Chapter 11
The Path Computation Element (PCE)

Francesco Paolucci
Scuola Superiore Sant'Anna, Italy

Filippo Cugini
CNIT, Italy

ABSTRACT

The Internet Engineering Task Force (IETF) has promoted the Path Computation Element (PCE) architecture to provide effective network resource utilization while guaranteeing advanced Internet applications with adequate quality of service (QoS). The PCE is a dedicated network entity devoted to path computation. This chapter presents the state-of-the-art of the PCE architecture for different networking scenarios including single-domain networks, optical networks, and multi-domain/layer networks. Relevant architectural and implementation aspects are analyzed and discussed, highlighting related benefits, limitations and open issues. Recent progresses and future directions are also addressed, including the PCE evolution to operate in the context of software defined networking.

INTRODUCTION

Multi-Protocol Label Switching with Traffic Engineering extensions (MPLS-TE, Awduche et al, 1999) and Generalized MPLS (GMPLS, Mannie, 2004) provide the Traffic Engineering (TE) capability to forward traffic flows along explicit routes, namely Label Switched Paths (LSPs). The TE capability allows to perform path computation subject to additional QoS constraints typical of such networks, e.g., guaranteed bandwidth in MPLS networks, spectrum continuity constraint in optical networks. TE relies on resource availability and topology information collected through routing protocols, such as Open Shortest Path First with TE extensions (OSPF-TE, Katz, Kompella, & Yeung, 2003) or Intermediate System to Intermediate System with TE extensions (ISIS-TE, Li T. & Smith H. (2008). In LSPs provisioning, the path computation process represents one of the crucial steps to achieve TE objectives, including optimizing network resource utilization.

Within a given domain, the path computation is usually determined by the routing information collected at the head-end node, while resources are reserved during the signaling phase, exploited

DOI: 10.4018/978-1-4666-8371-6.ch011

through distributed protocols, such as the Resource reSerVation Protocol with TE extensions (RSVP-TE, Awduche et al, 2011). The separation between the routing and signaling operations may lead to sub-optimal TE solutions generally inducing a waste of network resources. In optical networks, the impairment-aware spectrum assignment process, may introduce additional potential TE inefficiencies (e.g., worst case impairment assumptions). Moreover, distributed path computation may require heavy processing at each source (control plane) node, especially when based on multiple constraints. Moving from single-domain single-layer scenarios to multi-layer/technology, multi-vendor and inter-domain, additional issues arise, such as restricted topology visibility due to scalability reasons and/or administrative constraints among others. For example, when the source and destination of a traffic request belong to different administrative domains, the need to preserve operator- and policy-specific information confidentiality and integrity across domains prevents the open advertisement of detailed intra-domain network resources. Such limitations considerably complicate path computation and affect the inter-layer/inter-domain TE performance in terms of the overall network resource utilization.

The aforementioned path computation restrictions for provisioning end-to-end connections are at the basis of a significant research and engineering activity carried on in the last years and still active nowadays in the context of core network control plane developments.

The Internet Engineering Task Force (IETF) has proposed a set of techniques defined under the umbrella of the Path Computation Element (PCE) architecture (Farrel, Vasseur, & Ash, 2006). Such techniques rely on path computation, performed by dedicated network entities (i.e., the PCEs).

The PCE collects link-state information from network nodes and performs path computation on behalf of network nodes. In addition, it may resort to other information sources, such as the network management system (NMS), to retrieve detailed information about resource utilization or physical network parameters (e.g., link/span length and impairments in optical networks). The PCE provides the additional advantage that network nodes can avoid highly CPU-intensive multi-constraint path computations and effective TE solutions are achievable also in case of legacy network nodes. For example, NMS can be used as Path Computation Client (PCC) to communicate with PCE to get path information and then supply head-end node with full explicit path (e.g. using the management interface, like the TE management information base (MIB) module (Srinivasan, Viswanathan & Nadeau, 2004).

Communication between a PCC (i.e., a network element or an NMS willing to request a path), and the PCE is implemented using the Path Computation Element communication Protocol (PCEP, Vasseur & Le Roux, 2009). The PCE is responsible for the path computation in its own layer/domain, where it has full visibility and updated information on available network resources. Cooperation between PCEs takes place in multi-layer/domain scenarios by sharing the result of each (intra-domain) path computation expressed as, for example, border node(s) to traverse, intra-domain path segments, metric values. The combination of these results provides the entire source-destination path, and no additional information is exchanged among different domains. Specific techniques and procedures have been proposed and defined for each specific scenario.

This chapter discusses the main activity efforts in utilizing the PCE architecture in the context of single-domain, multi-layer and multi-domain networks, including a specific focus on optical networks. The role of PCE is analyzed and discussed for what concerns LSP provisioning and also reliability aspects.

In the following sections we first provide a general overview of the PCE architecture. The main PCEP messages, objects and operations are also detailed. Then, we analyze the PCE applicability in various network scenarios, starting

Related Content