Inter-Domain Label Switched Path Setup on Diffserv Networks Using Bandwidth Brokers

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ABSTRACT

Bandwidth Brokers (BB) are a necessity to manage the intra and inter-domain resources in the Internet. In this paper we propose a way to setup inter-domain Label Switched Path (LSP) with the help of a BB in a MultiProtocol Label Switching (MPLS) over Diffserv network. We use traffic engineering extended Simple Inter-domain Bandwidth Broker Signaling Protocol (SIBBS-TE) to distribute the labels inter-domain. We also use a BB to interact with MPLS to setup an intra-domain LSP and to provision intra-domain traffic. With the help of a BB, we show how end-to-end Quality of Service (QoS) can be achieved.

Keywords : Multiprotocol Label Swicthing (MPLS), Diffserv, Label Switched Path (LSP), Bandwidth Brokers.

Diffserv Ağlarında Bantgenişliği Komisyoncuları Kullanılarak Otonom Sistemler Arası Etiket Anahtarlamalı Yol Kurulması

ÖZET

Diffserv teknoloji üzerine kurulmuş internetteki otonom sistemler arasında ve otonom sistemlerin kendi içindeki kaynakların iyi bir şekilde kullanılması için bantgenişliği komisyoncularının kullanılması bir gereksinimdir. Bu makalede Diffserv üzerinde Çok Protokollü Etiket Anahtarlama (MPLS) olan ağlarda bantgenişliği komisyoncusu yardımıyla sistemler arası etiket anahtarlamalı yol (LSP) kurmak için bir yöntem tanıtılmaktadır. Etiketleri sistemler arasında dağıtmak için trafik mühendisliği için genişletilmiş Basit Sistemler Arası Bandgenişliği Komisyoncusu İşaretleşme Protokolü (SIBBS-TE) kullanılmaktadır. Yine sistem içerisinde LSP kurmak için ve sistem içi kaynakları hazırlamak için MPLS'le etkileşen bandgenişliği komisyoncusu kullanılmaktadır. Bandgenişliği komisyoncusu yardımıyla uçtan uca servis kalitesinin nasıl sağlanabileceğini gösterilmektedir.

Anahtar Kelimeler : Çok Protokollü Etiket Anahtarlama (MPLS), Diffserv, Etiket Anahtarlamalı Yol, Bant Genişliği Komisyoncuları.

1. INTRODUCTION

Recent developments in Internet technology opened new horizons for the future of the Internet. Long awaited QoS-enabled technologies are on its way. Initial QoS research in internetworking focused on Resource Reservation Protocol (RSVP) and Intserv. It was seen that scalability problems prevent these technologies from broadly answering the needs of the current Internet. This led to the development of Differentiated Services (Diffserv), which eschews per-flow QoS reservation in favor of simplicity in routing through the network core. Diffserv is not as strong as RSVP-Intserv in terms of QoS but it is more scalable and simple to implement in a domain. Another technology is MultiProtocol Label Switching (MPLS). MPLS does not have strong QoS features but it is very useful for Traffic Engineering (TE) purposes and brings fast forwarding to backbones by deploying IP Switching.

To have robust QoS features and control over the domain, we need to implement MPLS technology over a Diffserv domain. Using MPLS inside a domain is well defined and MPLS technology is being studied intensively (1),(2),(3),(4). But there was not any focus on the use of MPLS technology inter-domain. If end-to-end QoS in an MPLS network is required, the inter-domain Label Switched Path (LSP) setup problem needs to be overcome. In this section we will answer these issues on Diffserv over MPLS networks by using Bandwidth Brokers (BB) (5), (6).

There are different approaches for interdomain label distribution. One of the approaches is to use Border Gateway Protocol (BGP) to distribute labels between peer edge LSR (7). In this approach authors propose to piggyback the label information with the BGP update message. This is done by using the BGP-4 Multiprotocol Extensions attribute (8). Another document gives a framework for inter-area LSP setup (9). The focus of this document is on setting up LSP across Interior Gateway Protocol (IGP) areas. IGP areas are the areas separated to make the autonomous system more manageable. Inter-area approach tries to set up an LSP across areas without prior knowledge of the resources available across the area boundaries. Recently, extensions to the RSVP for inter-domain LSP were proposed (10). The document discusses how current RSVP-TE cannot support inter-domain LSP setup, proposes extensions to the current protocol, and explains how extended protocol establishes inter-domain LSPs. A study on the cost of using MPLS for inter-domain traffic (11) shows that use of MPLS for high bandwidth flows and pure IP for low bandwidth flows can significantly increase the signaling scalability and also reduce the number of LSPs used for inter-domain.

In this paper we introduce a different approach to setup inter-domain LSP. We assumed BB supported Diffserv Internet with MPLS as the underlying QoS architecture. We introduce a new mechanism to establish inter-domain LSP on such a network. In order to connect LSPs in different domains Bandwidth Brokers (BB) are used. LSP setup is accomplished by Label Edge Routers (LER). We define a new way for domains to exchange labels that will be used to establish an LSP. Using traffic engineering extended Simple Inter-domain Bandwidth Broker Signaling Protocol (SIBBS-TE), BBs are capable of exchanging labels to setup inter-domain LSPs.

A. MultiProtocol Label Switching

MPLS is a technology that combines the best features of the layer 2 switching and the layer 3 routing to increase the performance and efficiency of the network (see (12)). An MPLS capable router is known as Label Switching Router (LSR).

An LSR is capable of understanding both layer 2 and layer 3 functionalities, and consists of two fundamental blocks: the control block and the forwarding block. The control block uses standard routing protocols to maintain a forwarding table. The forwarding block checks the header of the incoming packet and puts the packet into the corresponding output interface, as indicated by the forwarding table, using switching functionalities. These two components communicate with each other.

The MPLS uses labels to switch packets. Labels are short fixed length identifiers that are used during a forwarding process. Every packet is assigned a label and an LSR determines a forwarding path looking at the packet's label. Labels are distributed via RSVP or Label Distribution Protocol (LDP). Labels are associated with forwarding equivalency classes (FEC) and are local to that particular link. Peer LSRs distribute labels to each other. LSRs decide the next hop by looking up the *(label, incoming port)* pair in the forwarding table, and extracting a corresponding *(label, outgoing port)* pair. The path that LSP takes can be either decided by using conventional routing algorithms or can be defined explicitly. One of the strongest features of the MPLS is its traffic engineering capability. With this capability, domain administrators can easily manage the resources inside a domain by setting up various LSPs and can offer quality of service to the customers.

Explicit LSPs are also known as LSP tunnels (13). Label distribution protocols, such as CR-LDP, RSVP-TE, associate QoS features with the tunnel.

2. LSP TUNNEL SETUP IN A DIFFSERV DOMAIN

In our proposed model an end-to-end QoS path is a concatenation of separate LSPs. Setting up a label switched path tunnel in a domain is well defined. An LSP is a path defined by two end points, the LSRs in between, and the labels associated with that path. In order to support traffic engineering in a domain, conventional routing protocols were extended (14),(15). These extended protocols have the ability to carry QoS constraints and determine a path that conforms to these constraints. An Ingress LSR (entry point to an MPLS network) uses this information to determine a path that an LSP should take. Once the path is decided, the ingress LSR initiates label distribution if there is not already one setup for the same destination. All the LSRs on the path assign a label for the LSP. Once the labels are assigned, LSP setup is complete and the LSP is ready to use.

In our architecture, BBs are the entities that are responsible for the resource management within a domain (and between domains through cooperation with other BBs). When a reservation request comes to ingress LSR, the LSR notifies the BB. In our model, LSP should be associated with a Diffserv QoS classification.

A.Label - PHB Scheduling Class (PSC) Match

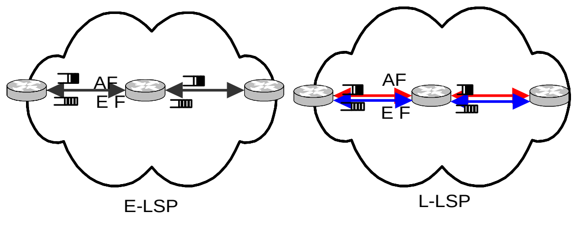

Figure 1. E-LSP: Packets use same LSP. LSR puts them in different queues. L-LSP: Packets use different LSPs and different queues (EF: Expedited Forwarding, AF: Assured Forwarding).

The basic LSP types for a Diffserv domain are suggested in (16). There are two different types of LSPs that can be used in a Diffserv domain. These LSPs are EXP-Inferred-PSC LSPs (E-LSP) and Label-Only-Inferred-PSC LSPs (L-LSP). An MPLS shim header contains a 3 bit EXP field, reserved for experimental use. In a QoS context this field is used to determine the QoS features that the label should be treated with.

Within a domain, an administrator can use combination of these methods to meet the QoS demands. E-LSP can support up to eight Behavior Aggregates (BA). Each BA can span multiple Ordered Aggregates (OA). This means that one LSP can support multiple different Per Hop Behaviors (PHB). In this case determination of the PHB to be applied depends on the EXP field of the label.

Using L-LSP, separate LSPs can be established for a single *(FEC, OA)* pair (16). PSC information is signaled during LSP establishment. This means a specific label is bound to that LSP and each LSR on the path knows exactly what kind of treatment that LSP should get. In this case a label has the information of what PSC that LSP has and EXP field is used to determine the drop precedence. Every LSR keeps the DSCP-LSP mappings. Ingress LSR looks at the DSCP of the packet and puts it into the LSP that has been associated with that specific QoS level. Intermediate LSRs check the label to decide the QoS treatment that a packet gets. Egress LSR pops the label and forwards the packet with its original DSCP.

B. Traffic Engineering Extended Simple Inter-domain Bandwidth Broker Signaling Protocol

For the interaction between BBs and domains we used Simple Interdomain Bandwidth Broker Signaling Protocol (SIBBS). SIBBS is developed by QBone Signaling Design Team (17). SIBBS only specifies inter-domain signaling protocol. The Bandwidth Broker in a domain can receive Resource Allocation Requests (RAR) from three different sources. One is the host in the domain that BB controls, and the other is the peer BB, and the last is a third-party agent acting on behalf of a host or application. The BB responds with a Resource Allocation Answer (RAA) to the request. The request may have certain side effects also, such as altering the router configurations at the access, at the inter-domain borders, and/or internally within the domain, and possibly generating additional RAR messages requesting downstream resources (17). For security reasons every BB authenticates the messages it receives from other BBs and signs the messages it sends to other BBs, suggested as an important issue in (18).

```
Originating BB:
get RAR;
IF (authentication and Resources and SLA conformation and Policy conformation)
THEN      egress-router = egress router;
Path = (Originating-router,..., egress-router);
IF (Label-Insert) THEN
Label = Request-Label;
ELSE;
RAR = RAR-swap (BB-ID, BB-Signature);
Forward RAR;
Wait RAA;
ELSE   Return RAA-Insert (Reason Code);

Transit BB:
get RAR;
IF (authentication and Resources and SLA conformation and Policy conformation)
THEN egress-router = egress router;
Path = (ingress-router,.., egress-router);
IF (Label-Insert) THEN
Label = Request-Label;
ELSE;
RAR = RAR-Swap (BB-ID, BB-Signature);
Forward RAR; Wait RAA;
ELSE    Return RAA-Insert (Reason Code);

Destination Domain:
IF (authentication and Resources and SLA conformation and Policy conformation)
THEN    egress-router = dest-router;
Path = (ingress-router,…, dest-router);
IF (Label-Insert)
THEN Label = Request-Label;
ELSE
Forward RAR;   // to the end-system;
ELSE   return RAA-Insert (Reason Code);

RAA Processing:
IF (RAA) THEN
IF (Label-flag) THEN
RAA = RAA-Insert (Label);
ELSE;
RAA = RAA-Insert (BB-ID, BB-Signature);
Allocate Resources ();
ELSE
Return;
RAA-Insert(BB-ID,BB-Sign, Reason Code);
```

Figure 2. SIBBS-TE pseudocode for label Exchange.

We extend the SIBBS protocol by adding inter-domain label exchange capability for interdomain label switched path (LSP) setup. Addition of inter-domain label Exchange mechanism is twofold. One is extending RAR message with *label request* object, and the other one is extending RAA message with *label* object. Figure 2 is the simple pseudo-code for the label exchange operation of SIBBS-TE.

Following is an example scenario of setting up these two mechanisms. Considering ASs as nodes, labels should be distributed from downstream ASs to upstream ASs. SIBBS-TE is used for the inter-domain label distribution (Figure 4). As an extension, optional *label-insert* and *label* objects are introduces to the protocol.

There are two different cases that require an LSP setup process to run on the inter-domain. In the first case, two domains connect for the first time and set up the initial LSPs. In the second case, domains decide to accept a new flow into the tunnel and if necessary increase the tunnel capacity. This is directly related to the dynamic provisioning [19] and in this case it is not necessary to request a label from the downstream AS. In this paper, we are considering the initial LSP setup case.

C. Intra-Domain LSP Setup in a Diffserv Environment Using BB

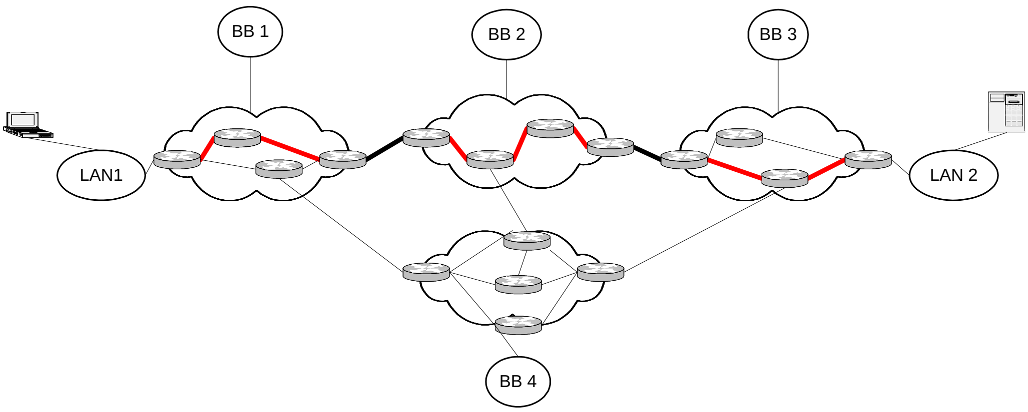

Figure 3. End-to-end LSP Setup

an LSP in a Diffserv domain with the help of a BB (

Figure **3**). Suppose the host at AS1 wants a QoS path with the server at AS4. The host generates a reservation request to BB1. BB1 first has to check whether the requesting entity has the right to ask for the request. BB1 also checks whether the request conforms to the SLA between the requester and the service provider. BB1 verifies that there is enough resources to support the requested traffic. A traffic engineering extended routing protocol gives possible paths and egress points to the destination considering the given QoS constraints. BB1 is the responsible entity to decide which path and egress point to use. This information is used to set up an LSP between the host and the egress point. LSP is established by the ingress router by distributing labels for the specified flow along the predetermined path. When the LSP setup is complete, BB1 sends back a resource allocation answer to the host.

3. INTER-DOMAIN LSP SETUP IN A DIFFSERV ENVIRONMENT USING BB

In the proposed model SIBBS-TE is utilized. In SIBBS-TE Resource Allocation Requests (RAR) travel downstream and Resource Allocation Answers (RAA) travel upstream. In MPLS LSP setup, labels are also distributed upstream. There is a logical match between

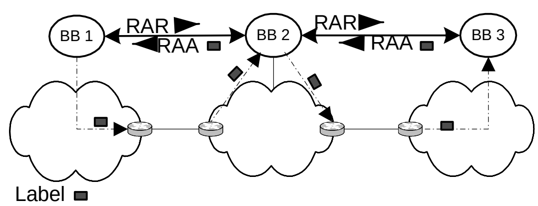

Figure 4. BB Signaling and label distribution.

For BB1 to send the RAR to the downstream BB, BB1 has to verify that LSP setup is possible in its domain. BB1 inserts a Label Request object into the RAR if there is no established LSP tunnel from egress to the ingress router or if the request can not be aggregated with other flows. Then BB1 sends the RAR to BB2, which is a transit domain BB. BB2 gets the RAR, and performs intra-domain LSP setup procedures. If LSP setup fails, BB2 sends back a negative RAA with a reason code. If the result is positive, then BB2 sends the RAR to the next domain bandwidth broker, which is BB3.

The destination BB, which is BB3 in the example, gets the RAR, checks whether it is possible to reach the destination, and sets up an LSP that supports the requested QoS. If the outcome is negative then the BB sends back an RAA with a reason code. In the case of a positive outcome, the BB forwards the request to the destination host. The destination host performs the routine checks specified in SIBBS and if the outcome is negative, it sends back a negative RAA to the BB. Otherwise, it sends back a positive RAA to the BB. If a label was requested, the BB asks the associated ingress router to assign a label for that flow, inserts that label into the RAA and then sends the RAA back to the upstream BB.

A transit BB receives the RAA. If a label was requested for that flow in the associated RAR, and if there is a label object in the message, the BB extracts the label from the RAA and sends the label to the assigned egress router. The BB asks for a new label from the associated ingress router, and then inserts that label in place of the extracted label. If a label was requested for that flow and associated RAA does not contain a label object, BB sends a negative RAA to the originating BB. If the label exchange is successful, the transit BB sends the RAA back to the upstream BB, which is BB1 in the example.

The origin BB (BB1) receives the RAA and processes it. If a label object is in the message, BB1 extracts the label from the RAA, and informs the egress router about the label. BB1 modifies the RAA, which includes taking out the label object from the RAA, and forwards the RAA to the requesting end-system.

When the host receives a positive RAA, this means that all the ASs on the path to the destination have established LSPs to support the requested QoS parameters. The intra-domain LSPs are connected to each other with inter-domain LSPs. As a result, the host has an end-to-end QoS path to the destination.

4. CONCLUSION

In this paper a new mechanism to exchange labels between two neighbor edge routers that are in different domains is introduced. As a result of a label exchange, edge routers establish an LSP relationship between them, which means that two domains those routers reside also establish an LSP relationship. Together with other proposals in the literature [20] the mechanism introduced in this paper is the only mechanism to establish an inter-domain LSP on a Diffserv internet using BB.

One of the advantages of using MPLS and Diffserv together is the scalability of the approach. Diffserv has 64 potential different classes. Currently only 14 of them are defined. Therefore, this is the maximum number of behaviors that must be support between domains. Since all the flows with the same QoS class receive the same treatment, they can be easily aggregate at an egress router. Another advantage of using MPLS is that it is easy to identify a flow by looking at a label. At the egress point, an LSR pushes one label for the flow and one for the tunnel. When the flow comes out of the tunnel at the ingress of the other domain, the ingress LSR pops the first label and swaps the second label. In addition, using MPLS with Diffserv we eliminate IP lookups at border routers.

By using MPLS-Diffserv-BB altogether the following problems are solved:

- Inter-domain LSP setup.
- Inter-domain flow management for Diffserv networks.
- Fast forwarding at border routers.

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