Review on the Operation, Administration, and Maintenance (OAM) of BcN

Kyung Gyu Chun, Jongtae Song, and Soon Seok Lee

Abstract: **This paper briefly reviews ITU-T recommendations associated with multi protocol label switch (MPLS) and Ethernet operation, administration, and maintenance (OAM). The broadband convergence network (BcN) architecture with a centralized network controller is introduced. An aggregation structure employing Ethernet, MPLS, and time division multiplexing (TDM) signal is presented for the BcN. A physical link failure scenario is examined to investigate how the maintenance signal is propagated between different layers.**

Index Terms: **Broadband convergence network (BcN), Ethernet, multi protocol label switch (MPLS), operation, administration, and maintenance (OAM), time division multiplexing (TDM).**

I. INTRODUCTION

BcN project has been launched in 2004 as a part of the IT839 project which has been derived by Korea ministry of information and communication (MIC) [1]. The goal of broad conversance network (BcN) is to provide premium quality based network infrastructure. BcN also aims to provide a platform combining the wire and the wireless service, and further to converse the existing transmission service and broadcasting service. Currently, the BcN is focused on providing the high quality based multimedia services such as IP-TV or the video phone and the premium IP service such as voice over IP (VoIP) or virtual private network (VPN) service.

Since BcN is a network based on the internet protocol, the well defined operation, administration, and maintenance (OAM) for the BcN is highly demanded to overcome the drawback such as network survivability and network quality monitoring for the packet network.

The past OAM signals defined in ITU-T have been developed for the circuit-based system such as synchronous digital hierarchy/synchronous optical network (SDH/SONET), and they have been well operated so far in the real networks without any modification. However, the international standard bodies ITU-T recently published the multi protocol label switch (MPLS) OAM recommendation Y.1711, and IEEE has published the drafted Ethernet OAM IEEE P802.1ag, and ITU-T is now drafting Y.1731 associated with Ethernet OAM as well. BcN OAM is designed to be compliant to ITU-T recommendations, but it has a kind of server-client relationship between layers to properly propagate the forward maintenance signals.

To explain the role of each OAM signal, OAM signal types associated with MPLS and Ethernet is classified depending on the surveillance purposes and their functionalities are briefly described in Section II. The BcN architecture is presented in Section III and the signal aggregation structure to employ virtual private wire service (VPWS) is introduced in Section III as well. Specifically, Ethernet over SDH technology is used to carry the VPWS signal format. Finally, to investigate the maintenance signal propagation in a failed network, a failure scenario including physical, MPLS, and Ethernet layer is examined in Section IV.

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II. ITU-T RECOMMENDATIONS ASSOCIATED WITH MPLS AND ETHERENT OAM

ITU-T recommends the OAM signals related to MPLS and Ethernet. We may classify the OAM signals into five different types as shown in Table 1 depending on the surveillance purposes of network. The OAM signal are used for the network maintenance, path continuity check, the established path connection check, the degraded signal performance monitoring, and diagnosis of network.

The network maintenance signal has two types of indication signal depending on the signal propagation direction, i.e., forward or backward. The forward maintenance signals are defined as the forward defect indication (FDI) of MPLS and alarm indication signal (AIS) of Ethernet, respectively. However, their roles in a network are same in a manner of server failure indication. The backward maintenance signals are defined as the backward defect indication (BDI) of MPLS and remote defect indication (RDI) of Ethernet. The SDH uses the same terms, i.e., AIS or RDI as that of the Ethernet. The forward maintenance signals are the indication signal for server failure whereas the backward ones are just indicators informing the peer transmitter of the receive signal failure status. These are not used for the server signal failure indicators.

The continuity check (CC) signal is used for checking signal disruption under the continuous packet transmission. The MPLS has two different mode of the CC. The connectivity verification (CV) with 1 sec transmission period and the fast failure detection (FFD) with variable transmission period ranged 10 ms to 500 ms are defined. The FFD allows for the network operator to choose transmission period according to the network applications, but does not specify transmission period depending on the applications in MPLS network. If the CC or FFD is not received in a given period, then loss of CV (LOCV) defect is raised. The Ethernet has the continuity check message (CCM) similar to the FFD rather than CV. However, the CCM has different transmission periods depending on the applications as the following:

- 3.3 ms is for protection switching application,
- 100 ms is for error performance monitoring application,
- 1 sec is for fault management application.

The CCM has additionally 3.3 ms and 1 sec transmission periods compared to the FFD. It should be noted that the 3.3 ms

Table 1. MPLS and Ethernet OAM signals.

	MPLS (Y.1711)	Ethernet (Y.1731)
Maintenance signal	- FDI - BDI	- AIS - RDI
Continuity check	- CV - FFD	- CCM
Connectivity check	- TTSI	- MEG - MEP - ME level
Performance monitoring	- Not defined	- Frame loss ratio - Frame delay - Frame delay variation
Diagnosis	- Loop-back	- Loop-back - Link-trace - Lock - Test

is used to identify the valid loss of continuity (LOC) state with three consecutive incoming CCM frames. As for the automatic protection switching, the signal failure detection time requires at most 10 ms and the protocol processing time including the internal software processing time requires at least 50 ms as defined in ITU-T G.841.

The connectivity check signal is used to verify whether a deployed path between a pair of peers is the desired one or not. The trail termination source identification (TTSI) field within the CV or FFD frame is used for the connectivity check of the label switched path (LSP). It contains a source identifier such as the ingress label switched router (LSR) address and LSP tunnel label. At the egress router the received source identifier and the expected source identifier, which may be written manually or automatically by network management system (NMS) or LSP signaling prior to operation, are compared. If they are not matched, then the mismatch defect or the mismerge defect occurs. Both the LSR address and LSP label are referred for checking mismatch or mismerge defect. When the received source identifiers are the expected ones, the TTI_Mismatch defect occurs. When the received LSP source identifiers are mixed with the expected TTSI and the unexpected ones during a given time period, the TTSI_Mismerge defect occurs.

The connectivity check schemes for Ethernet flow are similar to those of MPLS in that the expected identifier and the unexpected one are compared. However, Ethernet uses the two different types of maintenance entity identifiers and one maintenance entity (ME) level for the connectivity check. One of maintenance entity identifiers is the maintenance entity group (MEG) ID, which is a group of Ethernet flows being monitored in the same administrative boundary, and the other one is the maintenance entity group end point (MEP) ID, which is the end point of the MEG. The ME level is used to distinguish between OAM frames belonging to different nested MEs and differently assigned up to 8 levels depending on the role in the network. Customer role is assigned 7, 6, and 5 ME levels, provider role is assigned 4 and 3 ME levels, and operator role is assigned 2, 1, and 0 ME levels. When the received ME level is correct but the MEP ID is not, the mismerge defect occurs. When the MEG ID is correct but MEP ID is not, the unexpected MEP defect occurs.

With respect to the performance monitoring of the Ethernet flow, frame loss ratio, frame delay, and frame delay variation are defined as performance parameters in Y.1731. Basically, the quality of packet network can not be accurately measured in contrast with constant bit rate (CBR). That is because of the randomness of packet transmission, which eventually requires the time synchronization to determine reference time point between two peer nodes. But, the CBR transmission allows calculating the bit error ratio (BER) by physical link degradation. Since the clock synchronization in the packet network is not realistic, the round trip delay measurement is preferred. In other words, the total elapsed time is measured for the returned packet from the remote loop-backed node. To measure the total elapsed time, the time stamp information should be transmitted along with packets. This mechanism may result in the complicated system. It is believed that a new algorithm without the time stamp should be introduced.

For the purpose of network diagnosis, MPLS has loop-back, and Ethernet has additionally link-trace, lock, and test functions. The loop-back is performed under out-of-service state. The predefined test signal patterns for loop-back are inserted at the transmitter and the returned signal patterns are compared to the sent signal at the receiver of the ingress node. If the received patterns do not match, then some failure occurred along the loop-backed path. The link-trace is used not only to search the failure location between two nodes but also to retrieve the adjacent relation which identifies adjacency relationship by sequentially requesting the known MAC address to every related node. The test signal is used to test bandwidth throughput, to detect frame disorder and to measure bit errors. It is performed unidirectionally. During the test signal transmission the lock signal is emitted to the immediate client layers. The lock signal is used to allow the client MEP to differentiate between the fault condition and diagnostic action being performed in the server MEP. When receiving the lock signal, the client MEP shall issue AIS to its client.

III. BCN ARCHITECTURE

One of services supported by BcN is virtual private wire service (VPWS). The virtual circuit (VC) of VPWS is a dedicated path for transporting Ethernet MAC, ATM, frame relay, or PPP/HDLC through the MPLS or IP [2]–[4]. A provision-based VPWS, which does not require signaling and routing functions for the network elements, is developed for the BcN. The provisioning function is performed by a centralized network controller called the network control platform (NCP). The NCP is responsible for network resource management, path calculation, path reservation and path allocation on the BcN. To efficiently control the BcN, the NCP is separated into the metro NCP and the backbone NCP depending on the control domain.

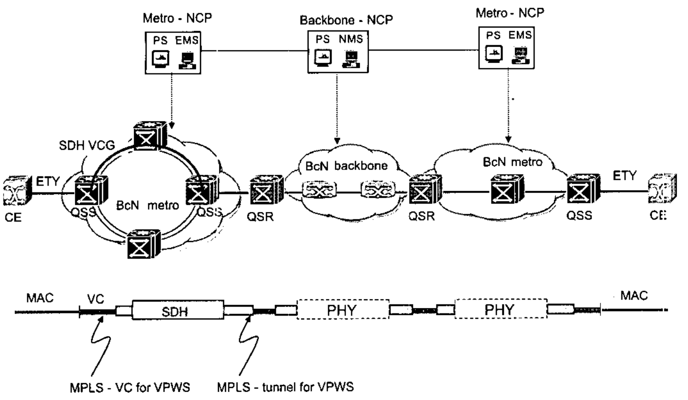

Fig. 1. BcN employing the VPWS.

The metro NCP is responsible for path reservation and path allocation across the metro area whereas the backbone NCP provides connection between the metro NCPs.

Fig. 1 shows an example of the BcN architecture employing VPWS. The BcN has SDH, PoS, and Ethernet interface. The QSS and QSR system are designed to transport MPLS, Ethernet and IP packet. The QSS is a system providing MPLS LSP, SDH virtual container (VC) and has L2 signal encapsulation capability at the edge of network as well. The QSR system extracts IP packet from MPLS and transports it to other routers. If we look at the procedure for the Ethernet signal to be delivered, firstly the Ethernet MAC signal coming from the customer equipment (CE) is encapsulated into MPLS VC and MPLS tunnel label at the edge QSS of the metro BcN, and secondly the MPLS tunnel is re-encapsulated into another Ethernet MAC', and lastly the MAC' is mapped into virtual concatenation group (SDH-VCG) via frame mapped generic framing procedure (GFP-F) for traveling across the SDH network. It shall be noted that the additional MAC' frame is used for the Ethernet over SDH (EoS) transmission, which provides capability of the Ethernet connection across the SDH networks. For the VPWS to be delivered through the MPLS network, the MPLS tunnel is extracted from the MAC' and SDH-VCG at the edge of SDH network. The MPLS tunnel is swapped in the QSR at the edge of backbone BcN. It is conveyed through the MPLS network and finally reaches the corresponding edge QSS system of the other metro BcN. The egress QSS extracts the original MAC frame from MPLS tunnel and VC and delivers to the peer CE. As far as the VPWS is concerned, EoS enables the BcN to be a transport independent network. In terms of BcN topologies, it is possible to build ring network using unidirectional path switched ring (UPSR) of SDH or mesh network using point-to-point connection of the Ethernet link or PoS link.

Fig. 2 shows an encapsulation and mapping structure of the STM-16 system deployed in BcN. The STM-16 has capability of providing EoS, Ethernet virtual private line (EVPL), and time division multiplexing (TDM). In the case of the EoS, the GFP-F plays a key role to translate packet to circuit signal and vice versa. The GFP-F selects SDH VCG depending on CE bandwidth, where the VCG is consist of VC-3-xV or VC-4-xV. If the bandwidth of CE is more than 50 Mbit/s but less than 155 Mbit/s, then the virtually concatenated frame VC-3-xV would be used, but in the case of more than 155 Mbit/s, VC-4-xV

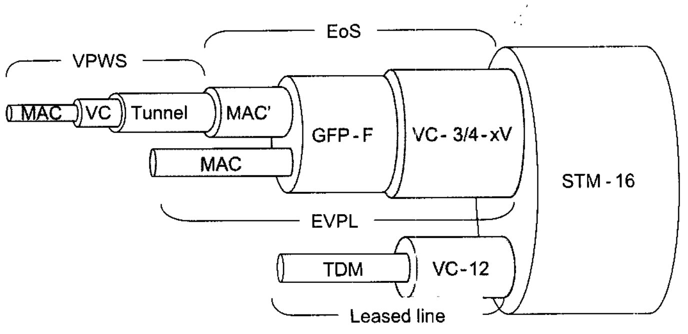

Fig. 2. Aggregation structure in SDH link of BcN.

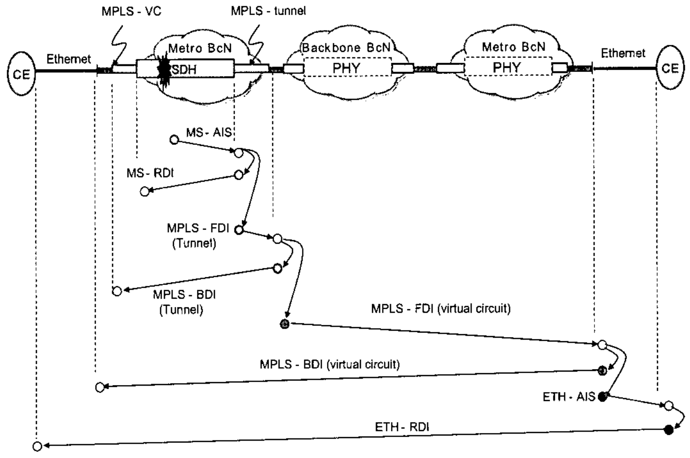

Fig. 3. Example of BcN maintainance signal operation.

would be more efficient.

The EVPL is used for point-to-point Ethernet service. The incoming MAC frame from the CE is directly mapped into the GFP-F but the MAC frame differs from the case of VPWS. The MAC frame for the EVPL has frame check sequence (FCS) byte whereas the MAC frame for the VPWS does not. By providing MPLS, Ethernet, and TDM service on a single STM-N system, the BcN can provide capability of protocol independent network but it may require a hierarchically managed OAM architecture.

IV. MAINTENANCE SIGNAL PROPAGATON IN BCN

It is believed that the most interactive signal between layers is the maintenance signal among the OAM signals stated in ITU-T recommendations. That is because the maintenance signal gives the client the server failure information. The maintenance signal can be used to identify the failure location and the failure causes occurred in a network other than indication of server failure.

In order to investigate how the maintenance signal should be operated, we examine a link failure scenario as depicted in Fig. 3, where the scenario is drawn based on the Fig. 1. For the convenience of explanation we use the terms of server and client. The server means the lower layer in OSI seven-layer. For instance, if Ethernet signal is conveyed by SDH frame, then SDH layer becomes the server and Ethernet layer is the client. In case where the highest server, i.e., physical link is failure its clients such as MPLS and Ethernet are to be disrupted. In this case, the client can never identify if the detected failure is occurred in server layer or its own layer. The signal indicating the server failure to the client or informing the transmitter of the detected failure is the maintenance signal. There are two types of maintenance signals. One is forward maintenance signal and the other is backward maintenance signal. The forward maintenance signal itself represents the indication of server failure, and AIS or FDI is defined as stated in the previous section. The AIS is the term used in SDH and Ethernet, and FDI is for MPLS. Though the terms are differently named, their roles are similar. The backward maintenance signal is used for indicating the received signal failure toward the ingress node. The SDH and Ethernet use the term RDI and MPLS uses BDI. Basically, the alarms raised in client due to the server failure should be suppressed because they are not raised due to the client failure.

When the SDH link is failed in Fig. 3, VC-AIS is inserted in a repeater and the detected VC-AIS activates MPLS VC-FDI, after that MPLS VC-FDI reactivates ETH-AIS. By propagating the forward maintenance signal the server failure information is handed down to the next client. Eventually, even to the last client, the Ethernet layer in this scenario, the failure information is able to be delivered. Accordingly, MPLS alarms can be suppressed by SDH VC-AIS, Ethernet alarms by MPLS- FDI and IP alarm by ETH-AIS. As the result all the unnecessary alarms can be suppressed and only the alarm associated with link failure is to be reported to the NCP. This will reduce huge amount of unnecessary alarm reporting and be able to efficiently use the control channel bandwidth between NCP and network elements (NEs). Especially, since the MPLS FDI is able to deliver the information associated with fault type and fault location, the network operator can easily find out the failed node or links by looking at MPLS failure information.

On the other hand, upon receiving the forward maintenance signal at each layer the backward maintenance signal will be activated and inform the ingress node of the failure of the established path. Another option of the MPLS-BDI is to be used for automatic protection switching (APS). Since the 1:1 MPLS APS structure does not require the APS control protocol unlike the SDH 1:1 structure, path switch LSR (PSR) [4] can use the BDI as the APS switching request source. Consequently, the 1:1 MPLS APS control mechanism is quite simpler than SDH using APC control protocol. We can consider another case such as MPLS over Ethernet which is more generally acceptable and may be suitable to the existing network, but it is straightforward. The CV or FFD instead of FDI is used as shown in Fig. 3. The LOCV activates MPLS-BDI and ETH-AIS, and other processes are the same as the previously stated scenario.

V. SUMMARY AND CONSIDERATIONS

We reviewed ITU-T OAM recommendations associated with MPLS and Ethernet. The OAM functions can be classified as five different types depending on the surveillance purposes. As for the automatic protection switching, MPLS has not been considered for real time APS processing whereas the Ethernet has reflected on the CCM signal transmission rate of 3 ms. This implies that Ethernet APS can be completed within 60 ms but MPLS APS processing time requires at least more than 80 ms under assuming that protection switching request signal is made in the same manner for two technologies. However, a fast protection switching mechanism for MPLS could be required in the case of the VPWS of BcN. We have considered a hardware-based MPLS OAM to realize the fast protection switching. It is believed that the FFD, FDI, and BDI packet should be generated every 3.3 ms to assure activation of the switch request signal to the protection path within 10 ms.

The performance monitoring is not yet clearly defined for MPLS, but Ethernet tries to measure the round trip delay to calculate the frame delay or jitter. But the delay threshold value or accumulated jitter value is not defined for services, for instance, VoIP, IP-TV, VoD, or Internet traffic.

Since the BcN is a network combined with SDH, Ethernet, and MPLS, it should be managed by a systematic OAM architecture. The BcN has a hierarchical OAM structure with server and client relationship between layers. The key idea of BcN OAM is to have a layer independent relationship. This enables the server to inform its client of the server failure regardless of the transported protocol. In other words, SDH-AIS activates MPLS-FDI and MPLD-FDI does ETH-AIS and so on. By performing the forward maintenance signal, the failure information of network is able to be reached even to the end user. Subsequently, the BcN makes it possible to achieve end-to-end QoS management with a hierarchical OAM architecture. Another key feature of BcN is to have capability of prohibition of alarm storming by suppressing the unnecessary alarms with AIS and BDI. This enables a network provider to effectively use the control channels bandwidth between NCP and NEs by reducing control traffic volume.

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