

Network Design Rules

Provided to the ACCC pursuant to and for the purposes of nbn co limited's Special Access Undertaking

29 June 2018





Network Design Rules

29 June 2018

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1 Introduction

These Network Design Rules (NDRs) provide an overview of the current physical network architecture and high level design of nbn co limited's (**nbn**'s) network and network components. The NDRs are linked to **nbn**'s Special Access Undertaking (SAU) – the initial version of the NDRs (dated September 2012) satisfied the requirements of clause 1D.7.1 upon commencement of the SAU on 13 December 2013. This updated version of the NDRs builds on previous updates provided to the ACCC, and satisfies the requirements of clause 1D.6, 1D.7.2 and 1D.7.4 (which relates to how the NDRs will be updated over time).

On 24 August 2016, the Shareholder Ministers provided **nbn** with a new Statement of Expectations (**24 August SoE**), which replaced all previous Statements and contained changes compared with previous Statements provided to it. One of those changes related to the requirement for **nbn** to be mindful of certain market-based principles. In particular, the 24 August SoE included the following key statements:

*"This statement provides guidance to **nbn** to help ensure its strategic direction aligns with the Government's objectives for the delivery of the network. This statement provides **nbn** with flexibility and discretion in operational, technology and network design decisions, within the constraints of the Equity Funding Agreement with the Commonwealth, and the Government's broadband policy objectives...*

...

Broadband policy objectives

*The Government is committed to completing the network and ensuring that all Australians have access to very fast broadband as soon as possible, at affordable prices, and at least cost to taxpayers. The Government expects the network will provide peak wholesale download data rates (and proportionate upload rates) of at least 25 megabits per second to all premises, and at least 50 megabits per second to 90 per cent of fixed line premises as soon as possible. **nbn** should ensure that its wholesale services enable retail service providers to supply services that meet the needs of end users.*

*To achieve these objectives **nbn** should roll out a multi-technology mix network and build the network in a cost effective way using the technology best matched to each area of Australia. **nbn** will ensure upgrade paths are available as required.*

***nbn** should pursue [the broadband policy objectives] and operate its business on a commercial basis. In doing so **nbn** should be mindful of the following principles:*

- **Rolling out the network:** *When planning the rollout, **nbn** should prioritise locations that are poorly served, to the extent commercially and operationally feasible. During the rollout, **nbn** should be guided by the following goals: service quality and continuity for consumers; certainty for retail service providers and construction partners; and achievement of rollout objectives as cost-effectively and seamlessly as possible. **nbn** should apply the Government's new developments policy.*
- **Vehicle for market reform:** *The Government expects the network to be a wholesale only access network, available to all access seekers, that operates at the lowest practical level in the network stack. The completion of the network will enable the structural separation of Telstra and a more competitive market for retail broadband and telephony services. **nbn** should retain optionality for future restructuring or disaggregation.*
- **Market environment:** ***nbn** is a commercial entity operating in a market environment and can compete and innovate like other companies in this environment in accordance with legal and policy parameters.*
- **Funding:** *Taxpayers have made a substantial investment in **nbn**. The Equity Funding Agreement imposes a cap on the maximum amount of equity funding that will be provided by the Government.*



***nbn** needs to remain disciplined in its operations, proactively managing costs to minimise funding requirements and working with the Government to optimise its capital structure.*

- ...”

In accordance with the 24 August SoE, **nbn** will continue to plan and design its network to pursue the Government’s broadband policy objectives, while operating on a commercial basis and being mindful of the market principles set out above.

The NDRs now include the network design for FTTx (including Fibre to the Premises (FTTP) (GPON), Fibre to the Node (FTTN), Fibre to the Building (FTTB) and Fibre to the Curb (FTTC)), Hybrid Fibre Coax (HFC), TD-LTE Wireless, Satellite Access, Transport and Aggregation network domains.

The NDRs have been updated in accordance with clause 1D.7.4 of the SAU to reflect the ongoing development of, and changes to, **nbn**’s network architecture since **nbn**’s last update. This includes (amongst other things) changes to the network design to account for the upcoming introduction of Business Satellite Services, which **nbn** expects to release in the second quarter of 2019. **nbn** is currently consulting with its customers on the Business Satellite Service and may make further changes to its network design as part of more detailed design and implementation work, and customer feedback. If such developments entail further changes to the **nbn**’s network, then **nbn** will include such changes in the next relevant version of the NDRs.

Going forward, **nbn** will continue to periodically update the NDRs to take account of variations, augmentations or enhancements to the design, engineering and construction of **nbn**’s network to reflect the development of new products consistent or in connection with the 24 August SoE (to the extent that those new products give rise to a variation, change, augmentation or enhancement to the design, engineering or construction of **nbn**’s network). An itemised summary of the substantive changes made in this updated version of the NDRs relative to the June 2017 version is provided in Appendix B. A list of non-substantive changes is also now provided in Appendix B, which covers refinements, clarifications and corrections to this document.



2 Network Design

2.1 High Level Design Overview

The **nbn**TM network has been divided into domains to allow for communication of the overall solution.

The target high level architecture is shown in Figure 1. This view includes the IT platforms, which are out of scope for this High Level Design, but must be interfaced to, to achieve a complete working solution. The target high level architecture will not be achieved for a number of years, and will be implemented in steps determined by the services introduced.

The focus of this document is captured in Figure 2. These are the domains for Fibre (GPON), Copper, HFC, LTE Wireless and Satellite.

The high level domains and their functions are as follows:

- **Network:** Key function is the carriage of customer traffic
 - **Access:** Various technology solutions to allow End Users to be connected to the **nbn**TM network. The long term technology domains covered by the NDRs are Fibre (GPON), Copper (VDSL), HFC, Wireless (LTE) and Satellite.
 - **Transport:** Provides transparent connectivity between network elements
 - **Aggregation:** Takes many interfaces from network elements and aggregates them for presentation on fewer interfaces back into network elements and vice versa. Also provides the point of interconnect for access seekers, the customers of **nbn**TM services.
 - **Service Connectivity Network (SCN):** Is the core IP/MPLS network and provides service connectivity for satellite access (RF Gateway to DPC and DPC to satellite central POI site) and flexibility of connectivity within the Aggregation network for support of HFC.
- **National Connectivity Network:** network that does not carry the Access Seeker to/from End User traffic. This network carries OA&M related traffic and signalling traffic.
- **Network Management:** Systems that support the network carrying the customer service traffic. Functions include element management, time information, Authentication, Authorisation and Accounting (AAA) for access to network elements and connectivity between the equipment providing Network Management functions and the Network Elements themselves
- **Control:** those required to operate in real time (or very near real time) to support the establishment of an End User connection through to the Access Seeker
- **Lawful Interception:** support the delivery of replicated customer traffic to Law Enforcement Agencies as legally required by the Telecommunications (Interception and Access) Act 1979.
- **IT Platforms:** Platforms supporting systems required for providing a customer portal, order acceptance, enforcement of business rules (e.g. number of active data services per NTD), activation, fulfilment, assurance and billing. Also includes systems required to interact with Element Management systems to operate the network carrying the customer traffic.

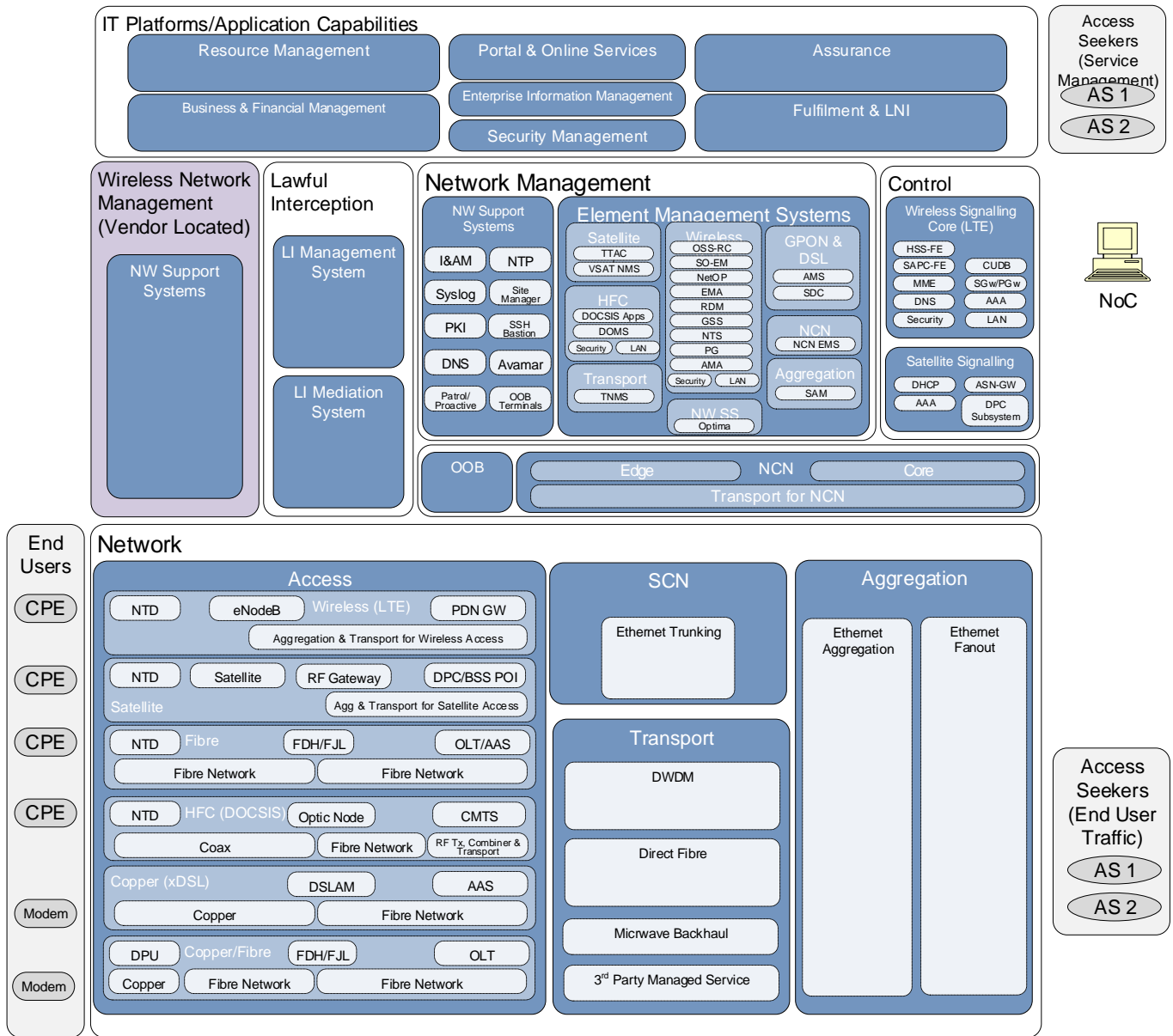


Figure 1 Target High Level Architecture Context Diagram

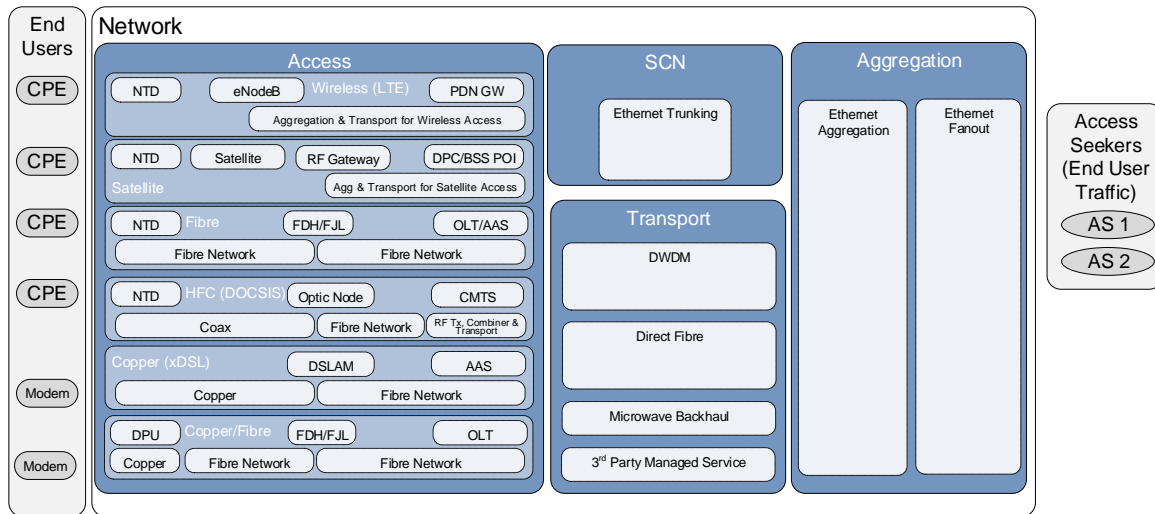


Figure 2 Focus of this Document

The **nbn**TM physical network architecture is designed to provide the required connectivity for **nbn**TM services whilst allowing for the required level of availability and resiliency in an efficient manner.

Each domain has a set of physical network elements that deliver the functionality and interfaces to support the **nbn**TM services.

2.2 Fibre (GPON) Access Domain

The Fibre (GPON) access domain solution consists of the following components:

- GPON NTD (ONT) - The Optical Network Terminal located at the end-user premises uses GPON technology to extend optical cable from an OLT shelf. It delivers UNI-V and UNI-D capabilities to a premises.
- Fibre Network (FN) provides optical pathways between the GPON NTD and OLT. Sections of the Fibre Network are shared by other access domains.
- OLT - The Optical Line Terminal provides FAN Site processing, switching, and control functions. The OLT aggregates GPON networks into a number of network-facing 10Gbps links.

2.2.1 GPON NTD (ONT)

The GPON NTD terminates the incoming physical fibre at the end-user premises and provides one or more User to Network Interfaces (UNI). A number of GPON NTD varieties will be used to suit different circumstances, end-user types and interface quantities. The variants included are Indoor and Outdoor Single Dwelling GPON NTDs. Both have the following:

- 1 x GPON fibre interface
- 2 x UNI-Voice interfaces
- 4 x UNI-Data interfaces
- Support for standard power supply or Uninterruptable Power Supply (UPS)

Indoor GPON NTD variants should be wall mounted inside the **nbn**TM GPON NTD enclosure. Outdoor GPON NTD variants will be permanently fixed to a surface (e.g. interior or exterior wall).

The GPON NTD enclosure combines mounting for a GPON Indoor NTD and a standard power supply with fibre, power and End User service cable management.



There are two basic types of power supply available for each GPON NTD variant; AC to DC standard power supply or power supply with backup. The standard power supply accepts ~240 VAC input and provides 12 VDC towards the GPON NTD via a specialised cable with captive connectors (indoor GPON NTD).

The power supply with backup also accepts ~240 VAC input but includes a battery facility for providing 12 VDC towards the GPON NTD even during an AC mains failure event, until the battery falls below the minimum energy capacity. DC power is fed to the GPON NTD via a specialised cable with captive connectors (indoor GPON NTD) or screw terminals (outdoor GPON NTD), the cable also allows for simple power related alarms to be forwarded from the UPS unit to the GPON NTD.

The UPS can be installed with or without a battery, allowing an Access Seeker or end-user to provide a battery at a later date, and perform maintenance of the battery facility without requiring **nbn** involvement. When there is no battery installed, the UPS operates like a regular AC to DC power supply.

Both the AC to DC power supply and UPS must be installed indoors. When installed with an Outdoor GPON NTD, the power cabling must extend within the premises to the power supply or UPS.

2.2.2 Fibre Network

The NBN Co Fibre Network provides the physical connectivity between the FAN site and the active equipment in the street or building.

The passive network component of a fixed network build comprises a significant part of the overall fixed network deployment. It is generally disruptive and expensive to augment or modify so it is important that the architecture, planning, design, and installation accommodates the long term needs and future growth and capacity. It is **nbn**'s aspiration that these facilities will be suitable not only for the **nbn**TM network's initial technology choice, but for fixed access technologies developed in the future, whatever they may be.

In order to provide a functional and operational network a high degree of uniformity of the passive infrastructure is desirable. Uniformity of design and construction facilitates education and training, the availability of competent staff, and economies of scale and efficiencies in the supply industry in general. Regionalised or localised variations in design or construction practices will be minimised where practical as these differences may disadvantage the affected communities due to the increased costs and complexity of managing variations in technical and operational processes.

The NBN Co Fibre Network includes the Distribution Fibre Network (DFN), the Local Fibre Network (LFN) and Premises Fibre Networks (PFN). The DFN provides the connectivity from the Fibre Aggregation Node (FAN) to the first point where individual fibres can be accessed for a Distribution Area (refer to 2.2.4.1 for description of a Distribution Area). The LFN provides the connectivity from this point towards the premises. The PFN provides the connectivity from the street through to the premises. There are currently two DFN architectures: Loop and Star. Star DFN deployments will be the default design used for all fixed access networks, providing a more cost effective solution. There are also two LFN architectures: LFN and Skinny LFN.

The common denominator of this network is the actual physical fibre strands. **nbn** has selected ribbon fibre technologies due to the cost and labour savings associated with the use of this technology where high fibre numbers are required. The Skinny LFN uses lower fibre count cables with stranded fibres. All fibres are accessible individually. This provides greater flexibility in relation to the deployment of the LFN.

2.2.2.1 Fibre

Ribbon Fibre

Ribbon fibre technology significantly increases the fibre cable core counts available, and also provides significant time savings when joining fibres via fusion splicing when compared to stranded or single fibre particularly where fibre counts are greater than 144. Ribbon fibre cables are available with fibre counts ranging

between 12 and 864 fibres, and these are virtually identical in size and handling characteristics to similarly constructed single fibre cables.



Figure 3 Ribbon Fibre

The cables match the core counts required where all premises require a fibre as part of the access solution (12, 72, 144, 288, 432, 576, and 864) and the 12 fibre matrix suits the modularity of the Factory Installed Termination Systems (FITS). The FITS is a pre-connectorised system which pre-terminates fibres in the Local Fibre Network onto multi-fibre connectors in groups of 12 and multi-ports are then connected into these as required.

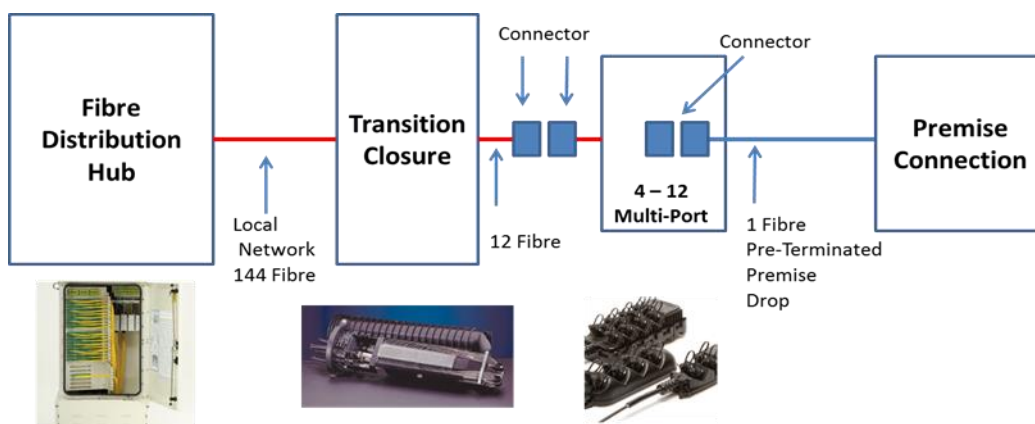


Figure 4 Connector and Multi-port Connections

Stranded Fibre

The stranded fibre cable permits access to individual fibres which in turn allows for a greater degree of flexibility within the LFN. For example, a geographic area may require an allocation of x fibres for an FTTN node + x fibres for FTTB, + x fibres for Fibre on Demand. This requirement to allocate fibres initially and also provides flexibility for in-fill allocation. It allows for access to the fibre on an individual strand level to permit them to be manipulated individually as opposed to groups of 12 fibre ribbons.

The following table provides a summary view of what fibre types and connectors are used in the network:

Network	Fibre Type	Connectors	Standards Reference (see Table 2 below)
DFN - Loop	Ribbon	<ul style="list-style-type: none"> Splice: 36 fibres (3 ribbons) per FDH. 2 ribbons spliced, 1 spare Splice: 288 fibre to multiple TFANs Splice: 72 fibre to single TFAN 	All Fibre Optic Cable

DFN - Star	Ribbon	<ul style="list-style-type: none"> Splice: 12 fibres (1 ribbon) per Distribution Area. DFN trunk cable has >33% spare capacity (for in-fill growth, and to support future technology and product directions) Splice: Input tail or individual fibres at a node (e.g. FTTN Cabinet) 	All Fibre Optic Cable
LFN	Ribbon	<ul style="list-style-type: none"> Splice: FDH (72) Tail to factory installed patch panel Connector: FDH Patching = SC/APC Splice: FDH Tail (e.g. 576) to Multiport Tail (12) Connector: Multiport tail = 12 fibre tether optical connector (proprietary format) Connector: Multiport Single Customer Connection = single fibre optical connector (proprietary format) 	All Fibre Optic Cable
LFN	Ribbon – Aerial	<ul style="list-style-type: none"> Splice: FDH Tail (e.g. 576) to Aerial Cable Splice: Aerial Cable to Multiport Tail (12) Connector: Multiport tail = 12 fibre tether optical connector (proprietary format) Connector: Multiport Single Customer Connection = single fibre optical connector (proprietary format) 	All Fibre Optic Cable
LFN - skinny	Stranded	<ul style="list-style-type: none"> Splice: 12 fibre ribbon splice at DJL to FSD (Flexibility Sheath Distribution), FSD installed into FJL (Flexibility Joint Location) and fibre de-ribbonised. Splice: Individual FSD fibres spliced to 1, 4, or 12 fibre stranded cables Splitter: Individual FSD fibres spliced to 1st stage passive splitter, outgoing splitter tails spliced to 1, 4, or 12 fibre stranded cables (FLS). Splitter: Individual FLS fibres spliced to 2nd stage passive splitter, outgoing splitter tails spliced to 1 fibre SSS cables. Connector: Multi-port Tail or Equipment Tail (Hardened), single fibre connector. Splitter: Connection to 3rd stage optical splitter (an example use of this is uplift from FTTC to FTTP) Connector: Multiport Single Customer Connection = single fibre optical connector (proprietary format) 	All Fibre Optic Cable
LFN - skinny	Ribbon - Aerial	<ul style="list-style-type: none"> Splice: 12 fibre ribbon splice at DJL to FSD (Flexibility Sheath Distribution), FSD installed into FJL (Flexibility Joint Location) and fibre de- 	All Fibre Optic Cable

		ribbonised (1:2 for FTTC, 1:4 or 1:8 for FTTP) <ul style="list-style-type: none"> FJL to aerial BJJ 12 f stranded (1:1 or 1:4 split) Splice FTTP: Aerial cable to Splitter Multiport Tail (1) Splice FTTC: Aerial cable to DPU (1) 	
PFN – SDU	Single Fibre Drop	<ul style="list-style-type: none"> Splice: Single Fibre Fusion Splice to PCD & FWO 	All Fibre Optic Cable + <ul style="list-style-type: none"> Fibre Optic Single Drop Cable Multiport Feeder Cable
PFN – MDU	Ribbon	<ul style="list-style-type: none"> Splice: PDH,FDT tail ,FWO Connector: PDH,FDT,FWO,NTD = SC/APC Connector: FDT,FCD = MPO/APC 	All Fibre Optic Cable + <ul style="list-style-type: none"> Fibre Optic Aerial Cable
PFN – MDU	Single Fibre Drop	<ul style="list-style-type: none"> Splice: Single Fibre Fusion Splice to PCD 	All Fibre Optic Cable + <ul style="list-style-type: none"> Fibre Optic Single Drop Cable

Table 1 Summary of fibre & connector types used in the network

Standards Reference Code	Title / Description
All Fibre Optic Cable	
ITU-T G.652	Characteristics of a Single Mode Optical Fibre and Cable, Table 4 G.652-G.652D attributes.
ITU-T G.657	Bend-insensitive single-mode fibres for access networks and customer premises, Table A2
GR-20-CORE	Generic Requirements for Optical Fibre and Optical Fibre Cable
IEC 60793	Optical Fibres
IEC 60794	Optical Fibre Cables
AS1049	Telecommunication Cables-Insulation, sheath, and jacket
Fibre Optic Aerial Cable	
IEEE 1222	Standard for All Dielectric Self Supporting Aerial Fibre Optic Cable
GR-3152	Generic Requirements of Hardened Multi-Fibre Optical Connectors.
GR-3122	Generic Requirements for a Factory Installed Termination System.
GR-771	Generic Requirements for Fibre Optic Splice Closures
Fibre Optic Single Drop Cable	
ITU-T G.657	Characteristics of a Bending Loss Insensitive Single Mode Optical



Standards Reference Code	Title / Description
	Fibre and Cable, Table A2
GR-3120	Generic Requirements of Hardened Fibre Connectors.
Multiport Feeder Cable	
GR-3152	Generic Requirements of Hardened Multi-Fibre Optical Connectors.
Multiport	
GR-771	Generic Requirements for Fibre Optic Splice Closures
GR-3152	Generic Requirements for Hardened Multi-Fibre Connectors
GR-3120	Generic Requirements for Hardened Fibre Connectors.
MPO / APC	
GR1435	Generic Requirements for Multi Fibre Optical Connectors

Table 2 Fibre Standards Reference Code

2.2.2.2 Distribution Fibre Network - Star

The Distribution Fibre Network (DFN) provides the underground fibre pathways between the FAN sites and the first point where individual fibres can be accessed for each Access Distribution Area.

The Star DFN topology is the default for the Fixed Access build (post-Multi Technology Mix) to achieve cost efficiencies in construction.

A Star DFN topology starts from a FAN site and extends outwards, with nodes connecting into it along its length. The Star architecture results in the fibre path for nodes being unprotected.

The DFN is routed to pass near the likely node locations without requiring significant construction works.

The Star DFN is considered to comprise five segment types:

- Distribution Sheath Segment (DSS) - Aggregation
- Distribution Sheath Segment (DSS) - Trunk
- Distribution Sheath Segment (DSS) - Branch
- Distribution Sheath Segment (DSS) - Feeder
- Hub Sheath Distribution (HSD)

Figure 5 illustrates the logical connectivity principles for DSS Aggregation, Trunk, Branch, Feeder and HSD configurations.

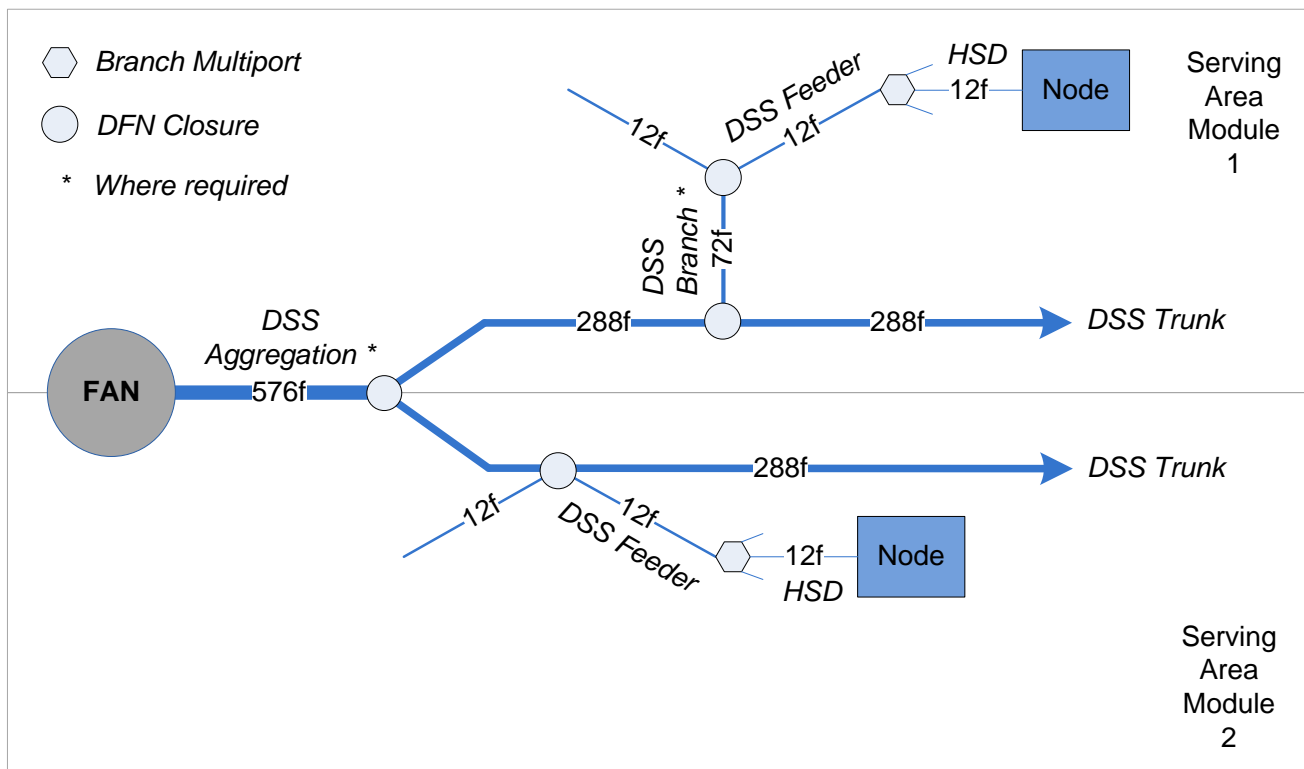


Figure 5 Example Star DFN Logical Connectivity

DFN Connectivity

The DFN is preferably installed underground, and by exemption aerially.

The DFN provides connectivity to the nodes located within the SAM modules (refer to Figure 5).

Multiple cables from different DFN cables can share the same duct-line, as well as sharing duct-lines with TFN and LFN cables.

Nodes are connected to the DFN cables and each node is allocated multiples of 12 fibres towards the FAN site.

2.2.2.3 Distribution Fibre Network - Loop

The Distribution Fibre Network (DFN) provides the underground fibre pathways between the FAN sites and the first point where individual fibres can be accessed for an Access Distribution Area. The DFN has previously been installed primarily for the support of GPON in a loop topology, starting from a FAN site and finishing at the same site, with FDHs connecting into it along its length. In this configuration, the DFN cables are typically higher fibre counts, with fibre core counts needed between 288 to 864 fibres. The DFN is also notionally allocated an A and B direction to assist in the identification of upstream connections at the FDH, where the A indicates a clockwise direction and B an anticlockwise direction.

The FDHs are street side externally rated cabinets which are used to house the GPON splitters used to facilitate connectivity between the DFN and the Local Fibre Network (LFN). The FDH also provides the ability to provide direct connectivity between the DFN and LFN.

The DFN was also required to provide diverse pathways for point to point services from FDHs where required.

The DFN fibre links cable into the FDH is provided by a single cable and has both A and B directions within the same cable sheath.

DFN Diversity

The FTTP network has been extensively modelled for availability percentages and expected downtime due to faults and this modelling has recognized that the DFN has a significant input into the availability calculations. This is the direct effect of the high fibre counts and distances required for the DFN.

The availability target indicates that a link distance of 4500 metres can be applied to a single connection pathway between the FAN and the farthest FDH or to a spur off the DFN without the need to provide diversity. For practical purposes this distance is reduced to 4000 metres to account for unforeseen alterations to the network in the construction phase and to provide flexibility for future maintenance.

This calculation allows the DFN to be installed in topologies other than fully diverse.

The default position for the DFN was to provide connection diversity to each FDH for the provision of diverse services and to provide the capability for a quicker Mean Time to Repair (MTTR). The quicker MTTR is achieved through the use of the diverse path available at the FDH to move affected services to the other "side" of the DFN effectively bypassing the affected cable link.

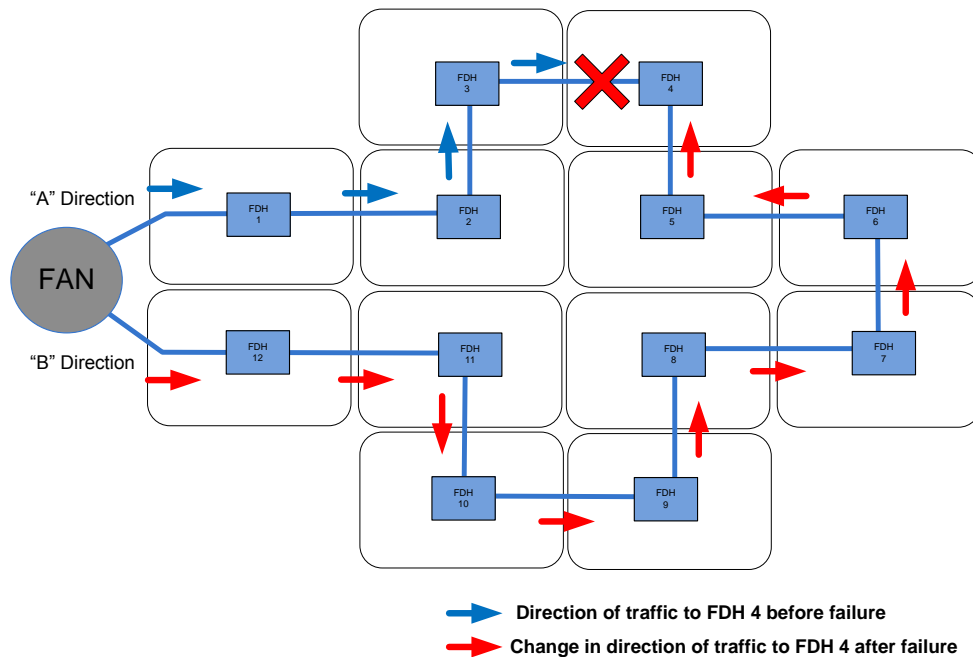


Figure 6 Traffic paths available when failure occurs

An alternate position is for a collapsible loop (referred to as a return spur) to be installed from the main diverse DFN, up to 4000 metres, with a maximum of 2 FDHs connected into the return spur. This topology does not permit service restoration patching for the two connected FDHs when the return spur is interrupted but does allow for restoration patching for the remainder of the DFN.

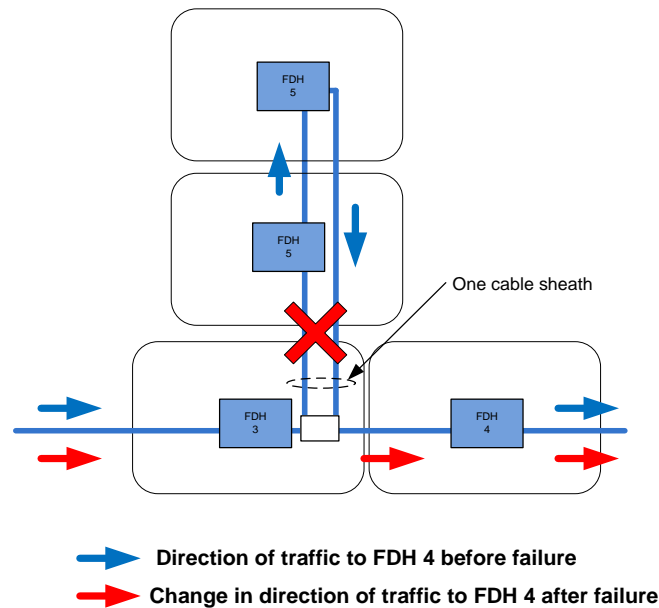


Figure 7 Traffic paths available when failure occurs on return spur

Another deployment option is for a spur in which only one pathway (either A or B and referred to as a single spur) is presented to the FDHs.

DFN Connectivity

The DFN is preferably installed underground, and by exemption aerially, and in the past was designed in a ring topology starting and finishing at the same FAN site. This effectively divided the DFN cable ring into an 'A' and a 'B' side.

The DFN provides connectivity to the Fibre Distribution Hubs (FDH) located within the FSAM modules and provides two diverse fibre pathways back into the FAN site for each FDH (refer to Figure 6).

Any individual DFN ring cable will be separated from any other portion of the same ring by the most practically achievable distance. Multiple cables from different DFN ring cables can share the same duct-line, as well as sharing duct-lines with TFN and LFN cables.

Fibre Distribution Hubs are connected to the DFN ring cables and each FDH is allocated fibres in both A and B directions towards the FAN site. This ring allocation provides a diverse pathway for end-user connectivity and allows for temporary service restoration when required. In the event of a serious service impacting event (e.g. cable cut, etc.) the services that are connected to the affected side can be manually re-patched at the FDH site and FAN site to the diverse pathway.

Therefore the DFN network must be capable of servicing these connections in both directions of the DFN within the optical constraints.

Whilst the DFN provides diversity from each FDH this diversity is not transferred into the LFN (the LFN is a star topology) and therefore the DFN should also be designed to align with potential users of point to point services (e.g. banks, schools, universities, business parks) to allow the LFN to provide the diverse links.

2.2.2.4 Flexibility Joint Location

The Flexibility Joint Location (FJL) is an aggregation and connection point between the Distribution Fibre Network (DFN) and the Skinny Local Fibre Network (LFN). A FJL is used to permit individual fibre access and management between the incoming DFN and the outgoing Skinny LFN.

Within the FJL are splice trays capable of single fibre management to permit direct splicing between the DFN and Skinny LFN for all fibre connectivity requirements.

The FJL has a capacity of up to 144 fibre splices and permits multiple configurations of splitters as required for the DA specific infrastructure. There is no patching facility within the FJL and all fibre connections are spliced.

Extra DFN capacity can be installed into the FJL as required, and a FJL can also be used to connect more FJLs to the same incoming Flexibility Sheath Distribution (FSD) cable depending on availability of spare fibres.

Split ratios are generally kept to 1:32 with the optical budget being managed to permit greater degrees of splitting if required for network growth. Splitters may also be reconfigured within the FJL, if required for capacity.

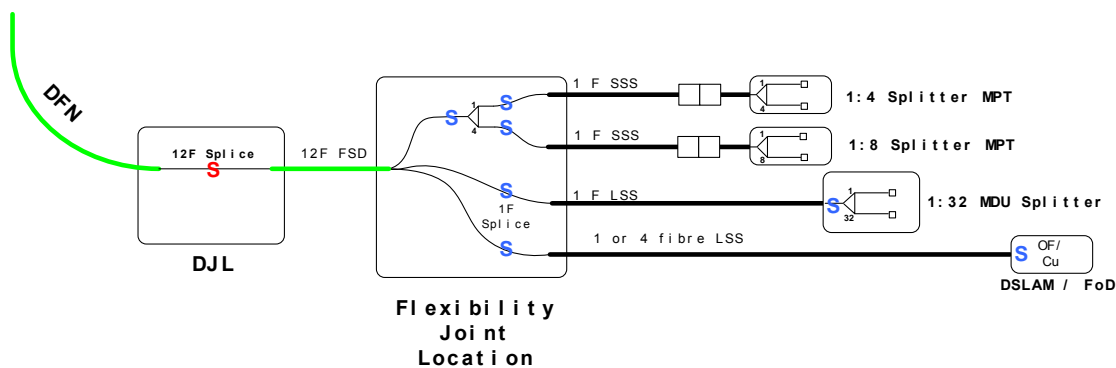


Figure 8 Flexibility Joint Location

2.2.2.5 Fibre Distribution Hub

The Fibre Distribution Hub (FDH) is an aggregation and connection point between the Distribution Fibre Network (DFN) and the Local Fibre Network (LFN). The FDH is available in 432, 576, and 864 LFN variants, however 576 has been the preferred choice.

The FDH is an environmentally secure passive device installed on street frontages and serves as a centralised splitter location. The splitter modules housed within the FDH provide a one-to-many relationship between the in-coming DFN fibres and the out-going LFN fibres. In keeping with the requirements of the GPON equipment, the splitters used are a 1:32 passive split.

The standard and most common connectivity type is a PON connection between an end-user and the output leg of a splitter module.

The splitter module is in a 1:32 planar configuration and these modules are pre-terminated with 1 x DFN SC/APC fibre lead and 32 x LFN SC/APC fibre leads and these connect into the network via the patch panel array within the FDH.

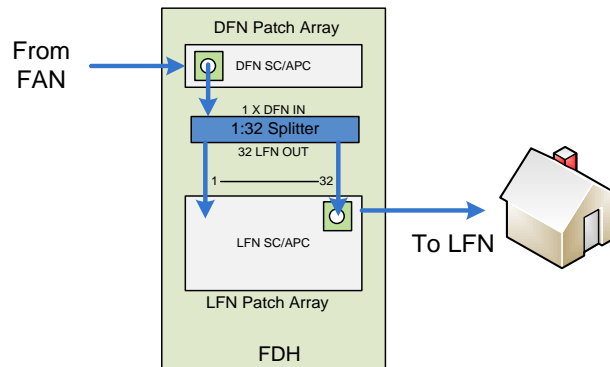


Figure 9 FDH PON Connection

2.2.2.6 Skinny Local Fibre Network

The Skinny Local Fibre Network (LFN) is installed from the FJL to the end user premises in a star topology with no inherent capacity for diversity.

The Skinny LFN architecture is the default for greenfield deployments, and is used to support the multi-technology mix model to achieve cost efficiencies in construction.

The Skinny LFN is comprised of a 12 fibre ribbon cable for the FJL feeder sheath distribution (FSD) from the Distribution Joint Location (DJL) and either a single fibre pre-connectorised cable of the Splitter Sheath Segment (SSS) to connect to SMPs or a Flexibility Sheath Local (FSL) cable containing 4 or 12 Fibres to connect to Breakout Joint Locations (BJLs).

The FSL cables are used to aggregate the individual SSS cables into either a 4 or 12 fibre stranded fibre cable in conjunction with a Breakout Joint Location (BJL) to minimise the hauling of multiple SSS cables and provide high utilisation of existing duct space (see Figure 10).

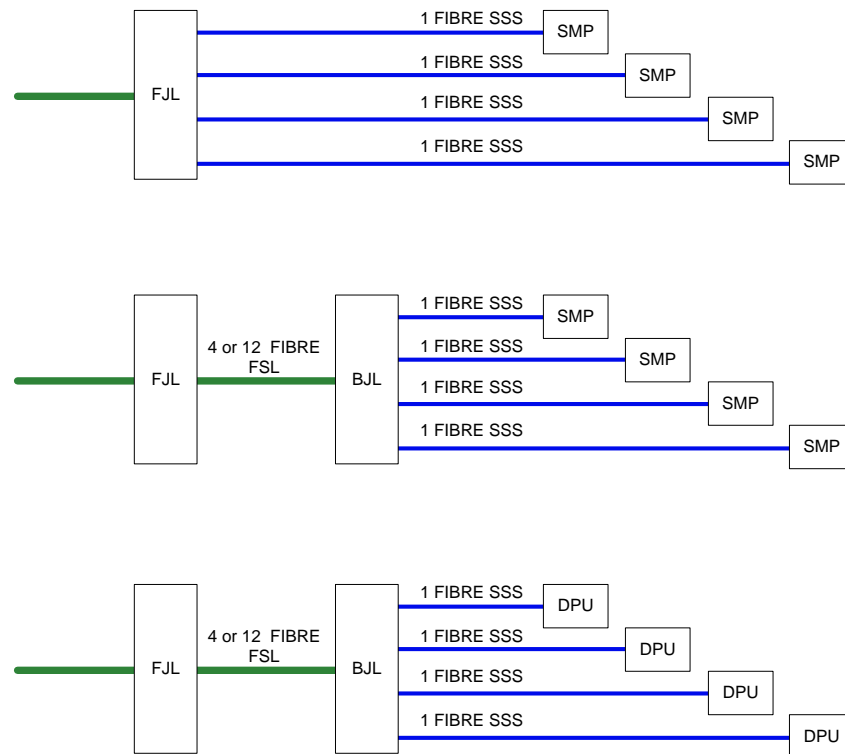


Figure 10: BJT Aggregation Utilisation example for FTTP and FTTC

The FSL cables may also be used to connect multiple BJTs to the same sheath with up to 3 BJTs sharing the same FSL cable and fibres allocated accordingly (see Figure 11).

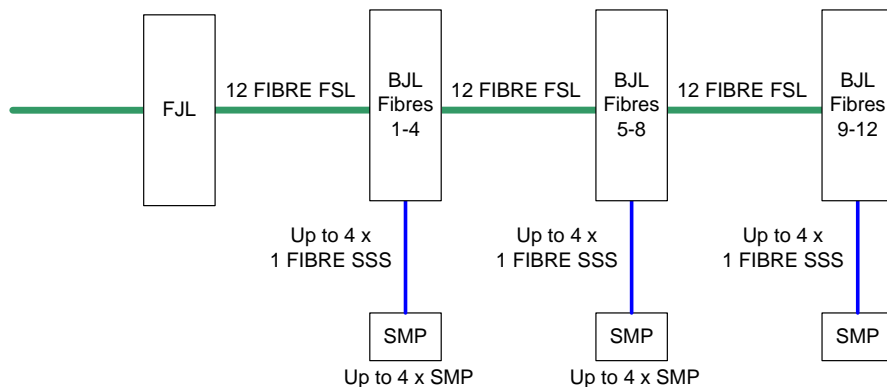


Figure 11: FSL Aggregation example for FTTP

FTTP: The FJL provides a 1:4 or 1:8 way split, spliced through the BJT. Downstream the SSS cables are used to connect the Splitter Multi-ports with integrated splitters factory-installed. The Splitter Multi-ports (SMP) used are commonly 1:8, however 1:4 may be deployed and each variant has a single fibre environmentally hardened connectorised input with each splitter output leg terminated to another single fibre environmentally hardened connectorised output.

FTTC: The FJL provides a 1:2 way split, spliced into the BJT. Downstream the SSS cables are used to connect to 4 port DPUs. The BJT contains a 1:4 optical split and has a single fibre environmentally hardened connectorised DPU input.



For aerial deployment, the LFN is a factory installed termination system (FITS) that utilises factory installed splice closures, referred to as overmoulds, to present the multi-fibre connector at each required location. The Splitter MPTs and DPUs are then connected in a similar manner as the underground method.

Single Dwelling Unit and Non Addressable Allocations

Each SDU is allocated one port at a SMP in the LFN. This port is utilised for the service connection. An allocation of 1 spare port per 1:8 SMP is provided and, although allocated, is available for use at the MPT for any non-addressable connections, extra connections per SDU, etc.

Non-addressable locations can be identified as locations without a physical address, e.g. power transformers, traffic light controllers, etc.

Any future in-fill or augmentation will be provided on an as needed basis and the LFN expanded accordingly.

Extra ports or fibre may be allocated to provide future capacity. Typically, fibre capacity is held within the FJL to permit its use anywhere within the DA and for any technology option.

2.2.2.7 Local Fibre Network

The Local Fibre Network (LFN) is installed from the FDH to the end-user premises in a star topology with no inherent capacity for diversity. Diversity is achieved by extending the LFN from any other FDH, dependant on the status of the other FDH's location in separate geographic pathways.

LFN cables are typically smaller fibre count cables, ranging between 72 and 288 fibre counts, and are installed in the aerial corridor and underground pathways typically alongside property boundary street frontages. The LFN cables are presented at the FDH on a connector array to facilitate connection to the upstream DFN either via a PON splitter or direct connection.

For an underground deployment, the individual LFN cables are extended from the FDH into the Local Fibre Network to multiple centralised splice closures or Access Joints (AJL) where the cables are joined into smaller fibre count "tether" cables via splicing. The tether cable is factory terminated on one end only with an environmentally hardened multi-fibre connector and is installed between the AJL and local fibre pits where they provide a connection point for the factory terminated Multi-Ports (MPT). Service fibre drops to End User premises are connected into the MPTs as required.

For aerial deployment, the LFN is a factory installed termination system (FITS) that utilises factory installed splice closures, referred to as overmoulds, to present the multi-fibre connector at each required location. The MPTs are then connected in a similar manner as the underground method.

Single Dwelling Unit and Non Addressable Allocations

Each SDU is allocated one fibre in the LFN between the MPT and the FDH. This fibre is utilised for the service connection. A second fibre is allocated to the same Multipoint location that the SDU will connect to and, although allocated, is available for any use at the MPT for any non-addressable connections, extra connections per SDU, etc.

Non addressable locations can be identified as locations without a physical address e.g. power transformers, traffic light controllers, etc.

Extra fibres shall be allocated to provide future capacity. It is recognised that there are different levels of growth expected across Australia. In areas of low growth the effective allocation on average is one and a half fibres per premises. In other areas, the effective allocation on average is three fibres per premises.

Multi-Dwelling Unit (MDU) Allocations

MDU layouts are varied and can be broadly divided into two configurations, horizontal and vertical MDUs. These two configurations can co-exist on sites, however the horizontal MDUs will generally be serviced via an SDU-like architecture and the vertical serviced via the MDU specific architecture.

The internal configuration of MDUs is based on a number of repeatable modules: the Premises Distribution Area (PDA), the Horizontal Distribution Area (HDA), the Backbone Distribution Area (BDA) and the Fibre Distribution Area (FDA).

The PDA, HDA, BDA, and FDA are repeatable modules used within an MDU to achieve fibre connectivity. These modules are utilised as design tools to provide conceptual boundaries to clearly identify the location of various devices and their functionality.

The physical topology is a star network radiating out from either the FDH or the Premises Distribution Hub (PDH) which may be either external or internal.

The hierarchy of the modules is shown below:

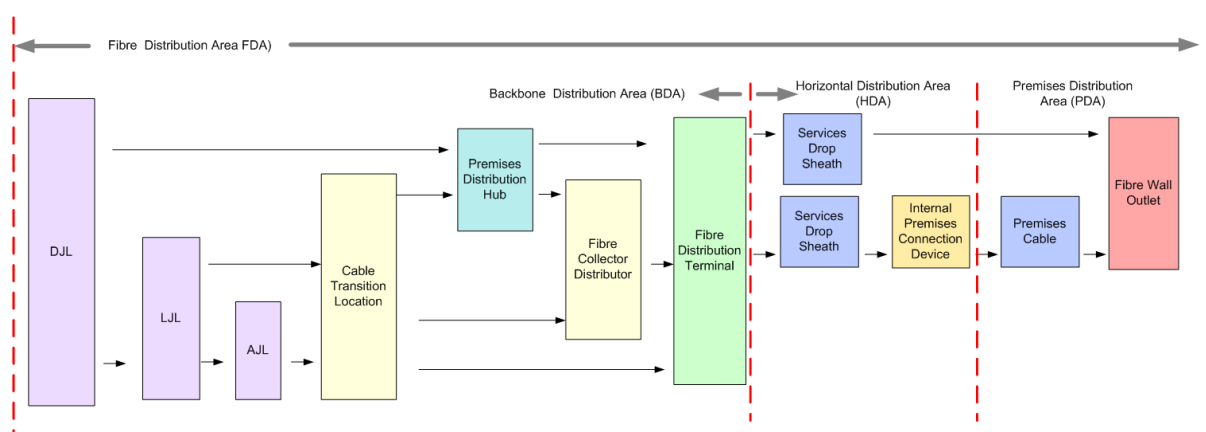


Figure 12 DA Module Hierarchy

The fibre configurations within MDUs are derived from the fibre allocations for the premises within the building.

Residential MDUs:

The fibre allocations within MDUs differ due to the minimal expansion work that is performed within MDU premises. Realistically a residential MDU will maintain its size due to the relatively contained nature of these types of buildings. Additionally most MDUs have already maximised the available land.

Residential premises within MDU sites are therefore allocated 1.5 fibres per premises with the first fibre allocated for service and the $\frac{1}{2}$ fibre allocated for future connectivity. In effect, the $\frac{1}{2}$ fibre is combined with another $\frac{1}{2}$ fibre from an adjacent MDU premises and the ratio of 3 fibres per 2 premises is used.

Fibre counts are rounded up to the nearest whole number when dealing with the $\frac{1}{2}$ fibre allocation.

Example: An MDU has 7 residential premises to be serviced, with each premises allocated 1.5 fibres for a total fibre requirement of $10\frac{1}{2}$ fibres. Therefore the total fibre count required is 11 fibres.

Commercial MDUs:

Commercial entities within premises are allocated 2 fibres. Due to the transient nature of some commercial entities combined with changing floor space usage (for example a commercial floor in an MDU could accommodate either one or multiple different entities) the minimum fibre count allocated per floor is 12 fibres. This fibre count is sufficient to service up to 6 commercial entities per floor and if there are additional premises over the initial 6 then the fibre allocations are added to the initial 12 fibre allocation.

MDU Building Services:

Building services such as lift phones and pay phones are to be allocated 1 fibre per service.

The following configurations are for explanatory purposes to illustrate the hierarchy of component connectivity.

These examples use fibre demand as opposed to premises numbers as a method to illustrate the functions and connectivity of the hardware.

Fibre Demand ≤ 24 Fibres:

This configuration will utilise FDTs fed via a Multiport Sheath Segment (MSS), a 12 fibre tether, from an AJL in the general vicinity to the Cable Transition Location (CTL) which provides the transition point from external to internal cable types.

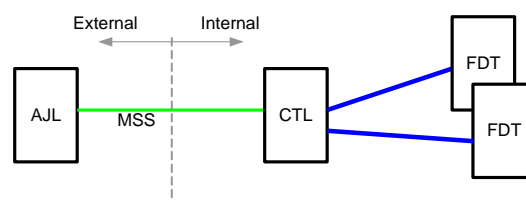


Figure 13 MDU Fibre Demand <24 fibres

The Fibre Distribution Terminal (FDT) provides the breakout point for the individual premises drop cables. Configuration shall be either a single 24 Fibre FDT or two 12 Fibre FDTs.

Fibre demand between 25-48 Fibres:

This configuration will utilise FDTs fed via a Local Sheath Segment (LSS) either from an LJJ or AJL.

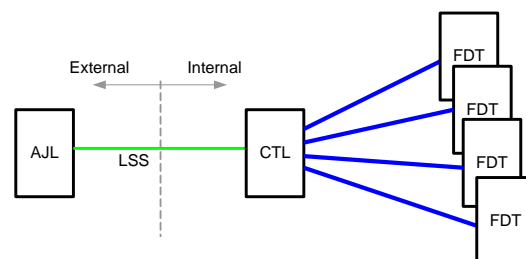


Figure 14 MDU Fibre Demand 25-48 fibres

The FDT configuration shall be a combination of either 24 Fibre FDTs or 12 Fibre FDTs.

Fibre allocations are based on using the external FDH as the centralised splitter location, and using these splitters and the fibres in the LFN to facilitate connection to the MDU. However, splitters connected to the LFN may be used for network augmentation when the LFN is at, or near, full capacity.

Fibre demand between 49-100 Fibres:

This configuration will utilise either a Fibre Collector Distributor (FCD) connected to multiple FDTs, or multiple FDTs, both fed via an LSS from an Local Joint in the LFN (LJL).

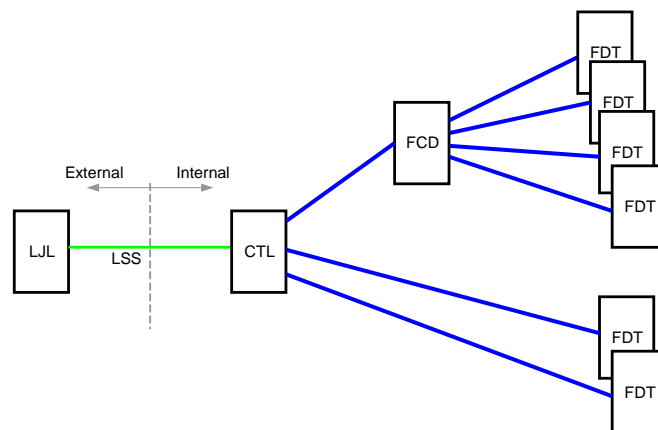


Figure 15 MDU Fibre Demand 49-100 Fibres

Fibre allocations are based on using the external FDH as the centralised splitter location, and using these splitters and the fibres in the LFN to facilitate connection to the MDU. However, splitters connected to the LFN may be used for network augmentation when the LFN is at, or near, full capacity.

Fibre demand over 100 Fibres:

This configuration will utilise Premises Distribution Hub (PDH) sized at either 144 or 288 fibres dependant on the fibre demand and will be connected into a DJL via a Distribution Sheath Segment (DSS).

The local fibre network within the MDU will be fed via a combination of FCDs connected to the PDH and FDTs connected directly to the PDH where required.

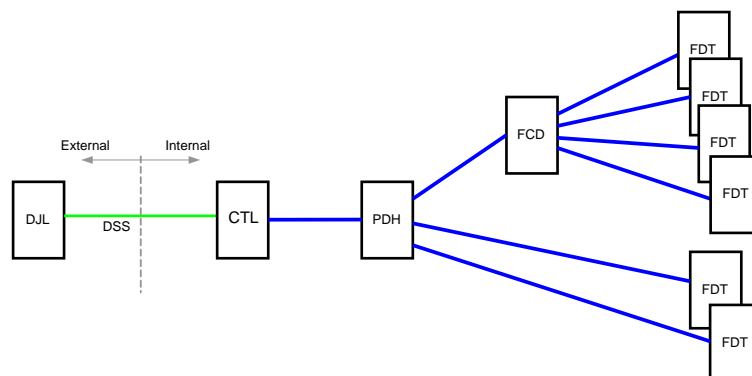


Figure 16 MDU Fibre Demand Over 100 Fibres

The DFN connectivity will be the same construct as the external FDH. In the case of a ring DFN architecture the A and B side of the DFN share the same sheath to the PDH.

2.2.2.8 Customer RF injection points

For new developments, two additional interfaces to the fibre network may be provided to allow delivery of customer content directly over a wavelength on the fibre to the end user premises.

- RF Receiver – generally located at the end user premises. The RF Receiver splits out the wavelength carrying the **nbn** Ethernet broadband service to the NTD and the wavelength carrying the Customer content signal to a RF UNI interface.
- RF Combiner – generally located in or near an **nbn** FAN site, or in a pit appropriate for supporting connectivity at the last DJL before the new estate LFN. The RF Combiner is the NNI, providing the injection point for the wavelength carrying the Customer content signal.

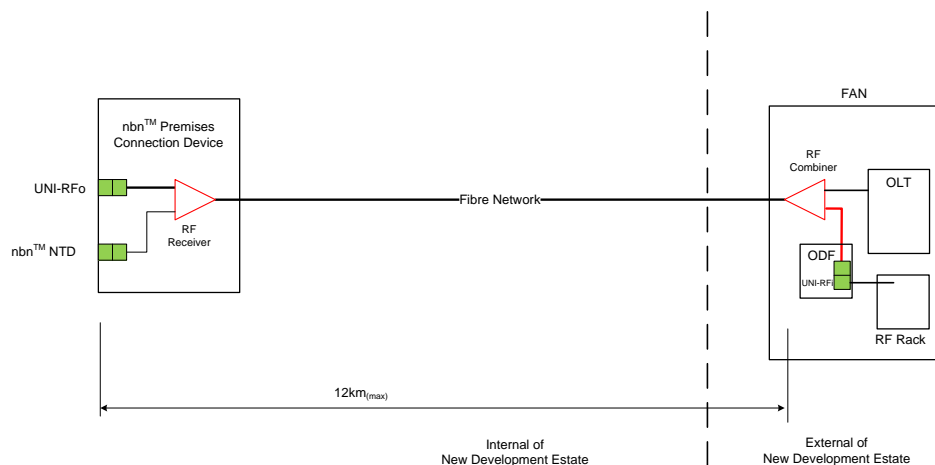


Figure 17 Example of Customer & end user RF interfaces

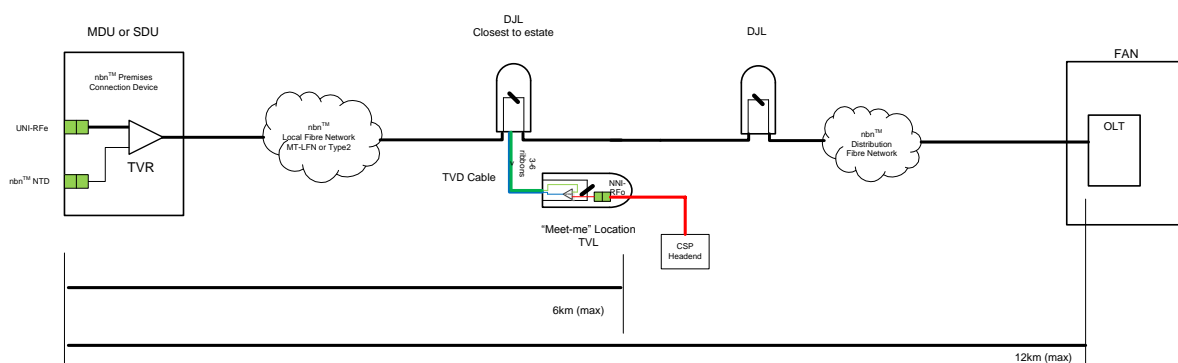


Figure 18 Example of Customer & end user RF interfaces

An option is also provided for content injection at MDUs, using an RF combiner with splitter in one unit.

2.2.2.9 Optical Budget

The optical budget allocation provides the most significant design constraint of the DFN and LFN Network. The combination of fibre strand attenuation, splice losses, passive optical splitters, connectors, and operating headroom provide an optical limitation on the distance between the Optical Line Terminals (OLT) located in FAN

sites and the terminating device, for example, the GPON NTD located at end-user premises. Distance and fusion splicing are generally the only variables in the external plant.

These limitations are based on the optical equipment transmit and receive parameters which are set via the optical devices as referenced in the Gigabit Passive Optical Network (GPON) standard ITU-T G.984. This equates to a maximum permissible optical loss of 28dB or a permissible distance of 15km, whichever is less, between the OLT and GPON NTD. This optical loss is calculated for the worst case combination of OLT and GPON NTD connection within an FDA and is applied to both the A and B direction. With Forward Error Correction (FEC) enabled between the OLT and the NTD, this can be extended to a maximum permissible optical loss of 30dB (17.5km) where required. Where Customer RF injection points are supported this equates to a permissible distance of 12km. The maximum optical losses used for detailed design optical budget calculations are listed in the table below.

Event	Maximum Optical Loss
Single Fibre Strands (DFN and LFN)	0.35dB/km @ 1310nm 0.21dB/km @ 1550nm
Fusion Splice (Ribbon)	0.20dB
Fusion Splice (Stranded)	0.10dB
Mated SC/APC Connector	0.30dB
1:32 Passive Optical Splitter	16.7dB
1:32 Passive Optical Splitter with RF combiner	17.8dB
1:8 Passive Optical Splitter (FJL)	10.32dB
1:4 Passive Optical Splitter (FJL)	7.1dB
1:2 Passive Optical Splitter (FJL)	3.7dB
1:8 Passive Optical Splitter (SMP)	11.3dB
1:4 Passive Optical Splitter (SMP)	8.0dB
Mated 12 Fibre Multi-Fibre Connector Environmentally Hardened	0.62dB
Mated SC/APC Single-Fibre Connector Environmentally Hardened	0.40dB
RF Combiner	1.1dB @ 1330nm 1.3dB @ 1490nm 8.6dB @ 1550nm
Pit located RF Combiner	3dB @ 1330nm 3dB @ 1490nm 10dB @ 1550nm
RF Receiver	1.0db

Table 3 Maximum Optical Loss

The calculation of the optical loss is performed with the following equation:



$(\text{DFN Distance (in km)} \times 0.35\text{dB}) + (\text{DFN planned splices} \times 0.20\text{dB}) + (\text{FDH Optical Splitter Loss}) + (2 \times \text{mated connector (at FDH)}) + (\text{LFN Distance (in km)} \times 0.35\text{dB}) + (\text{LFN splices} \times 0.20\text{dB}) + (\text{multi-fibre connector loss}) + (\text{mated environmentally hardened SC/APC connector}) + (2 \times \text{mated SC/APC connectors})$

2.2.3 Optical Line Terminator

The GPON Optical Line Terminator (OLT) function terminates multiple individual GPON connections, each with a number of ONTs or Distribution Point Units (DPUs) attached. The GPON OLT supports up to 128 GPON interfaces per shelf, with each GPON interface extending to one or more Fibre Serving Areas for connectivity to end-users. GPON interfaces are arranged in groups of 8 per Line Terminating (LT) card.

The GPON OLT system supports dual Network Termination (NT) cards for control and forwarding redundancy, and 4 x 10 Gigabit Ethernet (SFP+) network uplinks per NT for network connectivity. The system is fed by - 48VDC power, and power module/feed redundancy is incorporated into the shelf.

The OLT is located in Fibre Access Node (FAN) sites. To support Greenfields sites where a FAN site has not yet been established, a cabinetised OLT solution is deployed, known as a Temporary FAN (TFAN).

2.2.4 Fibre Access Planning Hierarchy

2.2.4.1 Fibre Access Planning Hierarchy – post Multi Technology Mix

To optimise the use of multiple fixed technologies the planning hierarchy covers all fixed access types. Please refer to section 2.6 for the MTM Fixed Access Network Planning Hierarchy.

2.2.4.2 Fibre Access Planning Hierarchy – pre Multi Technology Mix

For planning, design and construction purposes, the network is divided into hierarchical modules and network entities.

These modules are used to provide the planning constructs needed to provide connectivity between the individual end-user's premises through to the Access Seeker (AS) Point of Interconnection (POI)

The first identifiable connection point is an end-user premises. These are defined as physical address points. Each individual dwelling unit is required to have a unique service location, and is identified as an end-user. If the end-user premises is situated in an MDU environment then these are treated as individual connections.

The first module is the Fibre Distribution Area (FDA) which comprises an average of 200 end-users. The FDA is the catchment area of an FDH which provides a passive optical aggregation point for the LFN into the DFN.

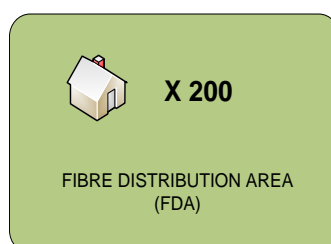


Figure 19 Fibre Distribution Area

The second module is the combination of a maximum of 16 FDAs to create an FSAM. An FSAM with the maximum of 16 FDAs will, as a result, have an average catchment of 3200 end-users.

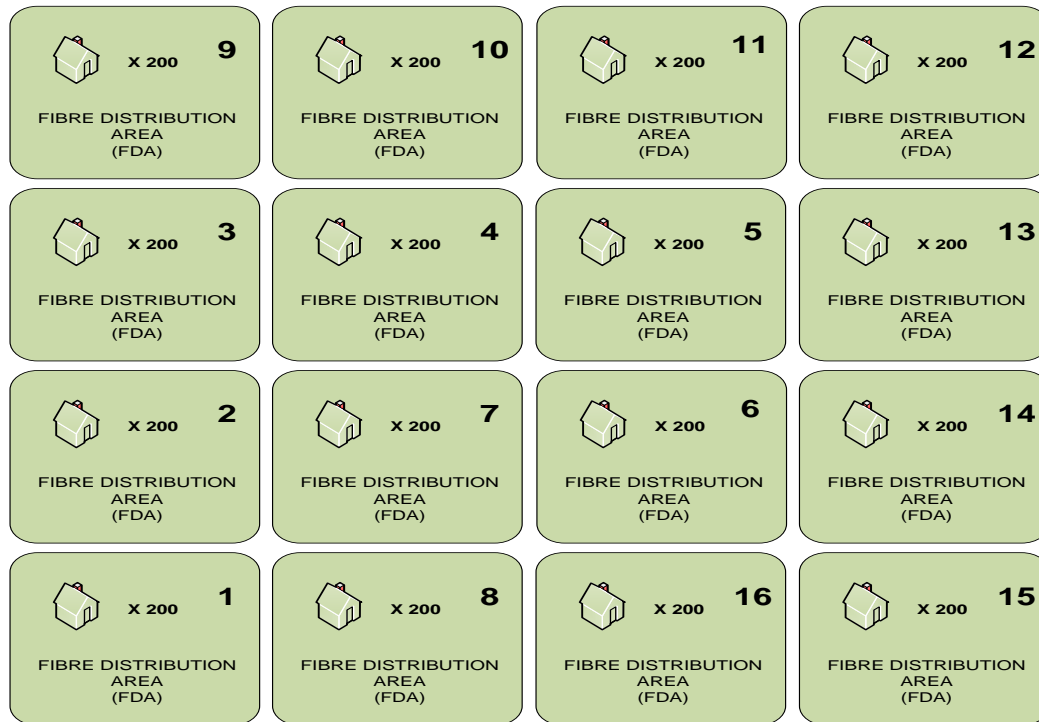


Figure 20 Fibre Serving Area Module Example

The modular size of the FSAM is dependent on the geography of the area to be served and can be constructed with any number of FDHs.

The maximum design shall allow for the grouping of 16 FDAs onto a single DFN cable. This grouping can contain between 13 and 16 FDAs and, for this, the DFN requires two loops, an inner and an outer loop, and these are used to provide connectivity of a maximum of 16 FDHs. The inner loop as shown in Figure 21 is used for FDHs 1-8 and the outer loop for 9-16. The cable links between FDA 3 back to the FAN and FDA 8 back to the FAN is a 576 fibre cable split evenly across the two rings at the splice closures located in FDA 3 and FDA 8.

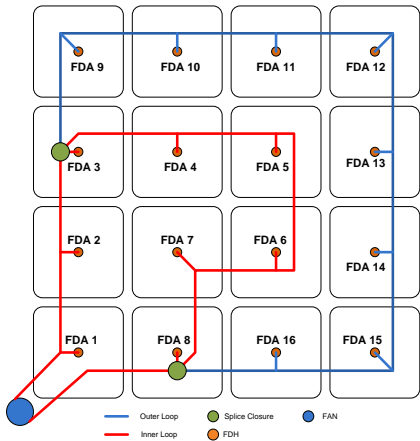


Figure 21 16 X FSAM Distribution Cable Connectivity

For an FSAM containing 12 FDAs or less the DFN is a single ring with the same size cable sheath installed between FDAs back to the FAN.

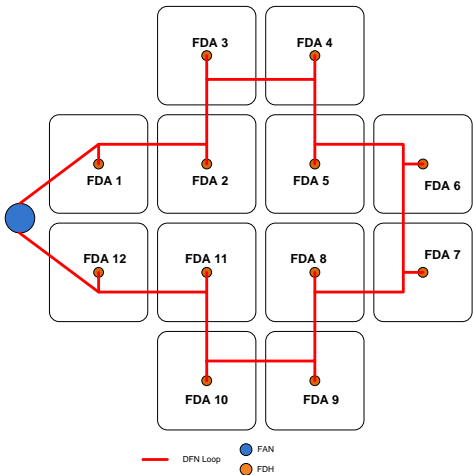


Figure 22 12 X FSAM Distribution Cable Connectivity

The DFN cable size also alters depending on the number of FDHs within the FSAM:

Number of FDAs per FSAM	DFN Cable Size
1	288
2	288
3	288
4	288
5	288
6	288
7	288

Number of FDAs per FSAM	DFN Cable Size
8	288
9	432
10	432
11	432
12	432
13	576 (Two loops of 288)
14	576 (Two loops of 288)
15	576 (Two loops of 288)
16	576 (Two loops of 288)

Table 4 12 FDH FSAM Fibre Requirements per FDH

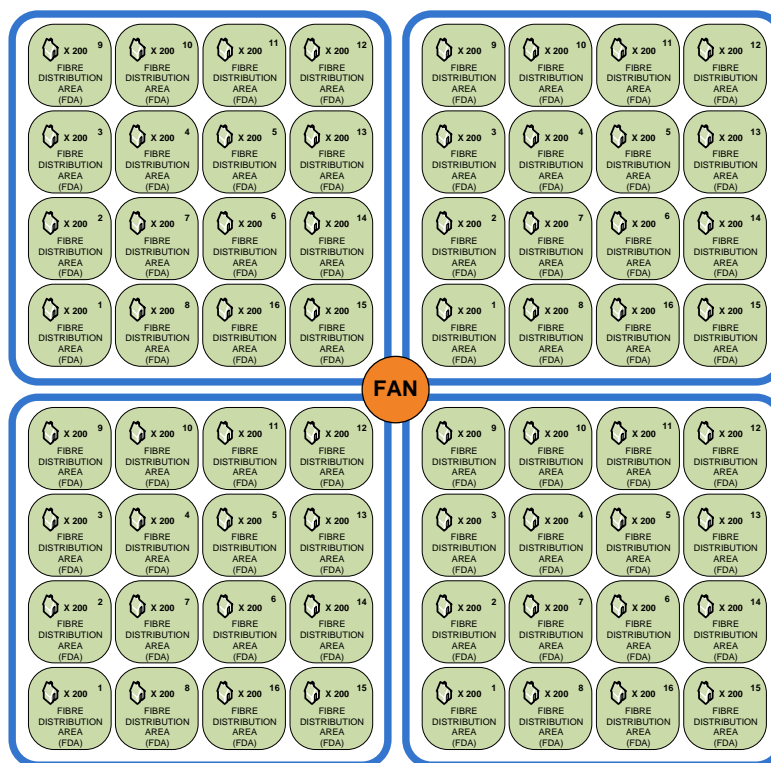


Figure 23 Fibre Serving Area (FSA)

The third module is the Fibre Serving Area (FSA) and is the combination of a number of FSAM modules located centrally around a Fibre Access Node.

The FSA is linked to a FAN and comprises multiple FSAMs linked into the FAN via the DFN cables.

The placement of the FAN site in relation to the FSAMs is derived by identifying as central a location as practical.



The FSA is increased by adding FSAM modules as required. The optical return path for the DFN needs to be identified and monitored during the planning and design phase for each FSAM to keep the DFN ring within the optical constraints.

2.3 Point to Point Fibre Access Domain

The point to point Fibre access domain solution consists of the following components:

- Ethernet NTD - The Ethernet Network Terminating Device located at the service location uses Ethernet technology to connect to the network. It delivers UNI capabilities to a service location.
- Fibre Network (FN) provides optical pathways between the NTD and AAS. Sections of the Fibre Network are shared by other access domains.
- Access Aggregation Switch (AAS) – provides aggregation of multiple point to point services to a number of network facing 10Gbps links. This switch is shared with other access domains.

2.3.1 Ethernet NTD

The Ethernet NTD terminates the incoming physical fibre at the service location and may provide one or more User to Network Interfaces (UNI). A number of NTD varieties will be used to suit different circumstances, service location types and interface quantities. The variants are expected to include Indoor and Outdoor NTDs.

- 1 x fibre interface
- Up to 4 UNI interfaces
- Support for standard power supply or Uninterruptable Power Supply (UPS)

2.3.2 Fibre

The fibre network supports point to point services. Refer to the Fibre Access (GPON) Domain Fibre section.

2.3.2.1 Distribution Fibre Network

The DFN is designed to support point to point services. Refer to Fibre Access (GPON) Domain Distribution Fibre Network section.

2.3.2.2 Fibre Distribution Hub/Flexibility Joint

Point to point connections use a different patching array to GPON services, with the FDH patching directly between the LFN and DFN. This links an individual end-user directly to a DFN fibre. The Flexibility Joint provides the same functionality but via direct fusion splicing.

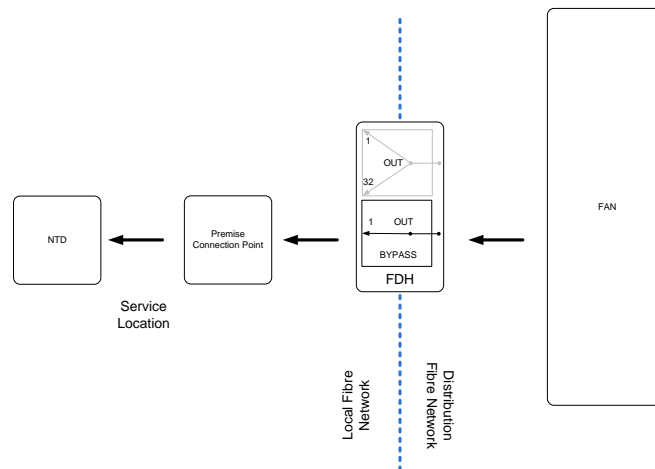


Figure 24 Point to Point Connection using DFN

2.3.3 Access Aggregation Switch (AAS)

Point to point services will make use of the existing AAS to provide an additional layer of aggregation for combining multiple 1GE access interfaces from the NTDs into 10Gbps interfaces preferred by the core (Transit and Aggregation) networks. This is provided by an Access Aggregation Switch (AAS). Refer to section 2.4.6.

2.4 Copper Access Domain

The Copper Access solution consists of the following components:

- A VDSL2 modem (provided by the Access Seeker or end user) for FTTN/B. This is on the customer side of the **nbn**TM network boundary and is not discussed further in this document.
- The Network Connection Device providing a modem and Reverse Power Unit, used only for support of FTTC deployments. This provides a power feed to the Distribution Point Unit (DPU) via the modem and copper plant, and the UNI to the end user.
- Centralised splitter, which is optionally installed in the end user's premises and is recommended to optimize VDSL performance. This is on the customer side of the **nbn**TM network boundary and is not discussed further in this document.
- The Copper Plant, which provides the UNI to the premises and a copper path between the UNI and DSLAM or DPU.
- Distribution Point Unit (DPU). The DPU aggregates a small number of end user Ethernet over VDSL2 (ITU-T G993.2) connections into a network facing GPON interface, used only for support of FTTC deployments.
- DSLAM, which provides processing, switching and control functions. The DSLAM aggregates end user Ethernet over VDSL2 (ITU-T G993.2) connections into a number of network-facing Ethernet 1Gbps links.
- Fibre Network, which provides the optical pathway between the DSLAM and FAN site.
- Access Aggregation Switch (AAS), which provides aggregation of multiple DSLAMs to a number of network facing 10Gbps links. This switch is shared with other access domains.

2.4.1 Network Connection Device

The Network Connection Device (NCD) is used only for support of FTTC deployments. It is located in the end-user premises and contains a modem and Reverse Power Unit (RPU) connected to the premises power supply. The RPU is connected into the in-premises copper network, between the **nbn** network boundary and the

modem. The RPU is used for providing a reverse power feed to the DPU via the in-premises copper and copper lead in.

The NCD modem terminates the DSL link and presents an Ethernet UNI-D to the end-user

2.4.2 Copper Plant

nbn is acquiring and utilising the existing Telstra copper plant to provide physical connectivity between the UNI and the DSLAM.

For SDU deployments the UNI is at the first socket in the premises. For MDU deployments that have a Main Distribution Frame (MDF), the UNI is located at the MDF.

Where growth in brownfields areas makes it appropriate for **nbn** to provide new copper lines, at least two copper pairs will be available per serviceable location in the catchment area of the cable section, with a fill ratio of up to 80%.

The copper network will be constructed and maintained on a like-for-like construction basis i.e. replacement of aerial routes with aerial and underground with underground where cables are replaced.

Available copper distribution cable sizes for underground deployment are: 2, 10, 30, 50, 100, 200 and 400 pairs with conductor gauges varying between 0.4, 0.64 and 0.9mm

Available copper distribution cable sizes for aerial deployment are: 2, 10, 50, 100 pairs with conductor gauges varying between 0.4, 0.64 and 0.9mm

2.4.3 Distribution Point Unit (DPU)

The FTTC DPU is an **nbn** owned device which can be located in an underground pit, or mounted on a pole close to the end user premises. The DPU terminates up to four individual copper pairs, each serving a single end user. The DPU is reverse power fed from an end user premises over the copper leads. The DPU is "GPON-fed" and as such the same physical architecture applies as for FTTP GPON from the DPU up to the OLT and on into the rest of the **nbn**TM network.

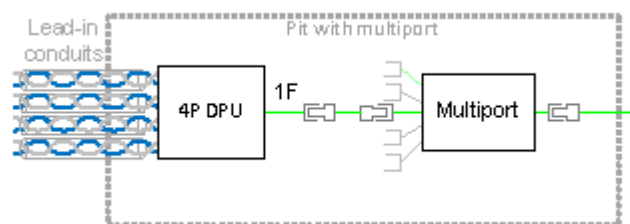


Figure 25 4 Port DPU with fibre connectivity

2.4.4 DSLAM

The DSLAM function terminates multiple individual copper pairs, each serving a single end user. DSLAM sizes vary, with the number of ports selected to most efficiently address the deployment scenario.

A DSLAM may be located

- within an outdoor enclosure (FTTN – Fibre to the Node);
- to provide service to premises of a multi-dwelling unit (FTTB – Fibre to the Building)

At the time of writing, **nbn** will deploy DSLAMs in the following deployment scenarios (further DSLAM sizes, are currently under investigation):



Deployment Scenario	Typical Maximum Number of Ports per DSLAM	Premises type
FTTN – DSLAM deployed near a Distribution Area pillar	48, 192 or 384	SDU and MDU
FTTB – DSLAM deployed at the premises of an MDU	48, 192 or 384	MDU

Table 5 Copper DSLAM Node Deployment Options

The interconnect of FTTN nodes can be performed at the following locations in order of preference:

- Directly into the Pillar
- Into an existing upstream joint
- Into a new upstream joint
- Into existing downstream joints
- Into new downstream joints
- A combination of these scenarios

The interconnect of FTTB nodes can be performed at the following location:

- Directly into the Main Distribution Frame (MDF) within the building

2.4.5 Fibre Network

For all DSLAM deployment options, the Fibre Network connectivity is provided by the DFN deployed in the area. Where the DSLAM deployment is within the Telstra copper Distribution Area, or DPUs are deployed, LFN connectivity is also required. Refer to the Fibre Access (GPON) Domain Fibre section for detailed information on the DFN and LFN Fibre Networks.

Currently, 4 x Point to Point fibres will be provided for each DSLAM.

Out of the 4 x Point to Point fibres, the equipment requires 2 x Uplink Fibres which are connected through to the Aggregation switch in the NBN Co Network. The additional 2 x Point to Point fibres are spares, to allow flexibility for future growth or migration activities.

DPUs will be connected with a single fibre connecting back to the multiport, splitters, DFN and GPON OLT.

2.4.6 Access Aggregation Switch (AAS)

The introduction of DSLAMs with lower customer density and higher node volumes created the need for an additional layer of aggregation for combining multiple 1GE access interfaces from the DSLAMs into 10Gbps interfaces preferred by the core (Transit and Aggregation) networks. This is provided by an Access Aggregation Switch (AAS).

The AAS solution is positioned in the FAN, which can be physically located in a FAN site or a POI site.

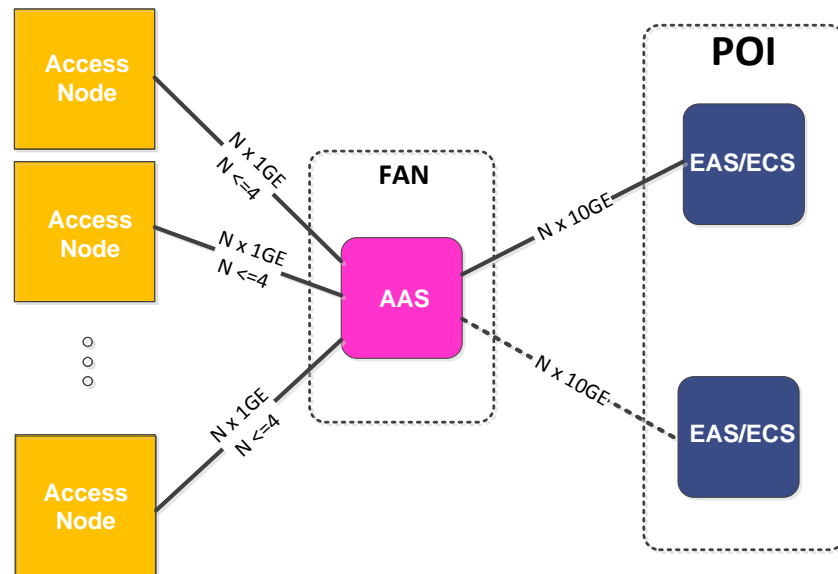


Figure 26 AAS Interfaces

From the diagram above, the AAS is used to aggregate multiple 1GE uplinks from access nodes to 10GE links, connecting to the Ethernet Aggregation Switch or Ethernet Connectivity Switch of the Aggregation Domain.

AAS will connect to DSLAMs via $N \times 1GE$ ($N \leq 4$) connections and will be dual-homed to EAS/ECS pair, each via $N \times 10GE$ connections. The backhaul connection from FAN to POI can be either direct fibre or DWDM and direct fibre.

2.4.7 Optical Line Terminator (OLT)

The DPUs make use of the OLT to aggregate large numbers of DPUs efficiently over fibre infrastructure.

Refer to section 2.2.3.

2.5 HFC Access Domain

The HFC Access domain solution consists of the following components:

- A HFC NTD (Cable Modem), which provides the UNI
- The coax plant, which provides the copper path between the NTD and HFC Optical Node
- An Optical Node, which converts RF signals from fibre to coax cable and vice versa
- Fibre Network (FN) which provides the optical pathway between the Optical Node and the site where the RF Combiner is located
- RF Transmission
- RF Combiner, which combines multiple RF signals into a common signal
- HFC Transport, which provides carriage of signals between the RF Combiner and CMTS where these are not co-located.
- Cable Modem Termination System (CMTS), which controls, aggregates and forwards the cable modem traffic. It also provides the interface to the Aggregation Domain.

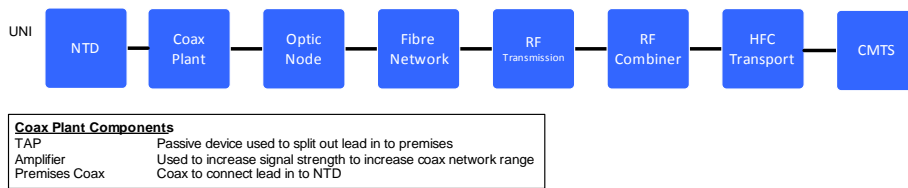


Figure 27 High level interconnection block diagram of HFC Access

2.5.1 HFC NTD (Cable Modem)

The HFC NTD terminates the incoming physical coax cable at the end-user premises and provides one User to Network Interface (UNI). The HFC NTD will have the following:

- 1 x coax interface
- 1 x UNI-Data interfaces

A standard AC power supply is used to power the NTD.

2.5.2 Coax Plant

nbn is progressively acquiring and is utilising existing coax plant to provide physical connectivity between the NTD and the Optical Node.

Coax plant may be aerial or underground.

Where growth or gaps in coverage in brownfields areas makes it appropriate, **nbn** will provide new coax plant.

The coax plant includes mainline trunk, tie, and lead-in coax cables, amplifiers, line-extenders, taps, power supplies, and premises coax to connect to the NTD.

2.5.3 HFC Optical Node

nbn is progressively acquiring and utilising existing HFC Optical Nodes. A HFC Optical node is a convertor from coax to optical signals and vice versa. It connects to the RF Combiner site via the fibre network and RF Transmission.

Where growth or gaps in coverage in brownfields areas makes it appropriate, **nbn** will provide new HFC Optical Nodes.

2.5.4 Fibre Network (FN)

The Fibre Network provides connectivity between a HFC Optical Node and the RF Transmission equipment and RF Combiner location. **nbn** has leased the existing Telstra and Optus fibres.

Where growth or gaps in coverage in brownfields areas makes it necessary, **nbn** will provide new fibre networks, in alignment with the fibre designs captured in section 2.2.2.

2.5.5 RF Transmission

The optical transmission equipment is co-located with the RF combiner at either the FAN site or the Aggregation Node site. It connects the RF Combiner to the Fibre Network, converting from electrical to optical signals and vice versa.



2.5.6 RF Combiner

The RF combiner is located in a FAN site or an Aggregation Node site. It connects HFC Optical nodes to upstream sources via the RF Transmission, including:

- **nbn** CMTS
- Foxtel Pay TV head end
- Telemetry and maintenance equipment

These systems connect electrically and the RF Combiner combines RF signals to allow for coexistence of signals for delivery over a HFC Optical Node and its associated coax plant.

2.5.7 HFC Transport

Where the RF Combiner and Cable Modem Termination System (CMTS) equipment is not co-located RF Transmission equipment is used in conjunction with the Transport Direct Fibre to provide connectivity.

2.5.8 Cable Modem Termination System (CMTS)

The Cable Modem Termination System (CMTS) equipment is located at either a FAN site or an Aggregation Node site. It connects to the RF Combiner via a coax interface and provides DOCSIS connectivity over RF to the Cable Modems. RF Segments (or Service Groups) are defined as the group of downstream and upstream RF channels that are seen by a Cable Modem.

Depending on the location of the CMTS it may connect to the EAS via the following methods:

- Local intrabuilding connectivity (co-located CMTS and EAS)
- Transport options as shown in section 2.9 (DWDM or DF expected)
- Service Connectivity Network as shown in section 2.11

2.6 The MTM Fixed Access Network Planning Hierarchy

For planning, design and construction purposes, the network is divided into hierarchical modules and network entities. To support the multi technology mix the modules are intended to be access agnostic, supporting all fixed access technologies.

These modules are used to provide the planning constructs needed to provide connectivity between the individual end-user's premises through to the Access Seeker (AS) Point of Interconnection (POI). The planning constructs are intended to be applied flexibly to reduce build costs.

The first identifiable connection point is an end-user premises. These are defined as physical address points. Each individual dwelling unit is required to have a unique service location, and is identified as an end-user premises. If the end-user premises is situated in an MDU environment then these are treated as individual premises.

The first module is the Access Distribution Area (ADA). The Access Distribution Area (ADA) is the aggregate footprint of the set of premises served by an **nbn**TM node. A node is the first point of aggregation (passive or active) encountered moving from the FAN site towards the premises. A node may be:

- The splitters of a Fibre Distribution Hub (FDH) or Flexibility Joint Location (FJL)
- a DSLAM with an Ethernet backhaul architecture,
- a physical HFC Optical Node

The ADA is guided by the existing duct and pit infrastructure of the Telstra Copper Distribution Areas, and in the case of HFC, the existing Optical Node and coax plant. Note that copper and HFC access technologies must be taken into account when considering the Fibre Network planning to optimise the Fibre Network where multiple access technologies are to be supported.



The second module is the combination of a maximum of 24 ADAs to create a Serving Area Module (SAM). The typical size of a SAM is expected to be 16 ADAs, but this is dependent on the access technology mix and geography of the area to be served. A SAM may have:

- one DFN providing connectivity to the nodes,
- one DFN and leased fibres providing connectivity to the nodes,
- no DFN and leased fibres providing connectivity to the nodes

The third module is the Fibre Serving Area (FSA) and is the combination of a number of SAM modules located around a Fibre Access Node (FAN).

The placement of the FAN site in relation to the SAMs is derived by identifying as central a location as practical.

The FSA is increased by adding SAM modules as required. The optical path for the Fibre Network needs to be identified and monitored during the planning and design phase for each SAM to keep the FN length within the optical constraints.

The following table provides an example of the planning hierarchy where the Fibre Network includes a single **nbn**TM DFN, and no leased fibre, such as will be encountered in areas where HFC access technologies contribute to coverage:

Main Conduit / Node Identification		Conduit selected. 28 Nodes identified, each serving a Distribution Area
-------------------------------------------	------------------------------------------------------------------------------------	--------------------------------------------------------------------------------

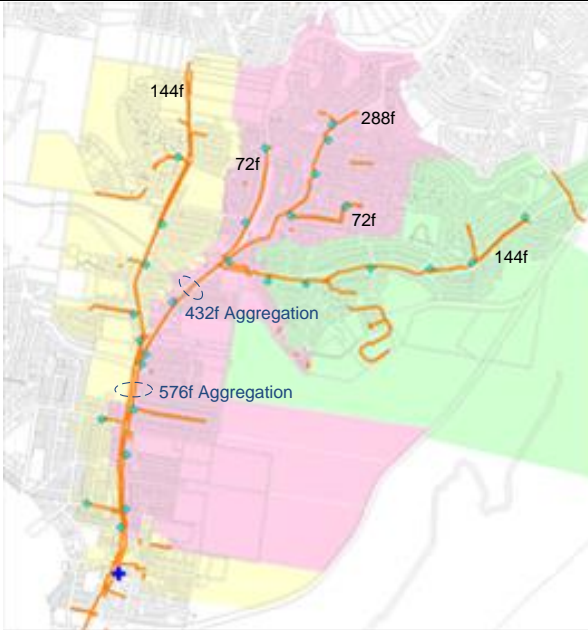
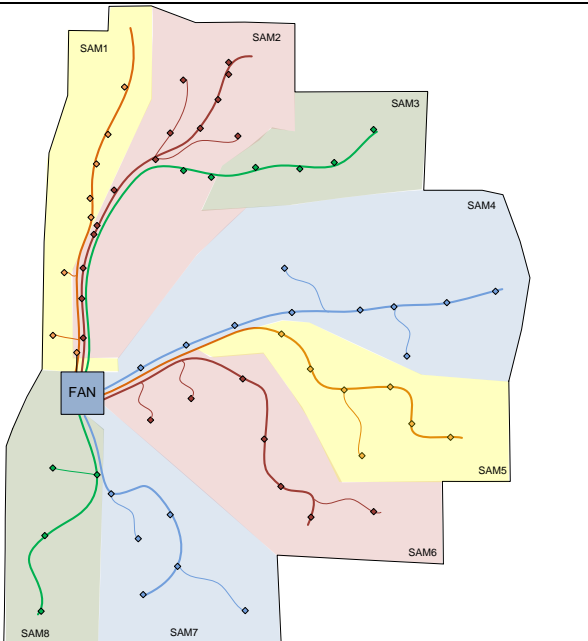
Node Groupings / SAM Identification		<p>8 Nodes clustered in SAM 1 (yellow) = 144f DFN</p> <p>14 Nodes clustered in SAM 2 (pink) = 288f DFN</p> <p>6 Nodes clustered in SAM 3 (green) = 144f DFN</p>
Fibre Serving Area Identification		<p>FSA comprises SAMs 1-8</p>

Table 6 Example of Planning Hierarchy

2.7 TD-LTE Wireless Access Domain

The Wireless Access domain solution consists of the following components:

- **Wireless Network Terminating Device (WNTD)** - The Wireless Network Terminal located at the end-user premises uses TD-LTE technology to connect back to the eNodeB. It delivers UNI-D capabilities to a premises.



- Radio Spectrum – **nbn** has radio spectrum to support the TD-LTE radio technology in line with the 3GPP specification
- eNodeB – provides the radio access interface for the WNTDs
- Aggregation and Transport for Wireless –
 - Microwave equipment is used to backhaul and where appropriate, aggregate traffic from eNodeBs back to a FAN site
 - Transport - provides the carriage between the FAN site, a further aggregation switch located in a POI site and the PDN-GW. Common infrastructure used for all connectivity between FAN and POI sites
 - POI Aggregation Switch is used in a POI site to aggregate the traffic from the FANs before transport to the PDN-GW. This is common infrastructure that provides the Aggregation Domain EAS/ECS functions as well
- The PDN-GW - provides policy and admission control for the WNTDs. It also provides the interface to the Aggregation Domain for the aggregated Wireless Access traffic.

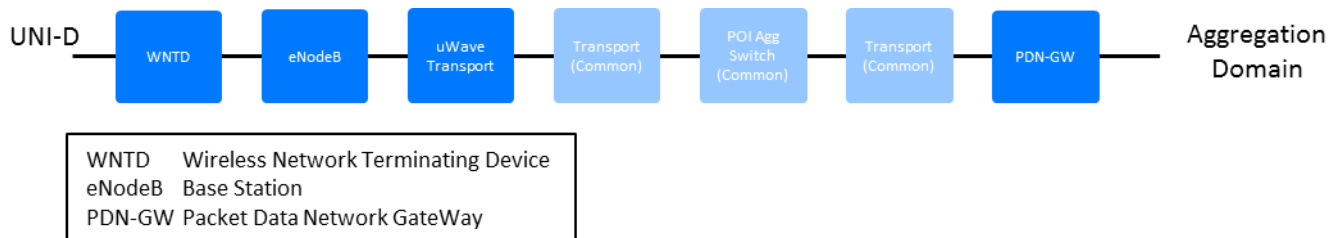


Figure 28 High level interconnection block diagram of Wireless Access

2.7.1 Wireless NTD (WNTD)

The WNTD terminates the incoming radio signal at the end-user premises and provides one or more User to Network Interfaces (UNI).

The WNTD consists of the following two physical components: an Indoor Unit (IDU) and an Outdoor Unit (ODU), connected together with a Cat 5 cable.

The ODU key components include:

- Cross-polar panel antenna
- LTE TRx and modem
- Control and Management board
- Interface to the IDU

The IDU key components include:

- 4 UNI-D ports,
- Switch
- Interface to the ODU

A standard AC power supply is used to power the IDU and through that the ODU.

There are three variants of WNTD. Band 40, Band 42 and dual band.



2.7.2 Radio Spectrum

nbn will use its spectrum holdings in the E-UTRA Operating Band 40 (2.3 GHz to 2.4 GHz frequency range) and E-UTRA Operating Band 42 (3.4 GHz to 3.6 GHz frequency range) in its deployment of Wireless Access Services.

nbn's spectrum holding is registered with the ACMA and can be found:

http://web.acma.gov.au/pls/radcom/client_search.client_lookup?pCLIENT_NO=1104329

http://web.acma.gov.au/pls/radcom/client_search.client_lookup?pCLIENT_NO=8129031

Generally, the spectrum held by NBN Co Limited in the 2.3 GHz and 3.4 GHz bands was purchased in the multiband spectrum auction (including most recently, in the multiband residual lots auction conducted by ACMA in late 2017), while the spectrum held by NBN Co Spectrum Pty Ltd was purchased from AUSTAR. The 2015 allocation of additional Band 42 spectrum has been allocated to **nbn** through ACMA as a result of a ministerial directive.

A licence number in the table links to the licence details, including a Licence Image. The Licence Image defines, among other technical requirements, the exact geographic area covered by the licence.

2.7.3 eNodeB (Base Station)

Each eNodeB has multiple sectors and is sited according to a site specific radio coverage plan to provide optimised coverage, and may have additional sectors added if there is capacity demand. The number of premises supported by each sector is determined by the radio condition. Each sector supports on average 60 premises, adjusting to a typical maximum of 56 premises as capacity demands change. Management of capacity to meet customer expectations is an ongoing process.

Some sites have existing sheltered accommodation available, while other sites will have none. Where none is available an environmentally protected housing will be provided to house the equipment.

The eNodeB provides the Air (Radio) Interface which connects the eNodeB to the WNTD, and a backhaul Interface which connects the eNodeB to the Microwave Backhaul equipment. A typical eNodeB comprises a number of interconnected modules:

- 3 RF Antennae
- GPS Antenna
- Remote Radio Unit
- Digital Baseband Unit
- Power Supply
- Battery Backup

2.7.4 Aggregation and Transport for Wireless

2.7.4.1 Microwave Transport Equipment

Microwave Transport equipment is used to connect eNodeB sites into a FAN site. Microwave Transport equipment is in most cases housed in the eNodeB cabinet. The Microwave Antenna is mounted on the radio tower where the eNodeB RF Antennas are mounted.

Microwave Transport equipment is also used to connect an eNodeB spur using a Microwave End Terminal to a Microwave Hub Site.

A Microwave Hub Site may have an eNodeB present. The Microwave Transport equipment at a hub site can communicate with various microwave sites and provides an aggregate point for connectivity to a FAN site. The

maximum bandwidth planned was originally 900Mbps but is now moving to 4Gbps to support capacity growth, allowing for the aggregation of up to 8 eNodeBs.

Microwave Hub sites can be connected to other Microwave Hub sites, as long as the final Hub to end terminal bandwidth does not exceed an aggregate of eight eNodeBs.

The exact number of eNodeB spurs that are connected back to a Microwave Hub Site or Repeater Site, and the location of the Microwave End Terminal to connect to the FAN site, is heavily dependent on local geography and End User distribution.

Example deployment scenarios are shown in the diagram below:

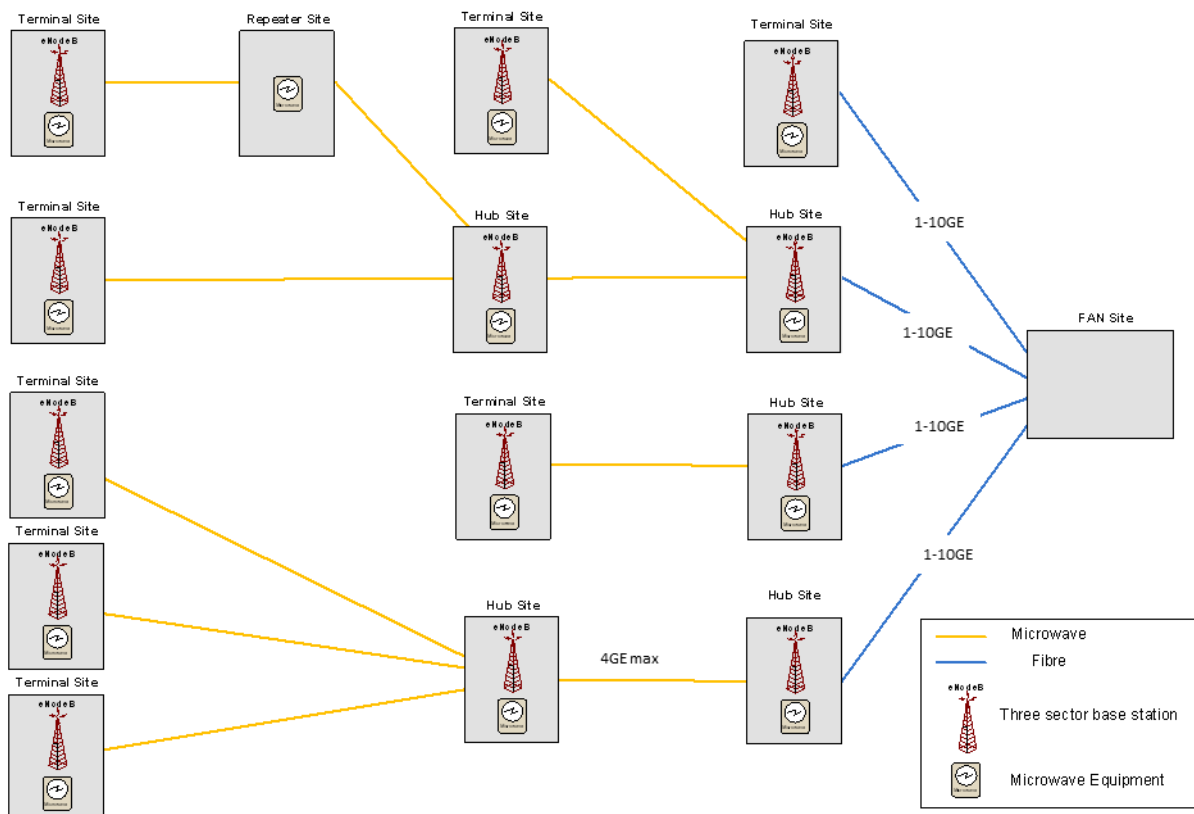


Figure 29 Microwave Transport Design

2.7.4.2 Fibre Transport Equipment

Where a wireless base station site has access to direct fibre tails to connect to a FAN site. A switch function is housed in the eNodeB cabinet to enable connectivity from the eNodeB to the fibres.

2.7.4.3 Transport

Transport from the FAN to the PDN-GW site is provided by either 3rd party backhaul or **nbn**'s DWDM solution. Refer to the Transport Domain section for further information.

2.7.4.4 POI Aggregation Switch

The POI Aggregation Switch is deployed in pairs in POI sites to aggregate the Wireless Access traffic from FAN sites.

2.7.5 Packet Data Network Gateway (PDN-GW)

The PDN-GW supports a total of up to 80,000 WNTDs by consolidating up to 16 AARs. It is provided as a pair for resiliency, each with its own internal resiliency of controller, traffic and line cards. Consolidation of the AARs is achieved via the POI Aggregation Switch.

The PDN-GW has two 4 x 10 Gigabit Ethernet (SFP+) interfaces to the Aggregation Domain for resilient network connectivity, and up to eight 8 x 10 Gigabit Ethernet (SFP+) interfaces to the POI Aggregation Switch pair for resilient network connectivity. The system is fed by -48VDC power, and power module/feed redundancy is incorporated into the shelf.

2.7.6 Wireless Access Planning Hierarchy

For planning, design, and construction purposes the network is divided into hierarchical modules and network entities.

These modules are used to provide the planning constructs needed to provide connectivity between the individual end-user's premises through to the Access Seeker (AS) Point of Interconnection (POI)

The first identifiable connection point is an end-user premises. These are defined as physical address points. Each individual dwelling unit is required to have a unique service location, and is identified as a premises.

The first module is the Wireless Serving Area Module. The eNodeB sectors provide adjacent or overlapping coverage and are grouped in clusters of up to eight sites.

The planned maximum number of connected premises in a sector has typically been 110 premises but is now moving towards 56 premises in each sector driving the need for additional sectors to support capacity demand (this may vary depending on the exact positions and radio conditions of the served premises).

The maximum bandwidth planned for the Microwave Hub Site back to a FAN site has been 900Mbps, but is now moving to 4Gbps to support capacity growth, allowing for the aggregation of up to 8 eNodeBs, with a maximum of 2640 End Users.

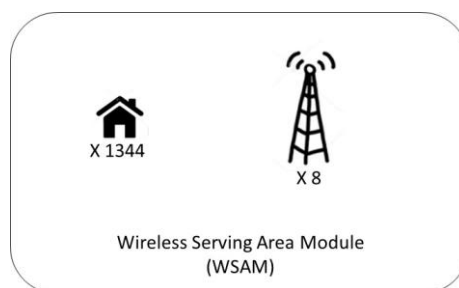


Figure 30 An example Wireless Serving Area Module

The second module is the Wireless Serving Area. All Wireless Serving Area Modules connected to a common FAN site are grouped into a Wireless Serving Area. The largest WSA will have up to 24 WSAM connecting to a FAN.

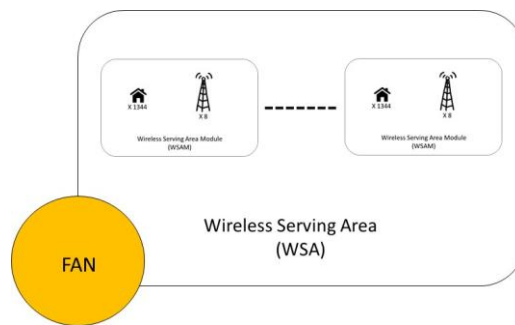


Figure 31 An example Wireless Serving Area

The third module is the Access Aggregation Region (AAR). The wireless area served by a single POI is an AAR. The maximum number of WSAs in an AAR is determined by the number of FANs that connect back to the POI. For the purposes of wireless dimensioning, the size of an AAR is based on the maximum number of End Users, rather than the maximum number of WSAs, with a maximum of 25000 End Users in an AAR.

2.8 Satellite Access

The Satellite Access domain solution consists of the following components:

- Satellite NTD (Very Small Aperture Terminals or VSATs) - The Satellite Network Terminal located at the end-user premises or service location communicates over the satellite RF links back to the VSAT baseband sub-system. It delivers UNI capabilities to a service location. Specific business service VSATs will be available.
- Satellite – two, multi-spot beam, geostationary, "bent-pipe", telecommunications satellites to connect VSATs to the VSAT Baseband sub-system. Located in geosynchronous equatorial orbit (GEO) overlooking Australia and operating in the Ka-band RF spectrum.
- RFGW – RF Gateway Facility supporting the RF and VSAT Baseband Sub-Systems.
 - RF Sub-System – Earth station RF antennas, transmission and reception equipment to provide trunk links to and from the satellites.
 - VSAT Baseband Sub-System – subscriber service termination equipment to manage and carry user traffic to and from Satellite subscribers.
 - Business Satellite Services Baseband Sub-System – subscriber service termination equipment to manage and carry user traffic to and from Business Satellite Services subscribers of RF spectrum
- Satellite Gateway Routing and Switching – provides the connectivity at the Gateway & DPC sites for local equipment and to the Service Connectivity Network (SCN)
- Business Satellite Services Gateway Routing and Switching – separate instance of Routing and Switching that provides connectivity at the Gateway for local equipment to the SCN
- Service Connectivity Network (SCN) - provides the connectivity between the RF GW site and the DPC site. Common infrastructure used for resilient carriage of traffic between **nbn**TM sites.
- DPC – Data Processing Centre supporting the Service Control Sub-System (SCS).
 - Service Control – Satellite specific user application and traffic management equipment to enhance the user experience due to the long latencies incurred over geostationary satellite links.
- Business Satellite Services Point of Interconnect – two Points of Interconnect specifically for Business Satellite Services, located at existing **nbn** POI sites
 - BSS Routing, Switching & Security – provides connectivity between the SCN and the local equipment, also securing an Internet connection

- BSS Hosting Infrastructure – provides infrastructure for the customer to host local applications

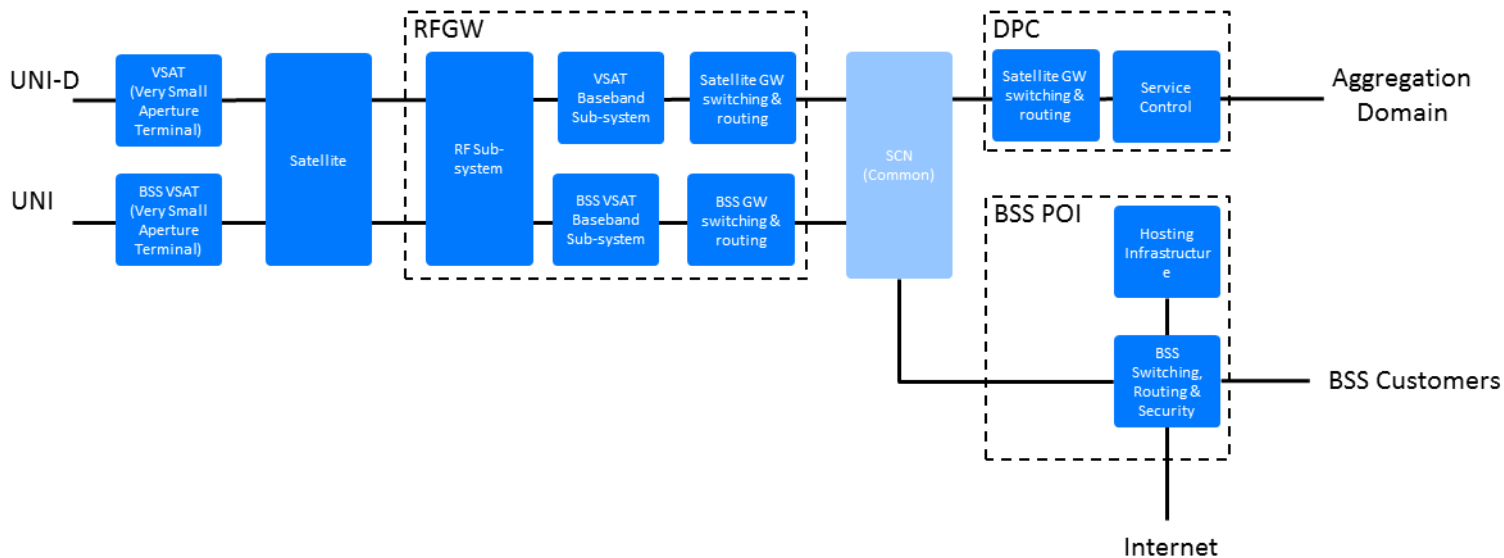


Figure 32 High level interconnection block diagram of Satellite Access

2.8.1 Satellite NTD (Very Small Aperture Terminal (VSAT))

The VSAT is located in the user premises or service location, provides the User to Network Interfaces (UNI-D) and connects to the **nbn**TM network via the satellite over Ka-band RF spectrum.

A number of Satellite NTD varieties will be used to suit different circumstances, end-user types and interface quantities. The variants included are Indoor and Outdoor NTDs for business and residential purposes.

The indoor VSAT consists of the following two physical components: an Indoor Unit (IDU) and an Outdoor Unit (ODU), connected together with a coax cable.

The ODU key components include:

- Parabolic satellite terminal antenna
- Ka-Band VSAT Transmit and Receive Integrated Assembly (TRIA)
- Interface to the IDU

The IDU key components include:

- Up to 4 UNI-D ports
- Layer 2 Ethernet Switch
- Embedded Transparent Performance Enhancing Proxy (TPEP) software client
- Interface to the ODU

A standard AC power supply is used to power the IDU and through that the ODU.

The outdoor VSAT consists of the same components, hardened to deal with environmental requirements.

2.8.2 Satellite

nbn uses two, multi-spot beam, geostationary, "bent-pipe", Ka-band, telecommunications satellites for the Satellite Access Solution with the following characteristics:

- Two satellites to enable load balancing of users and limited service redundancy.

- Multi-spot beam design on each satellite providing the combined total of 107 Gbps forward path and 28 Gbps return path system capacity to best support the regional and remote Australian population and utilise the optimum broadband user experience from the amount of RF spectrum available. The delivered solution has achieved an actual capability of 154 Gbps forward path and 31 Gbps return path.
- Geostationary orbital locations to enable full coverage of the Australian mainland and territories with the least number of satellites and at the lowest possible VSAT costs.
- “bent-pipe” design, meaning the satellite is only an RF transceiver for network to user traffic and user to network traffic, providing broadband services to the most remote Australians with minimum mass of the spacecraft.
- Ka-band operation to achieve the user experience speeds and the required system capacity from only 2 satellites.

The “satellite to user” spot beams are designed to achieve the system capacity requirements, by re-using the Ka frequency band as efficiently as possible. This is achieved through the combination of:

- Optimised placement of user spot beams
- Frequency re-use and polarity re-use of the Ka-band spectrum
- Highly directional satellite and VSAT antennas to minimise interference
- Optimised RF filter designs to achieve the highest order modulation techniques over satellite links.

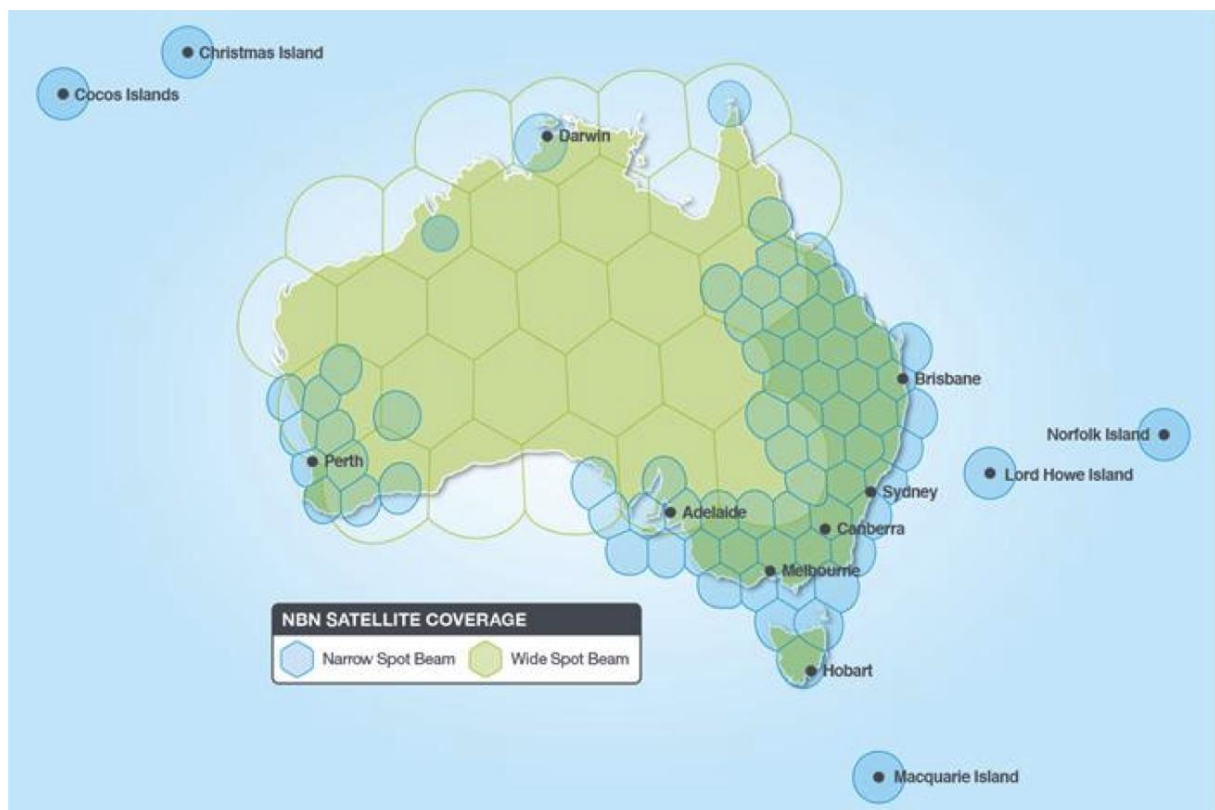


Figure 33 Design of User Spot Beams

The “RF Gateway to satellite” links are designed to carry the satellite traffic to the RF Gateways (RFGWs), which contain the RF Subsystem and VSAT baseband subsystem.

nbn uses the Ka-band radio spectrum through the appropriate ACMA domestic licensing regimes, including class licensed bands for “satellite to user” beams, and a combination of one **nbn** held spectrum license,



privately negotiated agreements with other current spectrum license holders and apparatus licenses issued by the ACMA for “RF Gateway to satellite” links.

Description	Frequency Range
RFGW to Satellite Uplink	27.0 – 28.5 GHz
Satellite to VSAT Downlink	17.7 –18.2 GHz, 18.8 –19.3 GHz and 19.7 – 20.2 GHz
VSAT to Satellite Uplink	28.5 – 29.1 GHz
Satellite to RFGW Downlink	18.2 – 18.8 GHz
RF Auto Tracking Downlink	29.5 – 29.54 GHz
Uplink Power Control	19.3 – 19.35 GHz

Table 7 RF Spectrum Plan

nbn’s satellites are designed to operate at the orbital slots of 140 deg E and 145 deg E. **nbn** has gone through the ITU international frequency coordination process.

2.8.3 RF Sub-System

In each RF Gateway, the RF Sub-System transmits and receives RF signals with the satellites, and connects to the VSAT baseband Sub-system. The RF Sub-system comprises of the following major components;

- 13.5m earth to satellite antennae on controllable mounting platforms
- RF amplification, filtering, conditioning and receiving equipment operating at Ka-band.
- Power Supplies
- Monitoring and Control systems.

2.8.4 VSAT Baseband Sub-System

The VSAT baseband system is located in the RFGWs and is the termination system for VSAT traffic and management signals. It is composed of the following components:

- Modulation and Demodulation equipment
- Air Resource Management equipment
- Traffic forwarding equipment

The dimensioning of each RFGW’s VSAT Baseband sub-system is based on the most efficient RF channel packing of the available Ka-band spectrum, the highest order modulation code points possible for transmission and reception to and from the satellite from the specific RFGW location and the required equipment resiliency supported by the VSAT Baseband sub-system supplier to meet the business requirements of service availability.

2.8.5 Business Satellite Services VSAT Baseband Sub-System

The BSS VSAT baseband system is also located in the RFGWs and is the termination system for BSS VSAT traffic and management signals. It is composed of the same components as the VSAT Baseband sub-system, but used for a subset of RF channels that are dedicated for BSS.



2.8.6 Satellite GW Routing and Switching

The Satellite GW routing and switching provides the connectivity between the gateway satellite baseband systems and the SCN for carriage through to the DPC. There is an additional instance at the DPC for connecting the Service Control system to the SCN.

2.8.7 BSS Satellite GW Routing and Switching

The BSS Satellite GW routing and switching provides the connectivity between the gateway satellite baseband systems and the SCN for carriage through to the DPC.

2.8.8 Service Connectivity Network

The Service Connectivity Network provides the connectivity between the RF gateway sites and the DPC sites, . This is a shared network, refer to section 2.11.

2.8.9 Service Control

The Service Control system is located in the DPC and is designed to enhance the user experience by intelligently accelerating and spoofing user traffic to counteract the latency effects of the very long distances encountered between earth to satellite, then satellite to earth RF links. Multiple Transparent Performance Enhancing Proxy (TPEP) techniques are being used in the Satellite Access solution design:

- Traffic payload and header compression and suppression
- TCP traffic acceleration
- Web traffic acceleration
- Traffic caching and pre-fetching

The TPEP system is implemented in servers located in the **nbn**TM DPCs as well as embedded software in the VSATs. No software or configuration is required by the Access Seeker or the user to enable the TPEP functionality.

Subscriber and POI traffic will be switched between the remote RFGW's, the DPCs and the satellite central POI via a nation-wide Service Connectivity Network (SCN) that will reuse the existing **nbn**TM transport network (refer to 2.11).

2.8.10 BSS Satellite POI Routing, Switching & Security

The BSS Satellite POI routing, switching and security provides the connectivity and control between the SCN, the hosting infrastructure, BSS customers and the internet for BSS customer traffic and management and operations traffic.

2.8.11 BSS Hosting Infrastructure

The BSS Hosting Infrastructure provides a computing infrastructure and storage capability for service related applications to be supported from.

2.8.12 Satellite Planning Hierarchy

For planning, design, and construction purposes the network is divided into hierarchical modules and network entities.

These modules are used to provide the planning constructs needed to provide connectivity between the individual end-user's premises through to the Access Seeker (AS) Point of Interconnection (POI)



For a satellite access network, this is a somewhat different process than for other access technologies due to the fixed nature of the satellite. The planning hierarchy is effectively set at the time of the system design, with few areas for adjustment once the satellite, RF Gateway and DPC are established.

The first identifiable connection point for the Long Term Satellite Solution (LTSS) is the end-user premises. These are defined as physical address points and/or Lat /Long. Each individual dwelling unit is required to have a unique service location, and is identified as a premises.

The first module is the spot beam. The spot beams have been planned to provide coverage as shown in section 2.8.2, taking into account the premises density and expected takeup of services. Where there is available capacity, some RF spectrum within a beam will be reserved for Business Satellite Services.

The second planning module for LTSS is the RF Gateway. Nine (9) RFGW's are used to carry the aggregated traffic load, with an additional RFGW for disaster recovery protection of the service. To achieve the optimum RFGW trunk link performance, the following design criteria are optimised:

- Maximum gateway to gateway geographical separation
- Location of gateways away from projected user high density areas
- Services available at gateway locations (highly reliable power, transit network connectivity, ACMA TX and RX license approvals, Australian security agency approvals, etc)
- Gateway to User beam RF interference characteristics
- Frequency and polarity reuse strategy for gateway and user beams
- The satellite's antenna specifications and RF filter design capabilities
- The VSAT system's advanced RF channel adaptive power management and modulation schemes.

Using these criteria the following RF Gateway locations have been selected: Ceduna, Geeveston, Bourke, Wolumla, Geraldton, Carnarvon, Roma, Broken Hill, Waroona and Kalgoorlie.

The VSAT Baseband sub-system in the RF Gateways is initially deployed with half of the total capacity of modulator and demodulator modules. As end user takeup grows more modulators and demodulators will be added to the system as required.

The third module is the Data Processing Centre (DPC). LTSS has 2 DPCs: a primary and a backup working in an active standby mode. All traffic is aggregated in the primary (or in case of a DPC failure, the backup) DPC. The initial planned aggregated capacity in the DPC is 80Gbps. The DPC capacity can be augmented as required.

The fourth module is the Satellite Serving Area. This is the complete footprint of the 101 user beams from each Satellite, as LTSS services are provided to Access Seekers through a single POI collocated with the primary DPC.

2.9 Transport Domain

2.9.1 Dense Wavelength Division Multiplexing (DWDM)

The **nbn**TM Dense Wavelength Division Multiplexing (DWDM) fibre optic transport network is made up of a number of DWDM Nodes (DNs) situated mainly at POI and FAN sites, all interconnected by Optical Multiplex Section (OMS) links. A DN may also be used within a link for amplification.

The DWDM network predominantly provides physical connectivity and transit backhaul capacity between POI and FAN sites. The network also provides connectivity to centralised depots, data centres and delivery points for the specific transport services that require them.

The following diagram shows the basic connectivity scenarios for the DWDM network. Each DN has a metric called "degree of connectivity", which is the number of fibre interfaces it has, and therefore the number of

other DNs it can connect to. The DN at POI 1, for instance, has a degree of two: it connects to the DNs at two FAN sites. The DN at FAN 7 has a degree of one.

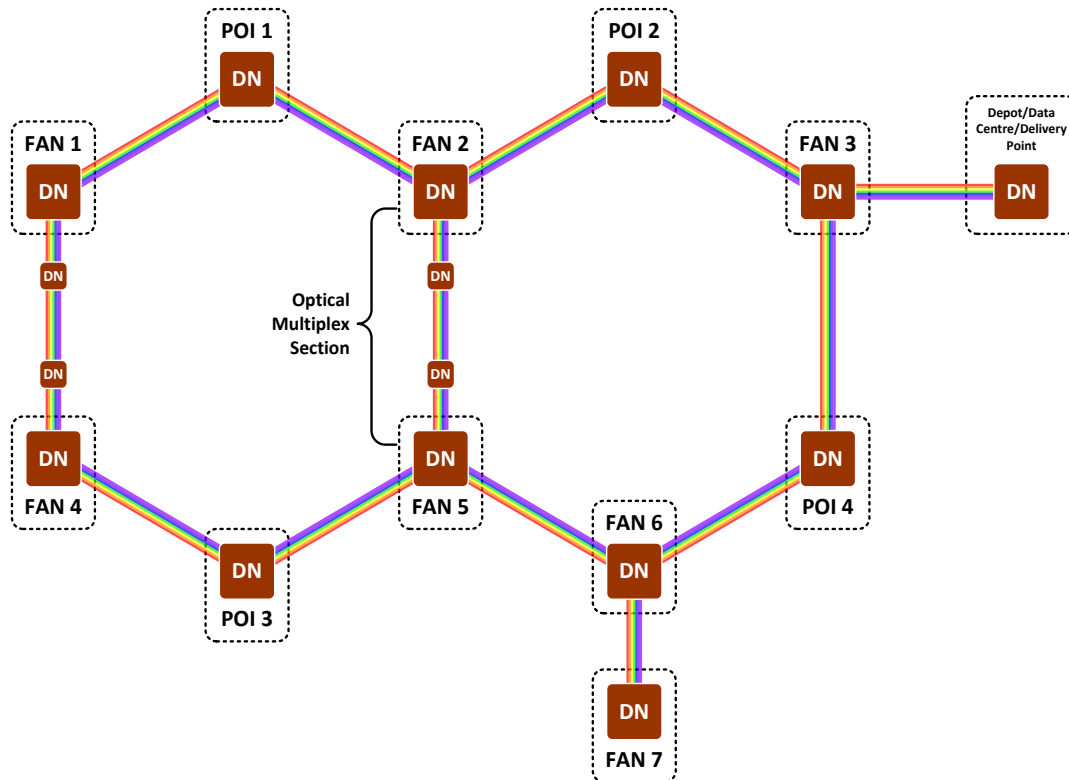


Figure 34 Basic DWDM physical connectivity scenarios

There are two types of DWDM Nodes: Reconfigurable Optical Add-Drop Multiplexers (ROADMs) and Optical Line Repeaters (OLRs). Each of these two types of DN comprises:

- Baseline elements: elements that have a fixed quantity per degree and do not expand with traffic growth unless that growth involves an increase in degrees. Such elements include amplifiers, add/drop filters and wavelength selective switches.
- Growth elements: these are elements within a degree that can be added to as growth requires. Such elements include channel cards, controller and chassis.

2.9.1.1 Reconfigurable Optical Add-Drop Multiplexers (ROADMs)

Reconfigurable Optical Add-Drop Multiplexers (ROADMs): these are one- (or more) degree nodes that can provide the following functions:

- Extract data from a wavelength on any of its degrees for presentation to a client interface
- Inject data from the client interface into a wavelength for transport on any of its degrees
- Transit wavelengths between degrees

The standard ROADM variant used allows transmission up to 96 wavelengths, each wavelength in effect a channel of 40Gbps, 100Gbps or 200Gbps. Standard ROADMs will be used at both POI and FAN sites.

A smaller, compact ROADM variant, for use where space is an issue, supports up to 8 wavelengths. The standard and compact ROADMs can be used together: although the compact ROADM only supports 8

wavelengths, those wavelengths can be any of the 96 produced by the standard ROADM. Compact ROADMs will be used only at FAN sites that require a maximum of two degrees and a maximum of 8 channels.

There is also a Long Span ROADM that is used to allow un-regenerated OMS links across Bass Strait. The Long Span ROADM allows up to 40 wavelengths (channels).

2.9.1.2 Optical Line Repeaters (OLRs)

Optical Line Repeaters (OLRs): these are two-degree wavelength-pass-through nodes that provide optical amplification only. OLRs may be required when transmission fibre distances between adjacent ROADMs exceeds the optical reach of the equipment.

2.9.1.3 DWDM Network Topologies

There are four network topologies that can be deployed. In most cases the overlapping physical ring topology will be used as the majority of dark fibre is being sourced from Telstra and only a single pair is being provided on most routes.

Standalone Physical Rings:

Each physical ring utilises one fibre pair. Wavelength routing and count within one ring has no dependencies on the physical attributes or traffic requirements on any other ring. If there are any DNs common between rings, they will require a degree of more than two. Any inter-ring wavelength connectivity will be performed via the wavelength selective switches within the common DNs.

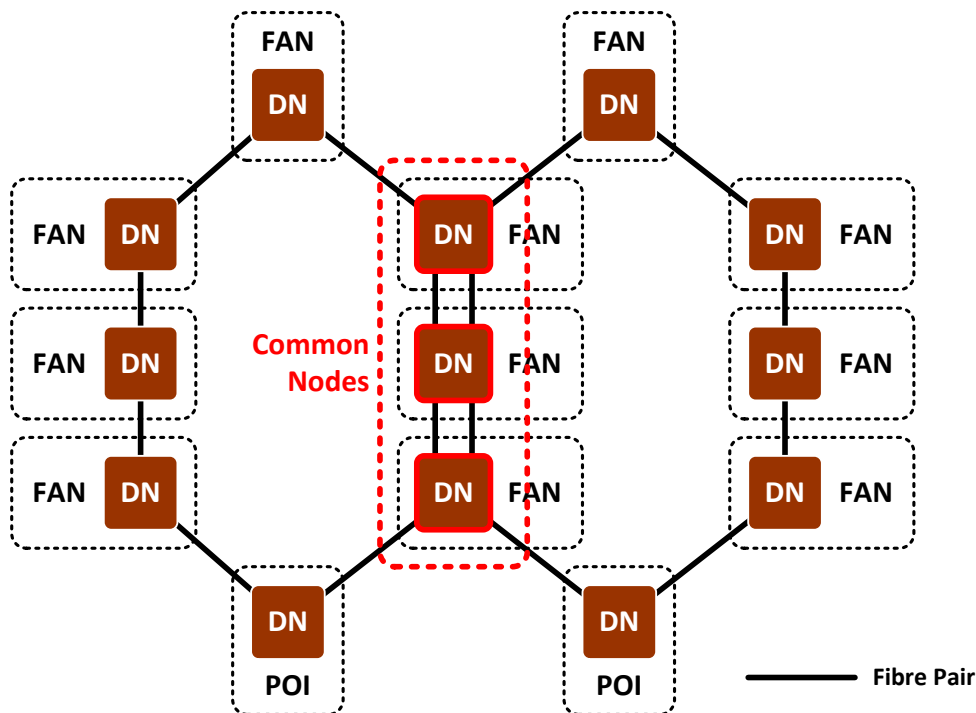


Figure 35 Standalone physical rings

The rings provide the 1+1 redundancy required between any two points in the network: if one link should fail, any node past the breach can be reached by routing in the other direction using a different wavelength. The re-routing can be achieved through either 1+1 Client Protection, where the client network recognises the break and uses a second connection for traffic continuity, or 1+1 Service Protection, where the DWDM network itself provides the rerouting capability.

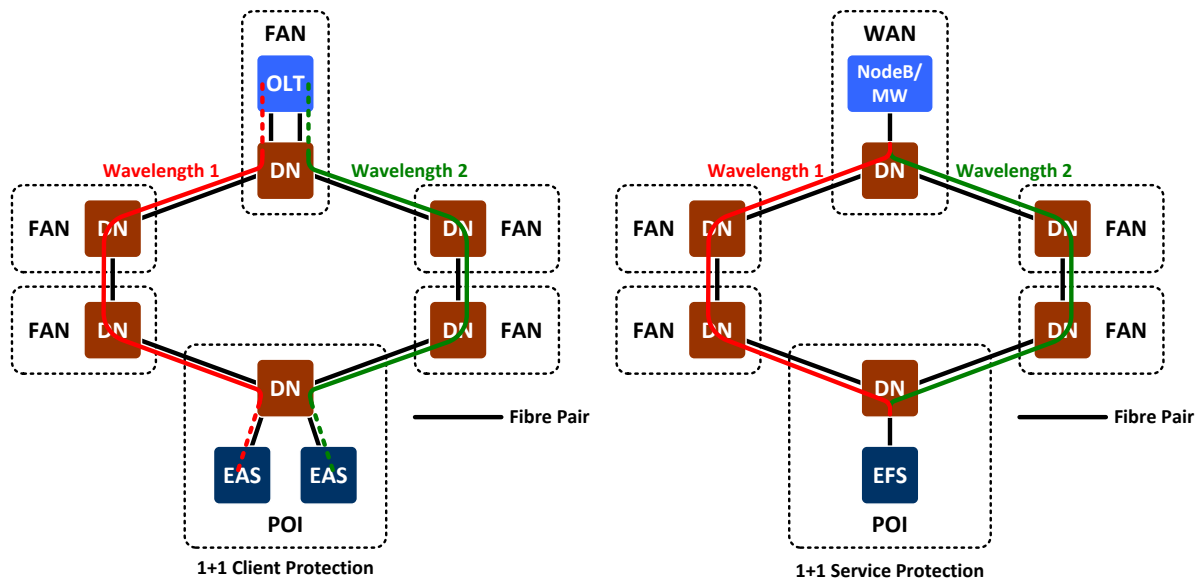


Figure 36 Examples of redundancy in the DWDM network (using 1+1 Client Protection and 1+1 Service Protection)

Overlapping Physical Rings:

This is the preferred topology where there are adjacent DWDM rings with shared physical routes. In this scenario physical rings can share common fibre pairs. This means that wavelength routing and counts within the shared links have dependencies on the physical attributes and traffic requirements of both rings. Like the standalone deployment option, some DNs will require degrees of more than two degrees. And again inter-ring wavelength connectivity will be performed via the wavelength selective switches within the common DNs.

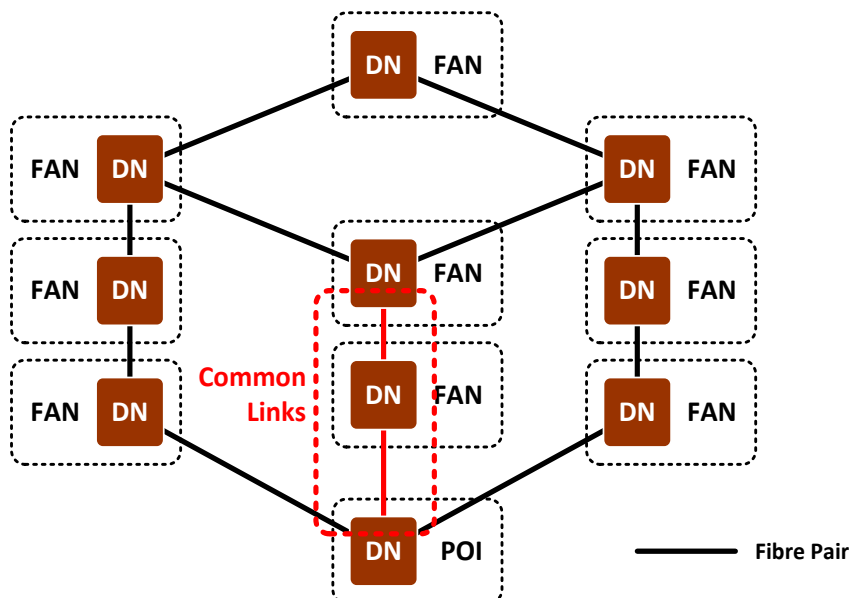


Figure 37 Overlapping physical rings

Point-to-Point Spur Links:

These are used to extend ring or POI connectivity to one or more isolated FAN sites. There is a preference to use two fibre pairs within a spur link to introduce diversity, but some spur links may be limited to one fibre pair. Standard and compact ROADMs can both be used as the far DN in spur links, but the DN that connects the

spur to the ring must have at least three degrees, and therefore must be a standard ROADM. OLR nodes may be required within the spur link when transmission fibre distances between adjacent ROADM nodes exceed the optical reach.

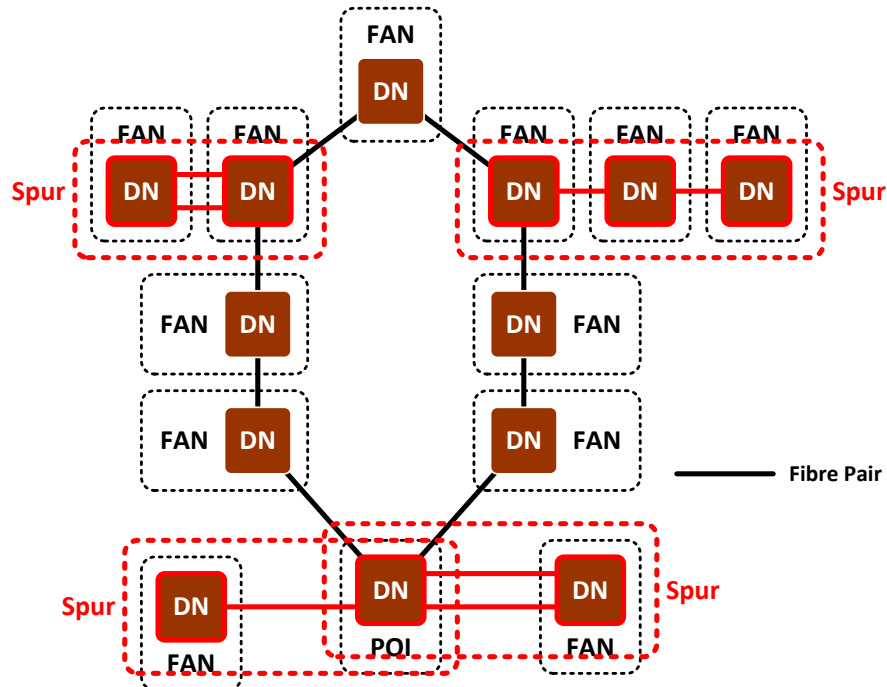


Figure 38 Point-to-point spur links

Point-to-Point Standalone Links:

Used only in the Bass Strait deployment, two point-to-point standalone links are deployed between the Long Span ROADM nodes.

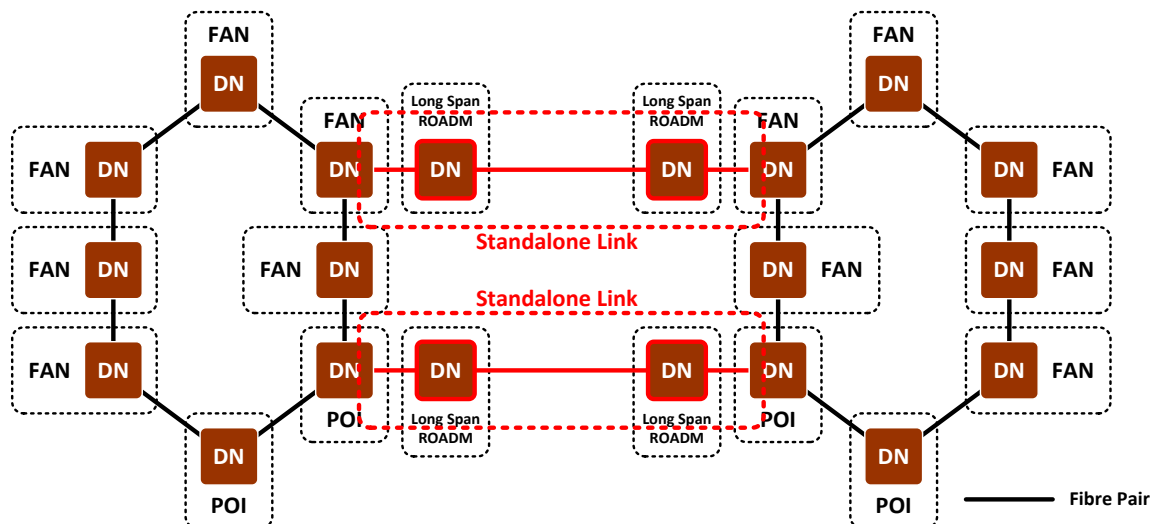


Figure 39 Point-to-point standalone links

2.9.2 Managed Services Transmission

Managed Services are required to supplement the direct fibre and DWDM transport solutions during the roll-out of the transit network. They may be used to provide a complete end-to-end solution or form part of a transport service in combination with DWDM and/or direct fibre.

Managed services are supported for the following connectivity scenarios:

- Fibre access transit (OLT to ECS/EAS)
- Greenfields fibre access transit (OLT to ECS/EAS)
- Wireless access transit (eNodeB or microwave transport to ECS/EFS)

Where multiple devices at a site require a managed service a solution is available to aggregate the traffic such that one managed service can be used instead of one per device.

Fibre Access Transit:

Transport is required between FAN and POI sites for the Fibre Access Service. The basic transport using Managed Services is a pair of fully redundant (1+1) point-to-point Ethernet services running at subrate, 1Gbps or 10Gbps speeds.

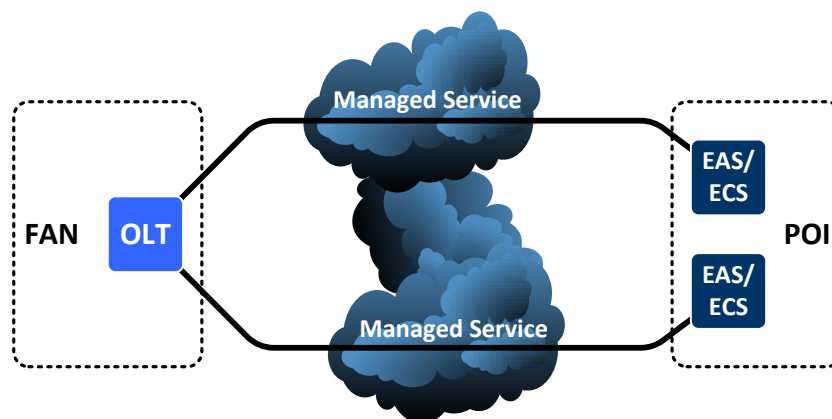


Figure 40 Fibre access transit

Greenfields Fibre Access Transit:

Transport is required between FAN and POI sites, much as with the standard fibre access transit. A single unprotected managed service will be deployed.

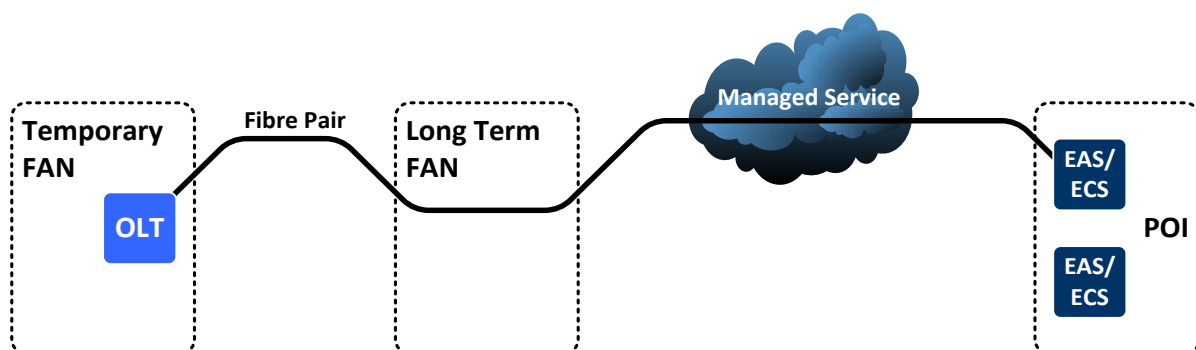


Figure 41 Unprotected Greenfields fibre access transit

Wireless Access Transit:

Wireless access transit is required between FAN and POI sites. As with the fibre access transit, the basic transport using Managed Services is a pair of fully redundant (1+1) point-to-point Ethernet services running at subrate, 1Gbps or 10Gbps speeds.

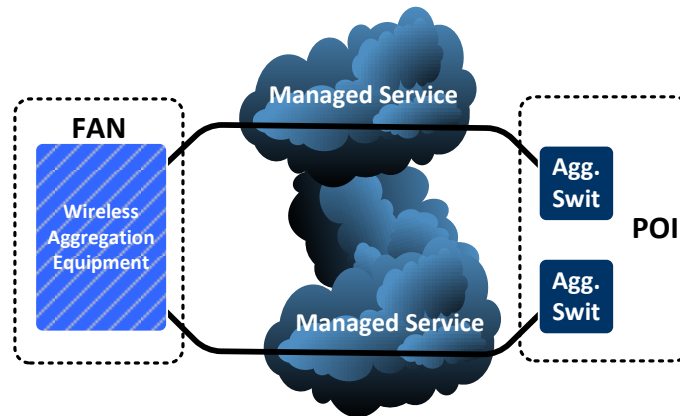


Figure 42 Wireless access transit

2.9.3 Direct Fibre

Direct fibre is the underlying building block of the Transport network domain. The following connectivity scenarios are either fully or partially supported by direct fibre:

- Fibre Access Transit
- Greenfields Fibre Access Transit
- Wireless Transit

Fibre Access Transit:

Direct Fibre for fibre access transit is limited by the interfaces supported on the OLT. The OLT only supports 10GBase-LR interfaces today, which limits direct fibre reach for fibre access to 10km. This is being upgraded to support 10Gbase-ER interfaces in 2012, extending the reach to 40km.

The following direct fibre transit scenarios are supported for fibre access transit:

- Direct fibre for both paths from the OLT back to the POI. This can be used when both fibre paths are $\leq 10\text{km}$ today, or $\leq 40\text{km}$ from mid-2012.
- Direct fibre on the short path from the OLT to the POI and direct fibre on the long path from the OLT to the nearest DWDM node. This can be used when the short path is $\leq 10\text{km}$ ($\leq 40\text{km}$ from mid-2012) and the path to the nearest DWDM node is $\leq 10\text{km}$ ($\leq 70\text{km}$ from mid-2012, as both the OLT and the DWDM nodes will support 10Gbase-ZR).

Greenfields Fibre Access Transit:

Direct fibre is used between the OLTs housed in temporary FAN sites and the Managed Services interface (see Figure 40 and Figure 41). Both 1000Base-LX and 1000Base-ZX interfaces are supported allowing for fibre distances of up to 70km to be supported.

Wireless Access Transit:

Direct fibre is supported between the Wireless Access network eNodeBs and Microwave Transport and the local FAN site. 1000Base-LZ and 1000Base-ZX interfaces are supported allowing for fibre distances of up to 70km to be supported.

2.9.4 Microwave Backhaul

Microwave Backhaul is used as a Transport solution for areas where other backhaul is unfeasible or cannot be deployed. It consists of routing capability to connect the end systems, and then the microwave transport itself.

Microwave Backhaul is used to support the following connectivity scenarios:

- Fibre access transit (OLT to ECS/EAS)
- Copper access transit (AAS to ECS/EAS)

Fibre Access Transit:

Transport is required between OLT of the Fibre domain and the nearest location of DWDM. The transport using Microwave Backhaul is a pair of fully redundant (1+1) point-to-point Ethernet services running at multiples of 1Gbps or 10Gbps speeds over up to four microwave hops.

Copper Access Transit:

Transport is required between the AAS of the copper access domain and the nearest location of DWDM. Again, the transport using Microwave Backhaul is a pair of fully redundant (1+1) point-to-point Ethernet services running at multiples of 1Gbps or 10Gbps speeds over up to four microwave hops.

An example is:

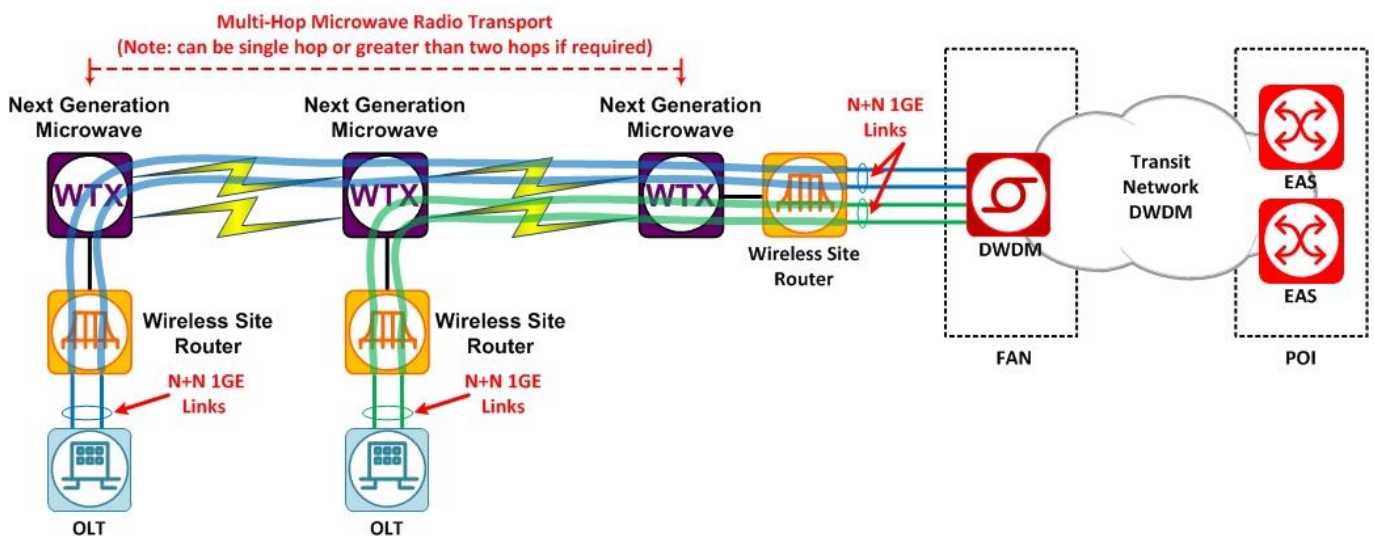


Figure 43 Microwave Backhaul Example

Microwave backhaul may be used in conjunction with other transport types to provide redundant paths where required.

2.10 Aggregation Domain

The Aggregation Domain performs fanout and aggregation of media between the Access Seekers and the Access Domain for Fibre, Copper, HFC, Wireless and Satellite Access Services. Aggregation Domain network elements are exclusively deployed in POI sites.

The majority of metropolitan FAN sites will also be POI sites, where Access Seekers can connect their network equipment into the **nbn**TM network – via the External Network-to-Network Interface (E-NNI) – to service all end-users hosted off the FANs associated with that POI.

In regional areas where end-user densities are lower, it will be more common for FAN sites and POI sites to be in separate physical locations.

In the very few locations where the selected POI site cannot host the **nbn**TM aggregation equipment, the aggregation equipment will be located at a nearby site and connected via direct fibre such that the POI site can still be serviced.

For the HFC Access service, the Aggregation Domain will where necessary provide any-to-any mapping between end users and POIs to resolve Optical Node boundary and AAR overlaps, using the SCN to carry traffic between the required EAS and EFS pairs. For the Wireless Access service, the Aggregation Domain connects locally at the POI to the Wireless Access Domain.

For the Satellite Access service, the central POI will connect to the Satellite DPC via the SCN network. The SCN network will also connect the DPC to the Satellite RFGW.

The Aggregation Domain network elements are:

- The Ethernet Aggregation Switch (EAS)
- The Ethernet Fanout Switch (EFS)
- The Ethernet Combined Switch (ECS)

2.10.1 Ethernet Aggregation Switch (EAS)

This platform is used to aggregate a number of Access Domain network interfaces and provide traffic forwarding towards other Aggregation Domain network elements such as the EFS, or another EAS. In support of the HFC access network it may also interface to the SCN where Optical Node boundary and AAR overlaps need to be resolved. In this case a dedicated EAS pair will be used. To support Access Domain network interface resiliency, EAS are deployed in pairs.

The EAS node is connected to its paired EAS node, to the EFS nodes and SCN using $N \times 10\text{Gbps}$ direct fibre links, or transport solutions where not co-located, where N is 1 to 5.

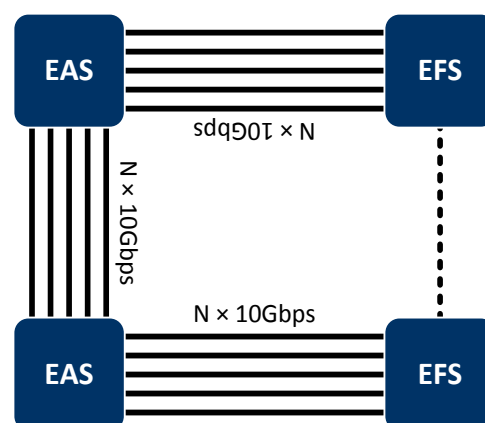


Figure 44 Aggregation Domain interfaces on the EAS

The EAS offers redundant connectivity to the access domains via 1Gbps, 10Gbps or sub-rate bit rates. The links can use any of the Transport Domain solutions for connectivity to remote locations (e.g. FAN sites), or direct fibre for any local connections within the POI (e.g. the PDN-GW for wireless access).

2.10.2 Ethernet Fanout Switch (EFS)

This platform is used to aggregate a number of Access Seeker interfaces (on the External Network-Network Interface, E-NNI) and fan out the traffic towards other Aggregation Domain network elements such as the Ethernet Aggregation Switch, or another EFS. In support of the HFC access network it may also interface to the SCN where Optical Node boundary (HFC Access Distribution Area) and AAR overlaps need to be resolved. To support E-NNI redundancy, EFS are deployed in pairs.

The EFS node is connected to its paired EFS node, to the EAS nodes and SCN using $N \times 10\text{Gbps}$ direct fibre links, where N is 1 to 5. Where the SCN is not co-located Transport solutions will be used.

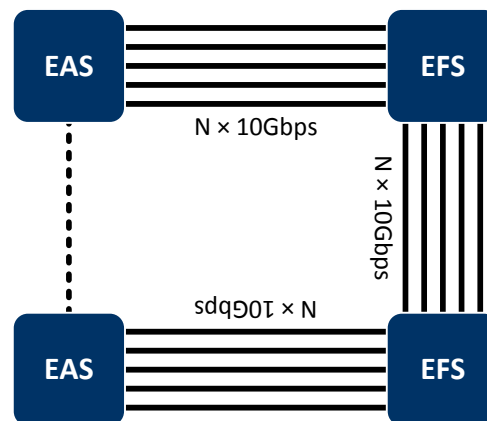


Figure 45 Aggregation Domain interfaces on the EFS

Depending on Access Seeker (AS) demand, EFS nodes may be equipped with a combination of 1Gbps, 10Gbps and 100Gbps (available for future use) Ethernet interfaces. The following connectivity models are supported for the AS E-NNI on the EFS nodes, referred to as the "E-NNI Mode":

- E-NNI Mode A: provides an $N \times 1\text{Gbps}$ or $N \times 10\text{Gbps}$ uplink to a single EFS node, where N is between 1 and 8 links.

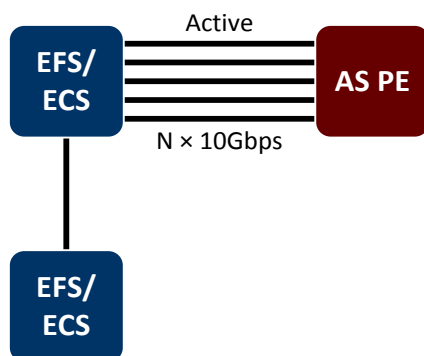


Figure 46 E-NNI Mode A connection model from an Access Seeker Provider Edge (AS PE)

- E-NNI Mode B: provides an $N \times 1\text{Gbps}$ or $N \times 10\text{Gbps}$ dual uplink with 4+4 protection to an EFS pair.

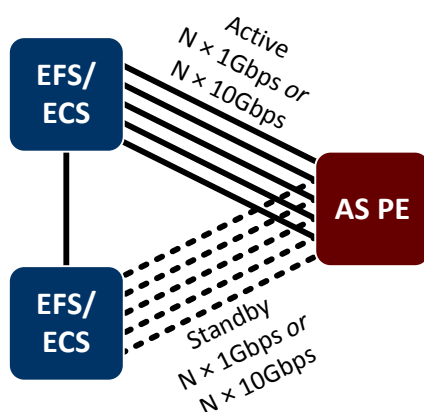


Figure 47 E-NNI Mode B connection model from a single AS PE

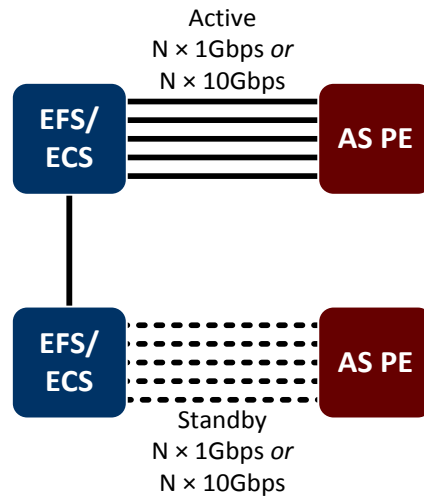


Figure 48 E-NNI Mode B connection model from two AS PEs

2.10.3 Ethernet Combined Switch (ECS)

This platform takes the functions of the EAS and EFS and combines them into the one physical box. It is used in the smaller POIs.

The ECS node is connected to its paired ECS using $N \times 10\text{Gbps}$ direct fibre links, where N is 1 to 5.

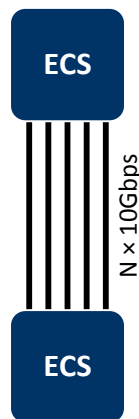


Figure 49 Aggregation Domain interfaces on the ECS

Like the EAS, the ECS offers redundant connectivity to the access domains via 1Gbps, 10Gbps or sub-rate bit rates. The links can use any of the Transport Domain solutions for connectivity to remote locations (e.g. FAN sites), or direct fibre for any local connections within the POI (e.g. the PDN-GW for wireless access).

The ECS has the same interfaces to Access Seekers as those on the EFS. See the section above on EFS Access Seeker interfaces.

2.10.4 Aggregation Domain and POI Architecture

To support E-NNI redundancy, a POI site will contain one pair of EFSs or ECSs. The EFSs attach downstream to the EASs, which aggregate connectivity across all Access Domain nodes associated with the POI site. The ECSs combine the functionality of the EFSs and EASs.

There are two physical architecture types for Points of Interconnect sites, based on whether the EAS/EFS is used, or the ECS:

- **Two Tier:** this architecture type uses at least two pairs of nodes, an EAS pair (which can grow to four EAS pairs, depending on the size of the POI site) and an EFS pair.

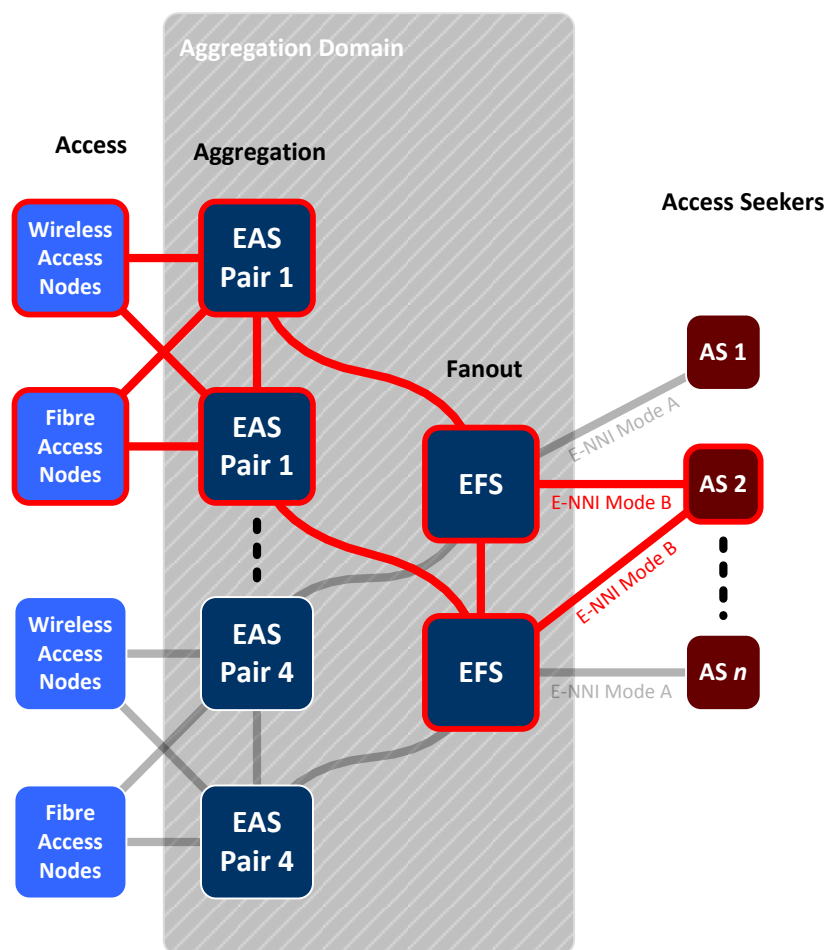


Figure 50 Two tier aggregation architecture

- **One Tier:** this uses a pair of Ethernet Combined Switches (ECSs), which is a single platform that combines the EAS and EFS functions.

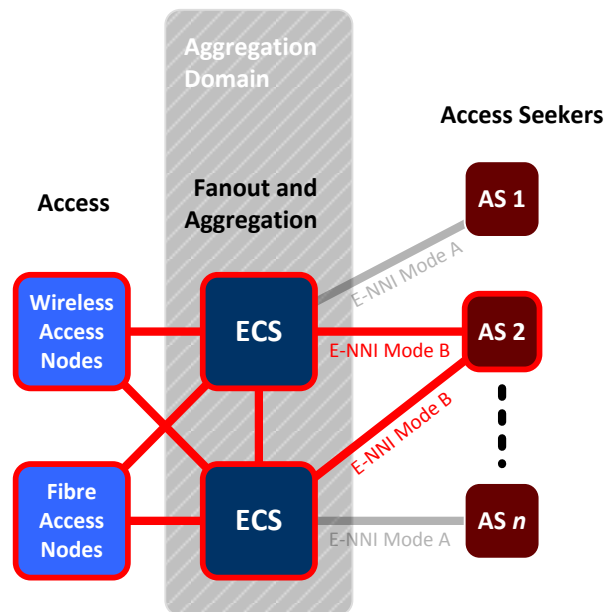


Figure 51 One tier aggregation architecture

Whether the one tier or two tier architecture is used depends on the size of the Customer Serving Area (CSA).

A CSA is comprised of a number of access service areas: Fibre Serving Areas (FSAs; each served by an OLT) and Wireless Serving Areas (WSAs; each served by a pair of PDN-GWs).

2.11 Service Connectivity Network Domain

The Service Connectivity Network (SCN) is a national MPLS connectivity network, which provides routed carriage of customer traffic between **nbn**TM network elements to allow flexibility of routing traffic across the underlying **nbn**TM transport network.

The main component of the SCN is the Ethernet Trunking Switch (ETS). The LTSS and the HFC access network will utilise the SCN.

The ETS connects to the following nodes:

- ETS to ETS
- ETS to Satellite RFGW
- ETS to DPC
- ETS to ECS (Satellite Central POI)
- ETS to EAS
- ETS to EFS

2.11.1 ETS to ETS Connectivity

The ETS to ETS connectivity is made via N x 10GE connections. Here N = 8 for ETS located in NSW and VIC, whilst N = 4 in all other sites. These nodes will be connected in pairs, forming a ladder topology, and will allow:

- support for active and standby links; and
- support for bundled links between ETS nodes.

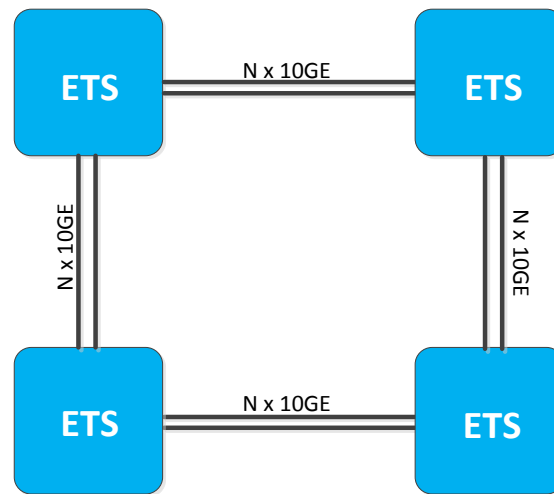


Figure 52 ETS to ETS Physical Connectivity

2.11.2 ETS to Satellite RFGW Connectivity

The SCN acts as a transit network to allow the 10 Satellite gateway sites to reach either of the two DPC sites.

The ETS to Satellite RFGW connectivity will be made via up to 2 x 10GE connections. These nodes will be connected in pairs, forming a ladder topology, and will allow:

- support for active and standby links; and
- support for bundled links between ETS and Satellite RFGW nodes.

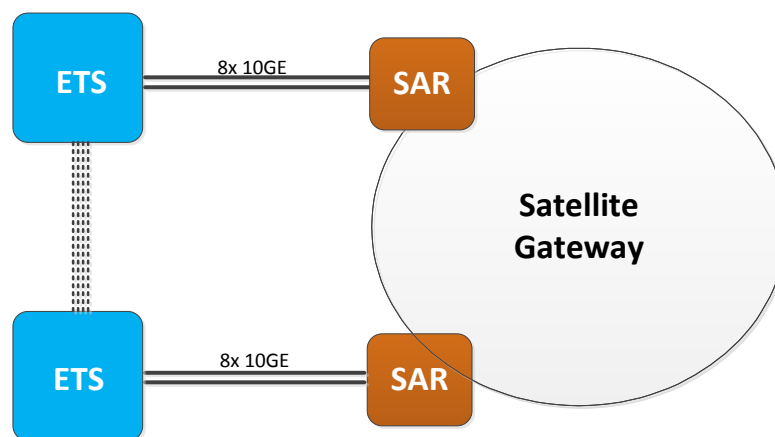


Figure 53 ETS to Satellite RFGW Physical Connectivity

2.11.3 ETS to DPC Connectivity

The ETS to SCS connectivity will be made via 8 x 10GE connections. These nodes will be connected in pairs, forming a ladder topology, and will allow:

- support for active and standby links; and
- support for bundled links between ETS and SCS nodes.

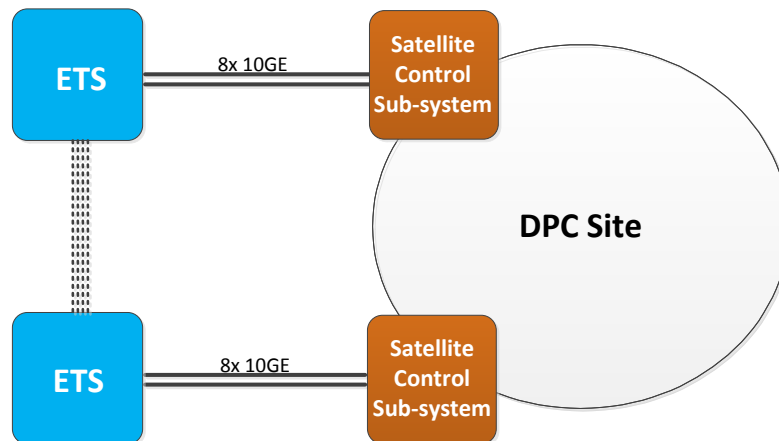


Figure 54 ETS to SCS Physical Connectivity

2.11.4 ETS to ECS Connectivity

With the Centralised Satellite POI, the SCN acts as the transit network to allow each of the two DPC sites access to the ECS, which is located in the Centralised Satellite POI. With the Centralised Satellite POI, each of the two DPC sites connects to the Centralised Satellite POI ECS node.

In the Centralised Satellite POI, the ETS to POI connectivity is between the ETS and the ECS node using $N \times 10GE$ optical fibre links. Here $N \leq 8$. These nodes are connected in pairs, forming a ladder topology, and allow:

- support for active and standby links; and
- support for bundled links between ETS and ECS nodes.

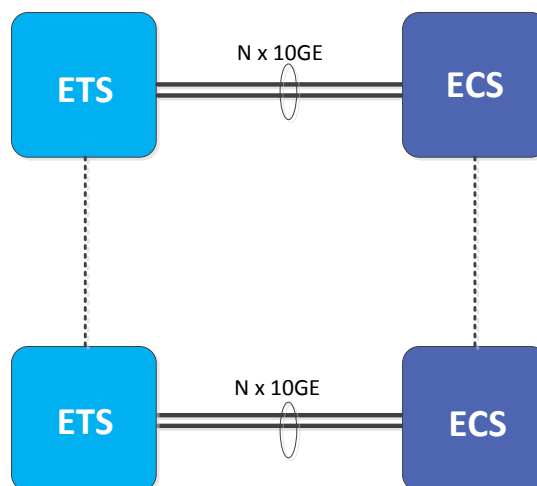


Figure 55 ETS to ECS (Satellite Central POI) Physical Connectivity

2.11.5 ETS to EAS Connectivity

For the HFC Access service, the Aggregation Domain will where necessary provide any-to-any mapping between end users and POIs to resolve HFC Optical Node boundary (HFC Access Distribution Area) and AAR overlaps.

This requires one EAS pair to be able connect to multiple EFS pairs. The SCN acts as a transit network between the EAS and EFS pairs.

In the selected POI, the ETS to EAS connectivity is between the ETS and the EAS node using $N \times 10\text{GE}$ optical fibre links. Here $N \leq 8$. These nodes are connected in pairs, forming a ladder topology, and allow:

- support for active and standby links; and
- support for bundled links between ETS and EAS nodes.

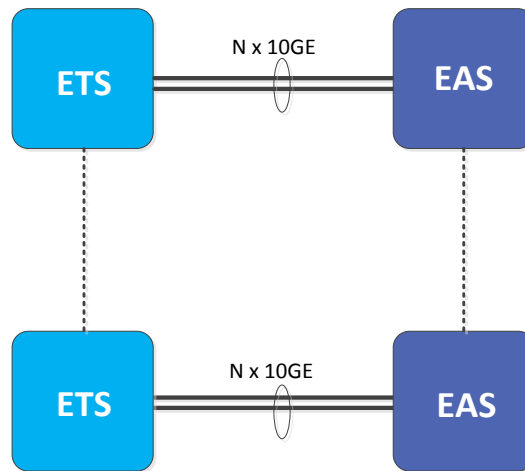


Figure 56 ETS to EAS Physical Connectivity

2.11.6 ETS to EFS Connectivity

For the HFC Access service, the Aggregation Domain will where necessary provide any-to-any mapping between end users and POIs to resolve Optical Node boundary (HFC Access Distribution Area) and AAR overlaps.

This requires one EAS pair to be able connect to multiple EFS pairs. The SCN acts as a transit network between the EAS and EFS pairs at designated POIs to maintain the AAR to POI mapping.

In POIs where the ETS node and EFS pairs are co-located, the ETS to EFS connectivity is between the ETS and the EFS nodes using $N \times 10\text{GE}$ optical fibre links. Where the ETS node and EFS pairs are not co-located a transport solution will be used to provide the $N \times 10\text{GE}$ connectivity. Here $N \leq 8$. These nodes are connected in pairs, forming a ladder topology, and allow:

- support for active and standby links; and
- support for bundled links between ETS and EFS nodes.

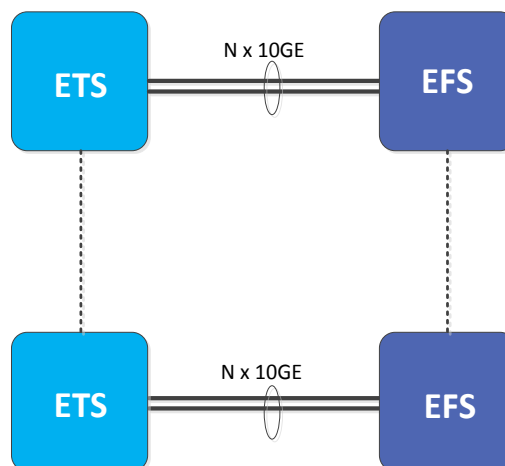


Figure 57 ETS to EFS Physical Connectivity



Appendix A Definitions

Acronym /Term	Definition
AAR	Access Aggregation Region
AAS	Access Aggregation Switch
ADA	Access Distribution Area
AJL	Access Joint Local
AS	Access Seeker
BJL	Breakout Joint Location
BSS	Business Satellite Services
CIR	Committed Information Rate
CMTS	Cable Modem Termination System
CTL	Cable Transition Location
DA	Distribution Area
DCN	Data Communications Network
DFN	Distribution Fibre Network
DJL	Distribution Joint Location
DN	DWDM Node
DOCSIS	Data Over Cable Service Interface Specification
DPC	Data Processing Centre
DPU	Distribution Point Unit
DSLAM	Digital Subscriber Line Access Module
DSS	Distribution Sheath Segment
DWDM	Dense Wavelength Division Multiplexing
EAS	Ethernet Aggregation Switch
ECS	Ethernet Combined Switch
EFS	Ethernet Fanout Switch
ETS	Ethernet Trunking Switch
eNodeB	Evolved Node B Base Station



Acronym /Term	Definition
FAN	Fibre Access Node
FCD	Fibre Collector Distributor
FDA	Fibre Distribution Area
FDH	Fibre Distribution Hub
FDT	Fibre Distribution Terminal
FITS	Factory Installed Termination System
FJL	Flexibility Joint Location
FN	Fibre Network
FSA	Fibre Serving Area
FSAM	Fibre Serving Area Module
FSD	Flexibility Sheath Distribution
FTTB	Fibre to the Building
FTTN	Fibre to the Node
FTTP	Fibre to the Premises
FWO	Fibre Wall Outlet
Gbps	Gigabits Per Second
GNAF	Geocoded National Address File
HFC	Hybrid Fibre Coax
HSD	Hub Sheath Distribution
IDU	Indoor Unit
LFN	Local Fibre Network
LJL	Local Joint Local
LSS	Local Sheath Segment
LTE	Long Term Evolution
LTSS	Long Term Satellite Solution
Mbps	Megabits Per Second
MDF	Main Distribution Frame
MPLS	Multiprotocol Label Switching



Acronym /Term	Definition
MPO/APC	Multi-fibre Push On/Angled Physical Contact
MPT	Multiport
MR	Management Router
MSS	Multiport Sheath Segment, a 12 fibre tether
MTM	Multi Technology Mix
NAP	Network Access Point
NBN	National Broadband Network
NCD	Network Connection Device
NMS	Network Management System
NNI	Network to Network Interface
NTD	Network Terminating Device
ODF	Optical Distribution Frame
ODN	Optical Distribution Network
ODU	Outdoor Unit
OLR	Optical Line Repeater
OLT	Optical Line Terminator
OMS	Optical Multiplex Section
ONT	Optical Network Termination. The GPON NTD.
PCD	Premises Connection Device
PDN-GW	Packet Data Network Gateway
PFN	Premises Fibre Network
POI	Point of Interconnect
PON	Passive Optical Network
ROADM	Reconfigurable Optical Add-Drop Multiplexer
RF	Radio Frequency
RFGW	Radio Frequency Gateway
RPU	Reverse Power Unit
SAM	Serving Area Module



Acronym /Term	Definition
SC/APC	Standard Connector/Angled Physical Contact
SCN	Service Connectivity Network
SDT	Splitter Distribution Terminal
SMP	Splitter Multiports
SP	Service Provider
SSS	Splitter Sheath Segment
TFN	Transit Fibre Network
TPEP	Transparent Performance Enhancing Proxy
TRIA	Transmit and Receive Integrated Assembly
UNI	User to Network Interface
UNI-D	User to Network Interface – Data
UNI-V	User to Network Interface - Voice
VDSL	Very high bit rate Digital Subscriber Line
VSAT	Very Small Aperture Terminal
WNTD	Wireless Network Terminating Device
WSA	Wireless Serving Area
WSAM	Wireless Serving Area Module
Access Seeker	<p>A Customer of nbn, providing one or more public telecommunications services whose provision consists wholly or partly in the transmission and routing of signals on a telecommunications network.</p> <p>Access Seekers may be retail or wholesale Service Providers.</p>
End User	A 'User' or 'End User' is the person/persons who subscribe to telecommunications services provided by Retail Service Providers
Optical Distribution Network	In the PON context, a tree of optical fibres in the access network, supplemented with power or wavelength splitters, filters or other passive optical devices.
Point of Interconnect	Designated point with the nbn TM network for Access Seeker connection.
Retail Service Provider	Retail Service Providers are Access Seekers who purchase the Ethernet Bitstream service from nbn and on-sell the service to their End Users.

Table 8 Acronyms, Terms and Definitions



Appendix B Document Control

This Appendix sets out key provisions of the SAU that govern the development, variation and updating of the Network Design Rules.

B.1 Prudent Design Condition [Clause 1D.6 of SAU]

Capital Expenditure in a Financial Year will satisfy the Prudent Design Condition for the purposes of clause 1D.3.2(a)(i)(B) to the extent the ACCC is satisfied that the Relevant Assets in connection with which the Capital Expenditure was incurred are materially consistent with or within the scope of:

- a. the Network Design Rules, in accordance with clauses 1D.7.1 and 1D.7.4;
- b. a Permitted Variation, as described in clause 1D.7.2; or
- c. an Endorsed Network Change, in accordance with the process described in clauses 1D.8 to 1D.12, or a Network Change as otherwise determined or permitted by the ACCC, including in any Regulatory Determination made by the ACCC.

B.2 Permitted Variation Category [Clause 1D.7.2 of SAU]

- a. NBN Co may vary, change, augment or enhance the design, engineering or construction of the Relevant Assets from that specified in the Network Design Rules where such variation, change, augmentation or enhancement:
 - i) is contemplated by, or made pursuant to, the Network Design Rules; or
 - ii) improves the performance or functionality of the Relevant Assets and results in the same or lower Total Cost of Ownership; or
 - iii) achieves savings in the Total Cost of Ownership; or
 - iv) is reasonably necessary to establish and maintain the quality, reliability and security of the Relevant Assets or the supply of the Product Components; or
 - v) is required in connection with a Force Majeure Event; or
 - vi) is required in order to comply with the Statement of Expectations, or a legal, policy, regulatory or administrative requirement, or any requirement of the Shareholder Ministers; or
 - vii) relates to the maintenance, replacement or re-routing of assets that comprise the NBN Network that has a substantial primary purpose other than the augmentation or extension to such network (e.g. straight swap out of assets for assets as part of routine maintenance); or
 - viii) subject to clause 1D.7.3(a), is the subject of an assessment by NBN Co (made at the time NBN Co becomes aware of the need for such variation, change, augmentation or enhancement) that the estimated Capital Expenditure incurred in connection with the relevant variation, change, augmentation or enhancement is likely to be less than the Minor Expenditure Limit; or
 - ix) is required to address an urgent and unforeseen network issue where it is necessary that the variation, change, augmentation or enhancement is operational within 6 months of NBN Co becoming aware of the urgent and unforeseen network issue and:
 - (A) the event or circumstance causing the required variation, change, augmentation or enhancement was not reasonably foreseeable by, and was beyond the reasonable control of, NBN Co; and
 - (B) a failure to implement the variation, change, augmentation or enhancement is likely to materially adversely affect the safe and reliable operation of the NBN Co Network or the supply of the Product Components, Product Features, Ancillary Services or the Facilities Access Service,



- b. NBN Co must ensure that each Permitted Variation is designed, engineered and constructed with the objective of achieving the lowest Total Cost of Ownership.

B.3 Update to the Network Design Rules [Clause 1D.7.4(a) of SAU]

- c. NBN Co must update the Network Design Rules to reflect a variation, change, augmentation or enhancement to the design, engineering or construction of the Relevant Assets in connection with:
 - i. a Permitted Variation;
 - ii. an Endorsed Network Change;
 - iii. any change to the Statement of Expectations; or
 - iv. any legal, policy, regulatory or administrative requirement, or any requirement of the Shareholder Ministers, which has the effect of varying the design scope in clause 1D.7.1.



B.4 Substantive Changes to Network Design Rules since June 2017

Section Number (old)	Section Number (new)	Section Title	Brief Description of Change	Prudent Design Category
2.4.1	2.4.1	Network Connection Device	Introduction of Network Connection Device, containing the RPU and modem function	1D.7.2(a)(iv)
2.7.1	2.7.1	Wireless NTD	Introduction of modems that can work on either single band or dual band mode to increase performance	1D.7.2(a)(iv)
2.7.2	2.7.2	Radio Spectrum	Update to nbn's spectrum holdings	1D.7.2(a)(iv)
2.7.3	2.7.3	eNodeB	Change to allow for capacity growth	1D.7.2(a)(iv)
2.7.4.1	2.7.4.1	Microwave Transport Equipment	Change to allow for capacity growth	1D.7.2(a)(iv)
2.7.4.3	Deleted	FAN Aggregation Switch	Deleted as now a straight through connection to Transport	1D.7.2(a)(iv)
2.7.6	2.7.6	Wireless Access Planning Hierarchy	Change to allow for capacity growth	1D.7.2(a)(iv)
2.8.1	2.8.1	Satellite NTD	Inclusion of new NTD types for Business Satellite Services	1D.7.2(a)(i) and 1D.7.4(a)(iii)
	2.8.5	Business Satellite Services VSAT Baseband Sub-system	New infrastructure introduced to support Business Satellite Services	As above
	2.8.7	BSS Satellite GW Routing & Switching	New infrastructure introduced to support Business Satellite Services	As above
	2.8.10	BSS Satellite POI Routing, Switching & Security	New infrastructure introduced to support Business Satellite Services	As above
	2.8.11	BSS Hosting Infrastructure	New infrastructure introduced to support Business Satellite Services	As above
2.8.7	2.8.11	Satellite Planning Hierarchy	Inclusion of use of RF for Business Satellite Services	As above
2.9.1.1	2.9.1.1	Reconfigurable Optical Add-Drop Multiplexers (ROADMs)	Introduction of 200Gbps capability	1D.7.2(a)(iv)



Section Number (old)	Section Number (new)	Section Title	Brief Description of Change	Prudent Design Category
	2.9.4	Microwave Backhaul	Introduction of Microwave Backhaul for use by FTTP/N	1D.7.2(a)(iv)

Table 9 Substantive Changes to NDRs since June 2017

B.5 Non-substantive Changes to Network Design Rules since June 2017

Section Number (old)	Section Number (new)	Section Title	Brief Description of Change
1	1	Introduction	Update describing changes made in latest update of NDRs.
	2.8.6	Satellite GW Routing & Switching	Additional detail of the Satellite solution introduced to contextualise the Business Satellite Service infrastructure
Appendix B	B.1 and B.3	Document control	More detailed inclusion of relevant SAU provisions

Table 10 Non-substantive changes to NDRs since June 2017