Network Management Model and Elements in Carrier Grade Ethernet

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***Abstract*—This paper presents model and elements for network management in Carrier Grade Ethernet by collecting standards and drafts of different standard bodies (IEEE, MEF, and ITU) in the area of Carrier Grade Ethernet. In this paper a short comparison to ATM management model in four categories is presented. Some proposals for improvements are also presented.**

I. Introduction

Since the invention of Ethernet in the 1970s, Ethernet has developed continually: it was initially developed as a LAN standard for connecting at 10 Mbps, but Ethernet offers 100 Mbps, 1 Gbps and now 10 Gbps speeds over both Copper and Fiber media. Ethernet has now evolved from LAN to the MAN and the ability to transport Ethernet over different transport technologies raises the exciting proposition of offering Ethernet services not only in campus or metro networks but also at a global level [2].

Carrier Grade Ethernet (CGE) is required for mass market to shift from using technologies like Frame Relay, ATM and PL to Ethernet [6]. As in [2] Carrier Grade Ethernet is a ubiquitous, standardized service that is defined by five attributes – one of these attributes is Service Management. Thus SLAs and service guarantees are a critical part of carrier Grade Ethernet. Without these many enterprises will stick with their current service [6].

Service Management is not seen as just one service level thing, only it means management of all the things – levels, participants – in the carrier Grade Ethernet concepts. Other attributes which are closely connected for managing are reliability and Quality of Service (QoS).

Automation, mechanization and scaling are required to ensure profitable services [6] and to ensure success of CGE.

This paper presents key concepts and components of managing CGE networks of different active CGE standard bodies: Metro Ethernet Forum (MEF), Institute of Electrical & Electronics Engineers (IEEE), and International Telecommunication Union (ITU).

This paper is organized as follows. Section II goes through management model and related standards. Section III presents the principle of a demarcation point. Section IV desribes maintenance domains and their hierarchy in CGE networks. In Section V some results of comparing of network management between ATM and CGE are shown, and finally Section VI presents conclusions.

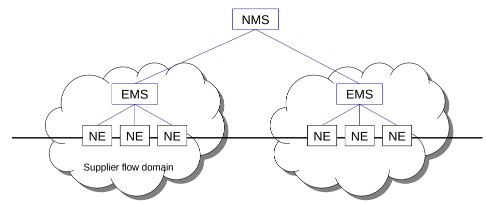

Figure 1. Overview management model defined by Metro Ethernet Forum.

II. Management Model

Management of Ethernet networks has two big parts: concept of network management and elements, and traffic level management.

Traffic level Ethernet management is divided to three levels: link, connectivity and service. Vertically there are also customers and operators. In Table I we can see these three different levels and which standards they have been defined. In addition we can see what kind of functionalities these have.

A. Overview Management Model

Metro Ethernet Forum (MEF) has defined generic reference model for network/service management [4], [8]. The model consists of network elements (NE), element management systems (EMS), network management system (NMS) and their interfaces (see Figure 1). With this model we can delegate responsibly further – for example now the NMS delegates the responsibility of managing the individual elements to the EMSs, and only manages the flow domains as presented by the EMSs [4]. The reference model allows for the representation of a topological view of network resources, the management of end-to-end connections or flows across the network and helps to define clearly responsibility limits of network management in Ethernet networks.

B. Link

Ethernet link management (IEEE 802.3ah) "Ethernet in the First Mile" enables service providers to monitor and troubleshoot a single Ethernet link [1]. There cannot be any bridges etc. on a link.

The capabilities of link-layer management are limited, being restricted to placing the remote device into loopback, setting

Table I

OVERWIEW ON NETWORK MANAGEMENT MODEL IN CARRIER GRADE ETHERNET - LEVELS AND PARTICIPANTS. THIS TABLE SHOWS FUNCTIONALITY OF DIFFERENT MANAGEMENT PROTOCOLS ON EACH EACH LEVEL: LINK, CONNECTIVITY AND SERVICES

Services and Performance (ITU Y.1731/MEF)	Basic Connectivity (IEEE 802.1ag,ITU)	Transport/Link (802.3ah EFM)
Discovery	Discovery	Discovery
Continuity check (keep alive)	Continuity check	Remote failure indication: Dying gasp, link fault and critical event
Loopback (non-intrusive and intrusive)	Loopback	Remote, local loopback
AIS/RDI/Test	-	Fault isolation
Link Trace	Link Trace	Performance monitoring with threshold alarms
Performance management	-	Status monitoring

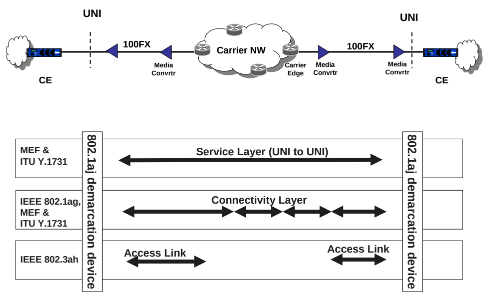

Figure 2. Model

flags indicating critical events, and querying the remote device's configuration [2]. More closely they are [9]:

- Discovery: It identifies the devices at each end of the link along with their management capabilities.
- Link monitoring serves for detecting and indicating link faults under a variety of conditions. It provides statistics on the number of frame errors (or percent of frames that have errors) as well as the number of coding symbol errors.
- Remote Failure Indication — Faults in link connectivity caused by slowly deteriorating quality are rather difficult to detect. Link management provides a mechanism for a management entity to convey such failure conditions to its peer via specific flags in the OAMPDUs. The failure conditions that can be communicated are a loss of signal in one direction on the link, an unrecoverable error (e.g., a power failure), or some critical event.
- Remote Loopback — An management entity can put its remote peer into loopback mode using the loopback control OAMPDU. In loopback mode, every frame received is transmitted back on the same port (except for OAMPDUs, which are needed to maintain the management session). This helps the administrator ensure the quality of links during installation or when troubleshooting. This feature is asymmetric in that the service provider device can put the customer device into loopback mode, but not vice versa.

C. Connectivity

The connectivity management issue is handled in the IEEE 802.1ag CFM project. IEEE 802.1ag allows service providers to manage each customer service instance individually even in multi-operator networks [9]. In principle mechanisms of 802.1ag can be used on link level; 802.1ag can be used over bridged links, 802.3ah not.

A customer service instance, or Ethernet Virtual Connection (EVC) defined by the Metro Ethernet Forum (MEF), is the service that is sold to a customer and is designated by the Service-VLAN tag. Hence, 802.1ag operates on a per-Service-VLAN (or per-EVC) basis. It enables the service provider to know if an EVC has failed, and if so, provides the tools to rapidly isolate the failure. [1]

This is critical in the following scenarios [9]:

- An SNMP trap indicates a fault has occurred in the network. How does the service provider know exactly which customers are affected?
- An EVC has failed. How does the service provider discover this?
- A link or device in an EVC fails. How do the other devices find out so they can re-route around the failure?

The connectivity level management provides tools to manage these issues.

EVC can be point-to-point or multipoint-to-multipoint connection (see Figure 3). Thus multicast makes easier for example to monitor network connectivity: one sender – many receiver. Now we do not have to for example ping every EVC entity to make sure that they are working, only send a certain frame to multicast address.

There are four types of messages to aid the administrator to manage networks in the connectivity level management [9]:

- Continuity check messages (CC) are "heartbeat" messages issued periodically by maintenance endpoints. They allow maintenance endpoints to detect loss of service connectivity among themselves. They also allow maintenance endpoints to discover other maintenance endpoints within a domain, and allow maintenance intermediate. CC messages are an extremely efficient way of monitoring network connectivity. They may be multicast from a single source, thus obviating the N^2 message streams to verify connectivity of a network with N network elements by pinging. Furthermore, CC messages may be sent at a relatively slow rate (e.g. once every second), for minimizing their impact on network bandwidth utilization [12].
- Link trace messages are transmitted by a maintenance endpoint upon request of the administrator to track the path, hop by hop, to a destination maintenance endpoint.
- Loopback messages are transmitted by a maintenance

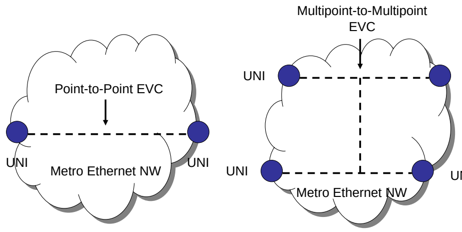

Figure 3. On the left a point-to-point Ethernet virtual Connection (EVC) and on the right multipoint-to-multipoint EVC. Multicast makes monitoring easier in Ethernet networks. User Network Interface (UNI) is boundary interface between subscriber and provider networks. SLAs are usually done between UNIs

endpoint upon request of the administrator to verify connectivity to a particular maintenance intermediate point or maintenance endpoint. Loopback indicates whether the target maintenance point is reachable or not (as used for example in demarcation device, see Section III). Loopback messages are similar in concept to ICMP Echo (Ping).

- Alarm indication messages provide asynchronous notification to other elements in the network that there is a fault in the Ethernet network.

D. Services

Service level management is built on IEEE 802.1ag. It is handled by MEF and ITU Y.1731. The service level management has four same types of messages/functionalities for handling services as we have on connectivity layer, see Table I and in addition to this we have to more messages [5], [7].

- **AIS/RDI-Test**
  - **Ethernet Alarm Indication Signal (AIS)** function is used to suppress alarms following detection of defect conditions at the server (sub) layer. It is not suited to Spanning Tree Protocol (STP) environments.
  - **Remote Defect Indication (RDI)** function can be used by a Management Entity Group End Point (MEP) to communicate to its peer MEPs that a defect condition has been encountered.
- **Performance management** functions for performance monitoring allow measurement of different performance parameters. The performance parameters are defined for point-to-point Ethernet connections. These parameters are frame loss ratio, frame delay, frame delay variation. Performance parameters are applicable to Service frames, and performance parameters and functions for multipoint ETH connectivity are for further study [7]. In addition, performance parameter throughput is identified as per RFC 2544.

III. Demarcation Point

A demarcation point in CGE networks is defined by MEF 11 [3]. The demarcation point is a very important marker in Ethernet based network. It is located between a provider's Ethernet network and a customer's private network and allows for management of the operational and administrative aspects of the network. Demarcation device is defined by IEEE 802.1aj. The demarcation point is a point where all Service Level Agreements (SLAs) are defined.

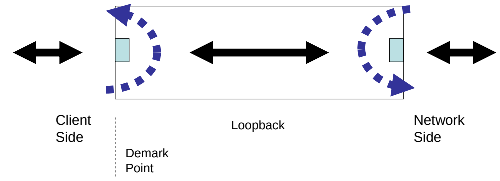

Figure 4. The principle of the demarcation point. An operator can connect to a NID and put it into loopback mode and test a connection. UNI has the same definition as demarc point.

A operator has access to demarcation device or Network Interface Device (NID) and is able to run some connection test between similar ones. This way the operator can be sure that its own network is working. The principle of a demarcation point is illustrated in Figure 4. In tests the operator puts NIDs in a loopback mode, then sends data to a certain address, the device sends it back to the sender. It is notable that a customer cannot make these tests with operator's NIDs, but they have to have their own. In addition NIDs are used between different operators' networks and network technologies.

The NID usually acts as a media converter and a bandwidth limiter. An operator can brings their connection as fiber when usually customer want to use a copper connection. The customer can connect via 100Mbit/s connection to a NID, but the operator can limit it to for example 2Mbit/s as agreed upon the terms, so the operator can easily limit bandwidth in the NID. Also other traffic shaping functionalities can be done in the NID, like giving some certain bandwidth to VoIP traffic, or mark the certain traffic for operator's internal network, or put the traffic in the certain class.

IV. Maintenance Domains

A Maintenance Domain (MD) is an administrative domain for the purpose of managing and administering a network [9].

The concept of maintenance domains is important due to the different scopes of management that must be provided for different organizations. Often there are three different organizations involved in a Metro Ethernet service: customers, service providers, and operators (see Figure 5). Customers purchase Ethernet service from service providers. Service providers may use their own networks, or the networks of other operators to provide connectivity for the requested service. Customers themselves may be service providers, for example, a customer may be an Internet service provider that sells Internet connectivity. [1]

Closely related thing to maintenance domains is Maintenance Points (MP). There are two types of MPs: Maintenance End Points (MEP) and Maintenance Intermediate Points (MIP). Maintenance end points reside at the edge of a maintenance domain, whereas maintenance intermediate points are internal to the domain [1].

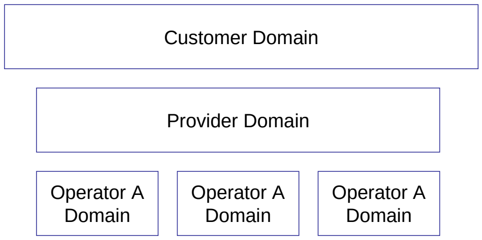

Figure 5. Different maintenance domains – customer, provider and operator. This figure also presents different Maintenance Points (MP) – MEPs reside at the edge of a MD on each maintenance domain level when MIPs are internal to the MD.

V. Comparing to ATM

Asynchronous Transfer Mode (ATM) was developed in the late 1980's, about 20 years ago. Typically new network technologies take some features from the old ones.

ATM can be used in whole network –end-to-end – in customer and operator networks, like CGE too. In this chapter a comparison between of ATM and CGE is done from the view of network management. Comparison of ATM is based on [10], [11], [13]. It is shortly done in four categories: model, levels, elements and management functions.

A. Model

The management model in both technologies is almost same: a generic model is defined how to manage network devices. A greatest difference been CGE and ATM management model is that in CGE we can have a fully centralized control (in Figure I: NMS), when in ATM we can only manage our own networks, but the management system of ATM is also centralized.

For example an article [13] presents a model to decentralized management of ATM networks: mobile agents. The existing procedures in network systems tend to be massive. Mobile agents do not statically reside on network devices; therefore, they can be created on demand, and destroyed when they are no longer required. They are usually smaller than the corresponding procedures in the classic network management systems because they normally perform a single task. Thus by using mobile agents the load can be reduced on the manager side because of delegating tasks to mobile agents.

B. Levels

ATM and CGE has the same number of levels in hierarchy. In ATM they are called: physical layer, ATM layer and ATM Adaption layer (AAL).

C. Elements

The demarcation device can also be found in ATM networks and it has the same purpose as in CGE network – to create demarcation point between private an public ATM networks. But in ATM this device is usually included in some network device (for example in an ATM switch) whereas in CGE network it is usually located in a separated device on a link.

Another difference demarcation device in CGE and ATM is that in CGE we are able to make more measurements (for example SLA measurements) between other ones. In CGE networks operators can monitor end-to-end SLA parameters in demarcation devices.

D. Management Functions

ATM has similar management functions as CGE has (see Table I). The both have different types of functions on each level. The task of functions is almost same: only the discovery function (connectivity and service levels) can not been seen in ATM. The greatest difference is maybe the lack of multicast functionality in ATM. In CGE with help of multicast for example continuity check (CC) can be easily implemented.

VI. Conclusion

The management model of Carrier Grade Ethernet networks is well-defined and many different standard bodies have effected on it. Multicast property of Ethernet networks give a lot of possibilities in network monitoring.

Network technologies travel in cycles – management system of ATM seems to very similar to CGE's one according to the comparison made in chapter V. CGE has some improvements or differences like fully centralized management if needed, better validation mechanisms of connections and SLA measurements.

A. Proposals for Improvement

Passive monitoring has lifted its head lately in the operator world. A passive monitor feature could be included in demarcation device or physically in NID. Some manufacturers have already put it on this device. With this an operator could on-demand capture traffic from network for example in case of troubleshooting or adding a new customer. In addition captured traffic could be transferred via a specific VLAN connection to the operator and analyze the data there.

In addition this passive feature could be used for billing information, but in this case the NID would need some processing power to analyze data in the NID, because there is no sense in continuous passive monitoring in such a device and environment. Only processed data would be transferred to the operator's billing systems.

B. Future Work

CGE networks have now fully centralized management model. However for ATM there are also some other models, for example mobile agents [13] for decentralizing the management. In the future this same system could be also solved to CGE networks or to test some other old concepts or to develop some new decentralized management models for CGE.

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