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Performance Analysis of MPLS network with Traditional IP Network in Service Provider Environment

Nishant N.Kale, Sunil A. Waichol

Abstract—**This paper gives us comprehensive performance analysis of MPLS enable network and IP enable network. It states the behavior of MPLS protocol with OSPF protocol .We have analysis these two on basis of throughput, packet loss, latency in the network with the help of network monitoring tool.We have used five Huawei NE20 Series router for testing network performance with MPLS and traditional IP routing. Results obtain in this testing shows How service provider can befit from MPLS services with increasing network throughput and additional benefits obtain from MPLS .**

Index Terms—**IP, MPLS VPN, OSPF, TCP**

I. Introduction

Computer network were circuit switched , where continuous bit streams carried over the physical links. This was well suitable for voice and data unicast communications. This leads to some severe consequences in case of failure. All the communications over the failed link are interrupted in such situation. These days packet switched networks are used in which data is divided into small chunks called as a packet and these packets are routed over the communication links. Different packets can take different paths .In case of link failure, the packets can be rerouted through alternate available path to avoid failed link and hence communication is not interrupted. This feature makes packet switched networks more reliable but on other hand as packets are routed individually , it is difficult to manage flow of data. Traditional IP networks offer little predictability of service, which is undesirable for applications such as telephony, and for rising and future real-time applications. IP networks are frequently layered over ATM networks, which is very expensive in terms of overhead (adding 25 percent or more of overhead to every IP packet), but had one great advantage, IP networks have no means of tagging or monitoring the packets that cross them. The history tells us the upper limit of transmittable bandwidth doubles and sometimes quadruples every nine to twelve months. We need matching data transferring topologies as well as improved system reliability[2].

Multiprotocol Label Switching is a tool applied in distinguished performance telecommunications networks that carries materials from on complex over to the next. Originally MPLS created by a crew of engineers that were consumed with improving the quickness of routers nevertheless from the time it has emerged as a classic in today's telecommunications. There have been a multitude number of attempts at developing many technologies with the identical goals, to date none have reached the position of success that we now see with MPLS. To this extent what benefits arise out of using MPLS you may wonder? Well firstly, they allow internet service providers the savvy to maintain rapidly growing internet. In addition allows for fundamental adjustability. Appreciating MPLS means looking to some of the parts that exist concerning to the MPLS such as the label which is a locally significant identifier that is allotted to a packet. Every label contains four fields, a label value, traffic class field which determines the quality of service, bottom of stack label which is not always set but when it is it signifies that the label is currently the last in the stack and finally there is the "time to live" (also referred to as TTL) field which is the limit of time that data can experience before it will be discarded. To realize the magnitude of MPLS one just has too measure it against some earlier technologies that are similar like the frame relay which focused on making previously existing physical resources more adequate. In recent days the use of frame relay has been given a poor name in several markets because of overdone bandwidth used by some companies hence making the use of MPLS much more alluring. One more similarity would be that between ATM (also referred to as Asynchronous Transfer Mode) MPLS when comparing the two have many differences both offer connection oriented service to allow for transporting data across networks.

An MPLS connection shows the most significant difference in its approach as they are able to work with various lengths of packets where as an ATM is only capable of dealing with a fixed length. The most favorable difference you will find between the two is MPLS configuration which was developed specifically for internet protocol. MPLS are just being used only with internet protocol networks and are

Manuscript received April, 2014.
Nishant N. Kale*, Electronics and Telecommunication, Mumbai University,MGMs College of Engineering and Technology, Panvel, India, Mobile No:9819842507.*
Sunil A. Waichol*, Senior Manager MTNL Mumbai, Mobile N:9869050866.*

standard. It can connect to two facilities or can control thousands of locations simultaneously. MPLS does not compete with IP forwarding but it complements IP forwarding. MPLS technology works to solve those flaws of IP, encapsulating IP packets within labels.

Emerge of MPLS is not for replacing IP, it is designed to add a set of rules to IP so that traffic can be classified, marked, and policed. MPLS (Multiprotocol label switching) as a traffic-engineering tool has emerged as an elegant solution to meet the bandwidth management and service requirements for next generation Internet Protocol (IP) based backbone networks. An MPLS network can offer the quality of service guarantees that data transport service like frame relay (FR) or ATM give, without requiring the use of any dedicated lines. The availability of traffic engineering has helped MPLS reach critical mass in term of service provider mind share and resulting MPLS deployments. Most carriers run MPLS underneath a wide range of services, including FR, wide-area Ethernet, native IP, and ATM. Advantages accrue primarily to the carriers. User benefits include lower cost in most cases, greater control over networks, and more detailed Quality of Services.

II. MULTI PROTOCOL LABEL SWITCHING

Multiprotocol Label Switching (MPLS) is a data-carrying mechanism, in computer networking and telecommunications ,which is highly scalable and protocol agnostic. Often referred to as "Layer 2.5 protocol" MPLS technology operates between the Data Link layer Layer 2) and the Network Layer (Layer 2) of the OSI Model. MPLS is part of the family of packet-switched networks. It was designed primarily to provide a unified data-carrying service for Circuit-based as well as Circuit-switching clients. Both the clients offer a datagram service model[2].

Multiprotocol Label Switching enables to carry diverse types of traffic such as Asynchronous Transfer Mode (ATM), Internet Protocol (IP) packets, Synchronous Optical Networking SONET), and Ethernet frames. Labels are assigned to the data packets in an MPLS network. Based on the label contents, packet-forwarding decisions are made, without necessitating examination of the data packets. Through this feature, end-to-end circuits may be created using any protocol over any type of transport medium. MPLS technology is beneficial as it helps to eliminate the dependence on ATM, Frame relay, SONET, Ethernet, etc., which are Layer 2 technologies. It also does not require multiple data ink layer networks to gratify different traffic types. In MPLS technology, a specific path is set up for a given sequence of data packets. These packets are identified by the packet label, thereby saving the time that a router takes to search the address where the packet should next be forwarded. MPLS is referred to as "multiprotocol" since it closely works with IP, ATM, and frame relay network protocols. The major benefits of MPLS networks include:

Traffic Engineering - The capacity to determine the path that the traffic will take through the network

MPLS VPN - Service providers can create IP tunnels all over their networks using MPLS, which does not necessitate encryption or end-user applications

Layer 2 services (ATM, Ethernet, frame relay) can carried over the MPLS core Simplified network management through elimination of multiple layers MPLS has become popular due to its capability to form multi-service networks with high speed. It can support pre-provisioned routes that are virtual circuits known as Label-Switched Paths (LSPs), across the network. Provision for backing up multiple service categories containing different forwarding and drop priorities, is also available with this technology. Multiprotocol label switching addresses common networking problems such as scalability, speed, Quality of Service (QoS), and traffic engineering, and provides them a viable and effective solution. Owing to its versatility, MPLS has emerged as a solution capable of meeting bandwidth and other service requirements for IP-based networks. Scalability and Routing -based issues can be resolved by MPLS technology, which also has the capacity to exist over existing ATM and Frame relay networks. Considering the positive points and shortcomings of ATM, MPLS technologies were designed to provide more leverage to network engineers and to be deployed flexibly. The marketplace is constantly being replaced with new technologies and technology devices. MPLS came to the forefront when there was a requirement for a protocol that needs less overhead and at the same time provides connection oriented-services for frames of variable length. Technology such as ATM and frame relay has been replaced in many areas by MPLS technology, which combines many options to satisfy the MPLS has dispensed cell-switching and signaling protocol used by ATM. Concurrently, Multiprotocol label switching technology continues to maintain the traffic engineering and bandwidth control, which was popularized by ATM and frame relay in large-scale networks. Migration to MPLS technology is beneficial especially since the benefits of traffic management are important. Performance level increases and so does reliability.

Currently, MPLS is used in large "IP only" networks. It is mainly used for forwarding Ethernet traffic and IP datagrams. MPLS VPN (Virtual Private Network) and traffic engineering are the major application areas of MPLS technology. MPLS IP VPN, a layer 3 VPN technology, is used to check, classify, and monitor IP packets. It is based on the service provider, to secure overlay VPN solutions. MPLS IP VPN is distinguished for its flexibility in networking modes, and features such as network scalability, QoS and traffic engineering. Today's business operations employ diverse applications across the Wide Area Networks (WANs) and it is essential to manage and prioritize traffic over the networks securely. This necessitates the use of technology such as MPLS IP VPN, which is a proven method for traffic engineering and network security.

Here is some MPLS terminology:

A. Label switch router (LSR):

It refers to any router that has awareness of MPLS labels. The entry and exit routers of an MPLS network are called edge LSR (or label edge routers – LER), which, respectively, inject (push) an MPLS label onto an incoming packet (label assignment) and remove (pop) it off the outgoing packet (label removal). An edge LSR is often a high-speed router device in the core of an MPLS network that participates in the establishment of Label Switched Paths (LSP) using the appropriate label signaling protocol and high-speed switching of the data traffic based on the established paths.

B. Label switched path (LSP):

Itis path defined by labels assigned between end points. An LSP can be dynamic or static. Dynamic LSPs are provisioned automatically using routing information. Static LSPs are explicitly provisioned.

C. Label virtual circuit (LVC):

It is a hop-by-hop connection established at the ATM transport layer 0 implement an LSP.

D. LFIB:

Used by the core MPLS routers (which are not ingress and egress MPLS routers). They compare the label in the incoming packet with the label they have in their LFIB. If a match is found, the routers forward that packet based on that match. If not, the packet will be dropped.

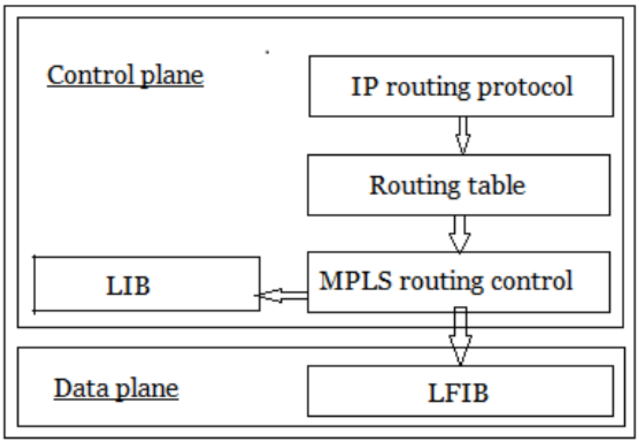

Figure 1.Planes of router

E. Label distribution protocol (LDP):

It communicates labels and their meaning among LSRs. It assigns labels in edge and core devices to establish LSPs in conjunction with routing protocols such as Open Shortest Path First (OSPF), Intermediate System to Intermediate System (IS-IS), Routing Information Protocol (RIP), Enhanced Interior Gateway Routing Protocol (EIGRP), or Border Gateway Protocol (BGP)[3].

III. IP BASED ROUTING

In traditional IP routing, each router in the network has to make independent routing decisions for each incoming packet. When a packet arrives at a router, the packet is stored in data plane of router. Each port of router is in its data plane. Now first layer 2 processing will be done on packet to check whether the packet is destined for that particular MAC of router. If yes then now layer 3 processing of packet is performed. Layer 3 process will check routing table, which is in control plane, the router to find the next hop for that packet based on the packets destination address in the packets IP header (longest match prefix lookup). Each router runs IP routing protocols like Border Gateway Protocol (BGP), Open Shortest Path First (OSPF) or Intermediate System-to-Intermediate System (IS-IS) to build the routing table. Now if next hop is available then again layer 2 processing will be done to change the destination MAC of the packet and then the packet is forwarded to required port. Now routing table, layer 2 and processes are present in control plane of router. Each time for each packet which in data plane, each router performs the same steps of finding the next hop for the packet. The main issue with conventional routing protocols is that for entire decision making process, there will be transfer of processing from control plan to data plan many times. So this is time consuming process. Also IP routing is performed at each hop of the packets path in the network. Entire IP header analysis is done at each hop which is time consuming[2].

IV. MPLS BASED IP ROUTING

Multiprotocol label switching (MPLS) is an addition to the existing Internet Protocol (IP) architecture. By adding new capabilities to the IP architecture, MPLS enables support of new features and applications. In MPLS short fixed-length labels are assigned to packets at the edge of the MPLS domain and these pre assigned labels are used rather than the original packet headers to forward packets on pre-routed paths through the MPLS network .

In MPLS, the route the packet is forwarded through the MPLS domain is assigned only once i.e., when the packet enters the domain. Before a router forwards a packet it changes the label in the packet to a label that is used for forwarding by the next router in the path. MPLS unicast IP forwarding logic forwards packets based on the labels, however when choosing the exit interfaces, MPLS considers only the routes in the unicast IP routing table. This results in the packet flows over the same path as it would have even if MPLS was not used. Using MPLS labels does not add any benefit by itself, but it essentially enables the MPLS traffic engineering in an MPLS network, and therefore a critical feature of the MPLS.

MPLS still requires the use of control plane protocols such as OSPF and LDP to learn the labels and relate those labels to particular destination prefixes for building correct forwarding tables. MPLS also requires a fundamental change to the data plane's core forwarding logic, it defines a completely different packet-forwarding logic. In an MPLS network, the hosts should not send and receive labeled packets. All labeled packets are only for the routing and only routers should be sending and receiving the labeled packets in an MPLS network. Here when packet arrives at a router, it is stored in data plane. Now to take forwarding decision , router refers the LFIB table which in data plane itself. Now decision will be done on basis of LFIB and taken in data plane only. Labeled packet is switched to required port and as it does not involve processing of control plane , the process is faster.

The principal difference between a lookup in the routing table and the MPLS LFIB is that the routing table lookup is concerned with longest prefix match, i.e. having potentially many (imprecise) matches and selecting the one that most closely resembles the destination IP address. On the other hand, the MPLS LFIB always performs lookups on fixed-length values and with equality operation, not with prefix-based logic. Hence, at least in theory, a routing table lookup is algorithmically more complex than a lookup in the LFIB, as finding a longest prefix match is more computationally intensive than simply finding a single matching value. Therefore the LFIB lookups should be faster. MPLS forwards packets based on the MPLS labels, instead of using the packet's destination IP address.

Advantage of using labels and not the destination IP address is that packet forwarding decision can be made on the other factors such as traffic engineering and QoS requirements. In MPLS the first device does a routing lookup, just like in traditional IP routing. But instead of finding a next-hop, it finds the final destination router. And it finds a pre-determined path from current router to that final router. The router applies a "label" (or "shim") based on this information. Future routers use the label to route the traffic without needing to perform any additional IP lookups. At the final destination router, the label is removed and the packet is delivered via normal IP routing. Therefore 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. FEC is forward equivalence class which means providing the type of behavior to reach the destination. Whatever is the type of traffic (unicast or multicast), the mechanism used and forwarding algorithm used to take decision is same. Hence MPLS is faster.

V. Experimental Setup

We have used NE20 series Huawei routers which are available in CETTM, MTNL (Service Provider in Mumbai) training center.

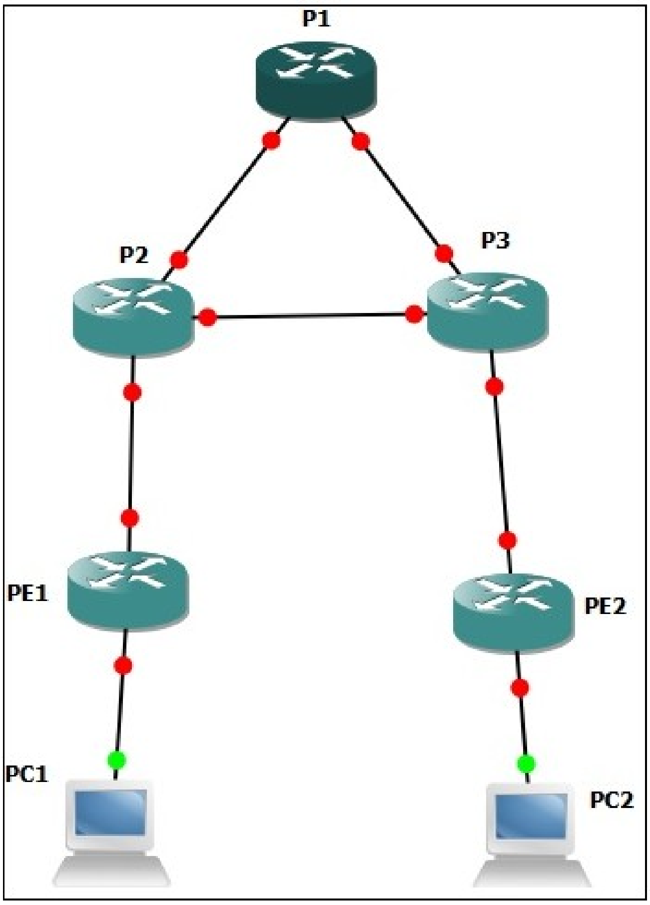

Figure 2. Experimental Lab Setup

We have made connection as shown in fig.2..Each routers are connected in series as shown fig.1 by gigabit Ethernetlink with optical fiber connectivity between them and at providers edge we have connected two laptops with Ethernet cable .For analysis of MPLS based and IP(OSPF) based network we limit the bandwidth to 10 Mbps on each port and send the traffic from PC2 to PC1 with three different flows .
Data,Video,Voice these are three flows we generated at PC2. We used JPERF for TCP (Data),VLC for Video streaming and 3CX Phone System software for making VoIP calls from one end to other end of the network .We analyze network with Wireshark Network Analysis tool installed on PC2 and PC1[8]. Jperf uses TCP flow for checking throughput of the network. In VLC streamingPC2 we use RTP/MPEG Transport stream.
3CX Phone System for Windows is a software-based IP PBX that replaces a proprietary hardware PBX / PABX. 3CX's IP PBX has been developed specifically for Microsoft Windows and is based on the SIP standard, making it easier to manage and allowing you to use any SIP phone . We use demo version of this software to make VoIP calls. It is also a client-server application.
Our focus for this experimental setup is to analyze network behavior in congestion with different traffic flows[1]. We test IP(OSPF) and MPLS based network with following parameters,

- Throughput
- Latency in the network

- Packet loss

We have connected devices as shown in fig.2.,We enable OSPF on each router and check the connectivity by pining PC1 to PC2 vice-versa., When network link is up, we set Jperf for 120 sec for TCP test with other traffic flows (Video, Voice). We have observed the network for 120 sec for TCP flow. All packets are captured at PC1.
Then we enable MPLS on each router and LDP (Label Distribution Protocol).We establish MPLS L3 VPN between PE1 and PE2 interface Ethernet 3/0/0 respectively[.In this case we use MP(Multi-protocol)-BGP(Border Gateway Protocol) for advertisement of route of VRF(Virtual Route Forwarding) between PE1 and PE2 . The Core network P1-P2-P3 are not aware about BGP, so Tunnel is established between PE1 and PE2[4].Now again we take captures at PC1 with same testing conditions in case of OSPF. Both the capture files capture at PC1 are compared with the wireshark tool.
Wireshark is a free and open-source packet analyzer. It is used for network troubleshooting, analysis, software and communications protocol development, and education .

VI. Experimental Result

Packets are captured at PC1 and we analyze packets based TCP on destination port based filter in wireshark (tcp.dstport==5016) . TCP destination port was set in Jperf at PC2 .

TABLE I : CAMPARISON OF PACKETS BETWEEN NON-MPLS BASED NETWORK AND MPLS BASED NETWORK

Sr. No.	Parameter	Non-MPLS Network	MPLS Based Network
1	**Number of TCP Packets**	106655	112834
2	**Time between first and last TCP packet**	120.032 sec	120.032 sec
3	**Avg.packets/Sec**	888.556	940.033
4	**Avg.bytes/sec**	1261586.478	1335007.943
5	**Avg.Mbits/sec**	10.093	10.68

Table 1.gives us the comparison between IP network and MPLS enable IP network . Throughput is increased in MPLS network .As throughput is increased no of Avg.bytes/sec also increased and number of packets received at destination port are also increased .

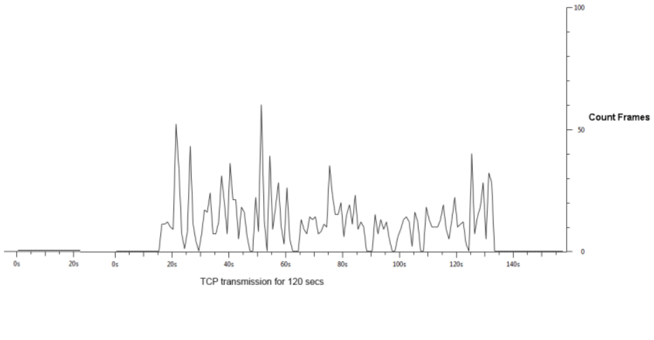

Figure 3. Packet Loss in Non-MPLS Network

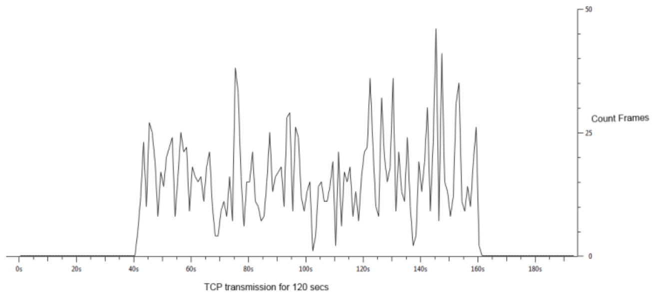

Figure 4. Packet Loss in MPLS Network

As shown in fig.3 packet loss is more than 50 inospf network for particular time interval and in mpls network packet loss less than 50 , Overall packet loss in MPLS based network is less as compared to OSPF network .

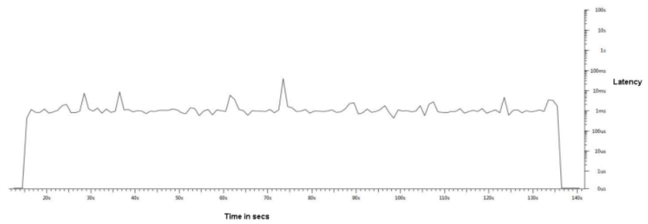

Figure 5. Latency in Non-MPLS Network

As we can see fig.5 latency avg. in non-mpls network is more than 1ms.

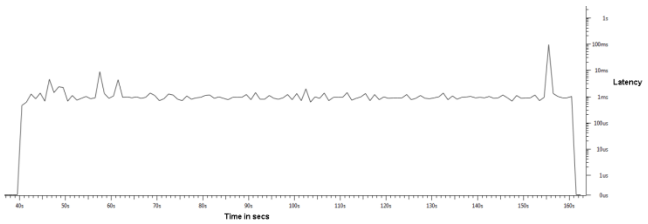

Figure 6. Latency in MPLS Network

Where as in MPLS network avg. latency is less than 1ms for most of the interval of the test . In terms of latency thempls enabled network show better performance than conventional IP network .Above results are obtained using wireshark tool by applying filters in the filter area .
Latency is critical park of the network by observing above latency graph some points in the graph showing latency in between 10ms and 100ms ticks.
Better analysis is needed with different traffic conditions in the network.

VII. Conclusion

This paper has been prepared based on the traffic flow over both conventional and MPLS network, where network topology and other experimental parameters are chosen as common to establish the performance of MPLS network over traditional network.
Based on the comparison of MPLS and OSPF protocol OSPF chooses next hop on the basis of bandwidth as a cost of network. As higher is the bandwidth lower is the cost and the lower cost path is preferred. In the MPLS L3 VPN case between PE1 and PE2, OSPF run as IGP (Interior gateway protocol).So, based on the comparison of signaling protocols,

it can be found that using additional features of MPLS like MPLS TE with RSVP or CR-LDP protocol we can increase the network performance by diverting roots of different traffic flows and by setting traffic flows to different paths.

The results are obtained in lab conditions where we have not changed default setting of router or PC. TCP window size and buffer values on PC and routers are not changed. The results are obtained after some experimentation and calculation with network scale (number of nodes, link capacity and delay) and traffic arrangements (sources and packet sizes, and rates). As expected, packet transmissions (in terms of both latency and loss) are improved in MPLS network. Throughput is also increased in MPLS enabled network. Although the chosen parameters can be disputed depends up traffic congestion to its extreme, the traffic engineering mechanism and setting MPLS experimental bits can enhance the performance of the service provider network.

VIII. ACKNOWLEDGEMENTS

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Authors:

Nishant N. Kale

Received B.E degree in Electronics engineering from University of Mumbai in 2011 . He work as Project Engineer from 2011 to 2012 . He is currently pursuing his Master's Degree in Electronics and Telecommunication engineering from University for Mumbai. During his master's program he works as Lecturer in MGMs College of Engineering and Technology, NaviMumbai , India. He has Published paper at "National Conference: Tech Stream" held at Pillai Hoc College of Engineering & Technology, paper title was "DWDM NGN Technology- Scenario of DWDM Networks". He has area of interest in networking , network security ,Virtualization , Cloud Computing ,Optical Fiber Communication subjects.

Sunil A. Waichol

He is working as Sr. Manager (MPLS) in MTNL Mumbai. His Academic qualification are that he is BE (Electronics & Telecommunication)from Amravati University , MBA (Information Systems) from Manipal University, Pursuing National Institute of Electronics & Information Technology (NIELIT) C level certification . He is responsible for Maintaining the MTNL Mumbai MPLS Network .

He has rich experience in the field of Telecommunications and has served MTNL in various capacities for 20 years.Prior to joining MPLS for six years, he worked as course coordinator in MTNL's Training Centre CETTM,Powai Mumbai, Where he was responsible for designing and delivering various training programs on OFC, SDH, DWDM, MPLS and wireless technologies like GSM& CDMA for National and International Participants. Beside many inhouse& vendor trainings in India on SDH, DWDM & MPLS, He has also been trained at Alcatel University, Lanion, France on 'GSM BSS' and also received the fellowship of Maastricht School of Management for the Executive program of 'Training for Impact' at Netherland. Prior to joining CETTM, he was working as Sub Divisional Engineer and was responsible for Installation of Transmission Systems in MTNL Mumbai. Where he has installed various OF Systems, SDH Rings & NMS of Various vendors like Fibcom, HFCL, Seimens, Tejas. He also has maintenance experience of one year in NMS of SDH Network.

