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A Review: Multi Protocol Label Switching (Mpls)

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Abstract
The demand for technology called MPLS is increasing day by day in most internet service provider networks. Majority of the carriers are deploying MPLS in their backbone networks to facilitate a number of services and applications such as virtual private networks, quality of service (QoS) and traffic engineering. MPLS is a scalable, protocol-independent protocol. MPLS allows for creating end-to-end circuits across any type of transport medium using any protocol. The primary benefit of MPLS is to eliminate the dependence on a particular OSI model data-link layer technology such as asynchronous transfer mode (ATM), Frame Relay or Ethernet and eliminates the need for multiple layer-2 networks to satisfy different types of traffic. This paper reflects a detailed overview on MPLS with its architectural terminology, working and the services that it offers.
Keywords: MPLS, LDP, Shim, LSR, QoS, Label.

I. Introduction

MPLS is an Internet Engineering Task Force (IETF) specified frame work that provides efficient forwarding, routing and switching of traffic flow through the network. As data, video and voice networks are converging on one platform the need for MPLS is a natural progression. It is a technology for the delivery of IP services. It gives the ability to offer highly scalable, advanced IP services end-to-end with simpler configuration and management for both service providers and customers. MPLS belongs to the family of packet switching networks and was designed to overcome the limitations of IP based forwarding. In a traditional IP network each router performs an IP lookup, determines the next hop based on its routing table and forwards the packet to the next hop thereby creating a lot of overhead at each routers interface. However, MPLS on the other hand makes packet forwarding decisions which are based entirely on the contents of label without the need to examine the packet itself. MPLS works in between OSI data link layer and network layer and is summarised as Layer 2.5 networking protocol. MPLS is an innovative approach that uses label based forwarding paradigm. Labels indicate both routes and service attributes. At the ingress edge of MPLS network incoming packets are processed and labels are selected and applied. The core routers only read labels, applies appropriate services and forwards packets based on labels. The detailed analysis and classification happens only once at the ingress edge router. At the egress edge router, labels are removed and packets are forwarded to their final destination.

II. MPLS Terminology

The terminology given below is fundamental to the concepts, design and operation involved in MPLS networks.

2.1 Label:

The label is a part of MPLS header called shim. It is placed between the data-link and IP headers. It identifies the path a packet should traverse. The shim is composed of 32 bits out of which 20 bits are allocated to the label also called label stack, 3-bits are experimental bits often used for specifying class of service. One bit is reserved for bottom of stack bit and is set if no label follows. 8-bits are used for time-to-live (TTL) used in the same way like IP.
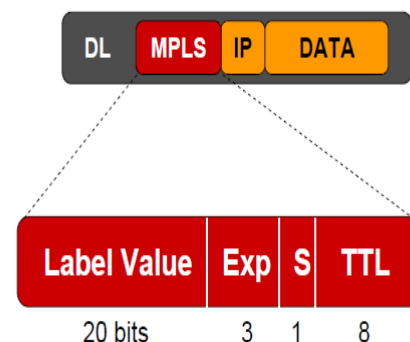

Fig: 1

- **Label forwarding information base:** A table created by a label switch-capable device (LSR) that indicates where and how to forward frames with specific label values

- **LSP:** It refers to Label Switched Path. It is a unidirectional tunnel between a pair of routers routed across MPLS network.
- **LER:** It refers to Label Edge Router/Ingress router. It is a router that first encapsulates the packet inside an MPLS LSP and also makes initial path selection.
- **LSR:** It refers to Label Switched Router. A router which only does MPLS switching in the middle of an LSP.
- **Egress Router**: The final router at the end of LSP which removes the label.
- **Label switched:** When an LSR makes forwarding decision based upon the presence of a label in the frame/cell.
- **Label switch controller (LSC):** An LSR that communicates with an ATM switch to provide and provision label information within the switch.
- **Label distribution protocol (LDP):** It is one of the primary signalling protocols for distributing labels in MPLS network. It is a set of procedures and messages by which Label Switched routers (LSR) establish Label Switched Path (LSP) through a network by mapping network layer routing information directly to data link layer switched paths. By means of LDP LSR can collect , distribute and release label binding information to other LSRs in the MPLS network thus enabling hop-by-hop delivery of packets in the network along routed paths.
- **FEC:** It refers to forwarding equivalence class and is a group of IP packets that are forwarded in the same way. Packets within an FEC are equivalent in terms of forwarding such as, same destination, same path and same class of service. A LSP is assigned to each FEC that is defined using IP interior routing protocols (OSPF).

2.2 MPLS/Tag-Switching

MPLS relies on two principal components i.e. forwarding and control. The forwarding component uses labels carried by packets and the label-forwarding information maintained by an LSR to perform packet forwarding. The control component is responsible for maintaining correct label-forwarding information among a group of interconnected label switches (LSRs). Details about MPLS's forwarding and control mechanisms follow.

- **Forwarding Component:** The forwarding paradigm employed by MPLS is based on the notion of label swapping. When a packet with a label is received by an LSR, the switch uses the label as an index in its label information base (LFIB). Each entry in the LFIB consists of an incoming label and one or more subentries (of the form outgoing label, outgoing interface, outgoing link-level information). If the switch finds an entry with the incoming label equal to the label carried in the packet, then, for each component in the entry, the switch replaces the label in the packet with the outgoing label, replaces the link-level information (such as the MAC address) in the packet with the outgoing link-level information, and forwards the packet over the outgoing interface. The forwarding decision is based on the exact-match algorithm using a fixed-length, fairly short label as an index. This enables a simplified forwarding procedure, relative to longest-match forwarding traditionally used at the network layer. This in turn enables higher forwarding performance (higher packets per second).

The forwarding procedure is simple enough to allow straightforward hardware implementation. A second observation is that the forwarding decision is independent of the label's forwarding granularity. The same forwarding algorithm, for example, applies to both unicast and multicast: A unicast entry would have a single (outgoing label, outgoing interface, and outgoing link-level information) subentry, while a multicast entry might have one or more subentries. This illustrates how the same forwarding paradigm can be used in label switching to support different routing functions. The simple forwarding procedure is thus essentially decoupled from the control component of label switching. New routing (control) functions can readily be deployed without disturbing the forwarding paradigm. This means that it is not necessary to reoptimize forwarding performance (by modifying either hardware or software) as a new routing functionality is added.

- **Label Encapsulation:** Label information can be carried in a packet in a variety of ways:
  I. As a small, shim label header inserted between the Layer 2 and network layer headers
  II. As part of the Layer 2 header, if the Layer 2 header provides adequate semantics (such as ATM)
  III. As part of the network layer header (such as using the Flow Label field in IPv6 with appropriately modified semantics)

As a result, MPLS can be implemented over any media type, including point-to-point links, multi-access links, and ATM. The label-forwarding component is independent of the network layer protocol. Use of control component(s) specific to a particular network layer protocol enables the use of label switching with different network layer protocols.

- **Control Component:** Essential to MPLS is the notion of binding between a label and network layer routes. MPLS supports a wide range of forwarding granularities to provide good scaling characteristics while also accommodating diverse routing functionality. At one extreme, a label could be associated (bound) to a group of routes (more specifically, to the network layer reachability information of the routes in the group). At the other extreme, a label could be bound to an individual application flow (such as an RSVP flow), or it could be bound to a multicast tree. The control component creates label bindings and then distributes the label-binding information among LSRs using a Label Distribution Protocol (LDP).

- **Label Distribution Protocols:** With destination-based routing, a router makes a forwarding decision based on the Layer 3 destination address carried in a packet and the information stored in the forwarding information base (FIB) maintained by the router. A router constructs its FIB by using the information that the router receives from routing protocols, such as OSPF and BGP.

 To support destination-based routing with MPLS, an LSR participates in routing protocols and constructs its LFIB by using the information that it receives from these protocols. In this way, it operates much like a router. An LSR, however, must distribute and use allocated labels for LSR peers to correctly forward the frame. LSRs distribute labels using a label distribution protocol (LDP). A label binding associates a destination subnet to a locally significant label. (Labels are locally significant because they are replaced at each hop.) Whenever an LSR discovers a neighbour LSR, the two establish a TCP connection to transfer label bindings. LDP exchanges subnet/label bindings using one of two methods: downstream unsolicited distribution or downstream-on-demand distribution. Both LSRs must agree as to which mode to use. Downstream unsolicited distribution disperses labels if a downstream LSR needs to establish a new binding with its neighbouring upstream LSR. For example, an edge LSR may enable a new interface with another subnet. The LSR then announces to the upstream router a binding to reach this network. In downstream-on-demand distribution, on the other hand, a downstream LSR sends a binding upstream only if the upstream LSR requests it. For each route in its route table, the LSR identifies the next hop for that route. It then issues a request (via LDP) to the next hop for a label binding for that route.

When the next hop receives the request, it allocates a label, creates an entry in its LFIB with the incoming label set to the allocated label, and then returns the binding between the (incoming) label and the route to the LSR that sent the original request. When the LSR receives the binding information, the LSR creates an entry in its LFIB and sets the outgoing label in the entry to the value received from the next hop.

2.3 MPLS Operation:

Step-1: The network automatically builds routing tables as MPLS capable router participate in interior gateway protocols (OSPF, IS-IS) throughout the network. Label distribution protocol (LDP) establishes label to destination network mappings. Label distribution protocol (LDP) uses the routing topology in the tables to establish label values between the adjacent devices. This operation creates Label Switching Paths (LSP) pre-configured maps between destination end points [3].

Step-2: A packet enters the ingress edge label switching router (LSR) where it is processed to determine which layer-3 service it requires, such as quality of service (QoS) and bandwidth management. The edge LSR selects and applies a label to the packet header and forwards it.
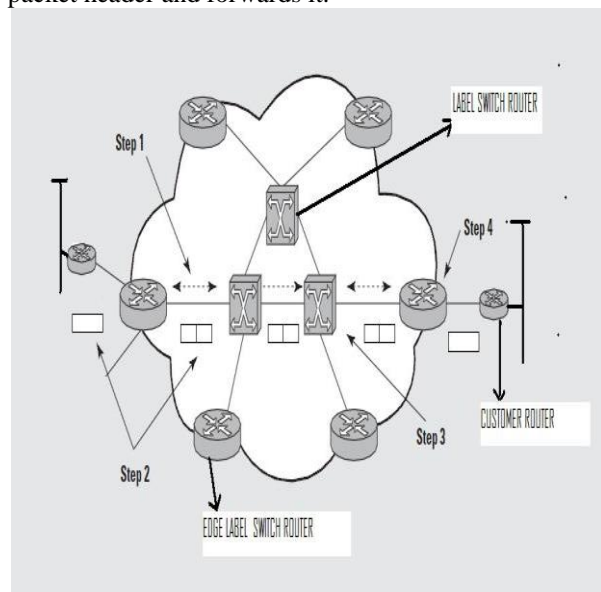

Fig 2

Step-3: The LSR reads the label on each packet replaces it with new one as listed in the table and forwards the packet.

Step-4: The Egress Edge Router strips the label, reads the packet header and forwards it to its final destination.[11]

III.   MPLS Services

MPLS VPNs: Virtual Private Networks (VPNs) are a method of interconnecting multiple sites belonging to

a customer using a Service Provider (SP) backbone network in place of dedicated leased lines [2]. Each customer site is directly connected to the SP backbone. The SP can offer a VPN service more economically than if dedicated private WANs are built by each individual customer because the SP can share the same backbone network resources (bandwidth, redundant links) between many customers. The customer also gains by outsourcing the complex task of planning; provisioning and managing a geographically distributed network to the SP.MPLS-enabled IP VPNs are connectionless IP networks with the same privacy as frame relay and multiple IP service classes to enforce business-based policies. MPLS-based VPNs make operations much more efficient.

The traditional overlay VPN solutions require tunnelling or encryption deployed over a frame relay, ATM or IP network. This mesh solution is built point-to-point, requiring separate configuration of each tunnel or Virtual Circuit (VC). Moreover, since traffic is tunnelled or overlaid, the circuit does not know which kind of traffic it carries. By contrast if the customer traffic can be classified by application type, such as voice, mission-critical applications or e-mail, the network can easily assign traffic to the appropriate VPN, without configuring complex, point-to-point meshes. Compared to a VPN overlay solution, an MPLS-enabled VPN network can separate traffic and provide privacy without tunnelling or encryption. Using labels, MPLS enabled networks provide privacy on a network-by-network basis much as frame relay provides it on a connection-by-connection basis.

The frame relay VPN offers transport while MPLS-enabled network supports services. MPLS is the technology that brings "VPN awareness" to switched or routed networks. It enables quick and cost-effective deployment of VPNs of all sizes—all over the same infrastructure.

MPLS provides a flexible and elegant VPN solution based on the use of LSP tunnels to encapsulate VPN data. [8] VPNs give considerable added value to the customer over and above a basic best effort IP service so this represents a major revenue-generating opportunity for SPs. The network distributes label to each VPN. It then route that VPN packet to egress node advertising that VPN prefix. IGP labels are used to VPN packets to egress node. Routers maintain separate VPN routing tables called VRFs (Virtual Routing and Forwarding tables). After that router then exports and imports routes using BGP extensions to identify and separate one VPN route from another and then exchange labels for VPN routes in addition to IGP route.

MPLS Traffic Engineering: Traffic Engineering is the process of routing data traffic in order to balance the traffic load on various links, router and switches in the network. [1] It has the ability to control specific routes across a network to reduce congestion and improves the cost of efficiency of carrying IP Traffic. [6] MPLS is capable of full traffic engineering. In MPLS TE, a Label Switched Path (LSP) is established for carrying traffic along an explicit traffic-engineered path, which can be different from the normal destination-based routing path. IP networks typically have multiple pathways that traffic can take to reach its destination. Relying solely on routing protocols such as Open Shortest Path First (OSPF) some of the paths may become congested while others are under-utilized. MPLS can specify an explicit route for certain traffic flows such as Voice over IP (VoIP) to take less optimal but less congested routes and avoid packet loss while maintaining very high link utilization.

MPLS and Quality of Service (QoS): Some types of traffic, such as video, place specific demands on a network for successful transmission.[5] QoS in an IP network gives devices the intelligence to preferentially handle traffic as dictated by each subscriber's network policy. QoS is defined as those mechanisms that give network managers the ability to control the mix of bandwidth, delay, jitter and packet loss in the network. At the ingress to the MPLS network, Internet Protocol (IP) precedence information can be copied as Class of Service (CoS) bits or can be mapped to set the appropriate MPLS CoS value in the MPLS label. This is the distinction between IP QoS that is based on IP precedence field in the IP header and MPLS QoS that is based on the CoS bits in the MPLS label. MPLS CoS information is used to provide differentiated services. Hence MPLS CoS enables end-to-end IP QoS across the network.

IV.   Conclusion

Multiprotocol Label Switching (MPLS) combines the intelligence of routing with the performance of switching and provides considerable benefits to networks with a pure IP architecture as well as those with IP and ATM or a mix of other Layer 2 technologies. This paper highlights the need for implementing MPLS technology to overcome some of the limitations involved in pure IP based forwarding. The innovative label based system simplifies IP based traffic routing from source to destination without affecting and manipulating the IP packets, thus highlighting the security aspect of MPLS networks. The paper also explains in-depth the technological standards involved and the use of these standards. The paper provides a detailed insight over the improved packet forwarding performance in

MPLS based networks. MPLS operation and the signalling protocol called LDP which is most widely used in service provider networks are discussed at length.

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