LIME Working Group
Internet-Draft
Intended status: Informational
Expires: April 27, 2015

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October 24, 2014

Existing Support for Network Operations in Multilayer Transport Network based upon unified approach to OAM (Layer 0 - Layer 2)

draft-lam-lime-summary-l0-l2-layer-independent-00

Abstract

This draft summarizes the existing ITU-T SG 15 standards, (Layer 0 - Layer 2) both technology-specific and generic across these technologies, relevant to leveraging OAM to support fault management, performance monitoring, and configuration management. Knowledge from this domain may be leveraged for the benefit of developing generic layer independent management for other layers.

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1. Introduction

A comprehensive set of Operations, Administration, and Maintenance (OAM) capabilities is essential for supporting the critical network operations of fault management, performance monitoring, and configuration management. For this reason in the ITU-T, Layer 0 - Layer 2 technologies have been designed with extensive OAM capabilities (e.g., as specified in [ITU-T_G.709], [ITU-T_G.707], [ITU-T_G.8012], etc.) Considerable effort has been expended to establish a coherent approach to OAM that allows monitoring of the status and performance of (stacked) connections, including generic layer independent principles and inter-layer interworking. Thus, the OAM architecture used in transport networks has a common behavior across all technologies and layer networks. This draft summarizes ITU-T Recommendations that specify the generic architecture, principles, and models, both technology specific and generic, developed to support management of L0-L2 connections based upon a unified and consistent OAM view of multi-layer networks. It should be noted that the OAM and management framework and requirements for MPLS-TP, which is L2.5, has also been based upon these principles (e.g.,RFC 6371 [RFC6371], RFC 5860 [RFC5860], RFC 5950 [RFC5950], and RFC 5951 [RFC5951].

It is believed that the generic architecture, principles and models specified in the material summarized herein may be leveraged in considerations of a common approach to OAM management for other layer networks (e.g., Layer 3-Layer 7).

1.1. Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [RFC2119].

2. Terminology

Anomaly: The smallest discrepancy that can be observed between actual and desired characteristics of an item. The occurrence of a single anomaly does not constitute an interruption in ability to perform a required function. Anomalies are used as the input for the Performance Monitoring (PM) process and for detection of defects (from [ITU-T_G.806], Section 3.7).

Defect: The density of anomalies has reached a level where the ability to perform a required function has been interrupted. Defects are used as input for performance monitoring, the control of consequent actions, and the determination of fault cause (from [ITU-T_G.806], Section 3.24).

Fault: A fault is the inability of a function to perform a required action. This does not include an inability due to preventive maintenance, lack of external resources, or planned actions (from [ITU-T_G.806], Section 3.26).

Fault cause: A single disturbance or fault may lead to the detection of multiple defects. A fault cause is the result of a correlation process that is intended to identify the defect that is representative of the disturbance or fault that is causing the problem (from [ITU-T_G.806], Section 3.27).

Failure: The fault cause persisted long enough to consider the ability of an item to perform a required function to be terminated. The item may be considered as failed; a fault has now been detected (from [ITU-T_G.806], Section 3.25).

Equipment Management Function (EMF): The management functions within an NE (see [ITU-T_G.7710]).

Element Management System (EMS)

Information Model (IM): An information model condenses domain knowledge and insights to provide a representation of its essential concepts, structures, and interrelationships. It models managed objects at a conceptual level, independent of any specific implementations or protocols used to transport the data.

Layer 0 - Layer 2: Refers to physical (photonic), physical (electrical), and data link (e.g., Ethernet) transport technology, respectively.

Network Management System (NMS)

Network Element (NE)

Operations, Administration, and Maintenance (OAM)

- On-demand OAM - OAM actions that are initiated via manual intervention for a limited time to carry out diagnostics. On-demand OAM can result in singular or periodic OAM actions during the diagnostic time interval.

- Proactive OAM - OAM actions that are carried on continuously to permit timely reporting of fault and/or performance status.

3. Network Operation Supported by L0-L2 OAM

OAM mechanisms include the tools and utilities to plan, install, monitor and troubleshoot a network layer. While the specific set of OAM mechanisms in a layer depends upon the technology (e.g., [ITU-T_G.709] on OTN, [ITU-T_G.707] on SDH, [ITU-T_G.8013] on Ethernet), they all support the same fault management, performance monitoring, and configuration management operations and processes. As noted previously, MPLS-TP OAM (e.g., [ITU-T_G.8113.2], [RFC6424], [RFC6428], etc.] was also designed to support L0-L2 operations and processes. Some OAM functions are implemented in hardware (data plane inherent, such as Tandem Connection Monitoring (TCM) or Performance Monitoring (PM)), while other functions can be implemented mostly in lower software layers.

Fault management includes defect detection, fault localization, fault reporting, and protection switching [OTN Handbook, Chapter 3].

- o Defect detection: Failures affecting the transport of client information are detected by continuous pro-active checking. Persistent failures are considered to be service-affecting defects. Detected defects are correlated with other detected defects to find the most probable cause of the failure and consequent actions, such as protection switching, are taken.

- o Fault localization: If the defect information is insufficient to locate the failure, on-demand OAM functions can be used to determine the cause of the defect more accurately.

- o Fault reporting: Persistent defects are reported to the network management system to provide the appropriate alarm reports to maintenance staff for maintaining the desired quality of service level.

- o Protection switching: After a defect has been detected, a protection switch can be initiated as a consequent action to restore the interrupted traffic, and thus improve the availability.

Performance monitoring includes measuring the performance (e.g., packet losses, bit errors, etc.) of the transport of client information in order to verify the quality of service and to estimate the transport integrity.

Configuration management includes indicating the operational state of a connection; e.g., whether it can be used to transport client data or whether the set-up of the connection is completed.

4. L0-L2 Architecture and Management Standards

Figure 1 below is a summary of relevant technology specific and generic L0-L2 transport architecture and management standards.

```
                  +-----------------------------------------------+
                  |Transport|    Transport Technology Specific     |
                  |  Tech.  |-------------------------------------+
                  | Generic |   OTN   |  Carrier | MPLS-TP  |  SDH  |
                  |         |         | Ethernet | Note 2   |       |
+-----------------------------------------------------------------+
|   Transport     |  G.800  |  G.872  |  G.8010  | G.8110.1 | G.803 |
|  Architecture   |  G.805  |         |          |          |       |
+-----------------------------------------------------------------+
|   Equipment     |  G.806  |  G.798  |  G.8021  | G.8121.x | G.783 |
|   Function      |         |         |          |  series  |       |
+-----------------------------------------------------------------+
|   Management    |  G.7710 |  G.874  |  G.8051  | G.8151   | G.784 |
|  Requirement    |         |         |          |          |       |
+-----------------------------------------------------------------+
| Mgmt Interface  |         |         |          |          |       |
|Protocol-neutral|  G.gim  | G.874.1 |  G.8052  | G.8152   | Note.1|
|  Info Model     |         |         |          |          |       |
+-----------------------------------------------------------------+
Note.1: The model had been specified (in ITU-T G.774 series),
        but not in a protocol neutral manner.
Note 2: MPLS-TP is actually L2.5; it is included as it falls
        under the generic transport management umbrella (as per design).
```

Figure 1: L0-L2 Architecture and Management Standards

4.1. Generic Transport Layer and Technology Independent Standards

4.1.1. Generic Transport Architecture

Recommendations [ITU-T_G.800] and [ITU-T_G.805] provide a technology independent and model-based description of transport network functionality. The first generic functional model based architecture Recommendation was ITU-T G.805, which describes connection oriented networks. ITU-T G.800 was subsequently developed to provide a common framework to describe both connection-oriented and connectionless networks. The descriptions are compatible with those of the earlier generic Recommendations (e.g., ITU-T G.805). These standard model-based approaches:

- o Enable the description of the generic characteristics of networks using a common language at a level that transcends technology and physical architecture choices.

- o Provide a view of functions or entities that may be distributed among various equipment.

- o Concurrently specify transport and management functionality.

These generic functional architectures of transport networks are the basis for a harmonized set of functional architecture Recommendations for specific transport layer network technologies that use circuit switching or packet switching technology (e.g. [ITU-T_G.803] for SDH, [ITU-T_G.872] for OTN, [ITU-T_G.8010] for Carrier Ethernet). These transport technology specific architecture Recommendations are used as the basis for a corresponding set of Recommendations for equipment specifications, including OAM and management.

4.1.2. Generic processing of transport equipment OAM functions

The development of the OAM architecture used by ITU-T in transport networks started around 1990, and basic generic OAM functions were first defined in the period 1990-1993 and described in Recommendation [ITU-T_G.806]. Since that time, this initial OAM architecture has been extended to assure it remains generic with respect to emerging transport technologies. The extended OAM functionality included the definition of a transport maintenance entity with end-points and intermediate-points, pro-active and on-demand OAM functions, defect correlation, and alarm suppression, etc. The generic OAM architecture in ITU-T G.806 has been used as the common basis for all technology-specific transport equipment specifications (e.g., [ITU-T_G.798] for OTN, [ITU-T_G.8021] for Carrier Ethernet, [ITU-T_G.783] for SDH, and also [ITU-T_G.8121] for MPLS-TP).

4.1.3. Generic management requirements

Recommendation [ITU-T_G.7710] specifies the equipment management function (EMF) requirements that are common to multiple transport technologies and common to packet-based and circuit-based transport networks. The Recommendation addresses the EMF inside a transport network element, including the configuration, fault, and performance monitoring (i.e. the C, F, P of FCAPS) management functions. The generic management requirements in ITU-T G.7710 have been used as the common basis for all technology-specific transport management specifications (e.g., [ITU-T_G.874] for OTN, [ITU-T_G.8051] for Carrier Ethernet, [ITU-T_G.8151] for MPLS-TP, and [ITU-T_G.784] for SDH).

4.1.4. Generic information model of transport network resources

Recommendation [ITU-T_G.gim] specifies a core information model for transport resources. The model is also applicable to the management and control of the transport network regardless of the technology of the underlying transport network. Furthermore, the applicability of the information model is independent of the choice of protocol to be used in the management and control interfaces. The core information model defined in this Recommendation can be used as the basis for the extension of transport/control-technology-specific information models. Such extension will be specified in the technology-specific Recommendations, such as [ITU-T_G.874.1] for OTN management, [ITU-T_G.8052] for Carrier Ethernet management, [ITU-T_G.8152] for MPLS-TP management, and [ITU-T_G.7718.1] for ASON control plane management.

4.2. Layer and Technology Specific Standards

4.2.1. Architecture

Recommendation [ITU-T_G.872] describes the functionality of the optical transport networks (OTN), L0 and L1, from a network level perspective using the generic principles defined in ITU-T G.805 and ITU-T G.800. ITU-T G.872 describes the specific aspects concerning the optical transport network layered structure, characteristic information, client/server layer associations, network topology, and layer network functionality. In accordance with ITU-T G.805 and ITU-T G.800, the optical transport network is decomposed into independent transport layer networks where each layer network can be separately partitioned in a way which reflects the internal structure of that layer network. In addition to reflecting the generic fault, configuration, and performance management requirements, it describes requirements for connection supervision (e.g., continuity, connectivity, required maintenance information), signal quality supervision, adaptation management, etc.) and connection supervision techniques (i.e., inherent, non-intrusive, intrusive, and sublayer monitoring).

Recommendation [ITU-T_G.8010] describes the functional architecture of L2 Ethernet networks using the modelling methodology described in ITU-T G.800 and ITU-T G.805. The Ethernet network functionality is described from a network level viewpoint, taking into account an Ethernet network layered structure, client characteristic information, client/server layer associations, networking topology, and layer network functionality providing Ethernet signal transmission, multiplexing, routing, supervision, performance assessment, and network survivability. Recommendation ITU-T G.8010/Y.1306 describes the relevant parts of the Ethernet specifications in

[IEEE_802.1Q] and [IEEE_802.3] using the ITU-T transport network modelling methodology. The ETH layer network provides the transport of adapted information through an ETH connectionless trail between ETH access points. The adapted information is a (non-) continuous flow of MAC service data units (IEEE 802.3).

Recommendation [ITU-T_G.8110.1] provides functional components, based on Recommendation ITU T G.805, that allow the Multi Protocol Label Switching Transport Profile (MPLS-TP) to be modeled in a way that is consistent with the description of other transport technologies defined by the ITU-T to simplify integration with other transport technologies. It provides a representation of the MPLS-TP technology using the methodologies that have been used for other transport technologies (e.g., SDH, OTN and Ethernet). In G.8110.1, the architecture of MPLS-TP forwarding, OAM, and network survivability are modeled from a network-level viewpoint.

4.2.2. Transport Equipment Functions

Recommendation [ITU-T_G.798] specifies both the components and the methodology that should be used in order to specify the L0 and L1 optical transport network functionality of network elements. This Recommendation uses the specification methodology defined in [ITU-T_G.806], in general for transport network equipment, and is based on the architecture of optical transport networks defined in [ITU-T_G.872] and the interfaces for optical transport networks defined in [ITU-T_G.709]. The description is generic and no particular physical partitioning of functions is implied. The input/output information flows associated with the functional blocks serve for defining the functions of the blocks and are considered to be conceptual, not physical. It also provides processes for OTN OAM based on ITU-T G.709. The functionality defined in this Recommendation can be applied at user-to-network interfaces (UNIs) and network node interfaces (NNIs) of the optical transport network.

Recommendation [ITU-T_G.8021] specifies both the functional components and the methodology that should be used in order to specify the L2 Ethernet transport network functionality of network elements. This Recommendation uses the specification methodology defined in [ITU-T_G.806] in general for transport network equipment and is based on the architecture of Ethernet layer networks defined in [ITU-T_G.8010], the interfaces for Ethernet transport networks defined in [ITU-T_G.8012], and in support of services defined in the ITU-T G.8011.x series of Recommendations. It also provides processes for Ethernet OAM based on [ITU-T_G.8013]. The description is generic and no particular physical partitioning of functions is implied. The input/output information flows associated with the functional blocks serve to define the functions of the blocks and are considered to be

conceptual, not physical. The functionality defined in this Recommendation can be applied at user-to-network interfaces (UNIs) and network-to-network interfaces (NNIs) of the Ethernet transport network.

Recommendation [ITU-T_G.8121] specifies both the functional components and the methodology that should be used in order to specify the multi-protocol label switching transport profile (MPLS-TP) layer network functionality of network elements. This Recommendation provides a representation of MPLS-TP technology which uses the methodologies that have been used for other transport technologies (e.g., optical transport network (OTN) and Ethernet). It also provides generic processes for MPLS-TP OAM. It specifies a library of basic building blocks and a set of rules by which they may be combined in order to describe digital transmission equipment. The library comprises the functional building blocks needed to specify completely the generic functional structure of the MPLS-TP layer network.

4.2.3. Transport management requirements

Recommendation [ITU-T_G.874] addresses management aspects of L0 and L1 optical transport network elements containing transport functions of one or more layer networks of the optical transport network (OTN). It is based on the architecture of optical transport networks defined in [ITU-T_G.872], the interfaces for OTN networks defined in [ITU-T_G.709], and the OTN equipment function description defined in [ITU-T_G.798]. The management functions for fault management, configuration management, and performance management are specified. Generic requirements in ITU-T G.7710/Y.1701 that are applicable to OTN are identified in ITU-T G.874 via pointer references to ITU-T G.7710/Y.1701. OTN-specific requirements explicitly specified include separation of management communication network and signaling communication network, OTN fault causes and failures, alarm reporting control (ARC) setting, operational state, trail trace identifier configuration, adaptation function configuration, connection function configuration, tandem connection monitoring control function configuration, and the management of the performance primitives.

Recommendation [ITU-T_G.8051] addresses management aspects of the L2 Ethernet Transport capable network element containing transport functions of one or more of the layer networks of the Ethernet transport network. The L2 Ethernet specific equipment functional blocks are defined in [ITU-T_G.8021]. In this Recommendation, fault management, configuration management, and performance management are specified. Generic requirements in ITU-T G.7710/Y.1701 that are applicable to Ethernet are identified in ITU-T G.8051/Y.1345 via pointer references to ITU-T G.7710/Y.1701. Ethernet-specific

requirements explicitly specified include the management communication channel, fault causes and failures, alarm reporting control setting, operational state, flow termination function configuration, adaptation function configuration, connection function configuration, diagnostic function configuration, traffic conditioning and shaping function configuration, performance monitoring requirements, and the management of the performance primitives.

Recommendation [ITU-T_G.8151] addresses management aspects of the MPLS Transport Profile (MPLS-TP) capable network element, which is separable from that of its client layer networks so that the same means of management can be used regardless of the client. In this Recommendation, fault management, configuration management, and performance management are specified. The generic requirements for managing transport network elements are specified in [ITU-T_G.7710] and the requirements for the management of equipment used in networks supporting an MPLS Transport Profile (MPLS-TP) are specified in [IETF RFC 5951]. This Recommendation specifies the requirements for managing the MPLS-TP specific equipment functional blocks, which are defined in [ITU-T_G.8121].

4.2.4. Management Information Models

Recommendation [ITU-T_G.874.1] provides a management-protocol-neutral information model for managing network elements in the L0 and L1 optical transport network (OTN) [ITU-T_G.872], [ITU-T_G.709], and [ITU-T_G.798] and supporting the management requirements specified in [ITU-T_G.7710] and [ITU-T_G.874]. It identifies the managed entities required for the management of OTN network elements, including Termination Points (TP), Tandem Connection Monitoring (TCM), Non-Intrusive Monitoring (NIM), Delay Measurement (DM), and the general Performance Monitoring (PM) Current Data (CD) and History Data (HD). These entities are relevant to information exchanged across standardized management interfaces. The management-protocol-neutral information model should be used as the base for defining management-protocol-specific data schema. The specific mapping of the management-protocol-neutral information model into management-protocol-specific data schema is the decision of the management-protocol-specific solution designer. The information model specified in this Recommendation allows for managing the OTN functional capabilities of the NE.

Recommendation [ITU-T_G.8052] provides a management-protocol-neutral information model for managing network elements in the L2 Ethernet transport network [ITU-T_G.8010], [ITU-T_G.8012], and [ITU-T_G.8021] and supporting the management requirements specified in [ITU-T_G.7710] and [ITU-T_G.8051]. It identifies the managed

entities required for the management of Ethernet transport network elements, including Termination Points (TP), Maintenance Entity Group (MEG) End Point (MEP), MEG Intermediate Point (MIP), Traffic Conditioning and Shaping (TCS), Loss Measurement (LM), Delay Measurement (DM), and the general Performance Monitoring (PM) Current Data (CD) and History Data (HD). These entities are relevant to information exchanged across standardized management interfaces. The management-protocol-neutral information model should be used as the base for defining management-protocol-specific data schema. The specific mapping of the management-protocol-neutral information model into management-protocol-specific data schema is the decision of the management-protocol-specific solution design. The information model specified in this Recommendation allows for managing the Ethernet functional capabilities of the NE.

It should also be noted that [MEF_7.2] specifies the EMS-NMS interface profile needed to support Metro Ethernet services, which provides the profile of management entities based on [ITU-T_Q.840.1] and [ITU-T_G.8052] and a mapping to the TMF's MTNM 3.5[TMF_MTNM] Ethernet model.

Recommendation [ITU-T_G.8152] provides a management-protocol-neutral information model for managing network elements in the L2 MPLS-TP network [ITU-T_G.8110.1], [ITU-T_G.8112], and [ITU-T_G.8121] series and supporting the management requirements specified in [ITU-T_G.7710] and [ITU-T_G.8151]. It identifies the managed entities required for the management of MPLS-TP network elements, including Termination Points (TP), Maintenance Entity Group (MEG) End Point (MEP), MEG Intermediate Point (MIP), Loss Measurement (LM), Delay Measurement (DM), and the general Performance Monitoring (PM) Current Data (CD) and History Data (HD). These entities are relevant to information exchanged across standardized management interfaces. The management-protocol-neutral information model should be used as the base for defining management-protocol-specific data schema. The specific mapping of the management-protocol-neutral information model into management-protocol-specific data schema is the decision of the management-protocol-specific solution design. The information model specified in this Recommendation allows for managing the MPLS-TP functional capabilities of the NE.

5. Discussion

This draft has provided an introduction to the significant body of specifications developed in ITU-T that detail the generic architectural principles for OAM in (multi layer) transport networks. It also provides an introduction to the specifications that apply those general principles in a consistent way to various layered transport network technologies. It is anticipated that the generic

and layer specific OAM architecture and management specifications described in this draft will prove valuable in considerations of generic unified approaches to OAM and management for additional multilayer networks.

6. Acknowledgements

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8. IANA Considerations

This memo includes no request to IANA.

9. Security Considerations

TBD

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Appendix A. Additional Stuff

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