MPLS 망에서의 신속한 LSP 복구를 위한 MPLS OAM 기능 연구

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A Study on MPLS OAM Functions for Fast LSP Restoration on MPLS Network

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요 약

현재의 인터넷은 폭발적으로 증가하는 다양한 멀티미디어 트래픽의 QoS 제공을 위한 트래픽 엔지니어링 기능을 갖고 있지 않다. 이러한 기능적인 단점들은 현격한 서비스 품질의 저하와 대량의 멀티미디어 서비스와 실시간 서비스 제공을 더욱 어렵게 한다. 이러한 문제를 해결하기 위한 다양한 기술이 개발되고 있다. 현재 IETF(Internet Engineering Task Force)에서 제안한 MPLS(Multi-Protocol Label Switching)기술이 이러한 문제를 해결할 차세대 인터넷의 백본 기술로 가장 유력할 것으로 예상된다[1][2].

MPLS와 같은 고속통신망에서 발생하는 장애는 대량의 데이터 손실과 서비스의 품질을 저하시키게 된다. 그러므로 이러한 장애에 대한 신속한 통신망의 자동복구 기능 및 OAM(Operation, Administration and Maintenance)기능은 필수적이라 할 수 있다. MPLS 통신망은 2계층에 독립적이기에 이에 적용할 장애검출, 장애보고 같은 OAM 기능 또한 다른 계층의 OAM 기능과 독립적으로 동작해야 한다.

본 논문에서는 OPNET 네트워크 시뮬레이터를 기반으로 MPLS 통신망에서의 성능측정과 장애의 검출보고, 장애의 위치 파악을 위한 MPLS OAM의 실험적인 결과를 나타내었다.

ABSTRACT

Today's Internet does not have efficient traffic engineering mechanism to support QoS for the explosive increasing internet traffic such as various multimedia traffic. This functional shortage degrades prominently the quality of service, and makes it difficult to provide multi-media service and real-time service. Various technologies are under developed to solve these problems. IETF (Internet Engineering Task Force) developed the MPLS (Multi-Protocol Label Switching) technology that provides a good capabilities of traffic engineering and is independent layer 2 protocol, so MPLS is expected to be used in the Internet backbone network[1][2].

The faults occurring in high-speed network, such as MPLS, may cause massive data loss and degrade quality of service. So fast network restoration function is essential requirement. Because MPLS is independent to layer 2 protocol, the fault detection and reporting mechanism for restoration should also be independent to layer 2 protocol.

In this paper, we present the experimental results of the MPLS OAM function for the performance monitoring and fault detection & notification, localization in MPLS network, based on the OPNET network simulator

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Ⅰ. Introduction

Fault management in telecommunication networks must monitor continuously the occurrence of any fault condition in each protocol layer. When fault occurs in a specific layer, the fault management function must be able to minimize the spread of the effect of the fault to the upper layer, and swiftly switch the service traffic of the affected path to an alternative path. A fast restoration is essential to increase the reliability of the quality of service of real time multimedia applications. For the fast restoration, speedy fault detection and report function are essential.

OAM functionality is very important in public networks for efficient network operation, verifying network performance and monitoring fault occurrence [3][4]. OAM functions are especially important for high-speed multimedia networks in which the provision of QoS(Quality of Service) is the most important priority. OAM functions have therefore been defined for SONET/SDH and also for ATM networks.

MPLS, as the key networking technologies for next generation Internet that should be provide QoS and support a diverse range of network services, definitely require good OAM functions. Since the MPLS is designed to be independent of the lower data link layer protocol and the physical transmission layer network, the MPLS OAM functions should also be designed to be independent of the OAM functions of the lower data link layer and physical transmission layer. With this independent OAM function, the MPLS network can provide guaranteed QoS upon any kind of layer 2 data link protocol, such as frame-relay, ATM or PPP-over-dedicated links.

In this paper we design and implement the MPLS OAM functions. For evaluation, we apply this OAM function to fast LSP restoration scheme[5] that is composed of network management function and system control function. Fault detection, fault report and fault localization functions are performed with OAM function. The fault management function prepares an alternative path for a possible erred path.

In section 2, we describe the requirement of OAM function for the MPLS network. In section 3 and section 4, we design and evaluate the MPLS OAM function, respectively. And we make conclusion in section 5.

Ⅱ. Requirement of OAM Function in MPLS

In the B-ISDN protocol frame, the OAM functions are defined as the layer management function for each protocol layer, such as network layer, data link layer and physical layer. The OAM functions provide the performance monitoring, the fault detection and notification, fault localization and activation/deactivation of monitoring functions. In the integrated system, the OAM functions is handled by network management system such as TMN (Telecommunications Management Network) and TINA(Telecommunications Information Networking Architecture). The OAM functions of each protocol layer generate and perform the protocol layer management operations.

2.1 Interaction of Signaling and OAM

In the MPLS network, the user data channel/path and the control signaling channel/path are explicitly separated. For example, the CR-LDP or RSVP-TE signaling message are transmitted through a separated control LSP among LSRs. The control signaling LSP may be established through different physical channel from the user plane data channel. As a result, the OAM functions for user plane data channel and the control signaling channel must be considered separately.

In this paper we focus on the MPLS OAM functions of the user plane data path. The in-band OAM packets for performance monitoring and connectivity checking are periodically transmitted through the user data LSP. The link/node failure can be detected by other mechanism, such as the lower-protocol layer's functions. The notification of the severe performance degradation or link/node failure can be implemented either by another in-band MPLS function, such as AIS, RDI in the ATM or by the MPLS signaling function, such as CR-LDP, RSVP-TE.

2.2 Required OAM functions

The IETF Internet draft[14] defines the required MPLS OAM functions as follows:

- Be available at any level in the MPLS label staking,
- Automatically detect most type of user-plane defects,
- Facilitate automated and timely network response to user-plane defects,
- Be independent of any control-plane maintenance functionality,
- Provide automatic and on-demand maintenance and diagnostic functions.

Most important area of OAM functions are fault management and performance management. For fault management, OAM function must have fault detection, notification and localization. For the performance management, the MPLS OAM should support performance monitoring such as QoS and traffic parameter monitoring.

Ⅲ. Design of MPLS OAM function

The management functions for MPLS LSP(Label Switched Path) have not been worked enough in IETF or in other papers[6-13]. Recently, the OAM functions for MPLS networks have been proposed by an IETF internet draft[13], but it does not provide detailed operational mechanism. In this paper, we propose an extended MPLS LSR(Label Switching Router) which has OAM function, as shown in Figure 1[13].

3.1 Continuity check OAM

The continuity check OAM function is designed for fault detection on the LSP. The CCP (Continuity Check OAM Packet) is periodically generated by the ingress LSR, marked with the departure time stamp, and passed through the LSP to be monitored. The egress LSR monitors the arrival time of the CCP which is sent every second. The ingress LSR ID and the LSP ID specify the LSP that is to be monitored.

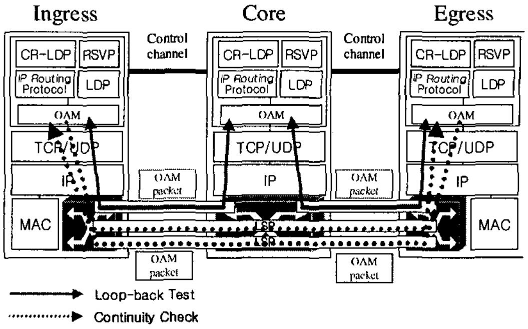


Fig. 1 MPLS LSR with OAM Function

If CCP is not received at the egress LSR for 3.5 seconds, the egress LSR determines that a connectivity problem has occurred[3]. Figure 2 shows the OAM packet structure for continuity check, and Table 1 shows its field information.

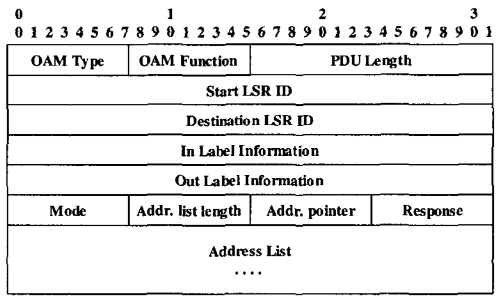


Fig. 2 Continuity check OAM structure

Table 1. Fields of Continuity check MPLS OAM packet

Field	Description
OAM Type	Performance management (0x01), Fault management (0x02)
OAM Function	Performance check (0x01), Loop-back test request (0x01), Loop-back test response (0x02), Continuity check(0x03), Fault report(0x04)
PDU Length	The total length of PDU
Ingress LSR Identifier	IP address of the Ingress LSR that is the starting point of the LSP
Egress LSR Identifier	IP address of the Egress LSR that is the ending point of the LSP
LSP ID	Identifier of the LSP under the Performance monitoring
Sequence Number	Packet sequence number of the generated OAM packet. This sequence number is used to check the possible packet loss.
Time stamp	The time stamp of the generation time of the OAM packet. This time stamp is used by the Egress LSR that calculates the packet delay and delay variance

3.2 Fault report OAM

FRP(Fault Report OAM Packet) is designed for fault report, it is similar to RDI(Remote Defect Indication) cell in ATM. If the egress LSR does not receive the CCP for 3.5 seconds[4], it sends FRP to the ingress LSP through the pre-assigned alternative LSP. FRP has the same structure as shown in Figure 2, except OAM type field is set to 0x04.

In order to give a chance to protect the working traffic by the lower layer protection switching functions, hold-off time is provided before the MPLS layer restoration takes place. As soon as the egress LSR detects a defect, hold off time is set at the egress LSR. FRP is sent after a few seconds. As example, the ATM protection switching defined the hold off time to be selected within the range of 0 to 10 seconds with the granularity of 50ms[4].

3.3 Loop-back test OAM

LBTP(Loop-Back Test OAM Packet)is used for discovering the location of fault occurrence. This function is performed after the fault restoration automatically or by user requirement. Figure 3 shows the structure of LBTP and table 2 shows its field informations.

0 1 2 3
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1

OAM Type	OAM Function	PDU Length	
Start LSR ID			
Destination LSR ID			
In Label Information			
Out Label Information			
Mode	Addr. list length	Addr. pointer	Response
Address List			

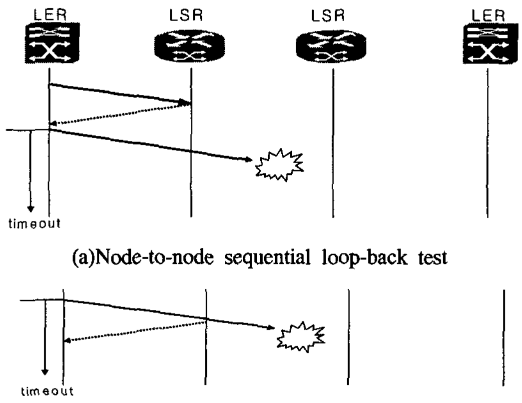
Fig. 3 Loop-back test OAM structure

In the figure 3, the mode field defines the loop-back test mode. There are two loop-back test mode, as shown in Figure 4: (a) the node-to-node sequential loop-back test and (b) the roll-call loop-back test. In the node-to-node sequential loop-back test, the loop-back start node and the loop-back end node are designated, and only the designated end node sends reply message.

Table 2. Fields of Loop-Back test MPLS OAM packet

OAM Field	Description
start LSR ID	The IP address of the LSR from where the loop-back test is started.
destination LSR ID	The IP address of the destination LSR where the loop-back test is finished.
In Label Info	MPLS input label
Out Label Info	MPLS output label
Mode	Hop-by-hop Loop-back test(0) Explicit Loop-back test(1)
Addr list length	In Mode 0, the Addr list length is 0 In Mode 1, the Addr list length is the actual size of the address list.
Addr Pointer	In Mode 0, the Addr pointer field is not used. In Mode 1, the Addr pointer points the IP address to be processed.
Response	Report on the result of the loop-back test
address List	Used in Mode 1. Address list specifies the IP address list of the LSRs through which the LSP passes.

For better performance, the roll-call loop-back test uses only one OAM packet, and all LSRs along the path send should reply message to the ingress LER at the arrival of loop-back test OAM packet



(b)Roll-call loop-back test

Fig. 4 MPLS OAM loop-back test mode

Figure 5 shows the loop back test operational procedure using LBTP. In this figure, each LSR compares LIB(Label Information Base) table information in each LSR to label information field of LBTP as follows:

- Ingress LSR sends LBTP to next LSR through the control channel. LBTP includes the routes and *OutLabel* information.

- The LSR that receives LBTP compares *OutLabel* information in LBTP to *InLabel* information in its LIB table. If they are same identical, the OAM process in LSR writes *InLabel* and *OutLabel* information to *InLabel* field and *Outlabel* field in LBTP, and sends to the next LSR through the control channel. And LSR sends response to the ingress LSR. If there is not identical, OAM process regards the LSP is disconnected, and reports loop-back test error message to the ingress LSR.

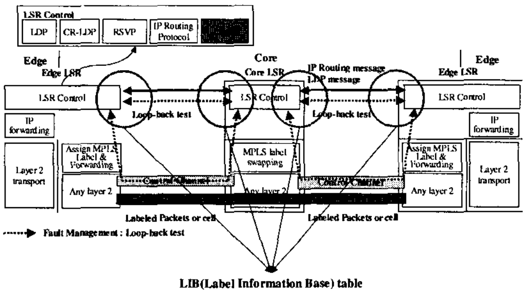


Fig. 5 Loop-back test operational procedure

3.4 Performance check OAM

PCP(Performance Check OAM Packet) is designed for the performance monitoring. The PCP checks the delay and jitter(delay variance) on the specified LSP. The OAM function in the ingress LSR periodically generates PCP, and sends the PCPs through the LSP that is under test. The PCP has same structure as shown in the figure 2, except the OAM header. The egress LSR receives the PCP, and calculates the end-to-end packet delay and the jitter.

The delay and jitter is calculated as follows:

- delay : the interval between the arrival time to the departure time

$$d(n) = T_{arrival}(n) - T_{departure}(n) \quad (1)$$

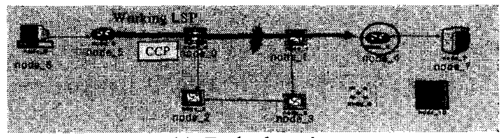
- jitter : packet delay variance

$$j(n) = d(n) - d(n-1) \quad (2)$$

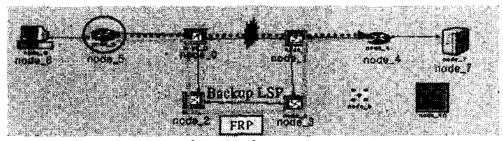
Ⅳ. The evaluation of MPLS OAM function for restoration

The proposed MPLS OAM functions have been applied to the MPLS network management functions. For the evaluation of the proposed MPLS OAM functions, we implemented continuity check, fault notification, the loop-back test and the performance monitoring functions in the OPNET.

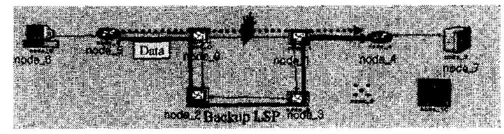
Figure 6 shows the test network topology and restoration scenario.



(a) Fault detection



(b) Fault report



(c) Fault restoration

Fig. 6 The simulation network topology and scenario

4.1 Fault Detection using CCP

When the physical layer does not have the link/node failure detection function, the MPLS CCP should be used to detect any abnormal disconnection in the LSP. In this case, the egress LER(node_4) detects the timeout of 3 consecutive CCP, and the failure detection takes more time than the failure detection by physical layer. Figure 7 shows the simulation timing procedure and figure 8 shows the simulation result of fault detection. In the simulation, the link failure was detected by connectivity check at 1203.32 second.

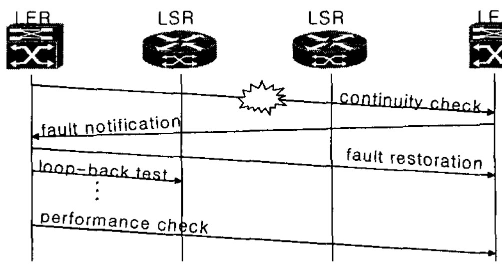


Fig. 7 The Simulation Timing Procedure

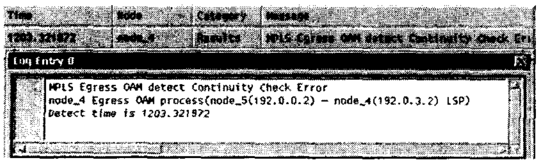


Fig. 8 The result of fault detection

4.2 Fault Notification using FRP

The fault notification using FRP is trigged after the hold off time. The hold-off time is for lower layer protection, and set to 4 second in this paper. The ingress LER(node_5) received the notification message at 1207.32 second (Figure 9). When the ingress LER receives the notification message, it checks the status of LSP backup preparation and determines the following fault restoration procedure. The detail of fault restoration procedure is beyond scope of this paper.

The delay time that is calculated by (3)

$$T_{recv\_notification} - T_{fault\_detection} - 4(hold\text{-}off\ time) = 1.9\ msec. \qquad (3)$$

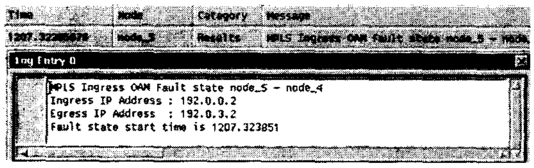


Fig. 9 The result of fault notification

4.3 Fault Localization using LBTP

When the physical layer does not have the failure detection function, the MPLS LBTP is used to find out the exact location of link/node failure. The ingress LER(node_5) sends LBTP to the egress LER(node_4) using the control channel, and each LER/LSR on the route of the LSP sends response message to the ingress LER when it receives the loop-back OAM packet. Figure 10 shows the simulation result of loop-back test. In this scenario, the ingress LER(node_5) initiated the loop-back test and node_0 sends response message to ingress LER(node_5). But the response from node_1 was not received and time-outs were generated. As the result of this loop-back test, we can determine that the link from node_0 to node_1 is the location of the link failure on the erred LSP.

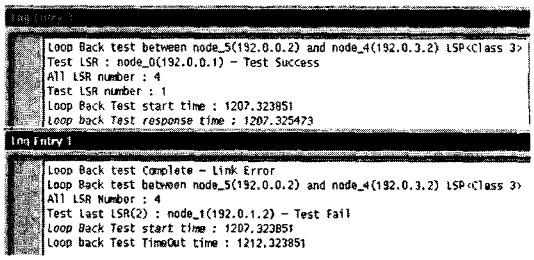
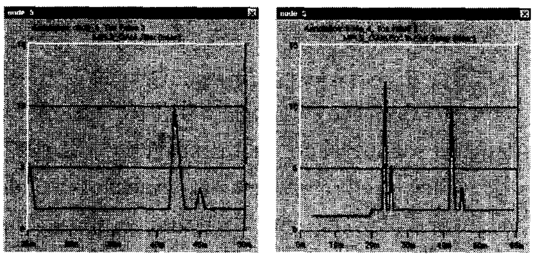


Fig. 10 The result of loop-back test

4.4 Performance monitoring using PCP

By using the PCP(Performance Check OAM Packet), we can measure the end-to-end delay and jitter from the ingress LER(node_5) to the egress LER(node_4). Figure 11 shows the results of performance measurement at node_4 for LSPs between node_5 and node_4. Figure 11-(a) and 11-(b) show the result of delay and jitter respectively. By these simulation results, we can see that the MPLS OAM function monitors correctly the degraded performance.



(a)jitter from node_5 to 4 (b)delay from node_5 to 4

Fig. 11 The result of performance test

V. Conclusion

In this paper, we proposed the OAM function for MPLS. Proposed MPLS OAM functions are independent to the layer 2 protocol such as ATM, Frame-Relay or dedicated line such as SONET/SDH, WDM(Wave Division Multiplex). The proposed MPLS OAM functions provide the fault detection and fault notification capability. But, we also provided the mechanism for the MPLS OAM functions to operate in coordination with the physical layer's fault detection capability and the MPLS signaling function for faster fault detection and fault notification

We simulated the MPLS OAM function and the fault restoration function using OPNET simulation platform. The simulation result showed the correct operation of OAM function for fault restoration. We believe that the proposed MPLS OAM functions can be implemented to enhance the traffic engineering capability of MPLS network.

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