A Study on End-to-End QoS Provision for Multimedia Services in Beyond 3G Convergence Networks

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Abstract

In Beyond 3G networks interworking with external IP-based networks, end-to-end QoS provision is a critical issue. To facilitate this, 3GPP proposes the policy-based network management and suggests IntServ and DiffServ as policy enforcement means. Even if DiffServ is preferable to IntServ in scalability and configurability, it has the limitation of not being able to leverage multiple paths, hence undesirable in the network utilization aspect. In this paper, we propose DiffServ-aware Multiple Protocol Label Switching (MPLS) as a policy enforcement means. It enables to provide differentiated levels of QoS as well as to improve network utilization by splitting packets over multiple paths. It is also able to avoid the per-flow packet ordering problem occurring when splitting a flow into multiple paths by using a hashing-based scheme. We verify the effectiveness of our proposed scheme by the NS-2 based simulation.

I. Introduction

End-to-end QoS provision in packet-based cellular services is gaining more importance as there emerge more cases that UMTS networks interwork with external IP networks. Particularly, the end-to-end QoS provision is a critical issue when it concerns delay-sensitive real-time traffic of which volume will increase significantly when the UMTS networks start in near future the full-scale adoption of IP Multimedia Subsystem (IMS)[1] to allow cellular users to access external IP network based services.3GPP[2] suggests adopting policy-based network management architecture in order to tackle the end-to-end QoS provision issues[3]. In the current proposed policy-based architecture, IntServ[4] and DiffServ[5] are employed as policy enforcement means and Common Open Policy Service (COPS)[6][7] protocol is used to carry policy-related control messages among network entities. A policy-based architecture using the COPS protocol for the resource management of diversified and heterogeneous radio environment in which UMTS, HiperLan, and DVB are integrated[10] and a policy-based architecture for IMS service is proposed[11]. Their work lists network entities and communication interfaces necessary to support QoS of session-based services of IMS. The same authors[12][13] suggest a policy-based architecture for the UMTS and WLAN integrated environment. Their work presents several WLAN interworking scenarios to show how the proposed architecture. In this paper, we propose DiffServ-aware MPLS as a policy enforcement means in the policy-based network management of Beyond 3G networks in Section II, One of the features is that it is able to avoid the per-flow packet ordering problem occurring when splitting a traffic flow into multiple paths. It is also able to limit the maximum allowed bandwidth per traffic class by using token buckets.

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NS-2 based simulation in Section III verifies the effectiveness of the proposed scheme.

II. Policy Enforcement using DiffServ-aware MPLS

MPLS is an IETF standard enabling high speed packet switching by circum venting CPU-intensive table lookup in the forwarding routing table necessary to determine the next hop router of an IP packet[8]. Instead, it uses packet switching based on labels, which are assigned to each packet by evaluating the pair of source and destination IP addresses of packets. The proposed DiffServ-aware MPLS based policy enforcement leverages multiple paths by routing the realtime and the non-realtime traffic through separate paths to destinations, as a consequence, being able to provide them each with differentiated QoS levels is illustrated in Figure 1. The applied policy is to detour part of non-real traffic along a non-optimal path in order to protect the bandwidth on a shortest path for realtime traffic. As a result, realtime traffic and part of non-realtime traffic move along a shortest path consisting of Label Switch Router (LSR)-1, LSR-2, LSR-3, and GGSN, while the rest of non-realtime traffic along a one-hop longer path, LSR-1/LSR-4/LSR-5/LSR-6/ GGSN.

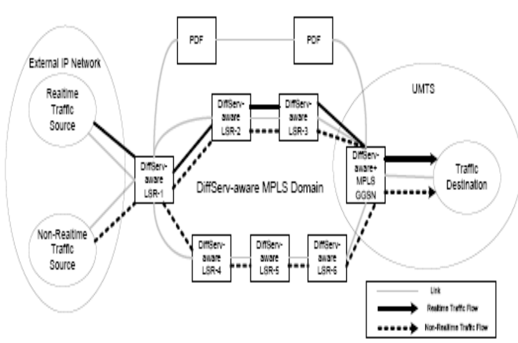


Fig. 1. The proposed DiffServ-aware MPLS based on policy enforcement management

The details of the applied policy operation are as follows. LSR-1 performing DiffServ-aware MPLS, firstly, uses DiffServ to mark DSCP on packets incoming from the external IP network. It marks Expedited Forwarding (EF) on the realtime traffic packets when its volume is below the maximum allowed bandwidth for the realtime traffic and Assured Forwarding (AF) when it goes beyond the limit. For the non-realtime traffic, it marks AF in case of below the maximum allowed bandwidth for non-realtime traffic and Best Effort (BE) otherwise. Secondly, LSR-1 uses Explicit Route LSP (ER-LSP) of MPLS , a LSP of which participating LSRs can be explicitly specified when the LSP is established. We suggest splitting traffic among multiple paths in a way that all the packets of a same flow are forwarded along a same path, preserving the packet ordering and at the same time leveraging the increased bandwidth because of the multiple paths.

Figure 2 shows the architecture of the LSRs to support the proposed DiffServ-aware MPLS based policy.

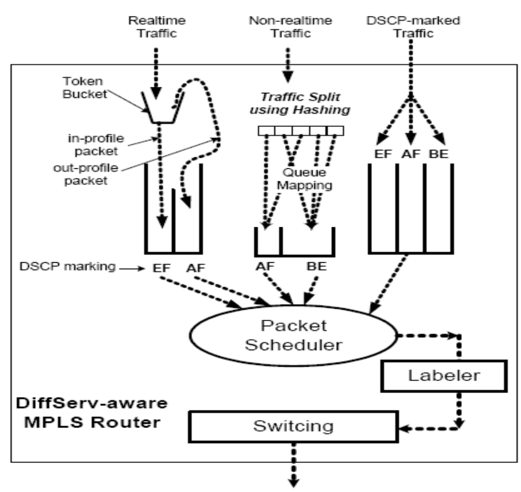


Fig. 2. The Label Switch Router structure supporting DiffServ-aware MPLS

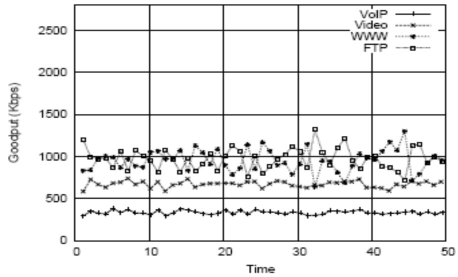
The router architecture consists of four parts from top to bottom: packet classifying queues, packet scheduler, labeler, and switching component. Firstly, incoming packets are classified according to their characteristics and, then stored in the corresponding packet classifying queues, which will be described in detail shortly. Secondly, the packet scheduler selects packets for transmission, and then the labeler marks the packets with labels for switching unless labeled yet. Finally, the switching component transmits the packets through one of outgoing network interfaces, which is determined by the label of the packets. There are three types of the packet classifying queues, which are for the real-time traffic, for non-realtime traffic, and for DSCP-marked traffic respectively. The realtime traffic queues use a token bucket to limit the maximum allowed bandwidth for the realtime traffic. The realtime packets of which rate are below the maximum allowed bandwidth go into *in-profile* queue and are assigned EF, and otherwise into *out-profile* queue and AF.

III. Simulation and its Results

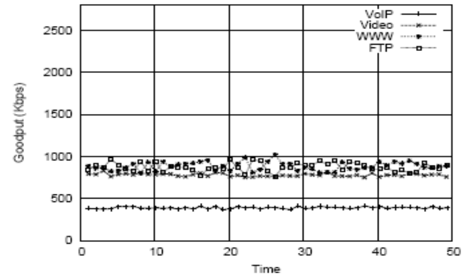
We perform a simulation to verify the performance and the effectiveness of the QoS provision of our proposed DiffServ-aware MPLS based policy enforcement. We use NS-2 version 2.29 [9] to run the simulation. To enable routers to support the DiffServ-aware MPLS, we make necessary modification to MPLS-related C-language modules of NS-2. We generate simulated traffic in a way that the non-real time traffic has more volume than the realtime traffic: 1.2 Mbps for realtime traffic and 4.8 Mbps for non-realtime traffic in total. For the realtime traffic, we generate 400 Kbps VoIP traffic and 800 Kbps video streaming by using UDP-based CBR traffic. For the non-realtime traffic, we use WWW traffic and FTP traffic each generating at 2.4 Mbps by using TCP-based traffic. We perform the simulation for five cases. First, we do not use any policy and related enforcement mechanisms, simulating best-effort based IP routing. Second, we apply a DiffServ-only policy by marking the realtime and the non-realtime traffic with different DSCPs and scheduling accordingly. Third, we employ a MPLS-only policy by routing realtime and non-realtime traffic into separate paths. Fourth, we use the proposed DiffServ-aware MPLS based policy, but without the per-flow packet ordering. Finally, we use the proposed scheme supporting the per-flow packet ordering. As the simulation results to be compared as the QoS metric, we measure goodput per traffic classes.

Figure 3(a) shows the simulation result of the first case which uses the besteffort nature of existing IP networks. We generate the VoIP and video traffic as 400 Kbps and 800 Kbps respectively but the actual goodput of those traffic reach only 330 Kbps and 670 Kbps, while the each goodput of the WWW and the FTP traffic is around average 1.0 Mbps which is far below the packet generating rate of 2.4 Mbps. It should be noted that the non-realtime traffic has a bigger drop ratio of the goodput, (= 1.0 Mbps/2.4 Mbps) than that of the realtime traffic (330 Kbps/400 Kbps and 670 Kbps/800 Kbps) because of the congestion control nature of TCP, which is not included in UDP.

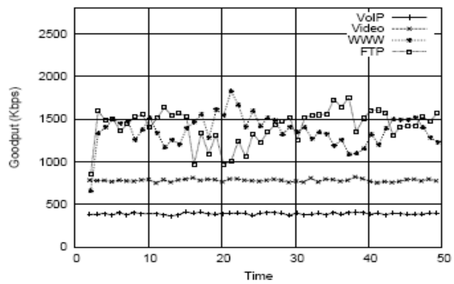
Figure 3(b) shows the result of the DiffServ-only policy application case in which the realtime traffic bandwidth is ensured at the sacrifice of the non-realtime traffic. We observe that the goodputs of the VoIP and the streaming traffic are guaranteed to support the source transmission rate of 400 Kbps and 800 Kbps respectively but the goodputs of the WWW and the FTP traffic, which are around 900 Kbps, are largely dropped compared with the source transmission rates of 2.4 Mbps. To set up the maximum allowed bandwidth per traffic, we allocate a token rate of 1 Mbps each for VoIP and video streaming traffic, and 500 Kbps each for WWW and FTP traffic. As a consequence, most of the WWW and the FTP packets which are given the BE code are dropped , on the contrary all of the VoIP and the streaming packets are coded as EF, reaching the destination successfully.



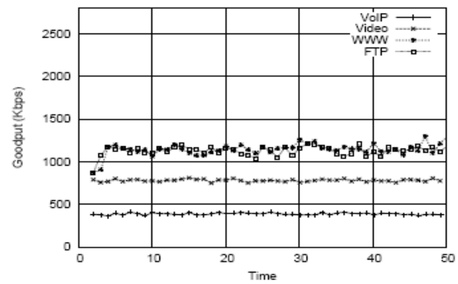
(a) No policy application



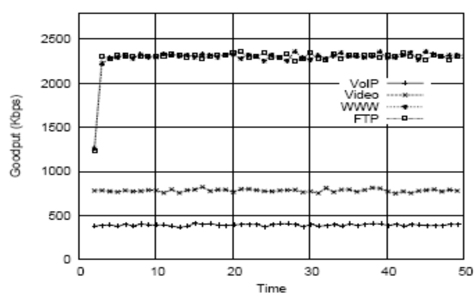
(b) DiffServ-only policy application



(c) MPLS-only policy application



(d) DiffServ-aware MPLS application without the packet ordering support



(e) DiffServ-aware MPLS application with the packet ordering support

Fig. 3. The goodputs of traffic classes measured for several different cases.

Figure 3(c) shows the result of the MPLS-only policy application case in which the realtime traffic bandwidth is guaranteed by preventing the non-realtime traffic from sharing the same path, path A of Figure 5, instead the non-realtime traffic is allowed to use the path B exclusively. However, it has a drawback of low network utilization. We observe that the goodputs of the VoIP and the streaming traffic are ensured to support the source transmission rate of 400 Kbps and 800 Kbps each, consuming 40% of the maximum bandwidth of the path A, and the goodputs of the WWW and the FTP traffic are average 1.4Mbps each, which are little less than the maximum bandwidth of path B.

Figure 3(d) shows the result of the DiffServ-aware MPLS based policy without the packet ordering support. The non-realtime packets are given AF and BE only depending on the packet rate, regardless of their belonging flow. Then, the AF packets are routed along path A, while the EF packets along path B, resulting in a case that the packets of a same flow are split into path A and B. As a consequence, the goodputs of the WWW and the FTP traffic are even smaller than those of the MPLS-only case shown in

Figure 3(c). The reason is that the disordering of TCP flow packets which are delivered through two delay-different paths, causes the false congestion signal, thus preventing the senders from raising the transmission rate. Nevertheless, the goodput of the realtime traffic is guaranteed.

Figure 3(e) shows the result of the proposed DiffServ-aware MPLS based policy application which supports the packet ordering. It splits the non-realtime traffic into path A and path B based on the flows. It not only guarantees the realtime traffic bandwidth but also increases the goodput of the non-realtime traffic as high as 2.3 Mbps each for the WWW and the FTP, which is much higher than 1.2 Mbps of the case without the packet ordering support. The reason is that the remnant bandwidth of path A as well as the whole bandwidth of path B is used by the WWW and the FTP traffic. Moreover, the packet order preservation by keeping a flow on a path contributes to the goodput increase.

IV. Conclusions

In this paper, we propose to use the DiffServ-aware MPLS as a policy enforcement scheme to provide the required QoS to packet-based services in Beyond 3G networks interworking with external IP networks. The DiffServ-aware MPLS as the policy enforcement scheme is able to not only satisfy specified QoS requirements but also improve the network utilization by complementing the drawback of DiffServ, enabling to use multiple paths. Also, we design a router architecture to use a hashing scheme to split traffic stream based on flow to be able avoid the packet ordering problem occurring when using multiple paths. By the NS-2 based simulation, we show that the performance of our scheme outperforms other cases including DiffServ-only, MPLS-only, and the case without the packet ordering support in both the performance and the network utilization aspects.

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