Telecommunications Standards Advisory Committee (TSAC)

Next Generation National Broadband Network (NGNBN)

Network Termination Architecture and Requirements

IDA RS NTE
Issue 1 Rev 1, May 2011

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Acknowledgement

The Info-communications Development Authority of Singapore (IDA) and the Telecommunications Standards Advisory Committee (TSAC) like to acknowledge the following members of the Technical Committee Working Group 1 (TSTC WG1) for their invaluable contributions to the preparation of this Reference Specification:

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Content

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Network Termination Architecture and Requirements

1 Scope

1.1 The Next Generation National Broadband Network (NGNBN) refers to a nationwide wired network that is capable of providing access speeds of 1Gbps or more to all physical addresses in Singapore. Most homes, schools, government buildings, businesses and hospitals will be connected to NGNBN, and the network coverage is expected to reach 95 per cent by 2012. There will be a wide variety of services and applications running on this network, and this is expected to result in more economic opportunities, business growth and social vibrancy for Singapore. Figure 1 shows the Service Model and Infrastructure Schematics of the NGNBN.

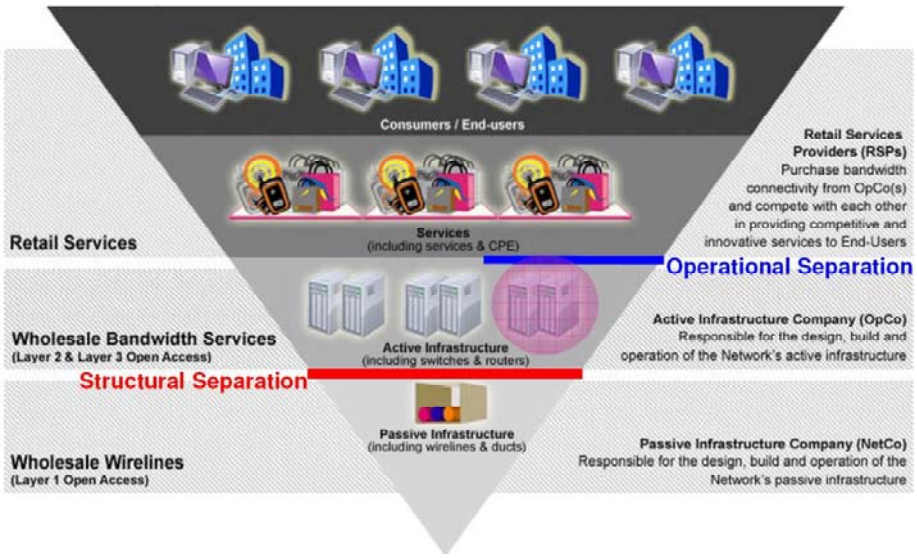

Figure 1: Service Model and Infrastructure Schematics of the Next Generation National Broadband Network (NGNBN)

1.2 This Reference Specification addresses the technical requirements and references pertaining to the Network Termination Point (NTP) of the NGNBN. As the NGNBN relies primarily on optical access technology such as FTTx to connect end users to the network, the scope of this Reference Specification shall cover Gigabit-capable Passive Optical Network (GPON) [2-7], Ethernet Passive Optical Network (EPON) [8] and Active Ethernet (also known as point-to-point Ethernet) [8]. Although the focus is mainly on defining the parameters for the physical layer of the network, some higher layer issues such as IP Multicasting and VLAN will also be addressed. Whenever possible, the Reference Specification will refer to existing international standards and recommendations from organisations such as the International Telecommunication Union (ITU) and the Institute for Electrical and Electronic Engineers (IEEE).

2 Abbreviations

This Reference Specification uses the following abbreviations:

AES	Advanced Encryption Standard
APC	Angle Polished Connector
ATM	Asynchronous Transfer Mode
CU	Point on the fibre joint (connector/splice) just before the NTE
EPON	Ethernet Passive Optical Network
FEC	Forward Error Correction
GEM	GPON Encapsulation Method
GPON	Gigabit-capable Passive Optical Network
IGMP	Internet Group Management Protocol
MIB	Management Information Base
MLD	Multicast Listener Discovery
MPCP	Multi-Point Control Protocol
NBN	National Broadband Network
ND	Not defined
NE	Network Equipment
NGNBN	Next Generation National Broadband Network
NGN	Next Generation Network
NTE	Network Terminating Equipment
NTP	Network Termination Point
ODN	Optical Distribution Network
ONT	Optical Network Terminal
OpCo	Operating Company
OSI	Open Systems Interconnection
PR	Symmetric-rate
PRX	Asymmetric-rate
PtP	Point-to-Point
SNI	Service Node Interface
SP	Point on the fibre joint (connector/splice) just after the NE
TDMA	Time Division Multiple Access
UNI	User Node Interface
VLAN	Virtual Local Area Network

3 Definitions of Various Interfaces

3.1 A generic representation of the NGNBN physical network is schematically shown in Figure 2. There are various interfaces in the network and the focus of this Reference Specification is on the two interfaces: the NTP and the CU, as well as the optical fibre patch cord that connects these two interfaces.

3.2 The NTP or the network termination point is the interface between the optical distribution network (ODN) and the fibre patch cord that connects the network terminating equipment (NTE) to the NGNBN. The NTE could be an optical network terminal (ONT) as defined in the GPON or EPON specifications, and it could also function as a home gateway. However, the exact definition of the NTE is beyond the scope of this Reference Specification. The CU is the interface between the fibre patch cord and the NTE. This interface will most probably exist within the optical connector of the NTE in most situations.

3.3 The optical fibre patch cord is an important part of the entire optical link between the service provider's equipment at the central office and the NTE at the user's premises, and thus its characteristics are also defined in this Reference Specification. Finally it should be pointed out that the design and implementation of the optical distribution network (ODN) of the NGNBN is not covered by this Reference Specification. The ODN could be a point-to-multipoint optical network used by GPON and EPON or it could be in the form of a point-to-point link used by Active Ethernet.

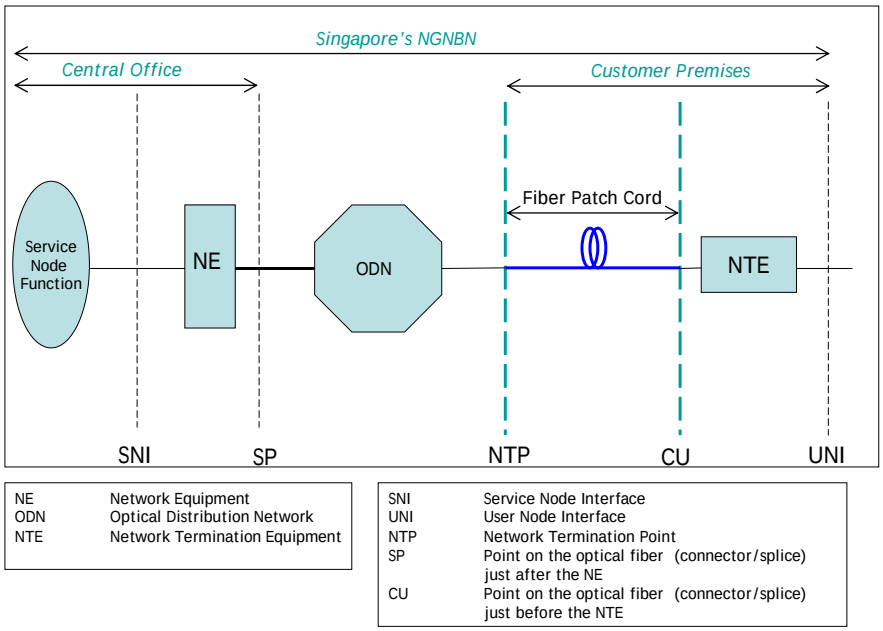

Figure 2: Definition of various interfaces in the NGNBN

4 Definition of Network Layers

4.1 The network layers of the NGNBN architecture corresponds to the Open System Interconnection Reference Model (OSI Reference Model or OSI Model) [15] as shown in Table 1. Based on OSI Model, the definitions for L1 to L7 are:

L7: Application Layer
L6: Presentation Layer
L5: Session Layer
L4: Transport Layer
L3: Network Layer
L2: Data Link Layer
L1: Physical Layer

4.2 The transmission medium is actually not part of the OSI networking layers so a L0 layer is proposed and added. The L0 layer defines the various transmission media such as optical fibres, patch cords, connectors, and so on. For the L1 and L2 layers, the recommended specifications for NGNBN will be mainly derived from GPON, EPON and Active Ethernet. For L3 and above, the implementations are usually vendor and application dependent, and thus the content of these layers will be outside the scope of this Reference Specification.

Table 1: Definition of Network Layers for NBN

<table>
<tr><th></th><th colspan="2">GPON</th><th colspan="2">EPON</th><th colspan="2">Active Ethernet</th></tr>
<tr><td>L7</td><td colspan="6">Application dependent</td></tr>
<tr><td>L6</td><td colspan="6">Application dependent</td></tr>
<tr><td>L5</td><td colspan="6">Application dependent</td></tr>
<tr><td>L4</td><td colspan="6">Application dependent</td></tr>
<tr><td>L3</td><td colspan="6">Application dependent</td></tr>
<tr><td>L2</td><td rowspan="2">OMCI Control Channel
ITU-T Rec. G.984.4</td><td>Transmission Convergence Layer
ITU-T Rec. G.984.3</td><td>OAM Mac Sub-layer[1]
IEEE 802.3ah-2004 (section 57)</td><td>MPCP
IEEE 802.3ah-2004 (section 64)</td><td>OAM Mac Sub-layer[1]
IEEE 802.3ah-2004 (section 57)</td><td>MAC Layer
IEEE 802.3ah-2004</td></tr>
<tr><td>L1</td><td>PMD Layer
ITU-T Rec. G.984.2, G.984.6</td><td></td><td>PHY+MII+Recon Layers
IEEE 802.3ah-2004</td><td></td><td>PHY+MII+Recon Layers
IEEE 802.3ah-2004</td></tr>
<tr><td>L0*</td><td colspan="6">Transmission medium: Fibers, patch cords, connectors
ITU-T Rec. G.652, G.657; TIA/EIA-568; IEC 61754.x</td></tr>
</table>

Note 1: The Operations Administration and Management (OAM) sub-layer is defined as optional in IEEE 802.3ah-2004.

5 Optical Fibre Patch Cord Specifications

5.1 The specifications for the optical fibre patch cord between the NTP and the CU is shown in Table 2. While GPON and EPON both have identical requirements, the fibre patch cord specifications for Active Ethernet will not be defined in this Reference Specification. This is because some of the existing networks that are not part of NGNBN may have already used Active Ethernet. Therefore, the specifications are intentionally designed to be flexible enough to accommodate these networks into the NGNBN in the future. It is also to be noted that this Reference Specification imposes a maximum length limit of 5m on the fibre patch cord, after taking into consideration some of the technical and implementation issues.

Table 2: Fibre Patch Cord Specifications

	Interface	GPON	EPON	Active Ethernet
Fiber Type	NTP	ITU-T Rec. G.657a, G.652d		ND
	CU	ITU-T Rec. G.657a, G.652d		
Connector type	NTP	SC		ND
	CU	ND		
Connector polish	NTP	APC		ND
	CU	APC		
Length		< 5m		ND

Note: The SC connector has been standardized as FOCIS 3 (Fibre Optic Connector Intermateability Standards) in EIA/TIA-604-03.

5.2 The connector type at both ends of a fibre patch cord may be different so it is separately defined for the NTP and the CU interface. However, it is recommended that the polish type for both ends to be of the same so as to eliminate the possibility of connector mismatch due to improper installation of the patch cord. The connector type for the NTP is SC type, but for the CU interface, it will not be defined. The polish type for both NTP and CU should be angle-polished connector (APC).

Laser Light Safety Precaution

Caution: ***Caution: Laser light can damage the human eye at high power levels. Do not look directly into the end face of a fibre or a connector.***

To prevent accidental exposure to laser light from the fibres, it is recommended to orientate the connectors of the termination box (at the NTP) downwards toward the floor (Figure 3).

Figure 3: Wall-mounted termination box (Courtesy of OpenNet)

6 Bit Stream and Protocol

As the NGNBN is an open access network, different optical access technologies can be implemented using a common physical layer infrastructure. This Reference Specification specifies three such technologies: GPON, EPON, and Active Ethernet. Table 3 shows the different characteristics of the data traffic for each technology.

Table 3: Bit Stream and Protocol for Different Optical Access Technologies

		Traffic Direction	
		Down	**Up**
Traffic Type	GPON or EPON	Continuous	Burst / TDMA / Delayed
	Active Ethernet	Continuous	
Protocol	GPON	ATM &/or GEM	ATM / GEM
	EPON	MPCP Ethernet (FEC optional)	
	Active Ethernet	Point-to-point Ethernet	

Notes:
1. The “down” direction refers to downstream traffic from the network equipment (NE) at central office to the NTE while “up” direction refers to the upstream traffic from NTE to NE.
2. GEM refers to GPON Encapsulation Method
3. ATM refers to Asynchronous Transfer Mode.
4. MPCP refers to Multi-Point Control Protocol.

7 Bit Rates

The data stream bit rates for GPON, EPON, Active Ethernet are shown in Table 4. In the case of GPON, when transmission at the maximum bit-rate is not required, a set of lower bit rates can also be selected. In addition, this Reference Specification also includes the 10G-EPON specifications [13].

Table 4: Bit Rates (Mbps)

GPON [1]	**Down**	1244.16	1244.16	1244.16	2488.32	2488.32	2488.32	2488.32
	Up	155.52	622.08		155.52	622.08	1244.16	
EPON [2]		1250						
10G EPON [3]	**Down**	10312.5			10312.5			
	Up	10312.5			1250			
Active Ethernet (Nominal)		10 [4]		100 [2]	1000 [2]		10000 [3,5]	

Notes:
1. ITU-T Rec. 984.2 [3]
2. IEEE 802.3ah-2004 [8]
3. IEEE 802.3av [13]
4. IEEE 802.3(a-j) [14]
5. IEEE 802.3ae [21]

8 Wavelength Assignment

The wavelength assignment for point-to-point and point-to-multipoint networks is shown in Table 5. Unlike GPON or EPON where a single fibre is used for both upstream and downstream transmission, Active Ethernet can be implemented using a dual fibre option using separate fibres for upstream and downstream transmission.

Table 5: Wavelength Assignment (nm)

(a) Point-to-point

Active Ethernet					
ITU.T Rec. G.985		IEEE 802.3ah - 2004			
		Upstream		Downstream	
Upstream	Downstream	Single fiber	Dual fiber	Single fiber	Dual fiber
1260 ~ 1360	1480 ~ 1580	1260 ~ 1360	1260 ~ 1360	1480 ~ 1500	1260 ~ 1360

(b) Point-to-Multipoint

GPON		EPON		10G-EPON	
Upstream (Single fiber)	Downstream (Single fiber)	Upstream	Downstream	Upstream	Downstream
1260 ~ 1360	1480 ~ 1500	1260 ~ 1360	1480 ~ 1500	1260 ~ 1280 (PR) 1260 ~ 1360 (PRX)	1574 ~ 1580

Notes:
PR: Symmetric-rate, 10Gbit/s downstream and 10Gbit/s upstream
PRX: Asymmetric-rate, 10Gbit/s downstream and 1Gbit/s upstream [13]

Analogue Video Overlay

Analogue video services can be implemented using the 1550nm to 1560nm wavelength band in GPON (ITU-T G.984.5) and EPON.

9 Optical Return Loss

Excessive optical return loss is detrimental to the performance of PON networks as it increases the likelihood of errors in the transmitted data. Table 6 shows the maximum tolerable optical return loss of the ODN when measured from the NTP interface.

Table 6: Optical Return Loss of ODN (dB)

GPON	ITU-T G.984(Class A)	32
	ITU-T G.984(Class B)	
	ITU-T G.984(Class C)	
EPON	IEEE 802.3 ah – 2004	20
10G-EPON	IEEE 802.3 av	20
Active Ethernet	IEEE 802.3 ah – 2004	ND*

Notes:

* A maximum tolerable return loss of 12dB is defined for a standards compliant transmitter.

10 Transmitter Launch Power

The transmission launch power for the GPON/EPON ONTs and Active Ethernet networking devices at the CU interface is defined in Table 7. The minimum and maximum power limits ensure that the optical transceivers conform to safety requirements and at the same time meet performance specifications when the transmitted data is detected at the central office.

Table 7: Transmitter Launch Power at Interface CU

(a) Point-to-point

Bit rate (Mbit/s)	Class	Launch Power (dBm)		Standards
		Min	Max	
100		-15	-8	802.3ah- 2004 100BASE-LX10
100		-14	-8	802.3ah- 2004 100BASE-BX10
1000		-9	-3	802.3ah- 2004 1000BASE-LX10
1000		-9	-3	802.3ah- 2004 1000BASE-BX10
10000		-1	4	802.3av- 2009 10GBASE-PR-U1
10000		4	9	802.3av- 2009 10GBASE-PR-U3

(b) Point-to-multipoint

Bit rate (Mbit/s)	Class	ONT		Standards
		Min	Max	
		1260-1360nm		
155.52	A	-6	0	GPON: G984 series
	B	-4	2	
	C	-2	4	
622.08	A	-6	-1	
	B	-1	4	
	C	-1	4	
1250		-1	4	EPON:IEEE 802.3ah 1000BASE-PX10, 1000BASE-PX20
10312.5 / 10312.5 (Downstream/Upstream)		-1 4	4 9	10G-EPON:IEEE 802.3av D3.4 10GBASE-PR-U1 10GBASE-PR-U3
10312.5 / 1250 (Downstream/Upstream)		-1 0.62	4 5.62	10G-EPON:IEEE 802.3av D3.4 10/1GBASE-PRX-U1/U2 10/1GBASE-PRX-U3
1244.16	A	-3 -2*	2 3*	GPON: G984 series
	B	-2	3	
	C	2	7	
2488.32	A	0.5	5	
	B	0.5	5	
	C	0.5	5	

Notes: * Applicable for power levelling schemes

11 Receiver Sensitivity

Table 8 shows the different receiver sensitivity requirements for two optical access scenarios at CU: (a) point-to-point and (b) point-to-multipoint. The received optical power measured at the CU interface should never exceed the overload limit to prevent damaging the optical transceiver in the ONT or Ethernet networking equipment.

Table 8: Receiver Sensitivity at Interface CU

(a) Point-to-point

Bit-rate (Mbit/s)	Class	Sensitivity (dBm)		Standards
		Min. Sens	Overload	
100		-25	-8*	802.3ah- 2004 100BASE-LX10
100		-28.2	-8*	802.3ah- 2004 100Base-BX10
1000		-19.5	-3*	802.3ah- 2004 1000Base-BX10 1000Base-LX10

(b) Point-to-multipoint

Bit rate (Mbit/s)	Class	Sensitivity		Standards
		Min Sens	Overload	
1250		-24	-1 +4*	1000BASE-PX10
		-27	-6 +4*	1000BASE-PX20
10312.5 / 10312.5 10312.5 / 1250		-20.5	+1*	10GBASE-PR-U1 10/1GBASE-PRX-U1 10/1GBASE-PRX-U2
		-28.5	-9*	10GBASE-PR-U3 10/1GBASE-PRX-U3
1244.16	A	-25	-4	G984 series
	B	-25	-4	
	C	-26	-4	
2488.32	A	-21	-1	
	B	-21	-1	
	C	-28	-8	

12 Additional Recommendations for Supporting End User Services and Applications

In addition to physical layer (L0 and L1) specifications, this Reference Specification also specifies some requirements for the upper layers (L2 and above) to support end user applications and services. Typical services offered by telecommunication companies include Ethernet connectivity, IP-based voice and video, and TDM circuit emulation. In order to provide such services, the system must satisfy certain minimal requirements and the goal of this Reference Specification is to provide suggestions on these requirements. It should be noted that in actual implementation of services, different providers will have their own unique requirements and thus it is not possible for this Reference Specification to be all encompassing.

12.1 System Requirement for Security

Since GPON and EPON is based on an optical broadcast technology, it is inherently less secure compared to point-to-point links using Active Ethernet. In order to ensure the confidentiality of the data in a PON network, it is recommended that encryption be used for both upstream and downstream data. The advanced encryption standard (AES) [17] with at least 128 bit key is recommended for both GPON and EPON.

12.2 System Requirement for VLAN

Service providers can use GPON or EPON to provide a variety of applications to different customers on the same physical network. Virtual Local Area Network (VLAN) tags [18] can be implemented in L2 to allow a service provider to identify a particular customer so that differentiated levels of services can be offered using VLAN tag and priority bits in the tag [19]. It is recommended that the OpCo support IEEE standards 802.1Q, 802.1p and 802.1ad [18-20].

12.3 System Requirement for IP Multicasting

IP multicasting is an important function for supporting streaming media and IP-based video applications. Table 9 shows the system requirements for enabling IP multicasting in both EPON and GPON. These include IGMP (IPv4), MLD (IPv6) and their related features. It is recommended that OpCos adopt the following features.

Table 9: List of Features for Multicast Support in GPON and EPON

	Feature	Reference	EPON	GPON	Remark
1	IGMP v2	RFC2236	YES	YES	Used by hosts to join or leave a multicast group (IPv4)
2	IGMP v3	RFC3376	YES (optional)	YES	Used by hosts to join or leave a multicast group with additional feature of subscribing/excluding a specific set of multicast sources
3	MLD	RFC2710	Not specified	YES	MLD is derived from IGMP V2. It is used in IPv6.
4.	MLD v2	RFC3810	Not specified	YES	MLD V2 is a translation of IGMP V3. It is used in IPv6.
5.	MIB	RFC2933	YES (Optional)	YES	Describes objects/tables for managing IGMP V1 and IGMP V2 (IPv4)
6.	MLD MIB	RFC3019	Not specified	YES	Describes objects/tables for managing MLD (IPv6)
7.	IGMP Snooping/Proxy	None	YES	YES	Feature that allows layer 2 devices (PON) to support IP multicast (IPv4)
8.	MLD Snooping/Proxy	None	Not specified	YES	Feature that allows layer 2 devices (PON) to support IP multicast (IPv6)
9.	Resource and Admission Control	None	YES	YES	Control permission to view channel (view/preview/reject)
10.	DHCP v6	RFC 3315	Not specified	Not specified	For assigning IPv6 addresses dynamically
11	Neighbor Discovery Protocol for IPv6	RFC 4861	Not specified	Not specified	For IPv6 nodes to discover each other's presence

13 References

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Annex A

Corrigendum / Addendum

Changes to IDA RS NTE Issue 1, Mar 10			
Page	**RS Ref.**	**Items Changed**	**Effective Date**
–	–	Change of IDA's address at cover page to Mapletree Business City.	1 May 11