Implementation of PCE-based Management and Control Plane for Heterogeneous Optical Networks

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Abstract: This paper presents the implementation of an effective PCE-based management and control platform for heterogeneous optical networks. Experimental results show that it works well on network with commercial SDH and OTN equipments.

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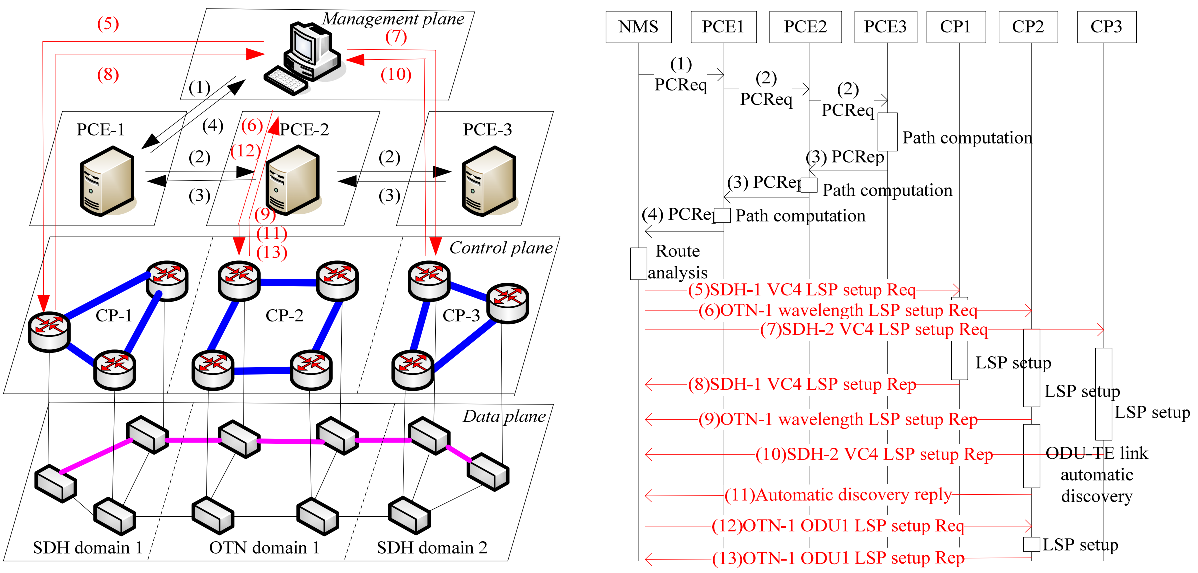
1. Introduction

With the development of general multi-protocol label switching (GMPLS), multi-domain and multi-layer architecture becomes more and more noticeable in large scale optical network. Path Computation Element (PCE), taken as a further extension of GMPLS, is a proper solution to multi-constrained Label Switched Path (LSP) computation. The basic PCE-based architectures are described in [1], and corresponding test-bed is built to evaluate their effectiveness. A centralized PCE-based architecture with inter-domain protected LSP provisioning is implemented [2-3], and the distributed PCE architecture combined with a service plane is also reported [4]. Besides, the architecture combining network management system (NMS), PCEs and network control plane (CP) is already validated to be a flexible preference in homogeneous network [5]. In this work, we propose the PCE-based Hybrid Control Heterogeneous Network (PHCHN) architecture, which transfers the inter-domain control from PCEs to NMS and remains the intra-domain control capability within CP. The PHCHN architecture is based on the fact that the control planes in different domains are sometimes not in existence, or independent and weak in communicating with each other in the commercial heterogeneous network. A network management system is designed to allocate the inter-domain resources and harmonize the inter-domain behaviors to upgrade the network smoothly. The experimental results show good performance in optical networks with commercial SDH and OTN equipments and the network scale is able to be extended to support more than 1000 nodes.

2. PCE-based network architecture



(A) (B)

Fig.1. The architecture and message flow of PHCHN: (A) Architecture; (B) Message flow

The PHCHN architecture is shown in Fig.1 (A). This architecture is mainly composed of four entities: an enhanced NMS, the PCEs, the GMPLS-based CP, and the data plane (DP). In our design, NMS is in charge of the global inter-domain information and multiple domains cooperation, such as multi-domain route analysis, inter-domain links control, automatic allocation of inter-domain resources and domain sequence determination etc. But the PCEs are distributed, holding only local information within their domains and concentrating only on the computation intensive assignments. Typically, both the working and protection paths can be computed by PCEs, based on intra-domain traffic engineering database (TED) synchronized from corresponding CP. The functional framework of each entity is also described in detail in Fig.2. This framework combines the advantages of both the centralized and distributed architecture together. Firstly, the centralized NMS reduces the overhead of interaction and cooperation among domains, and is more efficient for domain-sequence optimization. Secondly, multiple intra-domain LSPs can be established in parallel under control of NMS, which can reduce the setup delay of inter-domain connections, and performs better than other serial manners. Thirdly, the GMPLS control planes need little change to support the large-scale heterogeneous network, and both SDH and OTN networks can work well with each other by NMS based cooperation. Moreover, as the multi-domain and multi-layer route calculation is implemented by PCEs in a distributed manner, the network is much more scalable.

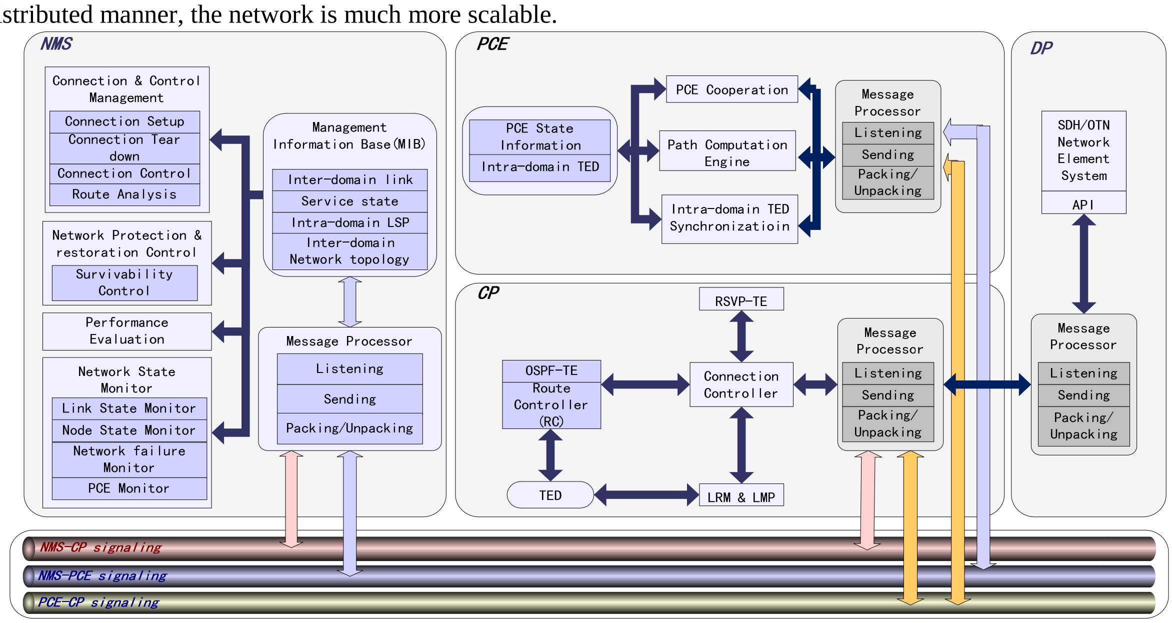


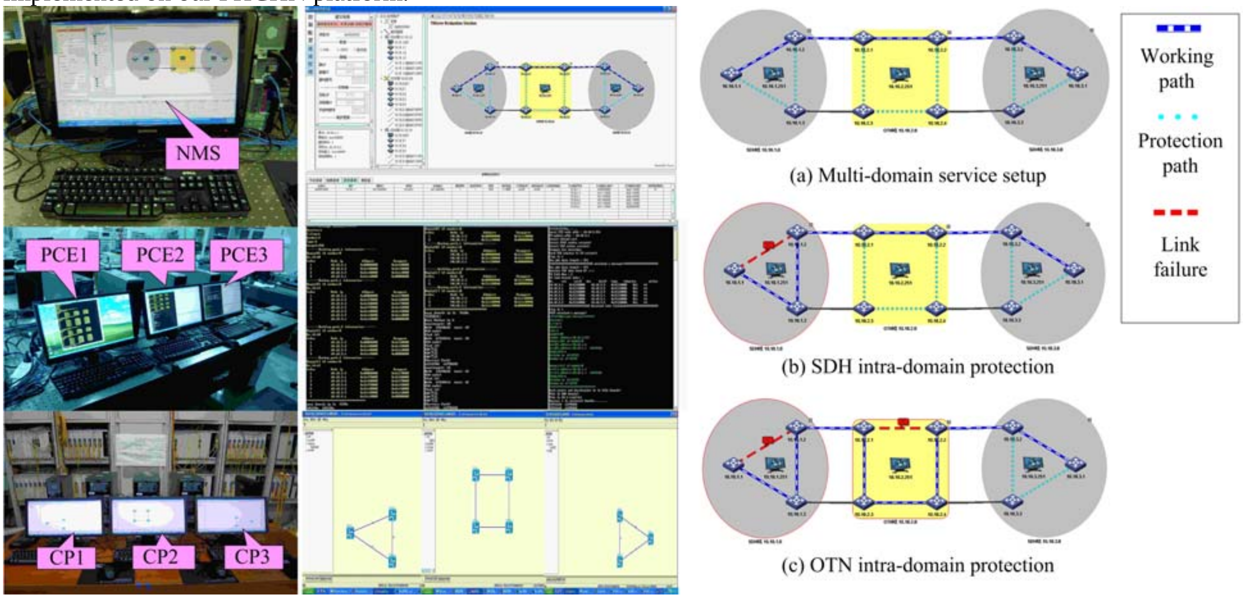
Fig.2. Internal frameworks and interactions of NMS, PCEs and CPs in PHCHN

An inter-domain and inter-layer connection setup procedure in PHCHN is taken as an example. The order of entity interactions and message flow can be found out in Fig.1 (A) and (B) correspondingly by sequence number in brackets. The PCE-n is in charge of the path computation in domain n, and the CP-n is responsible for dynamic control of nodes in DP of this domain. When a connection from domain 1 (SDH) to domain 3 (SDH) with no protection requirement comes, the NMS sends a path computation request (PCReq) message to the PCE in the source domain (PCE-1) (1). In order to transmit the PCReq to the PCE in the destination domain (PCE-3), PCE-1 passes the message to PCE-2 in domain 2 (OTN). The message is then relayed to PCE-3 by PCE-2 (2). With path being computed backward recursively by BRPC (backward recursive PCE-based computation) algorithm, the explicit route is formed and returned to PCE-1 (3), and then to NMS (4). The route analysis module in NMS splits the multi-domain route information into intra-domain ones and set them in parallel to the CPs respectively to establish LSPs (5~7). The confirmation messages from CPs are received and collected by NMS to decide the next operation (8~10). Especially, not the same as the route in SDH domain, the route in OTN is not a path in electrical layer but an optical path with larger granularity. So TE (Traffic engineering) links with smaller granularity on higher logical layer need to be discovered automatically by CP-2 and NMS. When the automatic discovery is completed (11), the NMS start to setup the up-layer LSP (12). The connection is set up after NMS receives the up-layer LSP reply (13). Besides, in this instance, a connection in VC4 granularity is considered. The LSP provisioning in domain 1(SDH-1 domain) and domain 3(SDH-2 domain) is also in VC4 granularity (with bandwidth in 155MHz), different from that in domain 2(OTN-1 domain) in ODU1 granularity (with bandwidth in 2.5GHz), which is carried on a lower optical layer (with bandwidth in 10GHz).

3. Multi-domain and multi-layer PHCHN test-bed

The PHCHN platform is constructed as shown in Fig.3 (A). Multiple servers are used to set up the test-bed, and the network entities communicate with each other in a virtual local area network (VLAN). A topology with 10 nodes and 14 links is presented as an example. It contains three domains as shown in Fig.3 (B): an OTN domain in the middle with yellow background, and two SDH domains on both sides with gray background. A connection from domain 1 to domain 3 is also presented in Fig.3 (B) (a).

Considering the network survivability requirements, intra-domain 1+1 protection and restoration in SDH and OTN domains are applicable on this platform as shown in Fig.3 (B) (b-c). Dynamic traffic grooming is also implemented on our PHCHN platform.



(A) (B)

Fig.3. The hardware platform of the large-scale PHCHN test-bed:
(A) Test-bed setup; (B) Protection switching in PHCHN with SDH and OTN equipments

4. Performance evaluation

Several performance parameters are evaluated through experiments on the PHCHN test-bed. With the parallel signaling mechanism between the NMS and CPs implemented, the real time characteristic is improved for the test-bed. As the experimental results show, the per-domain connection is established within 200ms, and the inter-domain connection with 1+1 protection sets up in 530ms, without considering the TE link automatic discovery procedure, due to the uncertainty of its implementation. The mean time interval for connection protection switching is within 220ms. Scalability is another feature to evaluate our test-bed. As the number of PCEs increases with the network scale, no less than 1000 SDH and OTN emulated optical nodes are supportable by this platform.

5. Conclusion

We have designed and constructed the PHCHN platform. The management and control plane for heterogeneous network are implemented and validated in the commercial SDH and OTN networks. Real time characteristic and scalability show good performance on the test-bed. A novel network based on this architecture with 1000 nodes is verified to be feasible and is being set up.

6. Acknowledgement

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7. Reference

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