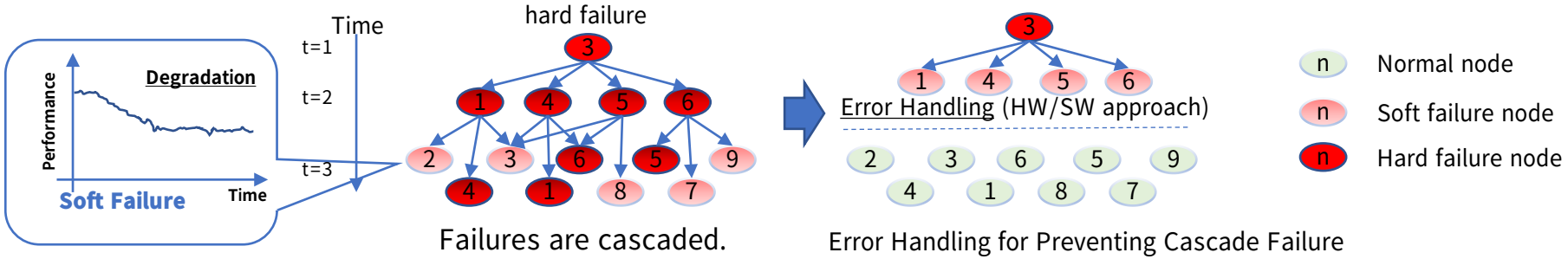
Resource balancing by PNE

How to best fit/match the *demands* (requests for network resources) from multiple DCPs to the *supplies* (available network resources) of the carriers?

# Task 3: Robustness strategies against cascading failure

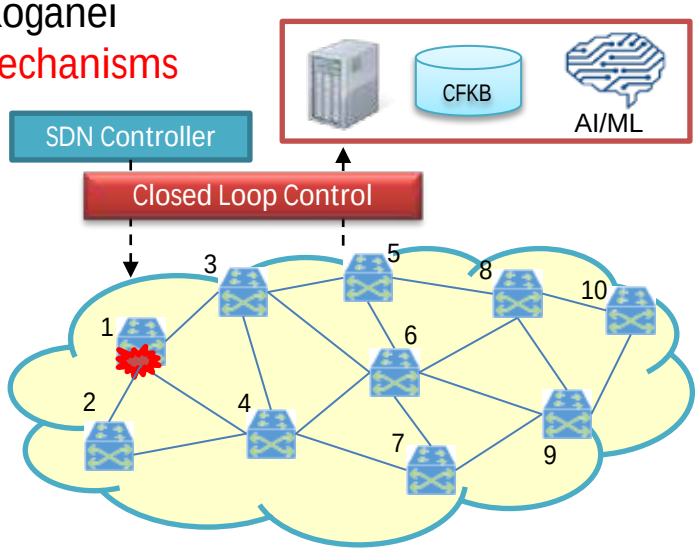
Cascading failure: A failure causes another failure of different part of interconnected system.

Cascade failures may degrade quality of transmission (QoT) as soft failure in optical networks - optical network characteristics need careful consideration




**Analyze and recognize cascading failures and proceed to the**

1. Investigate robust strategies against cascading failure using ML-based failure prediction mechanisms and evaluate its effectiveness using NICT testbed of optical networks in Sendai or Koganei
2. Study error-handling mechanisms




3-1. Analyze/Recognize Cascade Failure Using Sendai Testbed

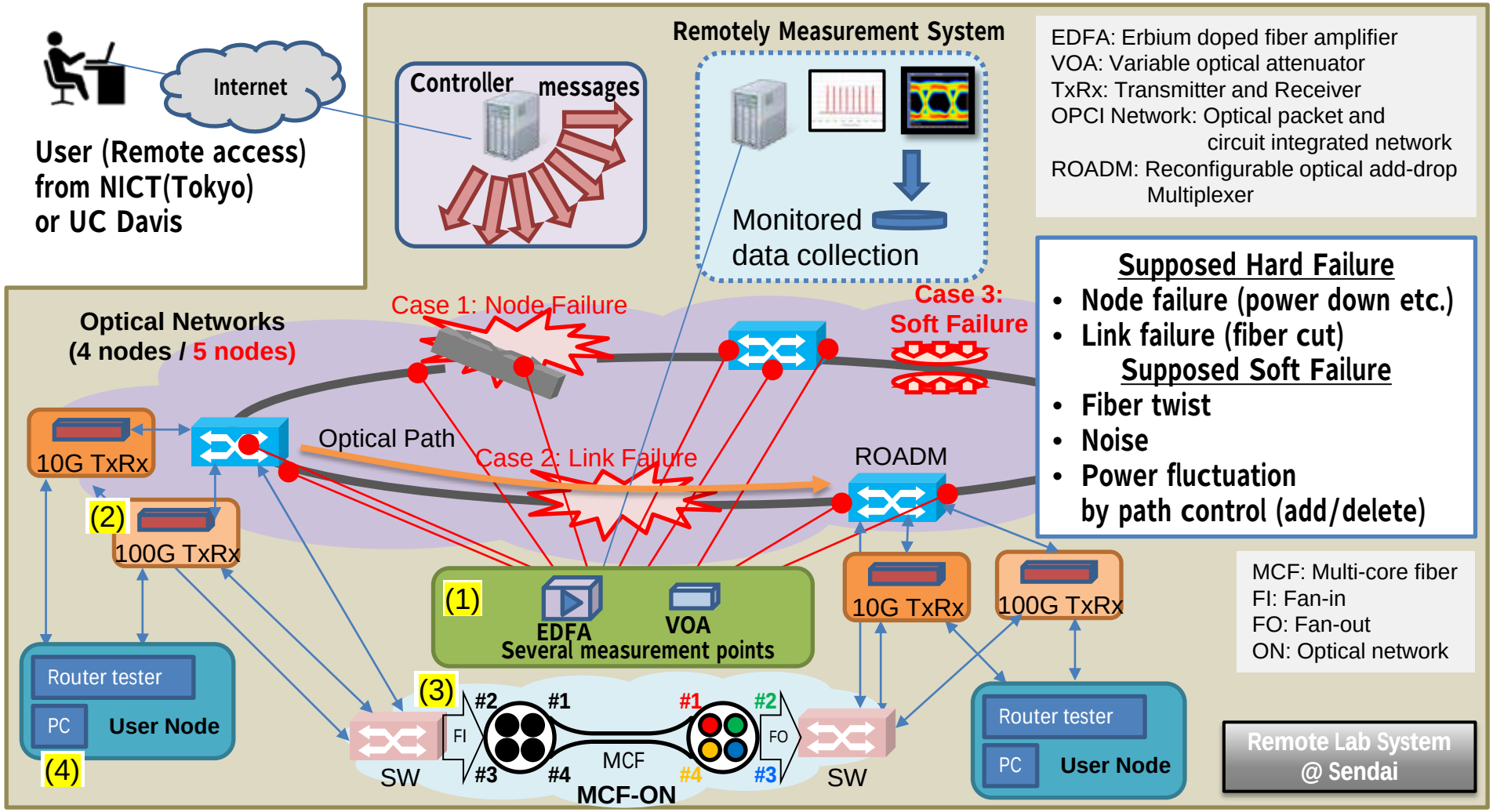
3-2. Cascade Failure Knowledge Base (CFKB) and Modeling

3-3. Error Handling Method in Programmable Optical Networks

Error Handling
HW approach: BM-EDFA etc.
SW approach: **Cascade Failure Prediction** etc.

(SDM) Programmable Optical Network

# Sendai Testbed for Advanced Network Functionality




(1) Multipoint measurement system developed for remote data acquisition

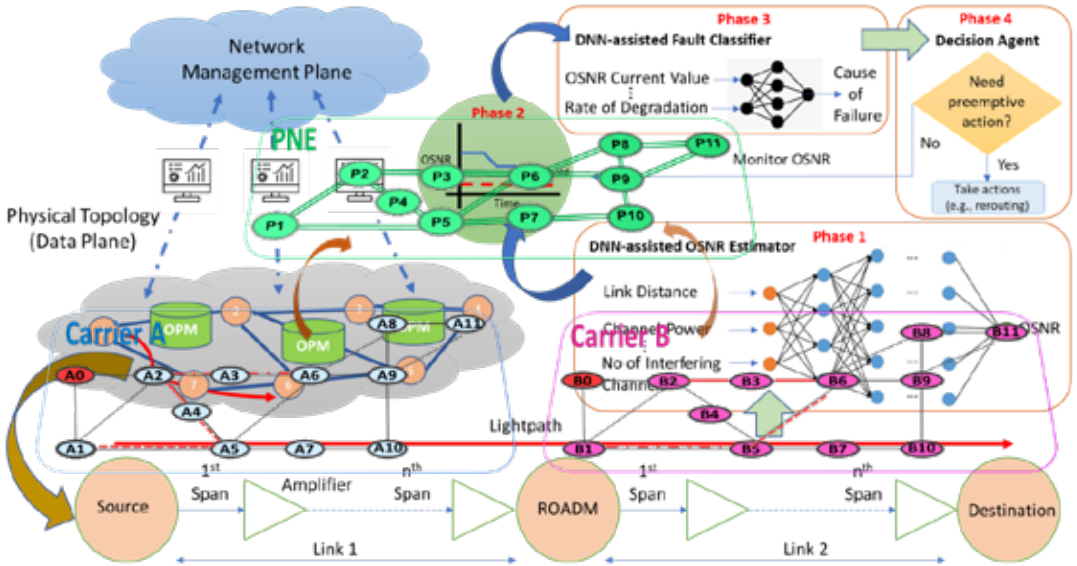
(2) Coherent optical signals generated by 100G transponders

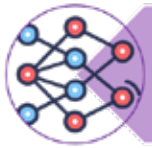
(3) Multi-core fiber optical network

(4) End-to-end network performance evaluation using application/IP traffic

# Task 4: Preemptive Failure Detection and Management

**Target:** Prevent service disruption and maintain seamless network connectivity among multiple entities (carriers, DCPs/ISPs) during cooperation

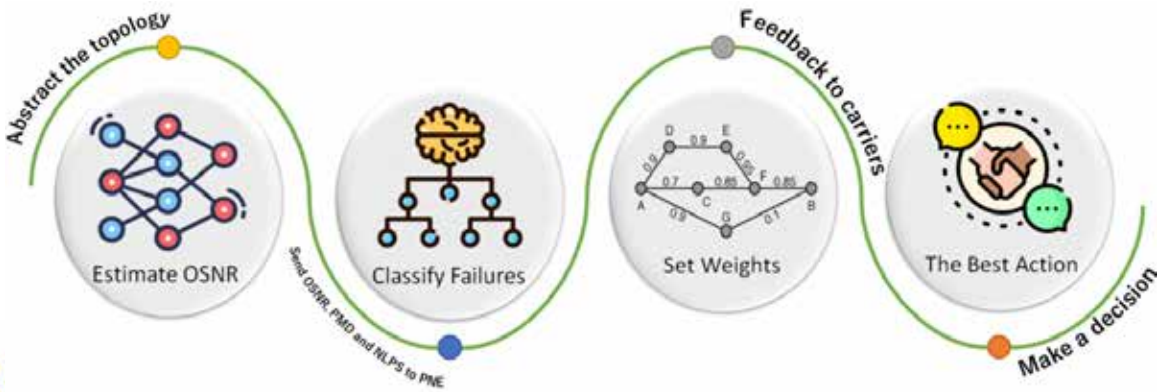


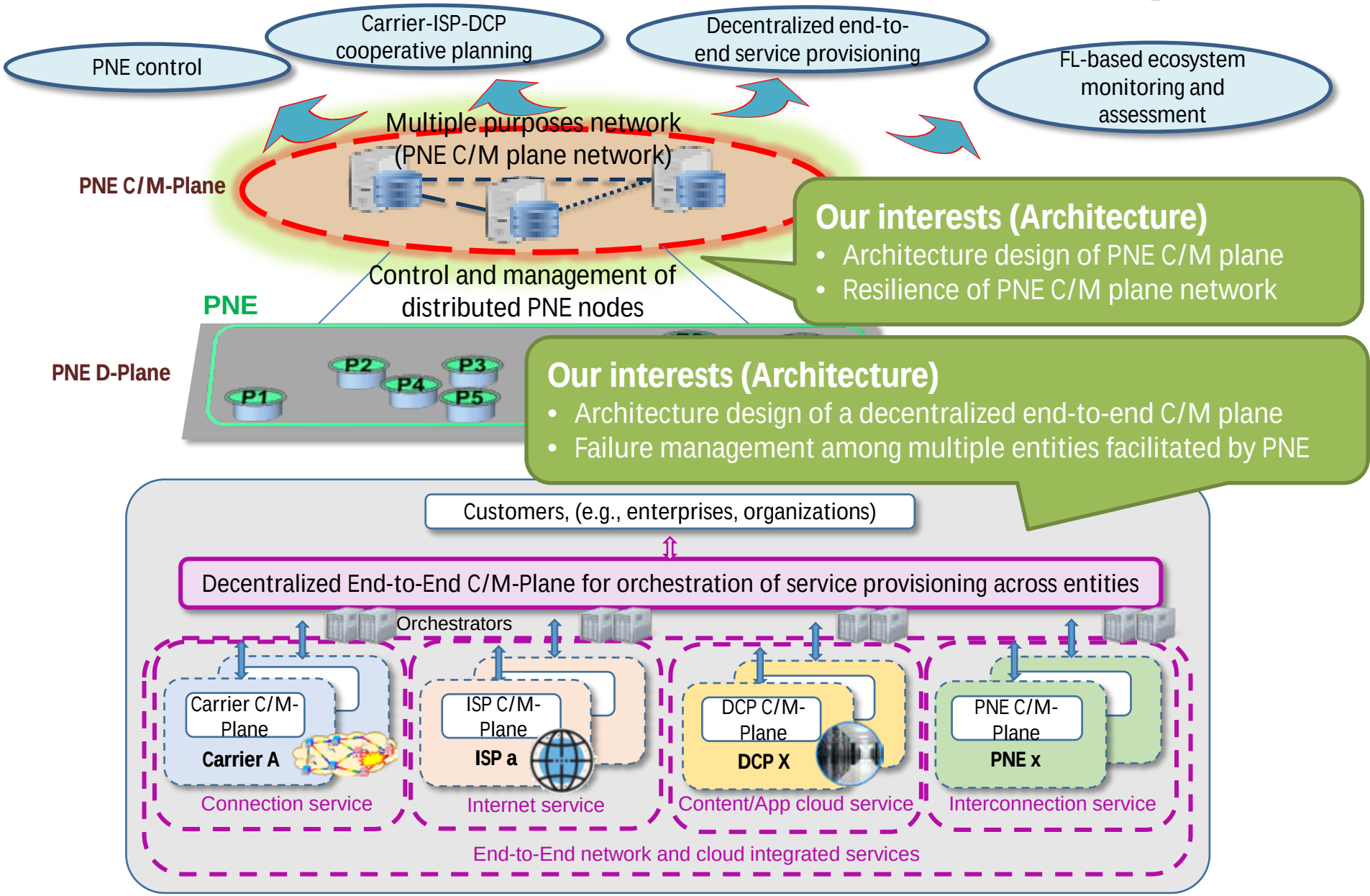
**Phase I**
- Abstraction and OSNR Estimation

**Phase II**
- Failure Classification and Feedback

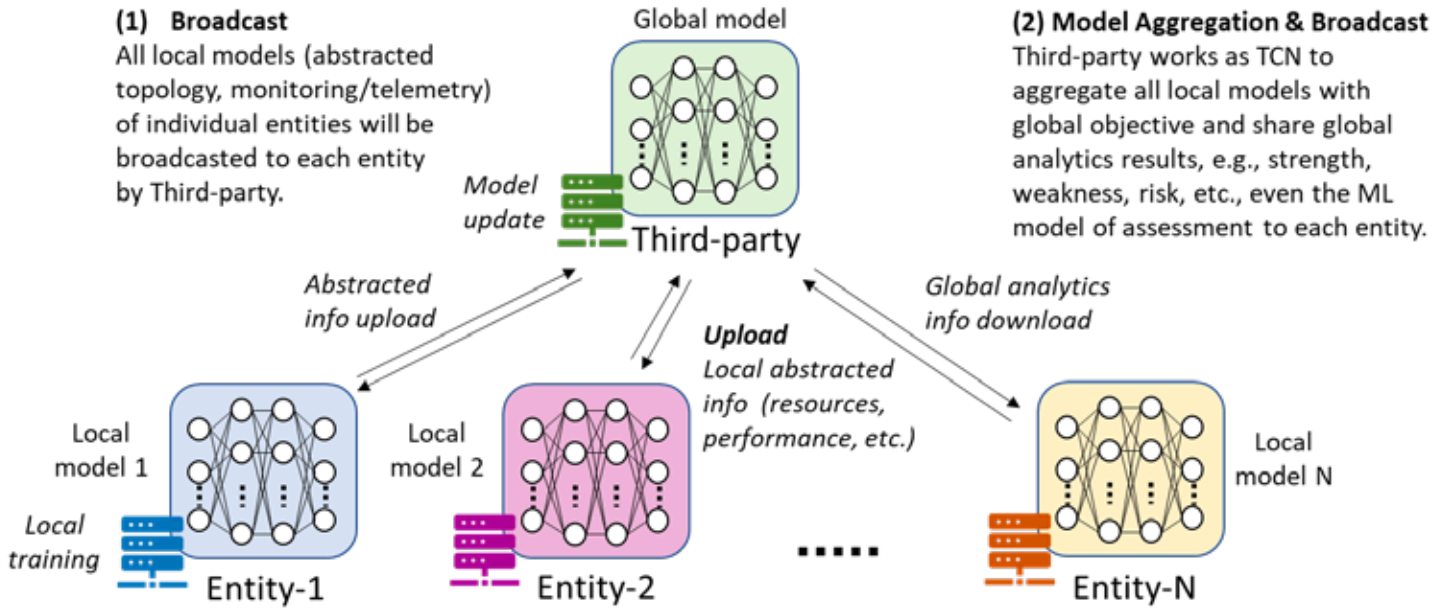
**Phase III**
- Negotiation and Post-Failure Action



# Task 5: Decentralized end-to-end C/M plane



# Task 6: ML-based Monitoring and Assessment Framework System




**Target:** Prepare all the entities for better monitoring/telemetry and cooperation

**Approach:** Federated learning (FL), a geo-distributed ML model can be utilized for privacy preservation

**Action plan:**

* Identify crucial data from different entities
* Develop the MAFS model

# Integration

- Integrated US and Japan Team responsibilities (per task)
  - Dr. Mukherjee and Dr. Ferdousi: Tasks 2, 4, & 6 and Dr. Awaji and Dr. Hirota: Tasks 1, 3, & 5
  - Practical examples of research integration (a summary):

    **Tasks 1-2:** UC Davis and NICT will investigate how to design a cooperation framework among multiple carriers/service providers. UC Davis will look into cloud-carrier cooperation and NICT will focus on integration of ISP

    **Tasks 3-4:** UC Davis will model ML-based QoT estimator for failure detection and generate training data set using NICT testbed for fault classifier training. Leveraging the testbed, NICT will investigate robustness strategies against cascading failures

    **Tasks 5-6:** Common topic is “Reliable C/M-plane design”. UC Davis focus is on ML-based monitoring and assessment framework and NICT focus is on decentralized end-to-end C/M plane

- NICT testbed
  - Data generation (for AI/ML) and solution verification (for NICT and UCD design approaches)

- In-person JUNO3 meeting

  *Davis, March 3, 2023*

  Pre-OFC visit by

  Dr. Awaji, Dr. Hirota, and Dr. Xu

- Online JUNO3 kick-off meeting

  *September 8, 2022*

  *October 6, 2022*

- Several other interactions via email/Zoom

# Publications

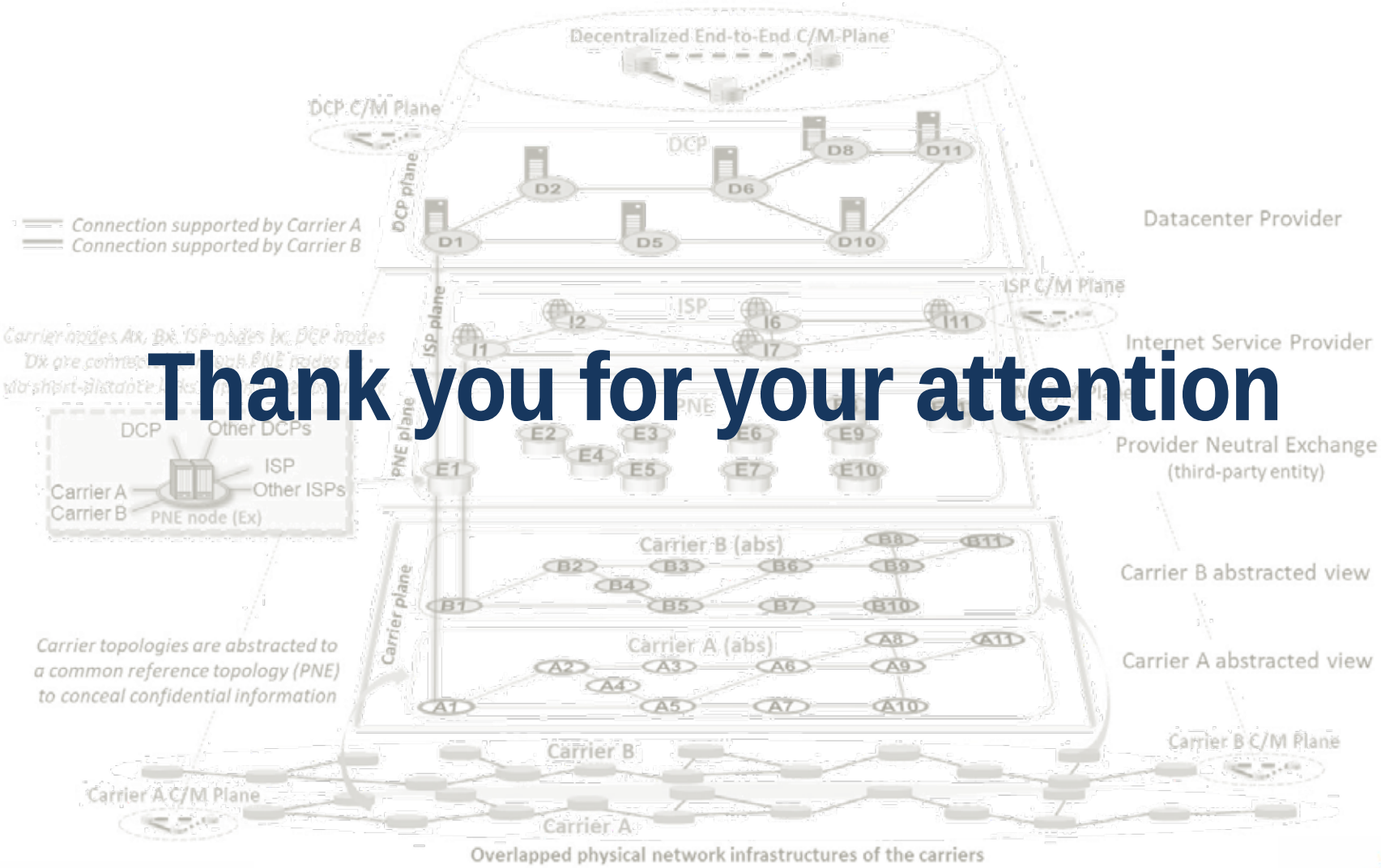
**TASK 1**

- S. Xu, N. Yoshikane, M. Shiraiwa, T. Tsuritani, X. Zhang, Y. Awaji, and N. Wada, "A novel carrier-cooperation scheme with an incentive to offer emergency lightpath support during disaster recovery," Photonic Network Communications, vol. 40, no. 3, July 2020.
- S. Xu, K. Ishii, N. Yoshikane, S. Sahoo, S. Ferdousi, M. Shiraiwa, Y. Hirota, T. Tsuritani, M. Tornatore, Y. Awaji, S. Namiki, and B. Mukherjee, "Enhancement of Network-Cloud Ecosystem Resilience with Openness Disaggregation and Cooperation [Invited]," *Optical Fiber Communication Conference (OFC)*, San Diego, California, USA, Mar. 2023.
- S. Xu, S. Sahoo, S. Ferdousi, M. Shiraiwa, Y. Hirota, M. Tornatore, Y. Awaji, and B. Mukherjee, "A Novel Strategy of Carrier Cooperation with Coordinated Scheduling for Swift Failure/Disaster Recovery," *Optical Network Design and Modelling (ONDM)*, Coimbra, Portugal, May 2023.

**TASK 2**

- S. Sahoo, S. Xu, S. Ferdousi, Y. Hirota, M. Tornatore, Y. Awaji, and B. Mukherjee, "Datacenter-Carrier Cooperation over Optical Networks during Disaster Recovery," *Optical Fiber Communication Conference (OFC)*, San Diego, California, USA, Mar. 2022.
- S. Sahoo, S. Xu, S. Ferdousi, Y. Hirota, M. Tornatore, Y. Awaji, and B. Mukherjee, "Strategic Cooperation among Datacenter Providers and Optical-Network Carriers for Disaster Recovery," *IEEE Global Communications Conference (Globecom)*, Rio de Janeiro, Brazil, Dec. 2022.

- +4 in preparation for journal submission (including IEEE Communications Magazine)
- 3 invited talks (ICETC 2022, ICM 2022, CPS-SNAP 2023)




# Thank you for your attention