Design of a Forwarding Engine Supporting Application-based Differential Services in MPLS ATM System

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Abstract: A number of MPLS ATM systems have been proposed to increase the access speed of current routers, which only support the best-effort service. However, the MPLS ATM systems have to support the so-called differential service, which discriminates the applications according to the service class because they do not be satisfied the Internet users who use diverse applications.

In this paper, to support this differential service a detailed forwarding procedure based on a LSP control method and an application-based marking algorithm is suggested. The LSP control method establishes several different LSPs for each FEC according to the service class and the application-based marking algorithm chooses a proper differential service depending on the application category. Also, a design scheme of forwarding engine, which can be easily implemented with a minimum modification of existing MPLS ATM systems is proposed. And, the best simulation result of high priority application category is gained when the proposed forwarding algorithm is compared with existing algorithms.

1. Introduction

As the internet is getting more and more popular and commercial and high speed modem, cable modem, high speed access equipment such as ADSL and home networking equipment are supplied, the number of users of the Internet are explosively increased[1]. However, the current router has the problem for high speed data transmission, scalability and QoS(Quality of Service). Also, it does not satisfy various requirements of users.

In order to solve these problems, MPLS ATM system is implemented. It achieved a high speed by a simple transmission method using a label which is simply a relatively short, fixed-length identifier that is used to forward packets. But, it needs additional functions to become a router which is possible to offer QoS.

Recently, many methods supporting the differential service using DSCP(Differentiated Service Code Point) of DiffServ model are working[2,3,4]. For accommodating differential service in MPLS ATM network, all of the existed MPLS ATM systems and the existed routers must be replaced by the new systems and routers, which process differential service. But the cost of replacement is too much. This paper is the study on a forwarding engine supporting differential service according to application categories, which is discriminated using destination address and port number of transferred packet from the existed routers. In order to support this differential service a LSP control method and an application-based marking algorithm are suggested. The LSP control method establishes several different LSPs for each FEC(Forwarding Equivalence Class) according to the service class. The application-based marking algorithm chooses a proper differential service depending on the application category and marks the CLP(Cell Loss Priority) field of ATM cells. Application categories are classified into four categories in terms of the delay and throughput requirement. And a proper mapping method between the application category and the differential service class is described. Also a design scheme of forwarding engine, which can be easily implemented with a minimum modification of existing MPLS ATM systems is proposed. And the best simulation result of high priority application category is gained when the proposed forwarding algorithm is compared with the existed forwarding algorithms.

The rest of this paper is organized as follows. Section 2 introduces MPLS ATM system and the forwarding information table. In Section 3, we propose an application-based forwarding engine model. We study the performance of our model in Section 4, followed by the conclusions in Section 5.

2. MPLS ATM system and Forwarding Information Table

MPLS ATM system can be utilized as LER or LSR. The system architecture of LER and LSR is the same. The MPLS ATM system consists of IPCP(Internet Protocol Control Processor) which is MPLS controller and ATM switch which includes OMP(Operation Maintenance Processor), CCCP(Call and Connection Control Processor), FE(Forward Engine) and IM(Interface Module).

Figure 1 shows the procedure, which makes forwarding information tables with LSP establishment. The procedure is processed in due order from (1) to (12) marked on the Figure 1. The packets inputted from IM connected to non-MPLS domain search the forwarding table using destination IP address and port number. If the forwarding entry does not exist in the forwarding table, FE requires RPHF(Routing Protocol Handling Function) which is the routing protocol handling block to add the information into RIB(Routing Information Base). RPHF makes RIB information having the inputted packet header information as shown in Figure 2(a). And then, when LDP receives RIB information constructed from RPHF, it makes FIB information using RIB information and FEC as shown in Figure 2(b).

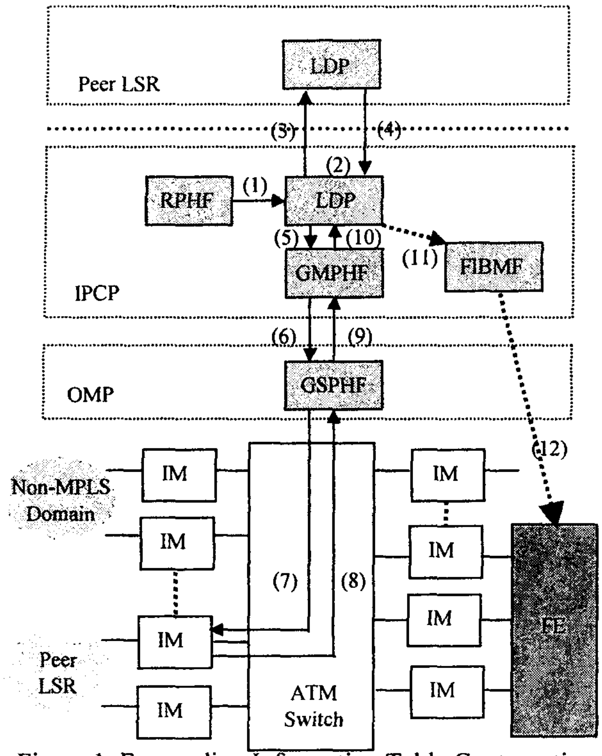

Figure 1. Forwarding Information Table Contrunction Procedure

Destination IP	Next Hop Address	Net Mask	Destination Port	Interface

(a) RIB Information Table

Destination IP	Next Hop Address	Net Mask	Destination Port	Interface	FEC

(b) FIB Information Table

Input Port	Input Label	Output Port	Output Label

(c) FIB Information Table

Figure 2. Forwarding Information Table

And LDP procedure which establishes the related LSP for creating the LIB information is started. After LDP requires the adjacent nodes to do the label binding, it receives the response message through the egress LER and makes LIB as shown in Figure 2(c). LDP requires GMPHF(GSMP Master Protocol Handling Function) to establish a LSP which is a PVC connection in ATM switch. GMPHF transmits this requirement to GSPHF(GSMP Slave Protocol Handling Function) using GSMP(General Switch Management Protocol) message. When GSPHF receives GSMP message, it establishes the required LSP connection using input port number, input label and output port number, output label to IM. GSPHF receives GSMP response message after LSP establishment is completed and it transmits the processing result to GMPHF. Also, GMPHF transmits the result to LDP. LDP sends FIB information and LIB information which is the established LSP connection information to FIBMF(FIB Management Function). FIBMF makes the forwarding information using FIB information and LIB information and transmits the forwarding information to FE.

3. Application-based FE Model

This chapter describes methods and algorithm needed to design a proposed forwarding engine model.

3.1 LSP control method

In order to support differential service, LSP control method establishes EF(Expedited Forwarding) LSP, AF(Assured Forwarding) LSP and DF(Default Forwarding) LSP for each FEC using the procedure of the existed LSP establishment for a minimum modification of existing MPLS ATM system.

These established LSPs are controlled differentially according to application category, which corresponds to the destination address and port number of packets inputted in MPLS ATM system. So the packets are transferred to EF LSP, AF LSP and DF LSP depending on the service class, which belongs to the application category.

3.2 Application Category

Applications are classified into four categories in terms of the delay and throughput requirement[5]. The first category is the real-time applications, which need guaranteed bandwidth and would not tolerate long individual packet delay. The second category is the interactive Internet applications such as TELNET, which uses port number 23. Normally, these kind of applications do not need much bandwidth, but cannot tolerate long delay. The third category is the popular TCP-based applications such as FTP or HTTP, which uses port number 21 or 80. The users of these applications mainly care about the overall throughput instead of individual packet delay. The last category is the non-urgent applications such as EMAIL, which uses port number 25. These kind of applications are not sensitive about how long the data takes to reach the destination.

3.3 Differential Service and Application Category Mapping

EXP is consisted of a pair <FCI, DPI> and has eight BA(Behavior Aggregate)s. FCI indicates MPLS forwarding class and uses the first two bits. DPI indicates drop precedence degree and uses last one bit. Network operator can group packets to require the similar service into one MPLS class because the number of MPLS BA is smaller than DSCP of DiffServ[6]. MPLS ATM system classifies applications into four categories and has four BAs.

The proposed mapping method is to map the differential services with the same FCI into the same application category. Table 1. shows mappings of the application category to the differential service.

Table 1. Proposed Application Category Mapping

Diffserv class		EXP	Application Category
PHB	**DSCP**		
EF	101110	110	Category1
AF11	001010	101	Category2
AF12	001100	100	
AF13	001110	100	
AF21	010010	101	
AF22	010100	100	
AF23	010110	100	
AF31	011010	011	Category3
AF32	011100	010	
AF33	011110	010	
AF41	100010	011	
AF42	100100	010	
AF43	100110	010	
DF	000000	000	Category4

3.4 Marking Algorithm

The marking algorithm in MPLS ATM system is shown in Figure 3.

```
if Category1 then
  mark CLP '0'
  transfer the cells into EF queue
else if Category2 then
  mark CLP '0'
  transfer the cells into AF queue
else if Category3 then
  if AF is OK then
    mark CLP '0'
    transfer the cells into AF queue
  else
    mark CLP '1'
    transfer the cells into DF queue
else if Category4 then
    mark CLP '1'
    transfer the cells into DF queue
```

Figure 3. Marking Algoritm

Category1 uses EF service. Category2 uses AF service. Category3 uses AF and DF services. Category4 only uses DF service. Cell packets belonging to Category1 correspond to EF service and are transferred to EF queue after the CLP field is marked with 0. Cell packets belonging to Category2 correspond to AF service and are transferred to AF queue after the CLP field is marked with 0. Cell packets belonging to Category3 correspond to both AF and DF services. If AF service can be accepted, they are transferred to AF queue after the CLP field is marked with 0 and are processed with the packets belonging to Category2. But, if DF service is only accepted instead of AF service, they are transferred to DF queue after the CLP field is marked with 1 and are processed with the packets belonging to Category4. The packets belonged in category4 only correspond to DF service and are transferred to DF queue after the CLP field is marked with 1.

3.5 Forwarding Engine Model

The forwarding engine supporting application-based differential service is shown in Figure 4. It is designed with a scheme that EF LSP, AF LSP and DF LSP are established in order to accept services of each application category before packets is arrived and then EF LSP, AF LSP, DF LSP is scheduled according to the precedence order and packets are transferred to the next hop differentially.

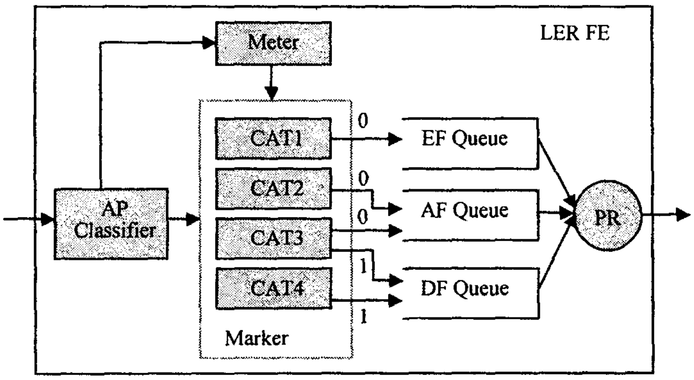

Figure 4. Forwarding Engine Model

4. Performance Analysis

Figure 5 shows the simulation model of the proposed forwarding engine.

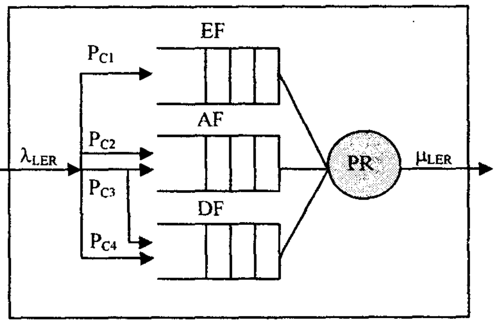

Figure 5. Forwarding Engine Simulation Model

The parameter using in the simulation model is defined follow.

- λ_{LER} : the arrival rate of cells inputted from the outside
- P_{C1}, P_{C2}, P_{C3}, P_{C4} : the probability which each cell belonging to application category 1, 2, 3 and 4 will enter
- μ_{LER} : the service rate of cells

We assumed that the arrival rate of each queue follows the poisson process and the service time interval is the exponential distribution. Our model has three priority queues such as EF, AF and DF and a server which process three queues. Each queue stores the related cells according to the application category. We supposed that the queue size of EF and AF is 20 because they is sensitive for the time delay and the queue size of DF is 100. Also, the time to process one cell in MPLS ATM system which only supports best-effort service takes from 1cell time to 10 cell time in the worst case. 1 cell time is 2.72 μs. So, we assumed that the time to process one cell in MPLS ATM system which supports the differential service is 2 cell time.

And we supposed that the size of packet is 53 byte which is same as the size of ATM cell and the cells belonging to application categories are entered at the same rate.

Table 2. Average Time Delay versus Traffic Load

Load \ Item	Delay			
	P-Diff		E-Diff	N-Diff
	C2	C3		
0.1	0.006	0.006	0.006	0.006
0.2	0.007	0.007	0.007	0.007
0.3	0.009	0.009	0.009	0.010
0.4	0.015	0.015	0.015	0.037
0.5	0.024	0.028	0.025	0.185
0.6	0.035	0.039	0.041	0.252
0.7	0.063	0.060	0.110	0.312
0.8	0.095	0.106	0.162	0.319
0.9	0.128	0.488	0.189	0.321
1.0	0.166	0.104	0.212	0.322

Table 3. Throughput versus Traffic Load

Load \ Item	Throughput			
	P-Diff		E-Diff	N-Diff
	C2	C3		
0.1	1.0	1.0	1.0	1.0
0.2	1.0	1.0	1.0	1.0
0.3	1.0	1.0	1.0	1.0
0.4	1.0	1.0	1.0	0.99
0.5	0.99	0.99	0.99	0.84
0.6	0.99	0.97	0.99	0.66
0.7	0.99	0.81	0.93	0.48
0.8	0.99	0.51	0.75	0.42
0.9	0.98	0.24	0.61	0.37
1.0	0.91	0.08	0.50	0.33

Table 4. Loss Rate versus Traffic Load

Load \ Item	Loss			
	P-Diff		E-Diff	N-Diff
	C2	C3		
0.1	0.0	0.0	0.0	0.0
0.2	0.0	0.0	0.0	0.0
0.3	0.0	0.0	0.0	0.0
0.4	0.0	0.0	0.0	0.0
0.5	0.0	0.0	0.0	0.15
0.6	0.0	0.03	0.0	0.33
0.7	0.0	0.19	0.06	0.51
0.8	0.0	0.49	0.24	0.57
0.9	0.02	0.75	0.38	0.62
1.0	0.09	0.91	0.50	0.66

In this section, using the AweSim simulation package[7] we estimate the performance behaviors of the non-different forwarding algorithm as well as the proposed and the existed forwarding algorithms supporting the differential service for application 2 and 3 on the same simulation environment.The simulation result compared with three algorithms for the average delay time, throughput and loss rate is shown in Table 2, 3 and 4 each. P-Diff, E-Diff and N-Diff of Table 2, 3 and 4 mean the proposed forwarding algorithm, the existed forwarding algorithm and the non-differential forwarding algorithm respectively. The existed forwarding algorithm using DSCP classfies application category 2 and 3 in the same category and uses the priority queue as the proposed forwarding algorithm. According to the simulation result, the performance of the proposed forwarding algorithm is better than the other algorithms for the high priority application category C2.

On the other hand, for the low priority application category C3, the time delay of the proposed forwarding algorithm is mostly better than the existed algorithm. But when the traffic load exceeds 0.7, the loss rate is increased and the throughput of the proposed forwarding algorithm is worse than the existed forwarding algorithm. Also, the time delay, throughput and loss rate of the proposed forwarding algorithm is mostly better than the non-differential forwarding algorithm but when the traffic load exceeds 0.9, the loss rate is increased and the throughput of the proposed algorithm is worse than the non-differential forwarding algorithm.

5. Conclusion

In this paper, we proposed a forwarding engine, which can be easily implemented with a minimum modification of existing MPLS ATM systems by discriminating applications using the well-known port number as well as establishing and controlling the differential LSPs using the existed LDP message. So MPLS ATM system can accommodate the differential service without the cost of replacement. And we expect that MPLS ATM system can be satisfied the users who use diverse applications by accommodating the differential service in MPLS ATM networks. Also, we got the best result that the performance of the proposed forwarding algorithm is superior to the existed forwarding algorithms.

We will study further the forwarding engine supporting the differential service for routers, which accommodate the diffserv model

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