

Annex 91A

(informative)

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 1 Gb/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 ONU~~ the transmit and receive data paths ~~operating operate~~ at 1 Gb/s and 10 Gb/s, respectively. The OLT may also support simultaneous operation (~~or~~ coexistence) of various types of ONUs: legacy 1 Gb/s ONUs (as described in Clause 64 and Clause 65), symmetric 10 Gb/s ONUs and asymmetric 10 Gb/s downstream and 1 Gb/s upstream ONUs (as described in Clause 92 and Clause 93). The remainder of this clause discusses ~~various~~ system considerations ~~that are important in vital for~~ the deployment of a symmetric or asymmetric ~~10 Gb/s 10G-EPON that coexists~~ coexisting 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, while in~~ symmetric ~~10 Gb/s 10G-EPON~~ architectures, the XGMII is the interface used to bridge between the MAC and the PHY. When using an asymmetric 10G-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:

- a) ~~Support~~ symmetric 10 Gb/s operation for transmit and receive data paths, providing all of the functionality of the XGMII defined in Clause 46.
- b) ~~Support~~ symmetric 1 Gb/s operation for transmit and receive data paths, providing all of the functionality of the GMII defined in Clause 35.
- c) ~~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.
- d) ~~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.
- e) ~~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.

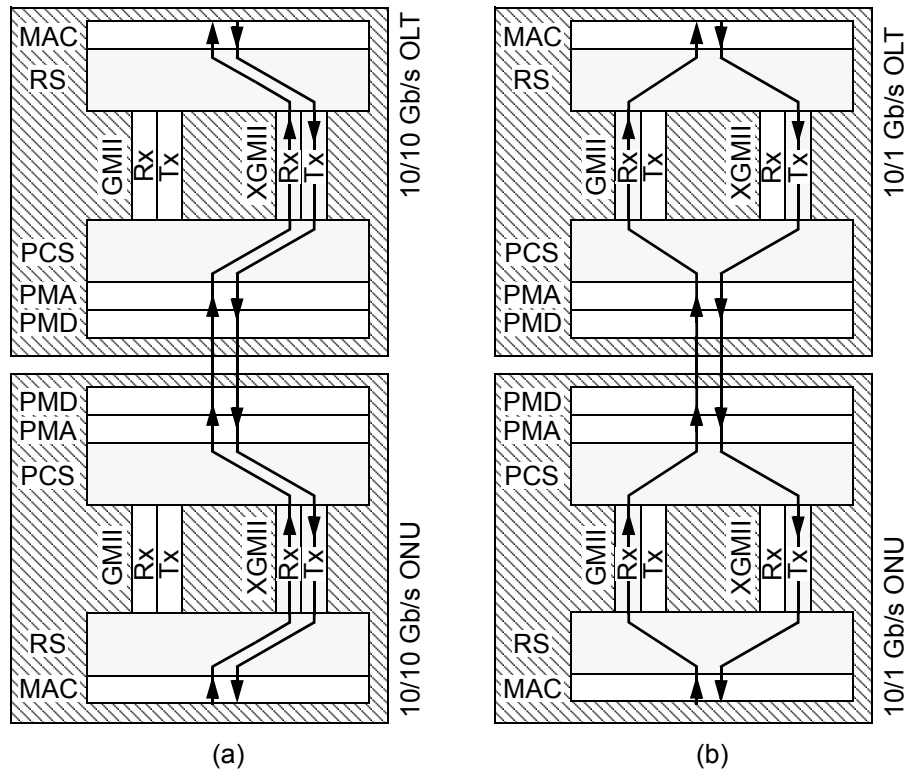


Figure 91A-1—Symmetric (a) and asymmetric (b) operation of OLT and ONU.

91A.2.3 ~~Dual~~Dual-rate mode

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

91A.2.4 Binding of XGMII and GMII primitives

Clause @@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~~below in Table 91A-1- ~~which~~ which shows the mapping of PLS_DATA.request primitives to transmit interface signals for different types of

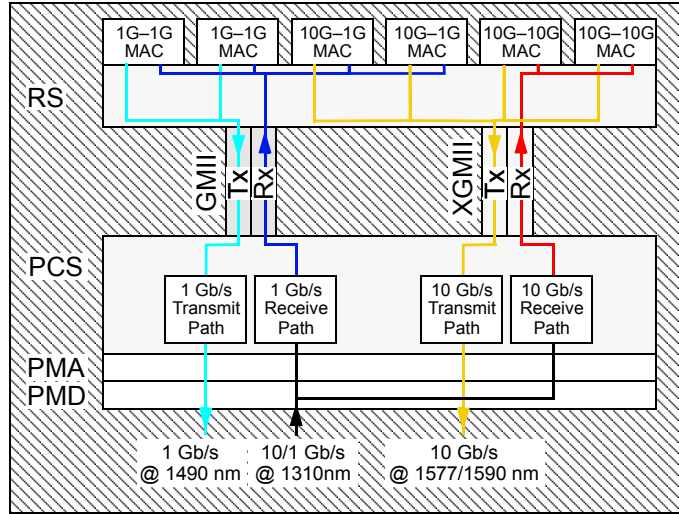


Figure 91A-2—Reconciliation sublayer for dual rate mode at OLT.

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	Transmit 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

Figure 91A-3 depicts the wavelength allocation plan for EPON and 10G-EPON systems, as discussed below.

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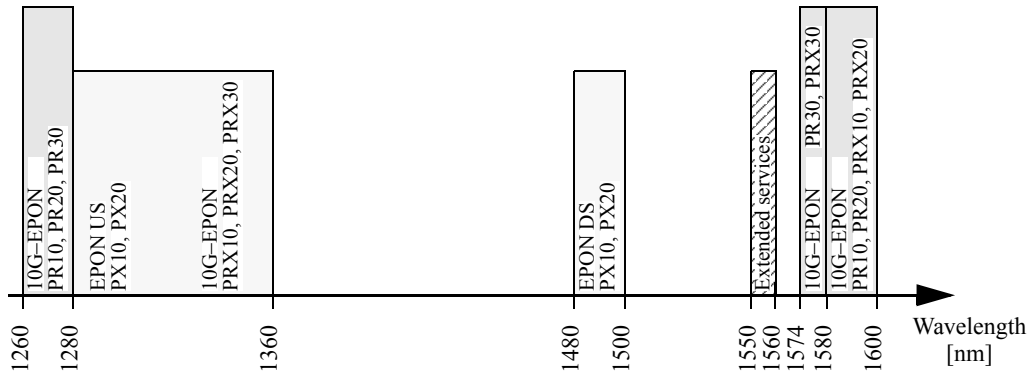


Figure 91A-3—Wavelength allocation plan for EPON and 10G-EPON.

91A.3.1 Downstream wavelength allocation

The ~~1.25 Gb/s~~ downstream transmission uses the 1480 – 1500 nm wavelength band, as specified in Clause 60. The ~~10.3125 Gb/s~~ downstream transmission uses the 1574 – 1600 nm wavelength band, as specified in Clause 91. Therefore, there are two distinct downstream channel ranges, as depicted in Figure 91A-3.

NOTE—different power budget classes use different sub-sets of the 1574 – 1600 nm band, i.e. PR10, PR20, PRX10 and PRX20 power budgets use 1580 – 1600 nm range while PR30 and PRX30 power budgets use 1574 – 1580 nm range.

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

~~An OLT supporting both downstream channels may multiplex the output of the two transmitters using a WDM device.~~

An OLT supporting both downstream channels may multiplex the output of the two transmitters using a WDM coupler, while an ONU will select selects the relevant downstream channel using an optical filter.

91A.3.2 Upstream wavelength allocation

The ~~1.25 Gb/s~~ upstream transmission uses the 1270 – 1360 nm wavelength band, as specified in Clause 60. The ~~10.3125 Gb/s~~ upstream transmission uses the 1260 – 1280 nm wavelength band, as specified in Clause 92. The two wavelength bands overlap, thus WDM channel multiplexing cannot be used to separate the two data channels.

An OLT supporting both upstream channels must use TDMA techniques to avoid collisions between transmissions originating from different ONUs, resulting in a dual-rate, burst mode transmission as discussed in Subclause 91A.5.

91A.4 Discovery

~~Enhancements~~ The enhancements introduced to the ~~EPON Clause 60~~ discovery process ~~have been made in order to for EPONs~~ facilitate the coexistence of ~~10 Gb/s 10G-EPON~~ with legacy ~~1 Gb/s~~ EPON.

91A.4.1 OLT speed specific discovery

The discovery GATE MPCPDU is defined in Clause @@XX@@ for 1 Gb/s operation and in Clause @@XX@@ for 10 Gb/s operation. An additional ~~field,~~ field (Discovery Information field,) was added to

the 10 Gb/s ~~Discovery~~ discovery GATE MPCPDU. ~~The purpose of this~~ This field ~~is~~ allows the OLT to relay speed specific information regarding the discovery window to the different ONUs that may ~~co~~ exist on the ~~E~~ PON ~~same~~ PON. The OLT has the ability to transmit common discovery GATE MPCPDUs 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.

Editors' Note #1 (to be removed prior to release): This section will require revision depending on the status of the Clause 64 option#2 ad hoc.

These different combinations allow the OLT Discovery Agent 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~~ MPCPDUs. For some combinations, it is necessary for the OLT Discovery Agent to open overlapping discovery windows by sending discovery GATE ~~messages~~ MPCPDUs on both the 1 Gb/s and 10 Gb/s downstream broadcast channels.

Table 91A-3—Discovery GATE ~~content~~ MPCPDUs for all ONU types.

<u>ONU type</u> <u>ONU types on the PON</u> <u>[DS/US transmission speed]</u>	LLID of discovery GATE(s)	Discovery Information			
		Upstream Capable		Discovery Window	
		1G	10G	1G	10G
1/ <u>1</u> Gb/s	0x7FFF	1	0	1	0
10/ <u>1</u> Gb/s	0x7FFE	1	0	1	0
1/ <u>1</u> Gb/s and 10/ <u>1</u> Gb/s	0x7FFF and 0x7FFF 0x7FFE ^a	1	0	1	0
10/ <u>10</u> Gb/s	0x7FFE	0	1	0	1
10/ <u>1</u> Gb/s and 10/ <u>10</u> Gb/s	0x7FFE	1	1	1	1
1/ <u>1</u> Gb/s, 10/ <u>1</u> Gb/s, and 10/ <u>10</u> Gb/s	0x7FFF and 0x7FFE 0x7FFE ^a	1	1	1	1

^aTwo discovery GATE MPCPDUs are transmitted in the downstream broadcast channel: one with the LLID of 0x7FFF transmitted on the 1 Gb/s downstream broadcast channel and another one the LLID of 0x7FFE transmitted on the 10 Gb/s downstream broadcast channel.

Figure 91A-4 shows the three primary combinations of discovery windows and the different types of ~~Regis-~~ ter ~~Request messages~~ REGISTER_REQ MPCPDUs that may be received during the window. Figure 91A-4(a) shows reception of messages from 1 Gb/s and 10/1 Gb/s ONUs. Figure 91A-4(b) shows reception of messages from 10 Gb/s ONUs. Figure 91A-4(c) shows reception of messages from all types of ONUs.

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~~ MPCPDU 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 ~~opened~~, the ONU may attempt to register on the EPON.

A dual speed ONU capable of asymmetric 10/1 ~~Gbps~~ Gb/s operation or symmetric 10/10 Gb/s operation is also only capable of receiving discovery GATE ~~messages~~ MPCPDU transmitted by the OLT on the 10 Gb/s

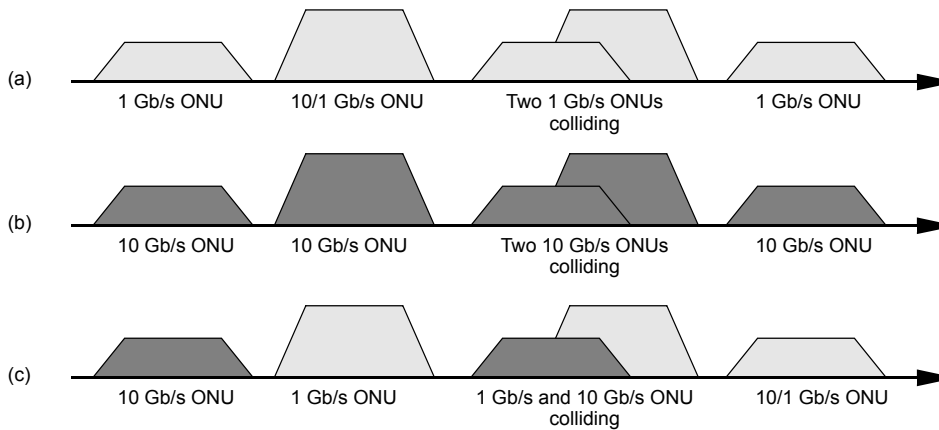


Figure 91A-4—Combinations of REGISTER_REQ MPCPDUs during discovery window for 10G-EPON and EPON coexisting on the same PON.

broadcast channel. These messages need to be parsed, and the ONU makes a ~~the registration~~ decision based ~~off of~~ on the available information. The ONU should attempt to register based ~~off of~~ during the discovery window announced as supporting the highest speed common to both the OLT and ONU. Table 91A-4 shows the action the ONU should take based ~~off of~~ on the ONU transmit capabilities and the received discovery information.

Table 91A-4—ONU action during discovery window

OLT Discovery Information				ONU Tx capability ^a		ONU Action
Upstream Capable		Discovery Window		1G	10G	
1G	10G	1G	10G	1G	10G	
1	0	1	0	+ _±	x _±	Attempt 1G registration
0	1	0	1	x _±	+ _±	Attempt 10G registration
1	1	0	1	0 _±	+ _±	Attempt 10G registration
1	1	0	1	+ _±	0 _±	Wait for 1G discovery window
1	1	0	1	+ _±	+ _±	Attempt 10G registration
1	1	1	0	0 _±	+ _±	Wait for 10G discovery window
1	1	1	0	+ _±	+ _±	Wait for 10G discovery window
1	1	1	1	0 _±	+ _±	Attempt 10G registration
1	1	1	1	+ _±	0 _±	Attempt 1G registration
1	1	1	1	+ _±	+ _±	Attempt 10G registration

^a~~“+”~~ in the 1G/10G column of the ONU Tx capability indicates that the given ONU Tx is capable of operation at the given data rate.

91A.5 ONU speed-specific registration

91A.5 Burst mode reception

The OLT receiver must support burst mode operation. If the OLT ~~is supporting~~ supports a single upstream ~~channel~~ channel e.g. only 1 Gb/s or 10 Gb/s data rate, the receiver can be designed to handle the designated

upstream data rate and line code. However, if the OLT supports both 1 Gb/s and 10 Gb/s upstream channels, then the upstream-OLT receiver must support both data rates in a time division multiplex form via TDMA.

From a topological point of view, the PMD has a single input optical channel of 1260 – 1360 nm, and two outputs: 1 Gb/s and 10 Gb/s. So Thus, at a certain point in the stack it is necessary to introduce a bifurcation of signal split, where the two channels must occur. The location of the such a signal split is an implementation choice. The incoming optical-signal can be split in the optical domain and fed into two detectors two, independent photodetectors as shown in Figure 91A-5(a). Alternatively, or electrically after the TIA, signal can be detected using a single photodetector as shown in Figure 91A-5(b) and then split in the electrical domain after the TIA block.

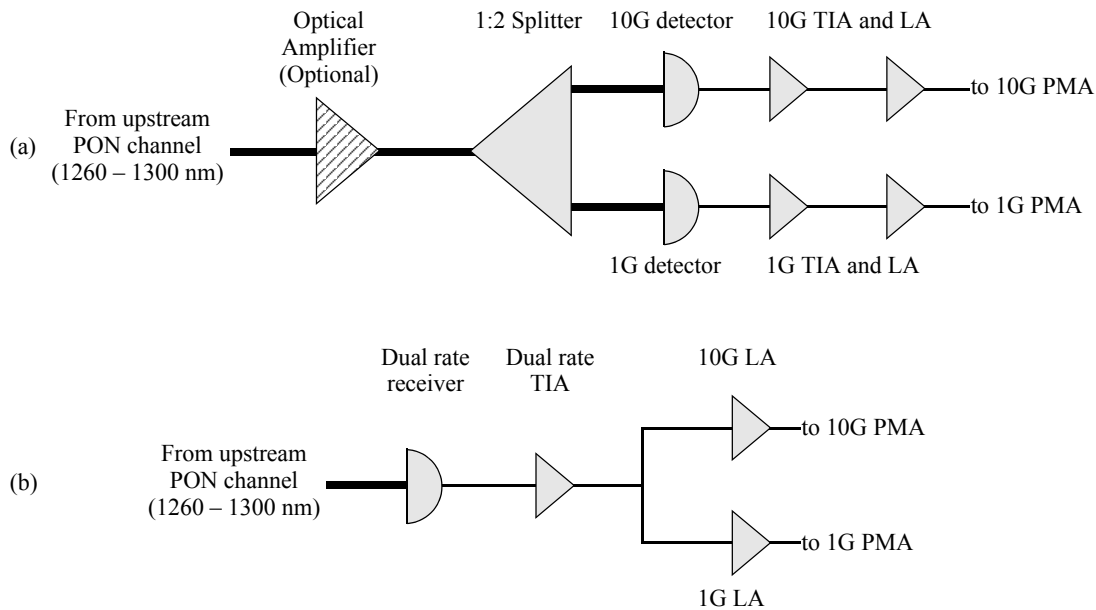


Figure 91A-5—Dual-rate PMD topologies with the split in the (a) optical domain, (b) electrical domain.

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.)

When the incoming signal is split in the optical domain, it is possible to design each PMD channel specifically to match the signaling speed, offering optimum sensitivity for both 1 Gb/s and 10 Gb/s signals. However, the additional 1:2 optical splitter presented in Figure 91A-5(a) will reduce the sensitivity of the following photodetectors by introducing additional loss and lowering the power of the optical signal. Such a sensitivity reduction may be tolerable in the PX10/PRX10/PR10 type PMDs, but the more stringent power budgets including PX20, PR20, PRX20, PR30 and PRX30 may be very challenging or even impossible to implement with such an additional loss on the OLT receiver side. This particular problem may be resolved via an additional, low-gain optical amplifier introduced in-line with the 1:2 optical splitter, as presented in Figure 91A-5(a), used to boost the power level of the incoming signal sufficiently to overcome the loss introduced by the 1:2 optical splitter.

The electrical domain, only one photodetector and one TIA units are used, and. The resulting optical sensitivity can be theoretically maintained in theory without the need for optical amplification, reducing the complexity of the OLT receiver. However, the detector-photodetector and TIA must cope with both data rates in quick succession, switching between 1 Gb/s and 10 Gb/s bursts during the guardband. 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 Figure 91A-5(a)-(c):

- a) The option (a) This design fixes the detector parameters at some predefined value. This results, resulting in a sensitivity the reduction of about the OLT receiver sensitivity by approximately 2 dB; however. However, it should be noted that this penalty can be divided in such a way that both the 1 Gb/s and 10 Gb/s sensitivities are 1 dB less-lower than their ideal values.
- b) The option (b) This design fixes the APD bias, but switches the TIA transimpedance depending on which the target signaling speed is desired. This results for the given incoming burst, resulting in a sensitivity the reduction of about the receiver sensitivity by approximately 1 dB. Said reduction-The said sensitivity penalty could be subdivided over-to both data rate channels by setting the APD bias to a compromise value.
- c) The option (c) This design switches both the APD bias and the TIA transimpedance depending on the signaling speed speed of the incoming burst. This results in ideal performance at both speeds 1 Gb/s and 10 Gb/s data rates. However, it is the most complex-complex design in terms of the number of elements and the control complexity, and it is unclear if the benefits outweigh the costs.

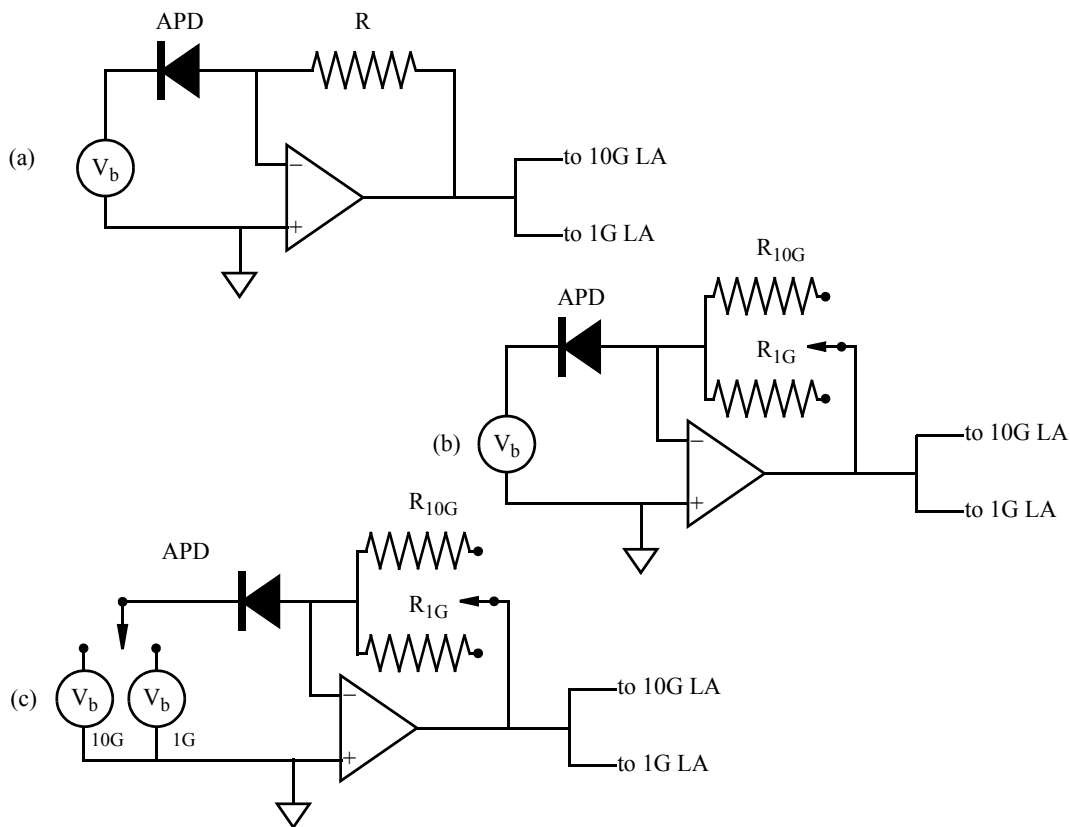


Figure 91A-6—Dual rate APD-TIA architectures: (a) static, (b) half-dynamic, (c) fully-dynamic

In the case of dynamic detector designs, it is necessary to determine the data rate of the incoming burst before adjusting the dynamic detector to match the target data rate.

~~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~~used in the given burst - such information is available only at the MAC Client level and its delivery to the PMD layer would violate the stack layering restrictions. Therefore, some sort of data rate detector circuit must be utilized. One ~~of the simple method would be to measure~~methods is based on measuring the spectral energy content of the received signal at frequencies well above 1.25 GHz (e.g., ~~2-~~in the range of 2 – 10 GHz). The 1 Gb/s signal has very little energy at said ~~frequencies~~frequency range, while the 10 Gb/s signal has ample energy there. Thus, the presence of 5 GHz energy indicates that a 10 Gb/s signal is incident. Other implementation specific methods to control the APD-TIA speed are also possible, though are not discussed in this document.

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