Introduction to Connectivity Fault Management

Norman Finn
Huawei Technologies Co. Ltd
nfinn@nfinnconsulting.com
60802-finn-intro-to-CFM-0721-v01

Purpose of this presentation

- The chair of TSN asked this author, who was the editor of IEEE Std 802.1ag-2007, Connectivity Fault Management, to introduce CFM to the Industrial Automation group.
- If appropriate, IEC/IEEE P60802 can reference CFM as an optional or a required feature for Industrial Automation.

What is CFM?

- CFM is a protocol supporting OAM (Operations, Administration, and Maintenance) functions on VLAN bridged Ethernet networks (not routers).
- There is one EtherType assigned, with a 1-byte OpCode field, of which about 18 PDU types have been defined, serving different functions. The PDU format is designed for extension and backward compatibility, and new PDU types can be defined, if needed.
- Certain PDU types, e.g. “frame loss” and “delay measurement”, are usually implemented in hardware. Others, e.g. “linktrace”, are usually implemented in software.

Why might CFM be of interest to 60802?

- CFM functions could be useful for Industrial Automation.
  - Connectivity testing and in-band failure notification
  - Load testing
  - Delivery time and frame loss measurements
  - Path tracing
- The standards have been written.
- These standards are widely implemented, at least in the service provider community.
- **The functions requiring hardware have been implemented.**

IEEE and ITU-T cooperation

- Two organizations: ITU-T Study Group 13 (2000) and IEEE 802.
- Two independent standards:
  - IEEE Std 802.1ag-2007 “Connectivity Fault Management”
  - ITU-T Y.1731-2008 “OAM functions and mechanisms for Ethernet based networks”.
- Y.1731 is a superset of 802.1ag, and there are some terminology differences, but common membership made sure that interoperability was not impacted.
- Today, these standards are contained in:
  - IEEE Std 802.1Q-2018 clauses 18-22 and 29, and
  - ITU G.8013/Y.1731-2015 “OAM functions and mechanisms for Ethernet-based networks” (plus amendments and corrigenda).
- (IETF also joined the party, with RFC 7319, but this has not been widely used.)

What executes CFM?

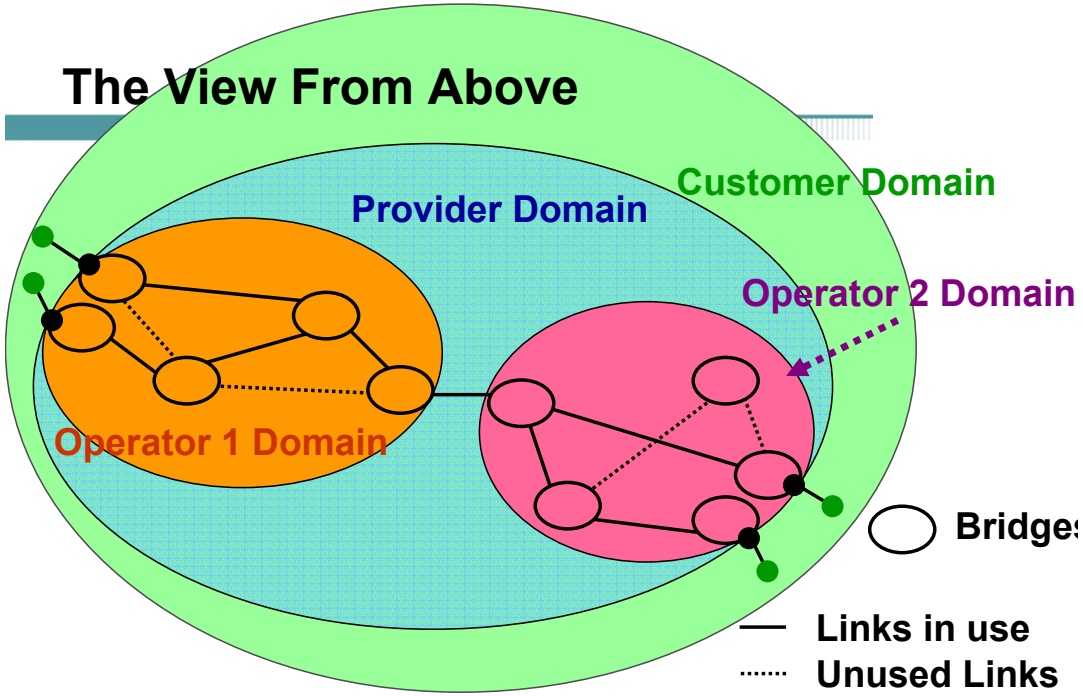
- Bridges and end stations instantiate **MEPs** (Maintenance End Points) and **MIPs** (Maintenance Intermediate Points) that use the CFM PDU types to perform various OAM tasks. These tasks include:
  1. Regular background tasks (e.g. periodic connectivity monitoring),
  2. Automatic response tasks (e.g. reply to a loopback message with a loopback response), and
  3. Fault diagnosis tasks (e.g. transmit a loopback stream at line rate).
- MEPs are configured and controlled by standard MIBs and/or YANG modules. MIPs are lightweight functions, often not controlled.

Layers in CFM

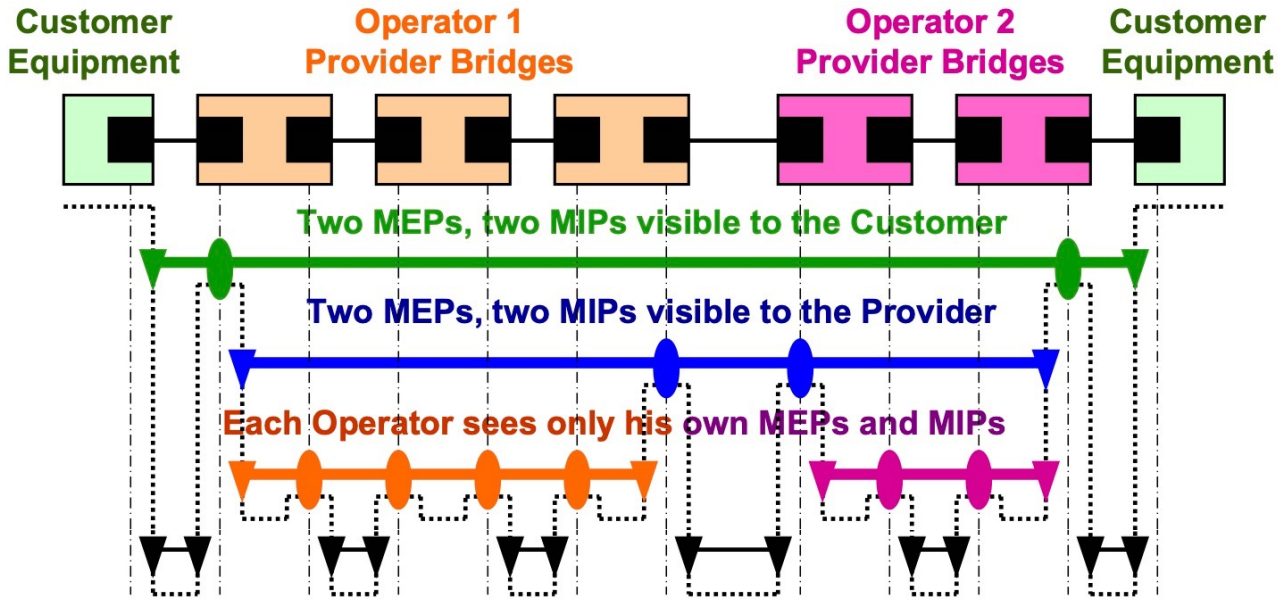
CFM is hierarchical in nature:

- Each Maintenance Association (MA) has a number of MEPs at its edge, and a number of MIPs in its interior. An “MA” is often a VLAN or multicast group.
- A Maintenance Domain can have any number of MAs in it. An MD is often a VLAN Bridged network or an administrative domain.
- Domains can be nested: An Ethernet link in a customer’s Domain can be a virtualized as a single Maintenance Association in a provider’s Domain, on so on up to 8 layers.

Layers in CFM



- Physical view of a network using CFM



- We can see the MIP/MEP relationships.

Diagrams from https://www.ieee802.org/1/files/public/docs2004/nfinn-cfm-tutorial-1.pdf

Layers in CFM

- CFM PDUs belonging to a higher layer (e.g. the Customer layer) pass transparently through MIPs and MEPs at lower layers.
- CFM PDUs at the same layer as a MEP or MIP are processed.
- CDM PDUs received by a MEP that are at a lower layer than the MEP are discarded.
- MEPs at a given layer usually coincide with MIPs for the next-higher layer.
- This establishes the hierarchy of nested domains.
- Generally speaking, layers require hardware filtering.

Basic IEEE Std 802.1Q CFM functions

- CCM: Connectivity Check Message
  - Each MEP is configured with a list of all MEPs in the connection.
  - Each MEP sends periodic broadcast or multicast CCMs, at up to 300 Hz.
  - Each MEP detects an error if it misses 3 CCMs from a known MEP, or if it receives any CCM from an unknown MEP.
  - Point-to-point operation modes are also allowed.
- LBM/LBR: Loopback Message/Response
  - A unicast LBM from a MEP elicits an LBR from the destination MEP or MIP.
  - MEP functions support sending LBMs individually or at line rate, and counting the returned LBRs.

Basic IEEE Std 802.1Q CFM functions

- LTM/LTR: Linktrace Message/Response
  - A MEP sends an LTM message to another MEP.
  - Each MIP along the path returns an LTR to the originating MEP.
  - The originating MEP collects responses to learn the path to the other MEP.

A sampling of ITU G.8013/Y.1732 Ether OAM functions

- CCM, LBM, LBR, LTM, LTR, as described
- DMM, DMR: Delay Measurement Message/Response
  - These messages utilize hardware timestamps, inserted into the messages, to measure the one-way (if clocks are synchronized) or two-way time for the DMM to go one MEP to another MEP, and be returned as a DMR.

A sampling of ITU G.8013/Y.1732 Ether OAM functions

- LMM, LMR: Loss Measurement Message/Response
  - Along with special counters implemented in hardware, the LMM/LMR messages allow the comparison of frames transmitted through one MEP to frames received through a peer MEP.
  - These messages account for frames in flight, and thus can measure the loss of a single frame.
- SLM, SLR, ISL: Synthetic Loss Message/Response
  - A MEP inserts ISLs (Inserted Synthetic Loss PDUs) into a connection.
  - SLMs and SLRs allow the MEPs to count inserted messages.
  - This allows statistical loss measurement in the absence of LMM/LMR hardware.

Other PDUs

- SFM: Send Frame Message (802.1Q)
  - A MEP sends, to another MEP, an SFM containing an inner frame. The receiving MEP transmits that inner frame back towards the first MEP.
- RFM: Reflected Frame Message (802.1Q)
  - A MEP is configured with a filter. When a frame that matches that filter is received, the MEP transmits that frame to another MEP, encapsulated in an RFM.
- A number of ITU-T messages exist for alarm suppression.
  - When many services use a single failed link, the network administrator would rather see one alarm from the root cause, rather than a flood of alarms from affected services.
- And several more in G.8013/Y.1731.

SUMMARY

- CFM/EtherOAM has been implemented widely, though primarily in the Service Provider space. This is especially important for features that require hardware support.
- CFM/EtherOAM support multiple administrative domains, both adjacent and hierarchical.
- The same tools work on one physical link, one virtual link, or end-to-end, all at the same time.
- VLAN connectivity, multicast connectivity, and point-to-point connectivity are all supported.

DISCUSSION

Thank you