Network Management Challenges and Trends in Multi-Layer and Multi-Vendor Settings for Carrier-Grade Networks

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***Abstract*—The exponential growth of Internet traffic gives no respite to the telecommunications industry, and is visibly shortening the life-cycle of the technologies used for core networking. To cope with the traffic demand, the industry has primarily focused on the evolution of the data and control planes, and has rapidly made progress in both subjects. However, the innovations in the market have not reached the management plane at the same speed. This stems from a number of factors, most of which point to the segmentation of competencies in managing multi-layer infrastructures. Current carrier-grade networks are organized as multi-layer infrastructures, typically composed of two layers: IP routers deployed in tandem with optical transport nodes. In turn, each of the two layers is typically composed of devices from different vendors, each of which usually supplies its own (proprietary) Network Management System (NMS). In practice, the lack of broadly accepted mechanisms for enabling interoperability among the different NMSs has led to the isolation of these proprietary systems. As a result, the operation and maintenance tasks on the network are becoming increasingly complex, which is leading to duplication of functions, higher OPEX, and significant delays in the coordination of multi-layer provisioning processes. In this paper, we examine in detail the interoperability challenges of managing multi-layer and multi-vendor carrier-grade networks, and review the current trends and recent standards in the area, with strong focus on industrial advances. We cover the Multi-Technology Operations System Interface (MTOSI) as well as OpenFlow, and analyze their potential impact and reach. We also discuss some of the reasons why relevant carrier-grade management proposals have not been able to fulfill the requirements of Internet Service Providers (ISPs), and identify a set of features that might help pave the way to market for new management products.**

***Index Terms*—Networks, management, multi-layer, multi-vendor, IP, optical, interoperability.**

I. Introduction

To cope with the ever-increasing bandwidth demand, current carrier-grade networks have evolved to multi-layer infrastructures, typically composed of IP switching and routing devices deployed in tandem with optical transport gear. Indeed, the convergence of IP and optical transport networks has been at the heart of telecom carriers' strategies and investments, not only for improving the scalability and switching efficiency in the IP core, but also for achieving higher switching capacities at lower costs. This trend is actually leading to the utilization of "more optics" in the network, since carriers are gradually offloading transit traffic from expensive high-end routers toward cheaper and more energy-efficient optical nodes [1], [2], [3], [4], [5], [6].

For the sake of clarity, in the context of this article we will refer to the *"IP Layer"* as the IP framing layer in the TCP/IP reference model [7], i.e., a layer ruled by packet-based switching, whilst the *"Transport Layer"* refers to the optical network providing the physical transmission layer, i.e., a layer ruled by optical-based switching. Observe that the latter is different from the Layer 4 (L4) of the traditional Open Systems Interface (OSI) and TCP/IP reference models. Figure 1 illustrates the mapping between the classical OSI and TCP/IP reference models and the layered model of a multi-layer carrier-grade network. Observe that we present three possible approaches for the layering model of a carrier network, which are representative of different deployment scenarios—mainly indicating the time progression from left to right. The term *Intelligent Optical Transport Network (OTN)* in Fig. 1, typically refers to an optical network endowed with more advanced control planes, such that it can offer rapid circuit provisioning, service flexibility, multi-vendor interoperability and enhanced survivability [8].

Overall, carrier-grade networks are currently experiencing considerable changes. In the process of evolving to multi-layer infrastructures, the telecommunications industry has made remarkable advances in the data and control plane technologies. The former is evidenced by the advances made from IP over optical transmission at 10G to 40G, and now 100G and beyond, while the latter is reflected in the increasing supply of equipment supporting cross-vendor interoperability in conformance with major standards, such as the Generalized Multi-Protocol Label Switching (GMPLS) [9], and the Automatically Switched Optical Network (ASON) architecture [10]. However, the innovations in the management plane have not been able to keep that pace. Indeed, the advances in this area lag far behind carriers' expectations, and they are making network management tasks increasingly more complex. This complexity lies in part on the rich set of functionalities that network

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