Study of Disaster-Resilient Network-Cloud Ecosystem with Open Disaggregation and Cooperation Technologies

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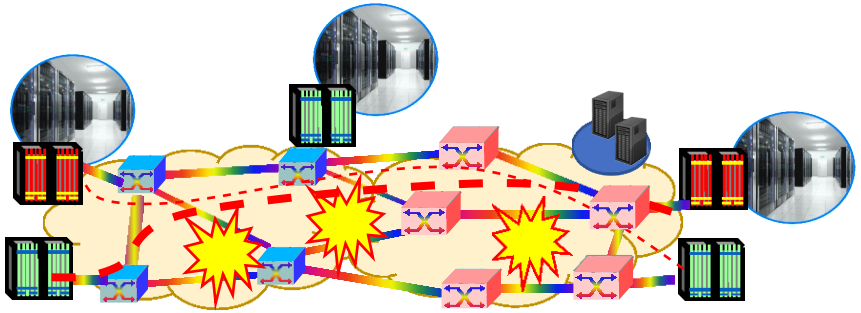
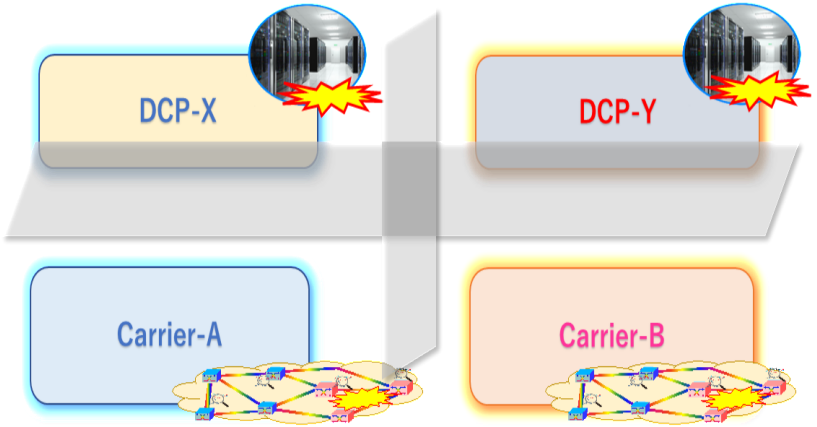
[1]NICT, [2]AIST, [3]KDDI Research Inc. [4.] UC Davis, USA, [5]Politecnico di Milano, Italy , [6]IBRI, China

Outline

- Background and motivations
  - Network-cloud ecosystem and resilience
- Research activities in disaster-resilient network-cloud ecosystem (Ecosystem) with openness, disaggregation and cooperation
  - **Part-1: Single-entity** ecosystem resilience enhancement with Openness and Disaggregation
  - **Part-2: Multi-entity** ecosystem resilience enhancement through Cooperation between DCPs and carriers
- Summary



Single-entity network-cloud ecosystem owned by a single entity, e.g., Telecom carrier or emerging Telecom/DC partnership company

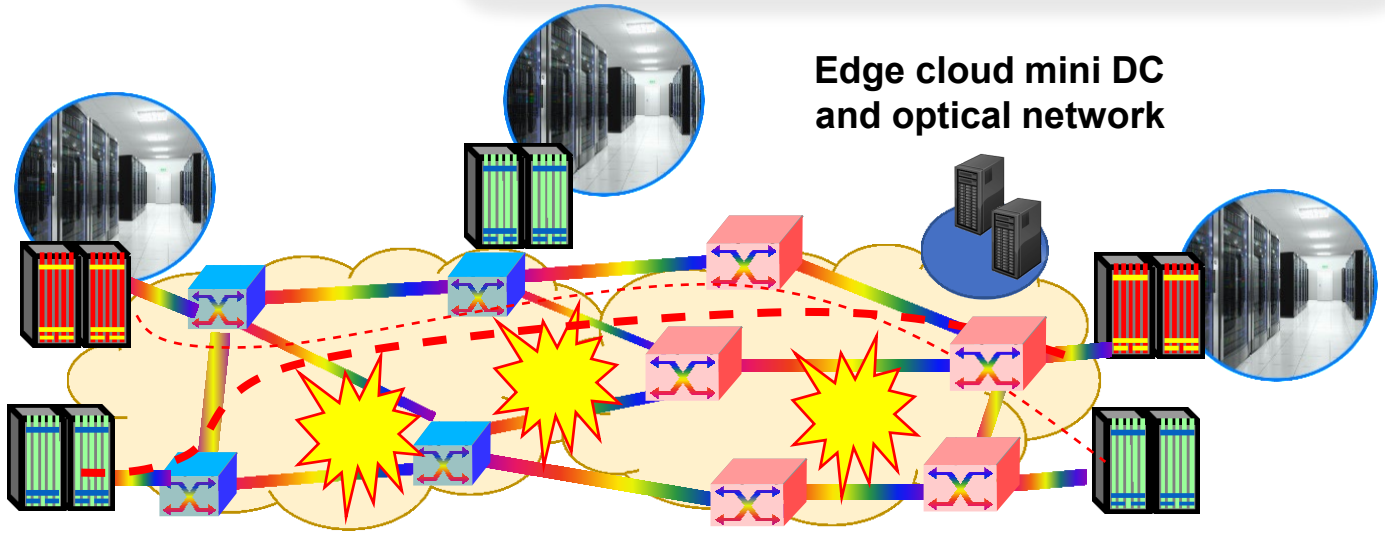


Multi-entity network-cloud ecosystem owned by a different entities, e.g., Telecom carriers and Data Center Providers (DCPs).

Motivations (Enhance the Resilience of Network-Cloud Ecosystems)

- Plenty of diverse optical network resources
  - ***Telecom*** multi-vendor multi-domain optical networks
    - Coexisting legacy/disaggregation optical networks
  - ***Data center (DC) /edge DC*** optical networks
    - Intra-DC optical network
    - Inter-DC optical network
- Enhance the resilience of network-cloud ecosystems in case of disasters

Plenty of diverse optical network resources



How to ease the recovery of network/cloud services in disasters?

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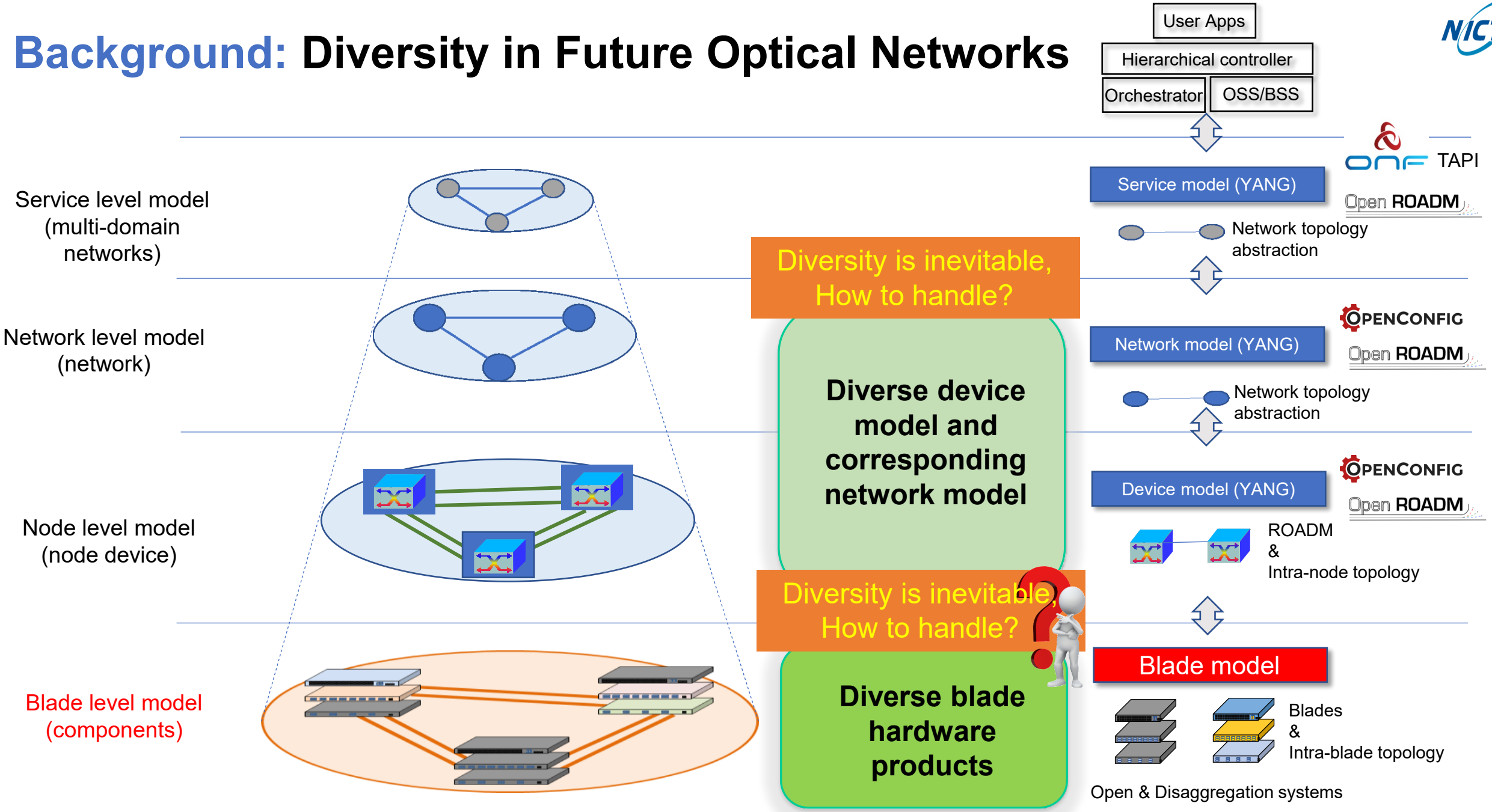
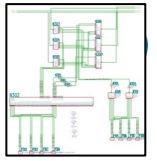
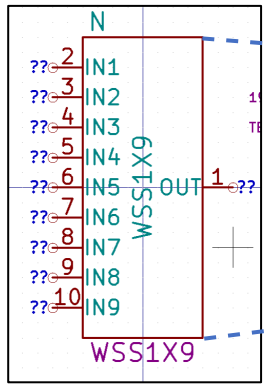
Background: Diversity in Future Optical Networks



Review: Fundamental Works for Diverse Hardware Integration Functional Block-based Disaggregation (FBD) Model



Component-level model



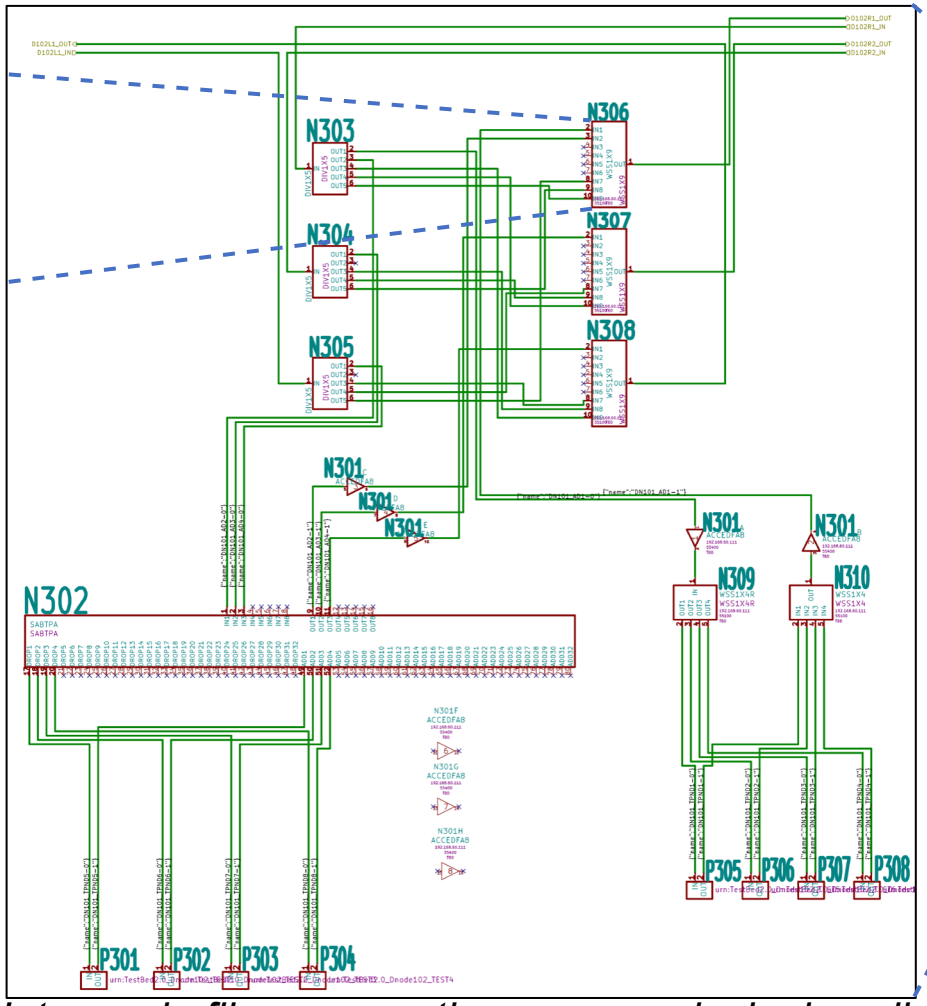
Intra-component connectivity constraints:

- 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;
```

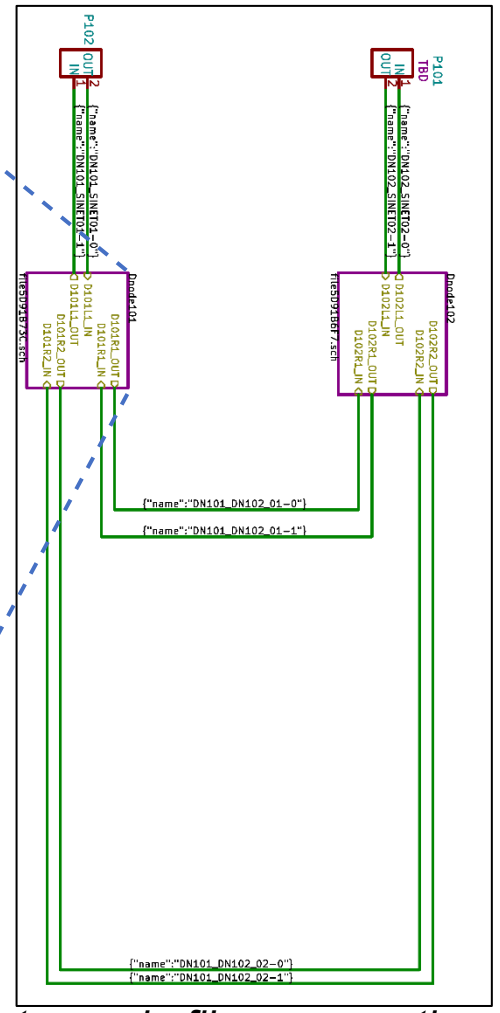
[K. Ishii, et al., IEEE/OSA JLT, vol. 37, no. 21, 2019]

Node-level model



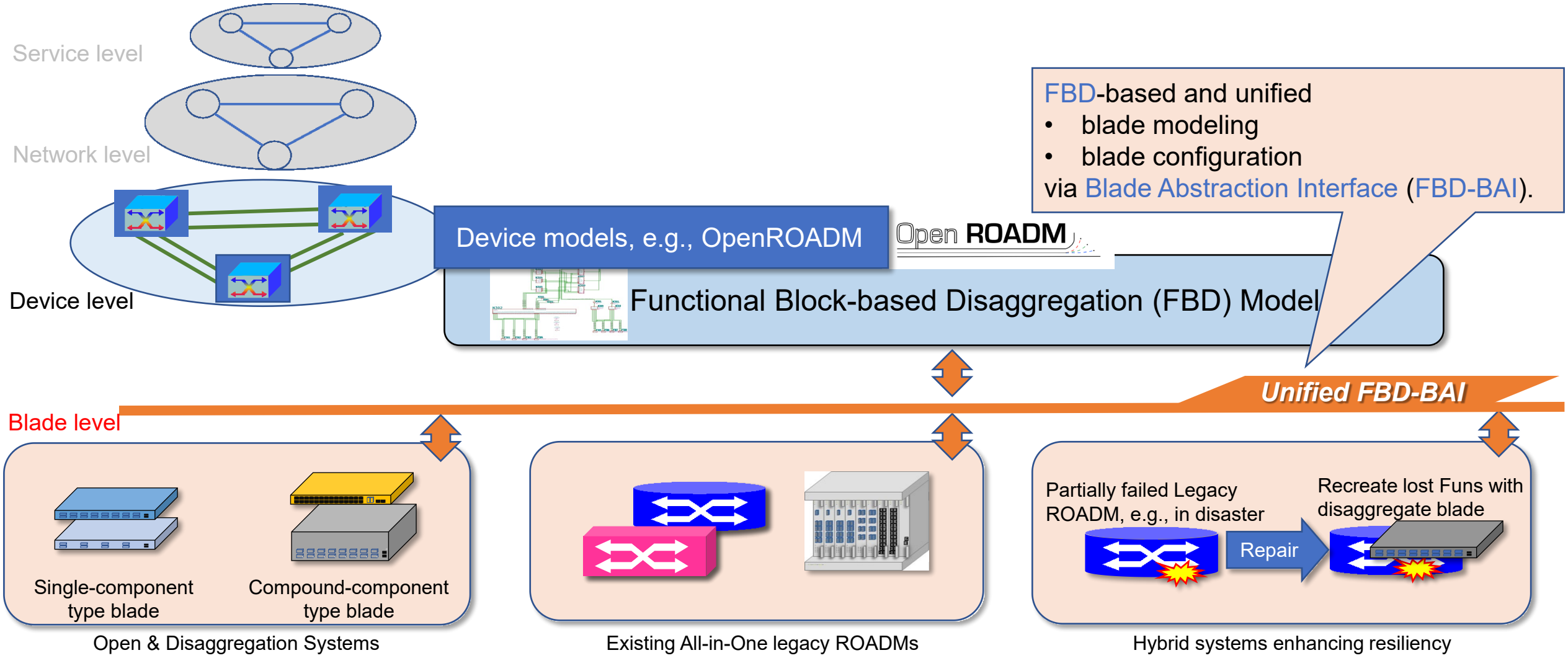
Intra-node fiber connections are precisely described

Network-level model



Inter-node fiber connections are described

Review: Blade Abstraction Interface (FBD-BAI) Handling the Diverse Hardware Systems

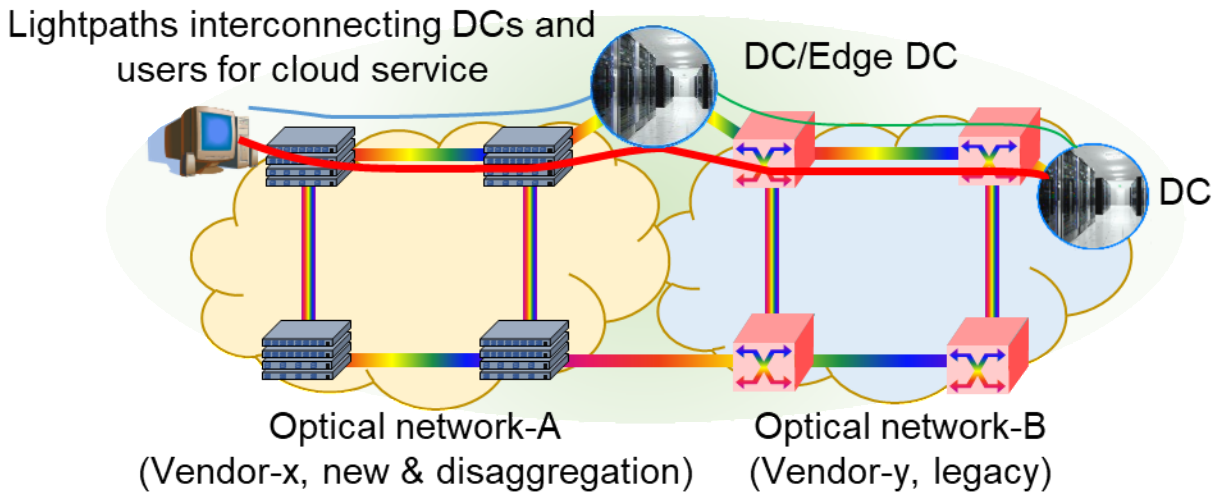


S. Xu et al., OFC2021, F1C.2, Jun. 2021.

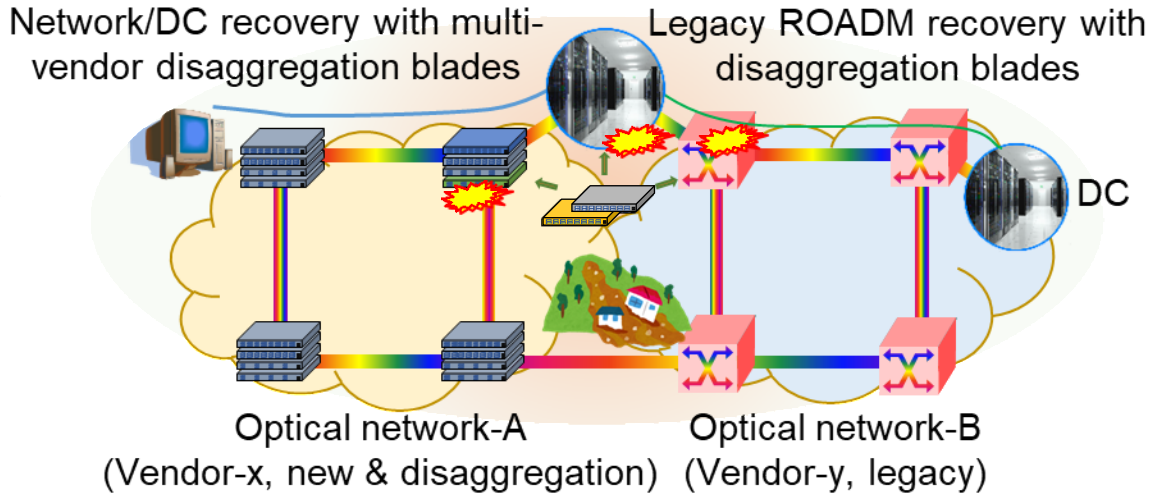
Heterogeneous systems with diverse Functionalities, Structures, Constraints, and APIs

Target Use Cases: Single-entity Heterogeneous Telecom/DC Integration

Facilitating Telecom/DC optical network integration with a unified approach



Enhancing the resilience of ecosystems



Questions:

- How to efficiently integrate such heterogeneous Telecom/DC optical networks with a unified architecture handling and facilitating the coexistence of diverse underlying hardware and upper SDN software in an ecosystem?

- How to achieve swift recovery in case of failures/disasters?

Proposal: A Common Approach for Integration/Control of Heterogeneous Telecom/DC Optical Networks aided by FBD & TAPI

Domain level model

Diverse network level models

Diverse node level (device) models

Diverse multi-vendor optical network products

Inevitable diversity

Inevitable diversity

TAPI network model

TAPI Mapper A

TAPI Mapper B

TAPI Mapper FBD

Network model A

Network model B

FBD model

Device model A

Device model B

Mapper A

Mapper B

FBD model

FBD-BAI (blade abstraction interface)

From fully disaggregate blades to existing all-in-one legacy ROADMs

FBD supports diversities in
- device models via Mappers
- devices hardware via FBD-BAI

TAPI model unifies the control of heterogeneous networks.

Target scenarios

Telecom networks

DC networks

FBD model unifies the integration of diverse optical network hardware products.

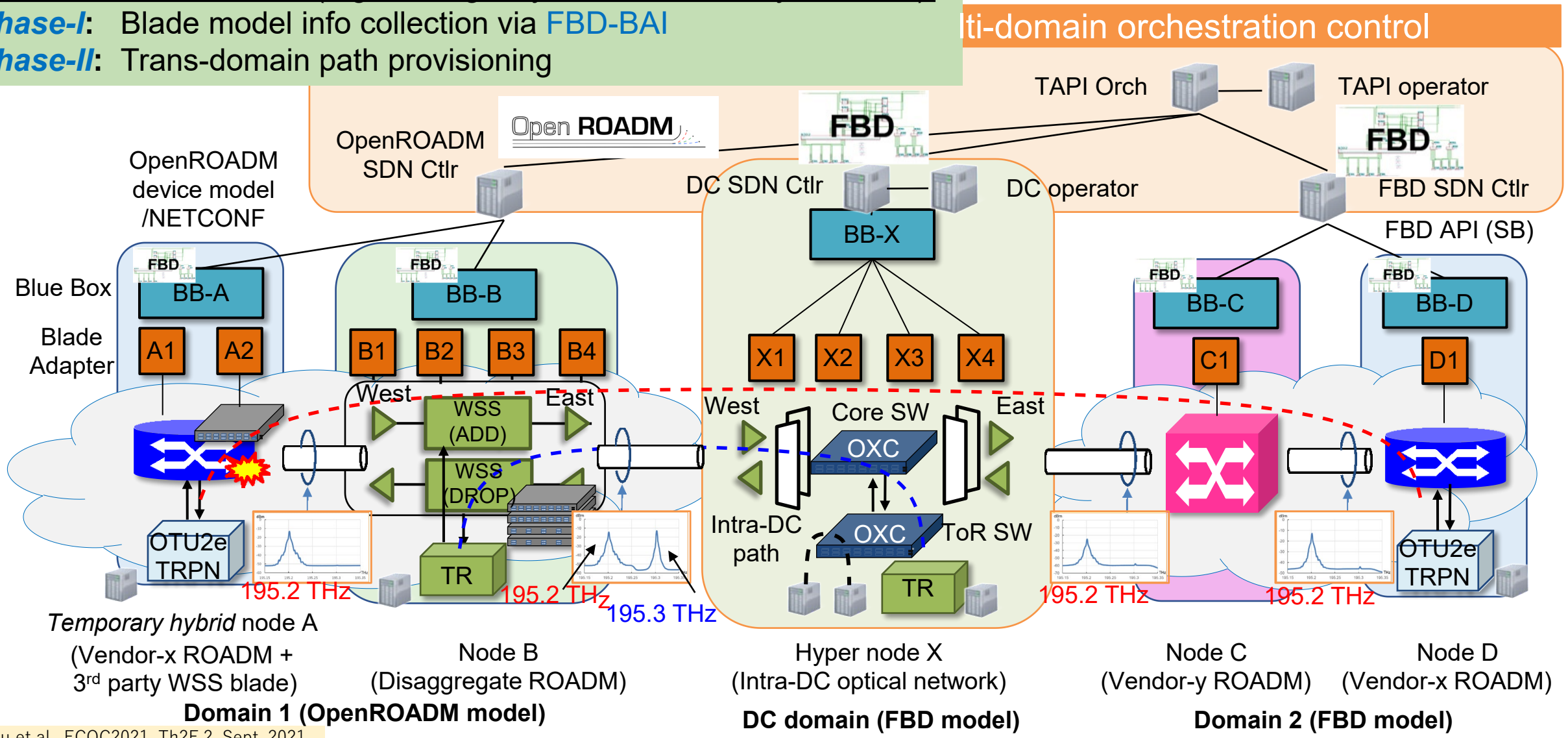
S. Xu et al., ECOC2021, Th2E.2, Sept. 2021.

POC: Experimental Setup of Integration/Control of Heterogenous Telecom and DC Optical Networks aided by TAPI and FBD

Demonstration Scenario (e.g., emergency disaster recovery scenario):

Phase-I: Blade model info collection via FBD-BAI

Phase-II: Trans-domain path provisioning



S. Xu et al., ECOC2021, Th2E.2, Sept. 2021,

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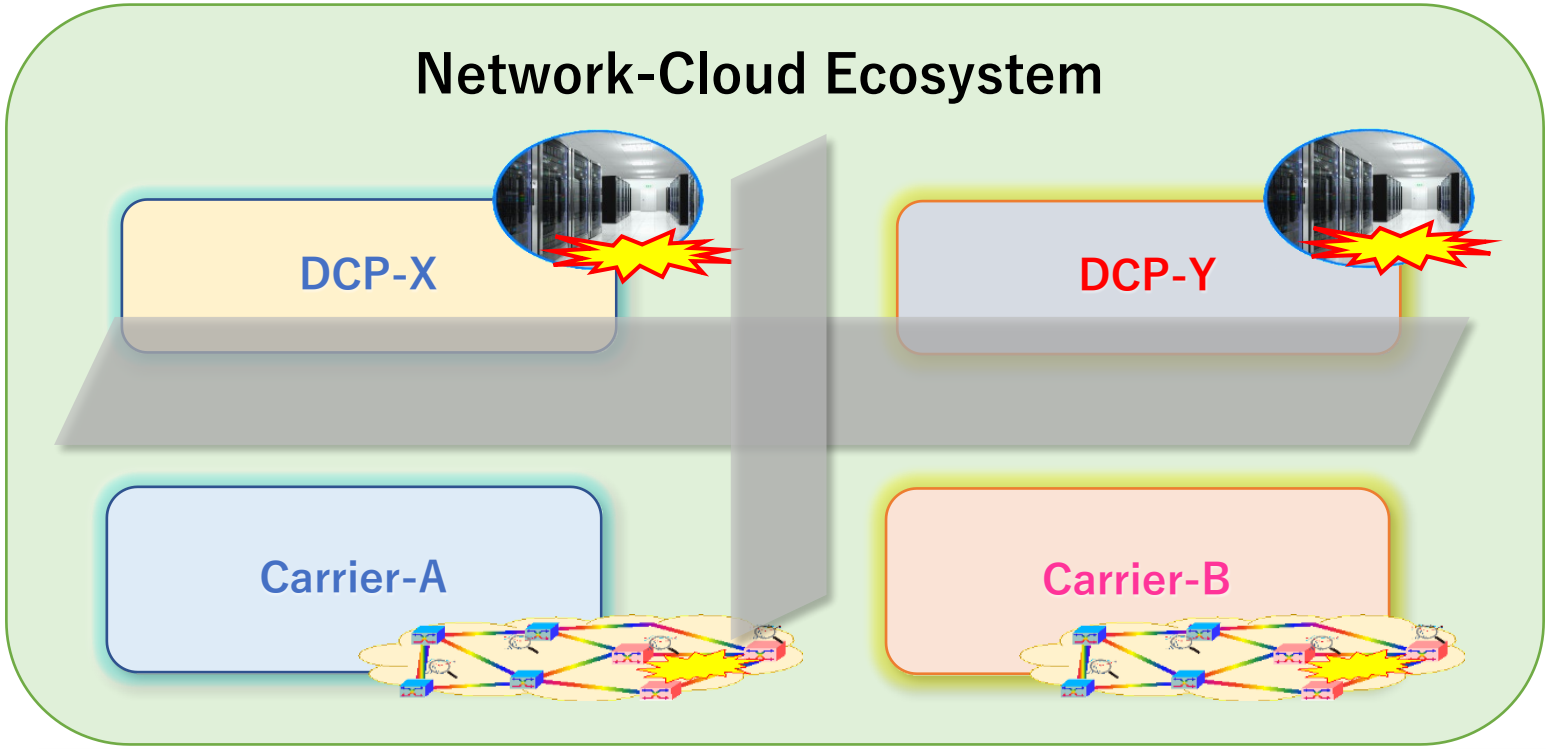
Background: Limited visibility In Multi-entity Ecosystem

Limited visibility of carrier and DC resource availability (confidential info); complexity in joint optimization

Entities:
- Carriers
- Datacenter providers (DCPs)

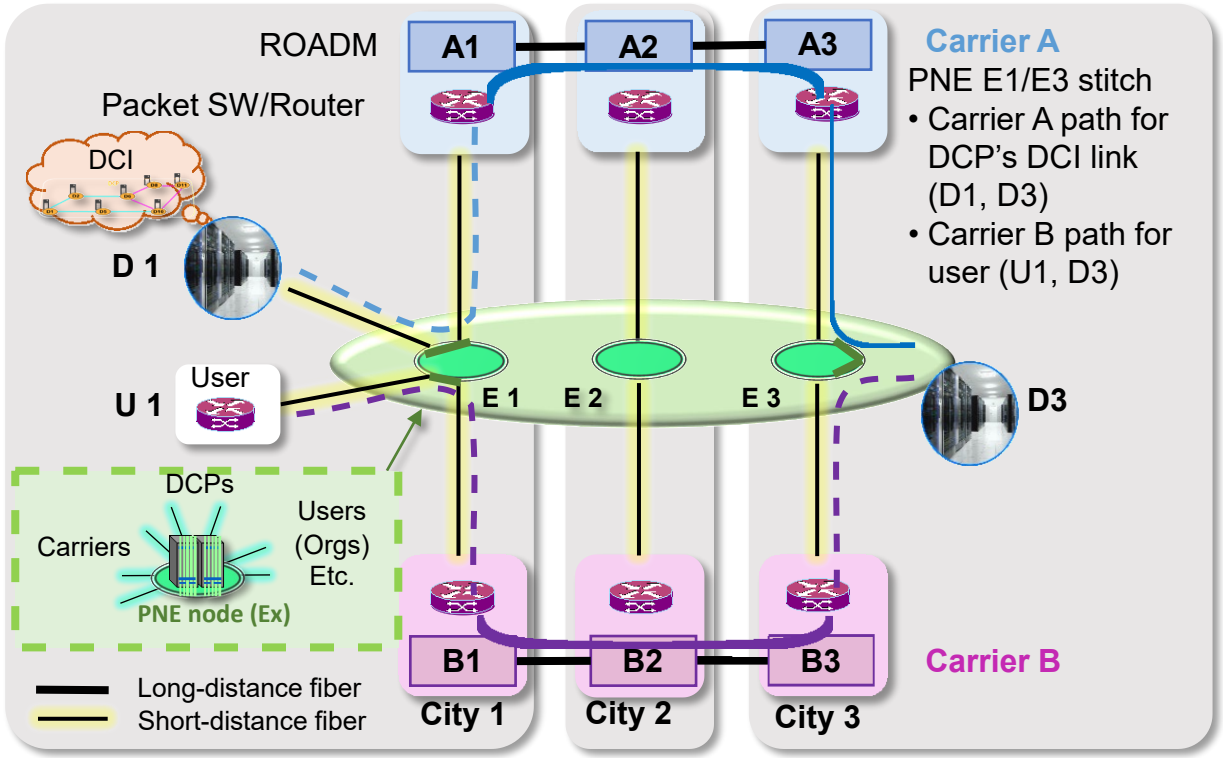


Challenges: Limited visibility of carrier and DC resource availability (confidential info) in *cooperation*

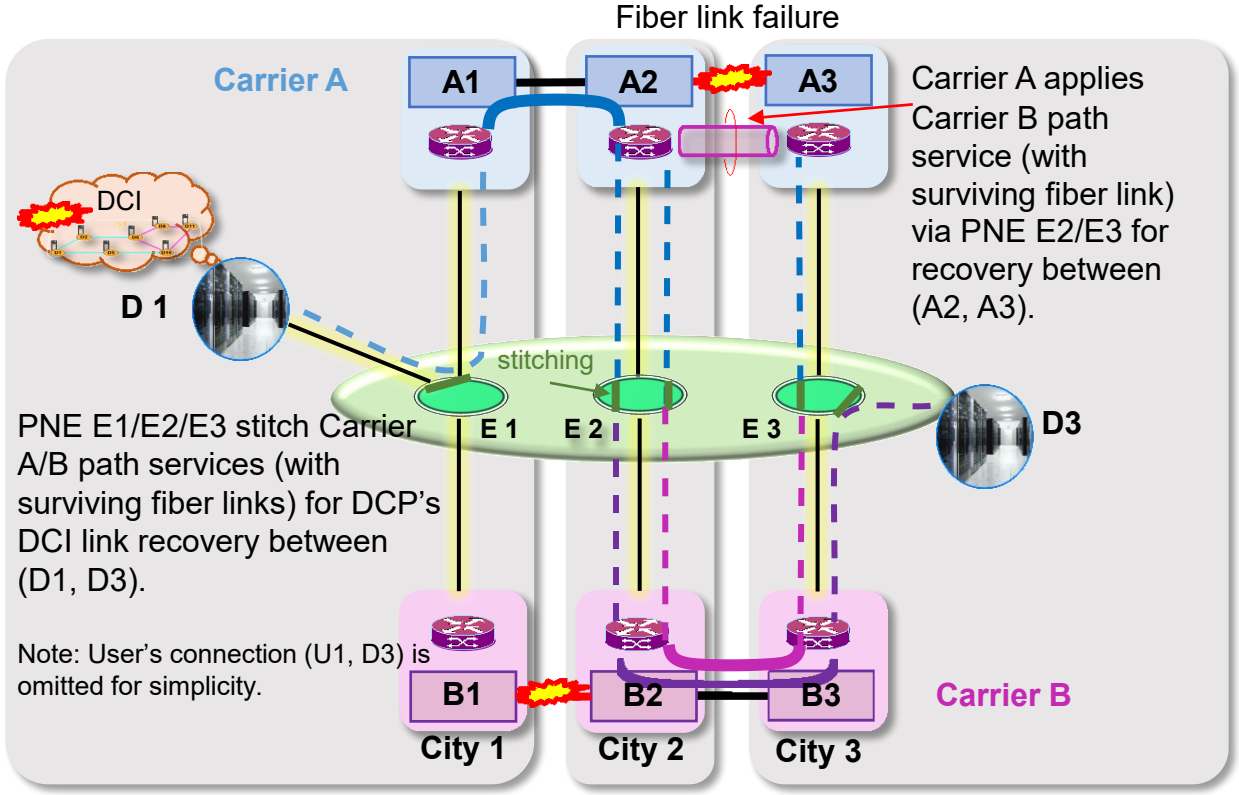
Cooperation among the entities w/ appropriate incentives and w/o violating confidentiality, is essential.

Target Use Cases: Cooperative Resource Allocation

Cooperative resource allocation and service provisioning



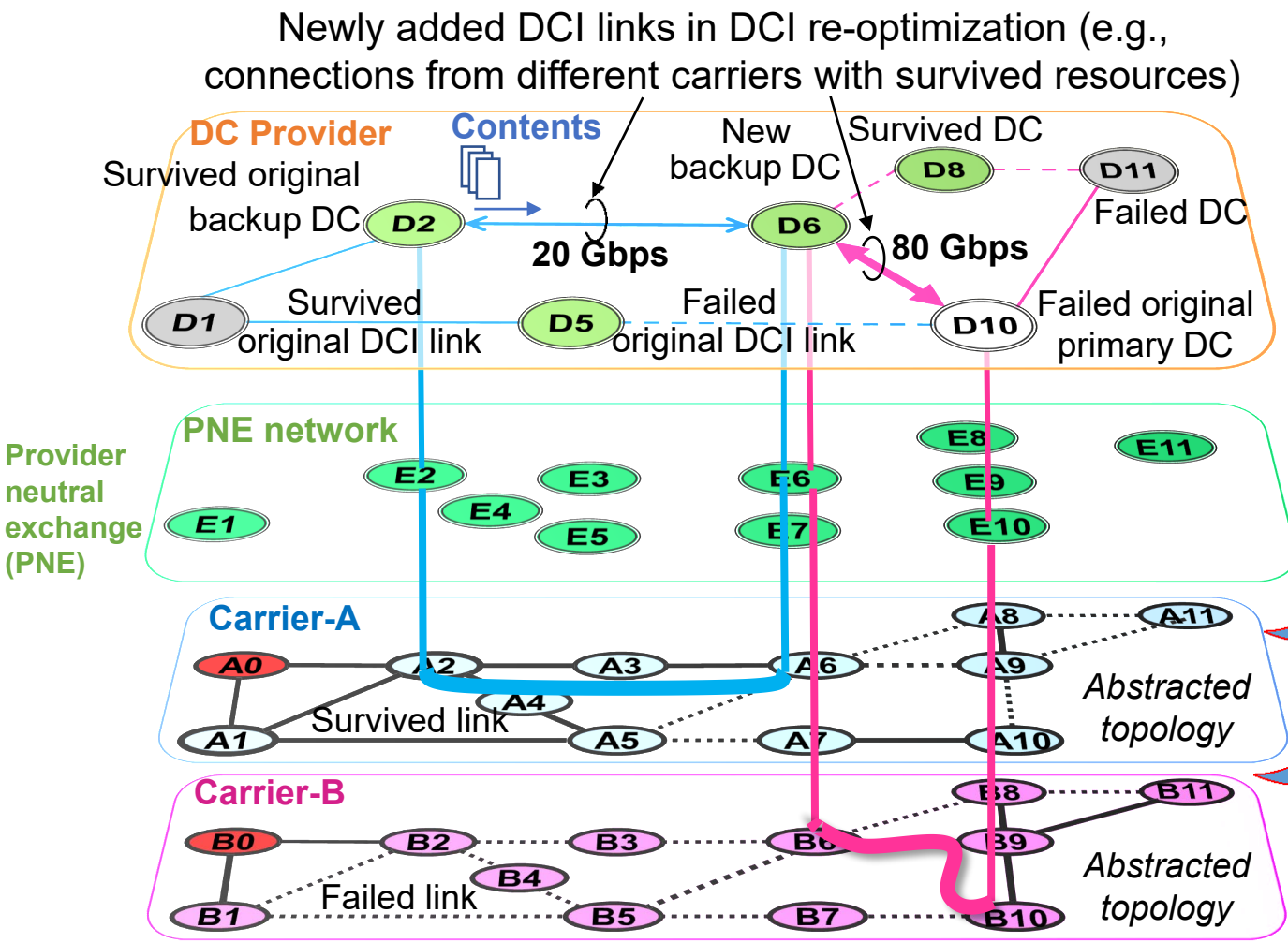
Enhanced resilience of ecosystems



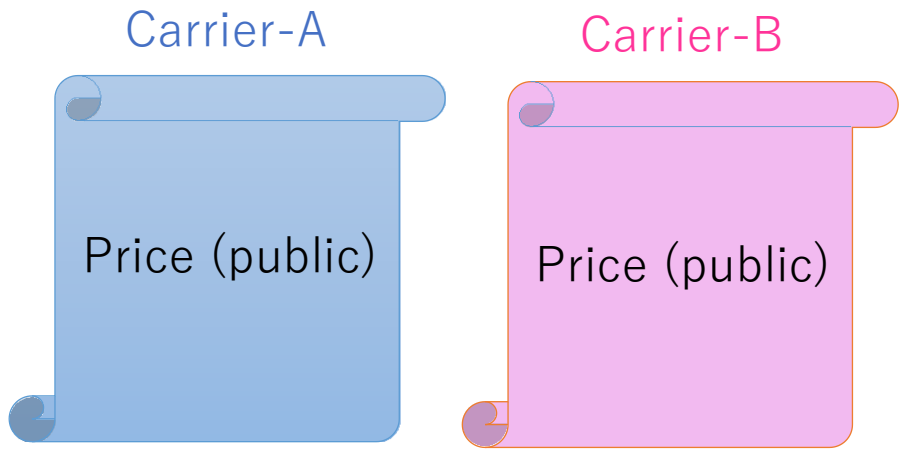
Questions:

- *How to facilitate DCP-Carrier cooperative resource allocation without violating confidentiality?*
- *In particular, how to achieve efficient restoration in case of network resource crunch, e.g., congestion, failures and disasters?*

Proposal: A third-party Provider Neutral Exchange (*PNE*)-based DCP-Carrier Cooperation



DCP: instead of waiting for carriers to recover services, DCP can re-optimize the DCI topology with survived resources for faster recovery.

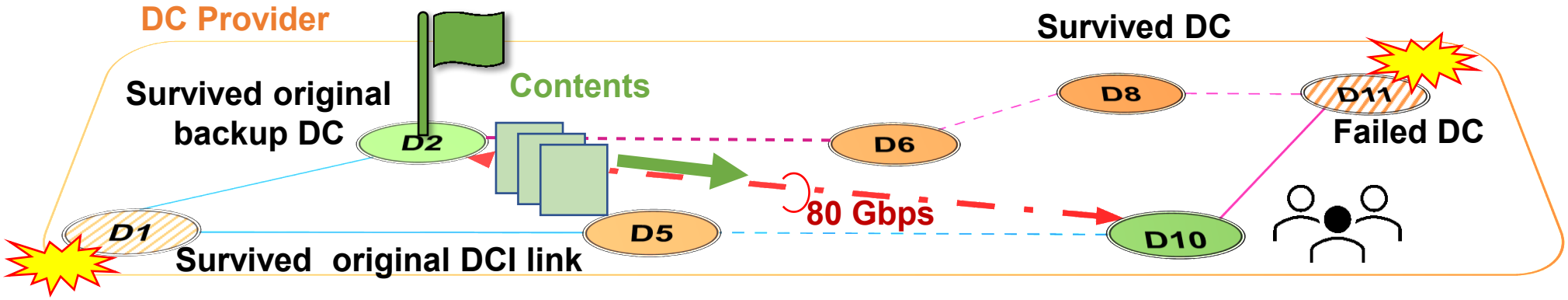


Carrier topologies are abstracted to a common reference topology (PNE) topology to conceal confidential topology information during cooperation

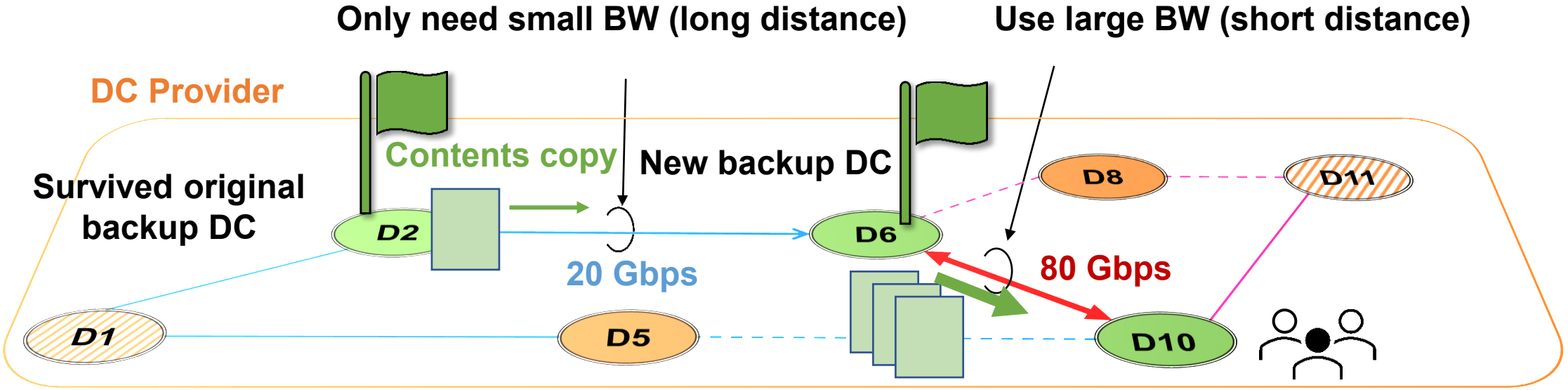
Shared/overlapped physical network infrastructures of the carriers

S. Sahoo et al., OFC2022, W2A.23, Mar. 2022.

Proposal (Continue): New Flexibility of DCP—Content Redistribution

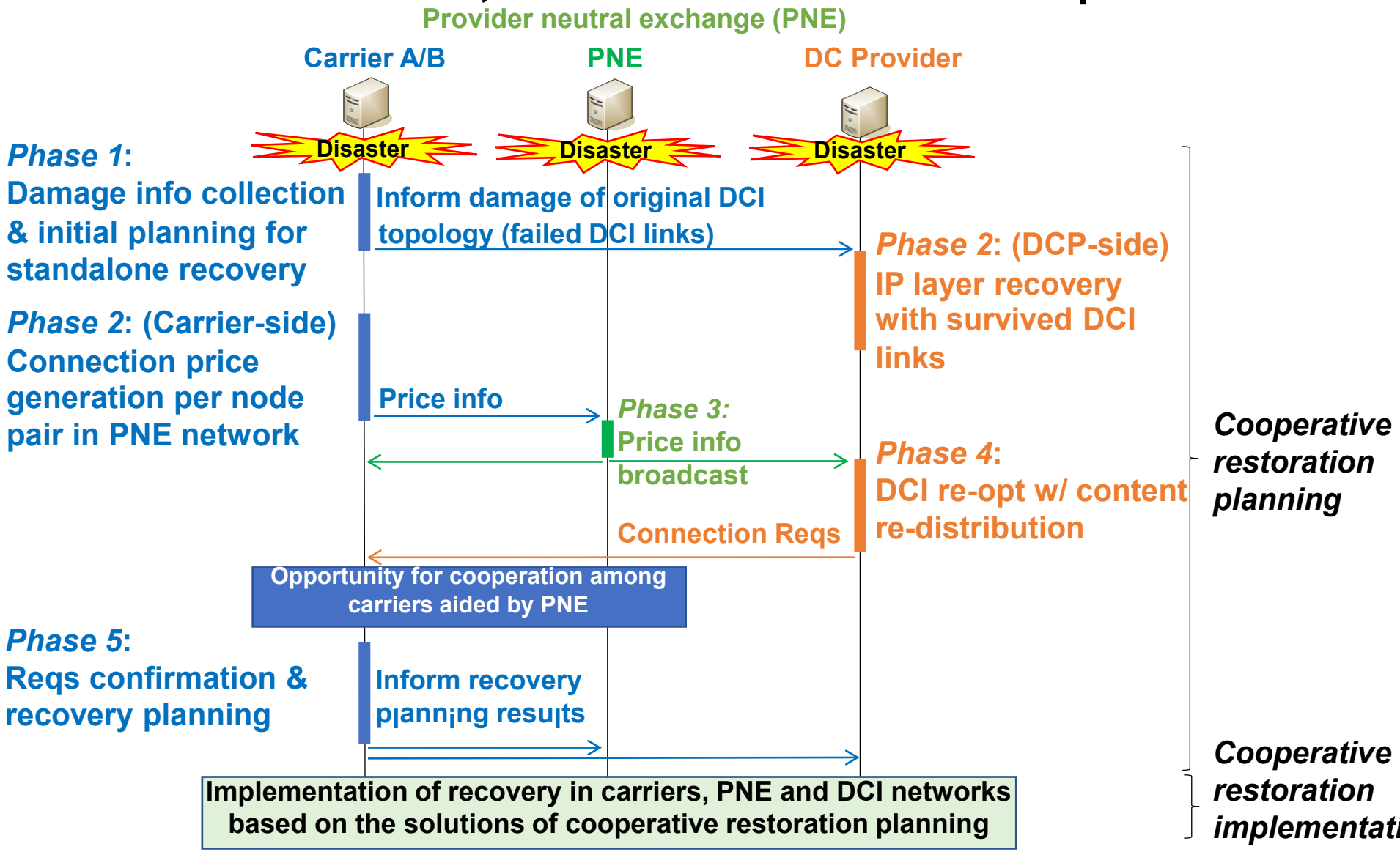


Introduce content redistribution capability in DCI re-optimization



S. Sahoo et al., OFC2022, W2A.23, Mar. 2022.

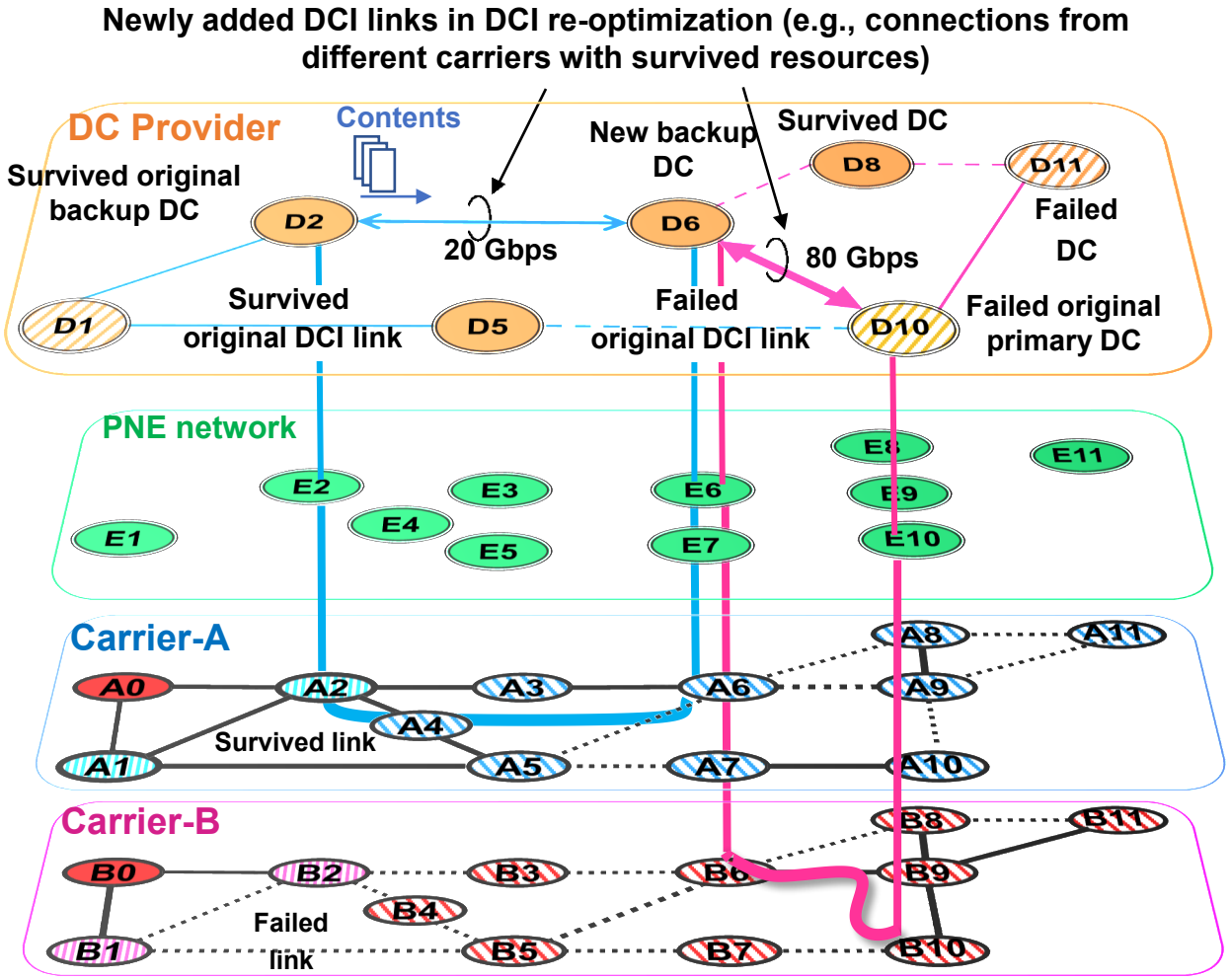
Proposal (Continue): Preliminary Study of Cooperative Restoration Strategy (Cooperation Mechanism Overview, DCP-side and Carrier-side Optimization Tasks)



S. Sahoo et al., OFC2022, W2A.23, Mar. 2022.

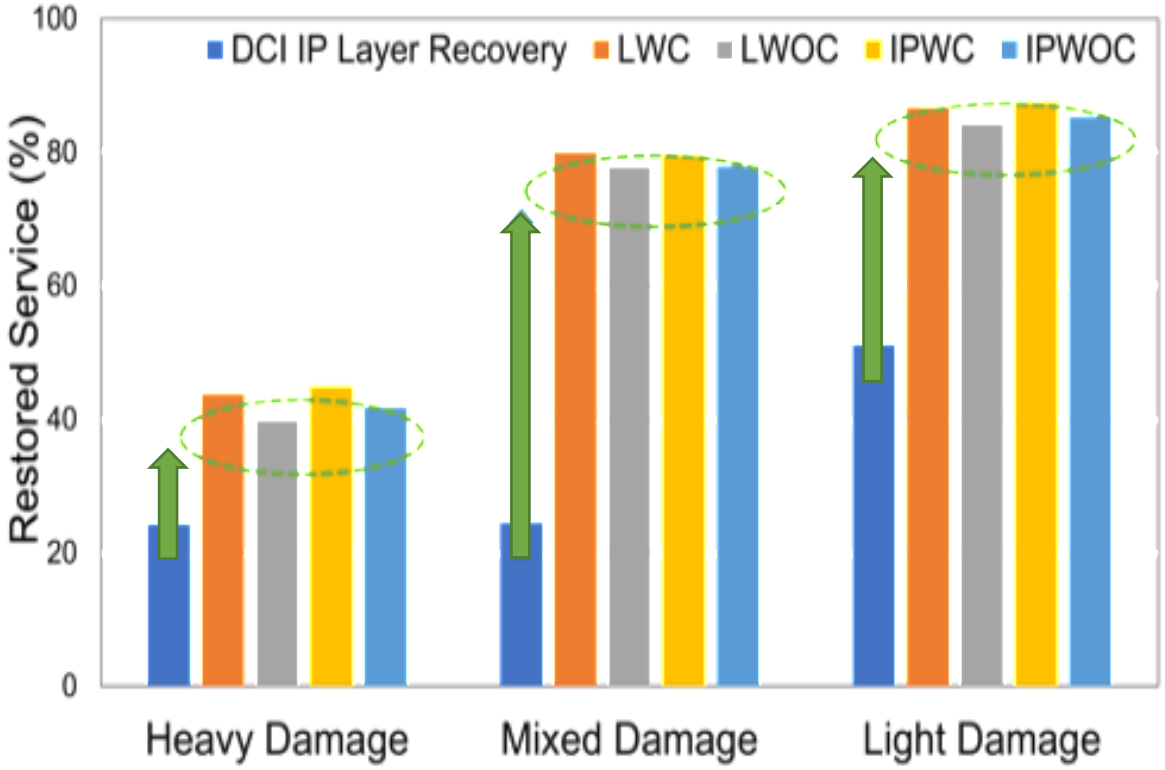
Preliminary Evaluations

- **Topology:**
  - **Carrier networks**
    - Both carriers are identical and abstracted to PNEN (a subset of Japan photonic network model [1] with 11 nodes) with 15 links
  - **DCI network**
    - DCI topology has 7 DC nodes collocated with PNE nodes
- **Damage scenario:**
  - **Damages in carrier networks**
    - *Heavy damage*: 5 survived links in Carriers A and B
    - *Light Damage*: 10 survived links in Carriers A and B
    - *Mixed damage*: 5 survived links in Carrier A and 10 survived links in Carrier B
  - **Damages in DCs**
    - 3-4 DCs are damaged.
    - 10,000 user requests are affected. Bandwidth requirement per user is 30-50 Mbps.
- **Etc**
  - **Lightpath capacity** 100 Gbps
  - **Pseudo price of a carrier's lightpath**
    - 2 units per survived links
    - Extra 50 units dummy price per damaged link in PNE topology



[1] T. Sakano et al., IEICE Tech. Rpt. PN2013-01, 2013.

Numerical Analysis (Selected Results 1/2)
Cloud Service Restoration Efficiency



Finding

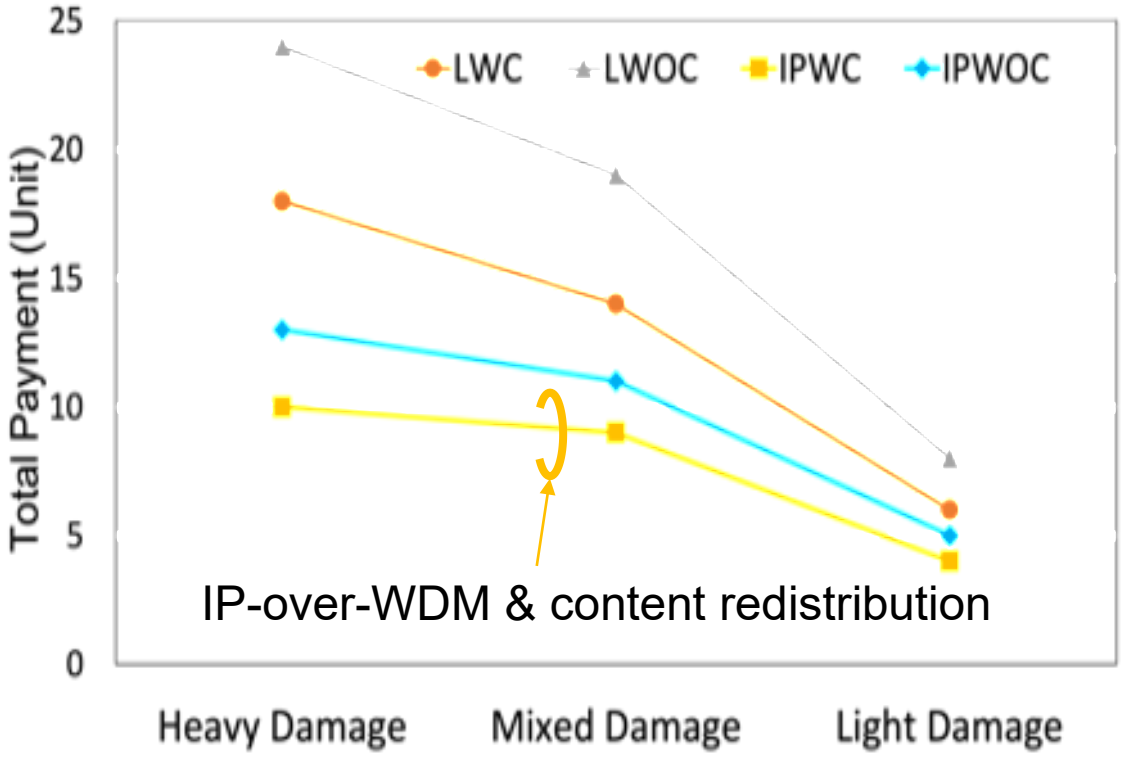
Efficient DCP-carrier cooperative DCI recovery:
Immediate restorations increased more than 70% in all strategies compared to standalone DCI IP-layer recovery.

4 strategies:

- **DCP requests lightpath service**
  - LWC lightpath connection with content redistribution
  - LWOC lightpath connection without content redistribution
- **DCP requests IP-over-WDM connection service**
  - IPWC IP-over-WDM connection with content redistribution
  - IPWOC IP-over-WDM connection without content redistribution

S. Sahoo et al., OFC2022, W2A.23, Mar. 2022.

Numerical Analysis (Selected Results 2/2)
Cloud Service Restoration Efficiency



Finding

- IP-over-WDM connection service is more efficient in case of disaster recovery.
- Content-Redistribution can further significantly reduce the cost of cloud service recovery.

4 strategies:

- **DCP requests lightpath service**
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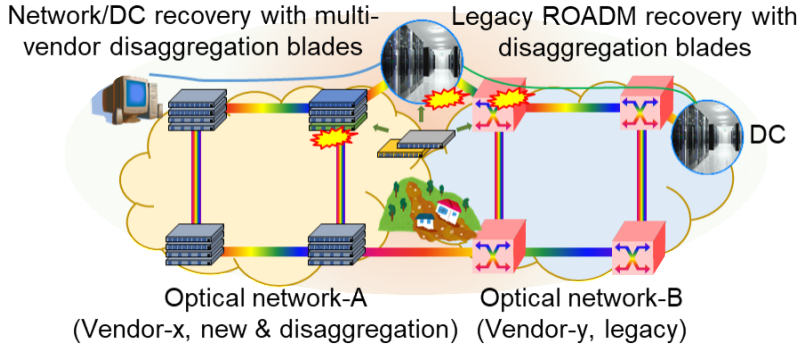
  - IPWOC IP-over-WDM connection without content redistribution

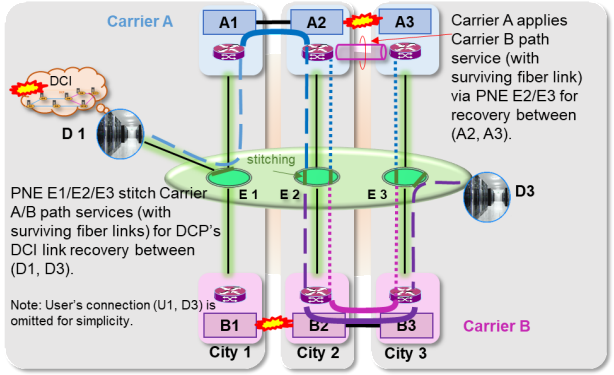
S. Sahoo et al., OFC2022, W2A.23, Mar. 2022.

Summary

- Openness, disaggregation and cooperation are beneficial to enhance resilience of network-cloud ecosystems
- Research activities in disaster-resilient network-cloud ecosystem (Ecosystem) with openness, disaggregation and cooperation
  - **Part-1: Single-entity** ecosystem resilience enhancement with Openness and Disaggregation



  - **Part-2: Multi-entity** ecosystem resilience enhancement through Cooperation between DCPs and carriers



Thank you very much!

Acknowledgements

The work in Part-1 is supported in part by JSPS KAKENHI JP19H02164
& Ministry of Internal Affairs and Communications grant number JPMI00316.

The work in Part-2 is supported in part by US-Japan JUNO3 project: NSF Grant no. 2210384..

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