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Comparison between Traditional IP Networks/Routing and MPLS

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Abstract: ***This paper gives the theoretical comparison between Traditional IP Networks and MPLS. MPLS stands for Multiprotocol Label Switching. MPLS was created to combine the benefits of connectionless Layer 3 and forwarding with connection-oriented Layer 2 forwarding. MPLS clearly separate the control plane, where Layer 3 routing protocols establish the paths used for forwarding, and data plane, where Layer 2 label switched paths forward data packets swapping. The simplicity of data plane packet forwarding and its similarity to existing Layer 2 technologies enable traditional WAN equipment (ATM or Frame Relay switches) to be redeployed as MPLS nodes just with software upgrades to their control plane. In traditional IP network, a router analyzes the destination IP address independently at each hop. Dynamic routing or static routing builds the database needed to analyze the destination IP address. Traditional IP networks/routing has several well-known limitations, ranging from scalability issues to poor support of TE.***

Keywords: MPLS, IP, TE, ATM

1. Introduction to MPLS

MPLS stands for Multi-Protocol label switching, is now a days a popular technology which has grabbed the attention of network service provider because of its routing performance. Internet Engineering Task Force (IETF) proposed this technology [1]. MPLS is a hybrid layer2/Layer3 service that attempts to bring together the best of words: Layer 2, Layer 3, ATM, and IP. Multiprotocol Label Switching (MPLS) has been around for several years. It is a popular networking technology that uses labels attached to packets to forward them through the network.
Multiprotocol Label Switching (MPLS) has evolved from being a buzzword in the networking industry to a widely deployed technology in service provider (SP) networks. In recent years, MPLS has also been adopted by the enterprise and federal market segments. MPLS is a contemporary solution to address a multitude of problems faced by present-day networks: speed, scalability, quality of service (QoS) management, and traffic engineering.
MPLS is a forwarding mechanism in which packets are forwarded based on labels.

The MPLS labels are advertised between routers. The IP packets are prefixed by these labels and forwarding is done on the basis of these labels and not by destination IP address that means forwarding of packets is based on lookup of labels rather than a lookup of the IP addresses hence speeding up the routing procedure.

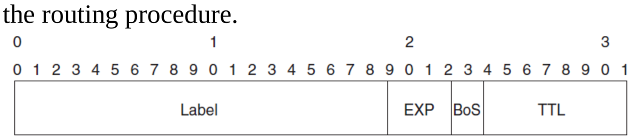

Figure 1: Syntax of MPLS Label

An MPLS label consists of the following parts:
- 20-bit label value
- 3-bit experimental bits for QoS (Quality of Service)
- 1-bit bottom of stack indicator
- 8-bit Time-to-Live (TTL) field

The 20-bit label value is the number assigned by the router that identifies the prefix.

The 3-bit experimental field defines the QoS assigned to the FEC that has been assigned a label. For example, the 3 experimental bits can map to the 7 IP precedence values to map the IP QoS assigned to packets as they traverse an MPLS domain.

A *label stack* is an ordered set of labels where each label has a specific function. If the router (Edge LSR) imposes more than one label on a single IP packet, it leads to what is called a label stack, where multiple labels are imposed on a single IP packet. Therefore, the *bottom-of-stack indicator* identifies if the label that has been encountered is the bottom label of the label stack.

The TTL field performs the same function as an IP TTL, where the packet is discarded when the TTL of the packet is 0, which prevents looping of unwanted packets in the network. Whenever a labeled packet traverses an LSR, the label TTL value is decremented by 1.

The label stack sits in front of the Layer 3 packet - that is, before the header of the transported protocol, but after the Layer 2 header. Often, the MPLS label stack is called the *shim header* because of its placement.

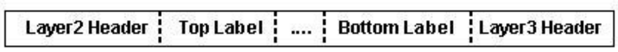

Figure 2: Encapsulation for Labeled Packet

2. MPLS and the OSI Reference Model

In computer networking and telecommunications, Multiprotocol Label Switching (MPLS) is a data-carrying mechanism which emulates some properties of a circuit-switched network over a packet-switched network. MPLS operates at an OSI Model layer that is generally considered to lie between traditional definitions of Layer 2 (data link layer) and Layer 3 (network layer), and thus is often referred to as a "Layer 2.5" protocol. It was designed to provide a unified data-carrying service for both circuit-based clients and packet-switching clients which provide a datagram service model. It can be used to carry many different kinds of traffic, including IP packets, as well as native ATM, SONET, and Ethernet frames.

MPLS is a hybrid layer 2/layer 3 service that attempts to bring together the best of both worlds: layer 2, layer 3, ATM, and IP. MPLS is a framework that contains enhancements to the current layer 3 and layer 2 technologies makes it hard to fit MPLS within one layer of the OSI model. MPLS alone cannot be considered a layer in the OSI sense, since it does not have a unified format for the transport of data from the layer above: It uses a shim header over SONET or Ethernet; it uses the existing VPI/VCI of ATM. And so on. However, an individual MPLS function could be categorized as either an OSI layer 3 or layer 2 functions [2].

3. Architectural Blocks of MPLS

MPLS has two major components:

(a) Control Plane
(b) Data Plane

The control plane exchanges layer 3 routing information and labels. It contains complex mechanisms to exchange routing information such as OSPF, EIGRP, IS-IS, and BGP. It also contains mechanism to exchange labels such as TDP, LDP, RSVP etc.

Data plane performs the functions relating to forwarding data packets. These packets can be either Layer 3 IP packets or labeled IP packets. The information in the data plane, such as label values are derived from the control plane. Information exchange between neighboring routers creates mappings of IP destination prefixes to labels in the control plane, which is used to forward data plane labeled packets.

The MPLS Control Plane consists of

(a) IP Routing Protocols
(b) IP Routing Table (RIB)
(c) Label information Base (LIB)

The MPLS Data Plane consists of

(a) Forwarding Information Base (FIB)
(b) Label Forwarding Information Base (LFIB)

4. MPLS Forwarding and Operation

Forwarding labeled packets is quite different from forwarding IP packets. Not only is the IP lookup replaced with a lookup of the label in the label forwarding information base (LFIB), but different label operations are also possible. These operations refer to the pop, push, and swap operations of MPLS labels in the label stack.

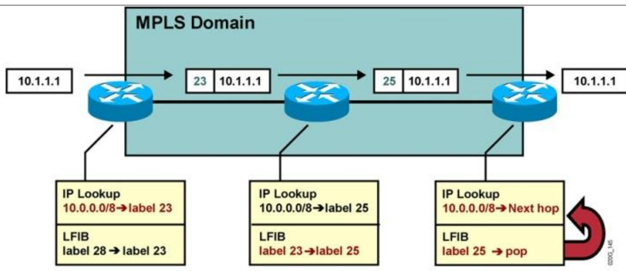

Figure 3: An example of MPLS Forwarding

Building the IP Routing Table

The IP routing protocols are used to build IP routing tables on all LSRs. FIBs are built based on IP routing tables with no labeling information.

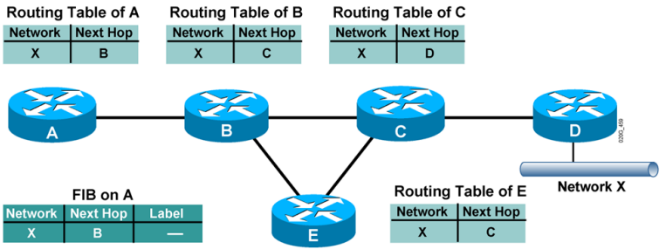

Figure 4: Formation of IP Routing Table

Allocating Labels

Every LSR allocates a label for every destination in the IP routing table. The labels have a local significance. The label allocations are asynchronous.

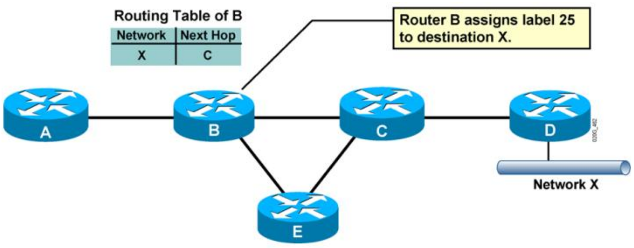

Figure 5: Allocation of Labels

Every LSR will eventually assign a label for every destination.

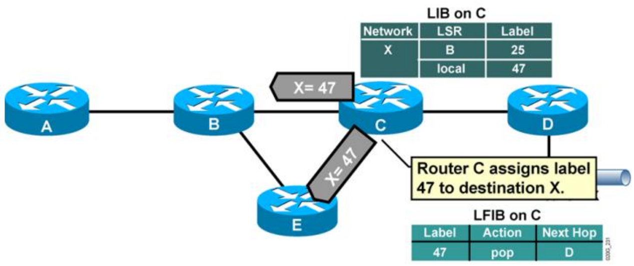

Figure 6: Further Allocation of Labels

LIB and FLIB Setup

LIB and FLIB structures have to be initialized on the LSR allocating the label.

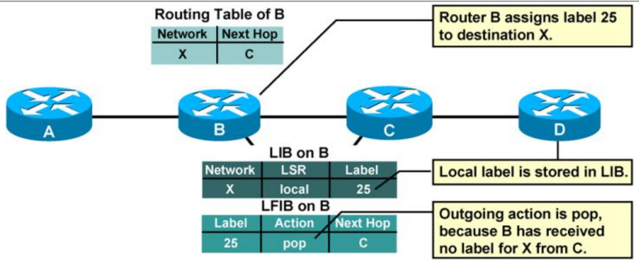

Figure 7: LIB and FLIB Setup Process

Label Distribution and Advertisement

The allocated label is advertised to all neighbor LSRs regardless of whether the neighbors are upstream of downstream LRSs for the destination.

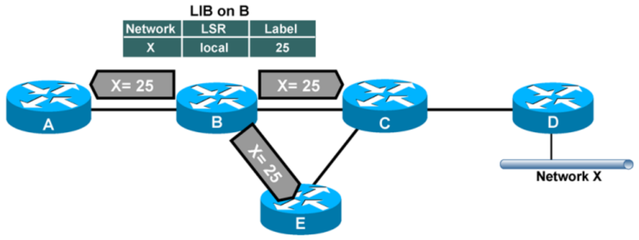

Figure 8: Process of Label Distribution and Advertisement

5. Literature Review

The MPLS protocol was initially proposed in RFC 3031 by Rosen, E.Viswanathan, and A. Callon [3]. A lot of study was carried out in the field of MPLS to know the benefits of MPLS.

Lee et al [4] studied a performance of MPLS-over-GRE based VPN. As per study, MPLS VPNs are one of the most widely deployed VPN architectures in the global Internet. However, a major prerequisite for MPLS VPN is the support for MPLS in all the provider core routers. The situation becomes complicated when service providers themselves use a backbone carrier to bring connectivity to their networks since the ability of the backbone to support MPLS connectivity would be crucial to the service provider. An MPLS-over-GRE (generic routing encapsulation) tunnel is a new concept that has been proposed to bring MPLS connectivity between networks that are connected by an IP-only network. The aim of this study was to evaluate the performance of MPLS carrier supporting carrier configuration with and without MPLS-over-GRE tunnels. The MPLS signaling and encapsulation is enclosed inside a GRE header between VPN sites routers, PE or CE. The drawback of this approach is less performance the native MPLS VPN and limited QoS guarantee when IP packet traverse single or multiple providers managed backbones.

Cyril et al [5] carried out Performance Evaluation of Multicast Transmission on MPLS network using PIM SM. This study evaluated the performance of Protocol Independent Sparse Mode (PIM-SM) multicasting protocol over Multi-Protocol Label Switching (MPLS). MPLS is now the De-facto standard for many carrier and service provider networks. MPLS is a simple and flexible solution for multiservice networks. Labels used in MPLS network for forwarding and routing packets provide indices to the routing tables enhancing the speed requirements. Hierarchical Virtual channeling imparts scalability to the MPLS networks. MPLS and Multicasting are two complementary technologies. Merging of these two technologies put forwards an efficient networking scenario that delivers solution to scalability and control overhead problems. MPLS supports multicasting. The simulator used for performance evaluation is NS2. The PIM-SM over MPLS network was found to have an edge over the traditional network. The throughput for MPLS with PIM-SM was very much higher in comparison to traditional network. Excellent packet delivery ration found in MPLS with PIM SM as against traditional networks. Also the percentage of dropped packet was substantially reduced.

Satish et al [6] studied the MPLS over ATM network. As per study, MPLS is high lightened as the most promising technology for the ATM backbone network. This MPLS improves in reducing the traffic in the network and increases the bandwidth. ATM switch network for the fast Internet services which makes use of virtual network for switching between routers by adding a layer 3 routing module to the existing ATM network and can provide scalable Internet services to users with various service levels. This paper presents an implementation of MPLS for an ATM network on FPGA which replaces the virtual circuits by use of labels in the network.

Mishra et al [7] did the Comparative Analysis of conventional IP network and MPLS Network over VoIP application. As per analysis, the MPLS technology makes it more suitable for implementing real-time applications such as Voice and video due to lower network delay, efficient forwarding mechanism, scalability and predictable performance of the services. In this analysis/study the performance of Voice over Internet Protocol (VoIP) application is compared in MPLS network and conventional Internet Protocol (IP) network. The comparison is based on the performance metrics such as Voice jitter, Voice packet end-to-end delay, voice delay variation, voice packet send and received. The simulation results are analyzed and it shows that MPLS based solution provides better performance in implementing the VoIP application.

Palmieri et al [8] studied VPN scalability over high performance backbones evaluating MPLS VPN against traditional approaches. The author's study tells that the rapid growth of the Internet and the widespread deployment of networks built around the Internet protocol suite are creating a demand for new capabilities in IP networks. The IP-based virtual private network (VPN) technology is rapidly becoming the foundation for the delivery of future Internet services, and many service providers are offering value-added applications on top of their VPN transport networks. Two unique and complementary architectures based on traditional industry standard encrypted tunnels (IPSec) and still developing multiprotocol label switching (MPLS) technologies are emerging to form the predominant framework for delivery of high performance VPN services. The study analyzed the strengths and the weaknesses of both the approaches, and compared their performance and scalability features by carefully testing them against the requirements of the future optical high performance backbones. The technical considerations and experimental results strongly emphasized the better scalability and reliability of the MPLS/BGP model that seems to be the most promising approach for the provisioning of VPN services on the future Giga-speed optical backbones.

Dumka et al [9] studied the difference between Layer 2 and Layer 3 VPN in MPLS. As per study, VPN is used in MPLS to provide a connection oriented service over non-connected nodes of a network. Layer 2 (L2) MPLS and Layer 3 (L3) VPN is based on logical implementation of tunnels for forwarding of packet. L2 VPN customer sites appear to be on same LAN even if sites are geographically dispersed whereas L3 VPN enable service providers to offer many value added services. Layer 3 VPN networks allow multiple customer sites to communicate securely at the IP level over a provider managed MPLS network. L3 VPN is connected to one or more provider routers and each associated provider router maintain a separate IP forwarding table for each VPN known as virtual forwarding table (VRF).

Khan et al [10] focused on using MPLS VPN as a Wide Area Network (WAN) technology with full support of QoS. Their analysis showed that implementing MPLS VPN with DiffServ showed a better performance over IP and MPLS without DiffServ. Using a real testbed consisting of Cisco Routers, results showed that end-to-end delay, jitter and packet loss in different packet transmission rates and in different traffic types had very low variations or was almost constant. Also MPLS TE utilized links much more than when a traditional IP network was used.

6. Traditional IP Networks

In traditional IP networks, routing protocols are used to distribute Layer 3 routing information. Regardless of the routing protocol, packet forwarding is based on the destination address alone. Therefore, when a packet is received by the router, it determines the next-hop address using the packet's destination IP address along with the information from its own forwarding/routing table. This process of determining the next hop is repeated at each hop (router) from the source to the destination.

7. Benefits of MPLS

The various notable benefits or advantages of MPLS are given as:

(a) Speed
(b) Optimal Traffic Flow
(c) Traffic Engineering (TE)
(d) Quality-of-Service (QoS)
(e) Overlapping Address Pools
(f) Better IP over ATM Integration

8. Comparison between Traditional IP Network and MPLS

The comparison between Traditional and MPLS Network is summarized below:

Traditional IP Networks/Routing	MPLS network
In traditional IP networks, each router must process every packet to determine the next hop that the packet must take to reach its final destination	In an MPLS network, only edge routers fully process each packet. Label switches within the network simply forward packets based on the label. This decreases latency experienced by traditional routed networks performing standard IP routing.
There is no such separation.	There is a separation of the control and data planes in MPLS.
IP based networks lack the quality-of-service features available in circuit-based networks, such as ATM and Frame Relay	MPLS support QoS. MPLS replaces the virtual circuits (VC) which reduces the hardware components for connection between routers in the ATM network. MPLS provides an increase in the performance enhancements and service creation capabilities to the network.
There is no such provision in traditional IP network.	In MPLS, routing table for every customer is separate from other routing table for another customer.
Traditional IP routing/networks has poor support for traffic engineering.	MPLS has good support for traffic engineering.
Traditional IP routing/networks has poor integration support with Layer 2 backbones already existing in large service provider networks.	MPLS has good integration support with Layer 2 backbones.
Traditional IP routing/networks is not scalable as compared to MPLS.	MPLS does not have any scalability issue.
Traditional IP routing/networks clearly fits in OSI Model.	MPLS does not fit in OSI Model.
Poor IP over ATM integration	Better IP over ATM integration
There is no provision of Overlapping Address Pools in case of traditional IP routing/networks	Overlapping Address Pools can exists in MPLS networks

9. Conclusion

The comparison between traditional IP networks and MPLS is made on focusing on QoS, Traffic Engineering (TE), Scalability, Overlapping IP addresses etc. Based on the theoretical study it can be concluded that MPLS has significant advantages over traditional IP networks and provides the best solutions because of the following reason:

- MPLS takes less processing time in forwarding the packets due to label switching.
- Implementing MPLS with TE minimises the congestion in the network and provides the better utilizations of network links.
- MPLS suffers minimum delay and provides high throughput compared to traditional/conventional IP network.

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- MPLS support overlapping IP addresses. It means same IP address scheme can be given to two or more different VPNs.
- MPLS VPNs are more scalable than traditional IP VPNs.
- MPLS provides better IP over ATM integration.
- MPLS provides better results when configured with Multicasting than traditional IP networks with Multicasting.

Because of these few notable benefits of MPLS, the service providers are adapting MPLS in their networks.

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