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# QUALITY OF SERVICES IN MPLS NETWORKS

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**Abstract.** As traffic networks have become increasingly complex, there has been a need to migrate from circuits to packet-based networks. MPLS is a promising solution for the growing number of applications that require different QoS treatments that share the same core network. This paper elucidates the role and objectives of QoS, general aspects of service quality in MPLS networks, implementation of MPLS TE network and its integration with IntServ and DiffServ, MPLS QoS applications on MPLS VPNs, as well as MPLS-TP integration with SDN, analyzing the advantages and challenges conditioned by their integration in optimizing the quality of services.

**Keywords:** *Quality of Services, Multiprotocol Label Switching networks, traffic engineering, IntServ, DiffServ.*

## Introduction

Communication is an indispensable element in any society. The evolution of communication tools reached its peak with the information age and the convergence of technologies. Convergence, which began in the mid-1980s, when there were three global communication networks: the telephone network for audio traffic, the television network for video traffic, and the Internet for data traffic. Also during this period it was decided to create a common network for all types of traffic. The result of the work was the ATM (Asynchronous Transfer Mode) protocol, which was not as successful as expected, but which introduced a very important concept - QoS (Quality of Services). Over the last 40 years, the concept has developed many sophisticated service quality (QoS) mechanisms to prevent the unintended consequences of imperfect networks [1].

The logic behind the use of QoS mechanisms seems to be irrefutable, and the word quality, with a strong positive connotation, reinforces the attractiveness of QoS. Therefore, many communication network developers share a common view that a network with smart QoS capabilities is better than a network without them [2].

Multiprotocol Label Switching (MPLS) can fully optimize network resources and provide quality of service (QoS) solutions to traffic, which has become the de facto standard for core network infrastructure. The separation between control and effective packet forwarding introduced by MPLS (MultiProtocol Label Switching) facilitates the use of QoS routing strategies [3, 4].

## 1. General aspects of QoS service quality in MPLS networks

MPLS (MultiProtocol Label Switching) is a standard developed by the IETF in 1997 for the efficient transmission of data packets according to the Internet Protocol (IP) [5]. All packet forwarding decisions are made on the content of the assigned tag, without the need to open and examine the IP packet. The wide area networks in which IP packets are transmitted according to the MPLS principle are called MPLS networks [6, 7].

Over time, the original concept of MPLS has been expanded, so that it can currently be used in both optical networks based on WDM (Wavelength Division Multiplex) technologies and SDH (Synchronous Digital Hierarchy) networks. The corresponding version of the network capable of integrating several technologies is known as GMPLS (Generalized MPLS). G MPLS networks are thus a new generation of wide area IP networks. If the connection-oriented MPLS network (G) is to be a universally usable and at the same time economical network solution for a wide range of applications, with its profiles and special traffic requirements, additional performance features are needed [8].

In any MPLS network a distinction is made between the ends of the network: the border area and its base area. This causes a differentiation between two types of so-called Label Switching Routers (LSR). LSR in the edge / border area is called (E-LSR - Edge Label Switching Routers), and basic LSR (C-LSR - Core Label Switching Routers) (fig. 10). Both types of LSRs are connected to the network via permanent logic connections, so that C-LSRs act as basic components and E-LSRs as edge / border components. Thus, they represent a logical routing network, superior to the physical traffic network. However, routers in an MPLS network exchange tag information not only between E-LSR and C-LSR, but also between neighboring C-LSRs, using the Label (Label Distribution Protocol) [9].

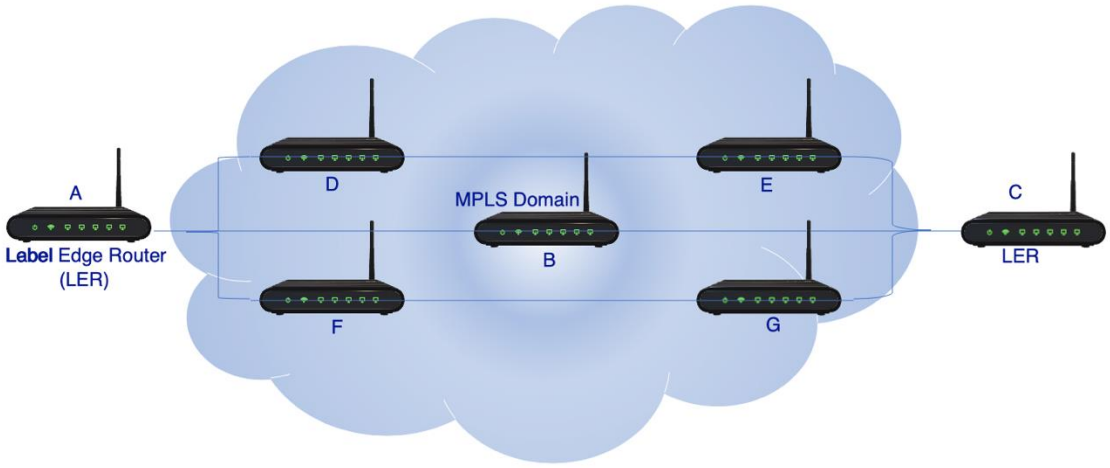


**Figure 1.** General Architecture of the MPLS Network.

**Advantages of the MPLS network**

- MPLS is scalable, connection-oriented and independent of any traffic technology capable of packet transmission;
- MPLS reduces the appearance of the Internet Protocol (IP) address on each router and minimizes network latency;

- MPLS improves packet forwarding on a network and overcomes the disadvantages of IP forwarding [10];
- An MPLS network can decide / select the best routing path, can allocate multiple services in the same network and can treat each traffic according to QoS requirements [11].

**Challenges of MPLS networks**

Despite the many advantages in MPLS networks, it is necessary to solve some problems such as:

- Improve scalability for routing network layers, using labels to agglomerate redirection information;
- Improving flexibility in the provision of routing services using MPLS tags to identify traffic with QoS;
- Implementing the label exchange paradigm to optimize networks and thus improve performance;
- Simplify the integration of the router with the technology based on cell switching using the common control of routing, routing and management [12].

MPLS has a strong and flexible routing function and can meet the requirements of various network applications, which allows it to be implemented on various physical media, such as Ethernet, PPP, ATM. Currently, MPLS is widely applied to networks and as a result, the quality of service (QoS) for MPLS networks needs to be implemented deliberately. MPLS establishes label switched paths (LSPs) to implement connection-oriented redirection. The quality of services for LSP provides QoS guarantee for the data flows transmitted through LSP. Therefore, the DiffServ and IntServ models are applied to MPLS networks. The combination of MPLS and IntServ forms the multiprotocol label switching traffic engineering (MPLS TE), and the combination of MPLS and DiffServ forms MPLS DiffServ.

## 2. MPLS traffic engineering (MPLS TE)

Traffic engineering allows service providers to drive network traffic, providing the best service to users, minimizing packet loss and latency, but maximizing throughput and supporting SLA enforcement.

MPLS-TE is implemented in the network with the main purpose of avoiding / minimizing network congestion and respectively to improve QoS. Congestion usually occurs in two conditions:

- when network resources are insufficient
- when there is inefficient mapping of traffic on available resources.

Network congestion can be addressed by:

- expanding the capacity of the network
- or the use of classical congestion control by limiting data rate, flow control, queue management and program-based control [13].

**MPLS-TE and IntServ integration.** MPLS traffic engineering automatically establishes and maintains switched Label Switched Paths (LSPs) across the network, using the Resource Reservation Protocol (RSVP). That protocol is used by IntServ to apply resources across the network and to maintain a forwarding state for each data stream, preventing extensibility. Therefore, IntServ does not prevail in networks. However, the relevant standards extend RSVP, allowing RSVP PATH messages to perform tag requests and RSVP RESV messages to

support tag allocation. The extended RSVP is called Resource Reservation Protocol-Traffic Engineering (RSVP-TE) and allows the MPLS to control the traffic crossing path and reserve resources during the establishment of the LSP. In this way, traffic can bypass congestion nodes. This method of balancing network traffic is called MPLS TE. MPLS TE monitors the path through which traffic passes, but cannot identify services. Traffic is transmitted along the LSP, regardless of service priorities. Therefore, if the actual traffic rate exceeds the specifications, the requirements for QoS-sensitive services are not met. Respectively, MPLS TE alone cannot provide the guarantee [12].

**MPLS and DiffServ integration.** Having only MPLS-TE does not ensure the quality of services, because MPLS-TE does not know the DiffServ classes. Therefore, DiffServ is introduced to ensure that TE is aware of the types of applications for each traffic situation and will be treated based on the QoS requirement. DiffServ aims to eliminate the need for separate physical networks for different applications [9]. The DiffServ model can distinguish services based on packet content and allows preferential transmission of high-priority packets and is widely applied to MPLS networks, respectively. However, DiffServ reserves its resources on only one node and cannot specify the width in advance. tape for each service. When the traffic rate exceeds the allowable bandwidth, high-priority services are preferentially transmitted at delayed costs and loss of low-priority service packs. In the event of severe traffic congestion, even high-priority services are delayed or lost. Thus, MPLS DiffServ hardly guarantees the quality of end - to - end services or may allow services to comply with the Service Level Agreement (SLA). However, the SLA still cannot guarantee with certainty, even after resources are deposited based on the level of applications with properly marked traffic. Network providers are currently using over-provisioning to achieve the goal of service guarantees, ensuring that more bandwidth is available than needed. However, overcharging has its own cost and can only work in normal cases, without guaranteeing success in the event of a network failure. DiffServ-TE works first by determining the type of traffic class. The basic requirement of DiffServ-TE is to be able to separate the bandwidth reservation for different traffic classes. This need requires the network to always keep track of the availability of bandwidth for each type of traffic dynamically, at a given time, on all routes and routers across the network. LSPs designed in traffic to guarantee bandwidth in a class type are called DiffServ-TE LSPs. After classifying the traffic, the path is calculated based on all available bandwidth per class type for all priority levels.

Traffic is mapped to a DiffServ-TE at the correct programming queue in two ways.

- The EXP bits in the MPLS header are set accordingly at the LSP E-LSP input.
- The planning behavior is encoded in the sending state of the LSP tag, and the EXP bits are used to transmit the drop preference for L-LSP traffic.

Once the traffic is mapped correctly to the LSP, it will be handled properly by DiffServ. DiffServ provides QoS by dividing traffic into a small number of classes and allocating class-based network resources. Theoretical research on DiffServ MPLS using the OPNET model simulator, confirmed that DiffServ allows high-priority traffic to reach its destination faster than low-priority traffic, while improving queue delay [2]. Meanwhile, MPLS-TE allows the reservation and optimization of network resources. The integration of DiffServ with TE combines the advantages of both, in which the FRR mechanism improves the general MPLS network.

**Quality of MPLS services on MPLS VPNs.** The quality of VPN services combines MPLS QoS and MPLS VPN to serve networks that have services with different priorities. VPN QoS distinguishes services with different priorities and ensures the preferential transmission of high priority services. This guarantees QoS for important services on VPNs. DiffServ, RSVP-TE and MPLS VPN can be used together based on real requirements for isolating services, distinguishing services with different priorities, providing bandwidth resources for important services or VPNs, and transmitting packets over VPN priority packet-based MPLS-TE tunnels or tunnels. It provides a solid technical basis for carriers to develop SLA-compliant voice, video and VPN services.

Depending on customer requirements, MPLS VPNs can be:

- Point-to-point;
- Layer 2
- Layer 3

MPLS Layer 2 and Layer 3 VPNs allow customers to have point-to-multipoint VPN connections. The VRF consists of one or more routing tables, a derived redirection table, the interfaces that use the redirection table, and the routing policies and protocols that determine the entries in the redirection table. Because each instance is configured for a particular VPN, each VPN has separate tables, rules, and policies that control its operation [7].

- With IP / MPLS, the paths between endpoints are dynamic and extremely fault-resistant;
- IP / MPLS will find a way as long as it exists, regardless of the number and locations of network failures.

### 3. Network defined by MPLS-TE software

When new technologies involve more services requiring significant advances and changes in MPLS networks, networks are forced to move towards network programmability, virtualization and cloud-based services [5].

With higher requirements for predictability, reliability and network performance, streamlining network management has become crucial. Service providers tend to implement smarter, more flexible and programmable networks. Programmable enabled networks are driven by intelligent software and use Programmable Application Interfaces (APIs) that serve as an interface to the device or controller to gather data or intelligent configuration configuration [13].

Software-defined Networks (SDNs) appear due to their flexibility and programmability and are an architecture that monitors the decoupling of the control plan and the data plan, making flexible and intelligent replays. With the separation of the control plan from the data plan, the network can be easily managed and innovated through programming. This feature allows local providers to perform delivery and monitoring efficiently, improving network agility. Through different protocols, control systems will train network devices to manage the packet.

The SDN architecture contains three layers:

- an infrastructure layer, which represents physical routers and switches;
- a control layer, which is the centralized controller responsible for managing the devices in the infrastructure layer;
- the application layer that interacts with the lower layers.

The main objective of the SDN is to allow the flexibility of network providers and to control the flow of data through the network. At the same time, SDN ensures the programmability and automation of configurations through a centralized control plan and open APIs. Network operators can implement their own protocols, rules and policies with common programming languages, gaining flexible control over network services such as routing, traffic technology, QoS and security [14].

With SD-WAN, the benefits of SDN are no longer limited to the data center. SD-WAN has become a concept for implementing SDN to WAN connections, as well as MPLS, broadband internet, 4 or 5G mobile networks, etc. SD-WAN management is centralized, using SDN to automatically determine the best route between two sites. The SD-WAN has the ability to monitor connections and, if necessary, dynamically direct traffic to connections with sufficient bandwidth for the application of each application. Unlike other network connection services, SD-WANs use application-based networks, where application traffic is transmitted through different WANs, based on priority QoS, Security and Business policies [12]. A QoS policy can be set so that voice packets can be transmitted over any WAN, as long as its QoS performance requirements are met (example: packet latency and loss). SD-WAN provides security, IP-based virtual overlapping networks that can use different coverage technology (example: dedicated Internet access, broadband Internet (cable, DSL or PON), Internet via LTE, MPLS over T1s or MPLS without fibers). Because IP-based SD-WANs are virtual overlap networks, there is a need to modify the coverage network, which is open to any topology [15].

In the MPLS network the traffic is dynamic and can be managed at any time. TE optimization on a single traffic matrix is insufficient and may have some limitations, especially when multiple applications are redirected to the network. This is explained by the fact that a single traffic matrix can have large measurement errors and can be the cause of traffic fluctuations. Moreover, large-scale networks pose major challenges in securing QoS for optimizing network management. The integration of MPLS-TE with SDN can completely optimize the network.

The literature also presents matrix approaches with multiple traffic to solve the large measurement errors that occur when a single traffic matrix is used. The TE / SDN network architecture can efficiently manage and deliver QoS requirements for multiple service traffic. The reliability of the proposed model depends on its ability to achieve high quality VoIP and video, with acceptable delay for HTTP. A related problem in MPLS-TE is the static bandwidth reservation mechanism of RSVP. The RSVP mechanism in the control plan reserves the same bandwidth for each jump along the tunnel and ignores the difference in available bandwidth of other links. This problem quickly leads to bandwidth depletion at the congested connection even with underused connections. TE / SDN can solve this problem by providing uneven bandwidth reserve to improve load balancing and network resource utilization. In MPLS packets are protected by performing a tag search on the labeling table in each LSR. Each application will have different EXP bits, and the LER input will decide the best path based on the priority level. However, as bandwidth and complexity increase, there will be a deficiency in MPLS tags. Label consumption is expanding rapidly, leading to management complexity, increased operational and capital costs, latency, and reduced performance and scalability. Therefore, some authors propose methods to solve the problem of reducing the label space in the MPLS network using an MPLS Open-Flow hybrid network scheme by LSP multiplexing. This goal was achieved by using tag stacking and TTL

bits to control packet switching between different LSPs. As a result, traffic with different sources and destinations can share the same LSP, thus solving the problem of reducing the label space with a transparent topology.

Studies have shown that congestion can occur even when TE is implemented in a network. Therefore, further research to optimize network traffic is needed. However, SDN is fully programmable and offers complete flexibility [16]. Despite the advantages of separating control plans and data, as implemented in SDN or network virtualization, the lack of a fast and reliable implementation prevents the network from growing to the desired capabilities. To improve this, MPLS could be integrated with network virtualization, so that the given architecture can extend the flexibility of the Internet and contribute to the development and commercialization of network virtualization and next-generation MPLS. As a result, the integration of MPLS with SDN could have a substantial impact on the future of the telecommunications industries.

## 4. MPLS-TP

Network providers are required to renew their network infrastructure to reduce operating costs. Currently, the circuit-based transport network is evolving towards packet-based transport, due to the flexibility and advantage offered by packet switching technology. To this end, MPLS-TP is currently being developed to form a basis for next-generation packet transport networks [17, 18].

The purpose of MPLS-TP is to ensure transport functionality in MPLS, while maintaining the existing MPLS architecture. The main requirement of MPLS-TP is to allow static LSP creation and to provide the same features and functionality as SONET / SDH networks, such as performance monitoring, fault detection, and delay measurement.

**MPLS-TP integration with SDN.** Similar to the MPLS network, MPLS-TP is integrated with SDN to improve the flexibility and integrity of the work network by providing programmability [19]. All work associated with the integrated SDN and MPLS-TP verifies whether the SDN can improve the network protection feature and improve the throughput. SDN reduces communication between operators of different network layers and can effectively cope with the volatile nature of traffic. Moreover, using cloud computing, users can use network resources in on-demand transport networks. By using virtual equipment, such as the virtual router proposed in, flexibility and automatic operational control are improved by programming, rather by using a hardware-based router.

**Quality of service issues in the MPLS-TP network.** Migrating from SDH to MPLS-TP networks has its own challenges. The bandwidth and QoS offered by the current service is no longer enough. The challenges facing service providers in moving from older SDH-based networks to MPLS-TP networks have been analyzed, and the results indicate that the integration of optical and packet-based networks does offer simplicity, flexibility and scalability and improved results in backhaul networks. Moreover, with TE capabilities, performance monitoring and QoS requirement could be improved. Providing on-demand bandwidth also improves network QoS. Separating different services into several network connections may seem like a cost-effective solution, but it does not meet the desired performance and increases the complexity of management. Although MPLS-TP itself could be well equipped with network protection schemes, traffic policies and TE, research is still needed to serve the growing number of network traffic [20, 21].

**Conclusion**

As traffic networks have become increasingly complex, there has been a need to migrate from circuits to packet-based networks. MPLS is a promising solution for the growing number of applications that require different QoS treatments that share the same core network.

MPLS offers one of the best technologies for dynamically managing traffic with different SLA requirements and overcoming failure promptly to ensure that consumers can enjoy uninterrupted services provided by their network providers.

Regarding the IP / MPLS extension, which is MPLS-TP: in such a network, important functions from the previous MPLS network are maintained, while inefficient functions are eliminated and improved protection functions are implemented.

Although MPLS networks can work well with sophisticated traffic engineering and awareness of more services, there is still a need for constant improvements.

Although MPLS networks can work well with sophisticated traffic engineering and awareness of more services, there is still a need for constant improvements. Based on current issues and research trends, the most common issue is protection, which is the main concern of every network. Protection research is still in progress.

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