P802.3av interim, Shanghai, PRC

08 – 09.06.2009

Overview of 10G-EPON

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Rev 1.2

P802.3av interim, Shanghai, PRC

08 – 09.06.2009

IEEE P802.3av

10G-EPON PMD specifications

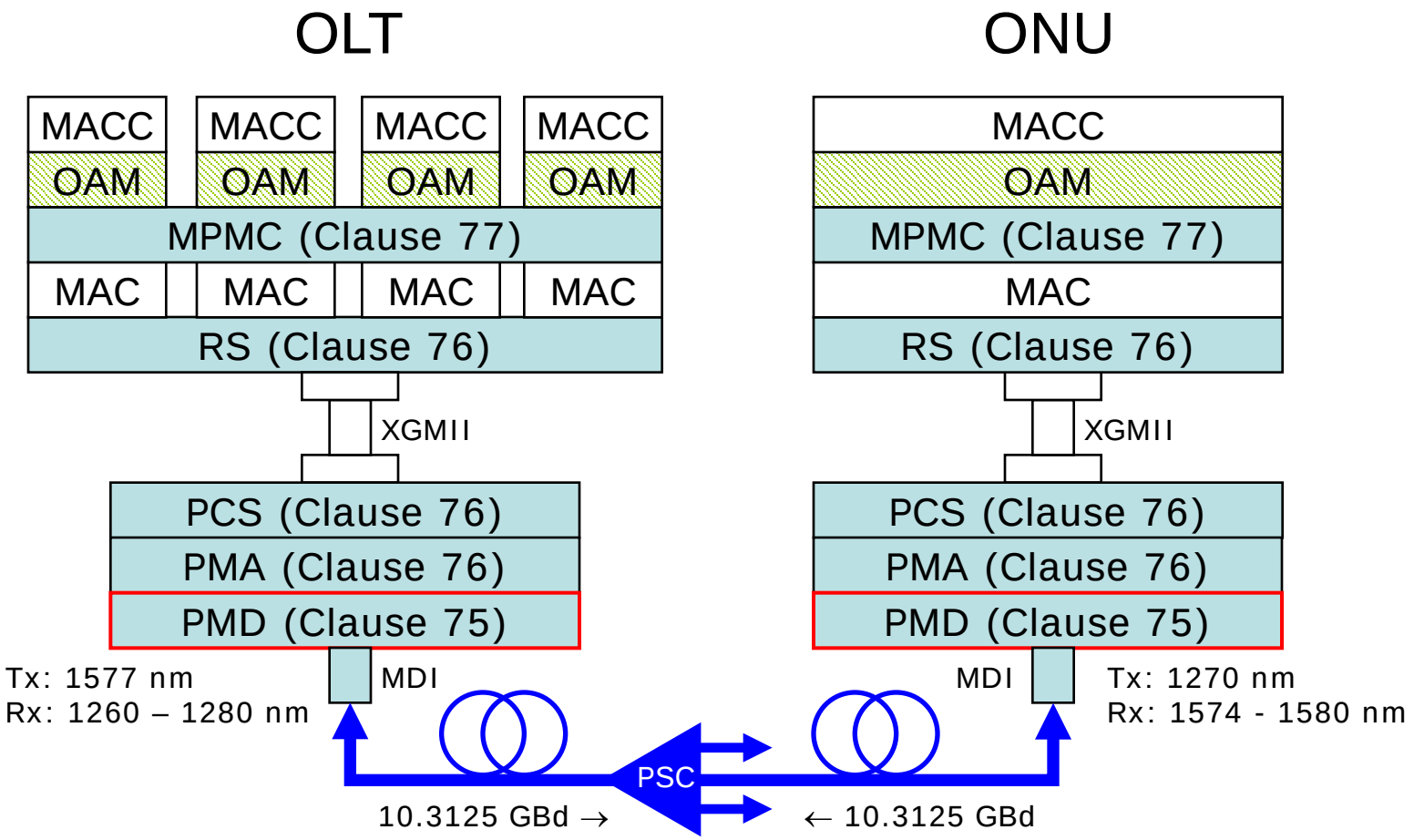
PMD definitions

Some definitions used in Clause 75 P802.3av:

- **Channel Insertion Loss (ChIL)** – total attenuation of optical channel (fibre, splitters, splices etc.), excluding penalties
- **Power budget** – total difference between minimum AVP launch power and Rx sensitivity = ChIL + penalties, including:

Power budget	Symmetric	Asymmetric	ChiL	ODN compatibility
PRX10		X	20	PR10
PRX20		X	24	PR20
PRX30		X	29	X
PR10	X		20	PR10
PR20	X		24	PR20
PR30	X		29	X

PR-type PMD in ISO/OSI stack



Notes:
- OAM is optional
- Green layers in scope of 802.3av

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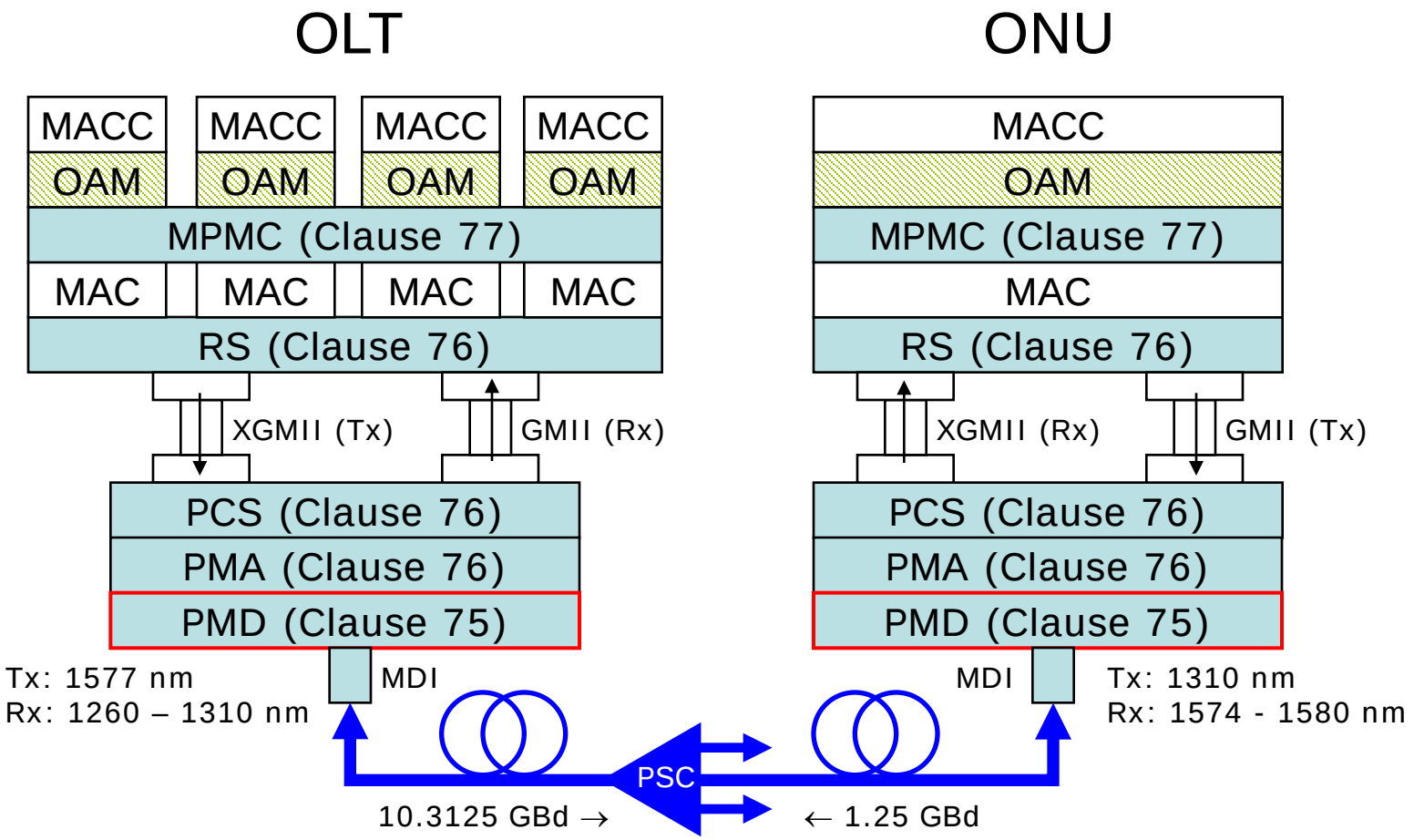
Layers:
MACC – MAC Client
OAM – Operation And Maintenance
MPMC – Multipoint MAC Control
MAC – Media Access Control

Layers:
RS – Reconciliation Sublayer
PCS – Physical Coding Sublayer
PMA – Physical Medium Attachment
PMD – Physical Medium Dependent
MDI – Medium Dependent Interface

PRX-type PMD in ISO/OSI stack



Notes:
- OAM is optional
- Green layers in scope of 802.3av
- XGMII and GMII interfaces are used in single direction only e.g. Tx path in XGMII in OLT

Layers:
MACC – MAC Client
OAM – Operation And Maintenance
MPMC – Multipoint MAC Control
MAC – Media Access Control

Layers:
RS – Reconciliation Sublayer
PCS – Physical Coding Sublayer
PMA – Physical Medium Attachment
PMD – Physical Medium Dependent
MDI – Medium Dependent Interface

Power budgets in Clause 75

Power budgets defined in P802.3av 10G-EPON (symmetric and asymmetric)

Description	Low power budget		Medium power budget		High power budget		Unit
	PRX10	PR10	PRX20	PR20	PRX30	PR30	
Downstream rate	10.3125						GBd
Upstream rate	1.25	10.3125	1.25	10.3125	1.25	10.3125	GBd
Downstream wavelength	1577						nm
Downstream wavelength band	5 [1575 – 1580]						nm
Upstream wavelength	1310	1270	1310	1270	1310	1270	nm
Upstream wavelength band	100	20	100	20	100	20	nm
Nominal maximum reach (min)	10		20		20		km
Nominal split	1:16		1:16		1:32		-
Maximum ChIL	20		24		29		dB
Minimum ChIL	5		10		15		dB

Note:

- Nominal maximum reach is informative – PMDs may support longer reach and remain standard compliant;
- PRX30 uses 1 Gb/s link parameters which were not included in P802.3ah specifications (29 dB ChIL) and based on ‘industrial’ standard

3 supported power budgets

- PR10 and PRX10
  - Channel insertion loss ≤ 20 dB
  - Specified for the same ODN as PX10
- PR20 and PRX20
  - Channel insertion loss ≤ 24 dB
  - Specified for the same ODN as PX20
- PR30 and PRX30
  - Channel insertion loss ≤ 29 dB
  - No 1G-EPON specs for backward compatibility

Nominal distance / split ratio for individual power budgets defined in P802.3av

	1:16	1:32
10 km	PR(X)10	PR(X)20
20 km	PR(X)20	PR(X)30

Reach and split factors are nominal i.e. devices exceeding these values are standard compliant !!!

Mapping: PMD ↔ power budget		10/1GBASE-PRX OLT PMD			10GBASE-PR OLT PMD		
		PRX-D1	PRX-D2	PRX-D3	PR-D1	PR-D2	PR-D3
ONU PMD	10/1GBASE-PRX-U1	PRX10	x	x	x	x	x
	10/1GBASE-PRX-U2	x	PRX20	x	x	x	x
	10/1GBASE-PRX-U3	x	x	PRX30	x	x	x
	10GBASE-PR-U1	x	x	x	PR10	PR20	x
	10GBASE-PR-U3	x	x	x	x	x	PR30

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PMDs count < power budget count, 10GBASE-PR-U1 used in two power budgets: 10GBASE-PR-D1 uses PIN Rx and 10GBASE-PR-D2 uses APD Rx

PMD name decoder ring …

Legacy (1G/1G) PMD

1000BASE-PX10-D

- P for PON
- X for 8b/10b coding
- Power budget [10,20]
- Location [D > OLT, U > ONU]

Asymmetric (10G/1G) PMD

10/1GBASE-PRX-U1

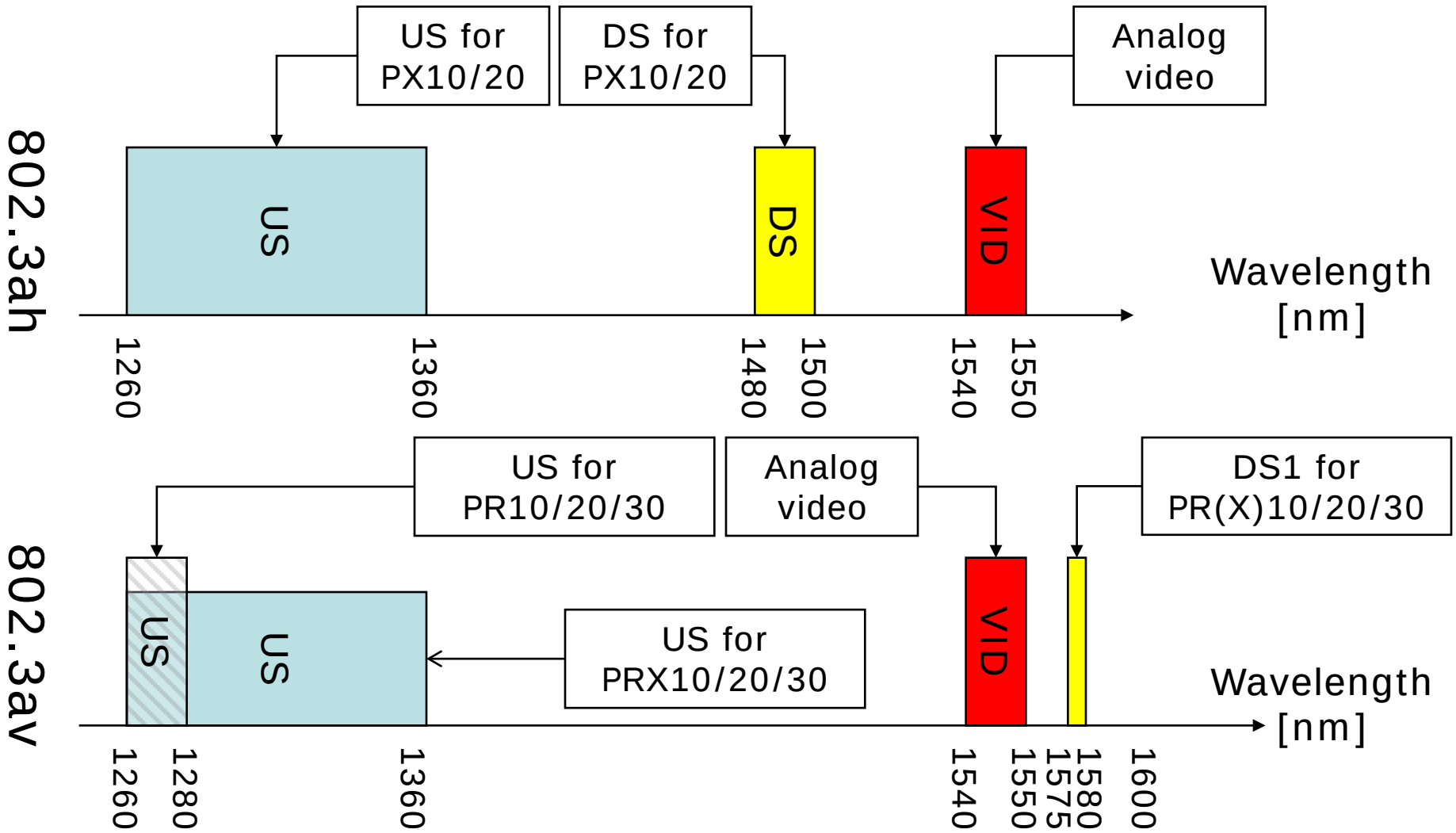
- P for PON
- R for 64b/66b coding
- X for 8b/10b coding
- Location [D > OLT, U > ONU]
- Configuration [1,2,3]

Symmetric (10G/10G) PMD

10GBASE-PR-D1

- P for PON
- R for 64b/66b coding
- Location [D > OLT, U > ONU]
- Configuration [1,2,3]

10G-EPON wavelength allocation plan



Band sizes are not-up-to-scale

Dual-rate & burst-mode

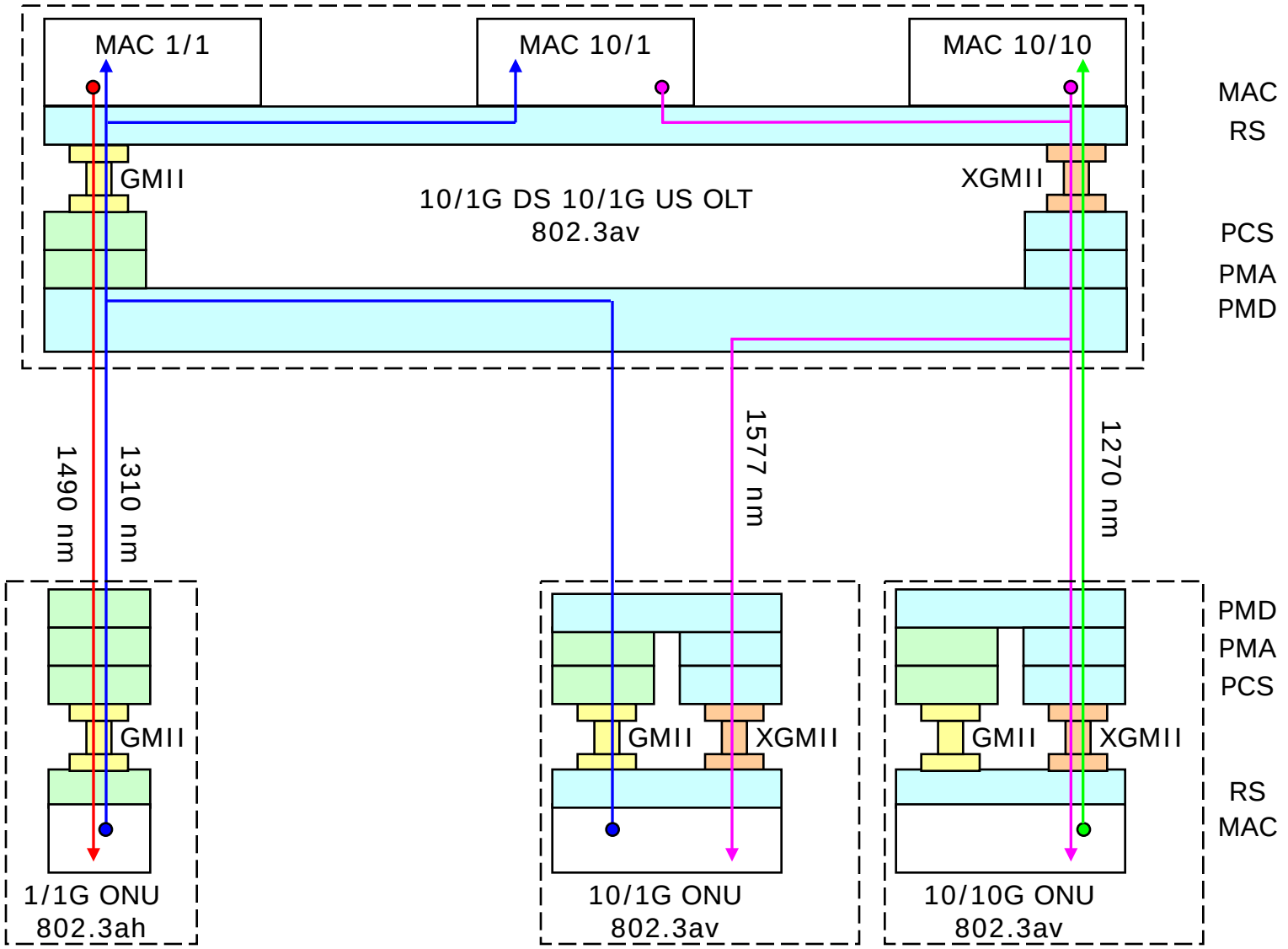
In order to support legacy 1G ONUs, 10G OLT must be able to:

- receive 1G / 10G transmissions and identify them on the fly;
- avoid using any signals from MAC Client layers – data rate detection must be performed at the PHY layer (no layer violations);
- assure minimum sensitivity penalty for 1G signals (none, at best);
- **dual-rate (1G/10G) burst-mode operation is required**!
- 1310 nm near zero dispersion transmission window can be reused

Serial and/or parallel configurations APD based configuration can be used for upstream 10G/1G coexistence

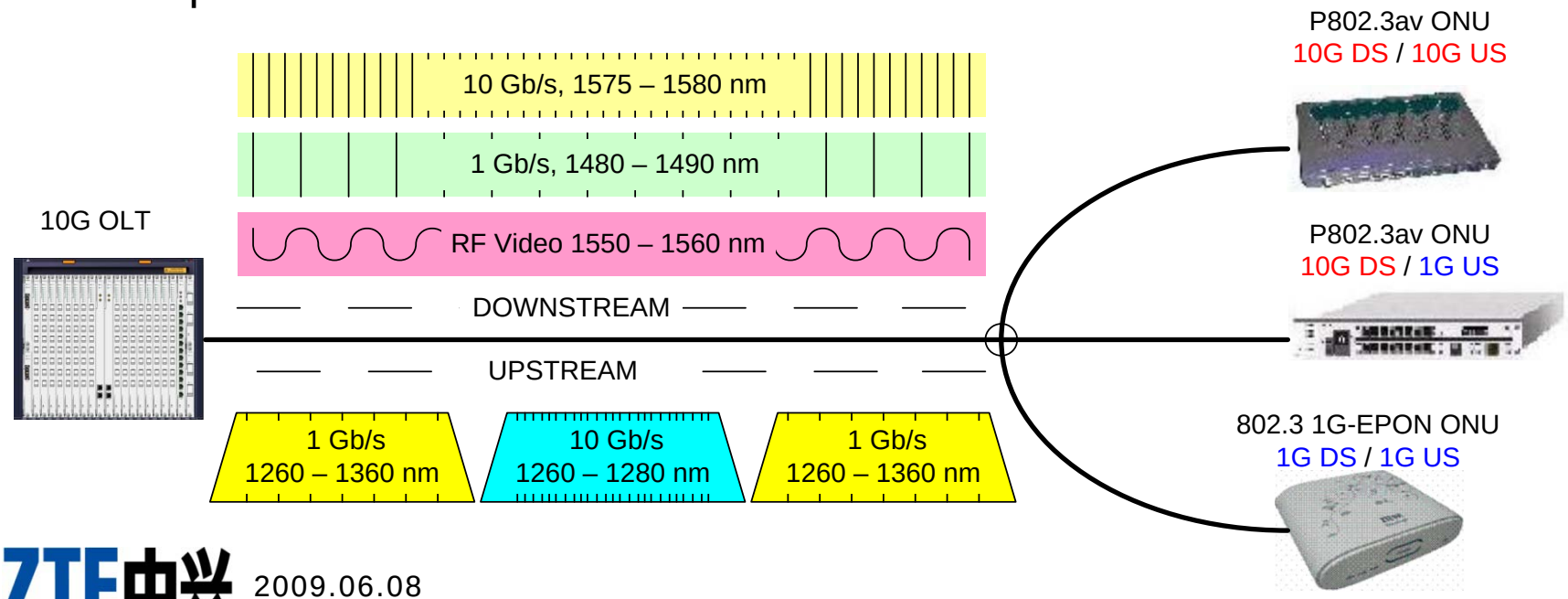
- the parallel configuration with 10G optimized APD is simpler compared to serial configuration
- half-serial configuration provides about 1 dB more sensitivity in 1G mode (see e.g. 3av_0703_effenberger_4.pdf)

Dual-rate 10G-EPON stack



1G-EPON & 10G-EPON coexistence

- Downstream:
  - WDM overlay for 1G and 10G signals
- Upstream
  - TDMA overlay for 1G / 10G signals (dual rate, burst mode)
  - Already considered as technically feasible (prototypes available)
  - Target configurations: 10/1G in downstream & 10/1G in upstream



Wrap-up for 10G-EPON PMD

- Clause 75 PMDs support symmetric and asymmetric operation:
  - WDM separation for downstream
  - dual-rate, burst-mode transmission for upstream
- 3 power budget classes defined: 20, 24 and 29 dB ChIL
  - RS (255,223) FEC is always enabled
  - some PMDs may have to use post/preamplifier (implementation dependent and not standard mandated)
- Backward compatible with existing P802.3ah equipment
  - evolutionary system upgrade supported
  - P802.3ah ONUs need not be replaced
- Challenging power budgets result in changes also in the MPCP sublayer (Clause 77)
  - FEC is always enabled
  - Stream-based FEC was chosen instead of frame-based FEC

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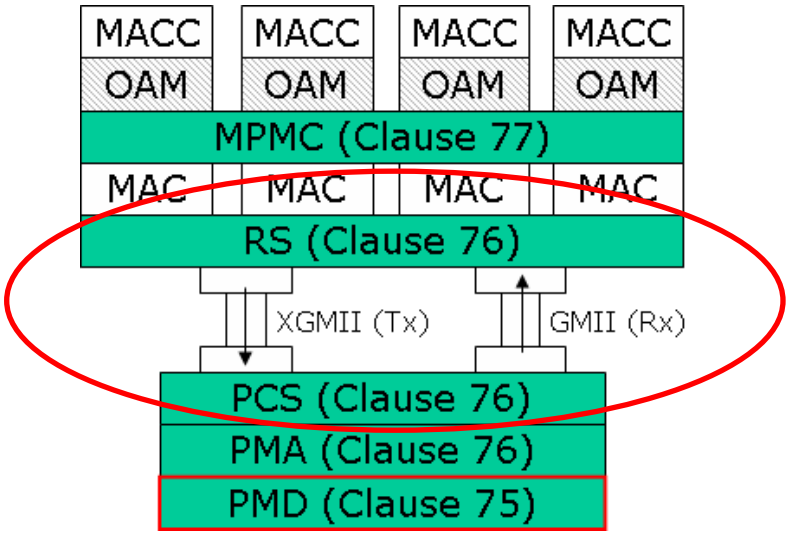
10G-EPON PCS / RS specifications

10G-EPON PCS/RS – features [1]

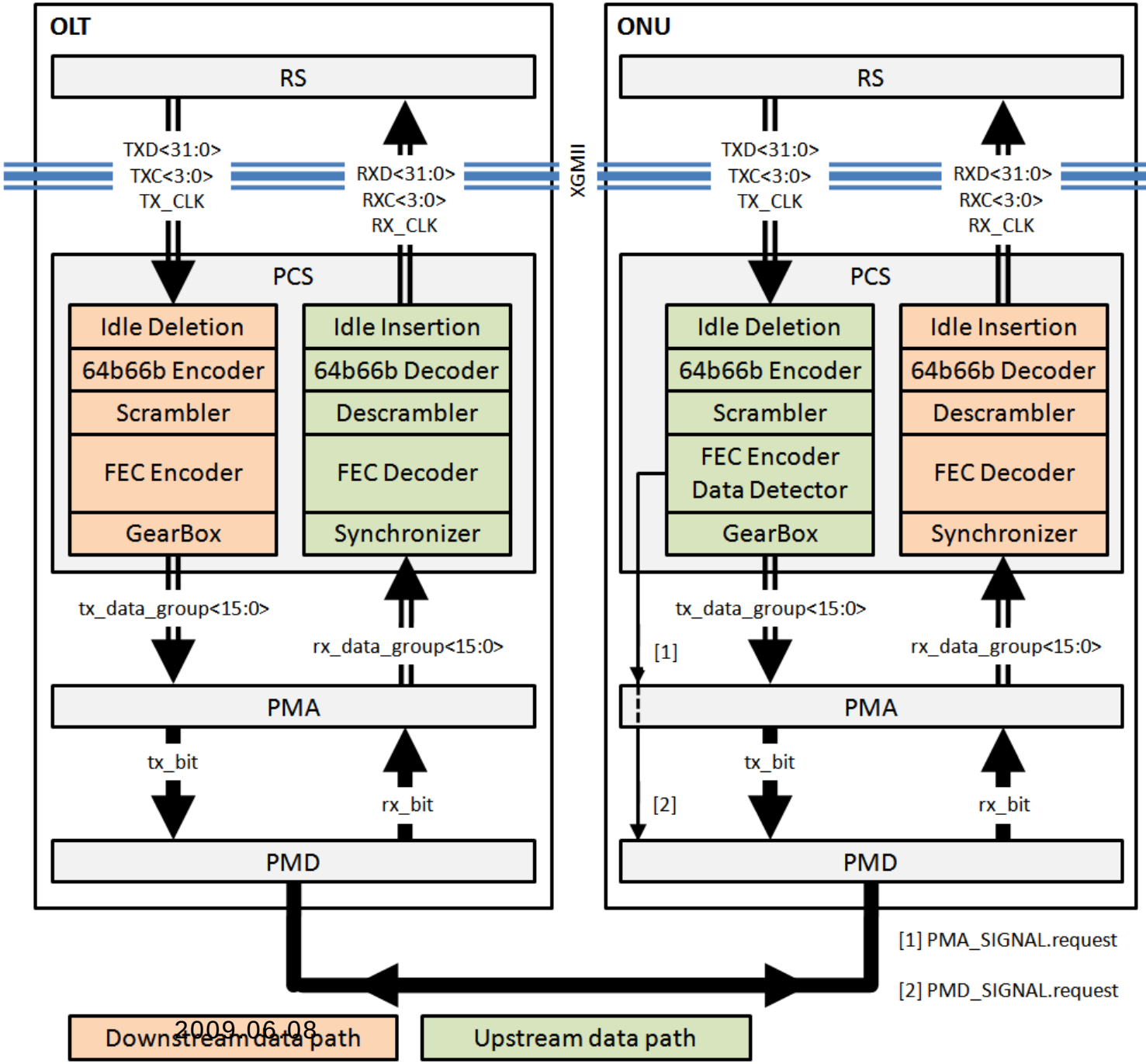
- 10G-EPON PCS and RS significantly extend 10GBASE-X PCS/RS
  - Mandatory, stream-based FEC mechanism (NEW)
  - 64b/66b line code (REUSE)
  - Burst-mode operation of the PMA (NEW):
    - Data detector for the ONU
    - Start_of_Burst and End_of_Burst delimiters
  - Extensions to RS:
    - to support P2P emulation over P2MP plant (NEW, REUSE part of 1G-EPON RS specs)
    - to support XGMII and GMII in asymmetric configuration (NEW)



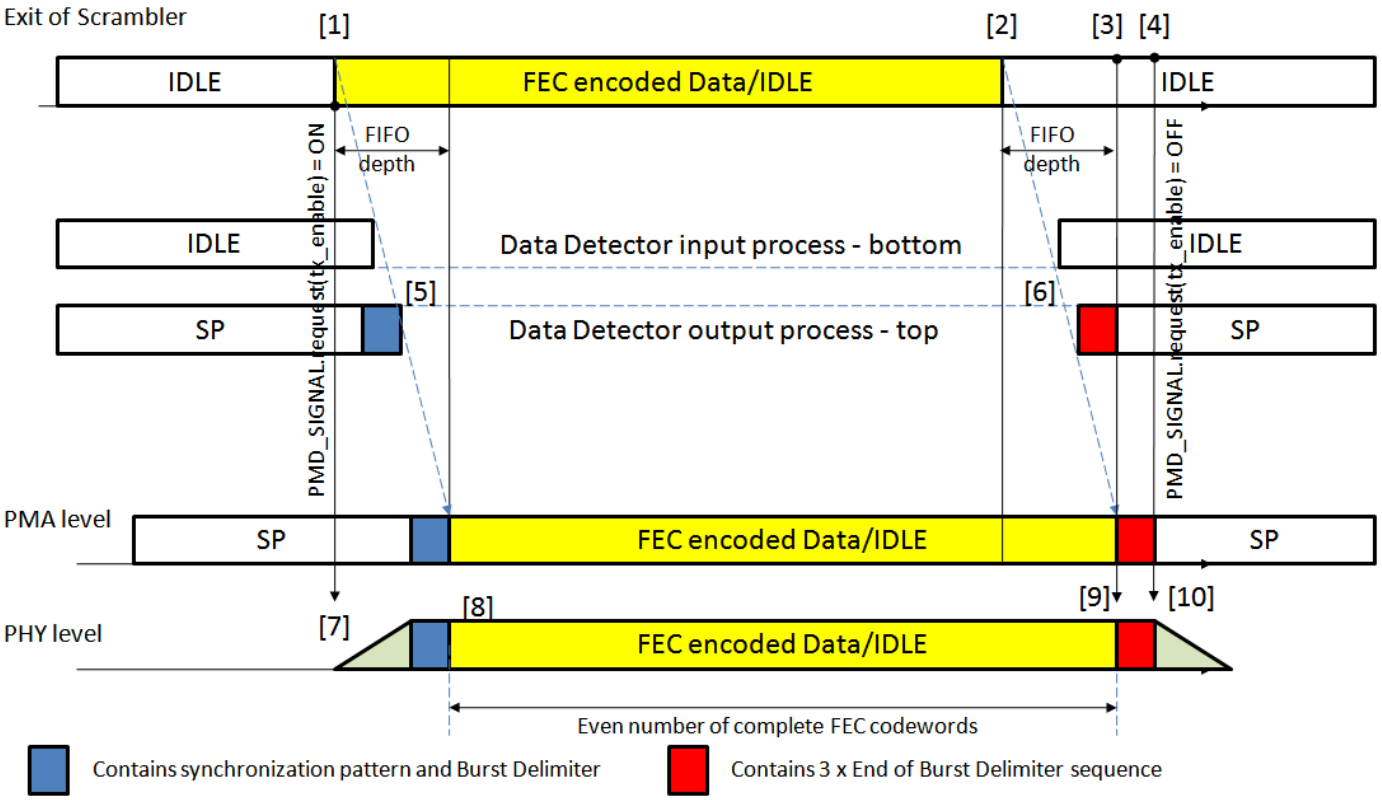
10G-EPON PCS/RS – features [2]

- Strong FEC is specified to achieve the required power budgets
  - RS(255, 223) (higher gain than 802.3ah FEC)
  - Stream-based versus Frame-based (802.3ah FEC)
  - Overhead is constant and equal to 12.9%
- Overhead is accommodated while maintaining the constant PHY data rate (10.3125 Gbit/s):
  - No internal interface is super-rated,
  - XGMII rate is preserved (312.5M transfers/s)
  - PHY line rate is preserved (10.3125 Gbit/s)
  - Data throughput is reduced:
    - inter-frame gaps are increased through extended operation of MPCP, which accounts for FEC parity insertion
  - Extra IDLEs are deleted in PCS and used to insert FEC partiy code in the FEC encoder (see two next slides)

10G-EPON data path

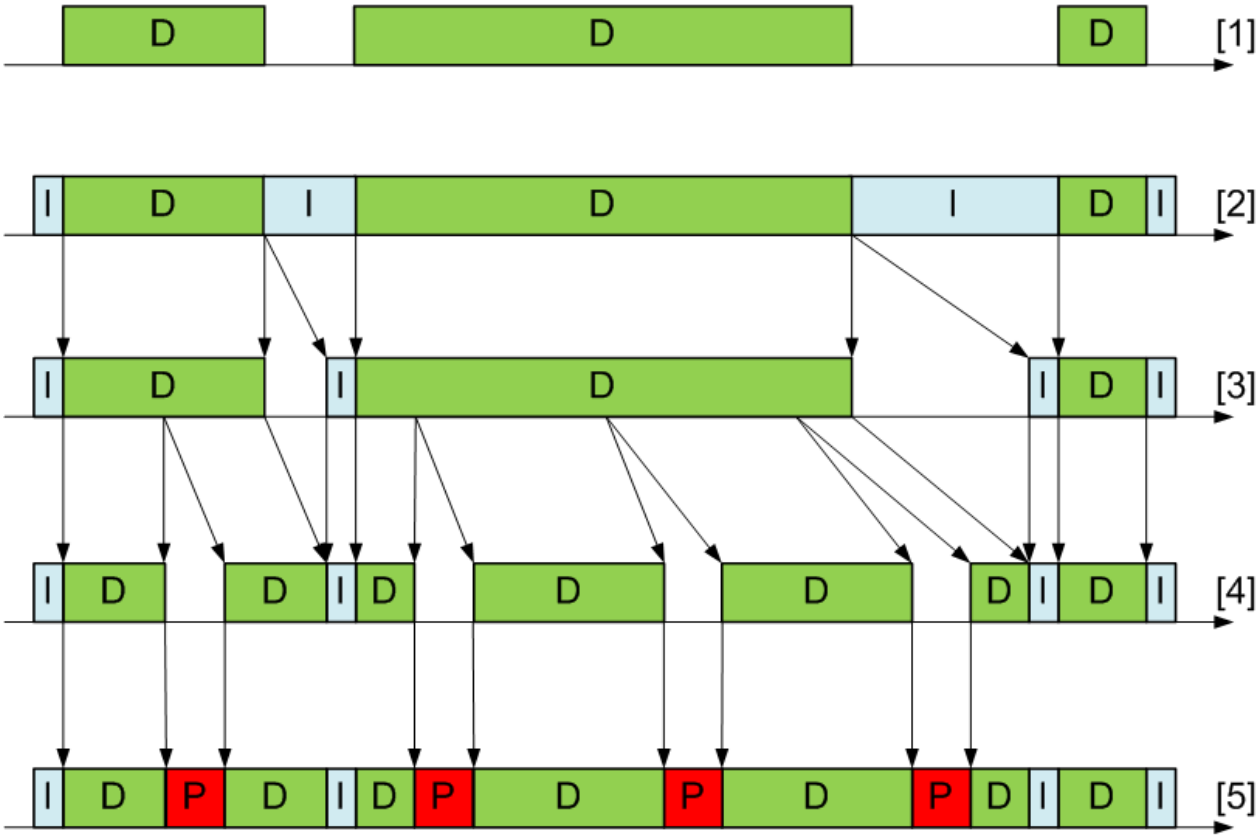


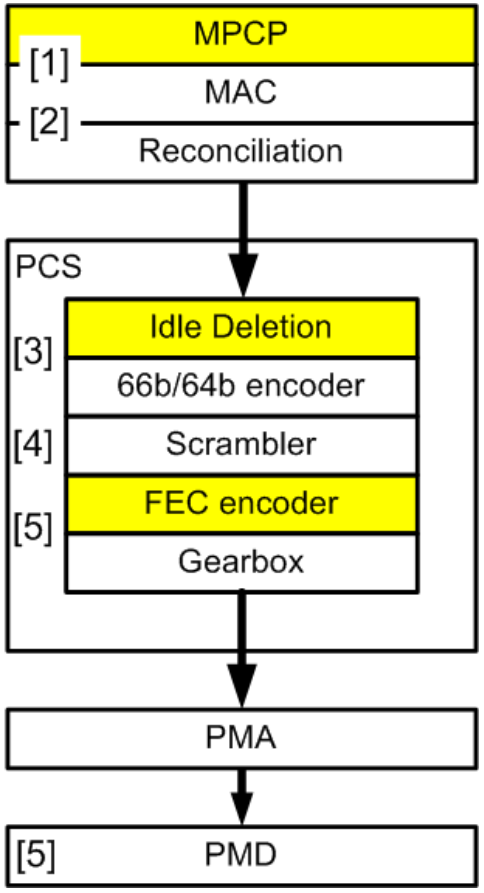
10G-EPON Data Detector



- Extended relative to 1G-EPON data detector
- SP (Synchronization Pattern) replaces 0x55 sequence of 1G-EPON
- Delimiters are added: Start_of_Burst and End_of_Burst to facilitate burst delineation on OLT Rx side

Transmit path in 10G-EPON





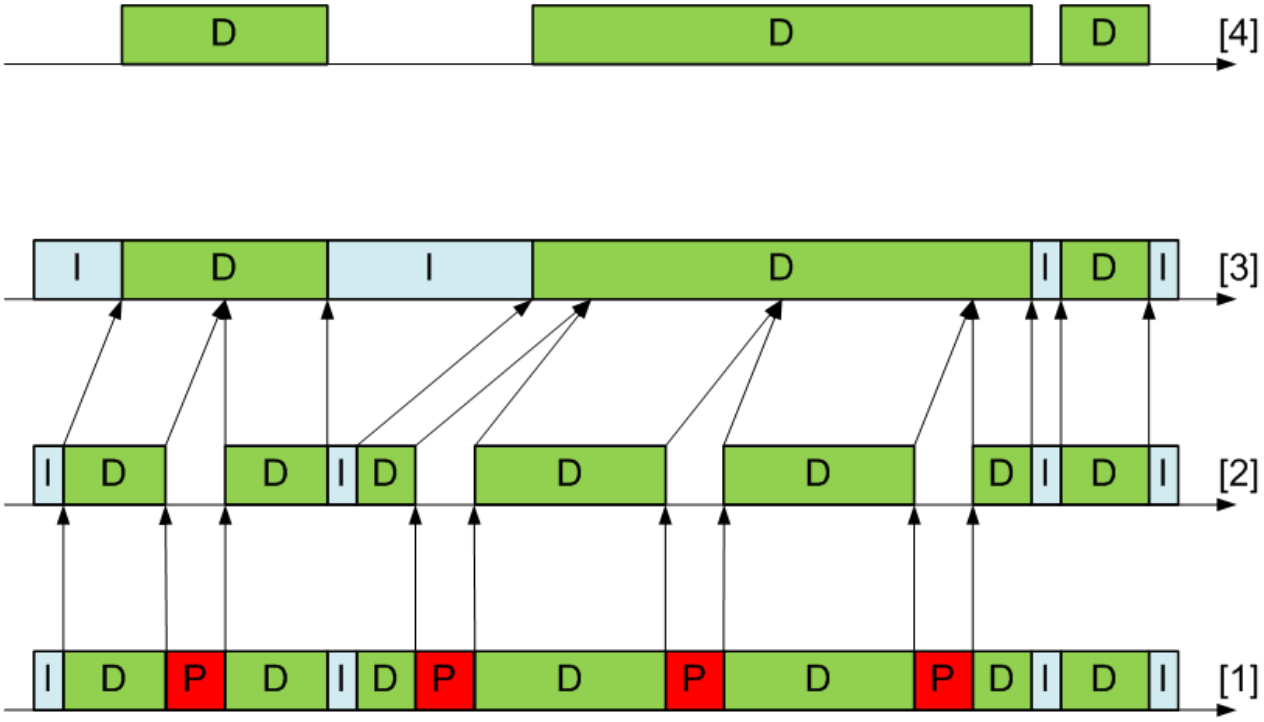
[1] data with gaps at output of MPCP

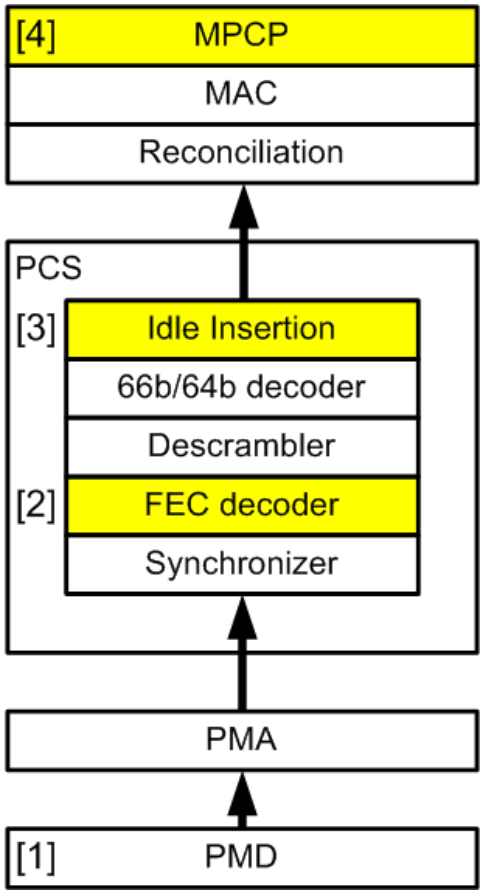
[2] MAC inserts IDLE characters into gaps

[3] IDLE deletion removes extra idles, making space for FEC parity

[4,5] Inside of Data Detector, frames are separated into blocks and parity is inserted; such stream is then passed to PMA and PMD

Receive path in 10G-EPON





[2] FEC decoder removes parity data blocks from incoming data stream, leaving gaps between frame fragments

[3] IDLE Insertion inserts the correct number of IDLE characters (always in front of the frame) to close the gaps generated by FEC decoder and removal of parity

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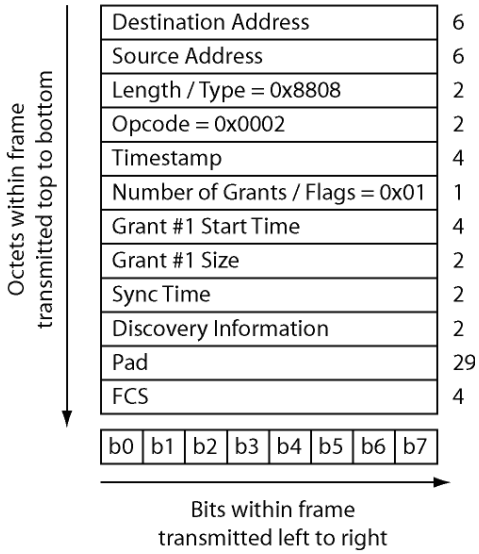
10G-EPON MPCP specifications

MPCP – general structure

- MPCP for 10G-EPON included in Clause 77
- Clause 77 versus Clause 64 (1G EPON MPCP)
  - Extensions to several MPCPDUs (see next slides)
  - Extensions to Discovery Process (see next slides)
  - Changes to the MAC service interfaces (see next slides)
    - Caused by P802.3as project
    - Impacts the MPCP clause definitions
    - Non-blocking character of the new MAC:MA_DATA.indication() primitive a source of serious concern for PON clauses - need to compensate for frame transmission time in state diagrams
  - Minor changes due to stream based FEC
    - overhead calculation at MPCP sublayer (see next slides)
    - Initial Carrier Sense mechanism used in RS was abandoned
    - FEC parity effect is now accounted for in MPCP when transmitting subsequent frames

GATE MPCPDU

Bit	Flag field	Values / Meaning
0	OLT is 1G upstream capable	0 – OLT does not support 1 Gb/s reception 1 – OLT supports 1 Gb/s reception
1	OLT is 10G upstream capable	0 – OLT does not support 10 Gb/s reception 1 – OLT supports 10 Gb/s reception
2-3	Reserved	Ignored on reception
4	OLT is opening 1G discovery window	0 – OLT cannot receive 1 Gb/s data in this window 1 – OLT can receive 1 Gb/s data in this window
5	OLT is opening 10G discovery window	0 – OLT cannot receive 10 Gb/s data in this window 1 – OLT can receive 10 Gb/s data in this window
6-15	Reserved	Ignored on reception



- 1 new flag field added to **Discovery GATE (only)**:
  - 2 bytes large, contains several flags and reserved fields
- Reason for changes:
  - MPCP must be aware of ONU US and OLT DS data rates – no way to get this information from MAC;
  - Discovery Window for 1G and 10G can be opened at different times – need to notify ONUs which window is opened at given time
- Reserved bits may be used for future extensions to higher data rates

REGISTER_REQ MPCPDU

Destination Address	6
Source Address	6
Length / Type = 0x8808	2
Opcode = 0x0004	2
Timestamp	4
Flags	1
Pending grants	1
Discovery Information	2
Laser On Time	1
Laser Off Time	1
Pad	34
FCS	4

Bit	Flag field	Values / Meaning
0	ONU is 1G upstream capable	0 – ONU transmitter is not capable of 1 Gb/s 1 – ONU transmitter is capable of 1 Gb/s
1	ONU is 10G upstream capable	0 – ONU transmitter is not capable of 10 Gb/s 1 – ONU transmitter is capable of 10 Gb/s
2-3	Reserved	Ignored on reception
4	1G registration attempt	0 – 1 G registration is not attempted 1 – 1 G registration is attempted
5	10G registration attempt	0 – 10 G registration is not attempted 1 – 10 G registration is attempted
6-15	Reserved	Ignored on reception

- 3 new fields added to **Register_Req**:
  - Discovery Information (2 bytes, with flags and reserved fields): ONU signals the OLT which Discovery Window it is using and what technical capabilities its Tx has (1G, 10G or both); bits reserved for future use will support new features / functions;
  - Laser On Time (1 byte), Laser Off Time (1 byte): identify the minimum laser on/off times for the ONU; OLT can chose to use them or force the ONU to increase their values (for calculations only);

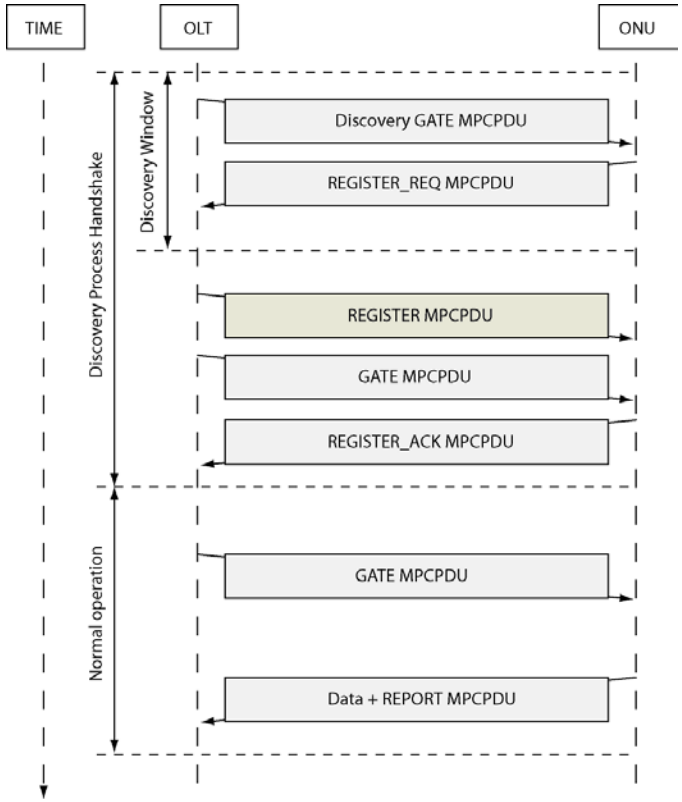
REGISTER MPCPDU & others

- 2 new fields added to **Register**:
  - Echoed Laser On Time (1 byte), Echoed Laser Off Time (1 byte)
    - identify the minimum laser on/off times for the ONU as transmitted by the OLT;
    - OLT can chose to use the values provided by the ONU in the Register_Req or force the ONU to increase their values;
    - ONU adopts the provided values for calculations of transmission overhead – actual laser on/off times are limited by H/W;
- No other changes in the remaining MPCPDUs were made at this time
- Threshold reporting for REPORT MPCPDU is still undefined in P802.3av

Destination Address	6
Source Address	6
Length / Type = 0x8808	2
Opcode = 0x0005	2
Timestamp	4
Assigned port	2
Flags	1
Sync Time	2
Echoed Pending Grants	1
Echoed Laser On Time	1
Echoed Laser Off Time	1
Pad	32
FCS	4

Extensions to Discovery Process

- Changes in Discovery Process result from changes in MPCPDUs
- The same MPCPDUs are exchanged during the process: GATE, REGISTER_REQ, REGISTER, REGISTER_ACK
- MPCPDUs carry more information:
  - GATE > information on OLT data rate and type of Discovery Window
  - REGISTER_REQ > information on ONU data rate and which Discovery Window is used to register at the OLT + laser on/off time for ONU Tx
  - REGISTER > echo of ONU Tx laser on/off times
- Additional processing for new data in MPCPDUs was included in state diagrams



Dual-rate Discovery Process [1]

- OLT must schedule both 1G & 10G Discovery Windows;
- 1G & 10G windows may be opened in a non-overlapping (one GATE) or overlapping (two GATEs). Table 77-10 in P802.3av describes recommended options.
- Potentially US dual rate ONUs can be also deployed (can switch between 1G and 10G upstream);

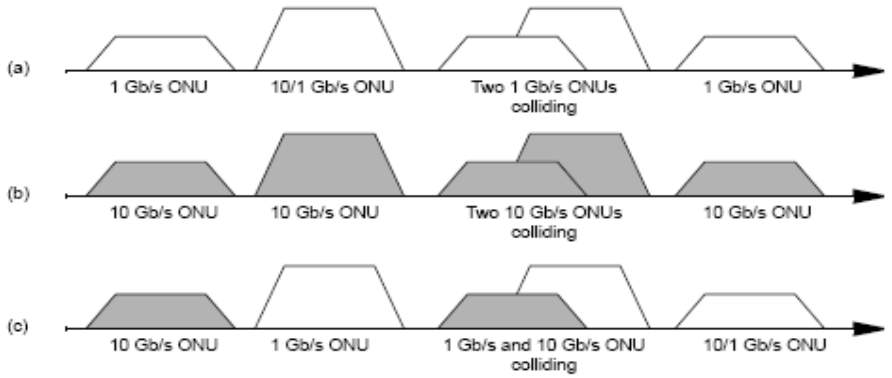


Figure 77–36—Combinations of REGISTER_REQ MPCPDUs during discovery window for 10G–EPON and EPON coexisting on the same PON.

- Behaviour of such dual-rate ONUs must be predictable;
- OLT must know which Discovery Window such dual-rate ONUs respond to (1G or 10G) - recommendations are included in Table 77-11 in P802.3av.

Dual-rate Discovery Process [2]

Table 77–10—ONU action during discovery window

OLT Discovery Information				ONU Tx capability		ONU Action
Upstream Capable		Discovery Window				
1G	10G	1G	10G	1G	10G	
1	0	1	0	1	X	Attempt 1G registration
1	X	1	X	1	0	Attempt 1G registration
X	1	X	1	X	1	Attempt 10G registration
1	1	0	1	1	0	Wait for 1G discovery window
1	1	1	0	X	1	Wait for 10G discovery window

Recommendations for behaviour of various types of ONUs during dual-rate Discovery Process

Table 77–9—Discovery GATE MPCPDUs for all ONU types

ONU types targeted by discovery GATE MPCPDU	LLID of discovery GATE(s)	Discovery Information			
		Upstream Capable		Discovery Window	
		1G	10G	1G	10G
1G–EPON	0x7FFF	No Discovery Information field present			
10/1G–EPON	0x7FFE	1	0	1	0
1G–EPON and 10/1G–EPON	0x7FFF[a]	No Discovery Information field present			
	0x7FFE[a]	1	0	1	0
10/10G–EPON	0x7FFE	0	1	0	1
10/1G–EPON and 10/10G–EPON	0x7FFE	1	1	1	1
1G–EPON, 10/1G–EPON, and 10/10G–EPON	0x7FFF[a]	No Discovery Information field present			
	0x7FFE[a]	1	1	1	1

Various settings for bits in Discovery Information flag field in Discovery GATE MPCPDU and LLID to be used in this GATE MPCPDU

Stream based FEC

- Stream based FEC in 10G-EPON introduces constant transmission overhead, independent from the frame size;
- After each frame, FEC parity must be added:
  - IDLE characters are inserted by MAC when no data is received from MAC Client,
  - extra IDLEs are removed at PCS and replaced with FEC parity
- Extra space between frames is added in MAC Control sublayer :
  - In effect of operation of Control Multiplexer
  - After transmission of each frame, artificial gap is created with size necessary to guarantee enough space for FEC parity
  - FEC_Overhead and CheckGrantSize functions account properly for FEC parity overhead
- Previously, FEC parity was accounted via CS in RS sublayer:
  - Problematic approach and hard to control precisely
  - Was abandonded after D2.0