Implementation and Experiments of Path Computation Element-based Inter-Domain Network Control and Management

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Abstract

This paper proposes PCE-based inter-domain network architecture, and verifies its feasibility through implementation and experiments. PCEP is implemented between PCE and management system, and inter-domain LSPs are successfully established.

Introduction

To automate control and management of multi-layer networks, Generalized Multi-Protocol Label Switching (GMPLS) is in progress [1]. Also, to ensure scalability improvement and policy considerations, the Path Computation Element (PCE) is being considered [2].

We have been proposing the PCE-based network architecture, by combining GMPLS, PCE and the management system [3]. This architecture allows that the management plane can off-load (near) real time tasks to the control plane (including to the PCE).

This paper proposes the enhancement of the PCE-based network architecture to support large-scale networks, i.e., inter-domain networks. The strength of this paper is that feasibility of inter-domain LSP provisioning (path computation and signalling) is verified by the use of GMPLS, PCE and the management system. Namely, not only path computation but also signalling is tested in the experimental network, where the management system glues these two steps (click and provisioning). There is a previous report on implementation of PCEs in support of inter-domain path computation [4], but to our knowledge, a report of feasibility verification of inter-domain LSP provisioning is for the first time.

PCE-based Inter-domain Network Architecture

Figure 1 shows the proposed PCE-based inter-domain network architecture. PCE communication Protocol (PCEP) is used between the management system and the PCE, and between PCEs.

The management system has an operator interface. It communicates with the node (or more precisely controller that implements GMPLS protocols, which may be out-of-box for each node) for configuration and network information collection (such as alarms). It also communicates with the PCE for path computation requests and replies.

The PCE stores network information (e.g., by listening GMPLS routing). It receives path computation requests, performs path computation, and sends path computation replies. For path computation across multiple domains, multiple PCEs cooperate.

This architecture has the following two key points.

- The path computation function is separated from the management system to the PCE. This ensures that CPU intensive complicated path computation can be performed in a dedicated server. The management system does not need to keep up-to-date network information. In addition, functional evolution of the management system and the PCE would be easier.
- PCEs are distributed per domain. This ensures scalable path computation, compared to the single PCE case. The PCE needs to contain only per domain network information, not global network information. In addition, computation load can be spread across multiple PCEs.

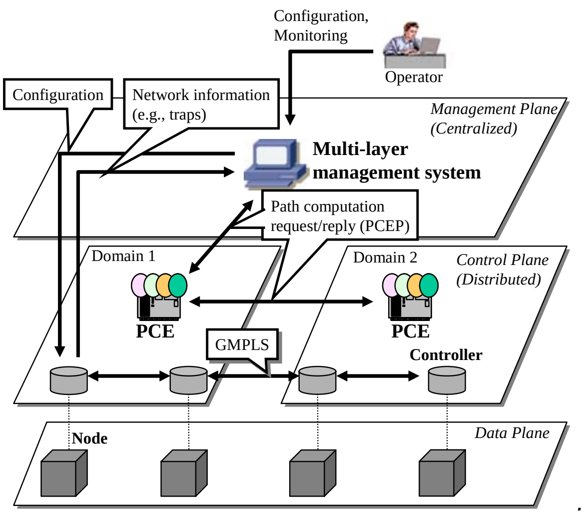

Figure 1: PCE-based inter-domain network architecture.

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Note that even though PCEs are distributed, it is still possible to guarantee that the shortest metric path is computed if it exits, under constraints such as bandwidth. This technique is called Backward Recursive PCE-based Computation (BRPC). This is a big advantage compared to path computation without PCEs, called per-domain path computation.

Implementation and Experiments

The proposed architecture is implemented to verify its feasibility. An operation scenario of inter-domain LSP provisioning is focused.

Figure 2 shows details on how the management system and the PCEs interact. When the management system receives operator command (1), it sends a path computation request (PCReq) to the PCE in the source domain (PCE1) (2). PCE1 then relays a PCReq to the PCE in the destination domain (PCE2) (3). PCE2 computes its own segment of path, and sends a path computation reply (PCRep) to PCE1 (4). PCE1 then computes the end-to-end path and send a PCRep to the management system (5). After operator check (6), the management system sends a CLI command to the ingress node to initiate LSP setup (7). Then, GMPLS signalling establishes an LSP (8). Finally, LSP setup is confirmed (9).

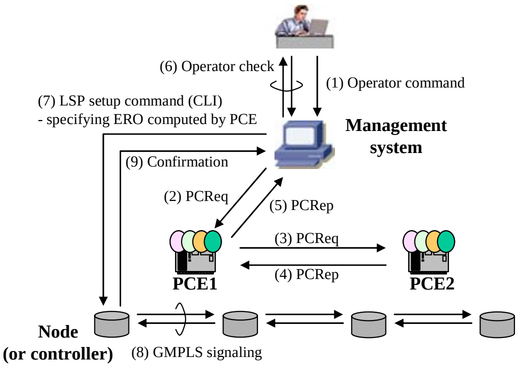

Figure 2: Provisioning scenario.

Figure 3 shows the network topology for experiments. It is inter-AS configuration composed of two domains. Six TDM cross connect emulators represented as Node1-6 in Fig.3 are used, which implement GMPLS signalling and routing. PCEP is implemented between the management system and the PCE, and between PCEs as mentioned.

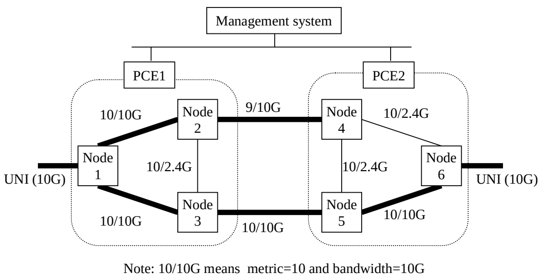

Figure 3: Experimental network topology.

Figure 4 shows the representative experimental result by the management system GUI. A solid line along Node1-Node3-Node5-Node6 is the established LSP. An LSP is requested between Node1 and Node6 with 10G bandwidth (OC192/STM64). PCEs compute the shortest metric path excluding links below 10G, and an inter-domain LSP is successfully established.

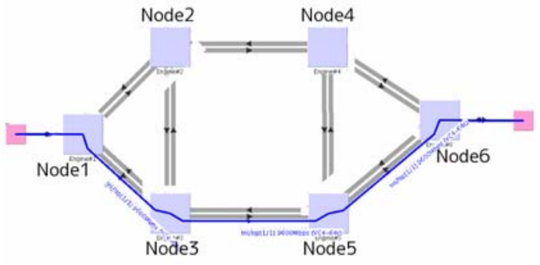

Figure 4: Provisioning result.

A provisioning scenario of inter-domain disjoint LSPs is also verified. Pair of link/node disjoint LSPs are established by the use of Exclude Route Object. Namely, after computing the primary LSP, the secondary LSP is requested with constraints to exclude hops along the primary LSP. Disjoint LSPs are established along Node1-Node2-Node4-Node6 and Node1-Node3-Node5-Node6.

Due to lack of space, details are not described, but inter-area configuration is also verified.

Conclusions

This paper proposed the PCE-based inter-domain network architecture, and verifies its feasibility through implementation and experiments. The proposed architecture is scalable yet allows end-to-end shortest metric path computation and diverse path computation. PCEP is implemented between the PCE and the management system, and inter-domain LSPs are successfully established.

Acknowledgement

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References

1. E. Mannie, "GMPLS architecture," IETF RFC3945, Oct. 2004.
2. A. Farrel, J. P. Vasseur and J. Ash, "A PCE-based architecture," IETF RFC4655, Aug. 2006.
3. K. Fujihara et al., “Implementation of Multil-Layer-Network Operation and Management Architecture,” IEICE Technical Report, Oct. 2007 (in Japanese).
4. F. Paolucci, F. Cugini, L. Valcarenghi, P. Castoldi, “Enhancing Backward Recursive PCE-based Computation (BRPC) for Inter-Domain Protected LSP Provisioning,” OFC 2008.