EFM OAM Tutorial

Current as of IEEE P802.3ah/D3.0™

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World Wide Packets®

Agenda

- **Overview**

- **OAM Protocol Data Units (OAMPDUs)**

- **Events**
  - **Critical Link Events**
  - **Link Events**

- **Variable Retrieval**

- **Remote Loopback**
  - **Internal block diagram**
  - **Starting and exiting timing diagrams**

- **Organization Specific Extensions**

- **Discovery**

- **Active & Passive Modes**

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Overview: Parent Organizations

- **IEEE 802 LMSC**

  - ***L**ocal Area Network/**M**etropolitan Area Network **S**tandards **C**ommittee*

- **IEEE 802.3 CSMA/CD**

  - ***C**arrier **S**ense **M**ultiple **A**ccess with **C**ollision **D**etect (CSMA/CD) Working Group*

    - **Commonly referred to as the Ethernet Working Group**

- **IEEE P802.3ah Ethernet in the First Mile Task Force (EFM)**

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Overview: OSI Layer Stack

P802.3ah Layers

OSI Reference Model Layers

OSI Reference Model	P802.3ah Layers
Application	**Higher Layers**
Presentation	**LLC**
Session	**Operations, Administration, and Maintenance (OAM)**
Transport	**MAC Control**
Network	**MAC**
Data Link	**Reconciliation Sublayer (RS)**
Physical	

1 Gb Link Segment	100 Mb Link Segment	2/10 Mb Link Segment
GMII	MII	MII
PCS	PCS	PCS
PMA	PMA	PMA
PMD	PMD	PMD
MDI	MDI	MDI
MEDIUM	MEDIUM	MEDIUM

OAM = Operations, Administration, & Maintenance
MDI = Medium Dependent Interface
(G)MII = (Gigabit) Media Independent Interface

PCS = Physical Coding Sublayer
PMA = Physical Medium Attachment
PMD = Physical Medium Dependent

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Overview: Objectives

- **OAM provides mechanisms to:**
  - **Monitor link operation and health**
  - **Improve fault isolation**

- **Method: OAM data conveyed in basic (*untagged*) 802.3 Slow Protocol frames**
  - **Sent between two ends of a single link**
    - ***Note: called a "DTE" in 802.3 terminology***
  - **Slow Protocols allows S/W implementation**

- **Fills major requirement to reduce EFM OpEx**

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Overview: Non-objectives

- **Does <u>not</u> provide capabilities for:**
  - **Station management**
  - **Protection switching**
  - **Provisioning**
    - *No SET functions*
  - **Bandwidth allocation**
  - **Speed/duplex negotiation**
  - **End-to-end OAM communication**
    - *802.3 scope restricted to single links*

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Overview: Compatibility

■ **Optionality**

- **OAM is optional; software and/or hardware implementations possible**
- **May be implemented on one or more ports within a system**
- **Individual OAM features are optional**

■ **Supported media**

- **All point-to-point (P2P) and emulated P2P links supported**

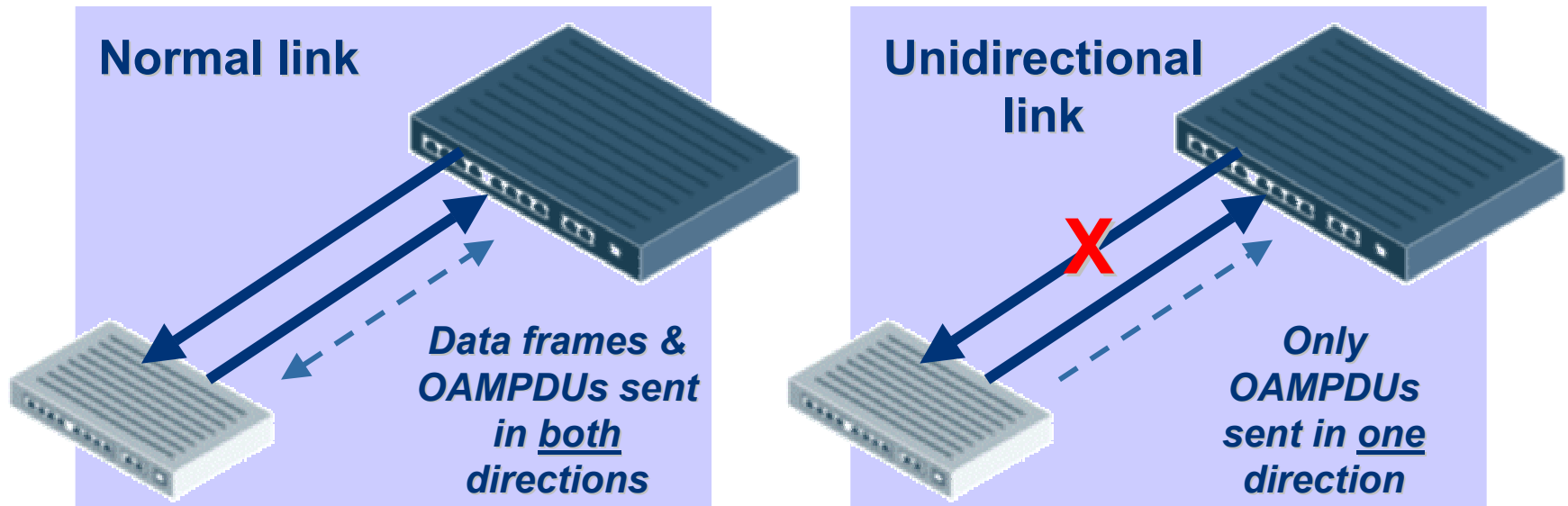■ **802.3x MAC Flow Control (PAUSE)**

- **Inhibits all traffic *including* OAMPDUs**

■ **802.3z Auto Negotiation**

- **Support for unidirectional fault signaling is *mutually exclusive* with 802.3z Auto Neg**
  - **802.3z Auto Neg *must be disabled* for fault signaling to be sent over 1000BASE-X unidirectional links**

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OAMPDU: Unidirectional

- **EFM OAM adding optional PCS feature to allow optical links to operate unidirectionally**
  - *Legacy links become inoperable when one direction fails*
  - **Newer links can send Information OAMPDUs unidirectionally to signal link fault**
    - **100BASE-X, 1000BASE-X & 10GbE RS being updated by EFM**

Normal link

Data frames & OAMPDUs sent in both directions

Unidirectional link

X

Only OAMPDUs sent in one direction

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OAMPDU: Forwarding - NOT

- **Only traverse a single link**
  - **Not forwarded by bridges**
- **Communication beyond a single link left to higher layers**

OAMPDUs

OAMPDUs

OAMPDUs

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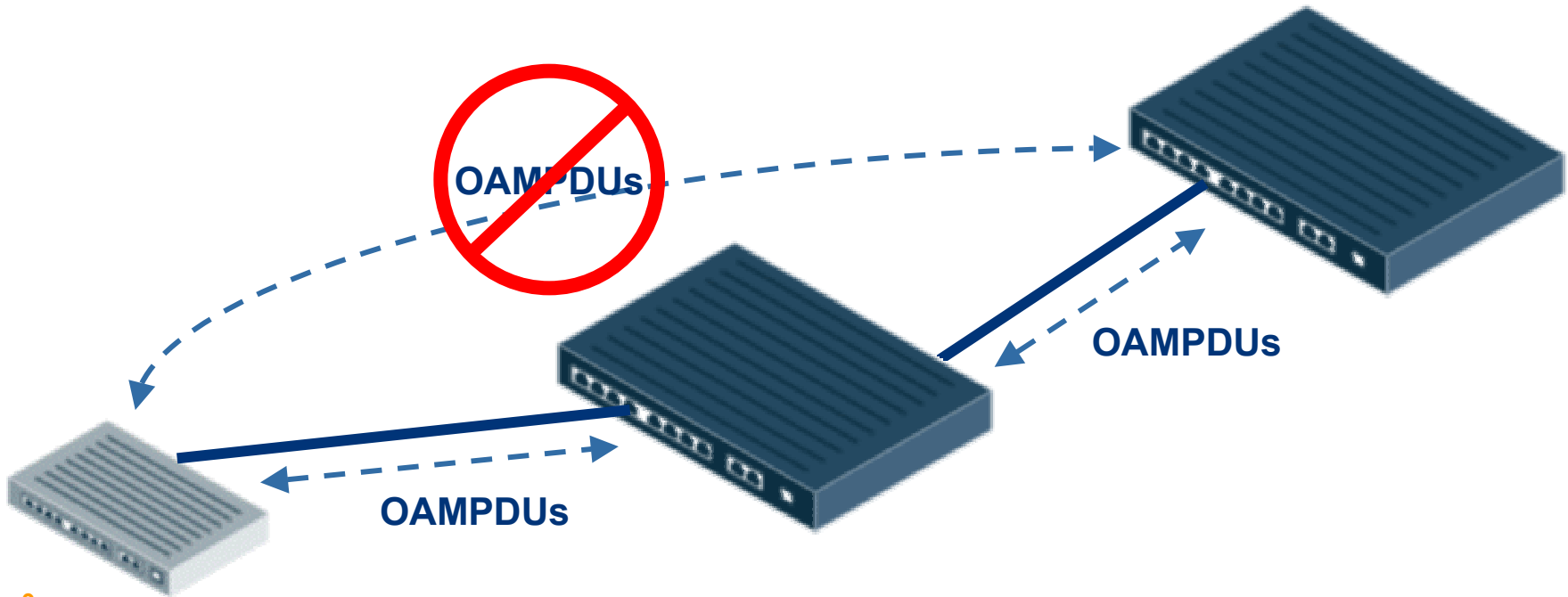
OAMPDU: Size/Rate

- **Must be standard frame length**
  - **64-1518 octets**
  - **Maximum PDU size determined during Discovery process**

- *Must be untagged*

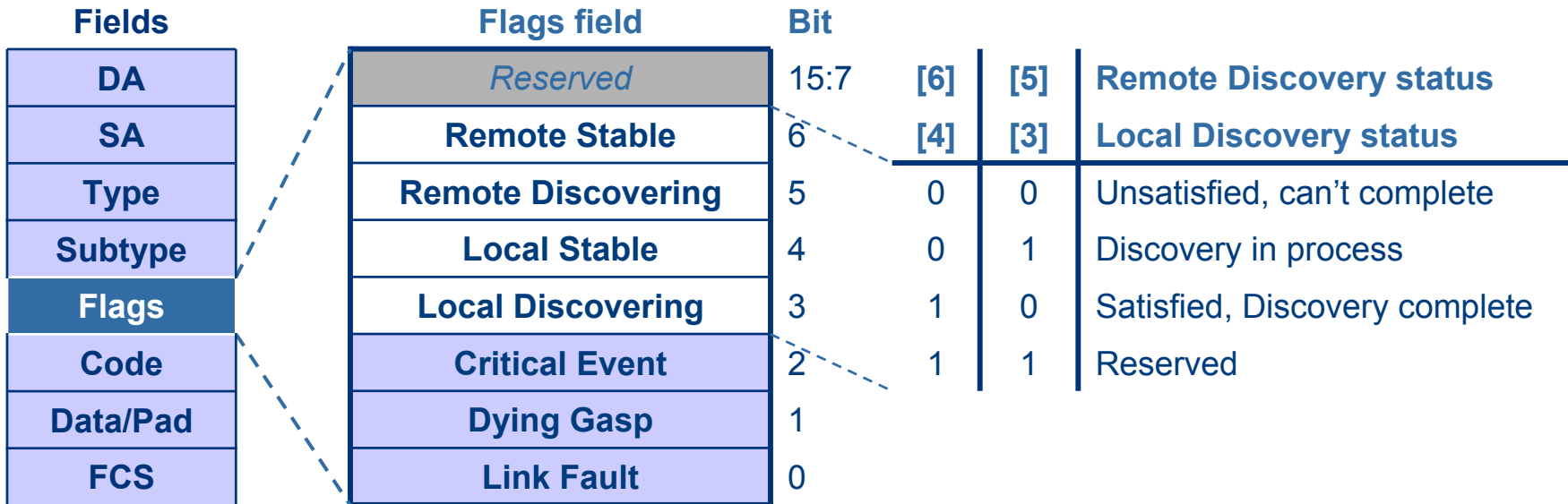| Octets	
6	01-80-c2-00-00-02 [*Slow Protocol*]
6	MAC Source Address
2	Type=88-09 [*Slow Protocols*]
1	Subtype = 0x03 [*OAM*]
2	Flags field
1	Code
42-1496	Data/Pad field
4	Frame Check Sequence
64-1518	

- **Maximum of (10) OAMPDUs per second**
  - **Max rate defined in Annex 43B as modified by EFM**
  - **May be sent multiple times to increase likelihood of reception by remote device (e.g., in the case of high bit errors)**

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OAMPDU: Flags field

- **Length: 2 octets**
- **Legend:**

Critical Link Event bit

State information bit

Fields		Flags field	Bit				
DA		Reserved	15:7	**[6]**	**[5]**	**Remote Discovery status**	
SA		Remote Stable	6	**[4]**	**[3]**	**Local Discovery status**	
Type		Remote Discovering	5	0	0	Unsatisfied, can't complete	
Subtype		Local Stable	4	0	1	Discovery in process	
Flags		Local Discovering	3	1	0	Satisfied, Discovery complete	
Code		Critical Event	2	1	1	Reserved	
Data/Pad		Dying Gasp	1				
FCS		Link Fault	0				

OAM Critical Link Events

- ## Link Fault
  - Signal remote device that receive path is broken
  - Sent once per second in Information OAMPDU

- ## Dying Gasp
  - Signal remote device that unrecoverable local fault (e.g. power failure) has occurred
  - May be sent immediately/continuously

- ## Critical Event
  - An unspecified critical event has occurred
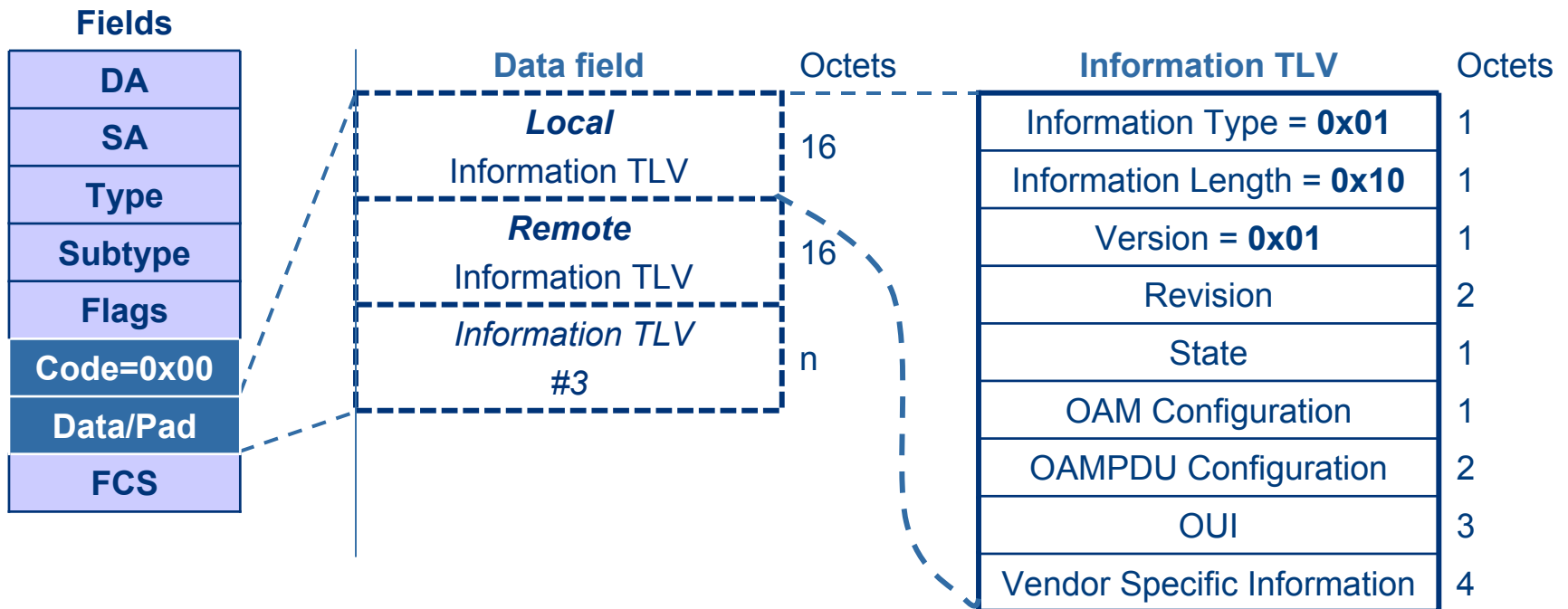 - May be sent immediately/continuously

OAMPDU: Codes

Code	OAMPDU	Length
0x00	Information	*varies*
0x01	Event Notification	*varies*
0x02	Variable Request	*varies*
0x03	Variable Response	*varies*
0x04	Loopback Control	64 octets
0x05-0xFD	Reserved	
0xFE	Organization Specific	varies
0xFF	Reserved	

♦ **Unknown/unsupported OAMPDUs sent to OAM client**

  ♦ *Different than 802.3x behavior, which filtered unsupported opcodes*

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OAMPDU: Information

- **Code: 0x00**
- **Data field: Information TLVs**
- **Length: varies**

Fields

DA
SA
Type
Subtype
Flags
Code=0x00
Data/Pad
FCS

Data field	Octets
Local Information TLV	16
Remote Information TLV	16
Information TLV *#3*	n

Information TLV	Octets
Information Type = **0x01**	1
Information Length = **0x10**	1
Version = **0x01**	1
Revision	2
State	1
OAM Configuration	1
OAMPDU Configuration	2
OUI	3
Vendor Specific Information	4

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Information TLVs

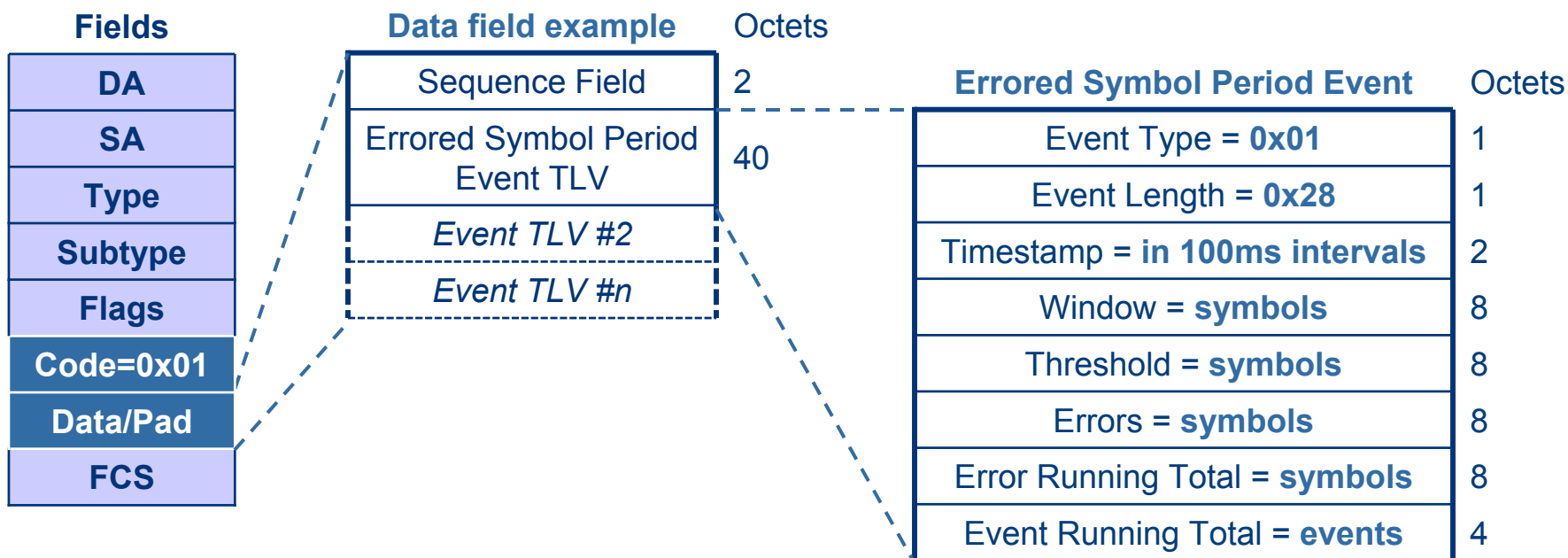| Information Type	Information TLV Name
0x00	*End of TLV marker*
0x01	**Local Information**
0x02	**Remote Information**
0x03-0xFD	*Reserved*
0xFE	**Organization Specific Information**
0xFF	*Reserved*

- ◆ **Sent as Information TLVs within Information PDU**
  - ● **Local & Remote used for Discovery Process**
  - ● *Optional* **Organization Specific Information used for extension purposes**

Local/Remote Information

		7	6	5	4	3	2	1	0
1	Information Type	8-bit Type							
1	Information Length	0x10							
1	OAM Version	0x01							
2	Revision	16-bit Revision							
1	State	*reserved*			Mux		Parser Action		*rsvd*
1	OAM Configuration	*reserved*		Vars	Events	LB	Unidir		Mode
2	OAMPDU Configuration	*reserved*					Max OAMPDU Size		
		Maximum OAMPDU Size							
7	Vendor Identifier	24-bit Organizationally Unique Identifier							
		32-bit Vendor Specific Information *Prior to D2.1, these four octets were called* *Device Identifier and Version Identifier*							

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OAMPDU: Event Notification

- **Code: 0x01**
- **Data field: One or more Link Event TLV(s)**
- **Length:** *Variable*

Fields

DA
SA
Type
Subtype
Flags
Code=0x01
Data/Pad
FCS

Data field example | Octets

Sequence Field	2
Errored Symbol Period Event TLV	40
Event TLV #2	
Event TLV #n	

Errored Symbol Period Event | Octets

Event Type = **0x01**	1
Event Length = **0x28**	1
Timestamp = **in 100ms intervals**	2
Window = **symbols**	8
Threshold = **symbols**	8
Errors = **symbols**	8
Error Running Total = **symbols**	8
Event Running Total = **events**	4

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OAM Link Event TLVs

Event Type	Event TLV Name
0x00	*End of TLV marker*
0x01	**Errored Symbol Period Event**
0x02	**Errored Frame Event**
0x03	**Errored Frame Period Event**
0x04	**Errored Frame Seconds Summary Event**
0x05-0xFD	*Reserved*
0xFE	**Organization Specific Event TLV**
0xFF	*Reserved*

- **Sent as Link Event TLVs within Event Notification PDU**
  - **May be sent multiple times to increase likelihood of reception (e.g. in the case of high bit errors)**
  - **Includes time reference when generated**

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Errored Symbol Period Event

- **A window, measured in number of symbols, where number of errored symbols exceeded a threshold**
- **Type: 0x01**
- **Length: 0x28 (40 octets)**
- **Value:**

Fields	Width	Description
Timestamp	16-bits	Time reference, in 100ms units, when generated
Window	64-bits	Lower bound: Symbols in 1 second Upper bound: Symbols in 60 seconds
Threshold	64-bits	Lower bound: 0 Upper bound: unspecified
Errors	64-bits	# of symbols errors in *Window*
Total Errors	64-bits	Total # of symbol errors causing events to be sent
Total Events	32-bits	Total # of events sent

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Errored Frame Event

- **A window, measured in 100ms intervals, where number of errored frames exceeded a threshold**
- **Type: 0x02**
- **Length: 0x1A (26 octets)**
- **Value:**

Fields	Width	Description
Timestamp	16-bits	Time reference, in 100ms units, when generated
Window	16-bits	Lower bound: 1 second Upper bound: 60 seconds
Threshold	32-bits	Lower bound: 0 Upper bound: unspecified
Errors	32-bits	# of frame errors in *Window*
Total Errors	64-bits	Total # of frame errors causing events to be sent
Total Events	32-bits	Total # of events sent

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Errored Frame Period Event

- **A window, measured in frames, where number of errored frames exceeded a threshold**
- **Type: 0x03**
- **Length: 0x1C (28 octets)**
- **Value:**

Fields	Width	Description
Timestamp	16-bits	Time reference, in 100ms units, when generated
Window	32-bits	Lower bound: # of 64B frames in 1 second Upper bound: # of 64B frames in 60 seconds
Threshold	32-bits	Lower bound: 0 Upper bound: unspecified
Errors	32-bits	# of frame errors in *Window*
Total Errors	64-bits	Total # of frame errors causing events to be sent
Total Events	32-bits	Total # of events sent

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Errored Frame Seconds Summary

■ **A window, in 100ms intervals, where number of errored frame seconds exceeded a threshold**

■ **Type: 0x04**

■ **Length: 0x16 (22 octets)**

■ **Value:**

Fields	Width	Description
Timestamp	16-bits	Time reference, in 100ms units, when generated
Window	16-bits	Lower bound: 10 seconds Upper bound: 900 seconds
Threshold	16-bits	Lower bound: 0 Upper bound: unspecified
Errors	16-bits	# of errored frame seconds in *Window*
Total Errors	64-bits	Total # of errors causing events to be sent
Total Events	32-bits	Total # of events sent

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Organization Specific Event

- **Organizations may define events that are of variable length and are distinguished by the OUI**
- **Type: 0xFE**
- **Length: varies**
- **Value:**

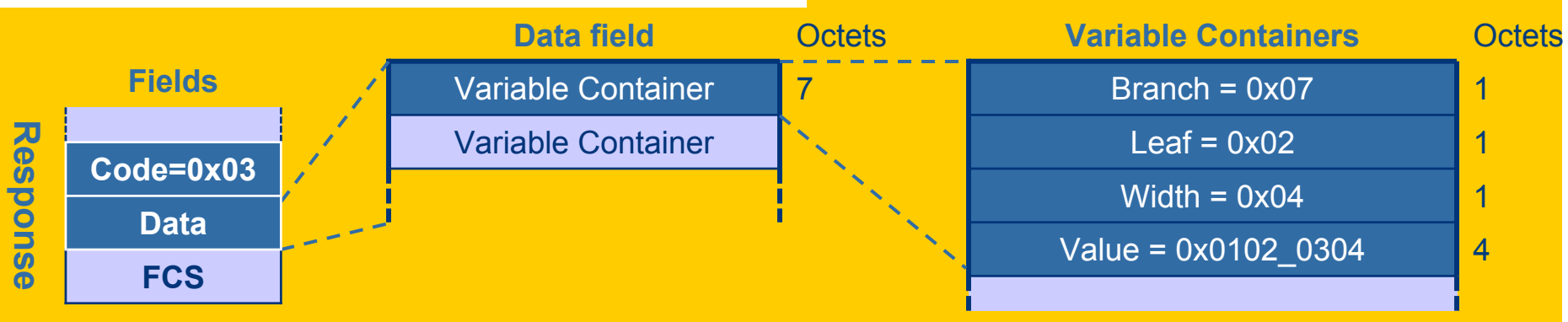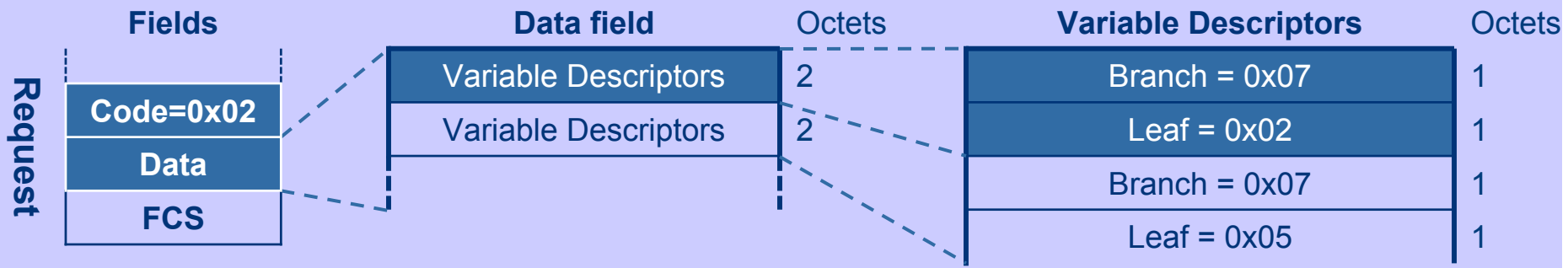| Fields	Width	Description
OUI	24-bits	Organizationally Unique Identifier
varies	*varies*	*varies*

OAMPDU: Variable Req/Resp

Variable Request

- Code: 0x02
- Data: Variable *Descriptors*
- Length: *Variable*

Variable Response

- Code: 0x03
- Data: Variable *Containers*
- Length: *Variable*

Request

Fields
Code=0x02
Data
FCS

Data field	Octets
Variable Descriptors	2
Variable Descriptors	2

Variable Descriptors	Octets
Branch = 0x07	1
Leaf = 0x02	1
Branch = 0x07	1
Leaf = 0x05	1

Response

Fields
Code=0x03
Data
FCS

Data field	Octets
Variable Container	7
Variable Container	

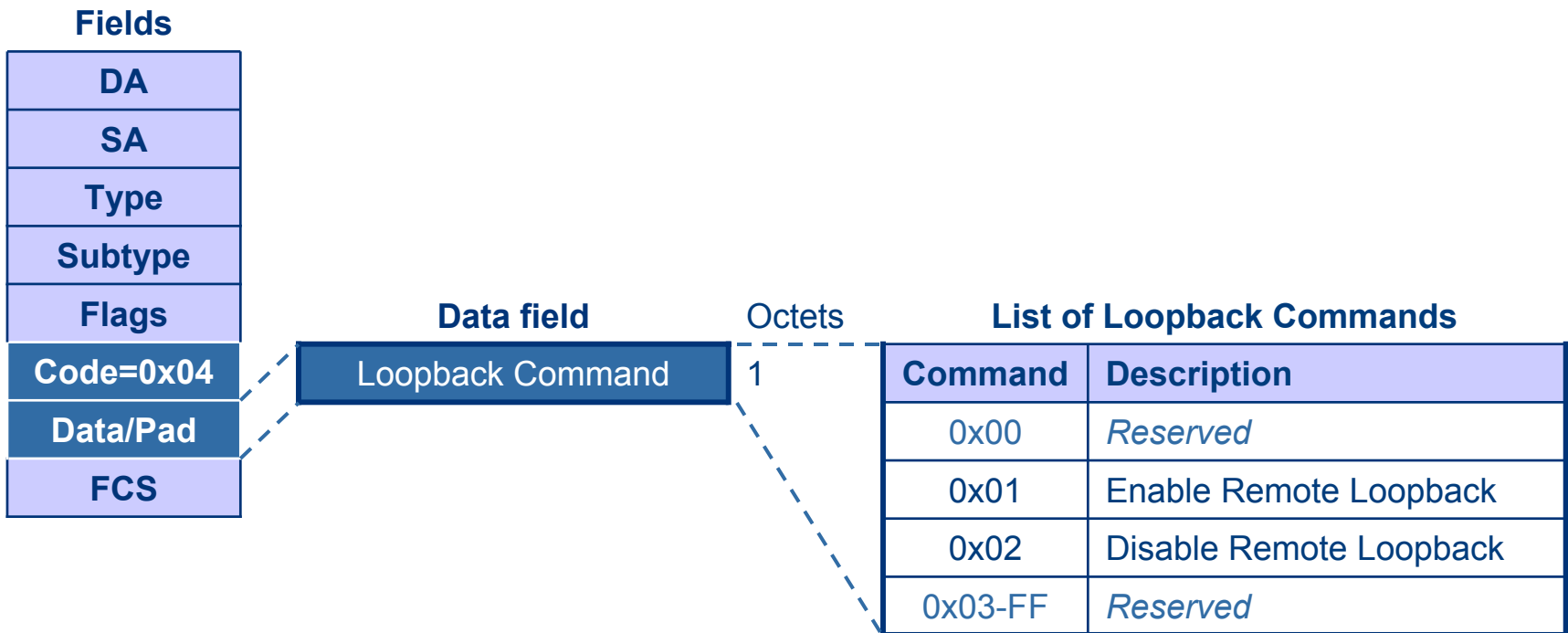| Variable Containers	Octets
Branch = 0x07	1
Leaf = 0x02	1
Width = 0x04	1
Value = 0x0102_0304	4

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Variable Retrieval

- **Transfer Ethernet counters and statistics via Variable Containers/Descriptors**

- **Variables are referenced using Annex 30A CMIP registration arcs**

- **Can be used to emulate L2 Ping**
  - **(i.e., Tx Variable Request, Rx Variable Response)**

- **Examples:**

Variable	CMIP Registration Arcs	
	Branch	**Leaf**
aFramesTransmittedOK	**0x07**	**0x02**
aFrameCheckSequenceErrors	**0x07**	**0x06**
aOctetsReceivedOK	**0x07**	**0x0E**

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OAMPDU: Loopback Control

- **Code: 0x04**
- **Data field: Loopback Command (1 octet)**
- **Length: 64 octets**

Fields

DA
SA
Type
Subtype
Flags
Code=0x04
Data/Pad
FCS

Data field | **Octets**

Loopback Command	1

List of Loopback Commands

Command	Description
0x00	*Reserved*
0x01	Enable Remote Loopback
0x02	Disable Remote Loopback
0x03-FF	*Reserved*

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OAM Remote Loopback

- **Local DTE sends arbitrary data frames**

- **Remote DTE returns data frames**

- **Frame BER equals bit BER to high probability when bit BER is better than 10^{-6}**

Local DTE   **Remote DTE**
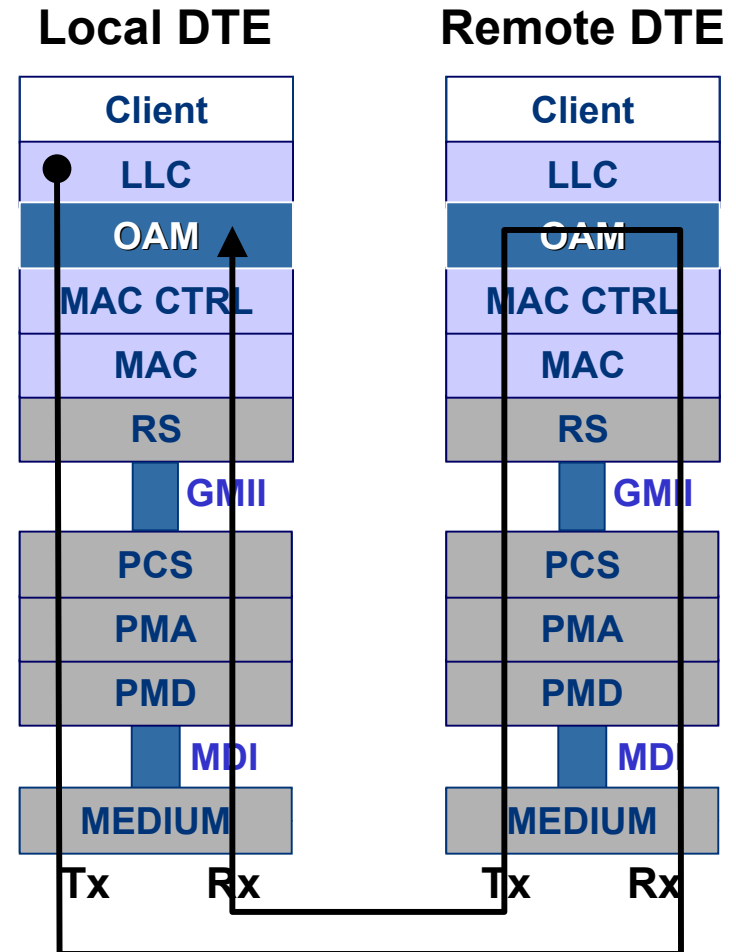
Can be implemented in H/W or S/W

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OAM Sublayer Block Diagram

- **OAM client**
  - **Configures OAM sublayer through Control**
  - **Processes received PDUs**
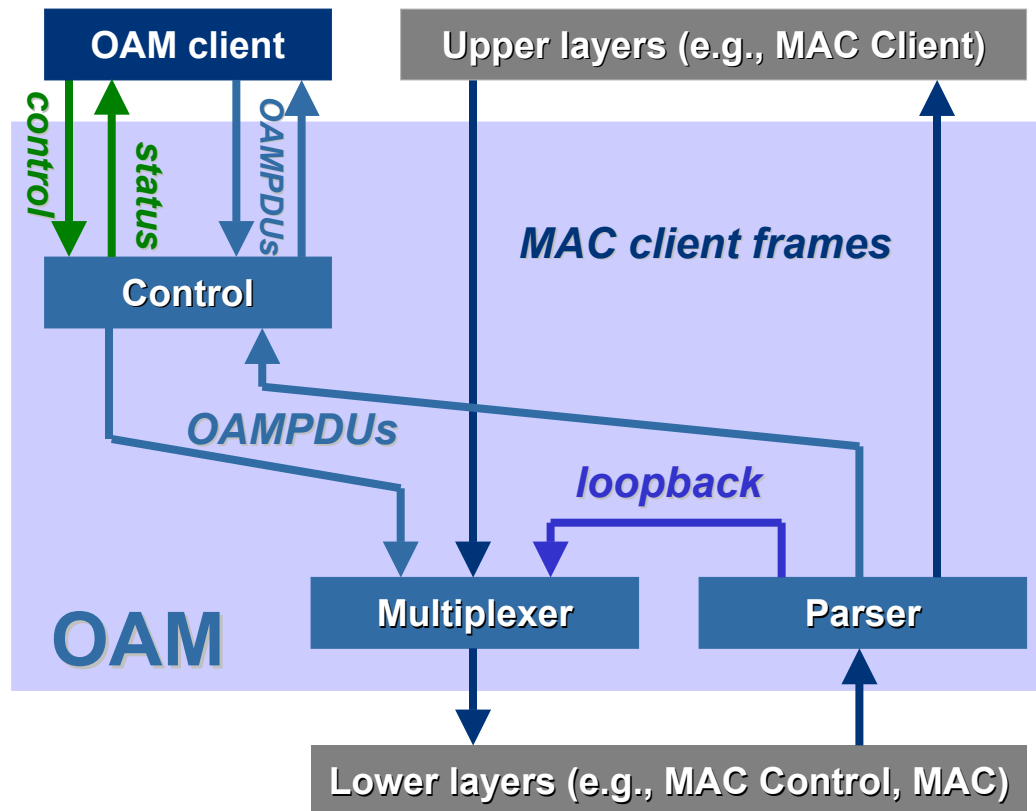 - **Transmits PDUs**
- **Control**
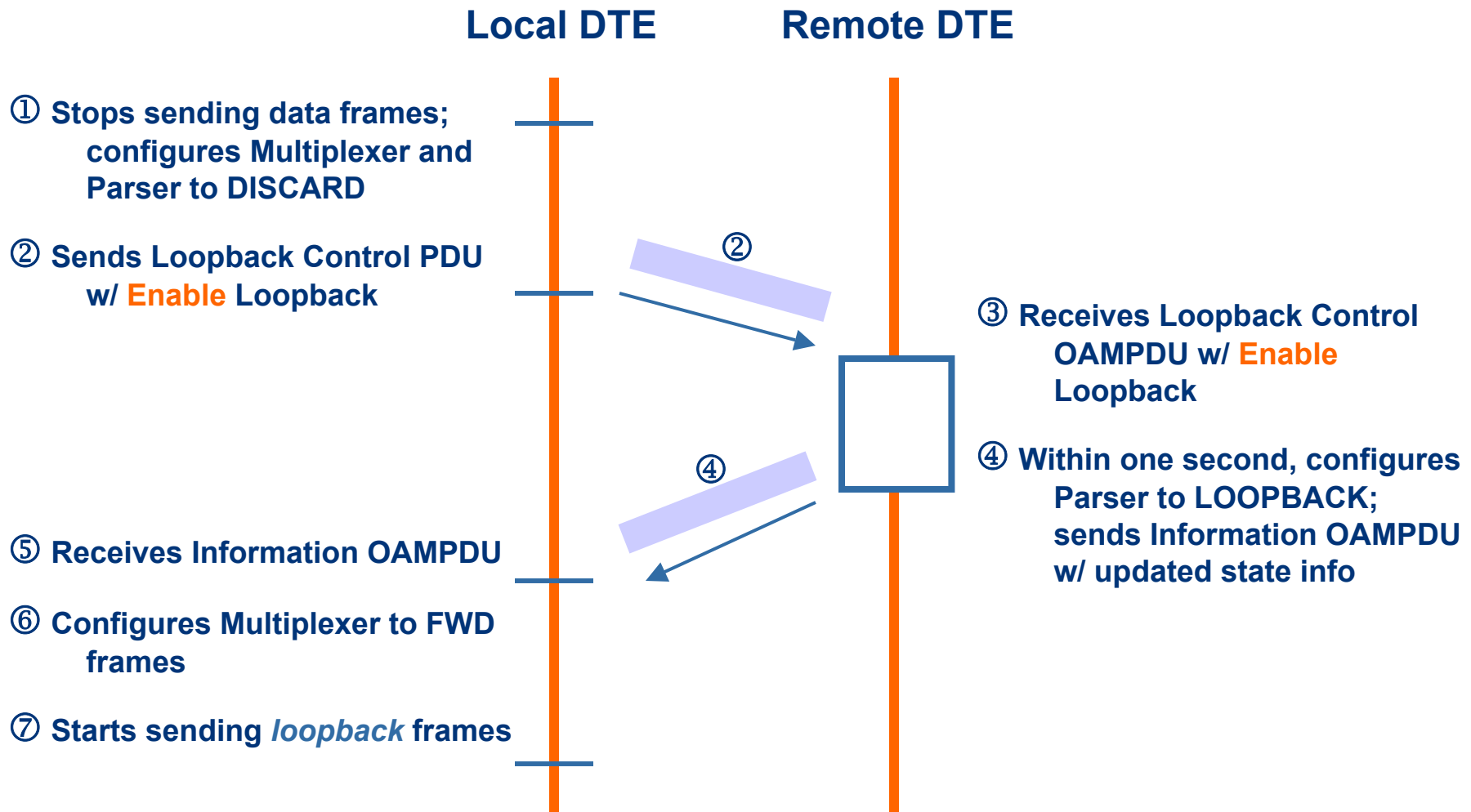 - **Provides interface with OAM client entity**
- **Parser**
  - **Inspects received frames, sends PDUs to Control and based on configuration, sends:**
    - **Non-PDUs to upper layer**
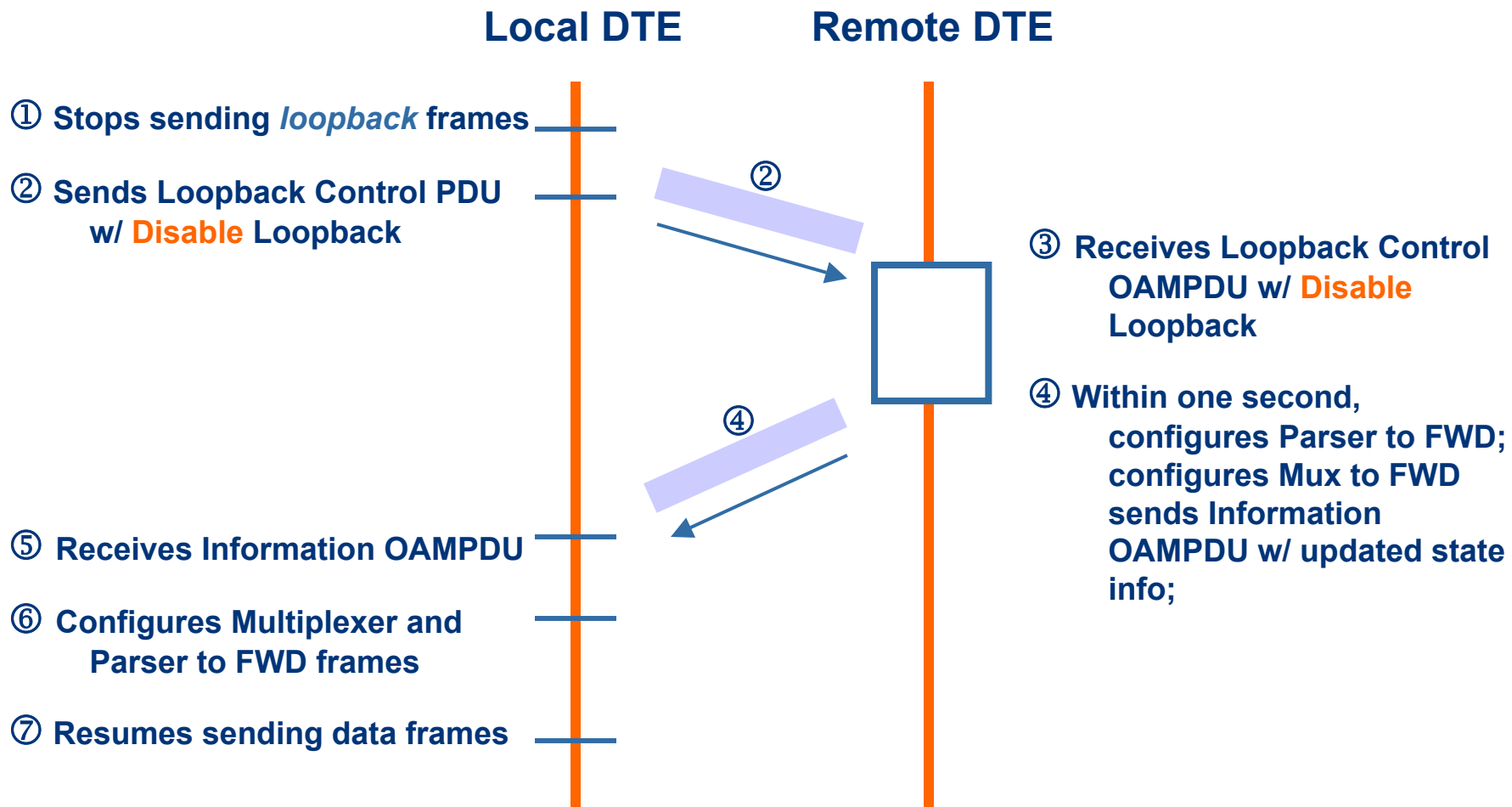   - or
    - **Non-PDUs to Multiplexer**
- **Multiplexer**
  - **Multiplexes PDUs and non-PDUs**

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Starting Remote Loopback

Local DTE   **Remote DTE**

① **Stops sending data frames; configures Multiplexer and Parser to DISCARD**

② **Sends Loopback Control PDU w/ Enable Loopback**

③ **Receives Loopback Control OAMPDU w/ Enable Loopback**

④ **Within one second, configures Parser to LOOPBACK; sends Information OAMPDU w/ updated state info**

⑤ **Receives Information OAMPDU**

⑥ **Configures Multiplexer to FWD frames**

⑦ **Starts sending *loopback* frames**

Source: Jee-Sook Eun, ETRI

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Exiting Remote Loopback

Local DTE — **Remote DTE**

① Stops sending *loopback* frames
② Sends Loopback Control PDU w/ **Disable** Loopback
③ Receives Loopback Control OAMPDU w/ **Disable** Loopback
④ Within one second, configures Parser to FWD; configures Mux to FWD sends Information OAMPDU w/ updated state info;
⑤ Receives Information OAMPDU
⑥ Configures Multiplexer and Parser to FWD frames
⑦ Resumes sending data frames

Source: Jee-Sook Eun, ETRI

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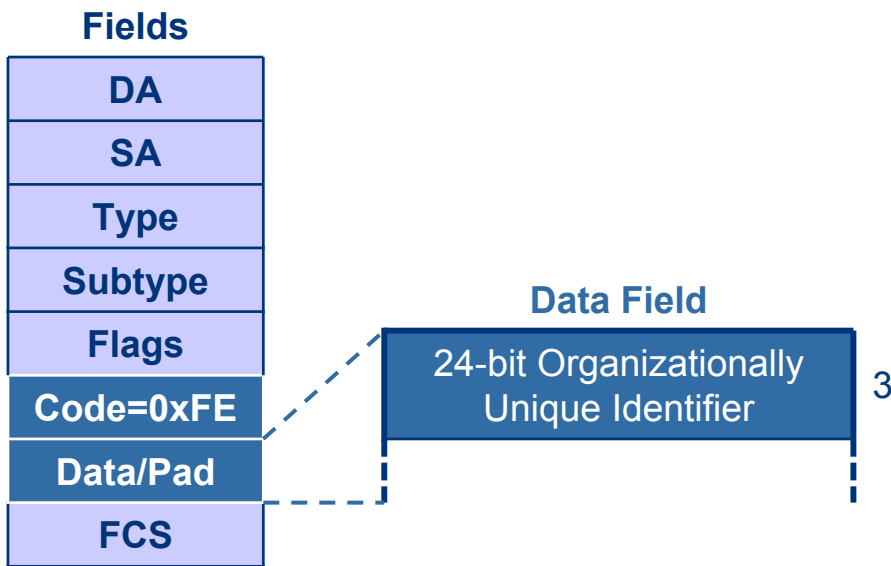# *OAMPDU: Organization Specific*

- **Code: 0xFE**
- **Distinguisher: IEEE 24-bit Organizationally Unique Identifier**
- **Data field: Organization Specific**

Fields

| DA |
| SA |
| Type |
| Subtype |
| Flags |
| Code=0xFE |
| Data/Pad |
| FCS |

Data Field

24-bit Organizationally Unique Identifier 3

OAM Discovery

- **Allows local DTE to detect OAM on remote DTE**

- **Once OAM support is detected, both ends of the link exchange state and configuration information**

  - **e.g. mode, PDU size, loopback support**

- **If both DTEs are satisfied with settings, OAM is enabled on link**

- **Loss of link and non-reception of PDUs for 5 seconds are causes of Discovery re-starting**

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OAM Active Mode

- **A DTE in Active mode:**
  - **Initiates the OAM Discovery process**
  - **Sends Information PDUs**
  - **May send Event Notification PDUs**
  - **May send Variable Request/Response PDUs**
  - **May send Loopback Control PDUs**
  - *Exceptions:*
    - **Does not respond to Variable Request PDUs from DTEs in Passive mode**
    - **Does not react to Loopback Control PDUs from DTEs in Passive mode**

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OAM Passive Mode

- **A DTE in Passive mode:**
  - **Waits for the remote device to initiate the Discovery process**
  - **Sends Information PDUs**
  - **May send Event Notification PDUs**
  - **May respond to Variable Request PDUs**
  - **May _react_ to received Loopback Control PDUs**
  - **Is not permitted to send:**
    - *Variable Request PDUs*
    - *Loopback Control PDUs*

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