A proposal of feasible architecture for harmonizing IMS with MPLS-based traffic engineering

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Abstract - IMS (IP multimedia subsystem) is a key technology for the next-generation network, to enable NSPs (network service providers) to provide various services over IP-based fixed and mobile networks. In order for the NSPs to provide stable network services, it is important to realize policy and QoS mechanisms in the transport network. In this paper, we propose feasible architecture of IMS harmonizing with MPLS (multiprotocol label switching) LSP (label switched path) selection. Our method uses IMS function to acquire the session profile for LSP selection. We further propose dual-phase capacity assignment, which achieves fair accommodation between the pairs of edge routers in our proposed architecture, and maximizes resource utilization.

Keywords: NGN, IMS, MPLS, Traffic Engineering

1 INTRODUCTION

Many fixed and mobile NSPs (network service providers) supporting PSTN (public switched telephone networks) services are now promoting convergence towards the NGN (next generation network) [1] architecture, in anticipation of cost-effective synergy between legacy and Internet services. NSPs will design and construct their IP-based NGN core network to provide various services on a single network infrastructure. These services also have various QoS requirements, for example, (a) VoIP (PSTN) traffic should be guaranteed, (b) some transaction or signaling/control traffic may be delay-sensitive, and (c) the Internet traffic can be best-effort.

Nowadays, NSPs are considering more traffic accommodation in the transport stratum to provide the network resources for various services. However, particular applications consume more bandwidth than before, and further, the traffic requirements of particular customers occupy most of the bandwidth in some NSP networks. It is therefore desirable to be able to accommodate as many customers as possible in a fair manner.

In the NGN architecture, IMS (IP multimedia subsystem) [2] is a key technology, where CSCF (call/session control function) [3] is responsible for call (i.e. communication session) control using SIP (session initiation protocol) [4]. NSPs can gain the QoS demand (e.g., bandwidth the delay) of each session before data transmission based on the SIP messages exchanged between UE (user equipment) and CSCF. Such a session demand is transferred to the policy control server (PCRF: policy and charging rules function) in order to determine whether the session can be accepted or not. However, IMS itself does not specify the transport stratum issues, (e.g., how to realize QoS in the core transport stratum). In addition, IMS does not assume any underlying mechanism with regard to the transport stratum.

On the other hand, many NSPs have introduced MPLS [5] in their transport networks to realize flexible traffic engineering, by setting up logical circuits (LSP [6]) between the pairs of edge routers reflecting various constraints and the operator's policy. In addition, the NSP could collect the traffic amount per LSP directly related to the pair of edge routers. This information is convenient in that it enables a PCRF's call admission control to realize more precise traffic engineering. From the viewpoint of the traffic control and management facilities in an NSP, it can be assumed that an MPLS is often adopted in their core networks. In this paper, we study the harmonization of an IMS with MPLS-based traffic engineering for the transport stratum. Our research goal is to provide a stable communication environment to customers and raising the traffic accommodation as well as maintaining fair resource utilization among the pairs of edge routers. We propose an efficient MPLS LSP configuration and extension of IMS function to achieve this goal.

This paper is organized as follows. We show several issues in QoS control in combining IMS and MPLS in Section 2 and design a traffic engineering policy in Section 3. We explain the details of the proposed architecture in Section 4 and evaluate the proposed capacity assignment method in Section 5. We show the conclusion in Section 6.

2 ISSUES OF QOS CONTROL IN NGN ARCHITECTURE

2.1 Session Control Procedure in IMS

The procedure for call/session establishment in a mobile packet-based network is standardized in 3GPP. SIP signaling originated by the UE is sent to CSCF,

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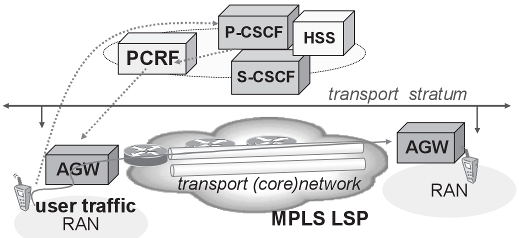

Figure 1 Functional structure of an NSP network using an IMS with MPLS

and CSCF responds to the UE as to whether the session can be accepted after obtaining a decision from PCRF.

Figure 1 abstracts a functional view of the NSP network using an IMS with MPLS. The transport stratum is composed of the RANs (radio access networks), AGWs (access gateways), and transport (core) network as shown in Figure 1. The AGW is located between the RAN and the core network and enforces QoS control for the user-data traffic (termed 'media traffic'). Gate opening/closing and marking the media traffic with the determined priority level. Packet marking is done by setting the bit value in the DSCP (diffserv code point) [7] or TOS (type of service) field in the IP header.

There are multiple signaling messages exchanged in establishing the session. The individual signaling messages go sequentially back and forth between UEs and CSCF. This implies that even if the one-way delay for a signaling message takes a few milliseconds, the completion of signaling takes several times longer than sending the single message. The delay requirement for the media traffic of SIP applications is less severe, comparing with the SIP signaling messages. Although the maximum domestic transmission delay (e.g., peaking at 10 milliseconds in Japan) may have little impact on the media traffic (application), but the round-trip time for exchanging the signaling messages is not small. Therefore, NSPs have to take these effects into account to minimize the signaling duration when designing and operating their networks. Based on these discussions, we presume that IMS-based services need, at least, the following traffic classes:

1. Class 1: both delay and loss sensitive, (e.g., signaling traffic)
2. Class 2: loss sensitive (e.g., VoIP traffic, and IPTV traffic)
3. Class 3: best-effort (e.g., Internet traffic)

2.2 MPLS Traffic Engineering

MPLS networks are composed of edge and core routers. Packets are transferred along one of the LSPs which are established between the ingress and egress edge routers. Once a packet enters the MPLS networks (the label for an LSP is assigned to the packet), core routers transfer the packet along the LSP. The mapped label value for an LSP expected by the egress router is delivered by RSVP (resource reservation protocol) [8] to an adjacent router along with the LSP. The adjacent router also delivers the mapped label for this LSP to its adjacent router towards the ingress router. Like this, the label delivery is conducted in a hop-by-hop manner.

MPLS traffic engineering provides benefits over IP network, that is to say, achieving the flexible control of the traffic in the transport stratum. The LSPs can either be routed explicitly (manually), or dynamically routed by the CSPF (constrained shortest path first) algorithm. In IP network, the shortest route to the destination is chosen by edge routers, even when it becomes more congested.

ABAF (automatic bandwidth adjustment function) has been specified and implemented [9] [10] [11] as one of a number of MPLS traffic engineering methods. This function not only automatically adjusts the LSP bandwidth but also dynamically reroutes the LSPs, when a certain physical link on the current LSP routes becomes short of capacity. The rerouting by the router is performed on an LSP basis; therefore, the ABAF may change the end-to-end delay of certain media traffic because of the sudden rerouting. In this situation the route is changed after the beginning of the communication, and the operators normally want to ascertain the route in the transport network. In ABAF, the route changes dynamically when no network failure occurs. Based on these issues, we assume that it is difficult for NSPs to adopt the ABAF in their MPLS networks.

From this discussion, it is clearly desirable that the edge routers have LSPs explicitly configured, have multiple LSPs for the traffic class, that the edge routers determine the route among them for arriving traffic and disperse the traffic over their networks, and that the total traffic in the network is taken into account for admission. The following function allows NSPs to meet these requirements: recognizing the demand for individual service traffic, selecting the LSP, and collecting the information on the utilization of the LSPs and the physical links.

When a pair of edge routers has multiple LSPs for a specific destination, most of the procedures for traffic dispersion are conducted by the ingress edge routers, as follows:

1. Rules to distinguish media traffic and determine one of the LSPs are stored in the ingress router beforehand.
2. The incoming traffic is distinguished into one of the traffic classes using the rules
3. The packet is marked in TOS or DSCP fields of IP header based on destination IP address and identified traffic class before the packet enters the ingress edge router.
4. The LSP is determined from the destination IP address and the mark of the packet, and the

MPLS forwarding table is looked up to find the label of the LSP.

Step 1 is realized using static rules or interworking with another entity to dynamically update the rules. The procedure for IMS enables the rules to be dynamically updated on a session basis as described in the next subsection.

2.3 Harmonizing IMS with MPLS

In this paper, we consider increasing the utilization of the transport (core) network by having IMS and MPLS cooperate. IMS provides session demands on UEs before the beginning of their communications. MPLS is used as the transport stratum and allows media traffic to be dispersion over LSPs and to provide fast reroute function [12]. IMS provides session demands on UEs before the beginning of their communications. Such information is useful to determine the target LSP for the communications; however, the following items should be considered for harmonizing IMS with MPLS-based traffic engineering:

1. deploying cooperative session control procedures between CSCF, PCRF, and AGWs,
2. recognizing the resource utilization of the transport stratum, and
3. an admission control method to deal with multiple traffic classes,

For item 1, although the QoS/policy control architecture is being standardized in 3GPP/3GPP2 [13], QoS/policy control in the core network is largely left for the deployment. In harmonization IMS with MSLS we, consider, LSP-based traffic statistics are collected, although physical link-based traffic statistics are after collected in the generic network operation. For item 2, the LSP traffic statistics concerning resource utilization are useful. For item 3, the method should take into account the fair accommodation described in Section 3.2 for the accepted amount of traffic at the ingress edges.

2.4 Related Work

ITU-T [1] standardizes the RACF (resource and admission control function) [14] as the QoS and admission control function in the NGN. The RACF has the same role as PCRF in 3GPP/3GPP2. However, the issue of how to adapt the RACF function to the control for the transport stratum also remains unresolved. We propose a function to control the transport stratum using MPLS.

Tamura et al. numerically examined that the optimal threshold for commencing traffic distribution over two LSPs and the optimal distribution over the two LSPs that will maximize the admitted traffic among *n* pairs of edge routers in reference [15]. This study presumed that each pair of edge routers would initially use a single LSP between them, and then begin to use a secondary LSP when the traffic exceeds the threshold. This study does not consider multiple traffic class. We presume that high priority traffic is always transferred into the shortest route even if the threshold is exceeded. We assume that the traffic demand can be recognized by tracking the traffic trend in every instance of the fixed time interval.

There is study to propose methods effectively minimizing the delay of signaling messages exchanged in IMS in order to ensure high communication quality [16] [17].In addition, various signaling methods in IMS have been investigated in 3GPP and academic research for this objective. However, there has been little study concerning the effective treatment of signaling in terms of traffic engineering, (e.g., the simultaneous treatment of signaling and media traffic) in IMS. Since the signaling includes various procedures during the session, a low-loss and minimum delay transport network is essential to ensure good communication quality that is perceived by users. Therefore, NSPs must take care when transferring signaling packets in the transport network.

3 DESIGN POLICY FOR TRAFFIC ENGINEERING

3.1 Traffic Class

We assume three traffic classes in our proposal, as described in Table 1. The primary class is for signaling which requires the minimum delay, while the standard class is for media traffic requiring sufficient bandwidth. We adopt IMS application traffic as standard-class traffic. Additionally, the best-effort traffic (e.g., Internet access) without a QoS requirement is taken into account.

Additional traffic classes for a more fine-grained treatment of traffic levels may be defined in certain NSPs. For example, the traffic for streaming applications requires a lower delay variation. We presume that such granular classes are treatable by a weighted round robin-based queuing discipline combined with priority queuing.

Table 1.Traffic Class

PRIORITY LEVEL	TRAFFIC CLASS	TRAFFIC TREATMENT
High priority	Primary class	Delay restriction needed - the shortest or sufficiently small delay routes
	Standard class	Loss sensitive - traffic distribution over multiple routes to gain capacity
Low priority	Best effort	Transferred into the shortest route if there is capacity.

We adopted at least three traffic classes in this paper to realize the traffic treatment in table 1. In this paper, a minimum three traffic classes was used in order to validate the effectiveness of the proposed architecture for harmonizing IMS with MPLS.

We assume that both primary and standard classes have a threshold, up to which traffic can be aggregated, while the remaining capacity can be allocated for the best-effort class. This threshold (termed *acceptable capacity*) is defined for each physical link. For the bandwidth requirement, we assume that the demand for the primary class is much less than the acceptable capacity for all physical links. However, the demand for the standard class exceeds the acceptable capacity. By using multiple LSPs, the standard class traffic can be transferred through these LSPs. The signaling traffic has a strong requirement for the minimum delay, so the primary-class traffic should take the shortest route among the LSPs between the pairs of edge routers. For the standard class, we assume the capacity requirement to be stronger than that of the delay. Standard-class traffic can be distributed over the multiple LSPs.

3.2 Fairness-aware capacity assignment policy

We consider that the bandwidth of any customer traffic is guaranteed at a certain minimum level. In this paper, fair accommodation means that a certain level of capacity is guaranteed on any pair of edge routers. This allows customers accommodated in any edge routers to have the successful rate of call/session establishment at some level even if the total demands in the networks severely exceed their capacity.

To increase the standard class traffic that can be admitted, while providing fair accommodation, we focus on two traffic assignments: one is for the lowest capacity among all capacity assignments for all pairs of edge routers, and the other is for the total capacity in the transport network. In order to satisfy the above principle, we propose dual-phase capacity assignment. In this capacity assignment, the first phase involves maximization of the lowest capacity assignment. During the second phase, the total capacity assignment is maximized from the remaining capacity of the physical links. For the first phase, an identical capacity is assigned to all the pairs of edge routers, and maximized, while for the second phase, we adopt the strategy of maximizing the total amount of the traffic admitted for the remaining capacity. The capacity of the physical link is assigned to the LSPs in order, starting with the smallest number of links composing each LSP. The way to maximize the total assigned capacity is as follows. When there is a certain capacity assignment $\boldsymbol{A}$, and assignment $\boldsymbol{A}$ has an LSP that can be composed of two or more distinct and shorter LSPs, another capacity assignment, whereby the former LSP is replaced by the latter LSPs has a greater total capacity than assignment $\boldsymbol{A}$ in terms of demand and based on the pair of edge routers. Details of the method for computing the capacity assignment that captures dual-phase assignment are described in Section 5.

4 PROPOSED ARCHITECTURE

4.1 MPLS LSP Configuration

Figure 2 shows the proposed network architecture. The AGW are connected to MPLS edge routers and filters the traffic from UEs. In typical MPLS network operation, single LSP with the shortest routes is established for every pair of (ingress and egress) edge routers. To best accommodate the traffic, traffic engineering is applied if another LSPs with detour routes are available. For example, in Figure 2, three LSPs along the shortest route (shortest LSPs) and an additional LSP along the detour route (detour LSP) are established between edge routers X and Y. Each shortest LSP (LSP-1, LPS-2 and LSP-4) is assigned to an individual traffic class (the primary-class, the secondary-class and the best-effort class, respectively). One of the shortest LSPs (LSP-2) and the detour LSP (LSP-3) are assigned to the standard traffic class. The standard class traffic is distributed over the two LSPs.

LSP-1 is for the primary-class traffic, while LSP-2 and LSP-3 are for standard-class traffic and LSP-4 is for best-effort traffic. LSP-2 preferably is separated from the standard-class LSP-2. The primary-class LSP, standard-class LSP-1, and the best-effort class LSP are established along with the shortest route between edge routers X and Y.

The traffic utilization for each LSP can be collected with SNMP [18]. Gathering statistics on the traffic of multiple LSPs (LSP1, 2, 3, 4) between any pair of edge routers, we can get the total traffic which is transferred among the edge routers. If we do not set up the LSP, we cannot acquire such traffic utilization easily by SNMP. It allows PCRF to acquire the traffic utilization for each LSP, and PCRF can use it for admission control.

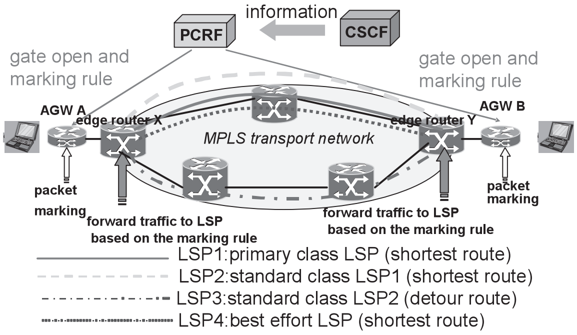

Figure 2 overview of network architecture

In our proposed architecture, we propose setting up multiple LSPs among each edge router. Our LSP configuration does not impose an additional load on the routers because the routers need not have functions like ABAF.

4.2 Admission Control Procedure

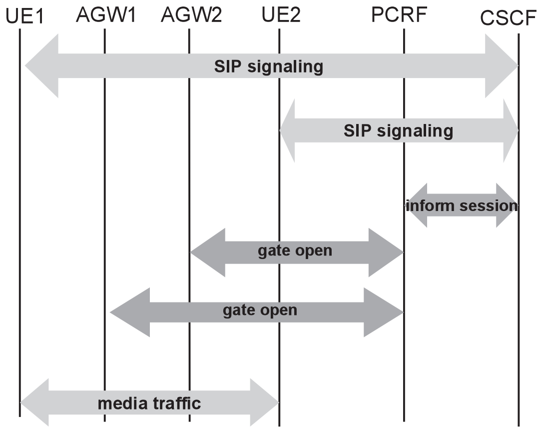

Figure 3 Session initiation procedure in IMS

Figure 3 illustrates the session initiation procedure in IMS standards. The AGWs set filters for QoS and policy control of the UEs' traffic. CSCF reports the session demands of the UEs to PCRF. Then PCRF requests the AGWs to open the gate for the UEs' media traffic, whereupon they begin the communication through the AGWs. In our proposal, the *gate open* procedure in the AGW is expanded to perform marking packets for traffic engineering. Based on the value of marking from PCRF, AGW performs marking packets for the media traffic. The detailed signaling procedures, e.g., the bidirectional media-traffic treatment, between UEs, AGWs, PCRF, and CFCS, are described in the following subsection.

Harmonization IMS with MPLS means that PCRF determines the admission and LSP selection for the media traffic with its demand which is provided by AGW and MPLS edge routers can acquire the rules used to distinguish the packets into traffic classes and marking before the media traffic arrives at the AGWs. We use the basic MPLS function, and need not expand the function of the MPLS edge router.

For media traffic session, the behavior of AGW is as follows:

1. The media traffic is marked in AGW to transfer it through the shortest LSP if the traffic is identified as primary class.
2. If the media traffic is identified as standard class, the traffic is distributed among multiple LSPs in MPLS edge router. Incoming media traffic is rejected if existing media traffic in each LSP has reached the acceptable capacity for one of the links composing the LSP.
3. Media traffic identified as the best-effort class is transferred into best-effort class LSP.

To prevent the loss of packet for the traffic going through of the primary and standard classes, admission control for the next call request of customers is important. The utilization of the physical links is regularly monitored and referred to decide whether media traffic is accepted, depending on LSP to which the media traffic is transferred. The monitoring is conducted by collecting the traffic counters for all LSPs, and the utilization of all the physical links is computed. We propose that PCRF performs the utility computation for admission control. PCRF can acquire the demand for arriving media traffic from CSCF.

We extend the standard session initiation procedure of IMS for the proposed traffic engineering, which is as follows:

1. The UE initiates the procedure with CSCF to establish SIP session.
2. CSCF queries PCRF to determine the LSP in the transport stratum through which the media traffic of the caller and the callee is transferred. Here, various parameters are informed to PCRF, (e.g., application type, IP addresses and port numbers).
3. PCRF distinguishes the media traffic into one of the traffic classes and determines whether the media traffic can be accepted. Here, PCRF refers to the utilization of the physical links along the LSPs assigned to the media traffic.
4. PCRF responds to CSCF if the LSP is determined.
5. CSCF report the establishment of the bearer to UEs.
6. PCRF sets up AGWs of the caller and the callee to open the gate for the media traffic and mark the media traffic.

PCRF and AGW routers have a common definition of the mapping between the mark (DSCP or TOS bit values) and the corresponding LSP.

In the transport stratum, the traffic controlled by IMS signaling can be mixed with the Internet traffic. We assume that non-IMS-based traffic is grouped into the best-effort class. So in this procedure, packets with the default mark (or no mark) are assigned to the best-effort class.

4.3 LSP selection procedure

In our proposal, we presume that whenever the call of standard-class traffic arrives, PCRF determines which standard class LSP the AGW should transfer the media traffic and whether it is accepted or not. PCRF calculates the capacity assignment for media traffic acceptance beforehand. The utilization of the physical links and LSPs which PCRF recognizes, is updated at specific time intervals (e.g., every 1 or 3 minute/s), since the traffic counter values for LSPs are collected at this interval. The capacity assignment for the media traffic acceptance for all the LSPs is also updated at this interval. The LSP selection for the standard traffic class is also conducted in proportion to the assigned capacity. On the other hand, PCRF responds with *cancel* to CSCF if any of the media traffic (e.g., a VoIP service using bidirectional traffic) is rejected.

5 CAPACITY ASSIGNMENT

5.1 Modeling of dual-phase capacity assignment

We applied the LP (linear programming) approach to achieve the goal of our research. We presumed that the demand was a real number to simplify the LP computation. We considered a model for dual-phase capacity assignment for standard-class traffic: the first assignment maximizes the minimum capacity among all the pairs of edge routers, with achieving fair accommodation for all the standard classes at minimum level; and the second assignment maximizes the total capacity for the remaining capacity in the transport stratum.

Maximizing the minimum capacity is computed by solving the LP, which maximizes the identical capacity assigned to all the pairs of edge routers. We define the following objective function for the first phase assignment:

$$C = d_k = \sum_i d_{k,i}$$

where d_k , $d_{k,i}$ denote the assigned total capacity of the edge router pair *k*, and the capacity of LSP *i* for edge router pair *k*. Here, we define the following constraint conditions for the above objective function:

$$\sum_k \sum_i x_{e,k,i} - u_e \leq 0 \text{ for } e \in E$$

where $x_{e,k,i}$ and u_e denote the assigned capacity of LSP *i* for the edge router pair *k* in the physical link *e*, and the available capacity for the standard class traffic in the physical link *e*. Although identical capacities are assigned to each pair of edge routers, this capacity can be distributed via multiple LSPs of each pair of edge routers.

Similarly, the second phase assignment is also computed by solving the LP, which maximizes the total capacity $C = \sum_k \sum_i f_{k,i}$ under the constraint conditions $\sum_k \sum_i y_{e,k,i} + \sum_k \sum_i x_{e,k,i} - u_e \leq 0$ for $e \in E$, where $f_{k,i}$ and $y_{e,k,i}$ denote the additional assigned capacity of LSP *i* for the edge router pair *k*, and that in the physical link *e*.

5.2 Evaluation Method

To evaluate the effect of the proposed capacity assignment in PCRF, we performed the simulation and compared the capacity assignment in all pairs of edge routers between four traffic assignments by varying the number of routers in the MPLS network (edge and transit routers). The first is the dual-phase capacity assignment with single LSP for the standard class traffic in each pair of edge routers. This is termed "*1-path max-min*". The second is the dual-phase capacity assignment with two LSPs in each pair of edge routers (termed "*2-path max-min*"). The third is the dual-phase capacity assignment with three LSPs in each pair of edge routers (termed "*3-path max-min*"). For the fourth, only the second phase of the dual-phase capacity assignment is applied without any fair accommodation consideration. It has the two LSPs for each pair of edge routers, and is termed "*2-path shortest-first* ".

To emulate the NSP topology, we used BRITE (Boston University Representative Internet Topology) [19]. BRITE is a tool for emulating network topology in an AS (autonomous system). BRITE provides the BA (Barabasi-Albert) model [20], which is often used to emulate the topology. We specified the number of routers and the degree, (the number of physical links per individual router) and generated network topologies for the simulation.

We specified that all links in the generated network topology had identical link capacities. In addition, the shortest LSP and detour LSPs (when multiple LSPs were used) were computed for all the pairs of edge routers. We need to be careful of the crossover of some detour LSPs, when setting up a detour LSP in the network topology.

In generating the network topology, we defined 80% of the routers as edge routers, and 20% as core (transit) routers. This reflects the situation in the NSP's MPLS networks, where there are many edge routers at the head and tail ends of the LSPs, and a smaller number of core routers, which transit traffic for the edge routers by switching the LSP. In the simulation, the edge routers had a degree of at least "2" since the edge router normally has two physical interfaces to connect the core (upper) network in the NSP. The core routers had a degree of over three.

The four capacity assignments were compared in the same network topology provided by BRITE, while BRITE also varies the topology as it generates. We tried ten simulations for each number of routers, and the results were averaged. To solve the modeled formula of LP, we used GLPK (GNU Linear Programming Kit).

5.3 Evaluation Result

The results of the simulations are shown in Figures 4 to 7. Figures 4 and 5 show the average and lowest amounts of traffic admitted at all the edge routers. The X-axis is the number of edge routers, while the Y-axis is the average or lowest volume of standard traffic class for each of edge routers and shows the ratio of traffic admitted to link capacity in edge routers. The value is normalized by the link capacity.

The average ratio of traffic admitted to link capacity (Figure 4) shows that 2-path shortest-first assignment achieves the largest traffic accommodation. Compared with 2-path max-min assignment and 2-path shortest-first assignment, the average amount of traffic admitted for 2-path max-min assignment is more than 80% of that for 2-path shortest-first assignment. But the object of 2-path max-min assignment is fair accommodation. Comparing 1-, 2- and 3-path max-min assignments reveals that traffic accommodation becomes increasingly similar, as number of edge routers increases.

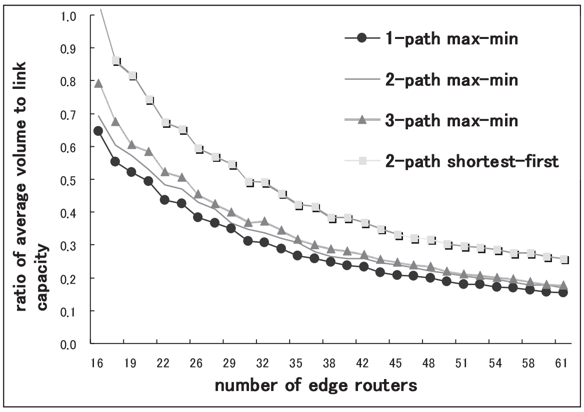

Figure 4 Average amount of traffic admitted in edge routers.

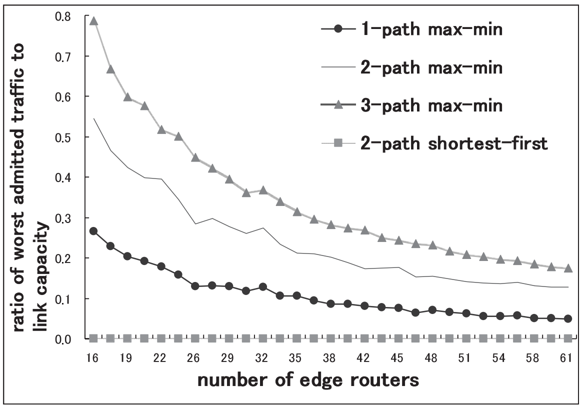

Figure 5 lowest amount of traffic admitted for each number of edge routers.

In the case of the lowest accommodation (Figure 5), 3-path max-min assignment achieves the largest traffic accommodation. 2-path max-min assignment admits about twice times as much traffic as 1-path max-min does. For 3-path max-min assignment, the admitted traffic is 1.2-1.3 times larger than with 2-path max-min assignment.

From the simulation data in Figure 5, 2-path shortest-first assignment generates a lot of “0” capacity assignment. 2-path-shorest-first assignment can achieve maximizing the capacity assignment in the network, but cannot assign minimum capacity assignment at some pairs of edge routers.

Figure 6 and 7 show the cumulative distribution functions for the ratio of traffic admitted to link capacity for 20 and 40 edge routers. These figures show that a relatively large number of edge routers cannot admit the demand for the 2-path shortest-first assignment. The results of the 2-path shortest-first assignment indicate that some of the edge routers cannot admit any traffic demand. For the other assignments, the fair accommodation is achieved.

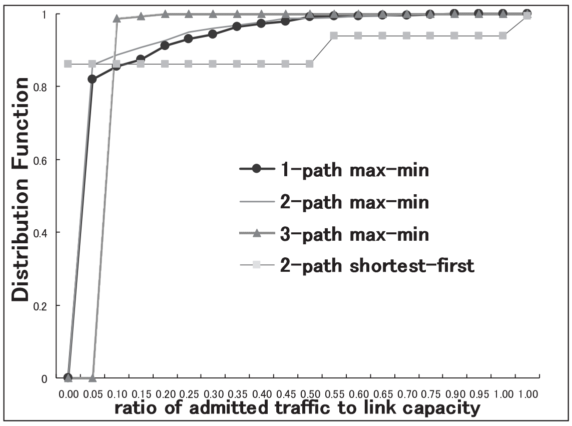

Figure 6 Cumulative distribution function in 20 edge routers

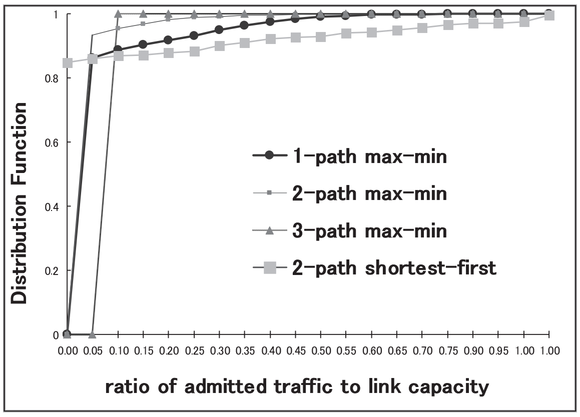

Figure 7 Cumulative distribution function in 40 edge routers

In terms of fair accommodation, it is too constraining to take the 2-path shortest-first assignment in the NSP's operation and service. These results indicate that the 2-path shortest-first assignment is impractical for an NSP's operation, while 2- and 3-path max-min assignments are effective in terms of fair accommodation.

Focusing on the number of LSPs in each pair of edge routers, the additional benefit of 3-path max-min assignment from 2-path max-min assignment is less than that of the change to 2-path max-min assignment from 1-path max-min assignment. And, comparing 3-path max-min with 2-path max-min, the benefit becomes more worthwhile as the number of edge routers increases. This is probably because the number of disjoint LSPs for the 3-path case is similar to that for the 2-path case. Moreover, this limitation may result from the number of degrees (two for edge routers and three for transit routers) in the simulation network topology. Generally, it is more difficult to set up multiple disjoint paths as the number of LSPs in each pair of edge routers increases. We presume that the progress of 4-path max-min assignment or cases using more paths is probably much less than that of 3-path max-min assignment from 2-path max-min assignment.

The differences of the admitted traffic ratio for each number of routers between the 1-,2- and 3-path max-min assignments in Figure 5 are is more than that in Figure 4. We can say from the results that the lowest value of capacity assignment is remarkably improved by setting more multiple LSPs between the pairs of edge routers. It achieves fair accommodation between each pair of edge routers more effectively

The number of variables in LP to solve the capacity assignment increases as the number of routers increases in the simulated topology. However, even with over 60 edge routers in our simulation, the computation time required to solve the modeled LP was generally less than one second. We used an off-the-shelf PC with a 2.00 GHz Intel Core™ 2 CPU and 1.99 GB memory for the simulation. Therefore, the computational load of our proposed capacity assignment is sufficiently low.

5.4 Discussion and Future Work

We set "two" as the value of the lowest degree in BRITE for the simulation. It is because edge routers usually have two physical interfaces for redundant access to core routers, taking account into the realistic network topology of NSPs. We presume that using "two" as the lowest degree is sufficient to simulate the realistic network topology. Using "one" as the lowest degree, we presume that the effect of 1-, 2- , 3-path max-min is not large. And, using "three" or larger value as the lowest degree, we presume that the effect has more progress.

However, increasing the number of LSPs for each pair of edge routers complicates network operation, in terms of LSP maintenance, e.g., recovering from failure and utility monitoring. The number of LSPs set up between pairs of edge routers entails a trade-off between operational cost and resource utilization. Issues for future consideration include performing validity of multiple LPSs at each pair of edge routers and increasing the number of degrees in the network topology. And, it is necessary to evaluate the performance of our proposed capacity assignment for a number call requests.

6 CONCLUSIONS

In this paper, we proposed the architecture for harmonizing IMS with MPLS-based traffic engineering. We showed the extended PCRF function as a way to utilize IMS session demands for resource management of the MPLS core network. IMS provides session demands on the media traffic and MPLS disperses media traffic following PCRF's determination of path assignment.

We presented the benefits of harmonizing IMS with MPLS and proposed the required functions, architecture, and procedure. To implement our proposal, the MPLS routers need not have additional functions. A variety of methods might achieve the objective of our work, however in this paper we proposed first of all that the signaling traffic is prioritized as primary-class LSP and that the media traffic is transferred into multiple standard-class LSPs.

With regard to traffic engineering in the proposed architecture for the standard-class traffic, we proposed a dual-phase capacity assignment to maximize the lowest value in the capacity assignment, and to maximize the remaining bandwidth for the standard-class traffic. In the evaluation of capacity assignment, we compare the effect of our proposed capacity assignments with the 2-path shortest-first, which is equivalent to the second phase of the proposed capacity assignment. We thus showed that the lowest amount of traffic admitted into the edge routers increased, corresponding to the number of LSPs per router pair. However, the average amount of traffic admitted into the edge routers when adopting one, two and three LSPs was almost identical, regardless of the number of edge routers.

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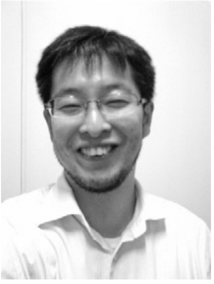

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