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NATIONAL BROADBAND NETWORK OPTICAL ACCESS

RELEASE 1

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National Broadband Network – Optical Access

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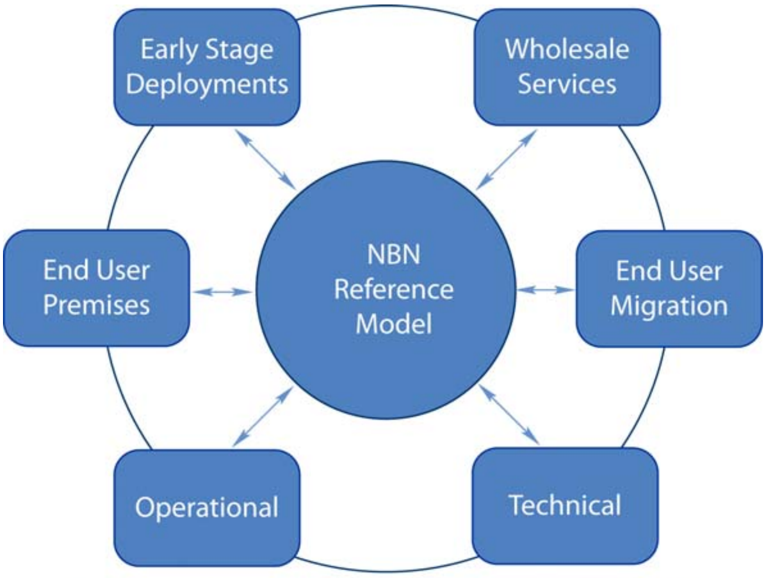
1 GENERAL

1.1 Introduction

The Communications Alliance NBN Technical working group developed the description of the generic elements in the passive optical infrastructure in this document.

1.2 Relationship with other Communications Alliance NBN Working Groups

1.2.1 The work of the Technical working group is related to activities within other NBN Project working groups in Communications Alliance. The general relationships can be seen in Figure 1.



Communications Alliance - NBN Reference Architecture - Release 1 - Jan 2010

FIGURE 1

Communications Alliance NBN Project Working Group Structure

1.2.2 The Technical working group is one of seven working groups established by Communications Alliance to address industry requirements for the National Broadband Network (NBN). The other six working groups address:

(a) **NBN Reference Model** - The NBN Reference Model working group has developed a reference model that seeks to identify within the NBN framework:

- the roles and responsibilities of Service Providers,
- key principles related to End Users,
- key principles related to Services, and
- key principles related to Interconnection of Networks.

(b) **Wholesale Services** - The Wholesale Services working group is developing high level service definitions relevant to the National Broadband Network (NBN) that will be required in an

NBN framework and supplied by NBN Co, FTTP greenfields carriers and other broadband access providers.

(c) **Early Stage Deployments** - The Early Stage Deployments working group is developing guidelines for infrastructure for Fibre To The Premises (FTTP) developments, plus information to guide stakeholders such as planning authorities, approvals bodies, premises owners and constructors that draws upon industry best practices.

(d) **End User Premises** - The End User Premises working group is developing advice on NBN installation practices for end-user premises, guidelines on in-premises distribution and suggested procedures for testing and provisioning services. The types of end-user premises include business, residential (including multi-dwelling), government, educational, infrastructure and backhaul sites.

(e) **End User Migration** - The End User Migration working group is defining processes, procedures and systems requirements to smooth the movement of services between the existing networks and the NBN.

(f) **Operational** – The Operational working group is proposing approaches to enable the best possible customer experience in provisioning, assurance and billing of NBN services.

1.3 Scope

This document defines the generic elements in the passive optical infrastructure, providing an explanation of the vocabulary of the passive optical network, its building blocks, and the technical issues which must be considered and resolved for the NBN.

NOTES:

1. This document presents a range of scenarios and options that Communications Alliance working groups have identified with the purpose of facilitating broader NBN discussion and decision making for NBNs. It does not represent the preferred position of Communications Alliance, its individual members, or the communications industry.

2. While the scenarios presented in this paper are technically feasible, any agreed final set of scenarios will require tradeoffs between technical and operational complexity versus requirements for maximum flexibility in support of functional and service requirements. These issues will need further analyses as part of more detailed Communications Alliance work stream activities.

1.4 Future Work

Areas identified for a future release include:

(a) the means to realize passive (dark fibre, dark PON) wholesale services.

(b) capabilities and fitout of a FAN site.

2 DEFINITIONS AND ABBREVIATIONS

2.1 List of terms

A current list of terms and their definitions is available at:
https://commswiki.dgit.biz/index.php/Agreed_Term_Definitions

2.2 Definitions and Abbreviations

Refer to Table 1 for a list of definitions and associated abbreviations used in the Guideline.

TABLE 1
Abbreviations and Definitions for Terms

Term	Abbreviation (where relevant)	Definition	Comments / References
Fibre Access Node	FAN	Active optical access equipment (e.g. OLTs, Aggregration Switches). The optical access equipment is collectively termed an *Access Node* by the Broadband Forum in TR-156.	The word “exchange” has been used in Australia over time to refer to both a building and the equipment within the building. NBN Co have adopted the expression Fibre Access Node (FAN).
Fibre Access Node Site	FAN Site	The building or cabinet used to house a FAN.	The word “exchange” has been used in Australia over time to refer to both a building and the equipment within the building. The American expression Central Office (CO) refers to the building. NBN Co have adopted the expression Fibre Access Node (FAN) Site.

2.3 Other Abbreviations

Other abbreviations used in the Guideline and their meanings are:

2.5 PON	2.5 Gbps Gigabit Passive Optical Network
10 GPON	10 Gbps Gigabit Passive Optical Network
APC	Angled Physical Contact
AWG	Arrayed Waveguide Grating
FAT	Fibre Access Terminal
FDH	Fibre Distribution Hub
FTB	Fibre Termination Box
FTTP	Fibre to the Premises
Gbps	Gigabits per second
GPON	Gigabit Passive Optical Network
NBN	National Broadband Network
ODF	Optical Distribution Frame
ODN	Optical Data Network
OLT	Optical Line Termination
ONT	Optical Network Termination
OSP	Outside Plant
PON	Passive Optical Network
PTP	Point To Point
RF	Radio Frequency
RSP	Retail Service Provider
WDM	Wave Division Multiplexing

3 THE PASSIVE OPTICAL NETWORK

3.1 Model Network and Terminology

3.1.1 In order to discuss issues associated with the Passive Optical Network, it is useful to define the generic elements used to construct modern optical networks supporting both point to point and point to multi-point services (refer to Figure 2).

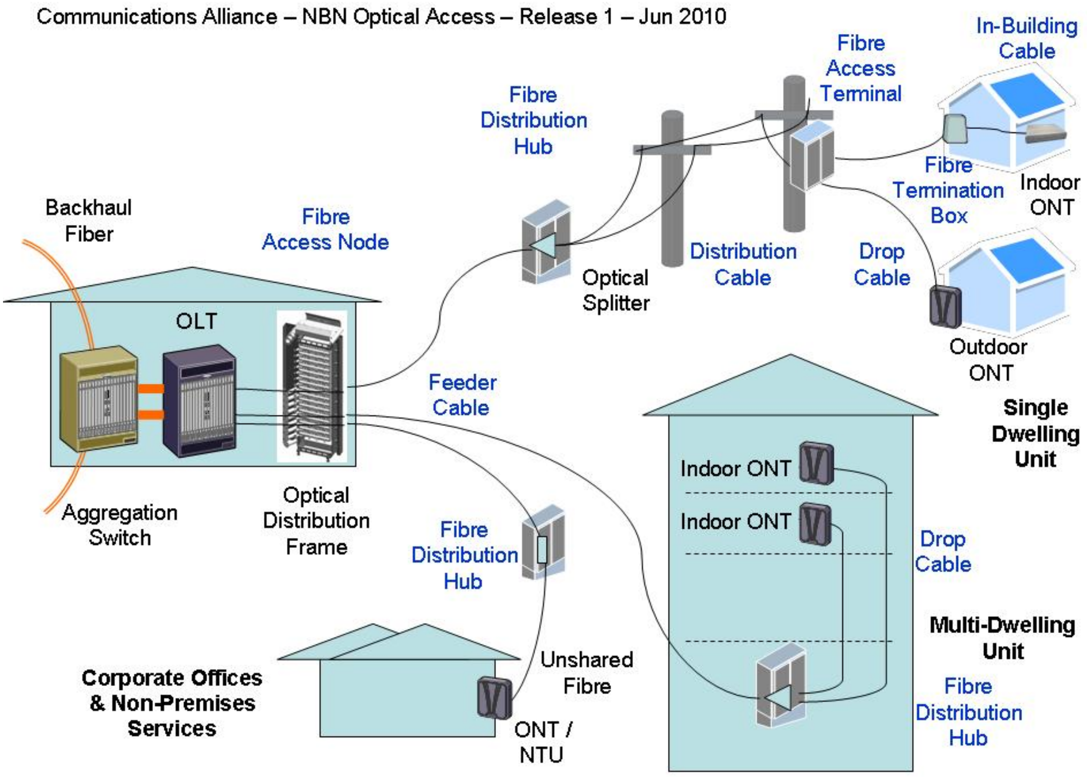


FIGURE 2

Generic elements of optical networks

3.1.2 An Optical Access Network originates from a FAN site, where the Optical Line Terminal (OLT) equipment connects to the Feeder Cables through an intermediate Optical Distribution Frame (ODF).

3.1.3 Feeder cable runs are the longest cable runs (potentially tens of kilometres), and the fact that the cable comes on fixed length drums to allow transport and handling, means that the fibres need to be connected by fusion splicing. There are optical losses resulting from attenuation of the optical signal along the length of the fibre cable, and additional losses introduced with splicing. For robustness feeder cables are generally deployed underground.

3.1.4 Feeder cables typically have a high fibre count (tens to hundreds of fibres) and reach from the FAN site to one or more Fibre Distribution Hubs (FDH). To reduce civil works costs it is common for the feeder cables to several FDHs to share a common physical route in a common duct or trench. The route can be linear, or in rings.

3.1.5 While Figure 2 shows a simple branching tree topology, an alternative topology in which the feeder cables are connected in loops from the FAN is possible. In this case an FDH has two diversely routed paths back to the FAN. Such a topology allows for service to be sustained when a feeder cable is cut. However the reach of the feeder cable network may be constrained as both paths must fit within the optical budget. A looped feeder topology is thus more appropriate in densely populated areas.

3.1.6 A Fibre Distribution Hub (FDH) is an optional network element that provides a local convergence point, housing optical splitters that link feeder cables from the FAN to distribution cables serving individual premises or non-premises locations (e.g. traffic light controllers, wireless base stations, etc.). Its compact size and modular-based platform aid in installation efficiency, while keeping initial deployment costs down.

3.1.7 FDHs have the benefit that they allow for an easily accessible test point in which fibres can be tested to the FAN and to the individual premises without the optical splitter in line. Leaving a vacant test point on each splitter in an FDH can also be used to easily measure optical power through the splitter without disrupting the service for end-users.

3.1.8 FDHs come in a range of sizes (i.e. capable of connecting tens to hundreds of end users) and styles (e.g. free-standing, wall mounted, underground). As they contain no electronics they do not require any power or ventilation, and they are relatively compact. They typically contain multiple sections for fibre management of feeder and distribution cable terminations, housing of splitters and patch panels, and "parking lots" for unused feeder and distribution cables.

3.1.9 Optical splitters/combiners are modular passive devices. They are available in a range of "fan-out" ratios (e.g. 1:4, 1:8, 1:16, 1:32, etc.). For increased reliability splitters with multiple upstream connections (e.g. 2:32) can be used to support redundant feeder cable connections in looped feeder topologies. For point to point (PTP) services a pass through connection (1:1) can be used.

3.1.10 Distribution cables extend from the FDH to outside end-users' premises or to non-premises locations (e.g. traffic light controllers). They:

(a) are typically short in length(<2km), compared to feeder cables;

(b) have a medium fibre count (i.e. low tens of fibres);

(c) are available in a number of forms (e.g. factory-made customised modular cables, blown-fibre through plastic micro-ducts, and field-terminated conventional cables); and

(d) can be manufactured for both aerial and underground deployments.

3.1.11 The different forms of construction techniques and technologies can result in a trade-off of:

(a) capital costs (aerial is cheaper than underground);

(b) robustness (underground is more robust than aerial); and

(c) speed of deployment/restoration, and optical budget (with different numbers of connectors and/or splices required).

3.1.12 A Fibre Access Terminal (FAT):

(a) is a small cable enclosure that allows individual fibres in a distribution cable to be separated out and spliced/connected to the drop cable to an end-user's premises;

(b) is a completely passive and sealed enclosure; and

(c) can be pole or wall mounted, or installed underground in a pit.

3.1.13 Drop cables, also known as lead-in cables:

(a) are relatively short (typically <200m);

(b) have a low fibre count (i.e. 1-8 fibres);

(c) only have to reach from the FAT to the outside wall of the end-user premises;

(d) are available in a number of forms (e.g. factory-made modular cable, blown-fibre through plastic micro-ducts, and field-terminated conventional cables); and

(e) can be manufactured for both aerial and underground deployments.

3.1.14 A Fibre Termination Box (FTB) is a small weather-proof enclosure which provides for the transition from the drop cable to in-building cabling. It is located so as to be accessible to field staff (e.g. typically on the outside of an exterior wall of the end-user premises) in order to facilitate testing and trouble-shooting.

3.1.15 When an outdoor ONT is used, the FTB is effectively provided within the weatherproof enclosure of the ONT.

3.1.16 When an indoor ONT is used, in-building fibre cables (typically "bendable" fibre cables or blown fibre through micro-duct) are used from the FTB to an internal wall plate. These fibres can be run in wall cavities, ceiling space or surface mounted. A loose fibre cable or "fly lead" is used to connect from the wall plate to the ONT.

3.1.17 A connector is always used to connect the fibre to the ONT. SC/APC connectors have proven to be popular and practical for this connection.

3.1.18 Figure 2 includes an example of a dedicated optical path to end-user premises such that there is no splitter used. This optical path could be used by a wide range of active technologies (e.g. point to point (PTP) Ethernet) as well as GPON. While the individual optical path is unique it nonetheless shares the same cable sheaths and enclosures as the other shared optical services (e.g. residential GPON). The ONT/NTU may be significantly different from mainstream residential or business ONT/NTU.

3.1.19 Figure 2 also includes a reference to "non-premises" services. Such services are to locations and devices that are not residential or business premises. Examples are traffic lights, security cameras, utility infrastructure (e.g. power transformers), and telecommunications facilities (e.g. wireless base stations). These services may be shared or dedicated, and may be connected after the FDH or FAT. The Reference Model shows them as potentially being layer 1 (dark fibre or dark PON), layer 2 (wholesale Ethernet) or layer 3 (wholesale IP) depending on what wholesale services are offered by the NBN operator.

3.2 Optical Budget

3.2.1 The fundamental design constraint for a FTTP network is the optical power budget, which is defined by the available launch power of the optics at the PON interface and the receiver sensitivity at the receiving interface. Refer to ITU-T G.984.2 Amendment 1 for recommended ranges for the:

(a) transmitter and receiver optical power levels for GPON interfaces (in Table III.1); and

(b) optical link budget (in Table III.2).

3.2.2 Unlike copper networks using DSL technologies, in which the speed of the access connection decreases as distance increases, optical networks will deliver a constant access speed irrespective of distance. However should the optical budget be exceeded the optical connection will suffer an increased bit error rate (BER) which may degrade the user experience of some applications (e.g. video) or slow communications due to retransmissions. It is only when the optical budget is greatly exceeded (e.g. by a crushed cable or dirty connector) that communications will fail entirely.

3.2.3 The factors that define the limits of the PON are:

(a) the limitations of the protocols in use (e.g. GPON, EPON). For example GPON has both maximum and minimum lengths of the optical path, as well as a maximum distance between the furthest and closest subscribers of <20km.

(b) the accumulation of optical power losses from the OLT to the ONT due to attenuation along the cable caused by the type and length of fibre and the wavelengths used.

(c) splices or connectors in the fibre.

(d) power reduction due to splitting.

(e) coupler/combiner to support the inclusion of a Radio Frequency (RF) Overlay (1550nm) or to allow for future co-existence with 10G PON (1271nm/1577nm) on the same passive infrastructure.

(f) misalignment/reflections at connector junctions.

(g) safety margins to account for ageing and maintenance of the passive network.

(h) tolerances (The laser transmit power has a tolerance, as does the receiver for overload and minimum received power.)

(i) use or not of Forward Error Correction (FEC) (FEC should not be required for normal operation.)

3.2.4 The optical budget quantifies a wide range of engineering decisions and trade-offs. It requires a careful balance of capital cost, operating cost, reliability, and service capability.

3.2.5 The output of an optical budget is the upstream and downstream optical margins, i.e. the extra loss that can be incurred before the access service is likely to fail. What constitutes an acceptable optical margin (i.e. a “margin of safety”) is a matter of technical and commercial judgment by the operator.

3.2.6 Typical budget calculations will allow for the losses due to the architecture and technologies used in the network and then specify a typical fibre length taking account for future performance degradation of the elements employed.

3.2.7 An example of an optical budget for an urban residential design is given below in Figure 3.

3.2.8 The design inputs are:

(a) Desired reach - 10km feeder, 3km distribution + drop.

(b) Provision made for connectorised 10G+2.5G PON combiner at the OLT end.

(c) Connectorised Splitter, 1:32 split ratio.

(d) Spliced FAT.

(e) Connectorised FTB with Indoor ONT.

(f) Margin for passive network ageing and repair splices.

3.2.9 Figure 3 shows the overall design of the passive network with an OLT and ONT attached. Table 2 lists the dimensioning parameters in terms of the components that induce losses in the passive network and shows an example of the resulting optical budget calculation based upon the design inputs and accrued losses.

3.2.10 It can be seen from the calculation in Table 2 that there exists an optical budget margin of 1.90 dB upstream and 3.10 dB downstream. The margin would allow for a greater reach or increased ageing and or repair margin.

Note: This is an example of an optical budget and is not a recommendation.

RF Overlay influence on the Optical Budget

3.2.11 An optical fibre network can have an RF Overlay channel added, which carries signals derived from radio frequency transmissions. These are commonly used to carry television signals and radio stations in a manner similar to Hybrid Fibre Coaxial (HFC) cable networks.

3.2.12 If an RF Overlay is required in the preceding example, allowance must be for an additional coupler/combiner to inject the 1550nm wavelength into the passive network. The insertion loss of this coupler/combiner is approximately 1dB and consequently reduces the optical margin by the same amount in the above example. The design requirements can still be met in this case, however the reduced optical margin in this example translates to a reduced lifetime for the optical plant as fibre cuts and repairs, and aging of the various optical components will eventually eliminate the 1dB margin.

3.2.13 Although out of the scope of this document, the design of the RF Overlay trunk and distribution network needs to ensure that the optical launch power available at the coupler/combiner input to each PON is sufficient to provide the desired picture quality at the ONT RF output given the desired PON reach and the mix of analogue and digital channels.

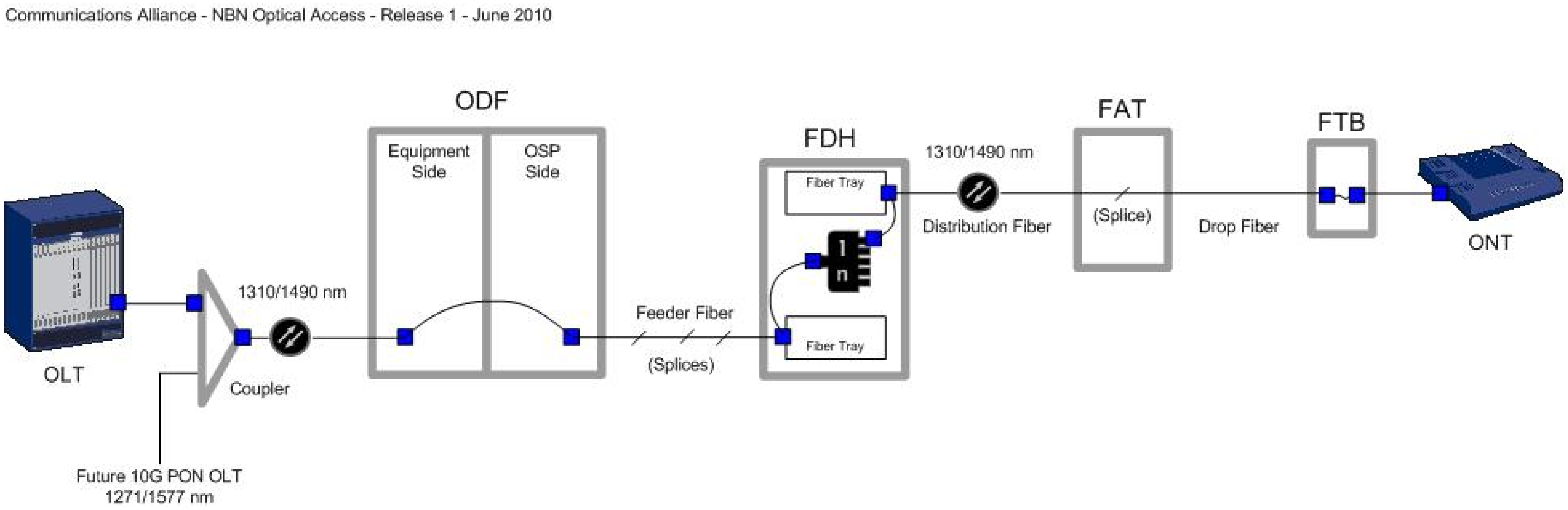


FIGURE 3

Urban Residential 1:32 Split, No RF Overlay, Allowance for 10G PON

TABLE 2

Dimensioning Parameters and Optical Budget Calculation

Dimensioning Parameters			Optical Budget			
Description	**Quantity**	**Values**		**Upstream ONT to OLT 1310nm**	**Downstream OLT to ONT 1490nm**	**Downstream RF Video 1550nm**
RF Overlay Coupler		1 dB				
10G PON Coupler	1	1 dB				
Quantity of CO/ONT connectors	4	0.3 dB per connector	CO Loss	1.2	1.3	
Quantity of OSP connectors	8	0.3 dB per connector	Splitter Loss	17	17	
Quantity of 1:2 splits		3.6 dB	Cable Margin	1	1	
Quantity of 1:4 splits		6.83 dB	Fibre Loss @ required distance	6.40	5.00	
Quantity of 1:8 splits		10.30 dB				
Quantity of 1:16 splits		13.30 dB	Total ODN Loss	26.60	25.40	
Quantity of 1:32 splits	1	17.00 dB	Equipment Power Budget	28.5	28.5	
Quantity of 1:64 splits		21.17 dB				
Total Feeder Length	10	km	Margin	1.90	3.10	
Total Distribution Length	3	km				

3.3 Connectorisation

3.3.1 In Optical Networks, there are many points in which the elements must be connected. These connections may take the form of fibre to fibre connections or fibres to other network elements. In many cases, there are options whether to form the connection via a fibre splice or via connectors. This section aims to outline the issues associated with these connection mechanisms (also refer to Table 3).

3.3.2 The following section provides some general considerations for connectorisation versus splicing followed by some practical considerations at specific points in the optical network.

TABLE 3

General considerations for connectorisation versus splicing

Connectorisation	Fusion Splicing
Lower operator/technician qualification requirement – particularly for customer connection / activation requirements	Lower insertion loss – important for optical budget considerations
Provides greater operational flexibility at aggregation points	Higher reliability over time
Easy test access at critical locations and simplifies testing requirement	Better fibre practices generally employed where splicing is required
Enables easy fibre section isolation for testing and flexibility	Is less expensive than connectorisation at large aggregation points and more compact
Simplifies replacement of small fibre count damaged cable sections	Easier to manage replacement of large fibre count cable sections
Facilitates service by service growth across limited installed PON base	Less likelihood of damage when used in high power applications (i.e. central office locations)

Fibre Access Node Site

3.3.3 The use of connectors in the FAN for patching is recommended to allow fast equipment trouble-shooting and replacement, and equipment upgrades. The SC/APC connector has proven to be the most popular due to its practical size and robustness.

3.3.4 Feeder cables entering the FAN site provide a service aggregation function and often have a mixed use. That is, the services on the cable can be a mix of point to point and point to multi point services such as PON. Connectorisation allows for the services to be readily reconfigured should the need arise for operational reasons or for the capacity management of the cable.

3.3.5 Where dedicated cables are run between equipment within the FAN site, and reconfiguration requirements are unlikely, splicing of the cables provides a higher degree of reliability as well as a lower optical loss.

Feeder Cables

3.3.6 Feeder cable runs are the longest cable runs (potentially tens of kilometres), and may have multiple points such as the end of cable drums or pre determined joint locations at which the fibres must be through connected. Other than in a pre determined joint location, there is no operational reason for accessing individual fibres within a feeder cable and this means that fusion splicing provides a highly reliable and low loss connection method. At joint locations, where the feeder cable is broken down, fusion splicing is recommended as it is unlikely the fibre path will require reconfiguration and a high level of robustness is maintained.

Fibre Distribution Hub (FDH)

3.3.7 Where connecting feeder fibres and distribution fibres to splitters, it is desirable to be able to test the fibre from the FAN and/or to the customer premises. Connectorisation is better suited for this purpose than splicing.

3.3.8 Connectorisation allows for service by service growth to be connected to an active splitter by a field technician without advanced fibre skills. This minimises the number of splitters and active PONs that need be deployed until demand requires their augmentation.

3.3.9 Connectorisation allows for much faster and cheaper transfer of end-users between OLTs in the future as technology changes, i.e. from a 2.5Gbps PON to a 10Gbps PON.

Distribution Cables

3.3.10 Distribution Cables will require a greater number of joints per unit of length than a Feeder Cable. This is due to the fragmented nature of the Distribution Cables as they split more often to feed individual customer premises or FATs. While there are architectures that allow for fibre tubes to remain intact until they reach a FAT, where joints do occur, it is recommended they are spliced.

3.3.11 Underground deployment of Distribution Cables requires that joints will typically be made in pits. As pits are vulnerable to flooding, these joints must be waterproof, further arguing for spliced joints rather than connectors.

Fibre Access Terminal (FAT)

3.3.12 The FAT is the interface point between the Distribution Network and the customer lead-in. Activation will likely be undertaken by a field technician with limited fibre handling skills, so it is recommended that the drop cable (or “lead- in”) interface at the FAT is connectorised, while any other connections within the FAT (i.e. distribution cables that continue on to other FATs) are spliced as these are constructed at the same time as the distribution cables.

3.3.13 Where FATs are located in pits they must be well-sealed against water entry when the pit is flooded.

Fibre Termination Box (FTB)

3.3.14 Where an indoor ONT is used, the FTB is a purely passive device connecting the drop / lead-in cable to the in-building cable. In this case the choice of connectorisation versus splicing is determined by whether the operator requires a test point on the exterior of the premises or is willing to test to a point internal to the customer premises (usually the wall plate).

3.3.15 Where the FTB contains a spliced connection, it is recommended that the splice is a mechanical splice that can be undertaken by the field technician.

3.3.16 Where the FTB is an external ONT, connectorisation is the norm.

Standards

3.3.17 The International Electrotechnical Commissions (IEC) has defined a number of standards for fibre optic connectors including:

(a) IEC 61753-1-1 for general information;

(b) IEC 61753-021-2 for single mode fibres; and

(c) IEC 61753-022-2 for multimode fibres.

3.4 Testing

3.4.1 The ability to test the passive optical network must be designed into the network. In particular consideration needs to be given to:

(a) the commissioning tests associated with the construction and handover of the network (which form a record or baseline for use in later testing); and

(b) the operational tests associated with maintenance of the network after the network has been commissioned.

3.4.2 The commissioning tests typically form part of the contract with cable installers. Every cable is tested (after splices or connectors are installed) and the optical characteristics of the assembled cable path are recorded (typically using an automated test tool). After verification that the cable path is within specifications (and remediation if necessary) the results are delivered as part of the acceptance process.

3.4.3 Operational tests on the passive plant are part of a hierarchy of test processes. As much as possible testing for connectivity and signal quality are done remotely. Ideally no field work would be scheduled until a failure in the passive plant had been diagnosed, however in some cases field troubleshooting may be required to actually diagnose the nature of the fault, or to diagnose its exact location. Connectorisation is used to design in test points (for example at the FDH and FTB) to simplify access to the optical path. Field maintenance technicians are required to exercise scrupulous care when opening testpoints to avoid damaging fibre contacts, and in cleaning fibre contacts before reassembly.

3.4.4 All passive infrastructure, including optical fibre networks, are subject to material aging and environmental damage. Consequently a maintenance regime should be established to test the optical characteristics of all optical paths, and compare the results to the baseline records taken during commissioning tests, in order to identify potential troublespots before they cause service outages. Some network designs build in test access points in the FAN so that test equipment can be introduced and routine testing conducted from the FAN.

3.4.5 There has been a trend around the world to adopt “centralized splitter” designs. With a "centralised splitter" design the FDH is the only point in the outside plant that contains splitters. While splitters can be cascaded through the optical network, such a "distributed splitter" design is more difficult to test (e.g. with an Optical Time Division Reflectometer) and requires more sophisticated record keeping systems.

3.4.6 Refer to Appendix A for links to ITU-T Recommendations on optical fibre characteristics and test methods.

4 OVERARCHING REQUIREMENTS

4.1 Robustness

4.1.1 Optical networks are deployed to support a range of services to varying customer segments. Different customer segments will have varying requirements in relation to the reliability and restoration characteristics of their services. While a network architecture can be developed to suit all service types, such an architecture will not be cost effective to roll out to all customers. It is important to understand the level of robustness of the network deployed to ensure that the network will maximize the potential of service carriage as well as maintaining cost effectiveness of the deployment.

4.1.2 Feeder cables can be used to build a branching tree topology, or a ring. Branching trees are common for residential services, and achieve maximum coverage at the lowest cost; however a cut feeder cable, with perhaps several hundred fibres in a common duct, can be slow to repair and thus leave users without service for an extended period. Loops can be established so that each FDH has a backup path and a backup OLT port, however this is more expensive to build, and the potential coverage is reduced (limiting the topology to high-density areas).

4.1.3 The NBN is assumed to support a major portion of Australia's access traffic, and as such must be reliable on a day-to-day basis, able to provide service in the presence of natural disasters, or when damaged to be promptly restored to service.

4.1.4 These capabilities will require the designing-in of features to automatically handle predictable faults (e.g. perhaps over diverse routes), to quickly identify faults (e.g. perhaps through specific test points), and to quickly restore services (e.g. perhaps through the use of modular cables and ducts).

Feeder Cables

4.1.5 The Wholesale Services working group activity on Ethernet services has introduced the concept of redundant points of interconnection in the FAN that is at the 3a PoI.

4.1.6 One method of realising this redundancy is to use a standard GPON feature which uses a 2:n splitter in the FDH, and diverse routed pairs of feeder cables connecting back to an OLT in the FAN. This approach does not provide redundancy for the distribution and drop cables from the FDH to the user premises. For maximum robustness each side of the pairs of feeder cables would be separately routed to one of a pair of FAN sites; which could necessitate a manual cutover to the backup feeder cables. The adoption of such an approach would mean that the optical budget would be constrained by the longest feeder path, potentially reducing the use of such an approach to high value, short run (e.g. CBD) services.

FDH cabinets

4.1.7 Connectorised distribution cables on splitters can be used to allow the introduction of test equipment.

4.1.8 FDH cabinets can be located to reduce the likelihood of vehicle impact, for example by setting them away from the road.

Distribution Cables

4.1.9 Aerial cables are more susceptible to storm damage, tall machine damage, and bird and insect damage, than underground cables. Underground cables are more susceptible to flooding, and backhoe damage.

4.1.10 The process of repairing a cut distribution cable depends on the type of cable technology used.

(a) blown fibre is repaired by blowing out the cut fibre sections, installing a patch on the micro-duct, and re-blowing and splicing on a connector or fitting a "mechanical" (unspliced) connector. This results in no degradation to the repaired fibre path.

(b) drawn cables are repaired by either:

(i) splicing in a new section of cable leaving a permanently degraded fibre path; or

(ii) running a new cable, either a factory-made modular cable or assembling and splicing a cable in the field, which results in no degradation to the repaired fibre path.

> *NOTE: To allow repair of drawn distribution cables common practice is to provide extra cable length ("slack") so that the cable can be repaired with a single splice, rather than two splices that would be required to insert a new fibre section. Alternatively using modular fixed length replacement cables will leave some "slack". Consequently there must be space provided in pits and on poles to hold the extra slack cable.*

Drop Cables

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  (i) splicing in a new section of cable leaving a permanently degraded fibre path; or

  (ii) running a new cable, either a factory-made modular cable or assembling and splicing a cable in the field, which results in no degradation to the repaired fibre path.

NOTE: To allow repair of drawn drop cables common practice is to provide extra cable length ("slack") so that the cable can be repaired with a single splice, rather than two splices that would be required to insert a new fibre section. Alternatively using modular fixed length replacement cables will leave some "slack". Consequently there must be space provided in pits and on poles to hold the extra slack cable.

User-Premises Robustness

4.1.13 Test points on the outside of the user premises, at a Fibre Termination Box (FTB) or at an outdoor ONT, should be located where they can be quickly and easily reached by field technicians.

4.1.14 Indoor ONTs are susceptible to accidental end-user damage and power loss. Outdoor ONTs are susceptible to malicious damage by third parties and storm damage.

Backhaul Robustness

4.1.15 The Ethernet Wholesale Services Group have introduced the concept of redundant points of interconnection (i.e. diverse PoI) for services carried to a regional location, that is at the 3b PoI.

4.1.16 This approach does not protect services connected to every FAN, but would sustain services to other FANs when one or a few FANs are lost through terrorist attack or natural disaster.

4.2 Future Proofing

Introduction

4.2.1 As the passive plant (e.g. cables, splitters, connectors) and associated civil works represent the largest investment when building the NBN, a future-proof design of the passive plant will be essential.

4.2.2 While the civil works (e.g. trenches, etc.) associated with cable runs are quite expensive, they can be expected to be extremely long-lived and reliable. To ensure adequate future capacity it is normal to provide extra spare cables and also empty ducts to allow further cables to be pulled for future growth.

4.2.3 Similarly the various enclosures (e.g. FDH, FAT) must be designed for future flexibility, by allowing extra capacity in the enclosures.

Anticipating Future Growth in number of Subscribers, Premises, and Devices

4.2.4 There are several reasons why the number of end-points connected to the NBN can be expected to grow to many tens of millions over coming decades. These include:

(a) Population Growth: Government forecasts for population growth[1] anticipate that the population of Australia will grow from approximately 21 million today to approximately 35 million by 2050.

(b) Services Growth: As well as connecting business and residential premises, it is assumed that NBN infrastructure will also be a pervasive resource that will be used for connecting "non-premises" devices, such as traffic lights, surveillance cameras, radio base stations, utility infrastructure, etc.

4.2.5 A well-designed modular approach to the core infrastructure (FANs, feeder cables and FDHs) with ample spare duct capacity in the initial build will allow population and services growth to be dealt with for several decades to come.

Anticipating Demographic Change

4.2.6 There are many reasons why the population of Australia may change its distribution. These include:

(a) Aging Population: may encourage older Australians to leave dense urban areas (e.g. sea/tree changing) and lead to increased for rural/regional broadband.

(b) Increasing Transport Costs: may encourage working Australians to favour high-density urban living and/or teleworking.

(c) Sea Level rise: may threaten major population and infrastructure centres in coastal regions, and could even impact the CBDs of several Australian capital cities, forcing the relocation of FAN sites, and the undergrounding of aerial cable plant.

(d) Government Policy: is encouraging the transition to higher density housing in cities that could exhaust the initially deployed fibre capacity; alternatively previously low population industrial areas could be re-zoned to higher density residential. Other policies may lead to the targeting of selected regional cities for growth, e.g. for the settlement

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[1] Source: Australian Treasury website on the *Intergenerational Report 2010*: http://www.treasury.gov.au/igr/igr2010/Overview/html/overview_05.htm

of refugees and immigrants, and as a way to relieve the pressure on water supplies to existing capital cities.

4.2.7 A well-designed modular approach to the core infrastructure (FANs, feeder cables and FDHs) with ample spare duct capacity in the initial build will allow demographic change to be dealt with for several decades to come.

Anticipating Extended Reach

4.2.8 The target for FTTP coverage of the NBN is 90% of premises. This target covers a strongly urban population, as even in small rural towns the bulk of the premises to be services will be almost as densely settled as business and residential premises in the major cities.

4.2.9 However with technical innovation the reach of GPON can be maximised and further extended. This may allow an even greater number of premises to be reached (e.g. properties on the fringe of cities and towns), and may also allow the same number of premises to be reached with fewer FAN sites thus saving cost.

4.2.10 There are several ways in which GPON reach can be maximised and extended. These include:

(a) Reducing the split ratio: If the split ratio is (for example) 1:32 in urban areas, substantially reducing this split ratio to 1:8 or 1:4 means that more light is available to reach the ONTs (optical modems) and would add many further kilometres to the reach of a PON. Admittedly the cost per subscriber is greater, but the increased cost of the proportion of active equipment is modest in comparison to the cost of cables and civil works for these long runs. A maximum reach of 50-60kms can be achieved in theory.

(b) Higher Transmit Power and Receiver Sensitivity: Newer forms of standard laser optoelectonics (e.g. the use of Class C+ instead of Class B+ laser modules) will be available for the NBN as it commences rollout in 2010, and these modules will thus allow increased reach, or enhanced margin for losses. Also various types of optical amplifier can be used to boost transmit power and receiver sensitivity. Such approaches allow the maximum GPON reach of 50-60kms to be achieved while still connecting multiple subscribers on a PON.

(c) Repeaters: Various approaches that terminate PON traffic and repeat packets onto a compatible medium (typically still using optical fibre) have become available.

4.2.11 It appears that there will be a range of tools available in the next few years which will allow the GPON portions of NBN to be extended in reach. The challenge is likely to be that long-reach connections will require higher costs for the active and (especially) the passive components.

Anticipating Faster Data Rates

4.2.12 The data rates offered to end users can be increased on a GPON access by reducing the split ratio used on each PON, e.g. 1:8 rather than 1:32 would allow an effective throughput increase from 100Mbps to 400Mbps per end-point. However such an approach would also require four times the number of splitters in the FDH and four times the number of feeder cables and PON ports on the OLT.

4.2.13 A more promising approach is that used historically, viz. using higher speed active technologies. 10Gbps is four times faster than today's 2.5Gbps GPON, and can thus achieve a comparable speed increase with no changes to the passive optical data network. However it does require replacing the ONTs (optical modems) and OLT ports.

4.2.14 To achieve even higher speeds such as 1Gbps or more per subscriber, even faster GPON technologies are anticipated.

Anticipating New Active Technologies

Next Generation Access

4.2.15 New access technologies currently being developed and standardized provide for faster access speeds by the use of more wavelengths on the fibre cable. ITU-T Recommendation G.984.5 *Enhancement band for gigabit capable optical access networks* (G.984.5) sets out a band plan of wavelengths to accommodate existing GPON wavelengths alongside wavelengths for the new access technologies, and with optional wavelengths allocated for video overlay and testing.

10Gbps GPON (XG-PON)

4.2.16 This next generation GPON standard uses a higher speed signal encoding such that signals are transmitted at 10Gbps (instead of the current 2.5Gbps). Different wavelengths are used for 10Gbps connections, however these wavelengths are selected such that they can co-exist on the same fibre PON as a 2.5Gbps service. (The band plan for 10Gbps GPON has been standardized in G.984.5. G.984.5 refers to 10Gbps GPON as XG-PON.)

4.2.17 This ability to co-exist on the same PON is intended to facilitate the transition from 2.5Gbps to 10Gbps services. To allow both types to co-exist a special type of filter ("combiner") is used to allow both the 2.5Gbps and 10Gbps OLT ports to be connected to the same feeder fibre. However this combiner introduces a further loss (approximately 1 dB) to the optical budget. Also if co-existence were to be required then the combiners would ideally be inserted when the original cable plant (using 2.5Gbps GPON equipment) is being built.

4.2.18 An alternative transition strategy is to keep 2.5Gbps and 10Gbps PONs separate, with separate PON OLT ports, feeder cables, and splitters, and to move premises from one PON to the other when their 10Gbps PON ONT is installed. To facilitate this approach, the distribution cables should mate with the splitters via a connector. This approach also requires the early installation of extra feeder cables and splitters in FDHs; indeed in the worst case the number of splitters and feeder cables could be double the number required by the previous (co-existence) strategy.

Wavelength Division Multiplexing (WDM) PON

4.2.19 WDM PON is a Next Generation Access system that refers to a range of PON models in which every ONT uses a different transmit/receive pair of wavelengths to/from the OLT. Consequently while the ONTs share a feeder cable, they do not time-share communications. This increases the speed of communications, but there remain a number of technical challenges which have not yet been resolved, such as:

(a) the development of "colourless" ONTs which can automatically discover a pair of wavelengths that they can use, and

(b) thermally stable Arrayed Waveguide Grating (AWG), the WDM equivalent of a GPON passive splitter.

4.2.20 Hybrid PONs have also been proposed, in which multiple 2.5Gbps GPONs transparently work over a common fibre, but use different wavelengths pairs. Thus communication between ONT and OLT is still based on time-sharing.

4.2.21 Today WDM PONs have not yet been completely standardised, and existing pilot installations are limited. Installations in which the approaches in 4.2.19 and 4.2.20 coexist may also prove feasible as a transition strategy.

4.3 Security

4.3.1 The NBN will carry a wide range of different applications/services, for a wide range of service providers and end-users. These will include high-value business services, and services that control important infrastructure (e.g. traffic lights). Consequently it will be expected to deliver a secure broadband access network.

Physical security of outside plant

4.3.2 The enclosures at test points (e.g. FDH, FAT, FTB) must be able to be locked, or secured by special tools.

4.3.3 To minimize malicious damage to outside plant (e.g. pulling down or crushing cables and enclosures, cutting cables, explosion or fire) cables should be in robust ducts (ideally underground) and enclosures located away from the public, and doors or covers secured.

Physical security of end-user equipment

4.3.4 Outdoor ONTs often have multiple locked compartments (e.g. optical fibre handling, user Ethernet and POTS connections, power supply and battery) such that different technicians only have access to specific compartments.

4.4 Environmental Sustainability

4.4.1 Increasingly modern telecommunications will be held to high standards regarding environmental sustainability. As a major consumer of electricity, the NBN operator will be obliged to report on its emissions, and plans to reduce these emissions over time. As a new network, the NBN represents an opportunity to greatly reduce the energy consumed (i.e. equivalent carbon-dioxide emissions) in operating and building the network, as well as other forms of pollution.

4.4.2 Reducing emissions due to operations can be achieved by selecting more efficient optical switch (i.e. OLT) and optical modem (i.e. ONT) technologies, as well as by implementing systems that allow Retail Service Providers (RSPs) and the NBN operator to remotely diagnose problems and reduce field worker travel.

4.4.3 The contribution to life-cycle emissions by the build of the passive infrastructure (i.e. civil works and cables) has been estimated by the FTTH Councils Europe and North America to range from:

(a) greater than 80% (in Europe with underground build); to

(b) less than 10% (in the USA with predominantly aerial build).

4.4.4 There are a range of approaches available to mitigate these emissions including:

(a) Civil works techniques that require less energy (typically diesel fuel) can be preferred (e.g. ploughing in cables rather than trenching),

(b) Purchase of emissions offsets.

4.4.5 Other carriers whose services complement NBN Co, such as transport operators and Retail Service Providers, are also expected to build their networks, and thus their emissions will also increase as an indirect consequence of the construction of the NBN.

4.5 IPv6

4.5.1 There are no issues regarding the use of IPv6 that are raised by the passive optical access network.

5 REFERENCES

Publication	Title
IEC Standards	
IEC 61753-1-1	Fibre optic interconnecting devices and passive component performance standard — Part 1-1: General and guidance—Interconnecting devices (connectors). http://webstore.iec.ch/webstore/webstore.nsf/Artnum_PK/39151
IEC 61753-021-2	Fibre optic passive components performance standard—Part 021-2: Fibre optic connectors terminated on single-mode fibre for Category C—Controlled environment, performance Class S. http://webstore.iec.ch/webstore/webstore.nsf/Artnum_PK/38704
IEC 61753-022-2	Fibre optic passive components performance standard—Part 022-2: Fibre optic connectors terminated on multimode fibre for Category C—Controlled environment, performance Class M. http://webstore.iec.ch/webstore/webstore.nsf/Artnum_PK/29726
IEEE Standards	
IEEE 802.3-2008	IEEE Standard for Information technology— Telecommunications and information exchange between systems— Local and metropolitan area networks— Specific requirements Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications Section 3 http://standards.ieee.org/getieee802/download/802.3-2008_section3.pdf NOTE: Popularly referred to as the GEPON section, formerly IEEE 802.3ah.
IEEE 802.3av-2009	IEEE Standard for Information technology— Telecommunications and information exchange between systems— Local and metropolitan area networks— Specific requirements

	Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications Amendment 1: Physical Layer Specifications and Management Parameters for 10 Gb/s Passive Optical Networks http://standards.ieee.org/getieee802/download/802.3av-2009.pdf NOTE: Popularly referred to as 10Gigabit Ethernet PON, or 10G-EPON.
ITU-T Recommendations	
G.652 (0x/0x)	Characteristics of a single-mode optical fibre and cable http://www.itu.int/rec/T-REC-G.652/en
G.657 (0x/0x)	Characteristics of a Bending Loss Insensitive Single Mode Optical Fibre and Cable for the Access Network http://www.itu.int/rec/T-REC-G.657/en
G.984.1 (03/08)	Gigabit-capable passive optical networks (GPON): General Characteristics http://www.itu.int/rec/T-REC-G.984.1/en
G.984.2 (03/03)	Gigabit-capable passive optical networks (G-PON): Physical Media Dependent (PMD) layer specification http://www.itu.int/rec/T-REC-G.984.2/en
G.984.2 Amendment 1 (02/06)	Gigabit-capable Passive Optical Networks (G-PON): Physical Media Dependent (PMD) layer specification Amendment 1: New Appendix III – Industry best practice for 2.488 Gbit/s downstream, 1.244 Gbit/s upstream G-PON http://www.itu.int/rec/T-REC-G.984.2/en
G.984.5 (09/07)	Enhancement band for gigabit capable optical access networks http://www.itu.int/rec/T-REC-G.984.5/en
G.984.6 (03/08)	Gigabit-capable passive optical networks (GPON): Reach Extension http://www.itu.int/rec/T-REC-G.984.6/en
G.987.1 (01/10)	10-Gigabit-capable passive optical networks (XG-

	PON): General requirements http://www.itu.int/rec/T-REC-G.987.1/en
G.987.2 (01/10)	10-Gigabit-capable passive optical networks (XG-PON): Physical Media Dependent (PMD) layer specification http://www.itu.int/rec/T-REC-G.987.2/en

APPENDIX

A PASSIVE STANDARDS

Possible source documents include:

ITU-T Recommendations

From the G-Series recommendations

Optical Fibre - Test Methods

G.650 Definition and test methods for the relevant parameters of single-mode fibres - divided into G.650.1 and G.650.2

G.650.1 Definitions and test methods for linear, deterministic attributes of single-mode fibre and cable

G.650.2 Definitions and test methods for statistical and non-linear related attributes of single-mode fibre and cable

G.650.3 Test methods for installed single-mode fibre cable sections

Optical Fibre - Characteristics

G.652 Characteristics of a single-mode optical fibre and cable

G.657 Characteristics of a Bending Loss Insensitive Single Mode Optical Fibre and Cable for the Access Network

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