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MULTIPROTOCOL LABEL SWITCHING PROTOCOL

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Abstract:
Multiprotocol Label Switching (MPLS) will be chosen as the bearer of IP in future large backbone networks. MPLS has recently been accepted as a new approach for integrating layer3 routing (IP) with layer 2 switching technology ATM, FR and GMPLS. MPLS tries to provide: the efficiency and simplicity of routing together with the high speed of switching. For this reason MPLS is considered to be a promising technology that addresses the needs of future IP-based networks.

Label switching technology enables one to replace conventional packet forwarding based on the standard destination-based hop-by-hop forwarding paradigm with a label swapping forwarding paradigm. This is based on fixed length labels, which improves the performance of layer 3 routing, simplifies packet forwarding and enables easy scaling.

1.Introduction:

Multiprotocol Label Switching (MPLS) is a mechanism in high-performance telecommunications networks which directs and carries data from one network node to the next with the help of labels. MPLS makes it easy to create "virtual links" between distant nodes. It can encapsulate packets of various network protocols.
MPLS is a highly scalable, protocol agnostic, data-carrying mechanism. In an MPLS network, data packets are assigned labels. Packet-forwarding decisions are made solely on the contents of this label, without the need to examine the packet itself. This allows one to create end-to-end circuits across any type of transport medium, using any protocol. The primary benefit is to eliminate dependence on a particular Data Link Layer technology, such as ATM, frame relay, SONET or Ethernet, and eliminate the need for multiple Layer 2 networks to satisfy different types of traffic. MPLS belongs to the family of packet-switched networks.

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.
As many high-bandwidth consuming Internet services, such as net-conferencing, Video on Demand, Internet games and so on, start to dominate the Internet world, both Internet users and providers are facing the dilemma between limited bandwidth and boosting requirement for Internet accessing speed. In order to overcome this problem, MPLS technology has been recently introduced to supply higher data exchanging speed. Since it's born in late 1990s, MPLS technology has been used by many global Internet Service Providers in building up

new service structures and delivering customer services Though there are many ways of binding MPLS technology within IP networks, most of them may end up consuming more system resource than expected because of the dramatically high data rates in nowadays highly burdened Internet, especially in the core area where most of the data exchanging operations took place. MPLS technology itself needs to be optimized before it could be added into IP networks, or else it won't last long before another bottleneck hits the Internet again. Based on this thought, we gave a layered MPLS model in this article, which could not only decrease label consumption in existing MPLS networks, but also bring more qualified QoS and lower resource consumption for the whole network. MPLS does not replace IP routing, but works along with existing and future routing technologies to provide very high-speed data forwarding between Label-Switched Routers (LSRs) together with QoS provision.
One challenge in current network research is how to effectively transport IP traffic .Over any network layer technology (ATM, FR, Ethernet, Point-to-Point).IP was independently developed .

2. MPLS ARCHITECTURE:

The basis of MPLS operation is the classification and identification of IP packets at the ingress node with a short, fixed-length, and locally significant identifier called a label, and forwarding the packets to a switch or router that is modified to operate with such labels. The modified routers and switches use only these labels to switch or forward the packets through the network and do not use the network layer addresses.

(A)SEPERATION OF CONTROL AND DATA PLANES:

A key concept in MPLS is the separation of the IP router's functions into two parts:
forwarding (data) and control. The separation of the two components enables each to be developed and modified independently.
The control plane consists of network layer routing protocols to distribute routing information between routers, and label binding procedures for converting this routing information into the forwarding table needed for label switching. Some of the functions accomplished by the control plane are to disseminate decision-making information, establish paths and maintain established paths through the MPLS network. The component parts of the control plane and the data plane are illustrated in Figure 1.1.

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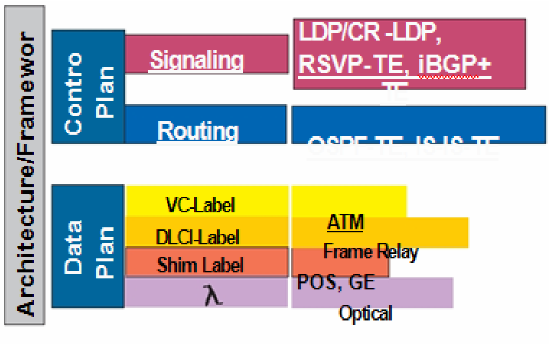

FIG 1.1:control and data plane components

The data plane (forwarding plane) is responsible for relaying data packets between routers (LSRs) using label swapping. In other words, a tunnel is created below the IP layer carrying client data. The concept of a tunnel (LSP tunnel) is key because it means the forwarding process is not IP based but label based. Moreover, classification at the ingress, or entry point to the MPLS network, is not based solely on the IP header information, but applies flexible criteria to classify the incoming packets.

(B)FEC :

Forward Equivalent Class (FEC) is a set of packets that are treated identically by an LSR. Thus, a FEC is a group of IP packets that are forwarded over the same LSP and treated in the same manner and can be mapped to a single label by an LSR even if the packets differ in their etwork layer header information. Figure 1.2 shows this behavior. The label minimizes essential information about the packet. This might

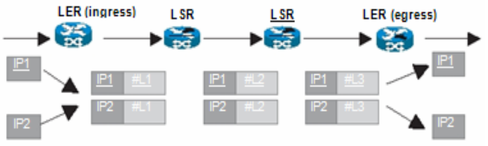

Figure 1.2 Forward Equivalent Class (FEC)

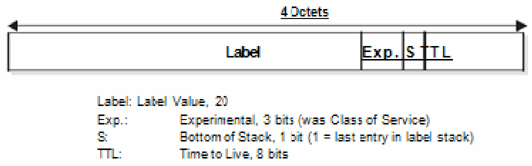

Figure 1.3 MPLS "shim" header format

include destination, precedence, QoS information, and even the entire route for the packet as chosen by the ingress LSR based on administrative policies. A key result of this arrangement is that forwarding decisions based on some or all of these different sources of information can be achieved by means of a single table lookup from a fixed-length label. This flexibility is one of the key elements that make MPLS so useful. Moreover, assigning a single label to different flows with the same FEC has advantages derived from "flow aggregation". For example, a set of distinct address prefixes (FECs) might all have the same egress node, and label swapping might be used only to get the traffic to the egress node. In this case, within the MPLS domain, the union of those FECs is itself a FEC. Flow aggregation reduces the number of labels which are needed to handle a particular set of packets, and also reduces the amount of label distribution control traffic needed. This improves scalability and reduces the need for CPU resources.

(c) Label:

A label called a "shim label", or an MPLS "shim" header is a short, fixed-length, locally significant FEC identifier. Although the information on the network layer header is consulted for label assignment, the label does not directly encode any in- formation from the network layer header like source or destination addresses. The labels are locally significant only, meaning that the label is only useful and relevant on a single link, between adjacent LSRs. Figure 1.3 presents the fields of an MPLS "shim" header. When a packet is forwarded to the next hop, this label is sent along with it, that is, the packets are "labeled". At subsequent hops there is no further analysis of the packet's network layer header. The label itself is used as hop index. This assignment eliminates the need to perform the longest prefix-match computation for each packet at each hop, as shown in Figure 1.4. In this way the computation can be performed just once, as shown in Figure 1.5.

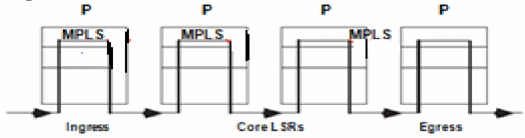

Fig 1.4 IP Forwarding: all LSRs extract information from layer 3 and forward the packets

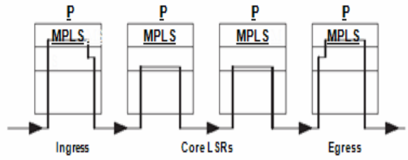

Figure 1.5 MPLS Forwarding: Ingress LSR extracts layer 3 information, assigns packet to FEC, pushes a label and forwards the packet. Core LSRs use label forwarding. Egress LSR pops the label, extracts layer 3 information and forwards the packet accordingly.

3. MPLS WORKING MECHANISM :

MPLS works by prefixing packets with **an** MPLS header, containing one or more "labels". This is called a label stack. Each label stack entry contains four fields:

- A 20-bit label value.
- a 3-bit *Traffic Class* field for QoS (quality of service) priority (experimental) and ECN (Explicit Congestion Notification).
- a 1-bit *bottom of stack* flag. If this is set, it signifies that the current label is the last in the stack.
- an 8-bit TTL (time to live) field.

These MPLS-labeled packets are switched after a label lookup/switch instead of a lookup into the IP table. As mentioned above, when MPLS was conceived, label lookup and label switching were faster than a routing table or RIB (Routing Information Base) lookup because they could take place directly within the switched fabric and not the CPU.

The entry and exit points of an MPLS network are called label edge routers (LER), which, respectively, **push** an MPLS label onto an incoming packet and **pop** it off the outgoing packet. Routers that perform routing based only on the label are called label switch routers (LSR). In some applications, the packet presented to the LER already may have a label, so that the new LER pushes a second label onto the packet. For more information see penultimate hop popping.

Labels are distributed between LERs and LSRs using the “Label Distribution Protocol” (LDP). Label Switch Routers in an MPLS network regularly exchange label and reachability information with each other using standardized procedures in order to build a complete picture of the network they can then use to forward packets. *Label Switch Paths (LSPs)* are established by the network operator for a variety of purposes, such as to create network-based IP virtual private networks or to route traffic along specified paths through the network. In many respects, LSPs are not different from PVCs in ATM or Frame Relay networks, except that they are not dependent on a particular Layer 2 technology.

In the specific context of an MPLS-based virtual private network (VPN), LSRs that function as ingress and/or egress routers to the VPN are often called PE (Provider Edge) routers. Devices that function only as transit routers are similarly called P (Provider) routers. See RFC 2547. The job of a P router is significantly easier than that of a PE router, so they can be less complex and may be more dependable because of this.

When an unlabeled packet enters the ingress router and needs to be passed on to an MPLS tunnel, the router first determines the forwarding equivalence class (FEC) the packet should be in, and then inserts one or more labels in the packet's newly-created MPLS header. The packet is then passed on to the next hop router for this tunnel.

When a labeled packet is received by an MPLS router, the topmost label is examined. Based on the contents of the label a *swap*, *push* (*impose*) or *pop* (*dispose*) operation can be performed on the packet's label stack. Routers can have prebuilt lookup tables that tell them which kind of operation to do based on the topmost label of the incoming packet so they can process the packet very quickly.

In a *swap* operation, the label is swapped with a new label, and the packet is forwarded along the path associated with the new label.

In a *push* operation, a new label is pushed on top of the existing label, effectively "encapsulating" the packet in another layer of MPLS. This allows hierarchical routing of MPLS packets. Notably, this is used by MPLS VPNs.

In a *pop* operation ,the label is removed from the packet, which may reveal an inner label below. This process is called "decapsulation". If the popped label was the last on the label stack, the packet "leaves" the MPLS tunnel. This is usually done by the egress router, but see Penultimate Hop Popping (PHP) below.

During these operations, the contents of the packet below the MPLS Label stack are not examined. Indeed transit routers typically need only to examine the topmost label on the stack. The forwarding of the packet is done based on the contents of the labels, which allows "protocol-independent packet forwarding" that does not need to look at a protocol-dependent routing table and avoids the expensive IP longest prefix match at each hop.

At the egress router, when the last label has been popped, only the payload remains. This can be an IP packet, or any of a number of other kinds of payload packet. The egress router must therefore have routing information for the packet's payload, since it must forward it without the help of label lookup tables. An MPLS transit router has no such requirement.

Label encapsulation:

MPLS is multi protocol because is intended to run over multiple data link layers such as: ATM, Frame Relay, PPP, Ethernet, etc. It is label switching because it is an encapsulation protocol. The label encapsulation in MPLS is specified over various media type. The top label on the stack may use the existing formats, lower label(s) use a new shim labels format.

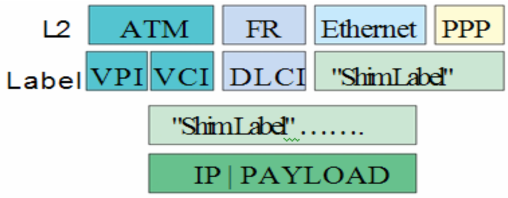

Figure 1.6 Label encapsulation

For IP-based MPLS, shim labels are inserted prior to the IP header. For ATM, the VPI/VCI addressing is the label. For Frame Relay, the DLCI is the label. Regardless of the technology, if the packet needs additional labels it uses a stack of shim labels. Figure 1.6 illustrates the label encapsulation in MPLS architecture.

Label swapping:

Label Swapping is a set of procedures where an LSR looks at the label at the top of the label stack and uses the Incoming Label Map (ILM) to map this label to Next Hop Label Forwarding Entry (NHLFE).using the information in the NHLFE, The LSR determines where to forward the packet, and performs an operation on the packet's label stack. Finally, it encodes the new label stack into the packet, and forwards the result.

This concept is applicable in the conversion process of unlabeled packets to labeled packets in the ingress LSR, because it examines the IP header, consults the NHLFE for the appropriate FEC (FTN), encodes a new label stack into the packet and forwards it.

Label Stacking:

A label stack is a sequence of labels on the packet organized as a last-in, first-out stack. A label stack enables a packet to carry information about more than one FEC which allows it to traverse different MPLS domains or LSP segments within a domain using the corresponding LSPs along the end-to-end path. Note that label processing is always based on the top label, without concern that some number of other labels may have been "above it" in the past, or that some number of other labels may be below it at present. The bottom of stack bit "S" in the shim header (see Figure 1.3) indicates the last stack level. The label stack is a key concept used to establish LSP Tunnels and the MPLS Hierarchy. Figure 1.7 illustrates the tunneling function of MPLS using label stacks.

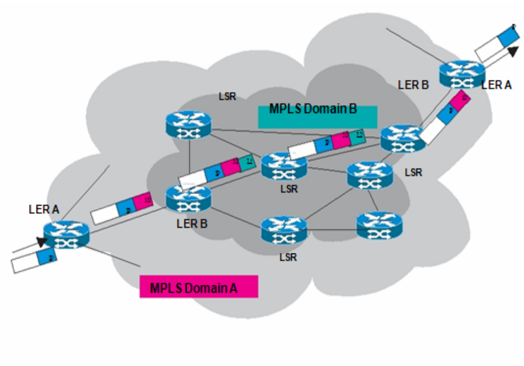

Figure 1.7 Label Stack. LERs A are for MPLS domain A and LERs B are for MPLS domain B

Label switch Router (LSR) :

A Label Switch Router(LSR) is a device that is capable of forwarding packets at layer 3 and forwarding frames that encapsulate the packet at layer 2. It is both a router and a layer 2 switch that is capable of forwarding packets to and from an MPLS domain. The edge LSRs are also known as Label Edge Routers (LERs).

The ingress LSR pushes the label on top of the IP packet and forwards the packet to the next hop When the packet reaches the egress LSR, the label is popped and the packet is delivered using the traditional network layer routing module. All the above descriptions are illustrated in Figure 1.8.
If the egress LSR is not capable of handling MPLS traffic, or for the practical advantage of avoiding two lookup times that the egress LSR requires to forward the packet, the penultimate hop popping method is used. In this method, the LSR whose next hop is the egress LSR, will handle the label stripping process instead of the egress LSR.

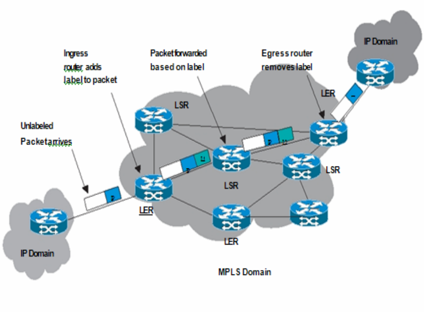

Figure 1.8 MPLS Architecture

Label switch path (LSP):

Label Switched Path (LSP) is an ingress-to-egress switched path built by MPLS capable nodes which an IP packet follows through the network and which are defined by the label (Figure 1.9). The labels may also be stacked, allowing a tunneling and nesting of LSPs. An LSP is similar to ATM and FR circuit switched paths, except that it is not dependent on a particular Layer 2 technology.
Label switching relies on the set up of switched paths through the network. The path that data follows through a network is defined by the transition of the label values using a label swapping procedure at each LSR along the LSP. Establishing an LSP involves configuring each intermediate LSR to map a particular input label and interface to the corresponding output label and interface (label swap). This mapping is stored in the label information based forwarding table (LIB).

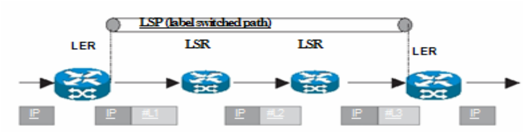

Figure 1.9 Label Switched Path (LSP)

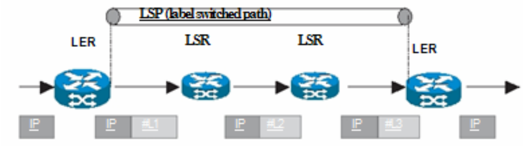

Figure 1.9 Label Switched Path (LSP)

5. BENEFITS/APPLICATION OF MPLS

(A)SIMPLE FORWORDING :

As MPLS uses fixed length labelbased forwarding, the forwarding of each packet is entirely determined by a single indexed lookup in a switching table, using the packet's MPLS label. This simplifies the label switching router forwarding function compared to the longest prefix match algorithm required for normal datagram forwarding.

(B)TRAFFIC ENGINEERING:

One of the main advantages of MPLS is the ability to do Traffic Engineering (TE) in connectionless IP networks.
MPLS traffic engineering provides a way to achieve the same traffic engineering benefits of the overlay model without the need to run a separate network. With MPLS, traffic engineering attempts to control traffic on the network using Constrained Shortest Path First (CSPF) instead of using the Shortest Path First (SPF) only.
CSPF creates a path that takes restrictions into account. This path may not always be the shortest path, but, for instance, it will utilize paths that are less congested.
The capability to forward packets over arbitrary non-shortest paths and emulate high-speed tunnels within an MPLS domain yields a TE advantage to MPLS technology.

(c)Source based QoS routing

Source based QoS routing is a routing mechanism under which LSRs are determined in the source node (ingress LSR) based on some knowledge of resource availability in the network as well as the QoS requirements of the flows. In other words, it is a routing protocol that has expanded its path selection criteria to include QoS parameters such as available bandwidth, link and end-to-end path utilization, node resource consumption, delay and latency, including jitter.

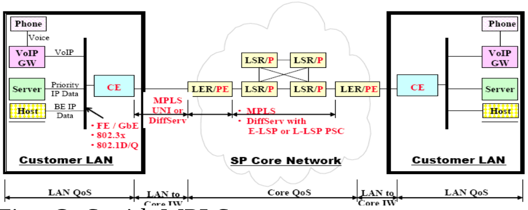

Fig :QoS with MPLS

network can be contrasted with a system of owned or leased lines that can only be used by one company. The main purpose of a VPN is to give the company the same capabilities as private leased lines at much lower cost by using the shared public infrastructure. The MPLS architecture fulfils all the necessary requirements to support VPNs by establishing LSP tunnels using explicit routing. Therefore, MPLS using LSP tunnels allows service providers to deliver this popular service in an integrated manner on the same infrastructure they used to provide Internet services. Moreover, label stacking allows configuring several nested VPNs in the network infrastructure.

6.SUMMARY:

Label switching technology enables one to replace conventional packet forwarding based on the standard destination-based hop-by-hop forwarding paradigm with a label swapping forwarding paradigm. This is based on fixed length labels, which improves the performance of layer 3 routing, simplifies packet forwarding and enables easy scaling.

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