Gigabit-capable Passive Optical Networks (GPON): General characteristics

SERIES G: TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

Digital sections and digital line system – Optical line systems for local and access networks

ITU-TG.984.1 (03/2003)

Outline

- Object
- Scope
- Definitions
- Architecture of the optical access network
- Services, user network interface and service node interface

Object

- This Recommendation describes a flexible optical fibre access network capable of supporting the bandwidth requirements of business and residential services and covers systems with nominal line rates of 1.2 Gbit/s and 2.4 Gbit/s in the downstream direction and 155 Mbit/s, 622 Mbit/s, 1.2 Gbit/s and 2.4 Gbit/s in the upstream direction.

- Both symmetrical and asymmetrical (upstream/downstream) Gigabit-capable Passive Optical Network (GPON) systems are described.

Object (cont.)

- This Recommendation proposes the general characteristics for GPON based on operators' service requirements.

- This Recommendation aims to improve on the G.983.1 system by reconsidering a supporting service, security policy, nominal bit-rate, and so on.

- In order to insure maximal continuity with existing systems and optical fibre infrastructure, this Recommendation maintains some requirements of ITU-T Rec. G.983.1.

Scope

- The general characteristics include examples of services, User Network Interfaces (UNI) and Service Node Interfaces (SNI) that are requested by network operators.

- As much as possible, this Recommendation maintains characteristics from ITU-T Rec. G.982 and G.983.x series of Recommendations.

- This is to promote backward compatibility with existing Optical Distribution Networks (ODN) that complies with those Recommendations.

Scope

- GPON systems are characterized, in general, by an Optical Line Termination (OLT) system and an Optical Network Unit (ONU) or Optical Network Termination (ONT) with a passive Optical Distribution Network (ODN) interconnecting them.

- There is, in general, a one-to-many relationship between the OLT and the ONU/ONTs respectively

Definitions

- Adaptation Function (AF):

  - AF is additional equipment to change an ONT/ONU subscriber interface into the UNI interface that is required by an operator or to change a UNI interface into an ONT/ONU subscriber interface
  - Functions of AF depend on the ONT/ONU subscriber interface and UNI interface.
  - AF is also used to change an OLT network interface into the SNI interface that is required by an operator or to change a SNI interface into an OLT network interface.

- logical reach:
  - Logical reach is defined as the maximum distance that can be achieved for a particular transmission system.

Definitions

- Differential fibre distance:
  - The differential fibre distance is the difference in the distance between the nearest and furthest ONU/ONT from the OLT.
  - An OLT is connected to several ONU/ONTs.

- Mean signal transfer delay:
  - The mean signal transfer delay is the average of the upstream and downstream delay values between reference points; this value is determined by measuring round-trip delay and then dividing by 2..
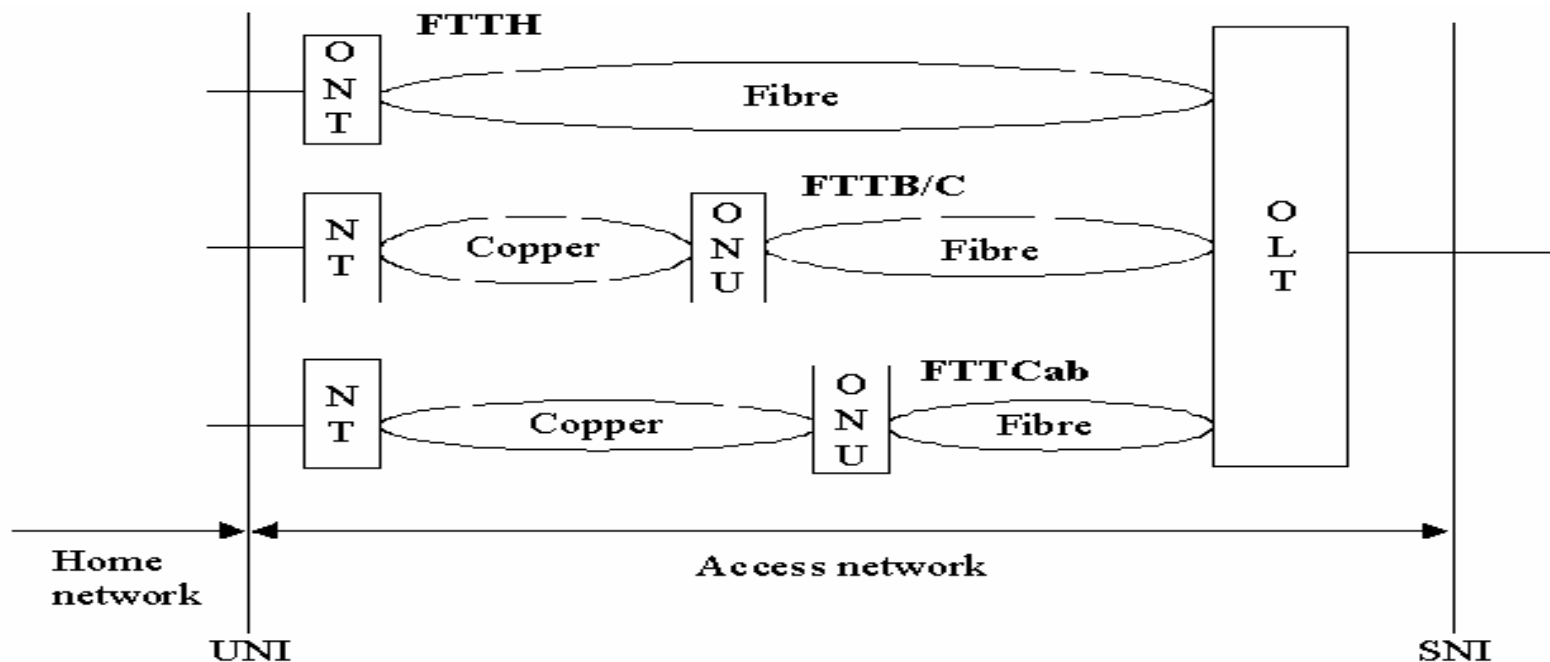
Definitions

- Distribution Network (ODN):
  - An ODN realizes the optical transmission from the OLT towards the users and vice versa. It utilizes passive optical components.

- Optical Line Termination (OLT):
  - An OLT provides the network-side interface of the OAN and is connected to one or more ODNs.

- Optical Network Termination (ONT):
  - An ONT is an ONU used for FTTH that includes the User Port function.

- Optical Network Unit (ONU):
  - An ONU provides (directly or remotely) the user-side interface of the OAN and is connected to the ODN.
- physical reach:
  - Physical reach is defined as the maximum physical distance that can be achieved for a particular transmission system.

Definitions

- service:
  - Service is defined as a network service required by operators..

- Service Node Interface (SNI):
  - See ITU-T Rec. G.902.

- User Network Interface (UNI):
  - See ITU-T Rec. I.112.Optical

Architecture of the optical access network

- The optical section of a local access network system can be :
  - active or passive
  - Its architecture can be :point-to-point or point-to-multipoint.

FTTH

Fibre

O N T

FTTB/C

N T — Copper — O N U — Fibre

FTTCab

N T — Copper — O N U — Fibre

O L T

Home network

Access network

UNI

SNI

G.984.1_F1

ONU	Optical Network Unit
ONT	Optical Network Termination
OLT	Optical Line Termination
NT	Network Termination

Architecture of the optical access network (cont.)

- FTTB scenario : FTTB for MDU and FTTB for business
  - FTTB for MDU (Multi Dwelling Unit)

    - Asymmetric broadband services (e.g., digital broadcast services, VOD, file download, etc.).

    - Symmetric broadband services (e.g., content broadcast, e-mail, file exchange, distance learning, telemedicine, online-game, etc.).

    - POTS and ISDN. The access network must be able to provide, in a flexible way, narrow-band telephone services with appropriate timing for the introduction.

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Architecture of the optical access network (cont.)

- FTTB for business
  - Symmetric broadband services (e.g., group software, content broadcast, e-mail, file exchange, etc.).

  - POTS and ISDN. The access network must be able to provide, in a flexible way, narrow-band telephone services with the appropriate timing for the introduction.

  - Private line. The access network must be able to provide, in a flexible way, private line services at several rates.

Architecture of the optical access network (cont.)

- FTTC and FTTCab (cabinet) scenario

    - Asymmetric broadband services (e.g., digital broadcast services, VoD, file download, online-game, etc.).

    - Symmetric broadband services (e.g., content broadcast, e-mail, file exchange, distance learning, telemedicine, etc.).

    - POTS and ISDN. The access network must be able to provide, in a flexible way, narrow-band telephone services with the appropriate timing for the introduction.

    - xDSL backhaul.

Architecture of the optical access network (cont.)

- **FTTH scenario:**
    - Asymmetric broadband services (e.g., digital broadcast services, VOD, file download, etc.).

    - Symmetric broadband services (e.g., content broadcast, e-mail, file exchange, distance learning, telemedicine, online-game, etc.).

    - POTS and ISDN. The access network must be able to provide, in a flexible way, narrow-band telephone services with the appropriate timing for the introduction.

Reference configuration for GPON

G.984.1_F2
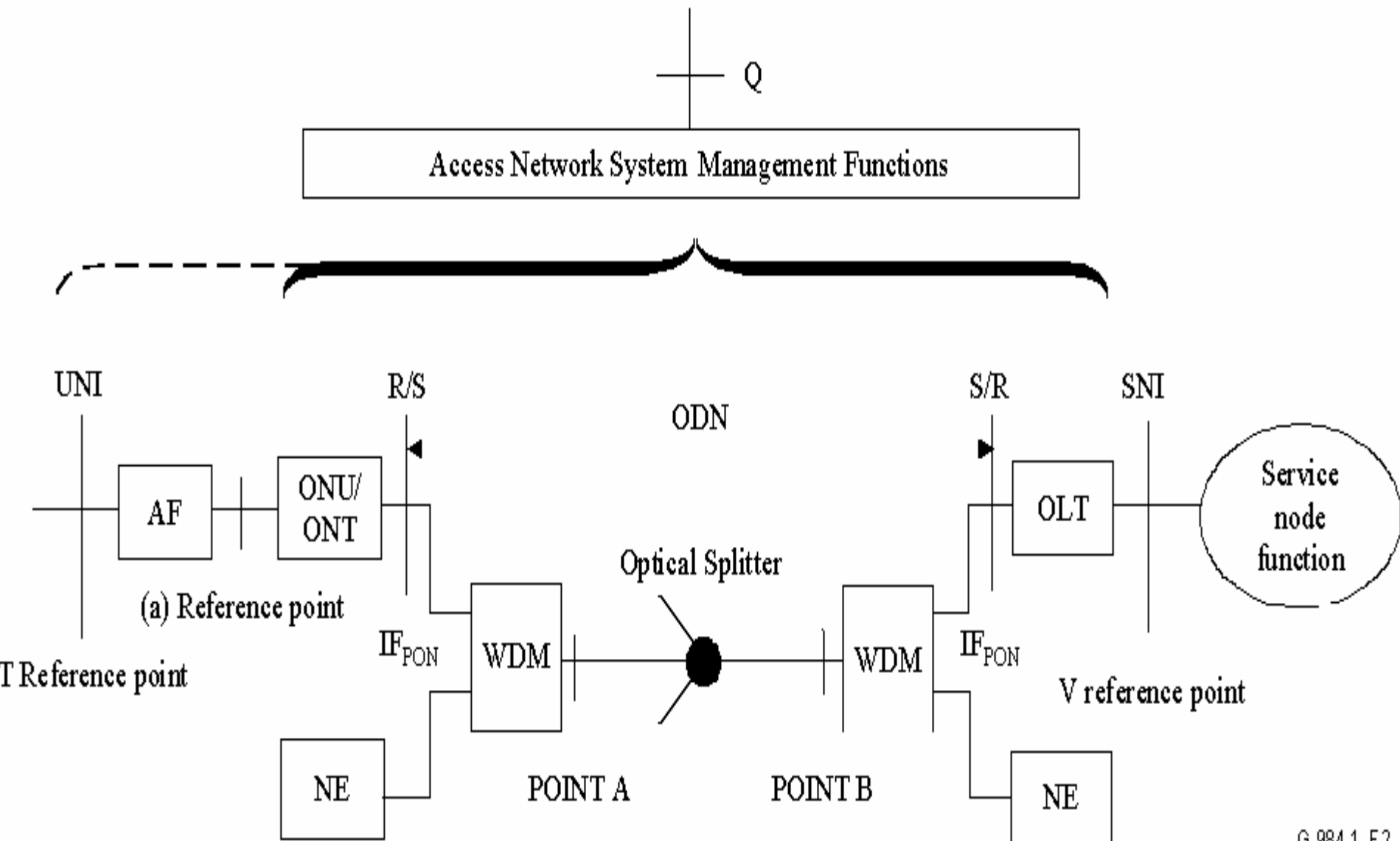
Reference configuration for GPON

- **Interface at the reference points S/R and R/S**
  - The interface at reference points S/R and R/S is defined as IFPON. This is a PON-specific interface that supports all the protocol elements necessary to allow transmission between OLT and ONUs.

- **User Network Interface (UNI) and Service Node Interface (SNI)**
  - ONU/ONT has UNI, as well as OLT, has SNI as described in Figure 2. UNI/SNI depends on which services are provided by the service operator.

Reference configuration for GPON

- **Bit rate**
  - Basically, GPON aims at transmission speeds greater than or equal to 1.2 Gbit/s. .GPON identifies 7 transmission speed combinations as follows:
    - 155 Mbit/s up, 1.2 Gbit/s down;
    - 622 Mbit/s up, 1.2 Gbit/s down;
    - 1.2 Gbit/s up, 1.2 Gbit/s down;
    - 155 Mbit/s up, 2.4 Gbit/s down;
    - 622 Mbit/s up, 2.4 Gbit/s down;
    - 1.2 Gbit/s up, 2.4 Gbit/s down;
    - 2.4 Gbit/s up, 2.4 Gbit/s down.

Reference configuration for GPON

- **Logical reach**
  - Logical reach is the maximum distance between ONU/ONT and OLT.
  - In GPON, the maximum logical reach is defined as 60 km.

- **Physical reach**
  - Physical reach is the maximum physical distance between the ONU/ONT and the OLT.
 - In GPON, two options are defined for the physical reach: 10 km and 20 km.

Reference configuration for GPON

- **Differential fibre distance**
  - In GPON, the maximum differential fibre distance is 20 km.

- **Maximum mean signal transfer delay**
  - GPON must accommodate services that require a maximum mean signal transfer delay of 1.5 ms.
  - Specifically, GPON system must have a maximum mean signal transfer delay time of less than 1.5 ms between T-V (or (a)-V, depending on operator's preference).
  - Although a section of the delay measurement is T-V for FTTH system or (a)-V for the other application in ITU-T Rec. G.982, in a GPON system the reference points are not restricted by the system configuration.

Reference configuration for GPON

- **Protection on the PON section**
    - Protection shall be considered as an optional mechanism because its implementation depends on the realization of economical systems.
    - This clause presents some possible duplex configurations and related requirements as examples of protected GPON systems. In addition, the required OAM message for protection is mentioned.
    - In the GPON system should be a part of the protection between the ODN interface in the OLT and the ODN interface in the ONU via the ODN, excluding the SNI redundancy in the OLT.
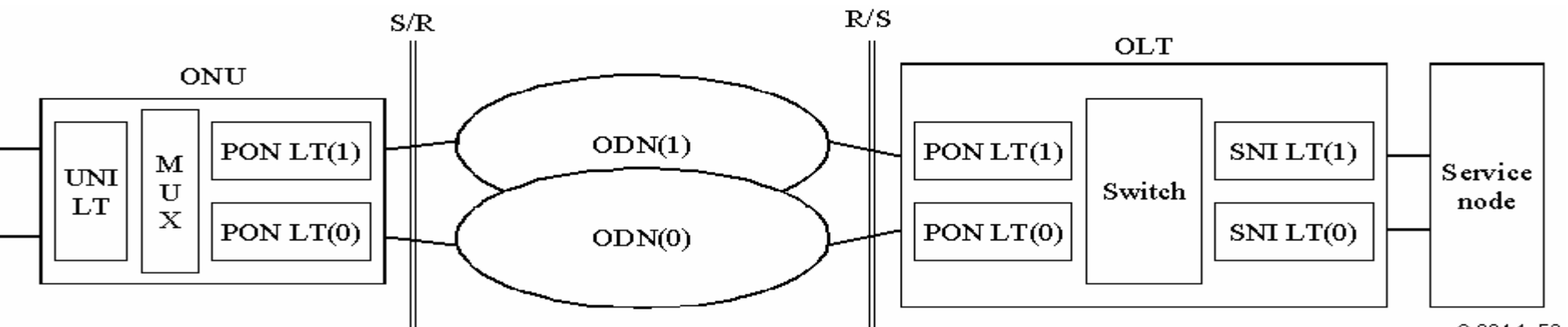
Figure 3/G.984.1 — Duplex system model

Reference configuration for GPON

- **Possible switching types**
  - There are two types of protection switching both of which are analogous to those of SDH systems:
    - (i) automatic switching; and
    - (ii) forced switching.
- The first one is triggered by fault detection, such as loss of signal, loss of frame, signal degrade (BER becomes worse than the predetermined threshold), and so on.

- The second one is activated by administrative events, such as fibre rerouting, fibre replacement, etc.

- Both types should be possible in the GPON system, if required, even though they are optional functions.

- The switching mechanism is generally realized by the OAM function, therefore, the required OAM information field should be reserved in the OAM frame.

Reference configuration for GPON

- **Possible duplex GPON configurations and characteristics**

  - There can be several types of duplex GPON systems, as shown in Figures 4a to d.

  - For example, no switching protocol is required for the OLT/ONU in Figure 4a, since the switching is only applied for the optical fibres. Also, in Figure 4b, no switching protocol is required since the switching is carried out only in the OLT.
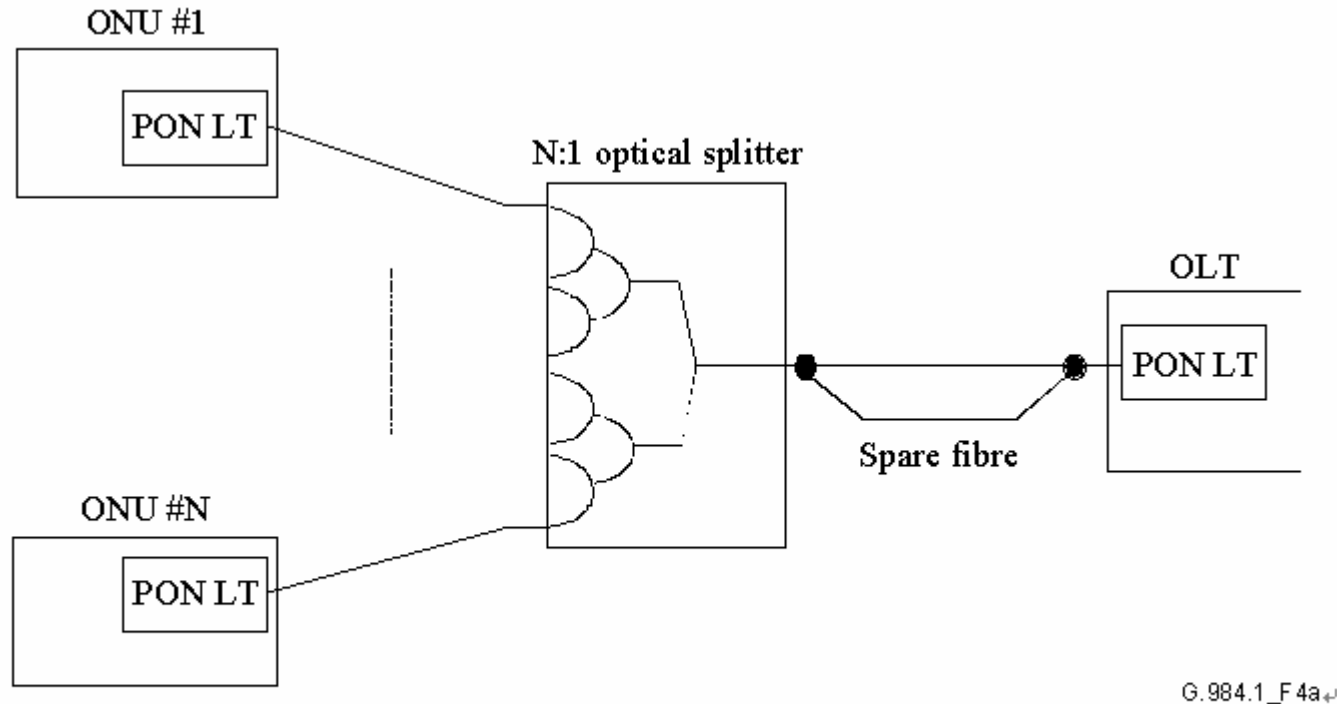
Reference configuration for GPON

Figure 4a/G.984.1 – Duplex GPON system: Fibre duplex system

Signal loss or even frame loss is inevitable in the switching period.
However, all the connections between the service node and the terminal
equipment should be held after this fibre switching.

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Reference configuration for GPON

ONU #1
PON LT
N:2 optical splitter
OLT
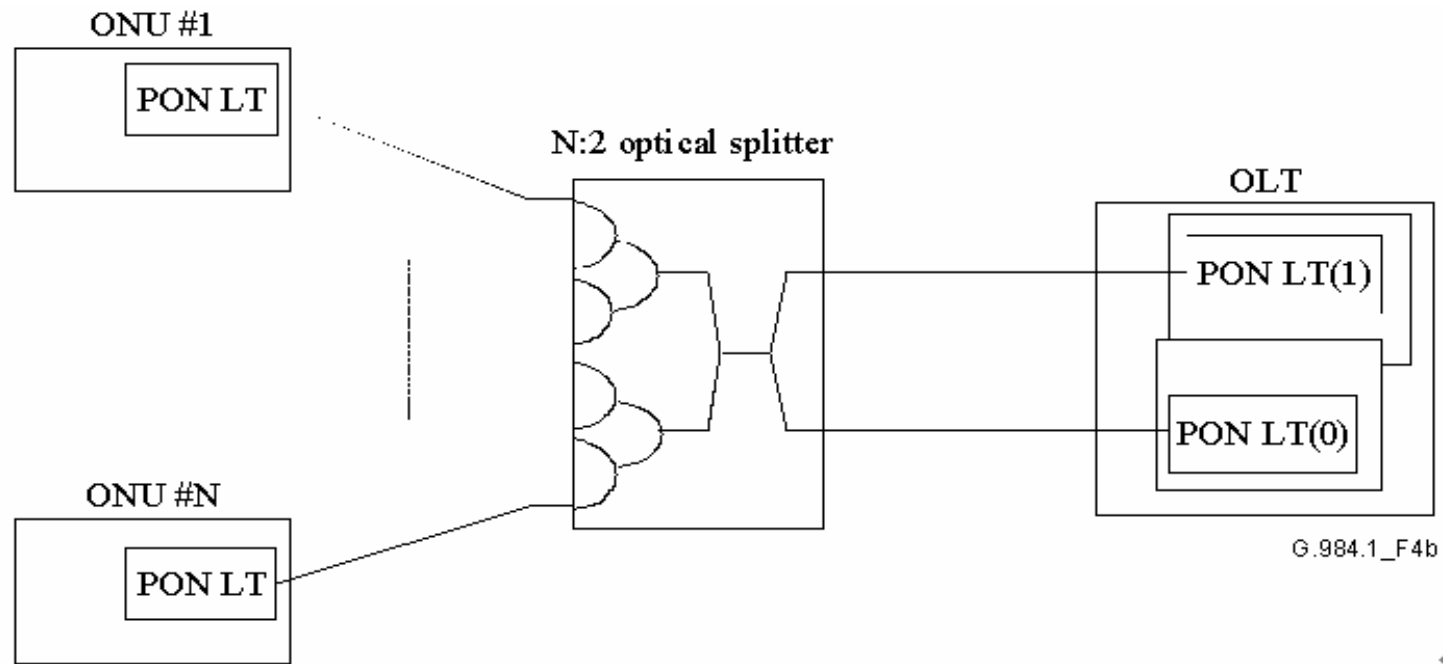PON LT(1)
PON LT(0)
ONU #N
PON LT
G.984.1_F4b

Figure 4b/G.984.1 — Duplex GPON system: OLT-only duplex system

This configuration reduces the cost of duplexing the ONUs.
This configuration requires cold standby of the spare circuit in the OLT side.
In this case, signal loss or even frame loss is, in general, inevitable in the switching period.

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Reference configuration for GPON

ONU #1
PON LT(1)
PON LT(0)

Double
N:2 optical splitter

OLT
PON LT(1)
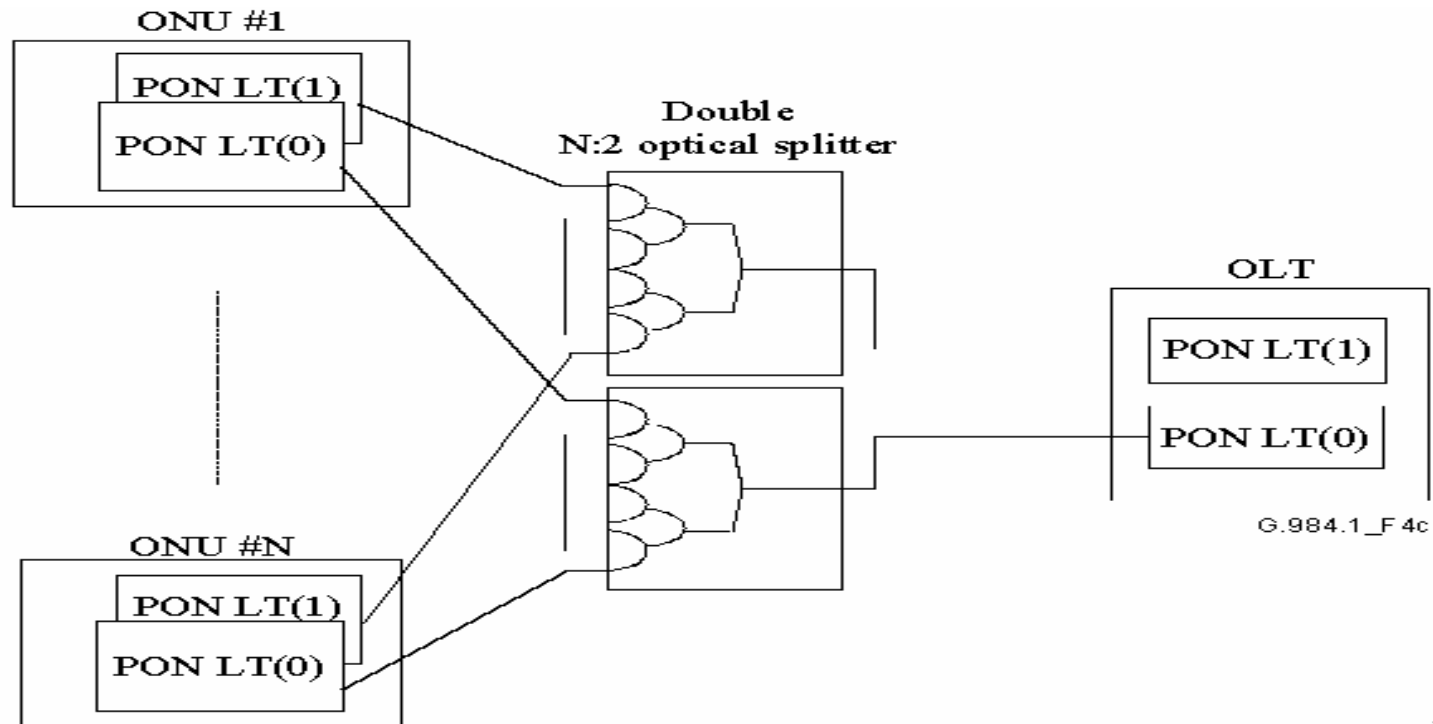PON LT(0)

G.984.1_F 4c

ONU #N
PON LT(1)
PON LT(0)

Figure 4c/G.984.1 — Duplex GPON system: Full duplex system

- In this configuration, recovery from failure at any point is possible by switching to the standby facilities. Therefore, the full duplex cost enables a high reliability.
- the hot standby of the spare receiver circuits is possible in both ONU and OLT sides.

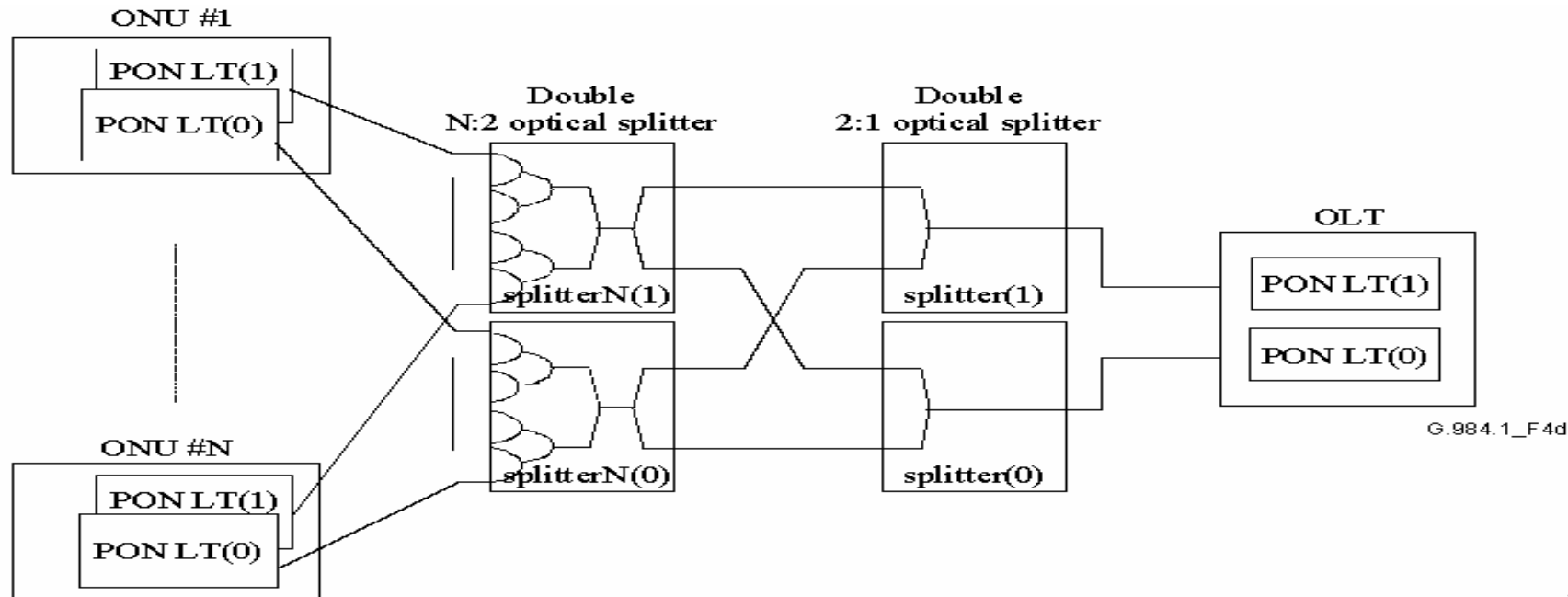# Reference configuration for GPON

Figure 4d/G.984.1 — Duplex GPON system: Partial duplex configuration

- The last configuration (Figure 4d) permits a partial duplexing on the ONU side.
- The characteristics of this type are the same as Type B.

Reference configuration for GPON

- **Requirements**

  (i) The protection switching function should be optional.

  (ii) Both automatic protection switching and forced switching are possible in the GPON system, if required, even though they are optional functions.

  (iii). The switching mechanism is generally realized by the OAM function, therefore, the required OAM information field must be reserved in the OAM frame.

  (iv) All the connections supported between the service node and the terminal equipment should be held after switching.

- Regarding the last requirement, one implementation of the POTS service node (exchange) requires the frame loss period to be less than 120 ms. If the frame loss period becomes longer than that, the service node disconnects the call, and the call set-up is required again after the protection switching.

- Since GPON supports the emulation of conventional services, such as POTS and ISDN, this value should be taken into consideration.

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Reference configuration for GPON

- **Required information fields for OAM frame**
  - The field mapping of the OAM frame for the protection will be required to be defined.

Reference configuration for GPON

- **Security**
  - Due to the multicast nature of the PON, GPON needs a security mechanism adapting the following requirements:
    - To prevent other users from easily decoding the downstream data;
    - To prevent other users from masquerading as another ONU/ONT or user;
    - To allow cost-effective implementation.

Example of service

Service category (Note 1)	Service	Remarks
Data service	Ethernet (Note 2)	Standardized in IEEE 802.3.
		Comply with IEEE 802.1D.
PSTN	POTS	Mean signal transfer delay time between T-V (or (a)-V) should be less than 1.5 ms. If echo cancellation is used in the network, the mean signal transfer delay time between T-V (or (a)-V) on the PON–based system may be longer, provided End-to-End transfer delay requirements are met.
		Synchronize with the network's 8 kHz clock.
		Signal on the T reference point and V reference point must be continuous.
	ISDN (BRI)	Bearer rate is 144 kbit/s.
		Mean signal transfer delay time between T-V (or (a)-V) should be less than 1.5 ms.
		Synchronize with the network's 8 kHz clock.
	ISDN (PRI)	Bearer rate is 1.544 Mbit/s and 2.048 Mbit/s.
		Mean signal transfer delay time between T-V (or (a)-V) should be less than 1.5 ms.
		Synchronize with the network's 8 kHz clock.

Table I.1/G.984.1 – Examples of services and related remarks

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Example of service

Private Line	T1	Bearer rate is 1.544 Mbit/s.
		Mean signal transfer delay time between T-V (or (a)-V) should be less than 1.5 ms.
		Synchronize with the network's 8 kHz clock.
	E1	Bearer rate is 2.048 Mbit/s.
		Mean signal transfer delay time between T-V (or (a)-V) should be less than 1.5 ms.
		Synchronize with the network's 8 kHz clock.
	DS3	Bearer rate is 44.736 Mbit/s.
		Synchronize with the network's 8 kHz clock.
	E3	Bearer rate is 34.368 Mbit/s.
		Synchronize with the network's 8 kHz clock.
	ATM	Standardized in ITU-T Rec. I.361.
		Complies with ITU-T Rec. I.356.
Video	Digital video	Deliver with same quality as class 1 specified in ITU-T I.356 or rt-VBR/CBR specified in ATM-Forum.

Example of UNI

Table I.2/G.984.1 – Examples of UNI and services

UNI (Note 1)	Physical interface (Note 2)	Service (Note 3)
10BASE-T (IEEE802.3)	—	Ethernet
100BASE-TX (IEEE802.3)	—	Ethernet
1000BASE- T (IEEE802.3)	—	Ethernet
ITU-T Rec. I.430	—	ISDN (BRI)
ITU-T Rec. I.431	—	ISDN (PRI), T1, ATM
ITU-T Rec. G.703	PDH	DS3, ATM, E1, E3
ITU-T Rec. I.432.5	25 Mbit/s metallic interface	ATM
ITU-T Rec. G.957	STM-1,4	ATM
ANSI T1.102, ANSI T1.107	PDH	T1, DS3

Example of SNI

■

Table I.3/G.984.1 – Examples of SNI and services

SNI (Note 1)	Physical interface (Note 2)	Service (Note 3)
1000BASE- X (IEEE802.3)	—	Ethernet
ITU-T Rec. G.965	V5.2	POTS, ISDN(BRI), ISDN(PRI)
ITU-T Rec. G.703	PDH	DS3, ATM, E1, E3
ITU-T Rec. G.957	STM-1,4,16	E1, ATM
ANSI T1.107	PDH	T1, DS3
ANSI T1.105.06, ANSI T1.117	OC3, OC12	T1, DS3, ATM