Enhancement of Network-Cloud Ecosystem Resilience with Openness Disaggregation and Cooperation [Invited]

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Abstract: We investigate the problem of enhancing the resilience of future optical network-cloud ecosystems. We introduce new solutions to build disaster-resilient single- and multi-entity network-cloud ecosystems with openness, disaggregation, and cooperation between networks and clouds.

1. Introduction

To accommodate the growing demand for cloud services, the underlying networks and datacenters (DCs) form network-cloud ecosystems (ecosystem for short) physically hosting these services and are continuously evolving. These large-scale ecosystems must be resilient for supporting critical services. 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. In the first part of this paper, for a single entity [e.g., Telecom carrier (carrier for short) or emerging Telecom/DC partnership company, etc.] who owns both the network and DC fields in the ecosystem, we introduce a new solution using open and disaggregation technologies for enhancing the resilience of the optical networks in an ecosystem, which is a heterogeneous multi-vendor, multi-domain, multi-field (i.e., Telecom network and DC) environment. For large-scale ecosystems in which the networks and DCs are owned by different entities, we observe that cooperation among datacenter providers (DCPs) and carriers is necessary to provide today's cloud services (especially for failure/disaster resilience); however, such cooperation is challenging since DCPs and carriers, being diffident entities, may not disclose confidential information, e.g., detailed resource availability. Hence, in the second part of this paper, we introduce another new solution for such multi-entity ecosystems to enhance the resilience of future ecosystems through cooperation between DCPs and carriers.

2. Resilient single-entity network-cloud ecosystems with openness and disaggregation

Motivation: Open and disaggregate reconfigurable optical add/drop multiplexers (ROADM) technologies are future proof for carriers to achieve lower CAPEX/OPEX. Moreover, they are beneficial to enhance the resilience of optical network in case of failure/disaster recovery, since carriers can flexibly select the equipment from multiple suppliers for repairing the damaged systems quickly, avoiding the risk of supply chain disruption of certain vendors. OpenROADM [1] is being developed to model the disaggregated ROADM and define the open specifications. A functional block-based disaggregation (FBD) model and an OpenROADM device model mapper have been developed and demonstrated to flexibly present/abstract the internal structures and constraints of disaggregated ROADMs at the component level [2][3]. For network orchestration, ONF transport API (TAPI) model [4] offers a unified abstraction scheme that facilitates the service integration across multi-vendor/multi-domain networks. In addition, studies towards open and disaggregated DC optical networks have been performed [5][6]. The FBD-based DC optical network integration has been introduced to handle the diversity of computing resource and facilitate future optically composable disaggregated computing [7][8]. To bridge research of Telecom network/DC fields and bolster the efficiency/resiliency of ecosystems, we are motivated to investigate new FBD-based solutions for flexible integration of Telecom and DC optical networks which are owned by a single entity via openness and disaggregation.

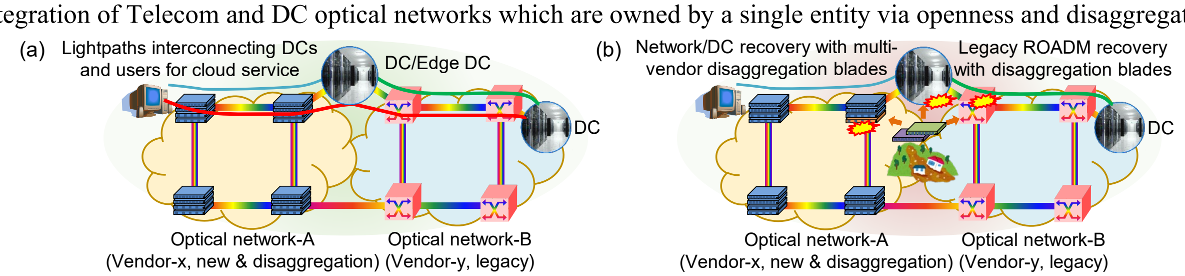

Fig. 1. Single-entity heterogeneous Telecom/DC integration use cases. (a) Telecom/DC optical network integration with a unified/open approach handling the coexistence of diverse devices and models in ecosystem, (b) Failure/disaster recovery with open/disaggregation technologies.

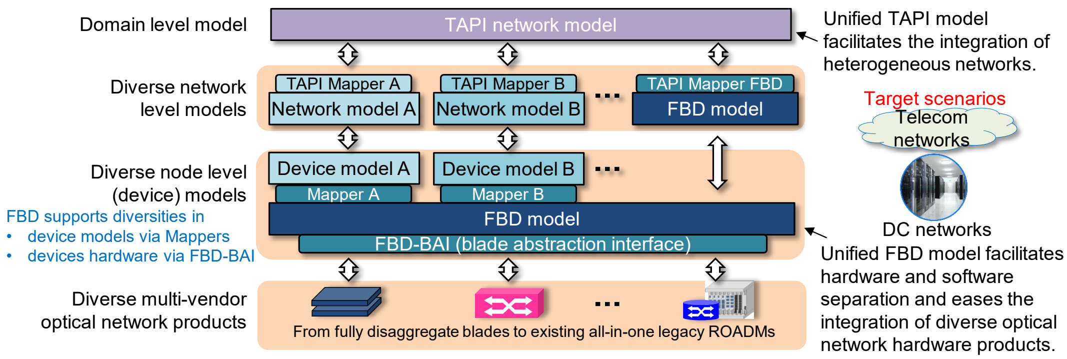

Fig. 2. Reference model for integration/control of heterogeneous Telecom/DC optical networks aided by FBD & TAPI.

Use cases: The use cases are illustrated in Fig. 1. (1) *Facilitating Telecom/DC optical network integration with a unified approach.* As shown in Fig. 1(a), to offer wider range of cloud service, distributed/Edge DCs are interconnected with multiple optical networks (*nb*: not only the newly built open/disaggregated networks but also the existing legacy ones with diverse hardware and device/network models). It is desirable that the heterogeneity in Telecom and DC optical networks can be handled in a unified and open way to simplify the lightpath/cloud service provisioning. (2) *Enhancing the resilience of ecosystems*. As shown in Fig. 1(b), in case of failures and disasters, to achieve swift recovery, the damaged blades in Telecom and DC open/disaggregation networks (e.g., network A and DC) can be quickly replaced by multi-vendor blades. Moreover, it is also desirable that the legacy ROADM can take advantage of openness and disaggregation to achieve quick recovery via vendors' new open/disaggregation products.

Problem and Research solution: Let us consider the problem: *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*? Fig. 2 shows our approach based on FBD [2][3] and TAPI [4] with a reference model. With this approach, we can handle the diversities in the vendors' hardware and different network integrators' device/network models. FBD model, an FBD-based blade abstraction interface (FBD-BAI) [9] and device/network model translation middle-ware (e.g., mappers) [3][10] between different models are presented. For device vendors such as blades or legacy ROADMs, FBD-BAI unifies the modelling method of the device with FBD and defines API between the node controller and diverse devices. FBD/BAI conceal the diversity of hardware and offer the unified blade model view (FBD) to node. For network system integrators using certain device/network models, with FBD/device-model mappers, diverse hardware can be recognized as the specified device and smoothly integrated into network with their device/network models. Owing to the enlarged scope of supporting devices, the supply chain can be significantly enhanced. For the single entity, with TAPI and TAPI-mappers, the integration of Telecom/DC with diverse network/service models can be achieved. We developed and demonstrated heterogenous Telecom/DC integration/control for disaster recovery [10]. The preliminary results will be introduced in the presentation.

3. Resilient multi-entity network-cloud ecosystems through cooperation between network and cloud

Motivation: Since a single entity has complete knowledge of network/DC infrastructures, it is possible to achieve both the optimal resource allocation for daily services and the optimal joint progressive network and DC recovery in case of failures/disasters [11]. But, in larger-scale ecosystems involving different entities, e.g., carriers and DCPs, confidential information, e.g., network topologies, content locations in DCs, etc., cannot be disclosed. Cooperation among the entities with appropriate incentives, is essential. To achieve the efficiency and resiliency in multi-entity ecosystems, we are motivated to investigate solutions to DCP-Carrier cooperation without violating confidentiality.

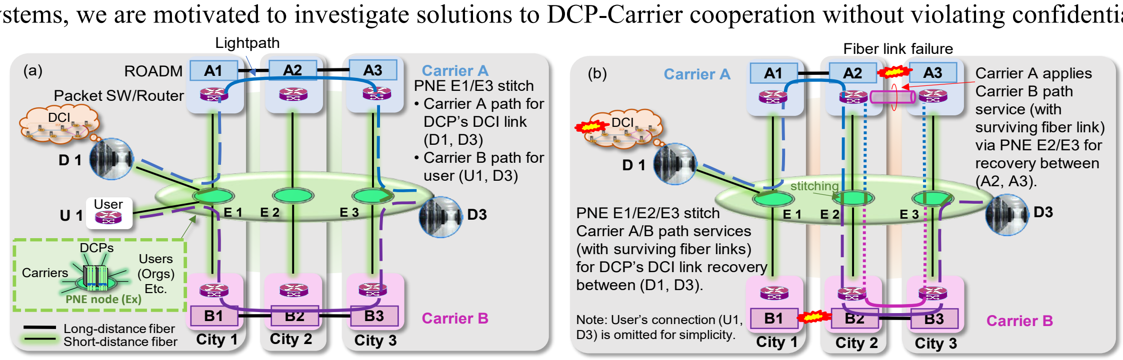

Fig. 3. Multi-entity DCP-carrier cooperation use cases. (a) network-cloud service jointed via PNE, (b) cooperative disaster recovery.

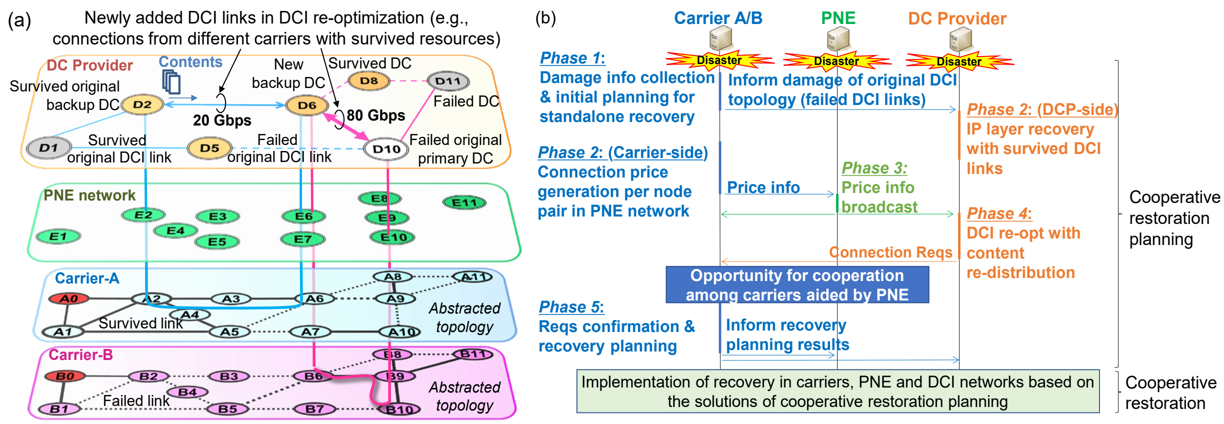

Fig. 4. Multi-entity DCP-carrier cooperative disaster recovery. (a) shared network view in cooperation, (b) distributed cooperative optimization.

Use cases: Fig. 3 illustrates two possible use cases. (1) *Cooperative resource allocation and service provisioning*. As shown in Fig. 3(a), *a third-party provider neutral exchange* (*PNE*) [e.g., distributed co-location centers or internet exchange points (IXPs)] interconnects different carriers (with overlapped coverage), DCPs, and users (organizations) that are in the same proximity at packet layer and offers DCPs/users multi-homing capability. Under cooperative resource allocation, DCP and user can establish a DC interconnection (DCI) link (D1, D3) and a user-cloud connection (U1, D3) with Carrier A and Carrier B connection services, respectively, via PNE nodes E1/E3. (2) *Enhanced resilience of ecosystems*. As shown in Fig. 3(b), in case of failures/disasters (e.g., concurrent failures of fiber links between Carrier A nodes A2 and A3, Carrier B nodes B1 and B2), under cooperation, the DCP's DCI link (D1, D3) can be quickly recovered via Carrier A and Carrier B connection services (e.g., with surviving resource and stitched by PNE node E2). Moreover, carriers can offer connection service to each other for swift recovery, e.g., a tunnel in Carrier A packet network between A2 and A3 is offered by Carrier B via PNE nodes E2 and E3.

Problem and Research solution: Let us consider the problem: *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?* Fig. 4 illustrates our DCP-Carrier cooperation approach mediated by a third-party PNE in a disaster recovery scenario. Fig. 4(a) shows a layered network view shared among cooperating carriers, DCP, and PNE. To conceal the detailed network topology and damage information, the carriers abstract their topologies to a common public PNE reference topology within the disaster area [12][13]. Carriers declare the price of connection service between PNE nodes (a higher price indicates a longer recovery time). Given this price (public) and the DC damage information (DC private), instead of waiting for carriers to recover services, DCP can re-optimize the DCI topology with survived resources for faster recovery. DCP can further perform content re-distribution (by replicating contents at suitable locations) to flexibly adjust the inter-DC traffic and better fit the carriers' network resource supply for efficient cloud service restoration. Fig. 4(b) shows the proposed cooperative planning for disaster recovery, including price sharing and individual optimization tasks on both the carrier-side and DCP-side. The optimization tasks distributed in multiple phases are performed based on the exchanged public information (facilitated by the PNE) and the private information of the stakeholders themselves without violating confidentiality. We investigate this solution [12] through preliminary evaluation and we observe the performance improvement in terms of cloud service restoration. The preliminary results will be introduced in the presentation.

4. Conclusion

We investigate the problem of enhancing the resilience of network-cloud ecosystems under different administrative scopes. For the single-entity ecosystem, we introduce and preliminarily evaluate a new solution with open and disaggregation technologies. For the multi-entity ecosystems, we introduce and preliminarily evaluate another new solution with cooperation between network carriers and DCPs. New open issues are envisioned as future work.

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