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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-03

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.

Status of This Memo

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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)

o 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.

o 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 |        |         |          |          | G.774 |
|Protocol-neutral| G.7711 | G.874.1 |  G.8052  | G.8152   | series|
|  Info Model    |        |         |          |          | Note 1|
+------------------------------------------------------------------+
```
Note 1: The model had been specified, 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,
[ITU-T G.8110.1] for MPLS-TP). 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.783] for SDH, [ITU-T G.798] for OTN, [ITU-T G.8021] for
Carrier Ethernet, 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
(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.784] for SDH, [ITU-T G.874] for OTN, [ITU-T G.8051]
for Carrier Ethernet, and [ITU-T G.8151] for MPLS-TP.

4.1.4. Generic information model of transport network resources

ITU-T Recommendation [ITU-T_G.7711] and ONF Common Information Model
(ONF-CIM) (see [ONF_Liaison]) specify a core information model
[I-D.lam-topology] 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.774] series for SDH,
[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

Recommendations [ITU-T_G.803] and [ITU-T_G.872] describe respectively
the functionality of the SDH and 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.803 and ITU-T G.872
describe the specific aspects concerning the SDH and 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

Recommendations [ITU-T_G.783] and [ITU-T_G.798] specify both the
components and the methodology that should be used in order to
specify the respective SDH and OTN functionality of network elements.
This Recommendations uses the specification methodology defined in
[ITU-T_G.806], in general for transport network equipment, and is
based on the architecture of SDH transport networks defined in
[ITU-T_G.783] and optical transport networks defined in [ITU-T_G.872]
and the interfaces for SDH transport networks defined in
[ITU-T_G.707] and 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. They also provides processes for SDH OAM based on ITU-T
G.707 and 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

7. Contributors

8. IANA Considerations

   This memo includes no request to IANA.

9. Security Considerations

   This informational document is solely intended to provide a summary
   of 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. No security threat is
   introduced by this informational document.

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Appendix A. Additional Stuff

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