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

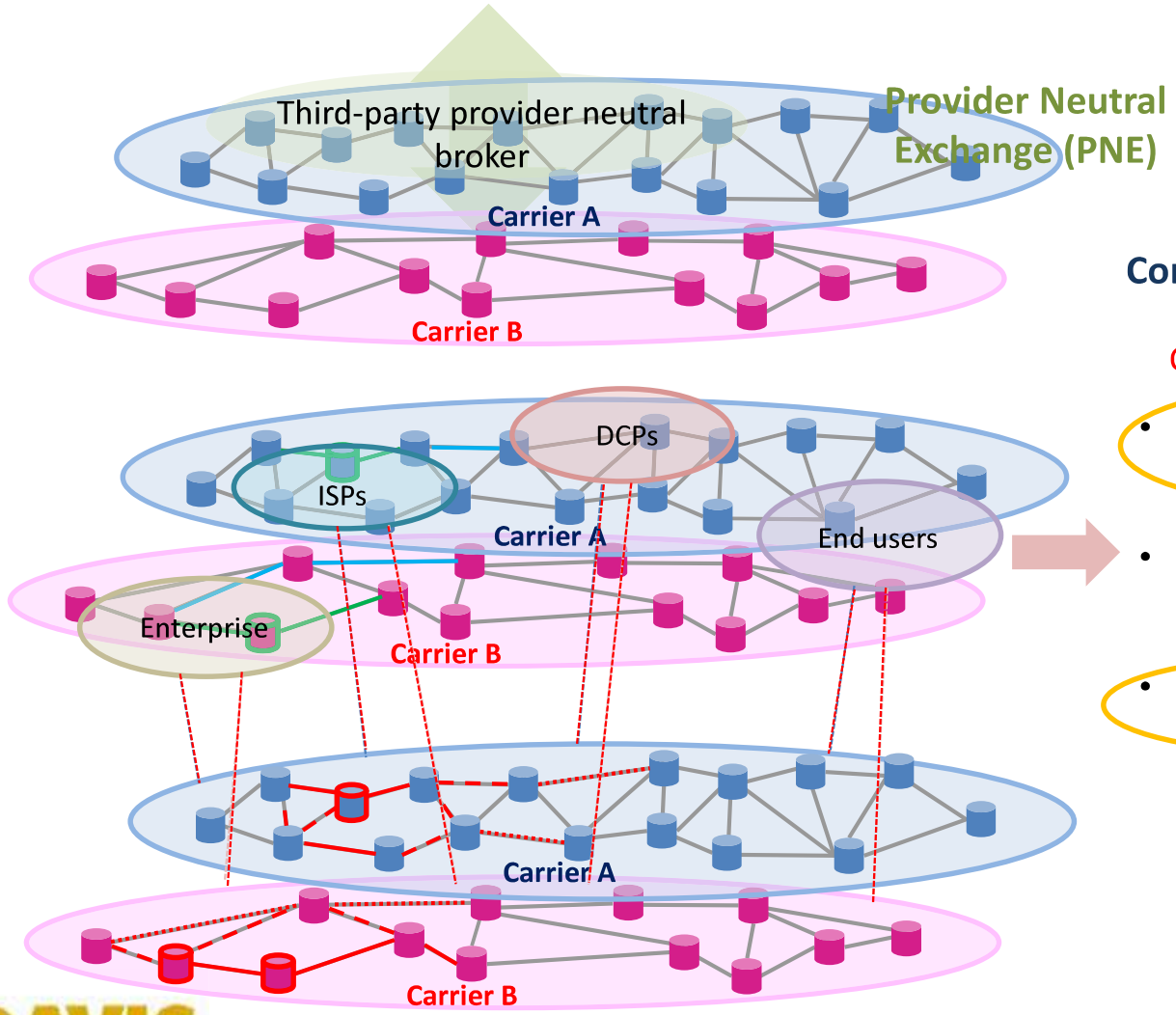
Introduction

- 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?



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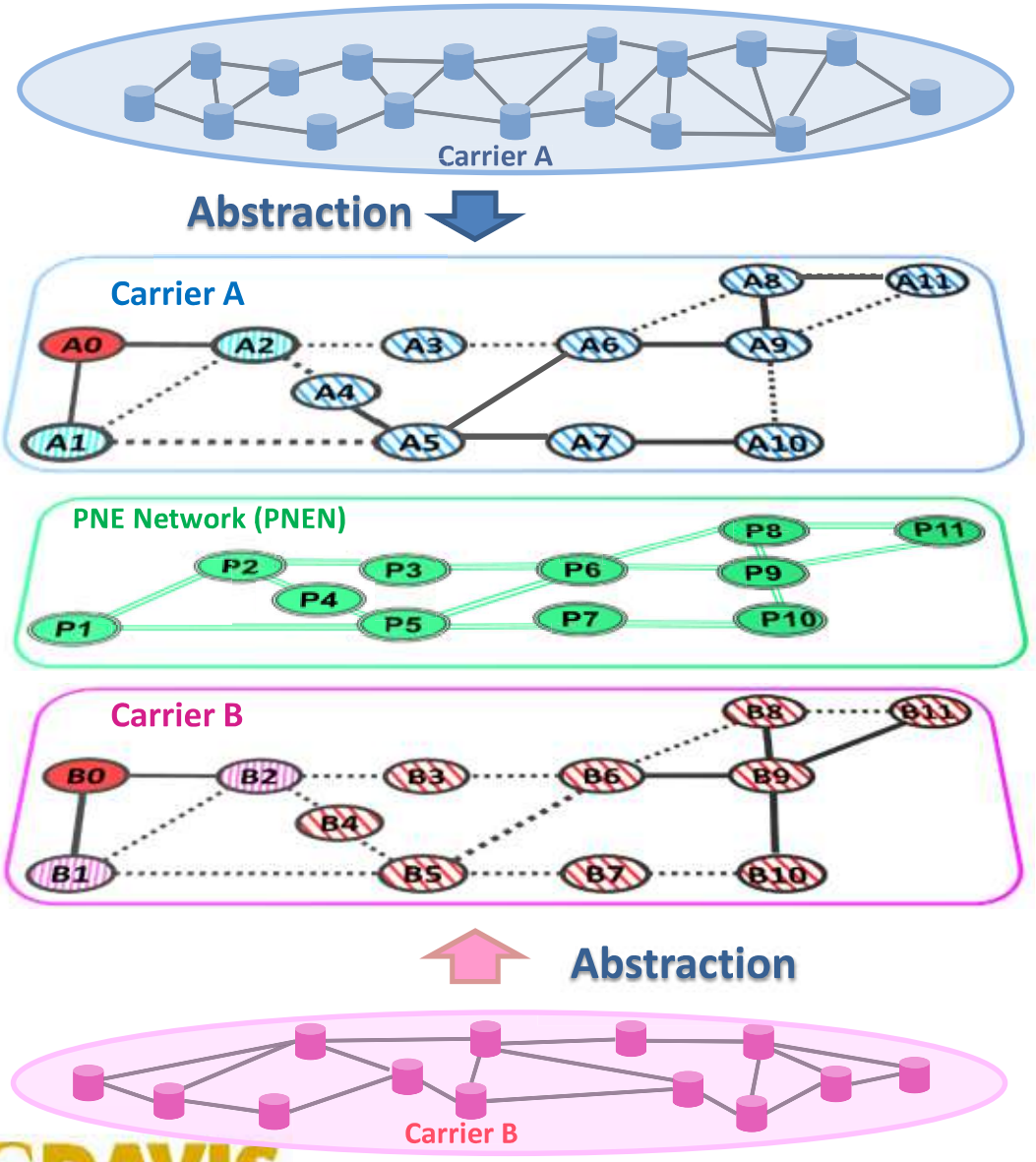
Cooperation possible?

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

Resource sharing possible?

Multi-Entity Ecosystem



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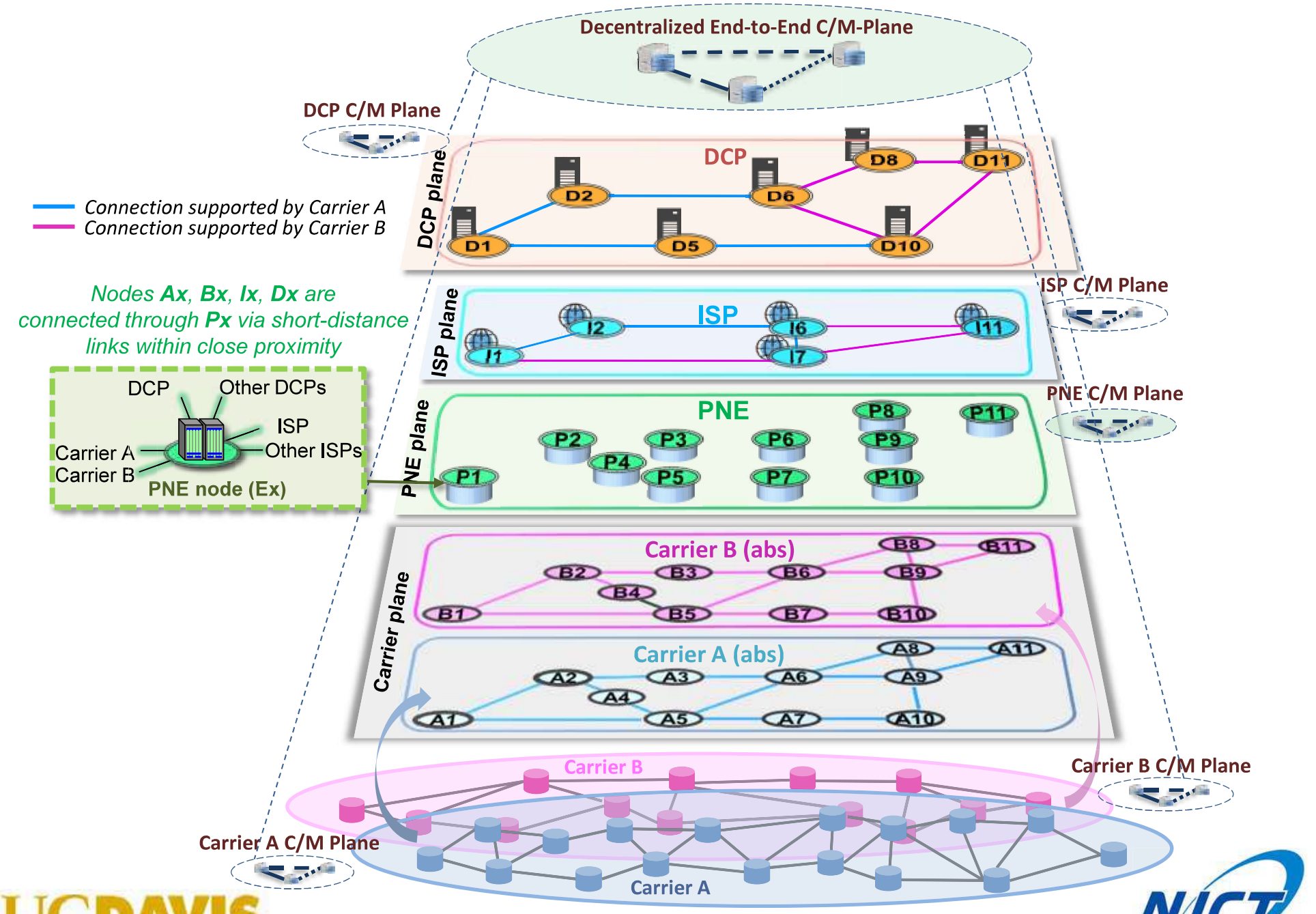

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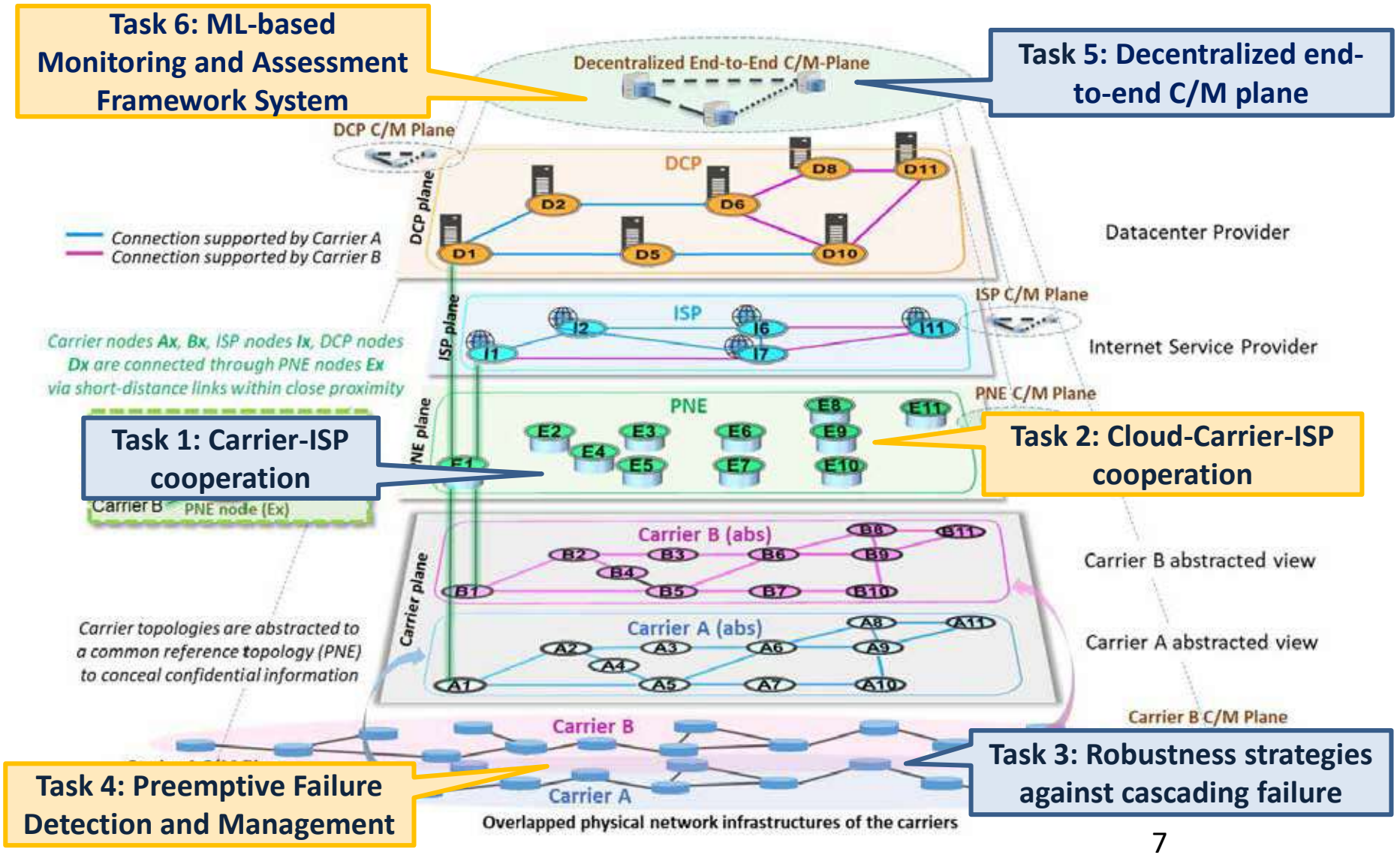

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NICT	Task 1 Carrier-ISP cooperation	Task 3 Robustness strategies against cascading failure	Task 5 Decentralized end-to-end C/M plane
UC Davis	Task 2 Cloud-Carrier-ISP cooperation	Task 4 Preemptive Failure Detection and Management	Task 6 ML-based Monitoring and Assessment Framework System

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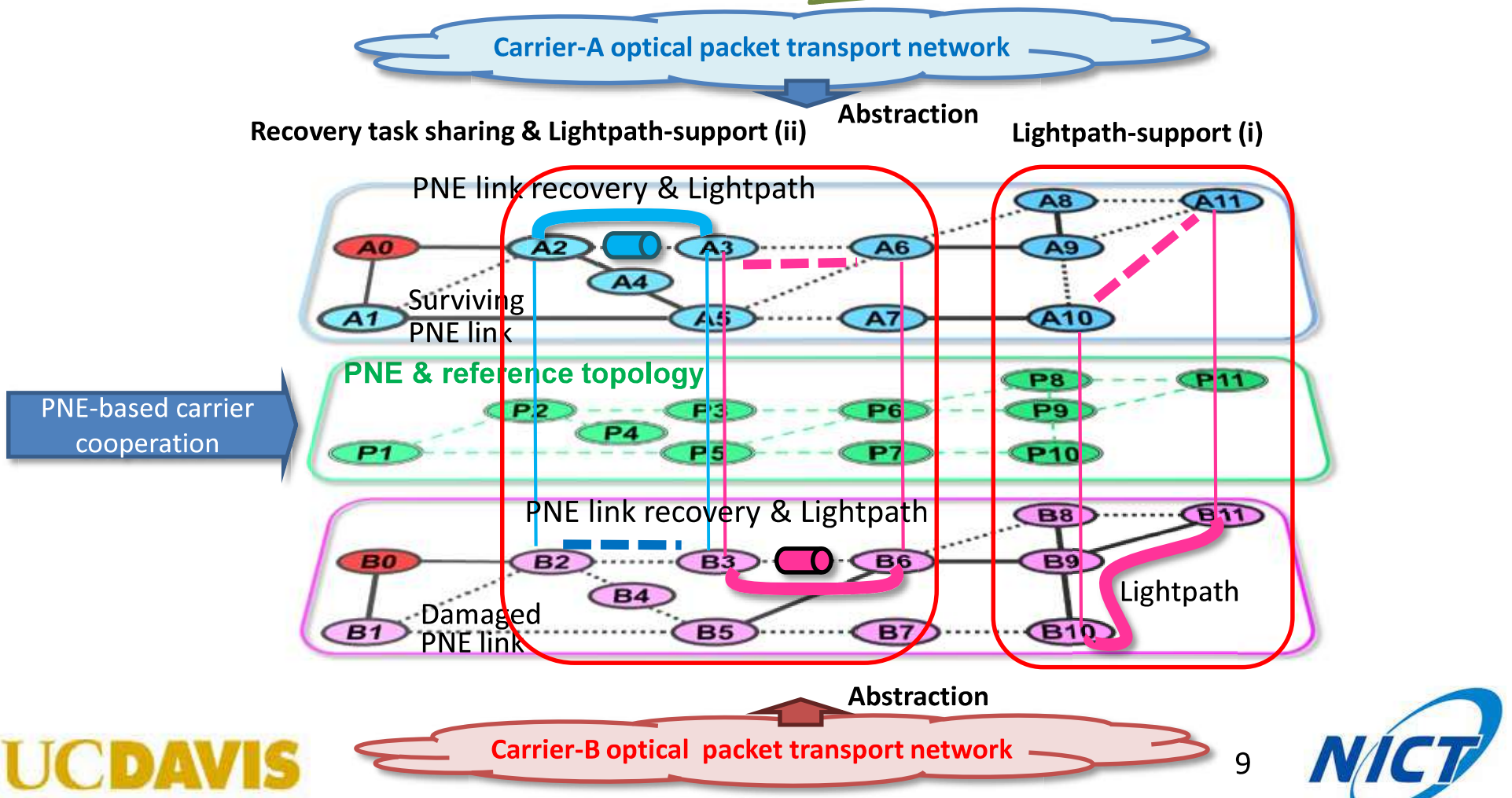
Our interests (Modeling)

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



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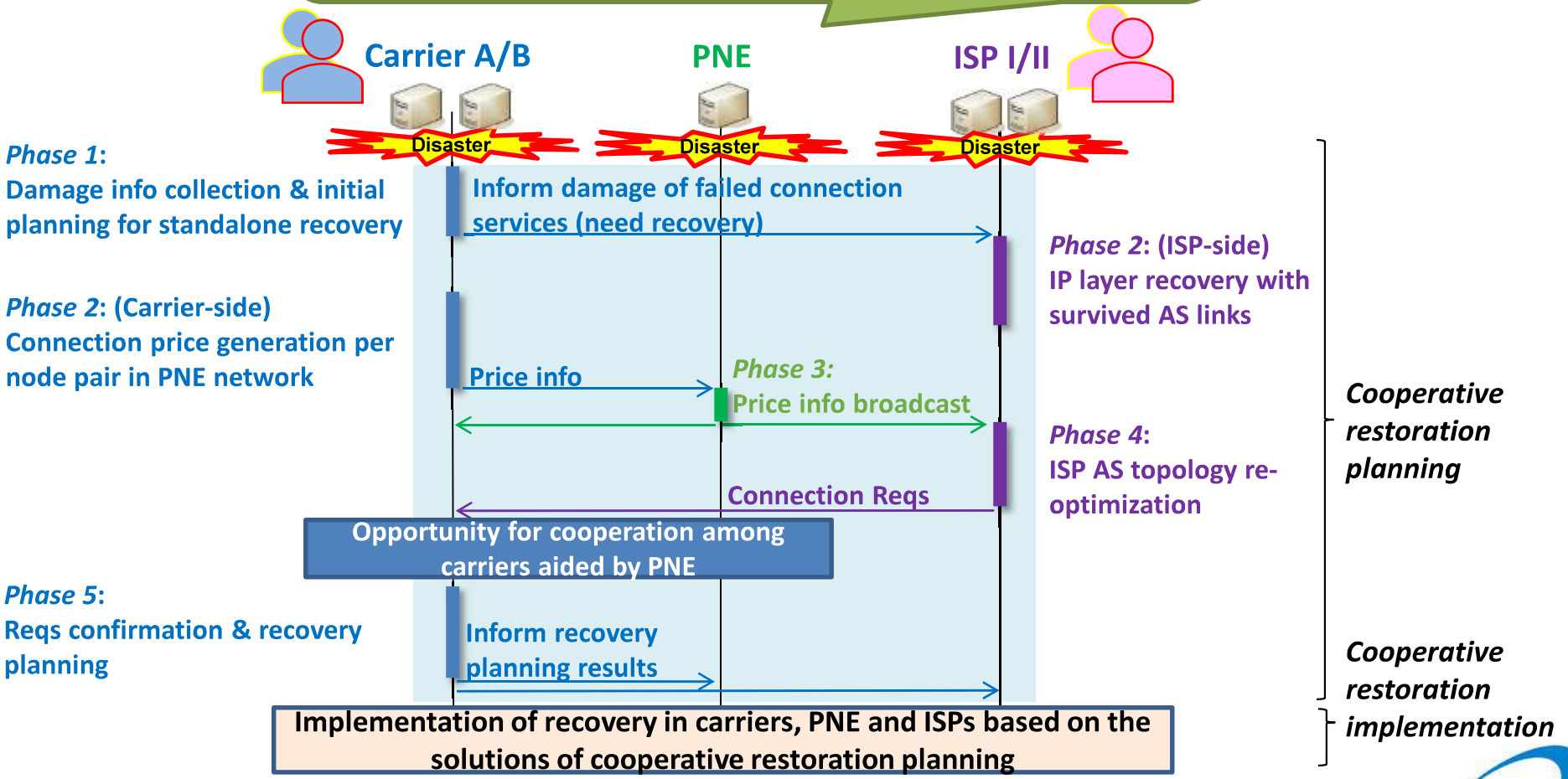

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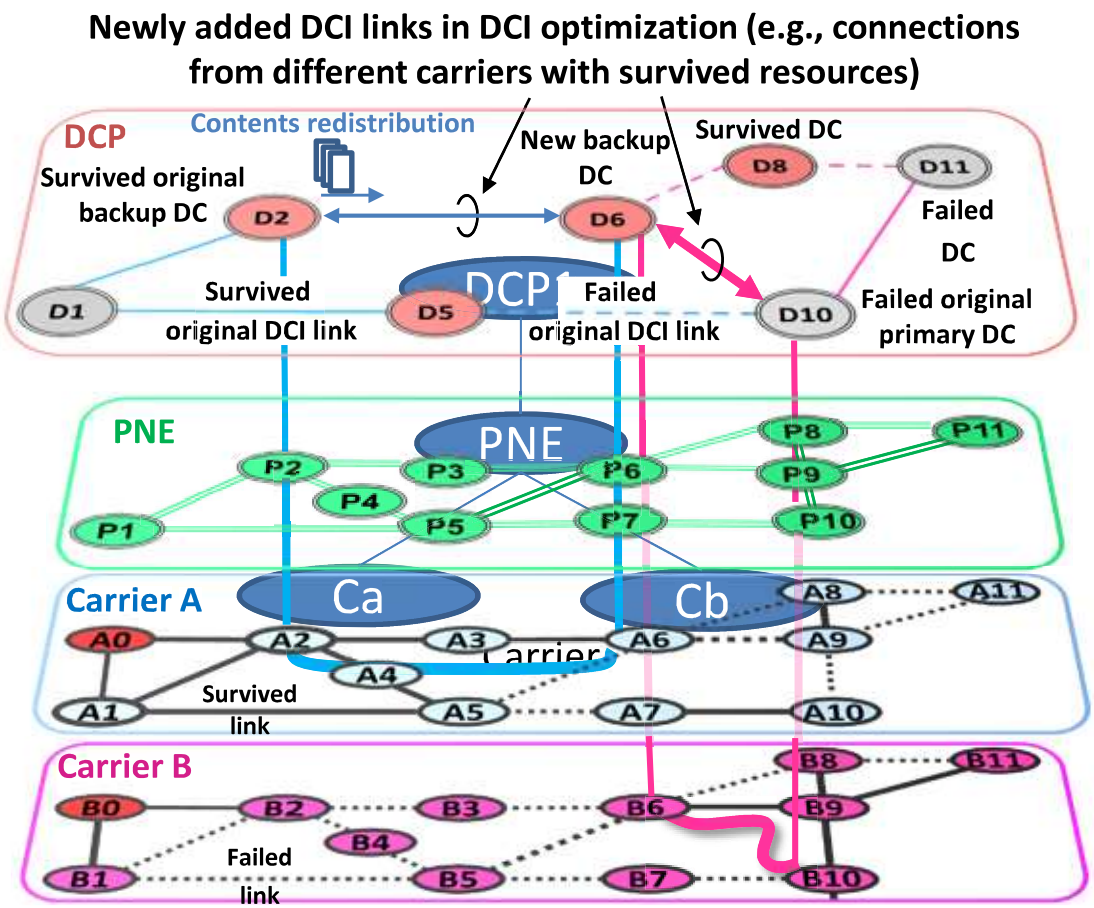

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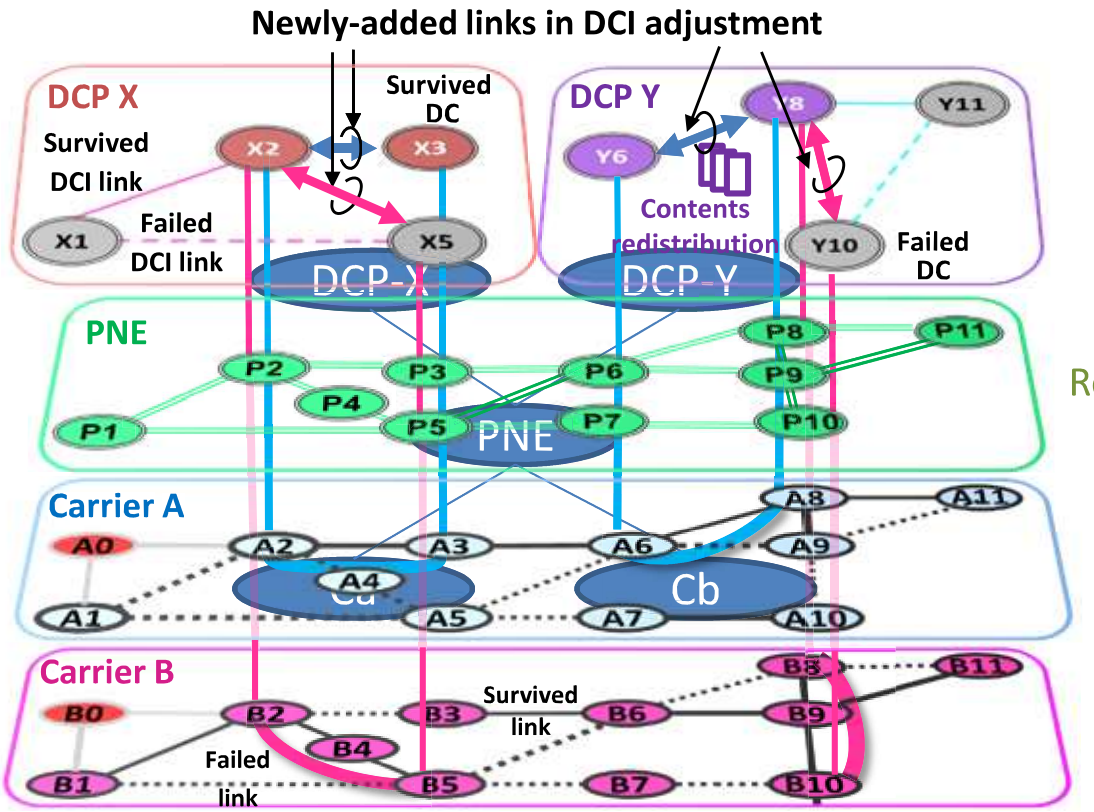

Multiple DCPs compete for resources

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

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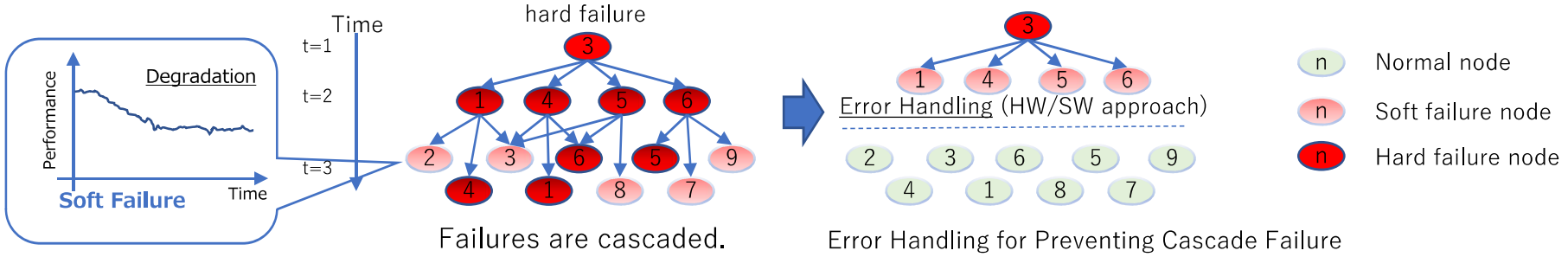

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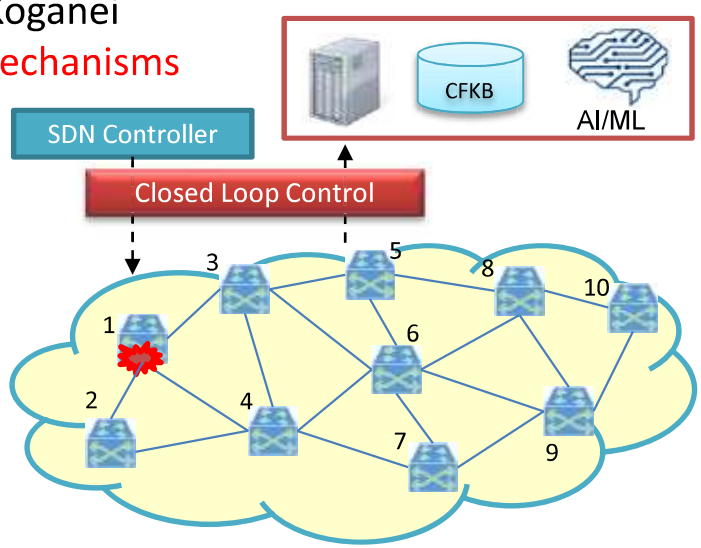

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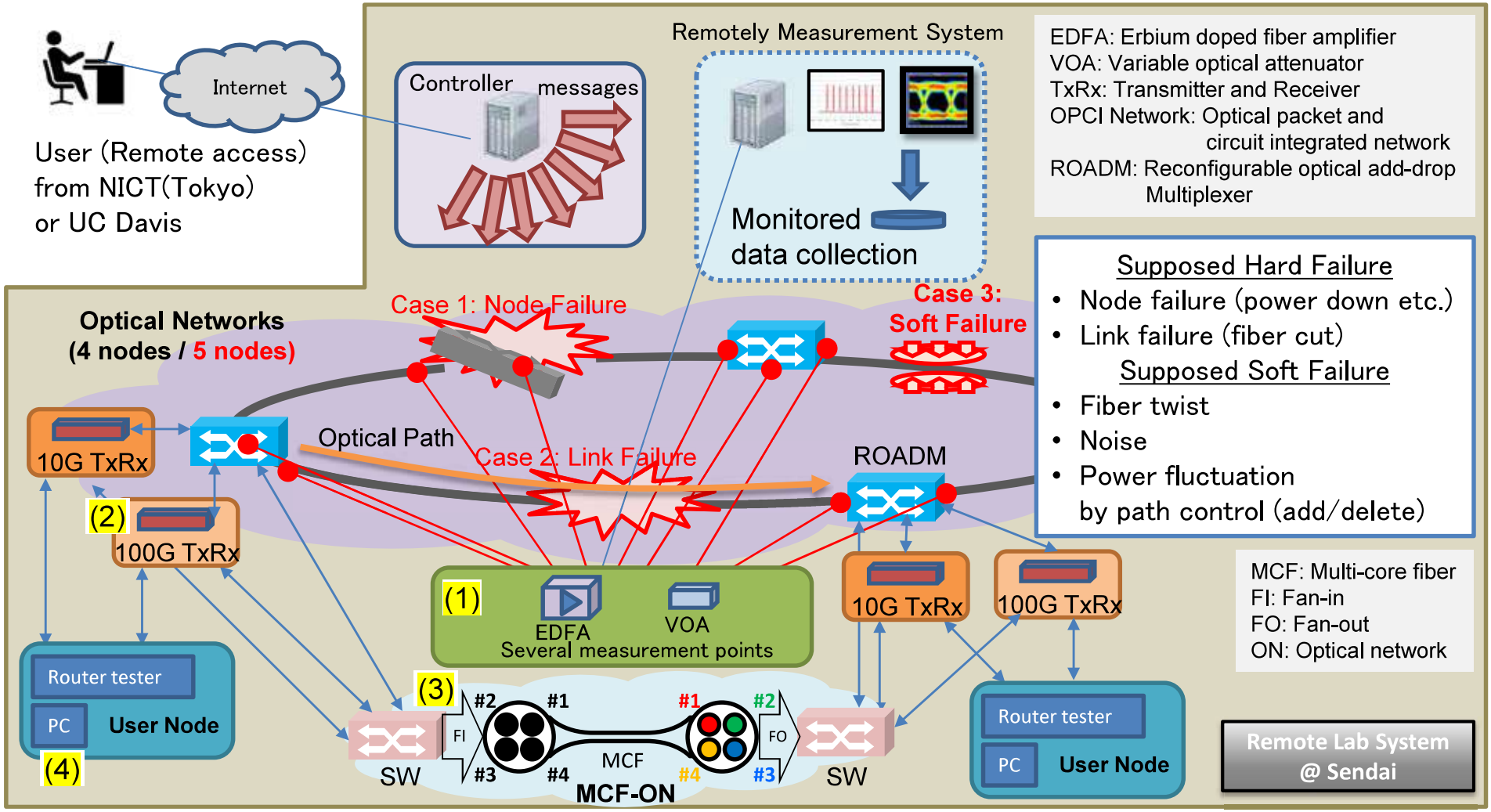
3-2. Cascade Failure Knowledge Base (CFKB) and Modeling

3-3. Error Handling Method in Programmable Optical Networks

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

Sendai Testbed for Advanced Network Functionality



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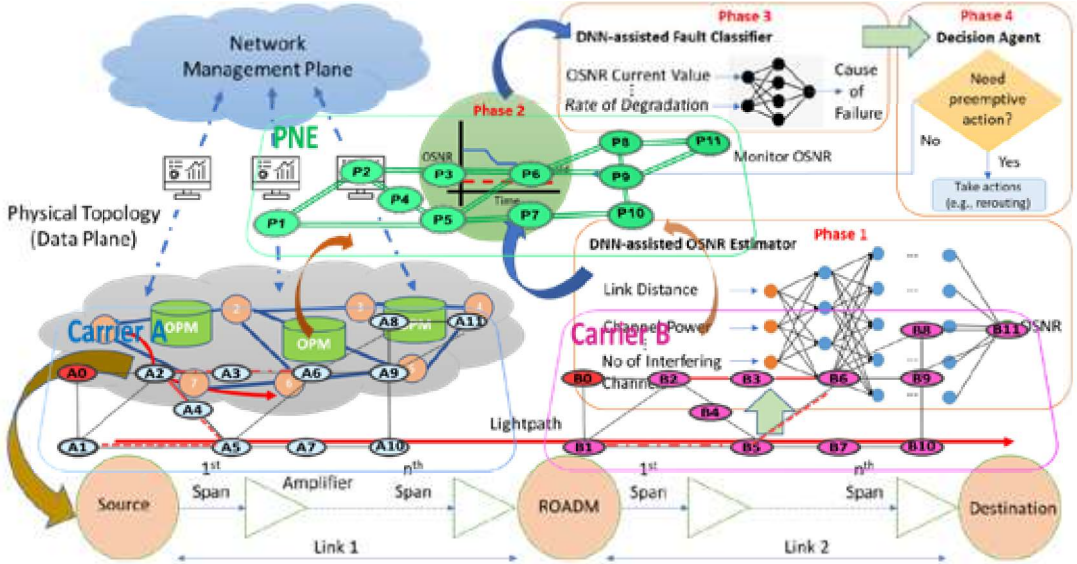

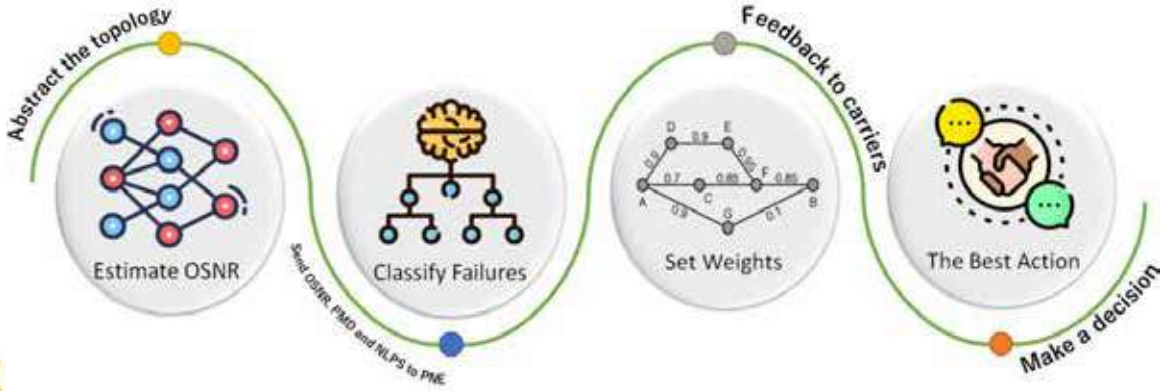

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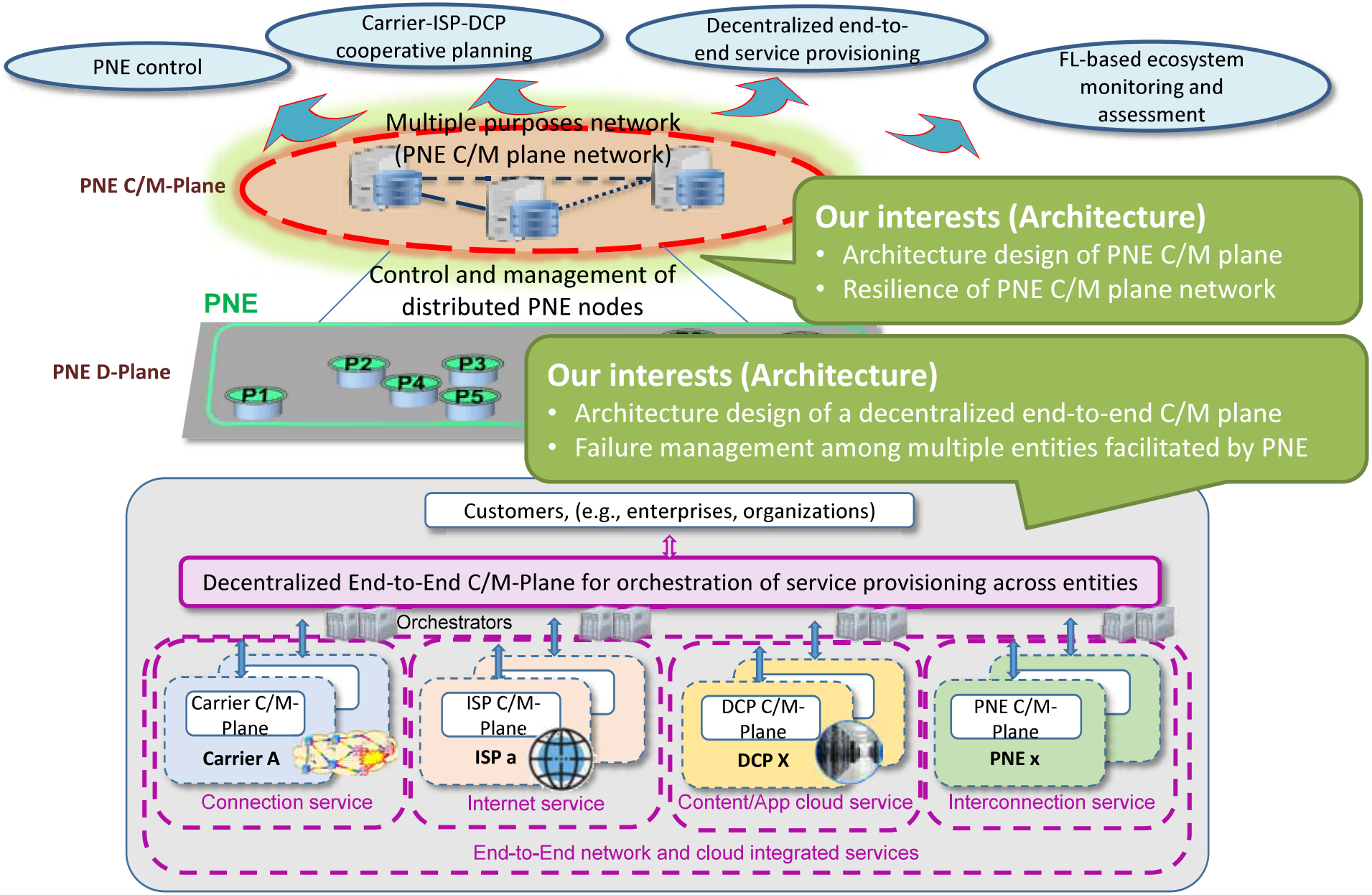

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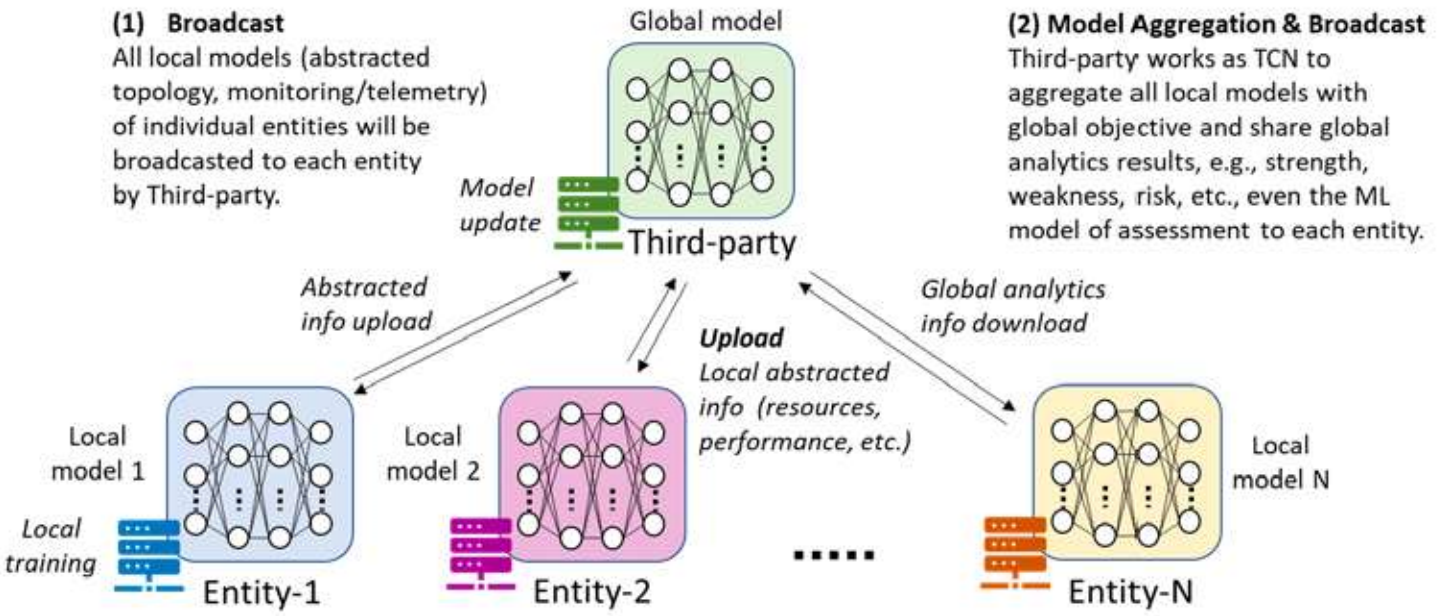

Target: Prepare all the entities for better monitoring/telemetry and cooperation

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

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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

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    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

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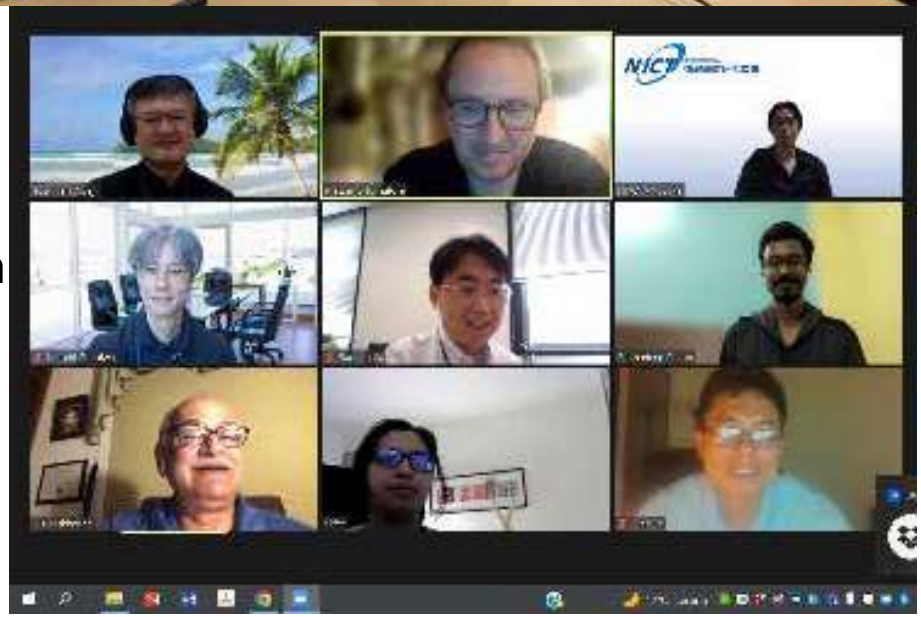


Publications

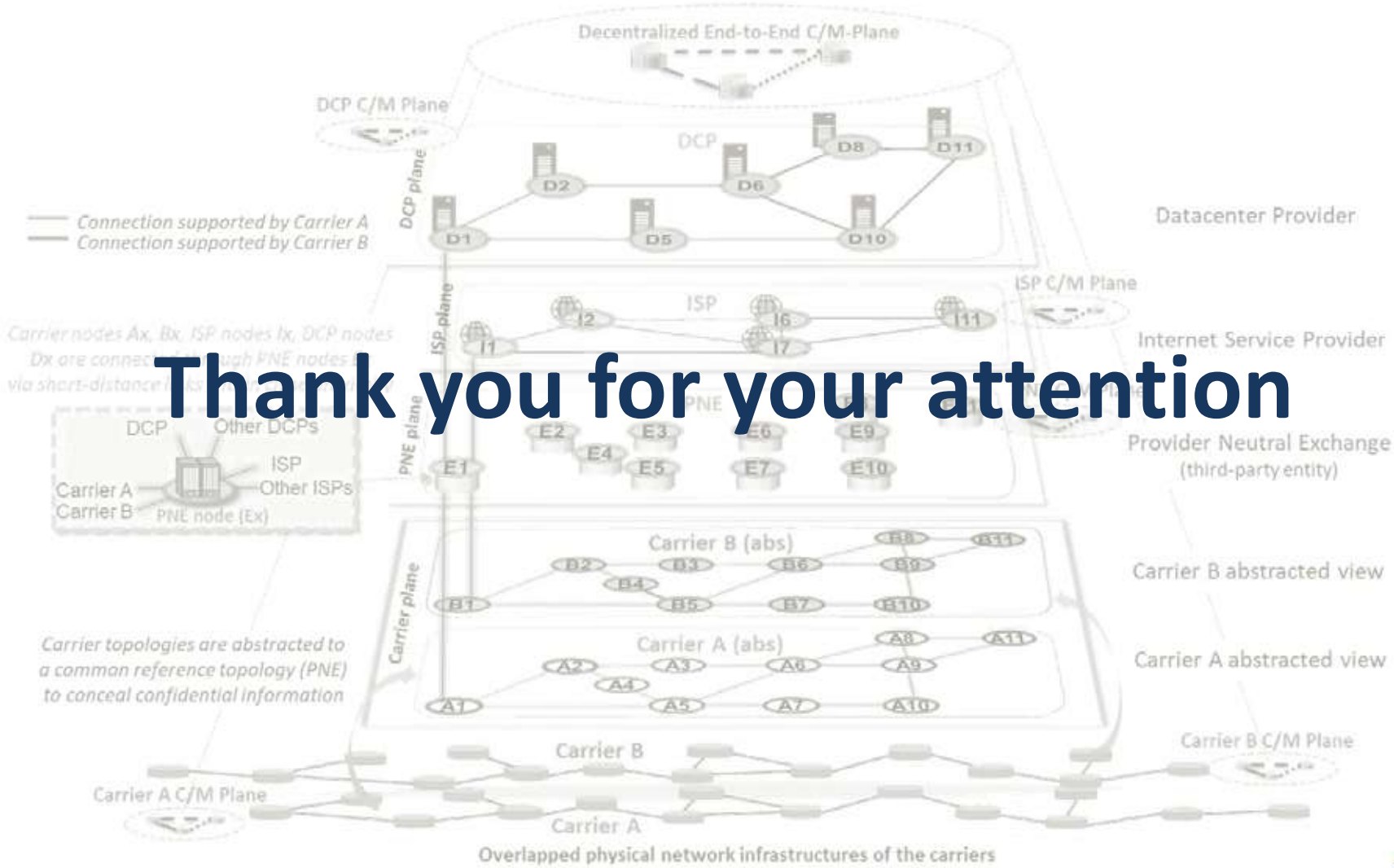
TASK 1

- 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

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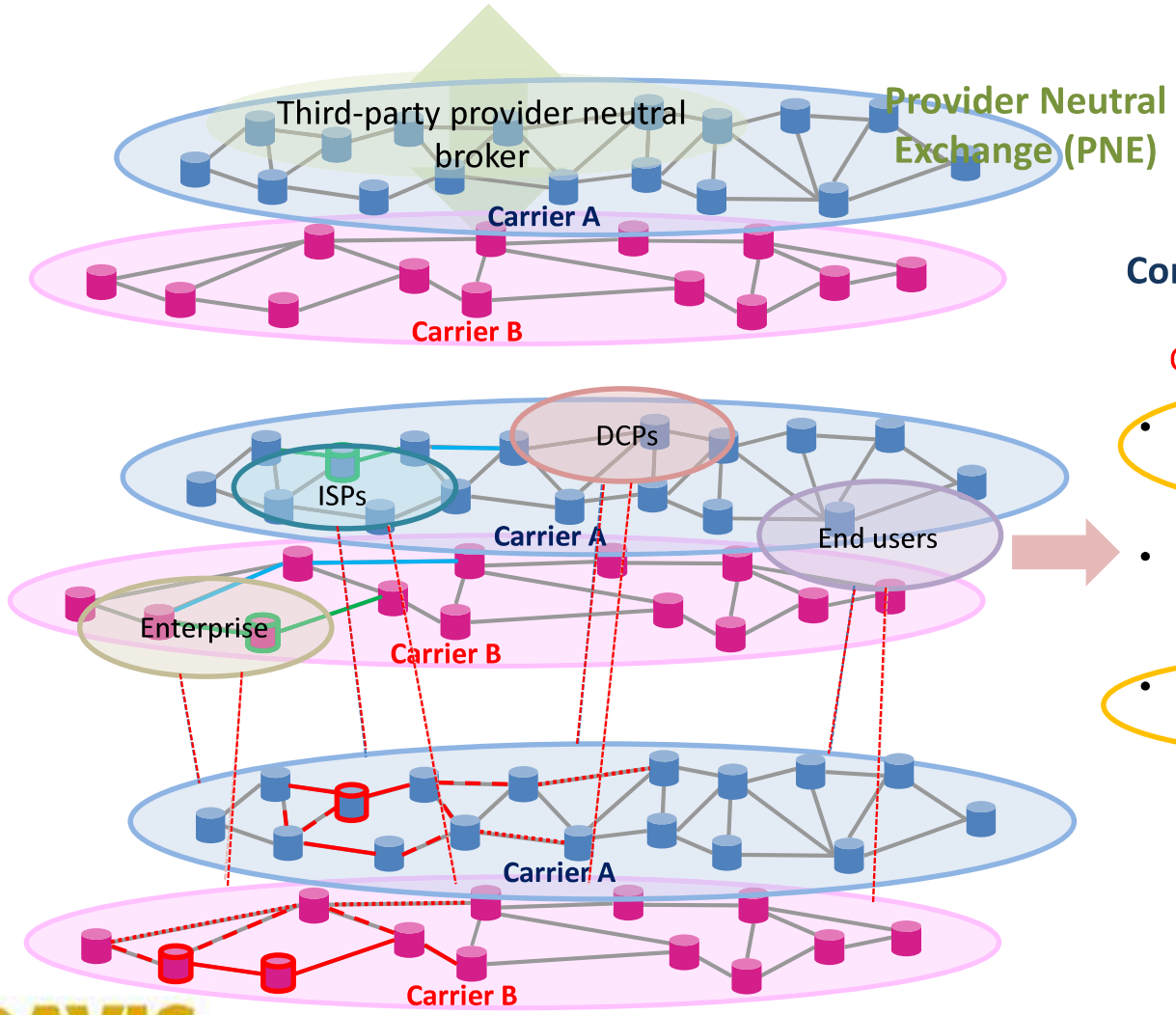

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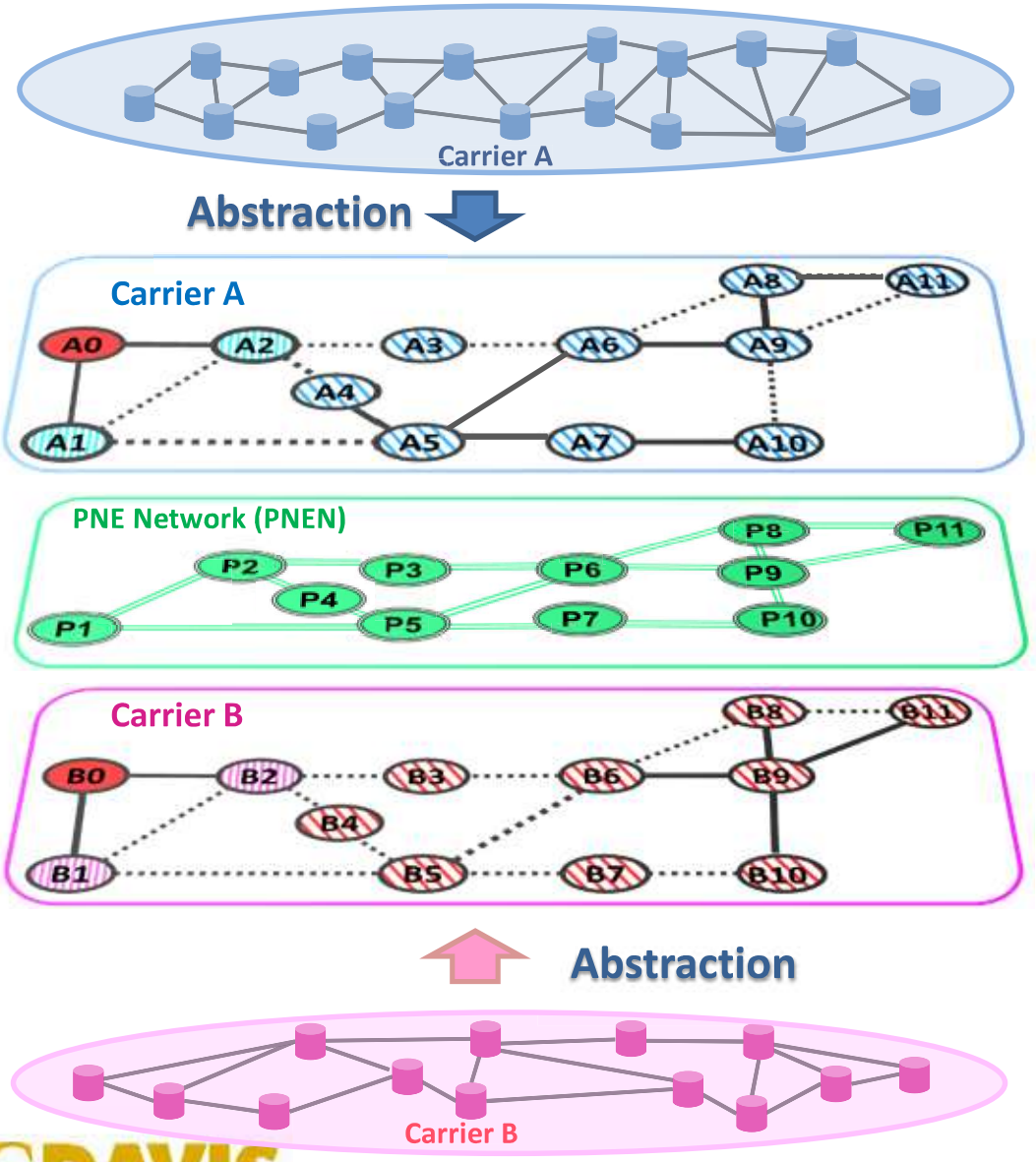

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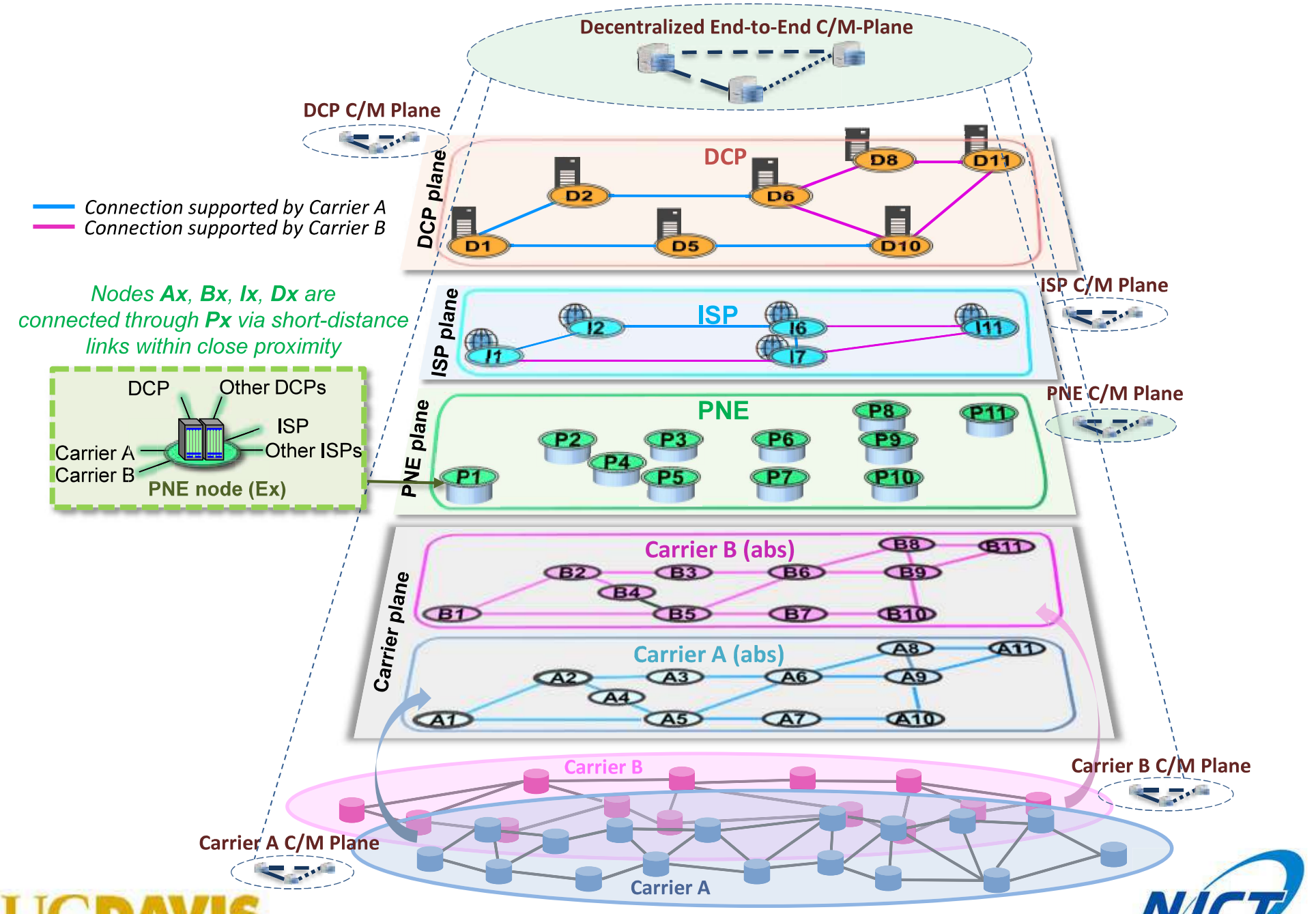

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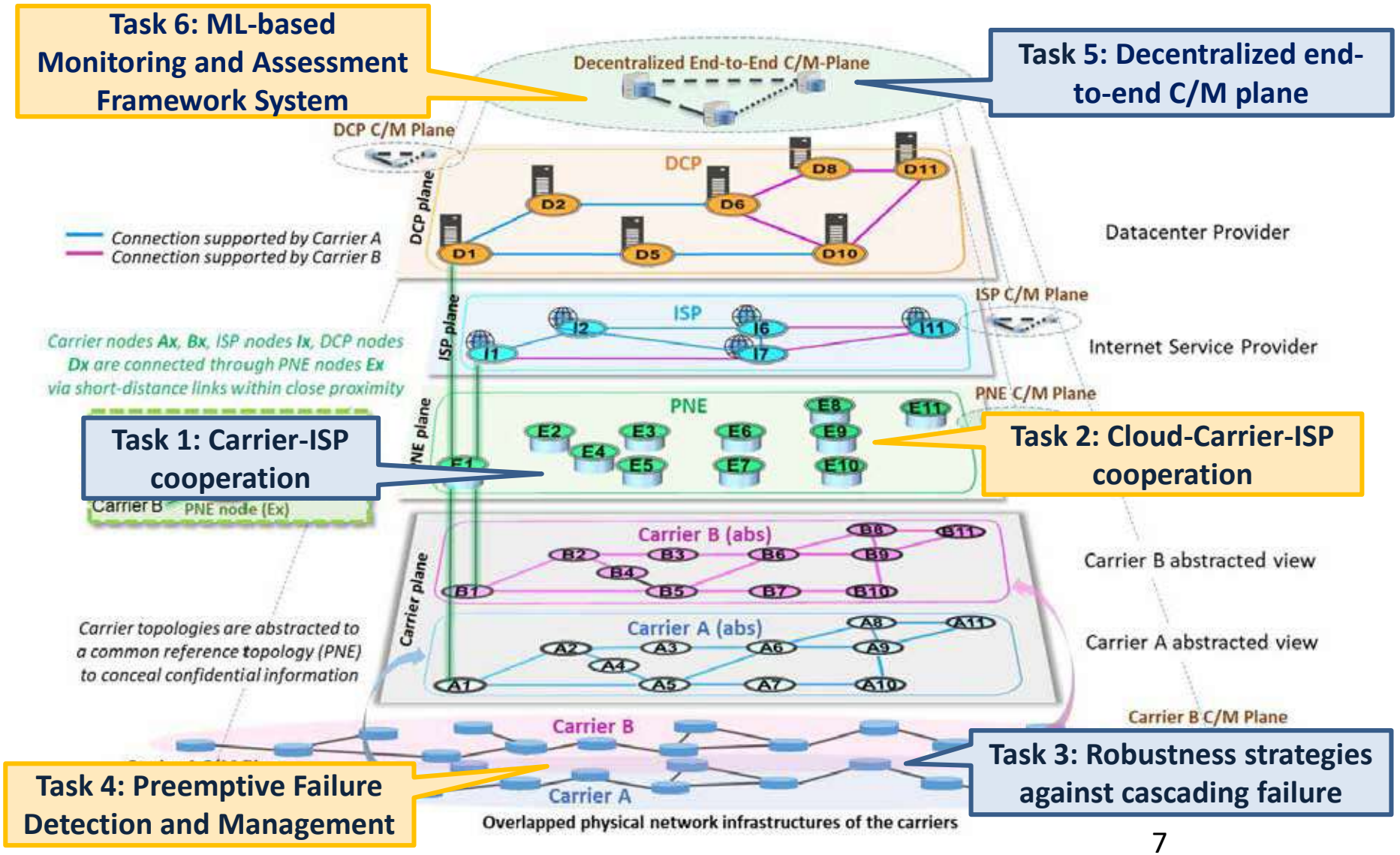

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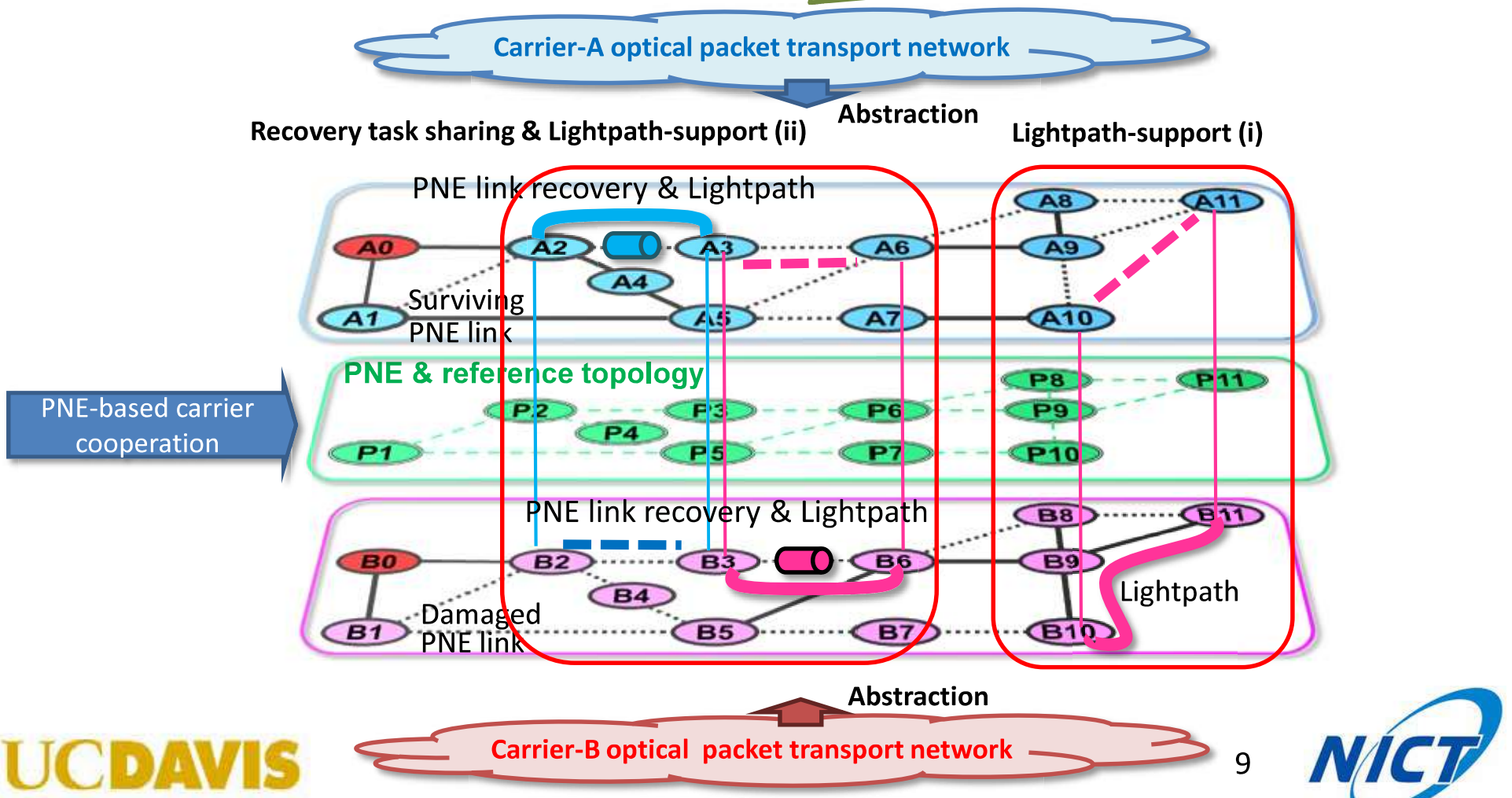

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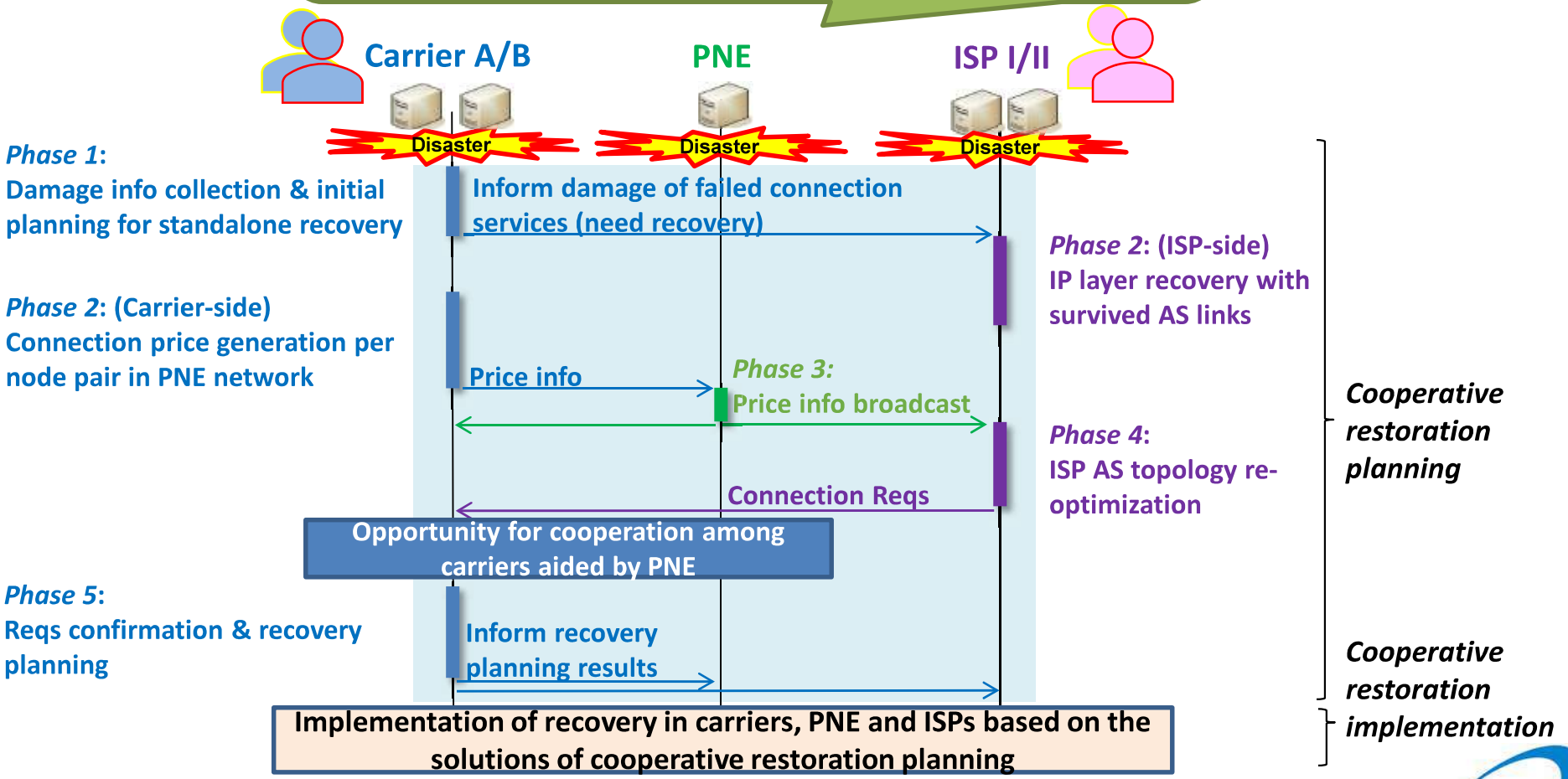

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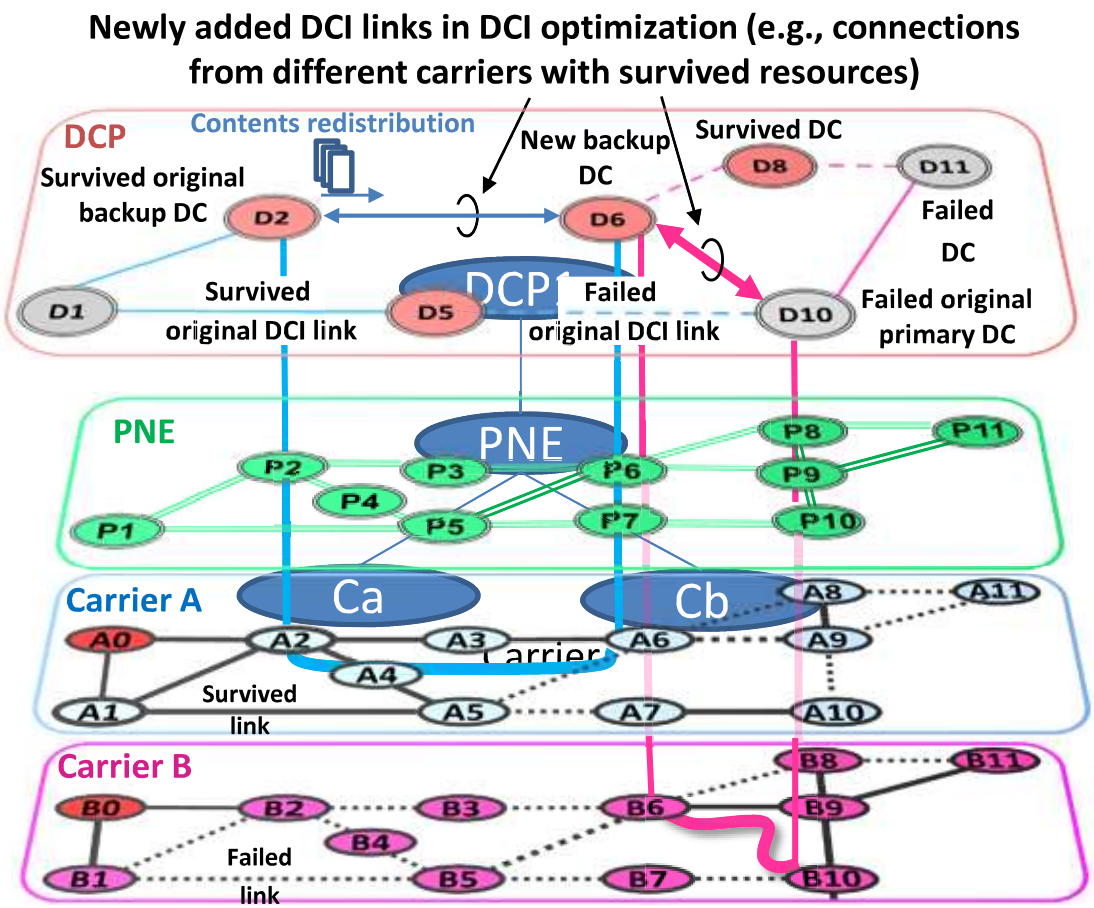

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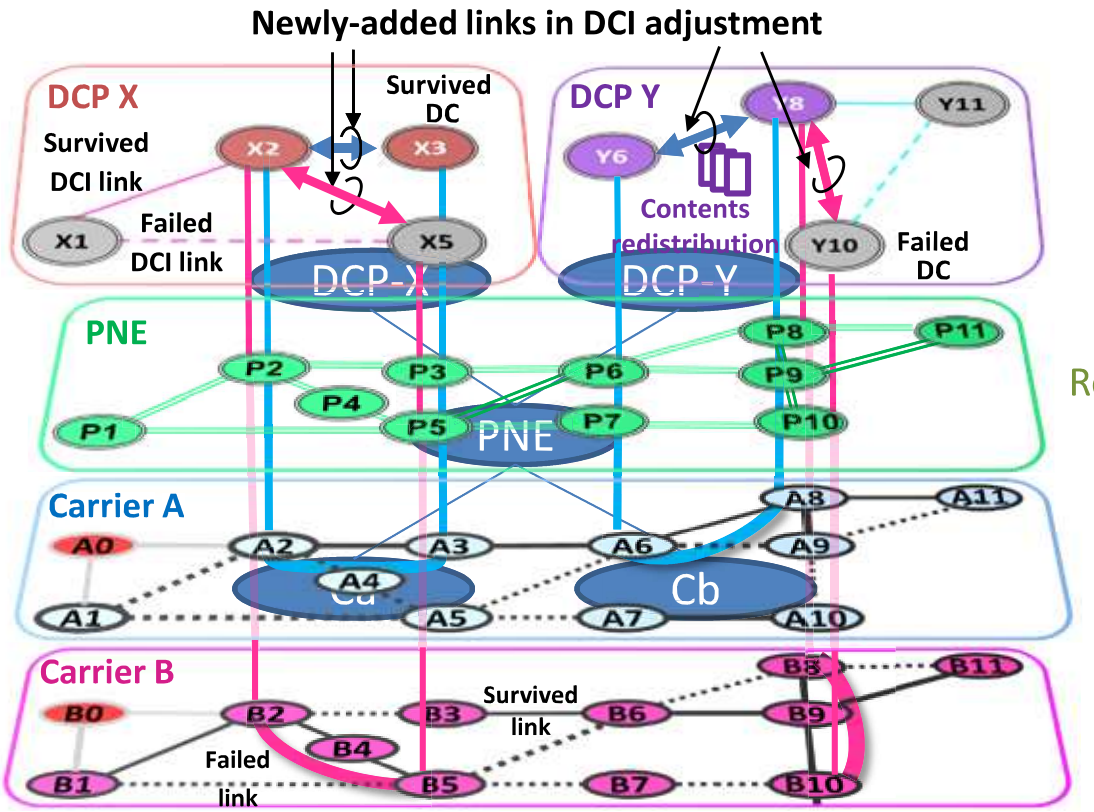

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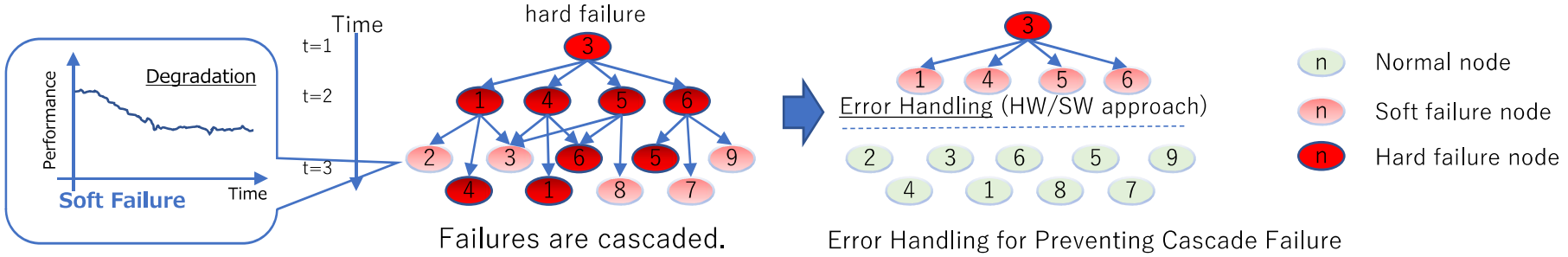

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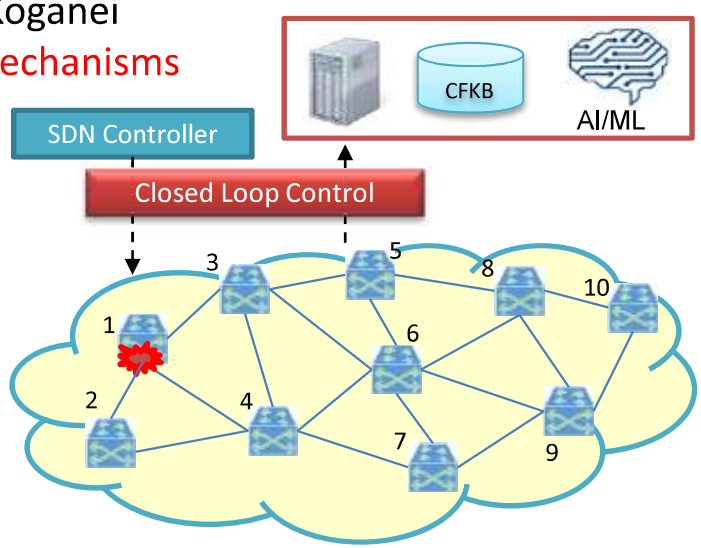

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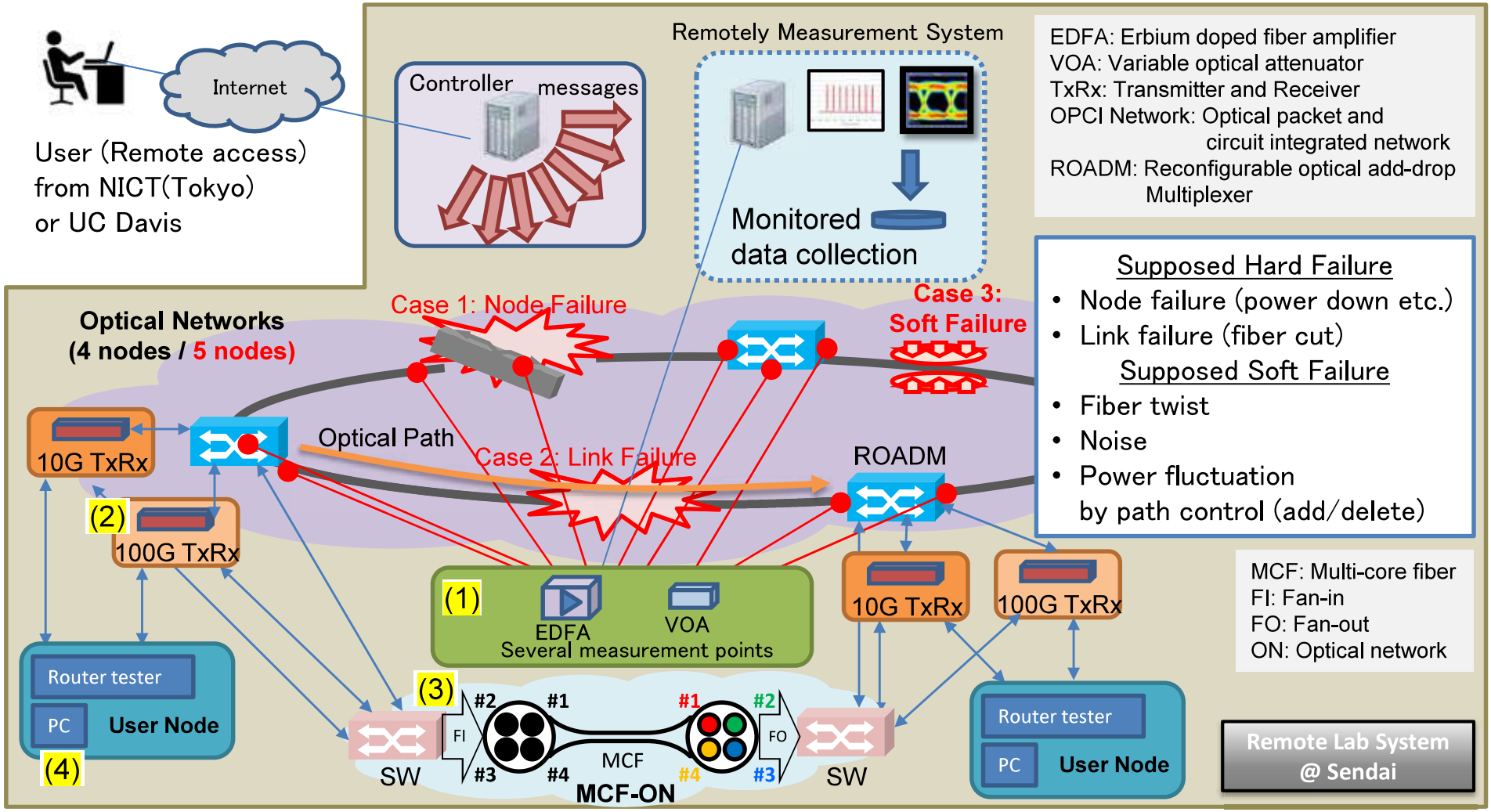

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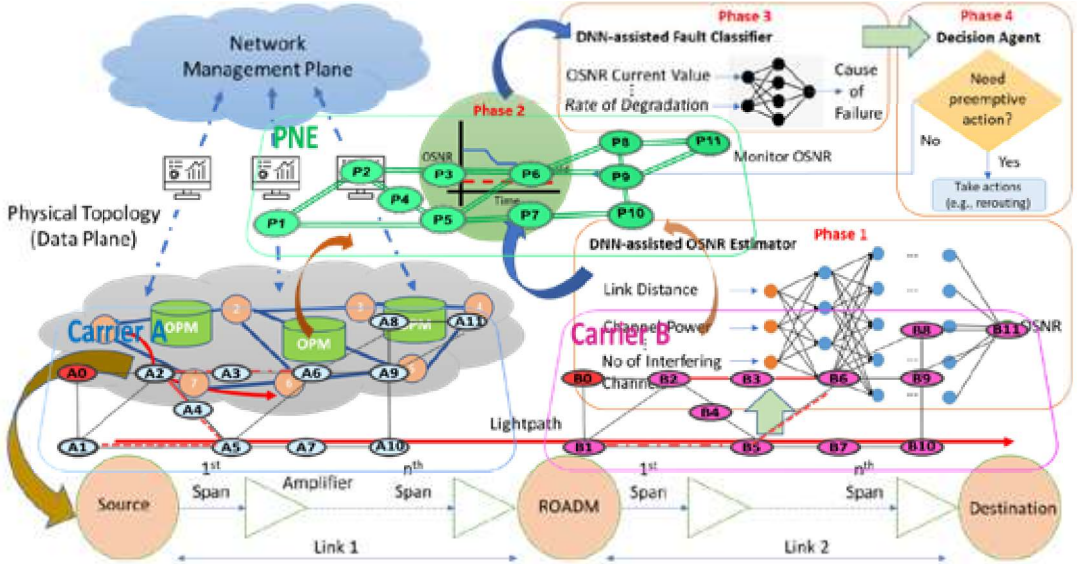

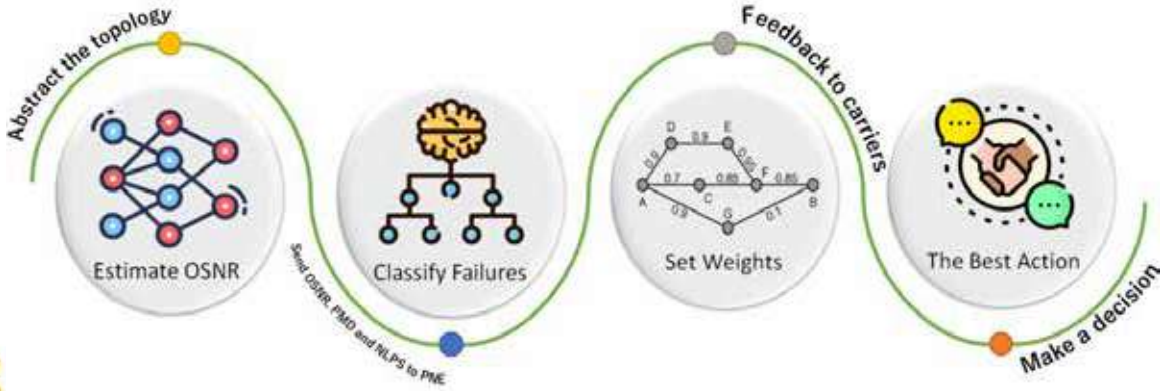

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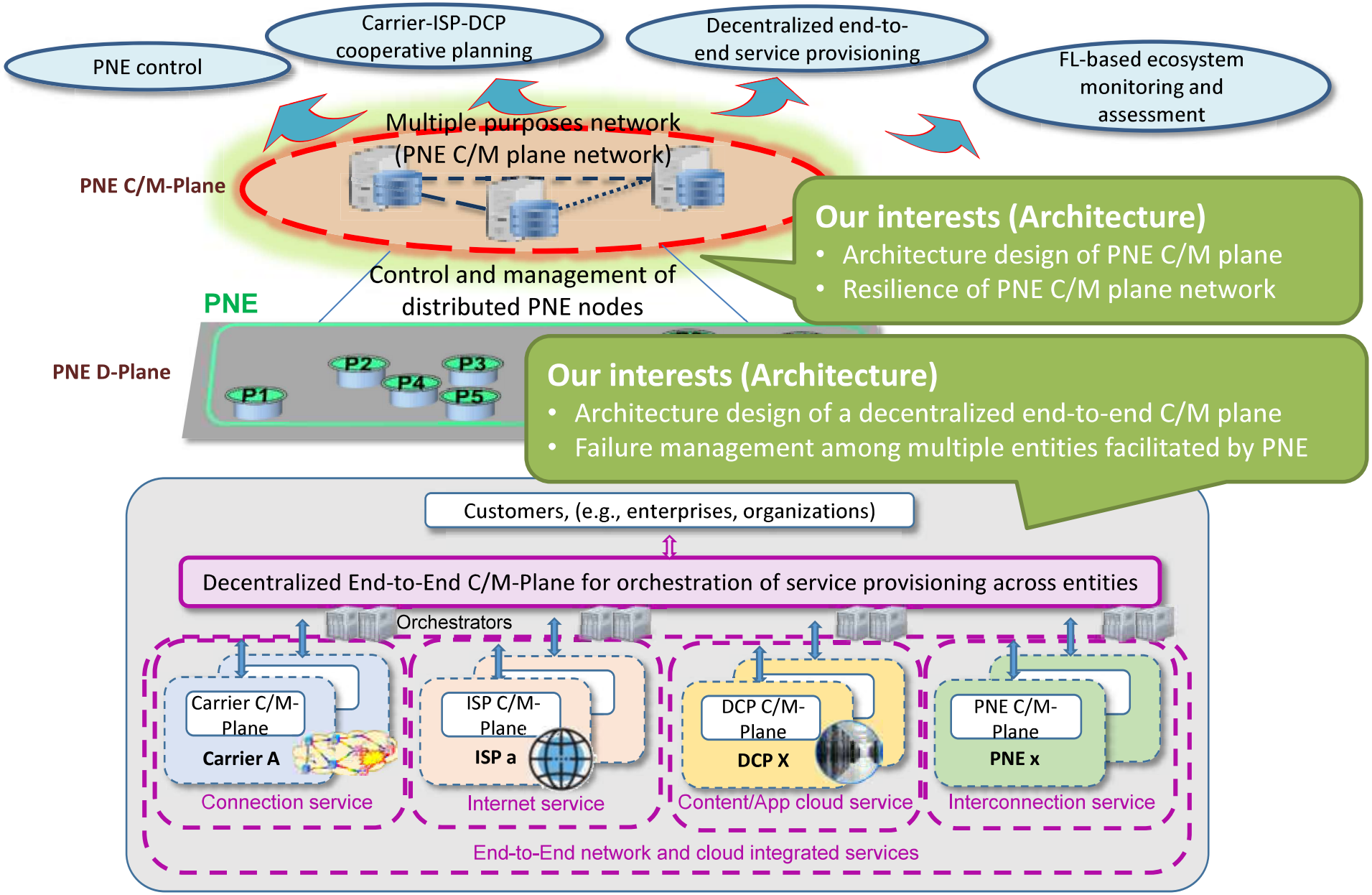

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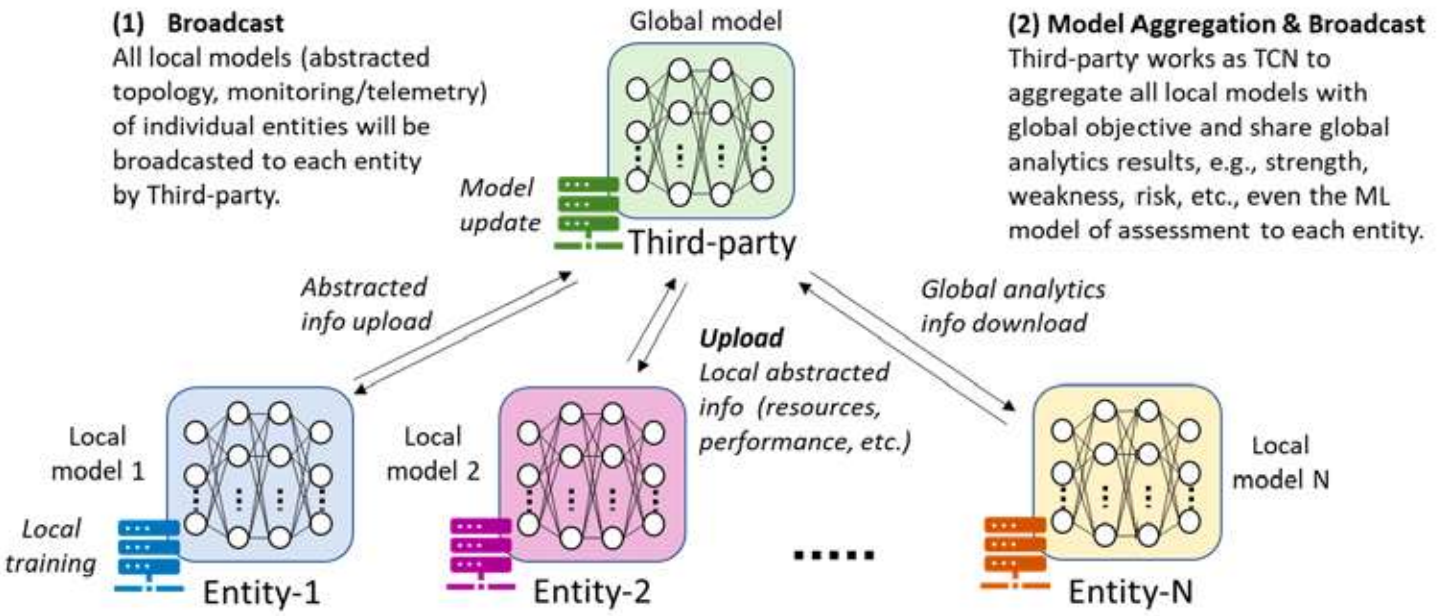

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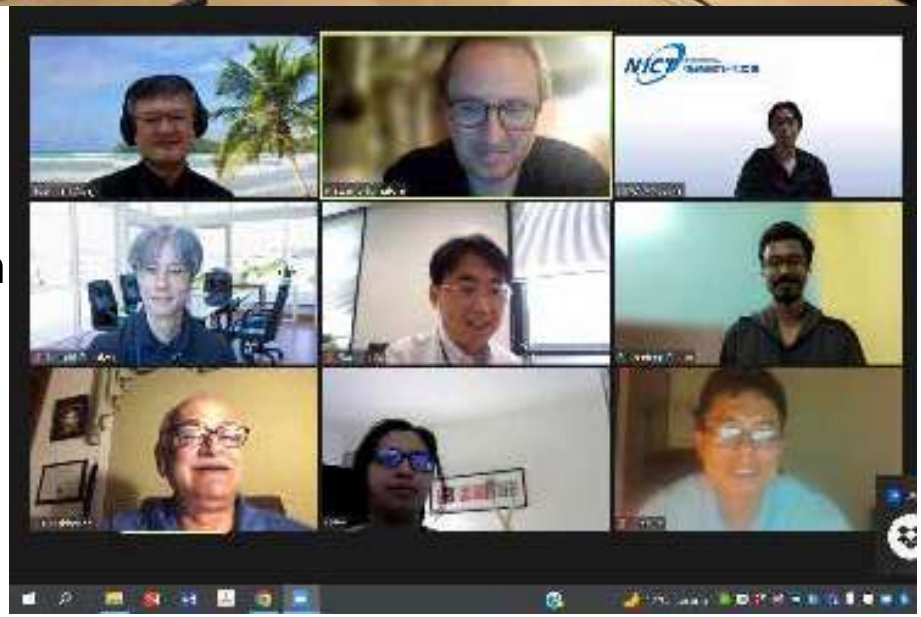

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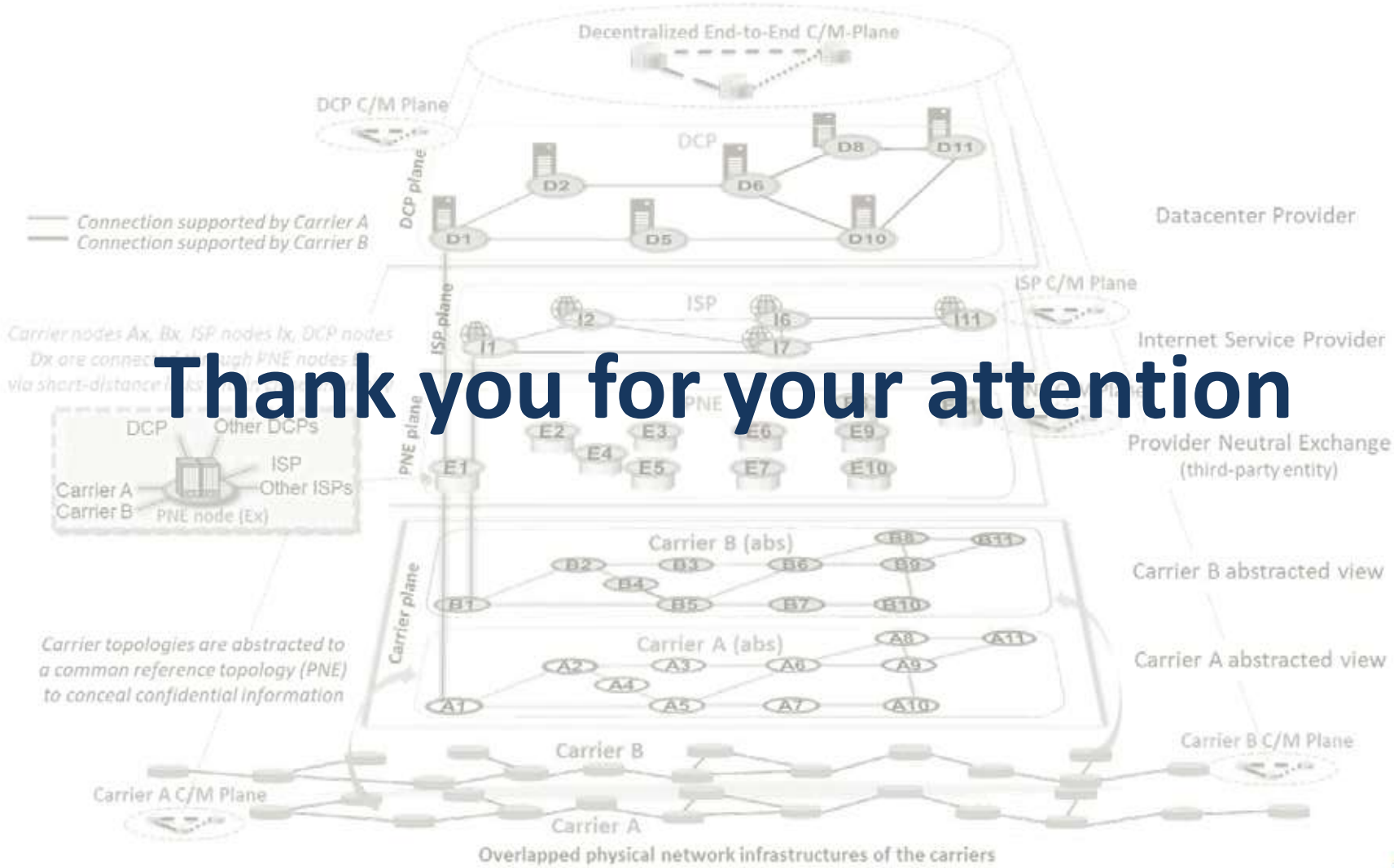
- ❑ 3 invited talks (ICETC 2022, ICM 2022, CPS-SNAP 2023)



Thank you for your attention

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

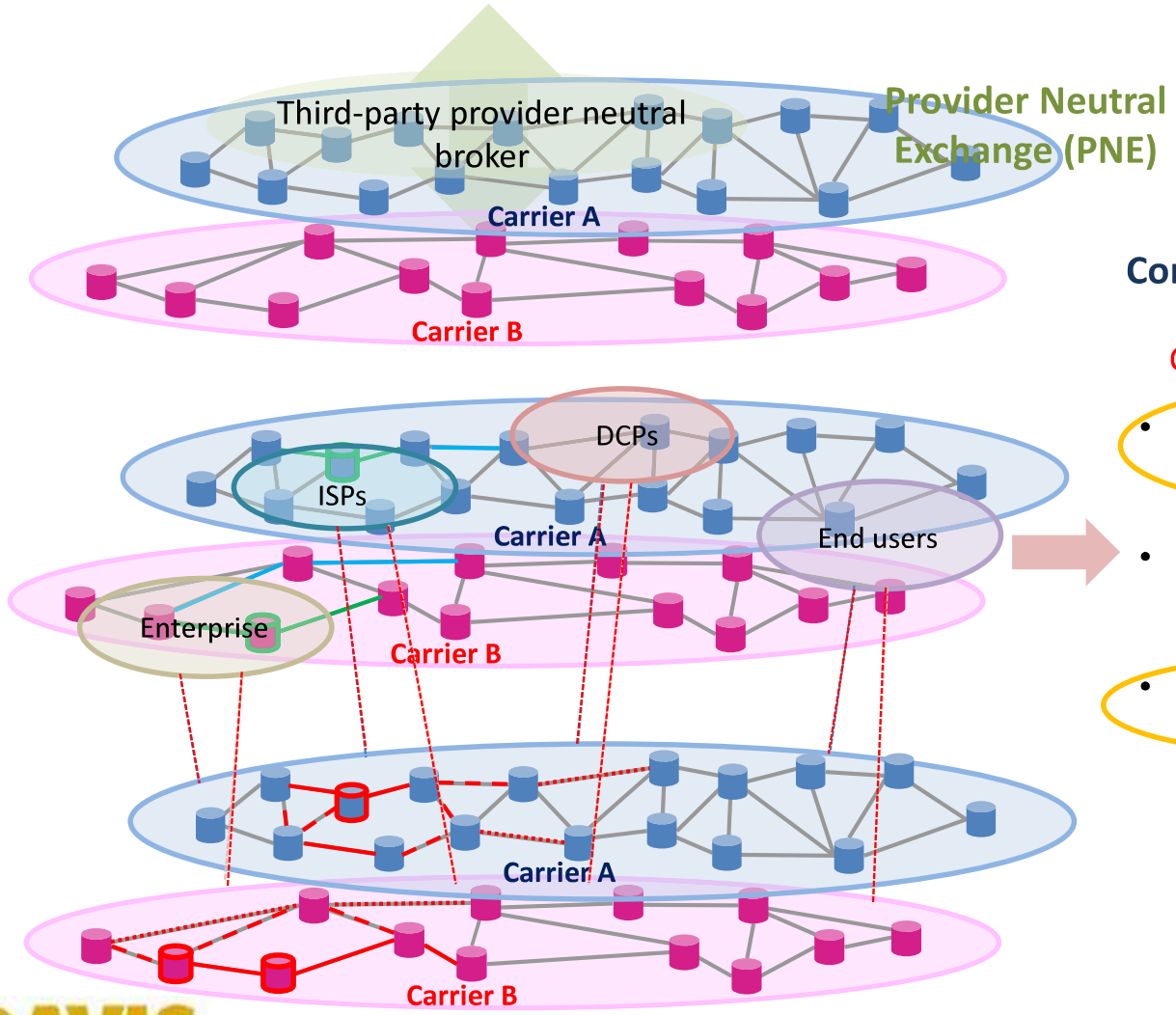
Introduction

- 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!

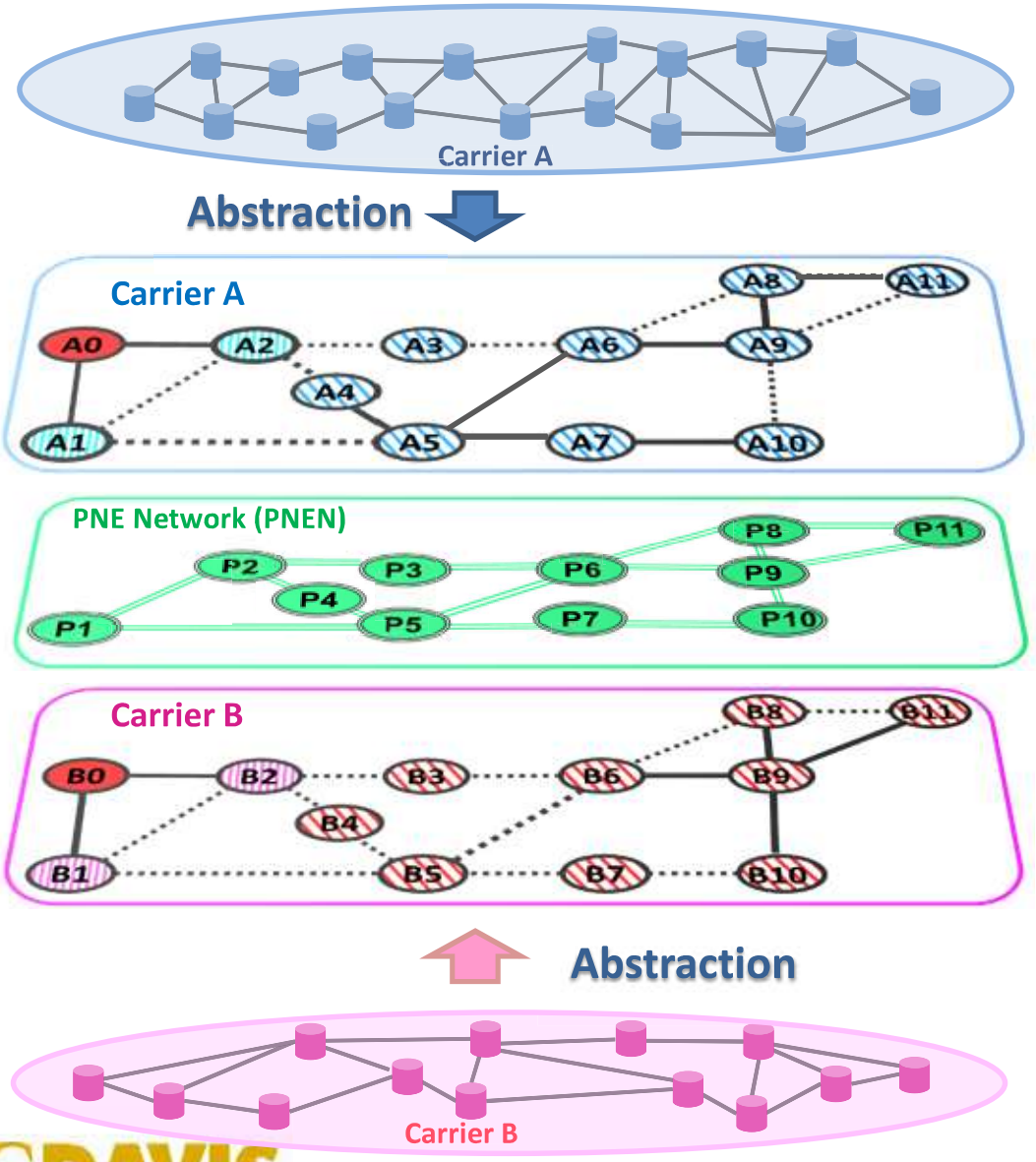
Confidential Information

Cooperation possible?

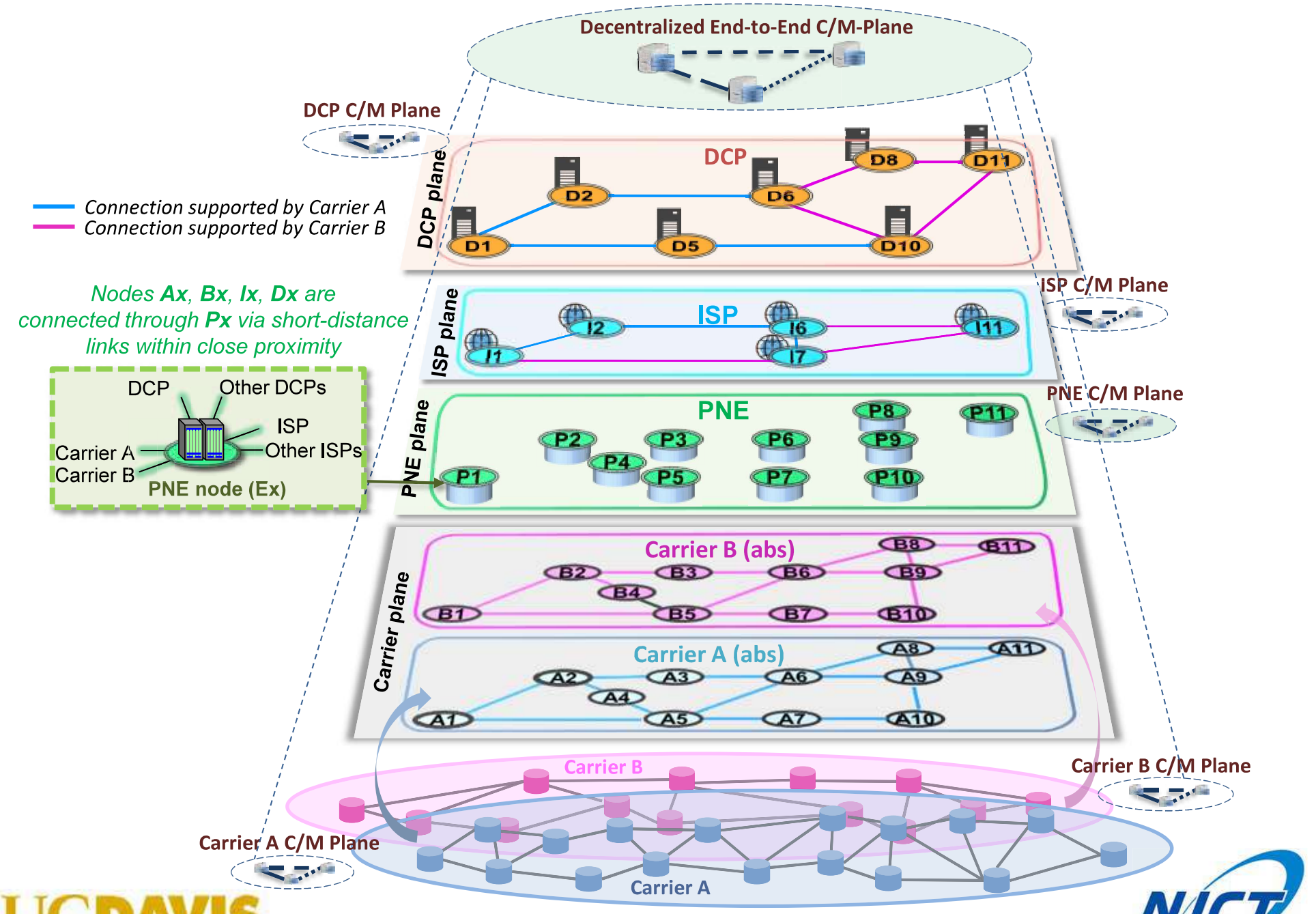
- Un-coordinated recovery planning
- Delayed service restoration
- Inefficient resource utilization

Resource sharing possible?

Multi-Entity Ecosystem

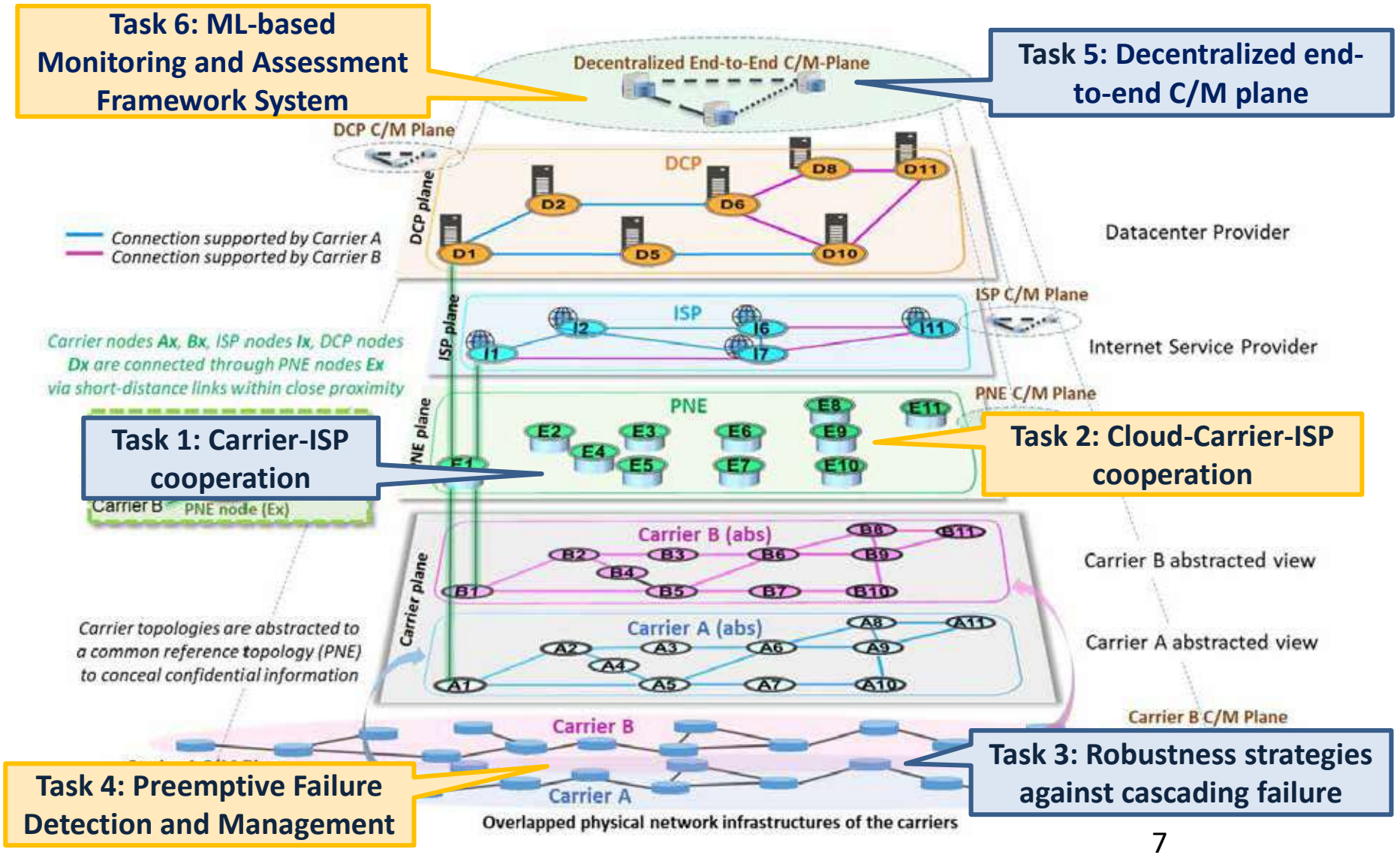


Abstraction is key



Overlapped physical network infrastructures of the carriers

Project Overview



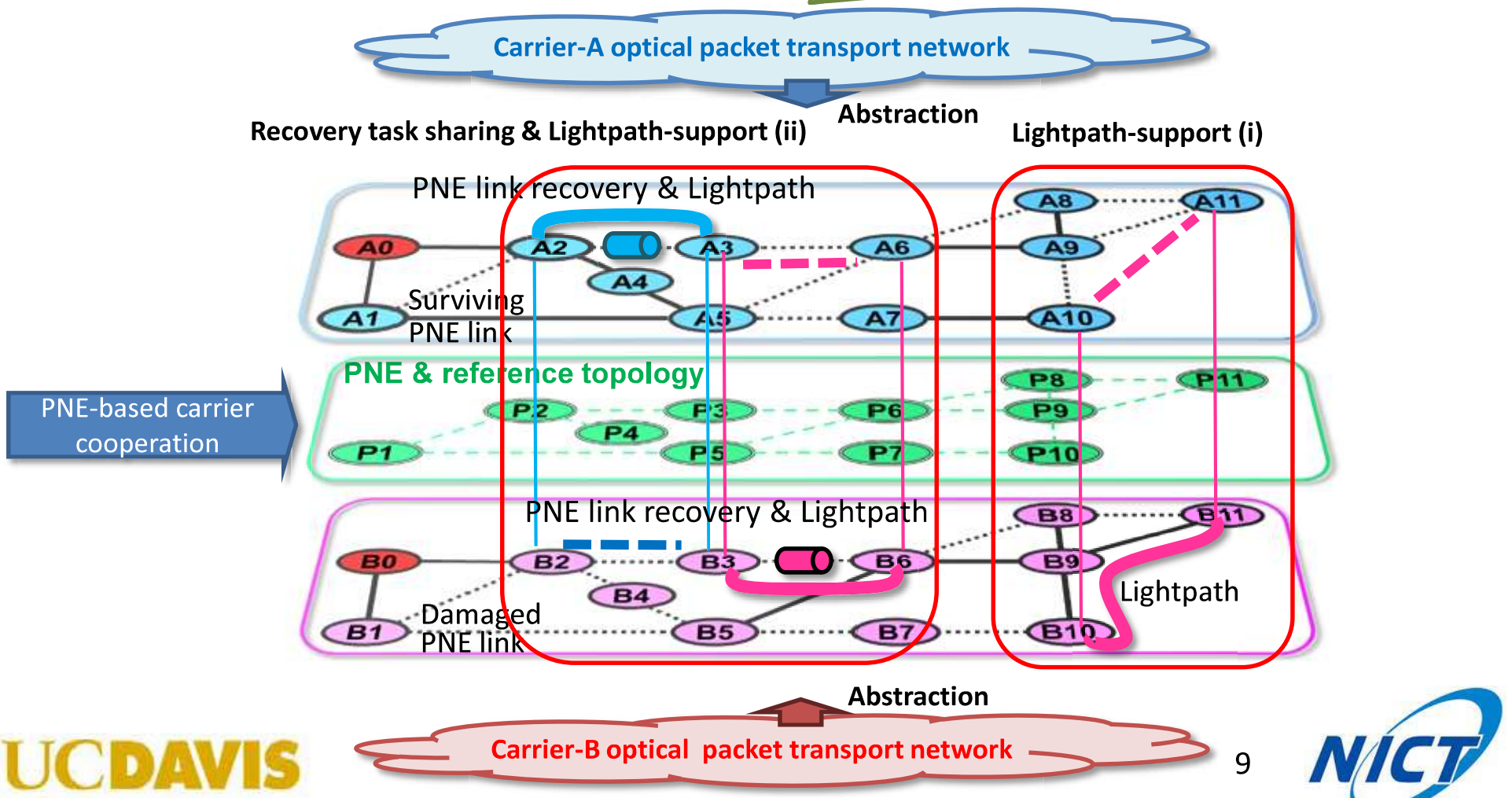
Overall Topics

Cloud-Carrier Cooperation			
Phase	Modeling phase		Implementation phase
Theme	Planning Cooperation framework	Preparedness Failure management	Implementation 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 Carrier-ISP cooperation	Task 3 Robustness strategies against cascading failure	Task 5 Decentralized end-to-end C/M plane
UC Davis	Task 2 Cloud-Carrier-ISP cooperation	Task 4 Preemptive Failure Detection and Management	Task 6 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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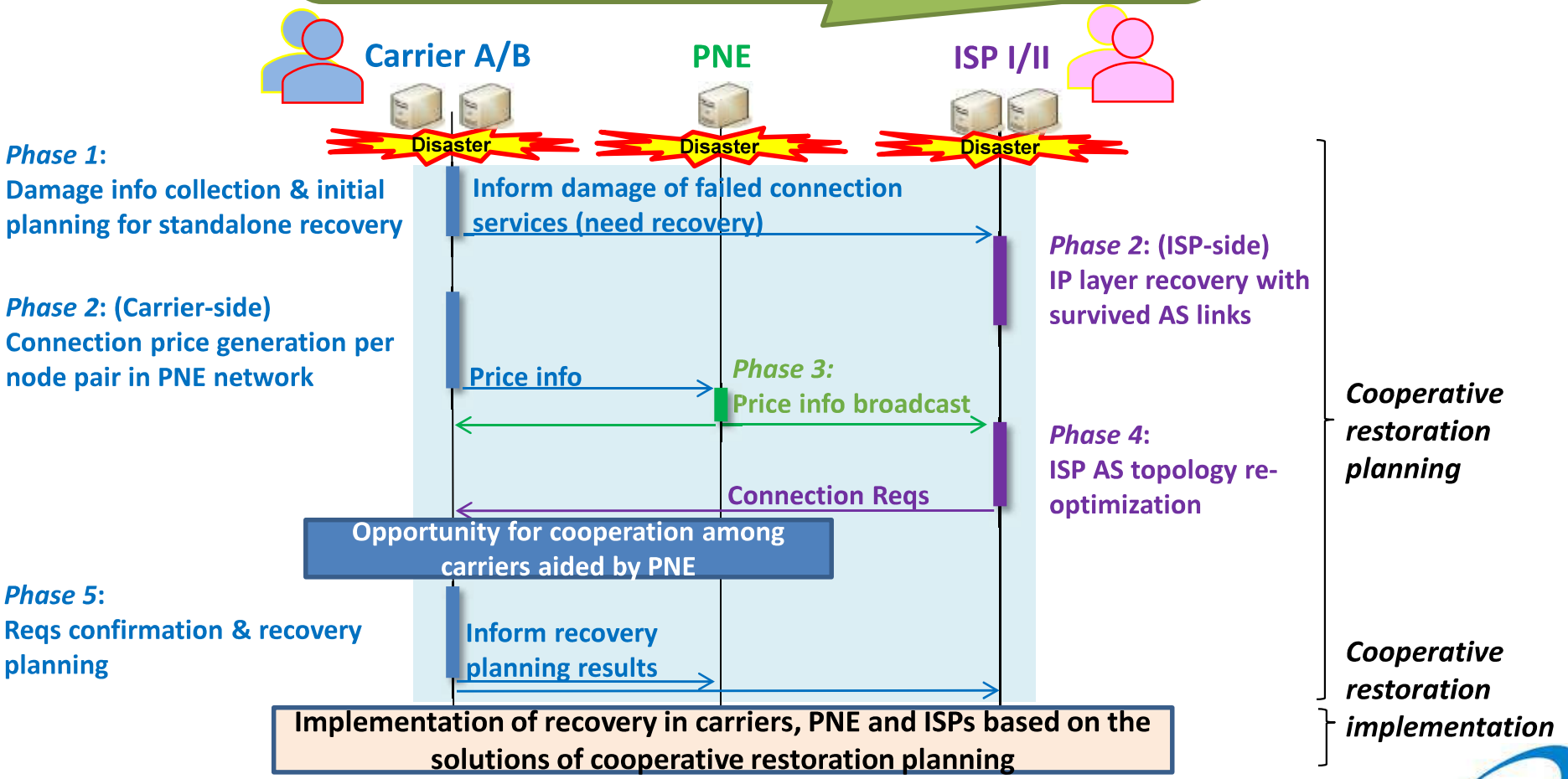
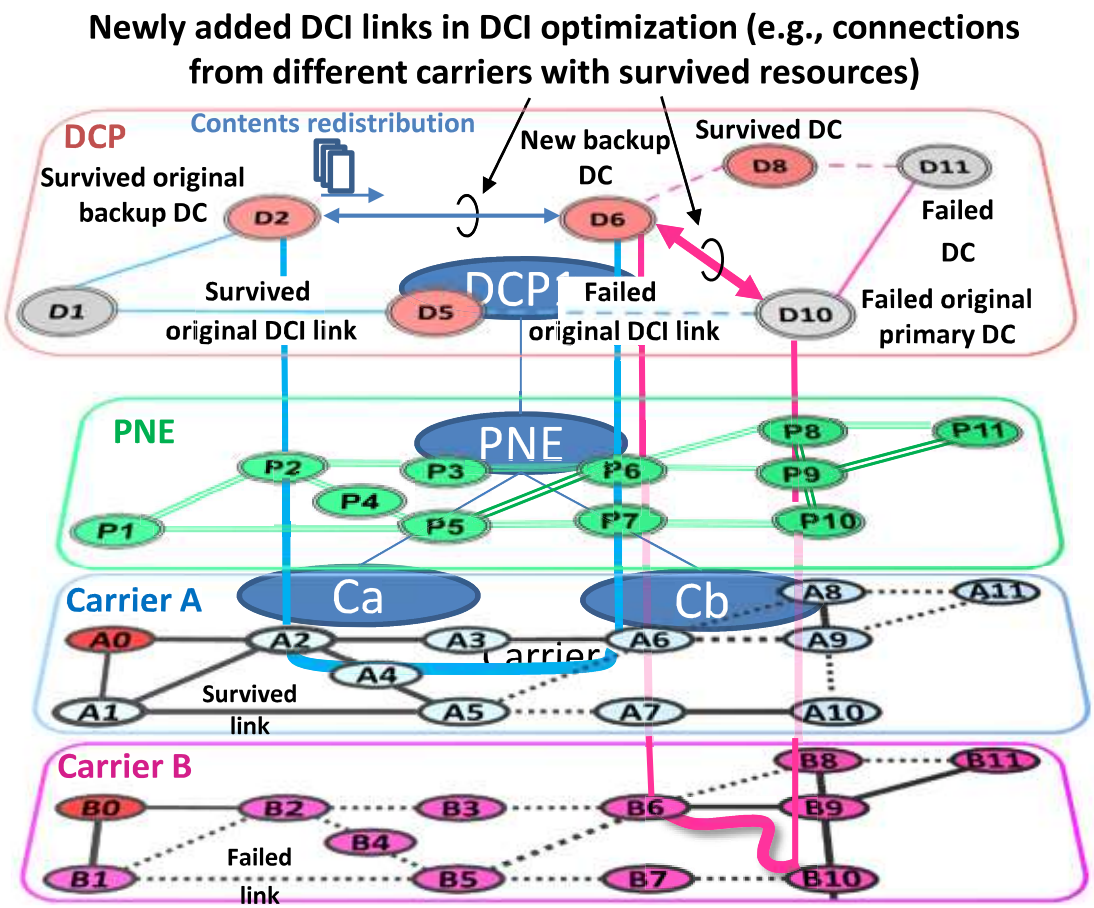
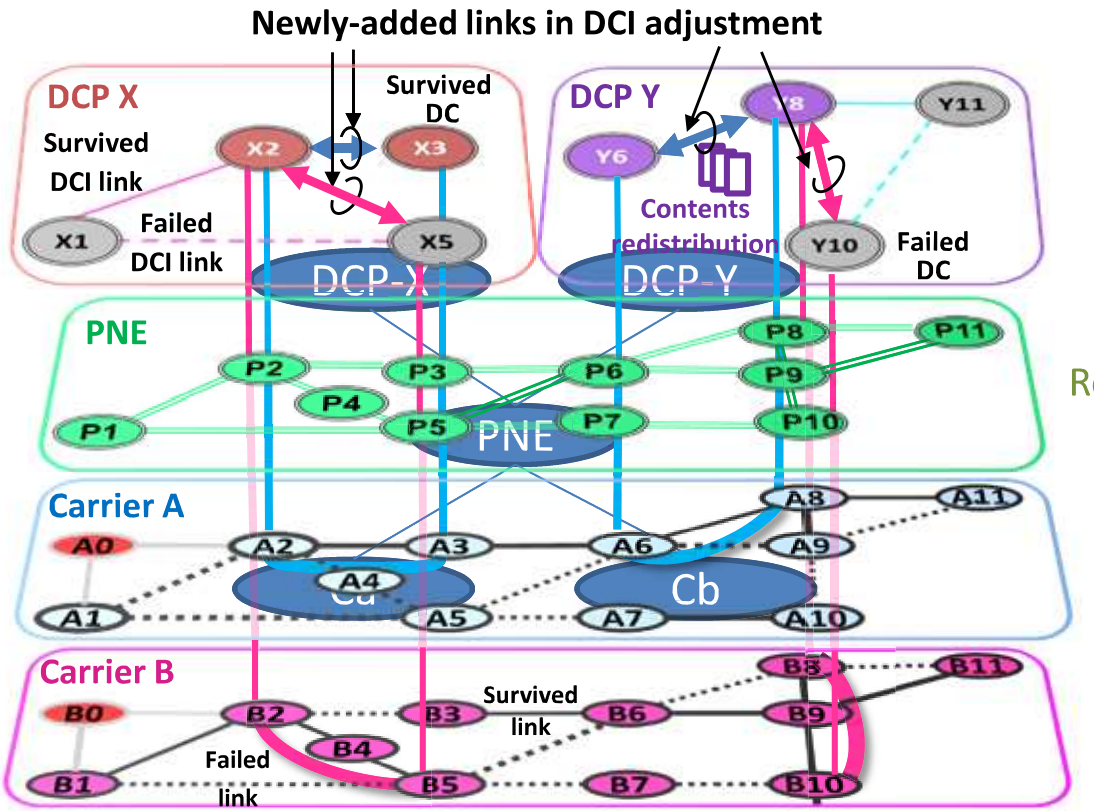


Task 2: Cloud-Carrier Cooperation



Maximize post-disaster cloud service restoration

Task 2: Cloud-Carrier Cooperation



Multiple DCPs compete for resources

⬇

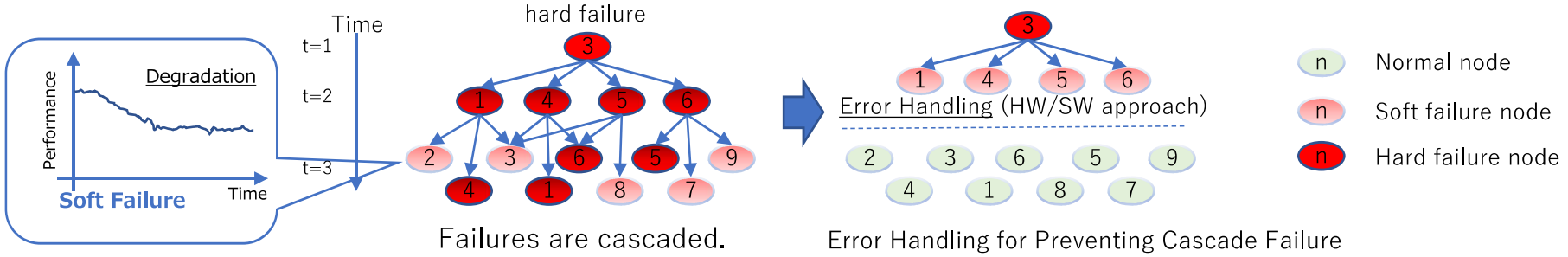
Resource balancing by PNE

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

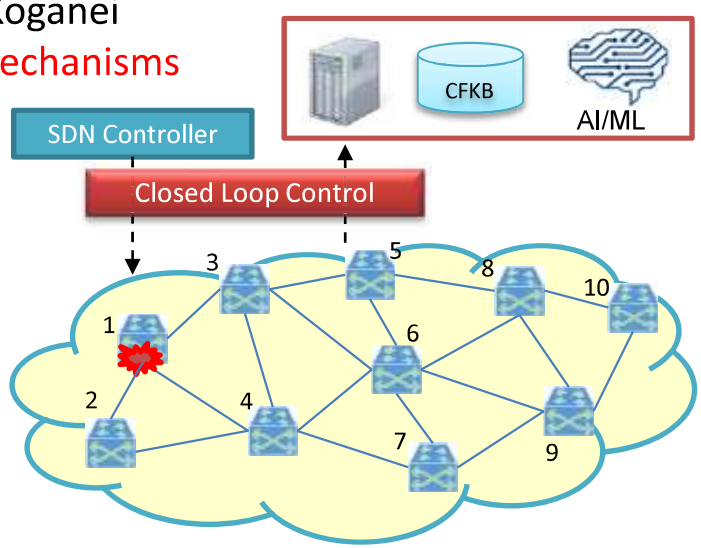
Cascading failure: A failure causes another failure of different part of interconnected system.

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 prevent them

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



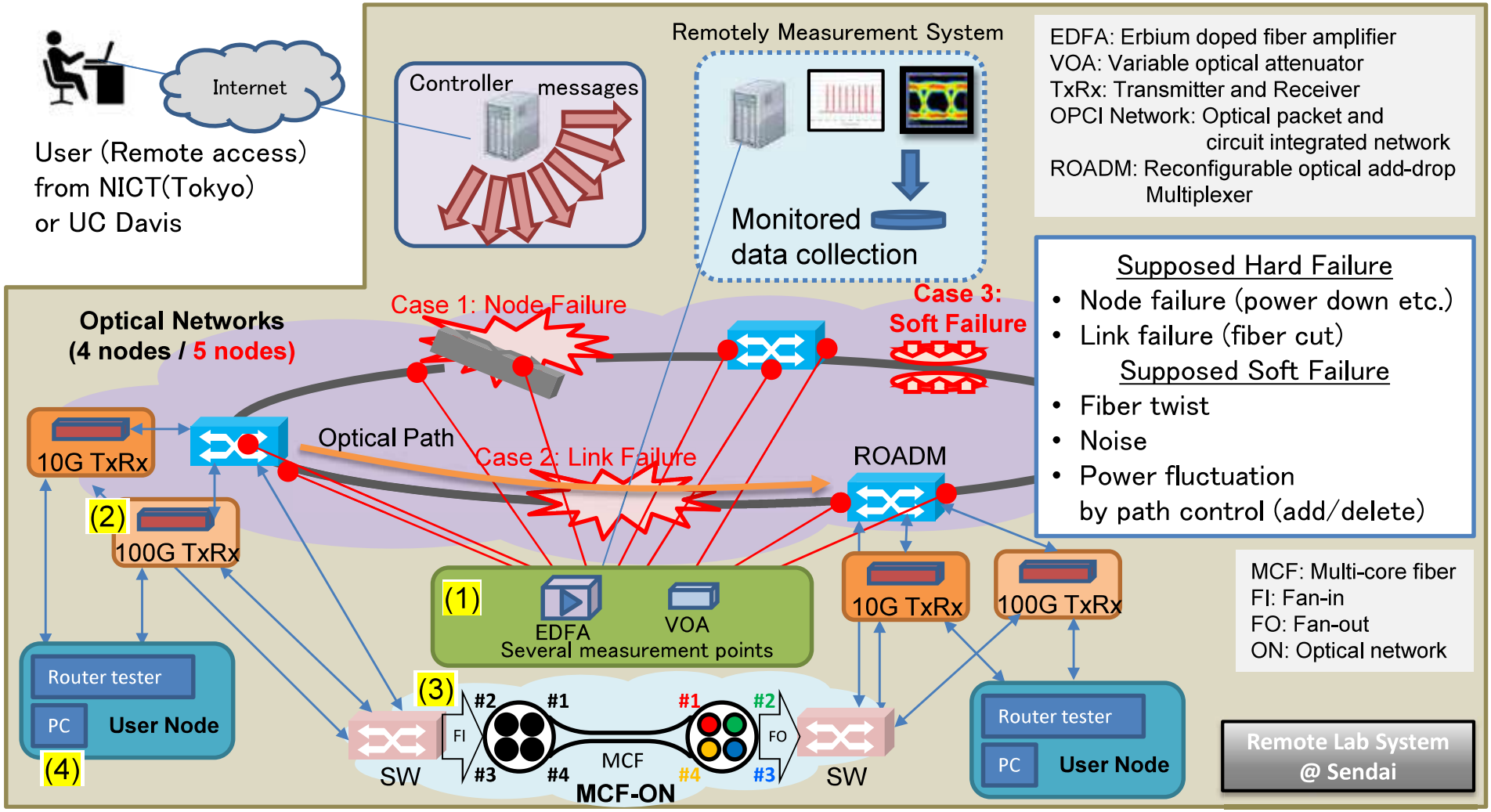
3-1. Analyze/Recognize Cascade Failure Using Sendai Testbed

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.

Sendai Testbed for Advanced Network Functionality



(1) Multipoint measurement system developed for remote data acquisition

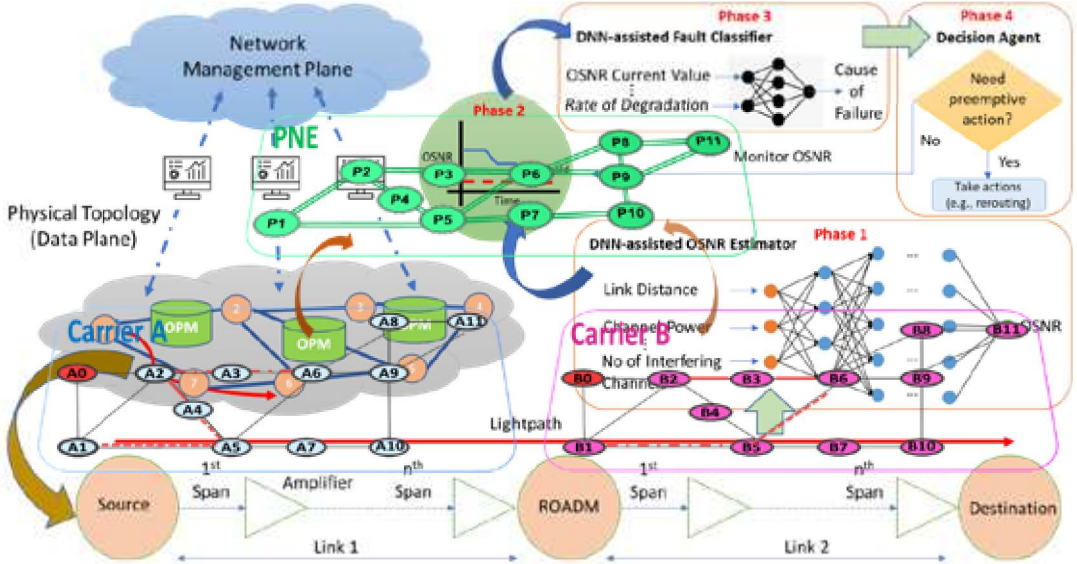
(2) Coherent optical signals generated by 100G transponders

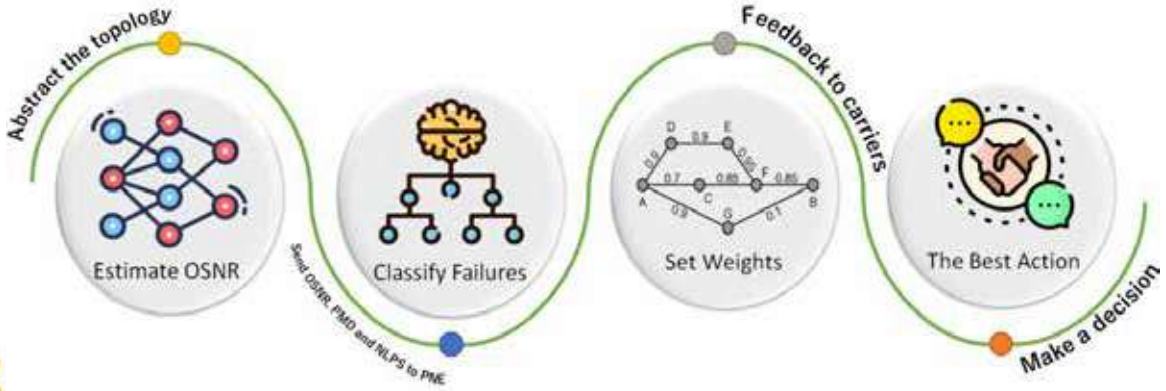
(3) Multi-core fiber optical network

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

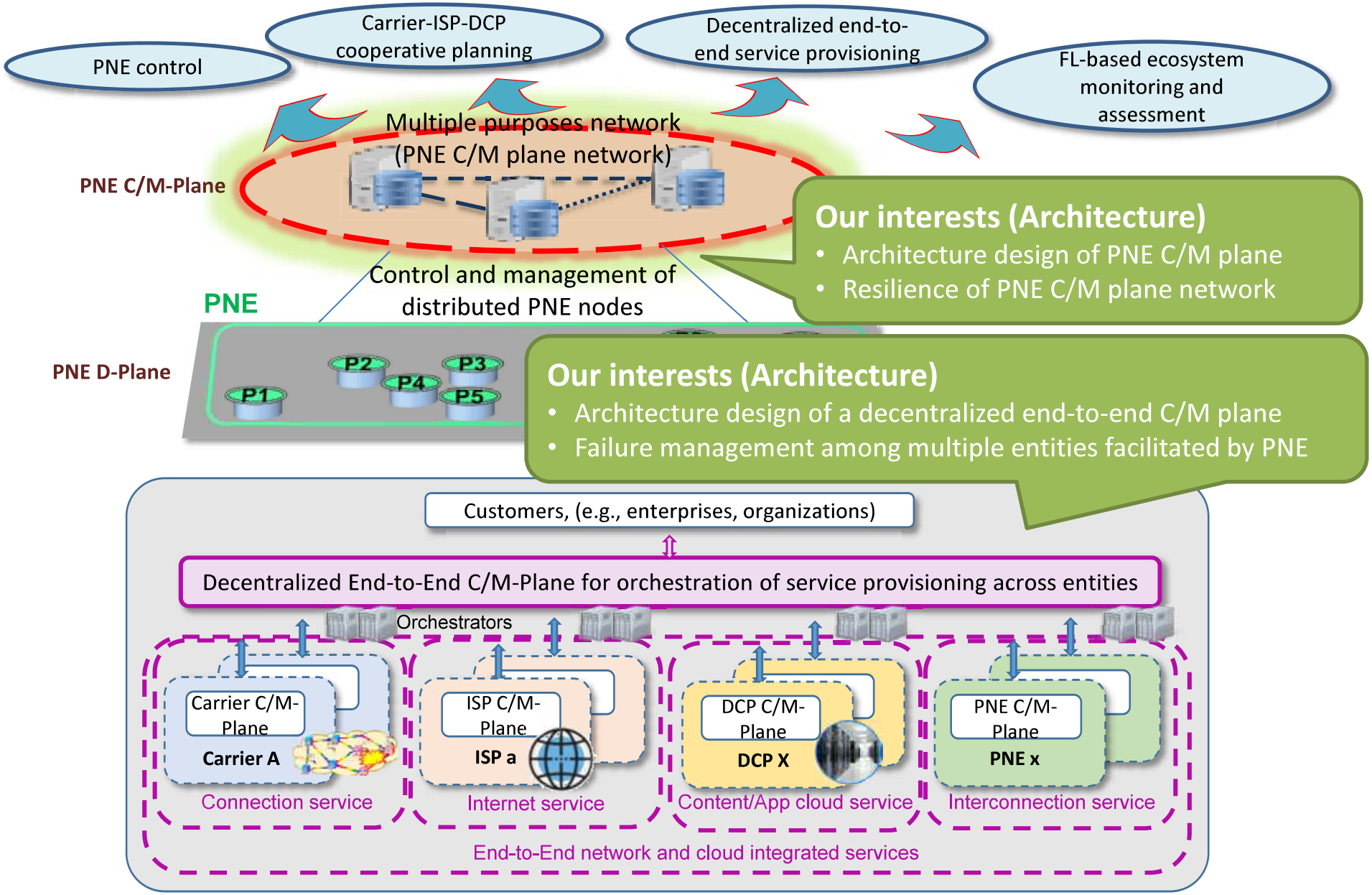
Task 4: Preemptive Failure Detection and Management

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

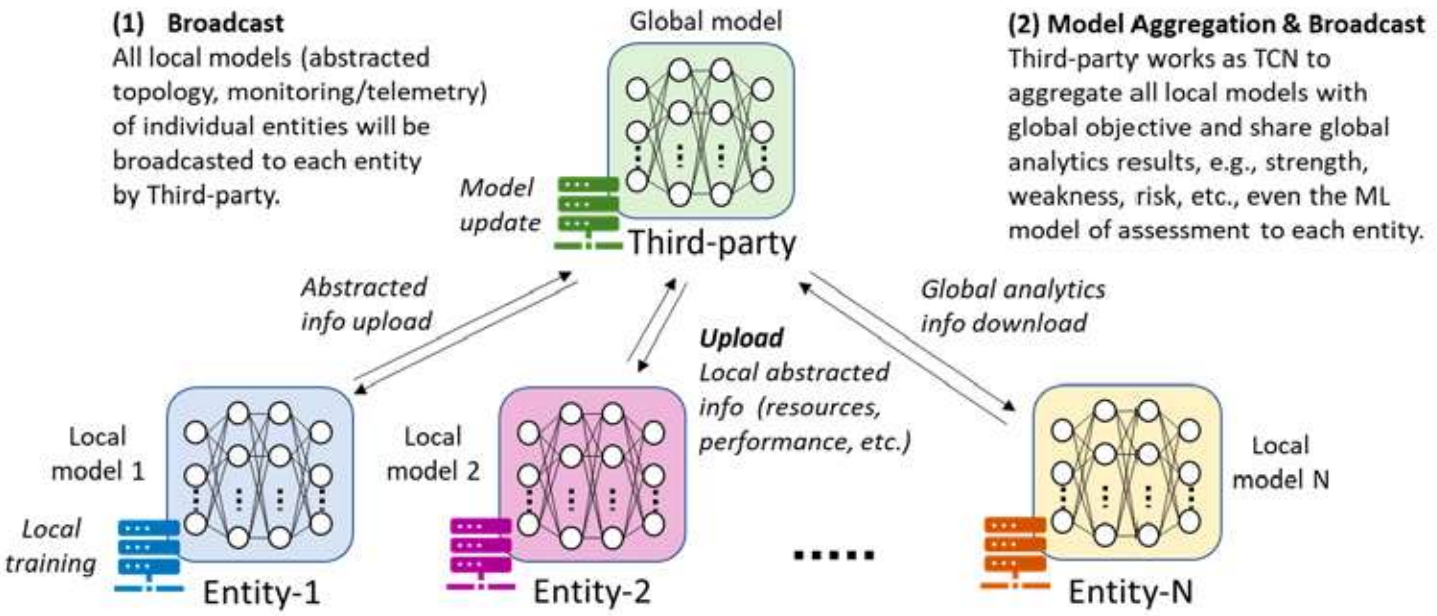




Task 5: Decentralized end-to-end C/M plane



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

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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

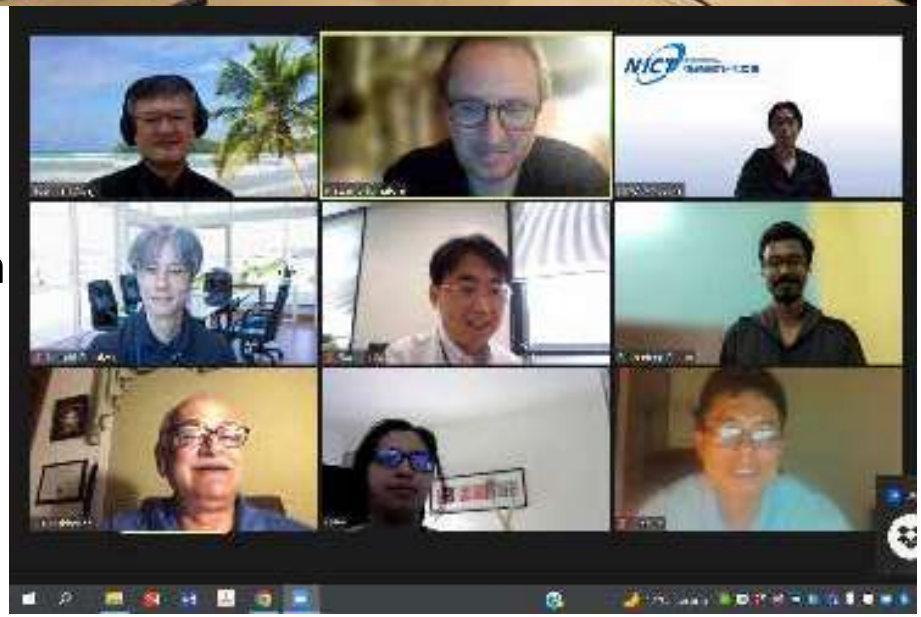
  Dr. Awaji, Dr. Hirota, and Dr. Xu

- Online JUNO3 kick-off meeting

  September 8, 2022

  October 6, 2022

- Several other interactions via email/Zoom



Publications

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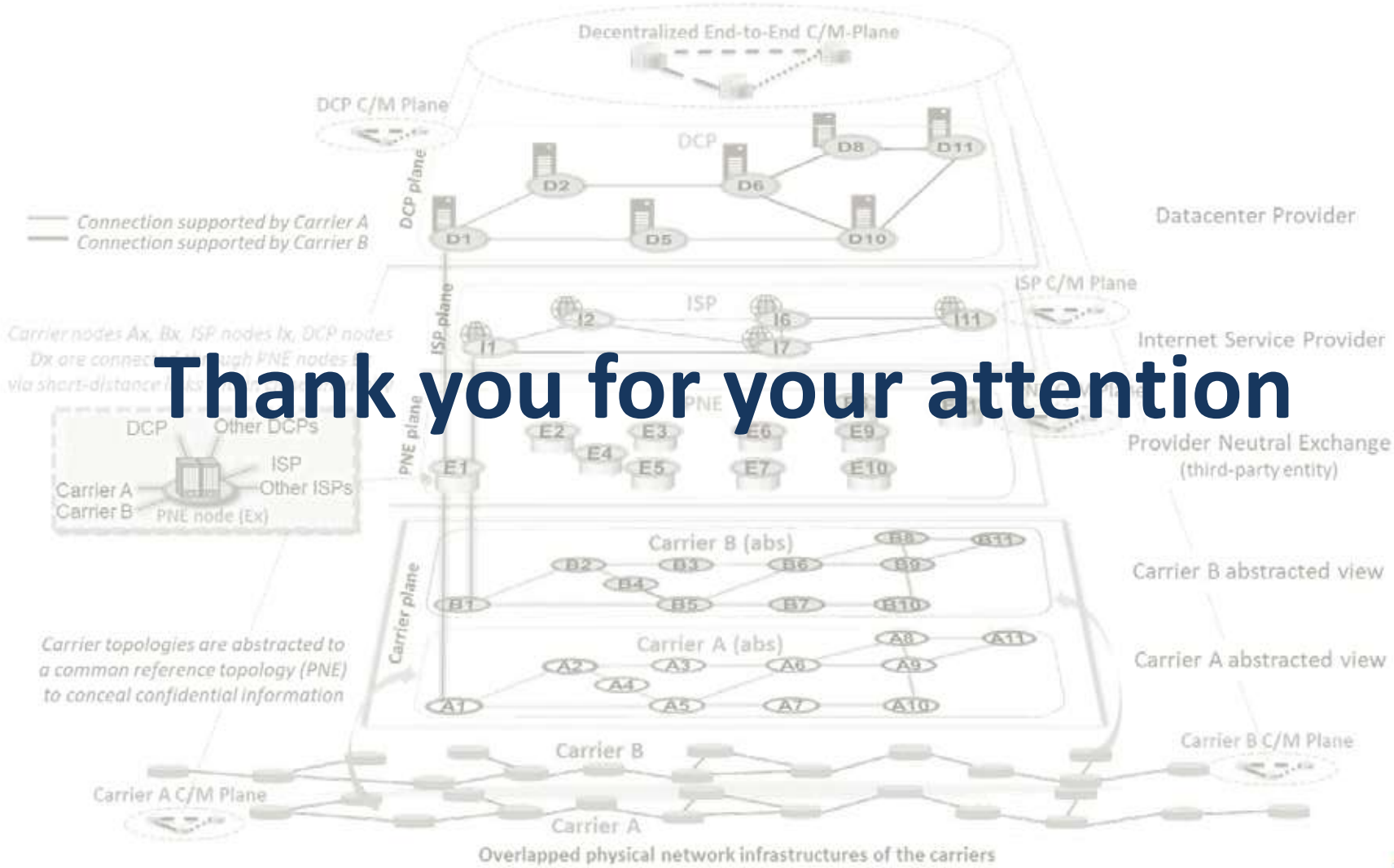

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