Annex 91A Coexistence of 1 Gb/s (symmetric), 10 Gb/s (symmetric) and 10/1 Gb/s (asymmetric) Ethernet Passive Optical Networks (EPONs)

91A.1 Overview

This clause provides information on building Ethernet Passive Optical Networks consisting of combinations of both 1 Gb/s and 10 Gb/s equipment. The 10 Gb/s P2MP network operates at either symmetric or asymmetric line rates. In the symmetric mode, both transmit and receive data paths operate at 10 Gb/s. In the asymmetric mode, the downstream rate is 10 Gb/s, while the upstream rate is 1Gb/s. Thus, at the OLT, transmit and receive data paths operate at 10 Gb/s and 1 Gb/s, respectively. At the ONU, the situation is mirrored, with the transmit and receive data paths operating at 1 Gb/s and 10 Gb/s, respectively. The OLT may also support simultaneous operation (or coexistence) of various types of ONUs: legacy 1Gb/s ONUs (as described in Clauses 64 and 65), symmetric 10Gb/s ONUs and asymmetric ONUs (as described in Clauses 92 and 93). The remainder of this clause discusses various system considerations that are important in the deployment of a symmetric or asymmetric 10 Gb/s EPON that coexists with a legacy 1 Gb/s EPON.

91A.2 Multi-speed Media Independent Interface

In legacy EPON architectures, the GMII is the interface used to bridge between the MAC and the PHY. For symmetric 10 Gb/s EPON architectures, the XGMII is the interface used to bridge between the MAC and the PHY. When using an asymmetric EPON architecture, a combination of both GMII and XGMII are needed in order to support transmission and reception of different speeds. Through the parallel use of the GMII and XGMII, the following modes are supported:

- Support symmetric 10 Gb/s operation for transmit and receive data paths, providing all of the functionality of the XGMII defined in Clause 46.
- Support symmetric 1 Gb/s operation for transmit and receive data paths, providing all of the functionality of the GMII defined in Clause 35.
- Support asymmetric operation for transmit and receive data paths at the OLT, providing transmit path functionality of the XGMII defined in Clause 46 and receive path functionality of the GMII defined in Clause 35.
- Support asymmetric operation for transmit and receive data paths at the ONU, providing transmit path functionality of the GMII defined in Clause 35 and receive path functionality of the XGMII defined in Clause 46.
- Support coexistence of various ONU types by utilizing different data paths within the OLT.

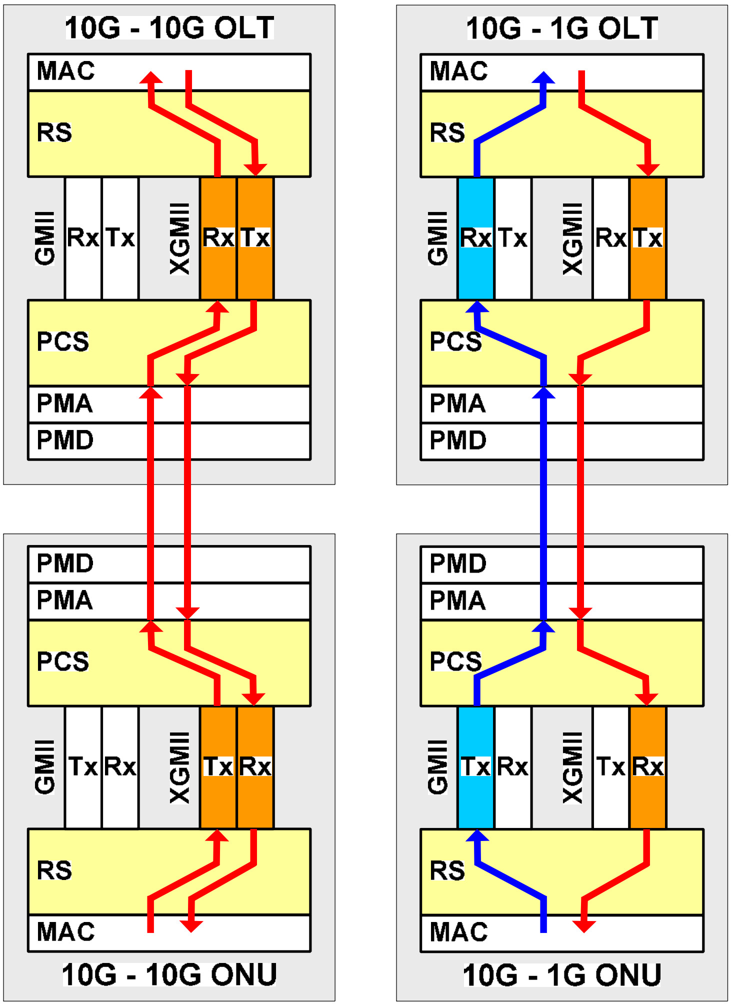
91A.2.1 Symmetric mode

Symmetric mode supports transmit and receive data paths operating at 10 Gb/s. When operating in symmetric mode, the XGMII transmit and receive data paths are used for both transmission and reception. Figure 91A – 1 (a) depicts the operation of the symmetric mode.

91A.2.2 Asymmetric mode

Asymmetric mode supports transmit and receive data paths operating at different line rates. When operating in asymmetric speed mode, a combination of XGMII and GMII data paths is used for transmission and reception.

At the OLT, the transmit path uses XGMII signals TXD<31:0>, TXC<3:0> and TX_CLK, while the receive path uses GMII signals RXD<7:0>, RX_ER, RX_CLK, and RX_DV.
At the ONU, the transmit path uses GMII signals TXD<7:0>, TX_EN, TX_ER, and GTX_CLK, while the receive path uses GMII signals RXD<31:0>, RXC<3:0> and RX_CLK.
Figure 91A – 1 (b) depicts the operation of the asymmetric mode.



(a)Symmetric rate operation (b) Asymmetric rate operation

Figure 91A – 1 Symmetric and asymmetric operation of OLT and ONU

91A.2.3 Dual rate mode

To support coexistence of symmetric, asymmetric, and legacy 1Gb/s ONUs on the same outside plant, the OLT may be configured to use dual-rate mode. Dual-rate mode supports transmission and reception at both 10 Gb/s and 1 Gb/s. When operating in dual-rate mode, a combination of XGMII and GMII data paths are used for transmission and reception. Figure 91A – 2 depicts the reconciliation sublayer operating in dual-rate mode.

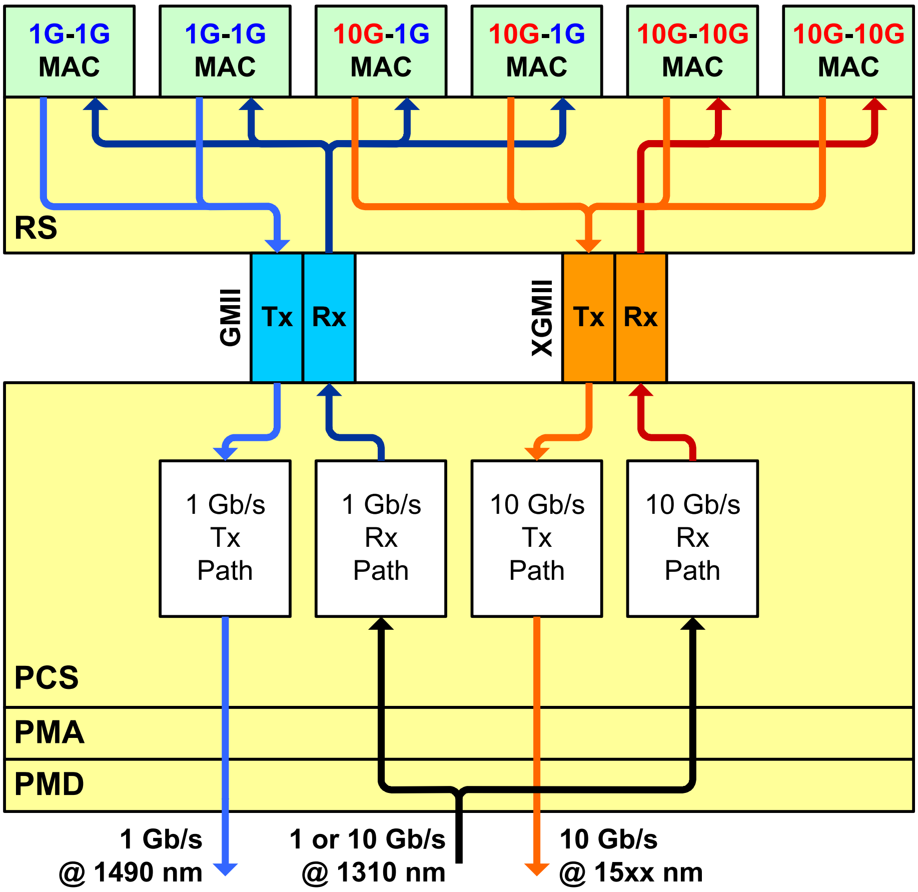


Figure 91A – 2 Reconciliation sublayer for dual rate mode at OLT

91A.2.4 Binding of XGMII and GMII primitives

Subclause 92.1.1.1 describes the mapping of XGMII/GMII signals to the PLS.DATA.request and PLS_DATA.indication primitives. Additional details are provided below. Table 91A-1 shows the mapping of PLS_DATA.request primitives to transmit interface signals for different types of OLTs and ONUs. Table 91A-2 shows the mapping of PLS_DATA.indication primitives to receive interface signals for different types of OLTs and ONUs.

Table 91A-1 Binding of PLS_DATA.request primitive

MAC Location	MAC operating speed	Transmit Interface	Signals
OLT	Legacy (Tx: 1 Gb/s)	GMII	TXD<7:0>, TX_EN, TX_ER, GTX_CLK
OLT	Symmetric (Tx: 10 Gb/s)	XGMII	TXD<31:0>, TXC<3:0>, TX_CLK
OLT	Asymmetric (Tx: 10 Gb/s)	XGMII	TXD<31:0>, TXC<3:0>, TX_CLK
ONU	Legacy (Tx: 1 Gb/s)	GMII	TXD<7:0>, TX_EN, TX_ER, GTX_CLK
ONU	Symmetric (Tx: 10 Gb/s)	XGMII	TXD<31:0>, TXC<3:0>, TX_CLK
ONU	Asymmetric (Tx: 1 Gb/s)	GMII	TXD<7:0>, TX_EN, TX_ER, GTX_CLK

Table 91A-2 Binding of PLS_DATA.indication primitive

MAC Location	MAC operating speed	Receive Interface	Signals
OLT	Legacy (Rx: 1 Gb/s)	GMII	RXD<7:0>, RX_ER, RX_DV, RX_CLK
OLT	Symmetric (Rx: 10 Gb/s)	XGMII	RXD<31:0>, RXC<3:0>, RX_CLK
OLT	Asymmetric (Rx: 10 Gb/s)	XGMII	RXD<31:0>, RXC<3:0>, RX_CLK
ONU	Legacy (Rx: 1 Gb/s)	GMII	RXD<7:0>, RX_ER, RX_DV, RX_CLK
ONU	Symmetric (Rx: 10 Gb/s)	XGMII	RXD<31:0>, RXC<3:0>, RX_CLK
ONU	Asymmetric (Rx: 1 Gb/s)	GMII	RXD<7:0>, RX_ER, RX_DV, RX_CLK

91A.3 Wavelength allocation

91A.3.1 Downstream wavelength allocation

The 1G downstream transmission uses the 1480nm to 1500nm wavelength band, as specified in clause 60. The 10G downstream transmission uses the 1574nm to 1600nm wavelength band, as specified in clause 92. (Note: the different loss budget classes use different sub-sets of this band.)

Therefore, the two downstream channels are distinguished based on their wavelength.

An OLT that wishes to support both downstream channels can multiplex the output of the two transmitters using a WDM device.

An ONU will select the relevant downstream channel using an optical filter.

91A.3.2 Upstream wavelength allocation

The 1G upstream transmission uses the 1270nm to 1360nm wavelength band, as specified in clause 60. The 10G upstream transmission uses the 1260nm to 1280nm wavelength band, as specified in clause 92.

As can be noted, the two wavelength bands overlap, and wavelength cannot be used to separate the two channels.

An OLT that wishes to support both upstream channels must use TDMA techniques to avoid the conflict between transmissions.

91A.4 Discovery

Enhancements to the EPON discovery process have been made in order to facilitate coexistence of 10 Gb/s EPON with legacy 1 Gb/s EPON.

91A.4.1 OLT speed specific discovery

The discovery GATE MPCPDU is defined in XX for 1 Gb/s operation and in XX for 10 Gb/s operation. An additional field, discovery information, has been added to the 10 Gb/s discovery GATE messages. The purpose of this field is to relay speed specific information regarding the discovery window to the different ONUs that may exist on the EPON. The OLT has the ability to transmit common discovery GATE messages on both the 1 Gb/s transmit path and 10 Gb/s transmit path, or it can send completely separate and independent GATE messages on these different paths. For each discovery window, the OLT is capable of opening windows for individual speeds or multiple speeds.

These different combinations allow the OLT to open a number of discovery windows for all of the different ONU types. Table 91A-3 shows the different types of windows that are possible, along with the necessary LLID and discovery information that also needs to be present in the discovery GATE messages. For some combinations, it is necessary for the OLT to open overlapping discovery windows by sending discovery GATE messages on both the 1 Gb/s and 10 Gb/s downstream broadcast channels.

Table 91A-3 Discovery GATE content for all ONU types

ONU type	LLID of discovery GATE(s)	Discovery Information			
		Upstream Capable		Discovery window	
		1G	10G	1G	10G
1 Gb/s	0x7FF	1	0	1	0
10/1 Gb/s	0x7FE	1	0	1	0
1 Gb/s and 10/1 Gb/s	0x7FF and 0x7FE	1	0	1	0
10 Gb/s	0x7FE	0	1	0	1
10/1 Gb/s and 10 Gb/s	0x7FE	1	1	1	1
1 Gb/s, 10/1 Gb/s, and 10 Gb/s	0x7FF and 0x7FE	1	1	1	1

Figure 91A – 3 shows the three primary combinations of discovery windows and the different types of Register Request messages that may be received during the window. Figure 91A – 3 (a) shows reception of messages from 1 Gb/s and 10/1 Gb/s ONUs. Figure 91A – 3 (b) shows reception of messages from 10 Gb/s ONUs. Figure 91A – 3 (c) shows reception of messages from all types of ONUs.

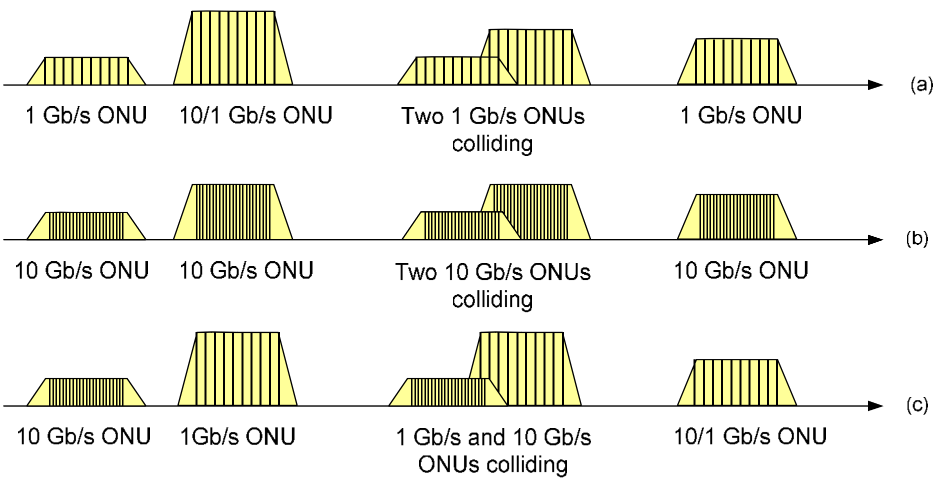


Figure 91A – 3 Register Request combinations available with coexistence

91A.4.2 ONU speed specific registration

A legacy 1 Gb/s ONU will only receive discovery GATE messages transmitted by the OLT on the 1 Gb/s broadcast channel. Operation and registration of these ONUs remains the same as previously, since no changes have been made to the existing 1 Gb/s discovery process.

A 10/1 Gb/s ONU is only capable of receiving discovery GATE messages transmitted by the OLT on the 10 Gb/s broadcast channel. These messages need to be parsed, and if a 1 Gb/s discovery window is to open, the ONU may attempt to register on the EPON.

A dual speed ONU capable of 10/1 Gbps operation or 10 Gbps operation is also only capable of receiving discovery GATE messages transmitted by the OLT on the 10 Gb/s broadcast channel. These messages need to be parsed, and the ONU makes a decision based off of the available information. The ONU should attempt to register based off of the highest speed common to both the OLT and ONU. Table 91A-4 shows the action the ONU should take based off of the ONU transmit capabilities and the received discovery information.

Table 91A-4 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
0	1	0	1	X	1	Attempt 10G registration
1	1	0	1	0	1	Attempt 10G registration
1	1	0	1	1	0	Wait for 1G discovery window
1	1	0	1	1	1	Attempt 10G registration
1	1	1	0	0	1	Wait for 10G discovery window
1	1	1	0	1	0	Attempt 1G registration
1	1	1	0	1	1	Wait for 10G discovery window
1	1	1	1	0	1	Attempt 10G registration
1	1	1	1	1	0	Attempt 1G registration
1	1	1	1	1	1	Attempt 10G registration

91A.5 Burst mode reception

The OLT receiver must support burst mode operation. If the OLT is supporting a single upstream channel, the receiver can be designed to handle the designated upstream data rate and line code. However, if the OLT supports both upstream channels, then the upstream receiver must support both data rates in a time division multiplex form.

From a topological point of view, the PMD has a single input optical channel of 1260nm to 1360nm, and two outputs: 1G and 10G. So, a bifurcation of the two channels must occur. The location of the split is an implementation choice. The incoming optical signal can be split into two detectors, as shown in Fig. 91A-4a, or electrically after the TIA, as shown in Fig. 91A-4b.

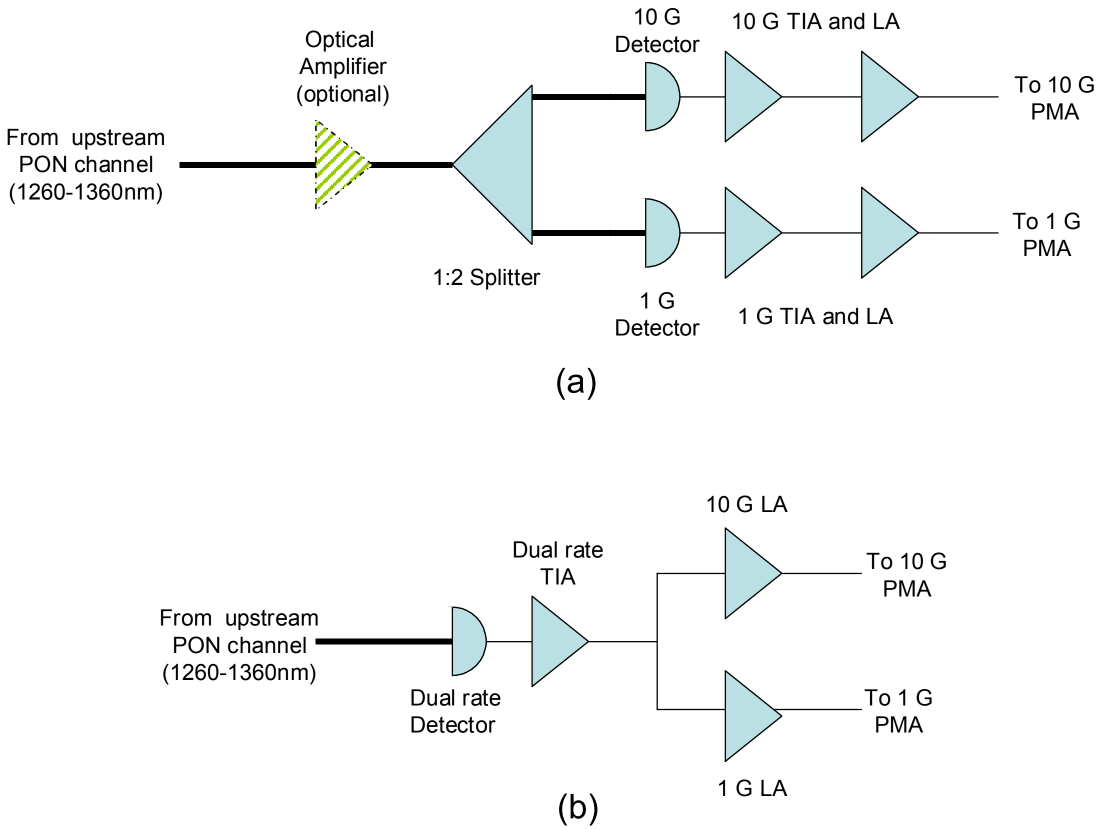


Figure 91A – 4 Dual-rate PMD topologies: a) optical split, b) electrical split

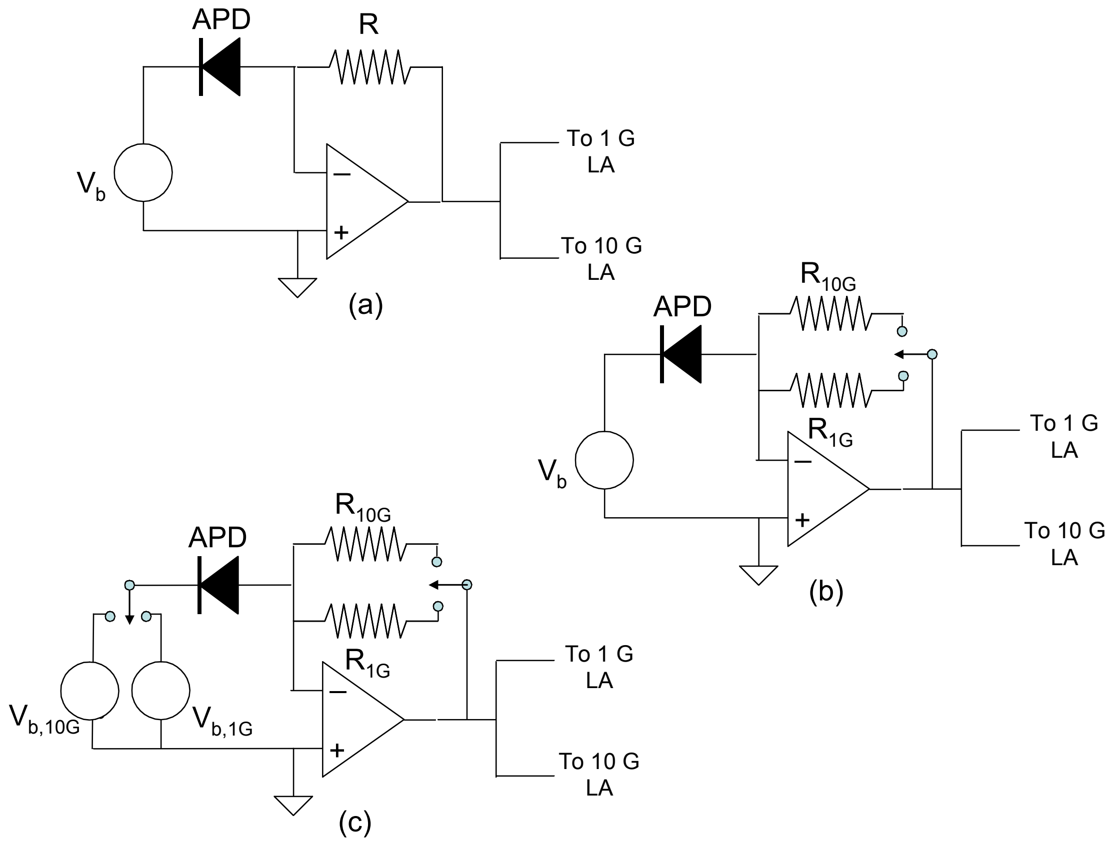
The optical split method has the advantage that each PMD channel can be specifically designed to match the signaling speed; however, the optical split will reduce the sensitivity by the loss of the splitter. This reduction of sensitivity may be tolerable in the PX-10/PR-10 type PMD system, but is likely infeasible in the other PMD types. This issue can be resolved by using some form of optical amplification before the split (shown as the optional amplifier in the figure.)

The electrical split method has the advantage that a single detector and TIA are used, and optical sensitivity can be maintained in theory without optical amplification. However, the detector and TIA must cope with both data rates in quick succession. The key aspect here is that the detector-TIA bandwidth directly affects the sensitivity. If the circuit parameters of the detector-TIA can be rapidly adapted to the correct value, optimum sensitivity can be maintained. There are three implementation choices in this regard, as shown in Fig. 91A-4a-c.

The option (a) design fixes the detector parameters at some value. This results in a sensitivity reduction of about 2dB; however, it should be noted that this penalty can be divided such that both the 1G and 10G sensitivities are 1dB less than their ideal values.

The option (b) design fixes the APD bias, but switches the TIA transimpedance depending on which signaling speed is desired. This results in a sensitivity reduction of about 1dB. Said reduction could be subdivided over both channels by setting the APD bias to a compromise value.

The option (c) design switches both the APD bias and the TIA transimpedance depending on the signaling speed. This results in ideal performance at both speeds. However, it is the most complex, and it is unclear if the benefits outweigh the costs.



91A – 5 Dual rate APD-TIA architectures: a) Static, b) Half-dynamic, c) Fully-dynamic

In the case of dynamic detector designs, the desired signaling speed must be determined. In general, the PMD layer does not have the a-priori knowledge of which data rate will be used. Therefore, some sort of data rate detector circuit must be utilized. One simple method would be to measure the spectral energy content of the received signal at frequencies well above 1.25GHz (e.g., 2-10 GHz). The 1G signal has very little energy at said frequencies, while the 10G signal has ample energy there. Thus, the presence of 5GHz energy indicates that a 10G signal is incident. Other implementation specific methods to control the APD-TIA speed are also possible.