Comparative Analysis of Signaling Protocols in Mpls-Traffic Engineering

Aruna Kapoor, Sunila Godara, Sanjeev Khambra, Amandeep

Deptt. of CSE, GJUS&T, Hisar, India

ABSTRACT
Multi-protocol label switching (MPLS) is rapidly emerging technology, which plays a key role in next generation networks by enhancing speed, scalability, delivering QoS and traffic engineering features. MPLS is a framework that provides for the efficient designation, routing, forwarding and switching of traffic flows through the network. In MPLS traffic engineering signaling protocols are used to increase the performance of traffic engineering in MPLS. This paper presents an analysis of MPLS signaling protocols for traffic engineering. The comparative study of signaling protocols RSVP-TE and CR-LDP is conducted on the aspects of LSP reliability and LSP adaptability to show that MPLS provides improved network performance for heavy traffic environments.

Keywords
QOS, MPLS, MPLS-TE, CR-LDP, RSVP, RSVP-TE

1. INTRODUCTION
IP-based networks typically lack the quality-of-service features available in circuit-based networks, such as Frame Relay and ATM. MPLS bring the sophistication of a connection-oriented protocol to the connectionless IP world. Based on simple improvements in basic IP routing, MPLS brings performance enhancements and service creation capabilities to the network.

Multi Protocol Label Switching (MPLS) technology offers the Quality of Service (QoS) that guarantees data communication service as Frame Relay (FR) and Asynchronous Transfer Mode without requiring the use of any dedicated lines which is due to its ability to speed up the traffic flow by using labels [1]. MPLS is a newer technology that offers service integration, layer 2 switching and connection orientedness, that allows traffic engineering controlled flows in the network. MPLS defines signaling mechanisms to support both Class of Service (CoS) and QoS[2].

This paper is organized as follows. Section 2 describes the MPLS while section 3 describes the MPLS-TE and section 4 describes the comparison of signaling protocols that are CR-LDP and RSVP with TE extension. The comparisons of CR-LDP and RSVP-TE are conducted based on the aspects of LSP reliability and LSP adaptability.

2. MPLS
Multiprotocol label switching (MPLS) is a framework that provides for the efficient designation, routing, forwarding and switching of traffic flows through the network. In the OSI model it lies somewhere between layer 2(data link layer) and layer 3(network layer). So it is often called layer 2.5 protocol. MPLS is a versatile solution to address the problems faced by present day networks-speed, scalability, quality-of-service (QOS) management and traffic engineering [1].
The Multi-Protocol Label Switching (MPLS) is used in Internet Service Provider (ISP) and as a backbone to Internet Protocol (IP) to provide guaranteed efficient bandwidth and Quality of Service (QoS) provisioning in the network. MPLS is a protocol end to end, its objective to give the router a big power of communication [3].In MPLS, the forwarding of packets is done based on a short fixed value known as a "label", inserted into a packet. All packets are labeled before being forwarded and consequently, at down-stream routers, analysis of the packet's network layer header is not required [9]. Rather, decisions on where to forward packets are made by using the inserted label. Furthermore, MPLS offers the following advantages [10]:

- Enhanced network layer routing scalability.
- Provision of routing flexibility.
- Increased network performance.
- Simplified integrations of equipment using non-IP forwarding paradigms.

Before forwarding a packet, a router may change its label. This label is used in the forwarding process at the next router. A protocol, such as the Label Distribution Protocol (LDP) or the Resource Reservation Protocol (RSVP) is used to exchange label information between neighboring routers. Label Edge Router (LER) is deployed at edge of the MPLS network and performs the role of inserting and removing labels. It also performs label binding by mapping label to Forwarding Equivalence Class (FEC). Label Switched Router (LSR) is a router used for making forward decisions with the help of MPLS label and label forwarding table [4].

3. MPLS Traffic Engineering (TE)
Traffic engineering refers to the process of selecting LS paths chosen by data traffic in order to balance the load on various links, routers, and switches in the network. This is most important in networks where multiple parallel or alternate paths are available. The goal of Traffic Engineering is to facilitate efficient and reliable IP network operations while simultaneously optimizing resource utilization and network performance [4]. In MPLS, traffic engineering is inherently provided using explicitly routed paths. The LSPs are created independently, specifying different paths that are based on user defined policies. However, this may require extensive

operator intervention. RSVP and CR-LDP are two possible approaches to supply dynamic traffic engineering and QoS in MPLS [4]. A major goal of Internet Traffic Engineering is to facilitate efficient and reliable network operations while simultaneously optimizing network resource utilization and traffic performance [4][6]. MPLS defines signaling mechanisms to support both Class of Service (CoS) and QoS[2]. MPLS networks can use native TE mechanisms to minimize network congestion and improve network performance. TE modifies routing patterns to provide efficient mapping of traffic streams to network resources. This efficient mapping can reduce the occurrence of congestion and can play an important role in the implementation of network services with quality of service (QoS) guarantees. These MPLS TE capabilities bring explicit routing, constraint-based routing, and bandwidth reservation to MPLS networks. MPLS TE relies on extensions to existing IP protocols (TE-RSVP, CR-LDP) [7].

4. MPLS SIGNALING PROTOCOLS

In an MPLS network an LSP (Label Switch Path) must be set up and labels assigned at each hop before traffic forwarding can take place. Based on the method used for determining the route, there are two kinds of LSPs: control driven LSPs (also called hop by hop LSPs), and explicitly routed LSPs (also referred to as constraint based routed LSPs, CR-LSPs). When setting up a control-driven LSP, each LSR determines the next interface for the LSP based on its IP forwarding table, and sends the label request to the next-hop router. When setting up a CR-LSP, the route for the LSP is specified in the setup message. The setup message traverses all nodes along the specified route. At each node, a label request is sent to the next indicated interface. Thus, a control driven LSP follows the path that a packet using default IP routing would have used. On the other hand, a CRLSP may be specified and controlled by the network operator or a network management application to direct the network traffic on a path independent of what is computed by IP forwarding. In this way CRLSPs may be used for traffic engineering. IETF MPLS brought up two signaling protocol called the Label Distribution Protocols (LDP) for setup and maintenance of control-driven LSPs. For setting up CR-LSPs, two approaches are being discussed: constraint-based routed LDP (CR-LDP), which requires a subset of LDP functionality that is enhanced to signal explicit paths, and extensions to the RSVP protocol. Before compare at glance RSVP and CR-LDP protocols, it is worthwhile to look at the desirable features of a signaling protocol for such applications [3]. The requirements for a signaling protocol used in MPLS based traffic engineering are as follows:

- **Robustness**: The signaling system must be able to ensure reliable and timely delivery of signaling messages even in the presence of network congestion or failure.

- **Scalability**: The size of ISP networks requires support for a large number of LSPs at each node.

- **Specification of QoS**: This includes the specification of the traffic descriptors (i.e., bandwidth requirements) associated with the traffic flow using an LSP, and the QoS requirements (e.g., delay, loss)

- **LSP establishment/teardown/maintenance**: The signaling protocol must be able to provide LSP establishment, teardown, and maintenance.

- **LSP priority/preemption**: Path preemption is a traffic engineering requirement to ensure that high priority LSPs may preempt (i.e., tear down) lower priority LSPs when there are not enough resources available to support both.

- **Flexibility in path setup options**: This includes strict and loose CR-LSPs, as well as the option to pin loose segments of a path [3].

5. 4.1 CR – LDP SIGNALING

CR-LDP standards attempt to enable the LDP protocol to work over an explicit route, transporting various traffic parameters for resource reservation as well as the options for CR-LSP robustness features [12]. Both LDP and CRLDP are hard state protocols, where signaling messages are transmitted once without any refreshing-information requirements. The transport mechanism for peer discovery is UDP, while TCP is used for session, advertisement, notification, and LDP messages. To setup an explicit route, a LABEL REQUEST message containing a list of nodes along the constraint-based route to be traversed is sent. The signaling message will be sent to the destination following the selected path, and if the requested path is able to satisfy the requirements, labels are allocated and distributed by means of LABEL MAPPING messages starting with the destination and propagating in the reverse direction back to the source. Assuming that resources are available, the LSP setup is completed after a single round-trip of the signaling message. CR-LDP is capable of establishing both strict and loose path setups with setup and holding priority, path preemption, and path re-optimization. The procedure for reporting failures in CR-LDP is based on ingress and egress router's TCP layer transport operations. CR-LDP enables multiprotocol operations by using an opaque FEC, which allows core LSRs to be indifferent with respect to the type of traffic being transported across the network. The opaque FECs are also used for security purposes as well, not enabling the LSRs to know the transport data services identity [15].

6. RSVP-TE SIGNALING

RSVP-TE is an extension to the RSVP protocol deployed in the Integrated Services (IntServ) architecture. Due to its soft state nature, state information in the network nodes along the path has to be refreshed periodically. RSVP-TE is a receiver-oriented protocol, meaning that label allocation and bandwidth reservation are driven by the receiver node. In particular, the standard specifies that label allocation has to be executed in downstream on-demand mode, that is the label is created by the downstream node and distributed to the previous hop only [17]. The RSVP [11] signaling protocol standard published by the IETF is intended for soft state resource reservation focusing on enterprise networks to support integrated services [14]. RSVP inherently is a soft state protocol that uses PATH and RESV commands to establish a LSP. In RSVP, based on the destination IP address and protocol ID, packets are transferred based on raw IP datagram routing. The ingress LSR uses a PATH message to inform every router along the selected LSP to acknowledge that this is a desired LSP to be established. Following this, the receiving LSR will use the RESV message with traffic and QoS parameters traversing upstream to reserve the resources on each node along the desired LSP. The node along the LSP will install the reservation for the related state by creating an entry on the label-forwarding table. At every node along the path, the PATH and RESV messages are used periodically to refresh the path and reservation states. Problems in resource reservation can result based on the RSVP soft state mechanism and the merging points along the selected LSP. Overall, there is no guarantee that the resources will be reserved based on the end-to-end request. RSVP-TE has been made and proposed to support ER-LSP as well as provide additional features to RSVP [13]. Since the RSVP protocol was proposed to support MPLS LSP setups, a considerable amount of modifications and extension have been made to the original protocol to cope up with the traffic engineering requirements. The major modifications and extensions fall into the areas of adding traffic engineering capabilities and resolving scalability problems. The revised RSVP protocol has been proposed to support both strict and loose explicit routed LSPs (ERLSP). For the loose segment in the ER-LSP, the hop-by hop routing can be employed to determine where to send the PATH message. Thus, RSVP also supports hop-by-hop downstream-on demand ordered mode [15].

4.2 Comparison Of Signaling Protocols

In this section, the signaling protocols of MPLS traffic engineering are compared. The signaling protocols in comparison are the CR-LDP, original RSVP, and the RSVP-TE. The features of the three signaling protocols are organized in Table[15].

A. Protocol Design Purposes and Fundamental Features

CR-LDP was created to enable LSP setup for reliable end to end differentiated services in MPLS networks. Compared to this, RSVP was established to support soft state resource reservation of integrated services over IP networks. RSVP was created before CR-LDP with originally a different intension of where it would be used. Therefore it is not surprising that RSVP is not suitable for traffic engineering in MPLS networks. The proposed RSVP-TE contains several modifications to support differentiated services with RSVP for MPLS traffic engineering networks, although some of the key components of the architecture are the same. For example, the original protocol base of using the internetworking protocol (IP) is the same, also the hop-by hop soft state refreshing algorithms are basically the same (although somewhat modified), as well as the reverse upstream LSP setup topology remains the same. Several features of CR-LDP, that were not a part of RSVP, are now possible by the proposed extensions that RSVP-TE possesses.

As in terms of scalability, CR-LDP is a hard state protocol, and due to this, it inherently possess better scaling properties in terms of the volume of signaling traffic in the network as the number of CR-LSPs increase. One of the significant drawbacks of RSVP is its scalability when there are a large number of paths passing through a node. This is due to the soft state characteristics of RSVP-TE, which require periodical refreshing of the state for each path [16].

B. LSP Reliability

In RSVP-TE signaling for traffic engineering, the failure notification process contains several problems. Relying on raw IP creates possible problems that RSVP may not be able to quickly inform the edge routers that the connectivity between them has failed. RSVP-TE does have explicit tear down messages, but due to relying on raw IP transporting they are not sent reliably enough. As a result, the edge LSRs may not start to re-route traffic until the expiration of the timeout interval. If the timing intervals were reduced, the traffic load due to the refresh operations would create more scalability problems [16].

In comparison to RSVP-TE, the TCP end-to-end connection oriented controlling mechanism of the CR-LDP relies on the ingress and egress LSRs to manage the LSP. Based on the fact that the CR-LDP is a hard state protocol, scalability is not an issue to consider. If a link is to fail, the TCP process will detect this and the ingress LSR will determine the procedures to take. In this case, the LSP options of being strict, loose, or pinned will define the options to take [16].

Table 1:
A Comparison of Cr-Ldp, Rsvp-Te

	CR-LDP	RSVP-TE
Protocol Objectives	Created to enable LSP setup for reliable end to end differentiated services in MPLS networks	Proposed with modification to differentiated services with RSVP for MPLS networks.
Network Positioning	Designed for carrier backbone networks	Revised designed for backbone networks
Differentiated Services	Supported	Supported
Routing Type	Strict, Loose, Pinning	Strict, Loose, Pinning
Scalability	Good	Marginal
User Security	Low	Low
LSP FEATURES		
LSP State	Hard	Soft
LSP State Refresh	None	Periodic, All Nodes
Resource Request	By sending LER	By receiving LER
LSP Setup Action	Forward Downstream	Backward Upstream
LSP Architecture	Sink Tree	Source Tree
RELIABILITY		
LSP Failure Detection	Reliable	Unreliable
LSP Failure Recovery	Local	Global
LSP Failure Recovery traffic	Low	High, all nodes
MULTIPLE CONNECTION SUPPORT		
Multipoint LSP Merging	Yes	Yes
Multicasting LSP Setup	No	No
ADAPTABILITY		
Loop Prevention	Yes	Yes
Path Rerouting	Yes	Yes
Path Preemption	Yes	Yes, but not reliable

C. LSP Adaptability

In RSVP-TE the shared explicit (SE) reservation style is used to set up alternative paths through "make-before-break" procedures. This requires a session to be established before leaving the previously used path. The newly selected LSP will have a different tunnel ID compared to the original one. In RSVP-TE, the protocol does have explicit tear down messages, although if this were to fail under high traffic pressure, the old LSP will be left to timeout (without being refreshed to stay alive) and will eventually be terminated. This possible scenario could result in serious problems for the network. First, the timeout period is much too long for backbone networks to be waiting for path termination, which results in a significant waste of bandwidth. Second, the remaining LSP may cause looping problems or other confusions to the LSRs, which is most undesirable.

For the case of path preemption, RSVP-TE uses setup and holding priorities to determine if a new path can preempt an existing path. Transport mechanism of RSVP-TE, which is on raw IP, may cause problems again for this feature support. Because preemption is often required when the network is running short of resources, the RSVP-TE signaling messages may get lost in this case. Then the path preemption feature would not be executed at all. Compared to this, CR-LDP relies on TCP, which shields the signaling protocol by continuously checking errors as well as the sequence of the data sessions executed. The rerouting capability in RSVP-TE may be used to re-optimize the path, which is executed by all participating nodes exchanging local traffic information to reselect the new path. The standards for RSVP do not have the pinning option included, although the RSVP-TE does contain the pinning option as an additional feature. In CR-LDP, path re-optimization is conducted by the ingress LSR, which is the most proper method to stably control the rerouting. The process is governed by the ingress LSR where end-to-end checking of the sequence of operation commands is protected by the TCP layer mechanism.

7. DISCUSSION

In discussion several features of signaling protocol, CR-LDP and RSVP-TE are similar. CR-LDP is hard state and RSVP-TE is soft state protocol. But the scalability issue of being soft state will be still left which is not a critical issue. This is based on the fact that the expected processing speed of the LSRs will be able to handle the computational tasks of the refreshing and other path modification requests. The key problem lies in the reliability. Inherently, as long as RSVP-TE is based on the transport of connectionless raw IP there will always be serious reliability issues. This is a critical issue especially under high traffic congestion periods where reliability is most important to support preemption capabilities or "make before-break" rerouting mechanisms. It is most likely that raw IP datagram will fail under these conditions, where on the other hand, even under high traffic loads, end-to-end connection oriented TCP session controlling topologies protect both end service users more reliably. Compared to RSVP-TE, CR-LDP relies on TCP, which shields the signaling protocol by continuously checking errors as well as the sequence of the data sessions executed. The rerouting capability in RSVP-TE may be used to re-optimize the path, which is executed by all participating nodes exchanging local traffic information to reselect the new path. The standards for RSVP do not have the pinning option included, although the RSVP-TE does contain the pinning option as an additional feature. In CR-LDP, path re-optimization is conducted by the ingress LSR, which is the most proper method to stably control the rerouting.

8. CONCLUSION

In this paper MPLS signaling protocols such as CR-LDP, RSVP-TE are summarized and analyzed based on how to set up LSP for TE with help of the protocol messages. CRLDP is a hard-state protocol and capable of establishing both strict and loose path setups with setup and holding priority, path preemption, and path re-optimization. RSVP inherently is a soft state protocol that uses PATH and RESV commands to establish a LSP. RSVP-TE has been proposed to support ER-LSP as well as provide additional features to RSVP and contains several specifications to support differentiated services with RSVP for MPLS traffic engineering networks. Based on comparison of signaling protocols, it can be found that RSVP has drawback in its scalability when there are a large number of paths passing through a node due to the periodical refreshing of the state for each path. In this paper, based on network reliability and QoS reservation capabilities, CR-LDP is considered to be superior to RSVP or RSVP-TE signaling, although both protocols require significant improvements in security and multicasting capabilities that need to be addressed.

9. REFERENCES

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