Improving Quality of Service by Label Space Reduction in Multi-Protocol Label Switching (MPLS) Networks

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ABSTRACT
Label Switching in Multi-Protocol Label Switching Networks is a most researched area in recent years. Many techniques have been proposed and implemented and their merits and demerits have been considered. Label Space Reduction is an issue which directly affects the quality of service of the MPLS network. The aim of the work is to design a network which optimizes the quality of service parameters like packet delivery ratio and throughput of the network. In many previous works tunnels are created which deals in only one label for the tunnel instead of swapping labels at each Label Switch Router (LSR). But the entry and exit points inside the tunnel are fixed which makes it difficult for the packets to enter and exit the tunnels. Also the packets entering will have to exit at fixed point and then it follows some other route to reach the destination which only increases the end to end delay and the packet drop in the network. In our proposed approach LCS algorithm is used to find the length of the tunnel according to the number of Label Switched Paths (LSPs) so that the packet can enter into the tunnel and exit at any point in the tunnel. Also each LSR maintains a table so that it tracks the labels which are assigned to the packets entering the tunnel and exiting at any point over the length of the tunnel. This technique results in the reduced number of packets lost in the network and also delay is reduced thus improving the throughput of the network. The results shown in the coming sections also proves the approach and the labels are significantly reduced along with the improvement of other performance parameters like throughput of the network, end to end delay and the packet delivery ratio.

General Terms
Networks.

Keywords
MPLS, LDP, LCS, Shim, LSR, QoS, Label.

1. 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.

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

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.

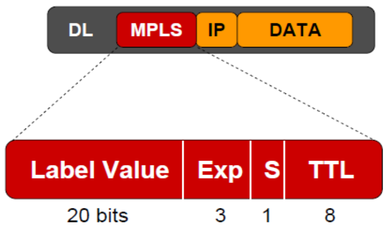

Figure1: MPLS LABEL

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).

2.1 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.

2.1.1 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.

2.1.2 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). 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.

3. RESULTS & DISCUSSION

MPLS Network is designed using 30 nodes and each node is connected to some other node using the full duplex link having characteristics like delay, bandwidth and queue type. The bandwidth of the link is 5Mb with a delay of 2 ms and queue type is Drop Tail queue. Figure below shows the network animator screenshot of the network.

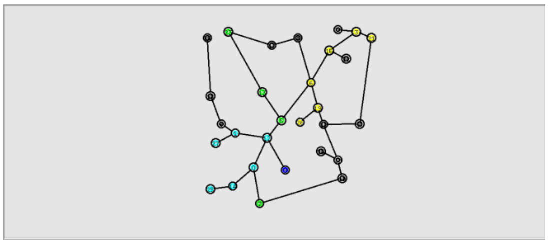

Figure 2: Network implemented in NS-2

In the network designed above the end nodes serve the purpose of label edge routers and other nodes are label switch routers where the colored paths serve the purpose of the label switched paths.

3.1 Throughput of the Network

Throughput is the ratio of the total packets received per unit time.

Throughput= (packets received)/ ((Stop time-Start time))

Since it is a wired environment, number of times wired node is allowed to share its data is low. Figure3 shows the comparison results of the proposed protocol with the basic approach. In basic approach the route considered is based on the entry and exit points of the LSP in the tunnel. In the proposed approach the entry and exit points of the tunnel are determined using the Longest Common Subsequence Algorithm.

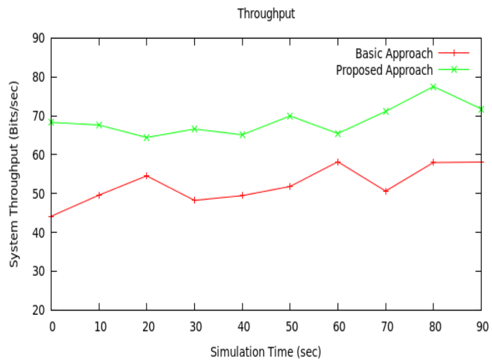

Figure3: Throughput of the Network

3.2 Average End-to-End Delay:

It is defined as the total time taken by the packet to reach to the destination from the source from which it is generated. As the number of nodes in network increases, the collision between packets in the network in case of base approach is greater than the proposed approach. The optimization of the tunneling approach using the LCS algorithm significantly reduces the end to end delay. Figure 4 shows the average end to end delay in the network.

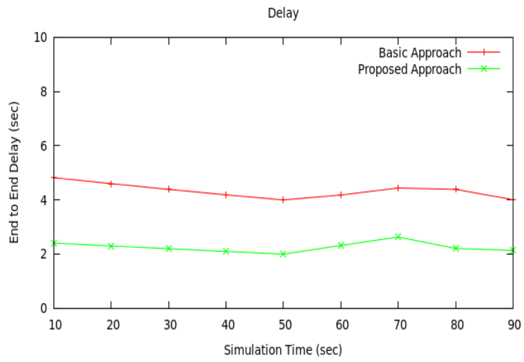

Figure-4: Average End to End delay in the network

3.3 Average Packet delivery Ratio:

It is defined as follows:

$$Packet\ Delivery\ Ratio = \frac{Total\ received\ Packets}{Total\ generated\ Packets}$$

It is an important measure for computing the performance of the system. In the above formula the total generated packets is a combination of transmitted packets and packets lost in the network. As the Average packet delivery ratio in the figure5 increases we can conclude that the packets lost in the network decreases.

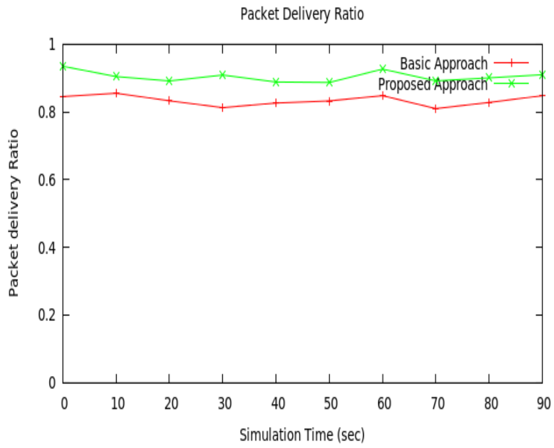

Figure-5: Packet Delivery Ratio of the Network

4. CONCLUSION

The problem of Label Space reduction in the MPLS can be solved by optimizing the tunneling approach using the Longest Common Subsequence algorithm. Using the proposed approach the optimized length of the tunnel can be found out and any Label Switched path can enter or exit the tunnel from any node or the Label Switch Router. Results presented in the results and discussions also show the improvement in various performance parameters of the network. The performance parameters include the throughput of the network, average end to end delay and the packet delivery ratio which are improved upon application of the proposed approach. In future the length of the tunnel can be further optimized using the machine learning algorithms. Meta-heuristic algorithms are multi objective constraint optimization algorithms which work on iterations and try to reach the global best solution after each iteration. These algorithms must be applied for the Label Space reduction problem in MPLS networks.

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