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Multi-layer architecture for realization of network virtualization using MPLS technology[☆]

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Abstract

Network virtualization (NV) increases Internet flexibility by separating policies from mechanisms. This makes developing new applications, managing the Internet, and supporting different applications much easier. In this study, we introduce a multi-layer architecture which combines multi-level multiprotocol label switching (MPLS) technology with NV. The proposed architecture combines the high speed advantage of MPLS with the high flexibility of NV. We use MPLS in MPLS technique and encapsulate each MPLS packet within another when it encounters a new virtual network. Our architecture has the potential to improve Internet flexibility and pave the way for deployment and commercialization of NV in next generation networks.

Keywords: Network virtualization; MPLS in MPLS; Two-level architecture; Multi-core internet

1. Introduction

As one of the most popular and continually growing technologies, the Internet has encountered several major deployment barriers much earlier than one might expect. Some current Internet limitations such as difficulties in supporting contradictory policies for beneficiaries, lack of flexibility in supporting new applications, and overwhelming management complexities could be handled through reasonable expenses [1,2]. The Internet research community has spent considerable effort over the past years to solve these problems. Particularly, network virtualization (NV) [1–7] and multiprotocol label switching (MPLS) [8–11] are of special importance because they tackle two fundamental drawbacks of the Internet: insufficient flexibility and inefficient packet forwarding. Despite these efforts, we must continue to develop new technologies or combine existing technologies in creative ways to overcome the major barriers of Internet with reasonable cost.

With the emergence of an increasing number of operators in cellular networks, all using a shared infrastructure, providing various services to end users with different needs and demands is easy. In a similar manner, a virtual internet service provider (ISP) leases a portion of routers' processing capability and links' bandwidth from an infrastructure network and creates a virtual network over it. The virtual ISP can then organize the leased resources to overcome traditional problems of the Internet such as quality of service (QoS) assurance, clients accounting, management complexities, and a limited variety of services. It can provide desired services to users much more efficiently than can a traditional ISP.

While NV is extremely flexible, the lack of a fast and reliable implementation prevents it from growing to its full and desired capabilities [4]. By contrast, MPLS, which is praised for its impressive performance in core networks, accelerates IP packets forwarding considerably. In this study, we combine the high flexibility of NV with the forwarding speed of MPLS to create a fast, deployable, yet flexible architecture. Our solution is simple

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and practical. We use MPLS in MPLS [9] and add a new label level to the MPLS label stack whenever the packet encounters a new virtual network. The idea of multi-level label switching is used by research communities for different purposes [8,12,13]. We use Petri nets modeling [14] and CPNTOOLS [15] for verification and performance evaluation of our architecture.

The rest of this paper is organized as follows. In Section 2, we briefly review NV and MPLS technologies. The proposed architecture is presented in Section 3. Section 4 presents simulation results. Related studies are discussed in Section 5, and Section 6 provides a conclusion.

2. Network virtualization and MPLS

2.1. Network virtualization

NV technology builds several isolated heterogeneous logical partitions under the following architectural design principles: concurrency, nesting (recursion), inheritance, and reuse. These partitions are created as logical layers on a shared physical layer so that each layer of a virtual network is independent and isolated from the physical and other virtual layers (Fig. 1) [3]. A **virtual node** is an abstraction of a physical node, which performs the role of a node in the virtual network. A virtual node can be a router or switch. **Virtual link abstraction** allows us to establish several virtual links on a single physical link. Each virtual link is identified by a label. Sometimes, a group of virtual links follow a shared route from a virtual node to another virtual node. A **virtual network** is a virtual isolated logical partition that has been created by an abstraction of other networks or infrastructure networks and has its own topology and technology [2–6].

2.2. MPLS

MPLS is a data transmission technology that inserts a new header to replace the IP lookup forwarding procedure with a much simpler label switching process. An MPLS header uses the label field in asynchronous transfer mode (ATM) and frame relay protocols, or a part of a packets header that lies between the link layer and IP layer headers. An MPLS header consists of the following fields:

- **Label**: a 20 bits field that includes the MPLS label.
- **Class of Service or Traffic Class**: a three-bit field that demonstrates the class of provided services.
- **Stack (S)**: a single bit field that shows the end of the label stack. If S is set, it means that the current label is the last one in the stack.
- **Time to Live (TTL)**: a 8 bits field that acts similarly to the TTL field in an IP header.

Two types of routers exist in the MPLS architecture: 1-**Physical Edge** (PE) and 2-**Core** (P) routers. A PE router is located on the edge of an MPLS network and acts as an entry or exit point for an MPLS network. At the entry point, a PE router receives incoming packets from the outside (e.g., from an IP network), and after inserting an MPLS header, delivers them to the P routers, which are located inside the MPLS core network. Typically, a P router forwards data packets using label switching. If the packet enters a different subnet (administrative-wise), a new label is added to its label stack by the subnet PE router. Inside the subnet, the packet forwarding process is performed according to that label. The label is removed by the PE router at the exit point of the network once the packet leaves the subnet [8–11].

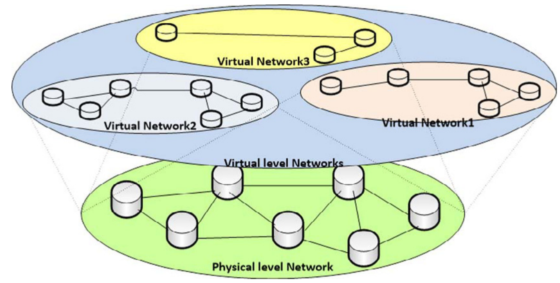

Fig. 1. Relation between virtual and physical networks.

3. Proposed architecture

In an MPLS networks, the infrastructure network is divided into three layers [8]:

- **Access layer** includes **Customer Edge** routers, which are located on the edges of the main network and act as access routers. They deliver incoming IP packets from a LAN to the next layer routers.
- **Intermediate layer** consists of PE routers that, after having an MPLS label added to the packets, receive incoming IP packets from the access layer and deliver them to the core layer.
- **Core layer** comprises P routers that receive packets from PE routers, add a second label, and forward them using the MPLS forwarding scheme.

This architecture suffers from three drawbacks. First, it lacks adequate flexibility to accept new services. Second, because all traffic flows converge to the core layer, it may easily become a performance bottleneck. Third, within this architecture, network applications cannot adjust their transmission rate freely.

3.1. MPLS in MPLS architecture

We divide the network into two levels: virtual and physical. More importantly, we employ MPLS technology at both levels to transmit data packets (see Fig. 2). We establish a virtual level inside the intermediate and core layers of the physical network (i.e., both PE and P routers support virtualization). In addition, each virtual network uses MPLS transmission technology to forward packets along constructed virtual paths. When a packet passes from a physical to a virtual level, the corresponding PE router adds a label to the label stack. If the packet is in the virtual level, the label is called a **virtual label** (VL). Similarly, the label is called **physical label** (PL) if the packet is in the physical level. Using additional labels has two side effects: first,