4 Building a fibre access network to 90+ percent of premises

SUMMARY

- NBN Co should build a fibre access network to deliver superfast broadband services to 93 percent of premises in Australia.
- Selecting the fibre topology to deploy in this network is one of the most important implementation decisions facing NBN Co and Government—it will shape the industry landscape for 40 years or more. NBN Co should deploy a topology that facilitates active-layer competition across a substantial portion of the network.
- A home-run topology provides a future-proof solution and delivers competitive benefits by enabling active-layer competition through physical unbundling of fibres. Implementation Study modelling suggests this topology can be deployed across 50 percent of premises in the fibre footprint for an approximately 4 percent increase in the total cost of the fibre access network, relative to a fully-shared topology.
- NBN Co should conduct trials of alternative topology options during its early roll-out to determine the appropriate mix of topologies to deploy, in consultation with Government and the ACCC, and determine its target topology by the earlier of the completion of the roll-out to 15% of premises or the end of 2013.
- Active equipment deployed on top of the fibre is expected to be a mix of GPON and Ethernet point-to-point technologies. 100 Mbps data rates are achievable in the access network using both technologies—20 Mbps is an appropriate speed for an entry-level broadband service. Technical standards for NBN Layer 2 services must support a range of high-bandwidth and next-generation retail services and facilitate entry by Layer 3 service providers.
- The NBN should achieve high penetration in the fixed-line market in the long term—with steady take-up year-on-year of 6-12 percent of homes covered in line with international experience. Mobile substitution is not expected to be a long-term threat to achieving take-up, and service providers will have an economic incentive to migrate customers onto the NBN.
- Pricing for NBN services should evolve over time to balance a range of considerations—take-up, affordability, usage, regulation and commerciality.

Government has set a coverage objective for the fibre solution of delivering 100 Mbps data rates to 90 percent of premises. Government has also set a long-term objective that NBN Co build and operate the fibre network as a commercial entity.

Achieving these outcomes requires a holistic approach to implementing the fibre access network. To deliver on coverage requirements, all network components must be capable of supporting the specified data rates. At the same time, the coverage obligation must be implemented efficiently, within Government's initial expenditure estimate. Once built, the network must attract customers and generate revenues sufficient to enable NBN Co to sustain its business.

This chapter begins with an overview of the FTTP reference model used throughout the Implementation Study, including terminology used for different network elements. Subsequent sections outline our recommended approach to implementing the fibre access network:

4.1 Defining the fibre-to-the-premises reference model

4.2 Establishing network specifications to meet the objectives

4.3 Meeting fibre coverage objectives within Government's initial expenditure estimate

4.4 Achieving take-up of services on fibre

4.5 Creating a robust revenue model for the NBN fibre network.

4.1 Defining the fibre-to-the-premises reference model

In deploying a fibre-to-the-premises (FTTP) network, a wide range of different topology and technology options are available. For the purposes of the Implementation Study, we have developed a 'reference model' FTTP network, which we have used as the basis for our modelling of the potential business case for NBN Co and as a basis for assessing the types of services and the degree of competition that can be enabled over time. As described in Chapter 7, we have also run a variety of sensitivity and scenario analyses.

This reference model was developed through extensive consultations with industry experts and with NBN Co engineers. It is consistent with industry standards and forms an appropriate basis for the work of the Implementation Study. It is not however, intended to be a precise and detailed depiction of the network NBN Co will build, which will be informed further by both additional modelling by NBN Co and input from additional stakeholders including Government, vendors and retail access seekers.

The terms and definitions outlined below are used throughout the report when referring to specific network components. We have not attempted to capture and define each individual component of the NBN. Rather, this reference model aims to assist the reader in understanding the recommendations and discussion contained in this report.

This reference model builds on existing work, industry standards and terminology wherever possible. In particular, we have drawn from published material from NBN Co and the Communications Alliance[71], with a focus on the fibre footprint.

This section covers:

4.1.1 Defining network components

4.1.2 Defining fibre access network architecture.

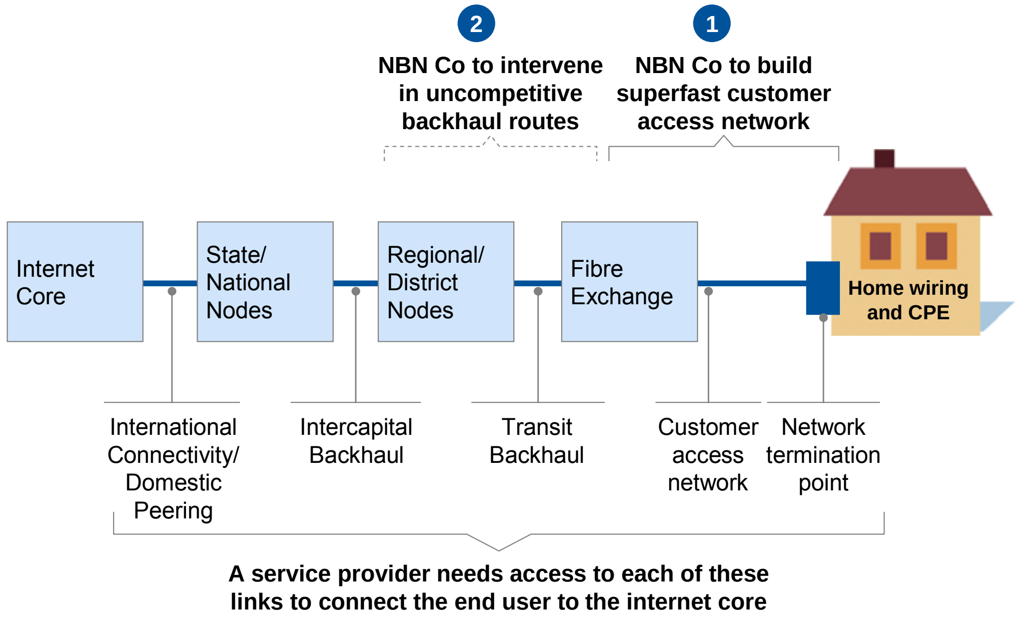
4.1.1 DEFINING NETWORK COMPONENTS

Exhibit 4–1 outlines the network components a service provider uses to link end users to the Internet core. Industry definitions of terms are not fixed, so the Implementation Study uses generic terms to define these network components.

We discuss differences between the types of backhaul in Section 6.1.1, and the rationale for limiting NBN Co's participation to the access network and targeted intervention in the backhaul market shown in Exhibit 4–1 in Section 2.1.1.

[71] Communications Alliance Ltd (2010), *National Broadband Network Reference Architecture: High-level Architecture Options for the NBN,* Release 1, January 2010

Exhibit 4–1. High-level depiction of network components

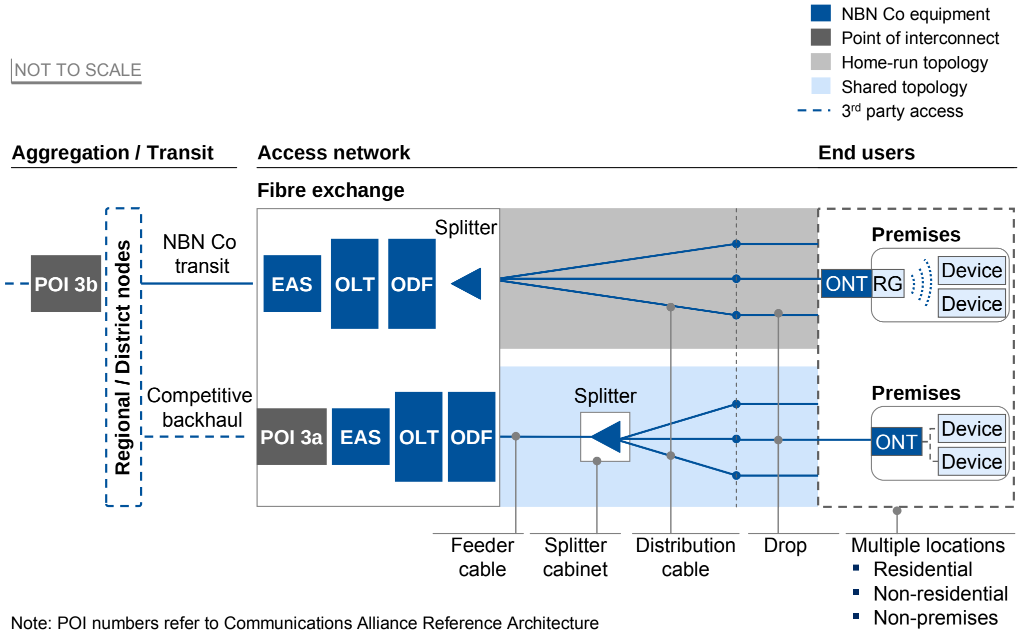


SOURCE: Implementation Study

4.1.2 DEFINING FIBRE ACCESS NETWORK ARCHITECTURE

Most of NBN Co's operations will be in the fibre access network, with targeted intervention in uncompetitive backhaul routes. Exhibit 4–2 outlines the major components of the fibre access network, each of which we describe below.

Exhibit 4–2. Fibre access network reference model



Note: POI numbers refer to Communications Alliance Reference Architecture
SOURCE: Communications Alliance; Implementation Study

Fibre Exchange

The fibre exchange—also commonly known as a Fibre Access Node (FAN)—houses the active equipment. This includes the Optical Line Terminal (OLT) equipment—in this case a gigabit passive optical network (GPON) OLT—and Ethernet aggregation switching devices (EAS), as well as equipment for physical fibre management, such as the Optical-fibre distribution frame (ODF). The fibre exchange is analogous to a copper exchange; however a fibre network typically requires fewer exchanges due to higher premises to exchange ratios.

In some cases, the point of interconnect (POI) where service providers connect to the NBN access network will be directly at the fibre exchange. In other cases where competitive backhaul is not available from the exchange back into the network, the POI is located at an aggregated node higher up in the network.

Passive network components

The passive architecture refers to the overall scheme for fibre cabling and passive (i.e. unpowered) optical plant. Its configuration is frequently referred to throughout this report as the 'network topology'. The choice of network topology influences both the physical deployment of the fibre and the passive equipment employed.

Network Topology

The network topology refers to the physical layout of fibre in the field. There are two main types of fibre topology:

- **Home-run topology**, where a dedicated access fibre connects every individual premises to the fibre exchange. This is analogous to existing copper access networks where premises connect by at least one dedicated line;
- **Shared topology,** where a single fibre runs from the fibre exchange to a passive 'splitter' in the field. This splitter divides the optical signal multiple times, with each split signal travelling down a separate fibre to a customer premises. Splits of 1:32 are common in FTTP systems and reduce the amount of fibre that must be run from an exchange to the point of the splitter.

Because the terms 'topology' and 'technology' (where technology refers to the active layer technologies deployed on the passive fibre) are often confused when referring to fibre architectures, we set out in Exhibit 4–3 how the Implementation Study uses these terms, along with a discussion of the relationship between common topology and technology choices.

Exhibit 4–3. Topology vs. active component technology

Clarifying what is meant by topology vs. active component technology

Our fibre access network reference model assumes a passive optical network is deployed from the fibre exchanges out to customer premises. Consequently no active electronic components are deployed beyond the exchanges (except at the customer premises). Within this architecture it is important to distinguish between the concepts of fibre topology and active layer technologies.

Topology refers to the physical layout of the fibres between the exchange and customer premises: in particular, whether part of this layout is shared (with splitters deployed in the field so that many customer premises can be served by a single fibre running from the exchange) or whether individual fibres run to every premises (home-run topology).

In many cases, specific active layer technologies have been developed to transmit signals down the fibre within a given topology. For example, with shared topologies a popular active layer technology is GPON (Gigabit Passive Optical Network) electronics, since GPON lasers are designed to be compatible with a fibre that is subsequently split into multiple downstream fibres. By contrast, Ethernet Point-to-Point electronics are typically deployed over home-run topologies.

Since GPON electronics are typically associated with a shared fibre topology, the term ‘GPON’ is sometimes taken to mean both use of GPON electronics and use of a shared topology. This does not necessarily have to be the case. Specifically, if a home-run topology is deployed (as is recommended by the Implementation Study for a significant portion of the network), GPON electronics can still be used. This is accomplished by relocating the optical splitters to the fibre exchange (a ‘central split’), so that there is an individual distribution fibre per premises.

An advantage of this model is that it allows the network operator to deploy OLTs with fewer ports (where the number of ports is driven by the number of fibres connected to the OLT).

Source: Implementation Study

While a variety of topologies and active technologies are possible, the Implementation Study reference model is based on GPON active components installed on a combination of home-run and shared topologies, which we expect to comprise the bulk of the fibre access network.

In practice, the network deployed by NBN Co will also contain Ethernet Point-to-Point components deployed over home-run topologies where very high throughput service is required, for example to enterprises, schools, hospitals or government departments .

Fibre access network segments

For the purposes of the Implementation Study, we define three segments of the fibre access network:

- Feeder is the shared fibre that runs from the OLT to the splitter cabinet or pit where it is split. It is only used in a shared topology;
- Distribution is the dedicated fibre for each user that runs from the splitter to the drop point (typically either a pole for an aerial deployment or a pit for an underground deployment);
- Drop is the fibre connection into the premises and includes the physical lead-in cable and the fixed installation (including ONT and wiring).

Passive equipment

- Splitters split the signal travelling over shared feeder fibres into dedicated distribution fibres;
- Splitter cabinets are enclosures that house splitters and enable in-field fibre management;
- Optical distribution frames (ODFs) sit in the exchange to enable efficient fibre management.

Active network components

Active equipment is installed on the passive components to provide active wholesale services. For ease of reference, the reference model outlines GPON components only. However, most fibre exchanges will also contain equipment to provide Ethernet point-to-point services. The active equipment includes:

- Optical line terminals (OLT), which is active equipment that typically sits at the exchange level and controls, allocates, transmits and terminates optical signals;
- Optical network terminations (ONT), which terminate the PON at the customer premises. The ONT can be placed inside or outside the premises, and will connect to residential gateways (RG) or directly to user devices.

Customer premises equipment

NBN Co will not take responsibility for installing customer premises equipment (CPE), which will instead be handled by the retailers providing services into the home. CPE within the fibre footprint will typically consist of one or more residential gateways (RGs)—for example, wireless routers, set top boxes—connected to the ONT, as well as any in-home wiring used to distribute signals around the house. In new developments, this in-home wiring should be of a standard capable of high-speed data transfer, such as CAT 5 or CAT 6 cables (Section 2.1.4).

4.2 Establishing network specifications to meet the objectives

The NBN fibre access network must be capable of delivering at least 100 Mbps. However, there are several network components required to enable the Layer 2 service, and the capabilities of each of these must be fully considered in the specification of the network.

The different layers of the network (shown in Exhibit 4–4) have starkly different life-times and implications for ultimate performance and competitive outcomes. The passive layer has a very long life and will shape the dynamics of the industry for generations. The active layer is expected to be upgraded much more rapidly over time. The services layer will be highly dynamic once a large number of users connect to fibre and an applications ecosystem develops.

As recommended in Chapter 3, NBN Co will operate both the passive layer and active layer (Layer 2) of the fibre network. This section describes the network specifications required to implement the coverage objectives and the minimum level of wholesale service that NBN Co should offer:

Exhibit 4–4. Brief overview of network elements and principal characteristics

Network layer	Description	Lifetime (years)	Principal characteristics
Service (Layer 3+)	Retail services provided to end users (NBN does not specify, but must be cognisant of demand)	n/a	■ Retail demand ■ Innovation of applications and services
Active (Layer 1/2)	Wholesale services offered to service providers	n/a	■ Wholesale inputs required for service providers to meet end-user needs
	Active equipment installed on the network (OLT and EAS switch)	7–10	■ Operational efficiency ■ Upgrade path ■ Cost
Passive (Layer 0/1)	Fibre topology	20–50	■ Desired competitive outcomes ■ Network performance ■ Cost
	Physical deployment: Poles, ducts and trenches	30–60	■ Open access ■ Security ■ Cost

Source: Implementation Study

4.2.1 Designing a passive architecture to deliver enduring performance

4.2.2 Deploying active equipment to deliver 100 Mbps

4.2.3 Specifying wholesale services to substantiate the NBN promise.

4.2.1 DESIGNING A PASSIVE ARCHITECTURE TO DELIVER ENDURING PERFORMANCE

The scalability of fibre provides the capability of delivering speeds in excess of 100 Mbps—more than sufficient to meet the needs of most premises today. However as we discuss in Chapter 9, the specific topology of fibre network selected will be a critical enabler of future competition at an active layer. Such competition is the best means of ensuring innovation and continual upgrades—sufficient to meet the needs of all premises in the future.

The passive architecture refers to the overall scheme for fibre cabling and passive optical plant, its configuration—referred to as ‘topology’—and the ducts and poles that carry the fibre equipment—which we refer to as the ‘physical deployment’. Collectively, these passive elements are the most costly part of the network, comprising about 70 percent of total network investment. They also have the longest life (Exhibit 4–4). The passive network must therefore be designed to deliver enduring performance as a future-proof national platform.

This subsection explains the options and considerations that apply to the three elements of the passive network: fibre as a physical medium; topology; and the physical deployment.

Laying fibre as the enduring physical medium

Fibre is the physical network platform of the future. It has potential to far exceed the short-term performance requirement of 100 Mbps. Already, single fibres can carry over 10,000 times this volume of data traffic. In addition, physical fibre has a very long life, with a low fault rate. Chapter 2 outlines the importance of fibre in creating the national platform for future needs. We now revisit these points in the context of the passive network specifications.

The NBN fibre network will be an enduring national asset, serving the communications needs of consumers, businesses and enterprises for a generation or more. If properly specified and deployed, the physical network should not need revisiting for 40 years and more. The passive network should be designed and deployed with a ‘dig-once’ mindset to ensure future generations receive the benefit of this transformational project.

Selecting a future-proof fibre topology

The decision of which fibre topology to deploy requires careful consideration. Although fibre-to-the-premises delivers a step change over copper performance, fibre topologies can vary significantly. There are three criteria on which different topologies should be assessed:

- Future network performance;
- Support for long-term competitive outcomes;
- Upfront cost.

> *Network design directly influences market outcomes and the nature and effectiveness of competition*
>
> FTTH Council Asia-Pacific (2009)[72]

The major trade-off for Government is cost versus future-proofing performance and long-term competitive outcomes—specifically, the extent to which the fibre topology supports future upgrade scenarios and passive-layer unbundling (the options for which are discussed in Chapter 10). However, making an informed trade-off upfront is challenging due to uncertainties about the magnitude of impact. In this section we assess a range of topology options against these dimensions, and emphasise the need for careful analysis to ensure any trade-offs are fully considered.

Introducing the options for fibre topology

There are two main types of fibre topologies: 'home-run' and 'shared' (or 'split') topology. In home-run, a dedicated access fibre connects individual premises to a fibre exchange. This is analogous to the existing copper access network where premises connect by at least one dedicated line.[73] In a shared network, a single fibre runs from the exchange to a 'splitter', which then distributes the optical signal amongst multiple premises through dedicated fibres. Home-run options are often referred to as 'point-to-point' and shared options as 'GPON' networks. However, those terms are imprecise, as they refer to both the fibre topology and the active electronics commonly employed on those topologies.

It is important to distinguish between the fibre topology and the active electronics when designing the network. Although a shared topology requires PON active technology, such as GPON, a home-run topology will support any optical electronics, including GPON. In addition, the passive and active layers have different life spans. The decisions on topology and active electronics should therefore be driven by different factors (Exhibit 4-4). For example, the permanent nature of the topology means the impact on the long-run network performance and competitive landscape is a primary

[72] FTTH Council Asia-Pacific 2009, *Submission to the New Zealand Government Broadband Investment Initiative*

[73] Except where a pair gain system has been used to extend the reach of a copper line (discussed later in this section)

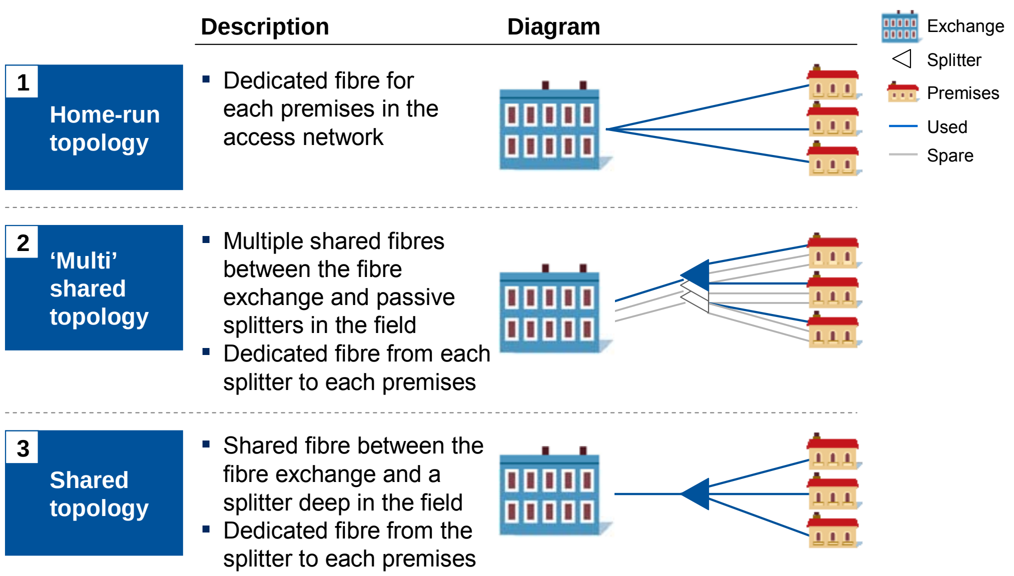
concern. Conversely, the 7–10 year generational lifecycle of active electronics increases the importance of cost and energy efficiency. Topology and technology for the NBN must therefore be treated separately, with careful consideration of the decision criteria, before committing to an investment of this magnitude.

> **Highlight**. The choice of fibre topology for the NBN is a critical decision that should be distinct from the active technology installed on it, despite these choices often being made jointly. The topology will shape the long-term network performance and competitive landscape, whereas the technology will be replaced every 7–10 years.

We have assessed three topology options. The home-run and shared topologies are the most common, and are widely deployed around the world. We also consider a variant of the shared topology that is being deployed in some countries around the world: a 'multi' shared topology, in which multiple fibres from the fibre exchange serve multiple splitters in the field, with multiple distribution links to the premises. Exhibit 4–5 outlines the three options.

Shared and home-run topologies are both capable of enabling short-term performance of 100 Mbps and each is being deployed in other markets (Exhibit 4–7). However, the options differ in performance against the key decision criteria (Exhibit 4–6). From this comparison, it is clear that Government faces a genuine trade-off in selecting the right fibre architecture for the country. We now address the detail of each criterion in turn.

Exhibit 4–5. Fibre topology options



SOURCE: Yankee Group; Implementation Study

Exhibit 4–6. Assessment of fibre topologies

Topology options	Decision criteria: Future network performance	Support for physical unbundling	Upfront cost
1 Home-run topology	✓✓ Full flexibility to upgrade individual premises ✓ Upgrades not restricted by technology	✓✓ Fully enables physical unbundling	✘ Likely cost premium ? However, premium depends on duct availability
2 'Multi' shared topology	✓ Upgrades possible on individual fibres	✓ Active competitors can access 'dark' fibres; however, competition limited by number fibres	✘ Additional cost driven by spare fibres, splitters and civil works
3 Shared topology	✓ Robust eco-system of active electronics	? Physical unbundling operationally difficult and economically unfeasible ? Technology for wavelength unbundling uncertain	✓ Generally cheapest option to deploy ? Depends on availability of existing ducts

SOURCE: Yankee Group; Implementation Study

Delivering future network performance

Home-run topology offers superior performance and flexibility over the long term. There are no requirements for smart electronics that share signals between connections; a dedicated connection is available to each premises, which can be 'lit' by any optical device, from a simple optical Ethernet switch to a GPON OLT. Shared topologies, by contrast, require PON technologies, which are slower and more complex. It is true that today's GPON services exceed current household needs, so the benefits of the latent potential for higher bandwidth using point-to-point electronics are not immediately obvious.

> *No one will need more than 637 kb of memory for a personal computer—640K ought to be enough for anybody*
>
> Bill Gates, Microsoft (1981)[74]

Home-run networks have the major advantage that upgrades are realisable on a per-line basis. Individual premises can therefore receive improved performance as it is demanded. Shared topologies do not allow the same degree of upgrade flexibility. All premises connected to an optical splitter must be upgraded concurrently (as a feeder fibre is shared).

[74] Crovitz, G 2009, 'Technology predictions are mostly bunk', *Wall Street Journal: Asia Edition*, 27 December, p. 14

> *Our strong recommendation is that the passive plant is designed to handle either technology*
>
> Ericsson Communications Limited (2009)[75]

There are large numbers of PON networks being constructed around the world, so the ecosystem is likely to continue evolving and improving. It is however possible that at some point in time, the cost of meeting market performance demands may be greater on a shared network than a home-run network, due to inherent performance restrictions of PON technologies.

Highlight. Home-run topology supports both GPON and Ethernet point-to-point technologies, giving the option of fast speeds with simple electronics; shared topology restricts the network to using PON technology.

Supporting physical unbundling

Physical unbundling is important for future competitive outcomes. It will ensure ongoing investment and innovation on the NBN at an active layer, and mitigate the risk of NBN Co becoming a long-term wholesale monopoly. We detail the rationale for this in Chapters 9 and 10. The ability to physically unbundle the network is determined by the fibre topology.

Home-run topology fully supports physical unbundling, as individual fibres from a fibre exchange can be used by an access seeker to serve any given premises. Unbundling on home-run topologies is analogous to copper networks today.

> *If [regulators] are serious about open access, they should impose topology restrictions to at least ensure that passive opening is viable if it is to be enforced in the future*
>
> Yankee Group (2009)[76]

Shared topologies, on the other hand, do not inherently support physical unbundling. Multiple premises are grouped on a single exchange fibre, so any access seeker would have to acquire the houses served by a single exchange fibre simultaneously. This gives rise to many practical complexities in unbundling end users. An alternative is to physically reconfigure the network, by changing the connections at the splitter. However, this requires the manipulation of fibre connections in-field, disturbing the fibre cabling and risking disruptions to services.

Some shared designs can make physical unbundling prohibitively expensive and operationally difficult. By placing the splitters in pits or inaccessible environments, or limiting the size of cabinets to require prohibitively high market shares for access-seekers or to prevent installation of their splitters, the network owner can render economic reconfiguration of the network impractical.

Intermediate unbundling options do exist. Multi-shared topologies partially overcome the risk by providing multiple fibres and splitters from the fibre exchange. This provides a

[75] Ericsson 2009, *Submission to New Zealand Government Broadband Investment Initiative*

[76] Yankee Group 2009, *GPON or P2P: Choosing an FTTH architecture*

number of dark shared fibres for access seekers. However, the number of access seekers is limited by the number of fibres deployed from the fibre exchange.

Wavelength division multiplexing (WDM) may also emerge as a viable option for unbundling on either topology. This option involves unbundling of wavelengths rather than physical fibres, and is therefore enabled by the technology rather than topology. We advise that Government not rely on it as the only option for unbundling on the NBN, for two reasons. First, the technology to enable wavelength unbundling in access networks is not currently in operation, and its development is uncertain. Second, it would require operation of the active electronics by NBN Co, which partially negates the competitive benefits associated with unbundling. We discuss WDM in more detail in the following subsection.

> *Wavelength unbundling is considered to be on the border of passive and active access. Although standards for 'grooming' the light are being developed, interoperability requirements mean that technology choices at the exchange will influence technology choices at the customer premises.*
>
> Ofcom (2009)[77]

Highlight. Home-run topology is open-access by design and fully supports physical unbundling of individual fibres; Shared topologies do not inherently support physical unbundling, and some designs can make it prohibitively expensive and operationally difficult—e.g. by locating splitters deep in the network (i.e. serving a small number of premises) or installing small cabinets; Uncertainty of technology for wavelength unbundling means Government should not rely on it as the only option for network unbundling.

Estimating upfront cost to deploy

The NBN will create an enduring platform to meet the needs of users and industry for generations. A project of this scale must be resilient to future developments in technology and demand. Home-run topology should therefore be preferred over shared topology, for a reasonable cost premium.

Home-run topology is generally considered to be the more expensive option. However, studies around the world show that a shared configuration may not always generate significant savings. In some circumstances, it saves less than 5 percent relative to home-run topology.[78]

However, accurately estimating the cost difference between home-run and shared topologies is challenging. It is difficult for the Implementation Study to make a blanket statement of the cost premium that may be required, for two reasons:

[77] Ofcom 2009, *Ethernet active line access: Updated technical requirements*

[78] Cisco 2009, *FTTH technology considerations,* viewed 15 December 2010, <http://www.bloobble.com/broadband-presentations/presentations?itemid=2340>

- Costs are difficult to estimate accurately in desk studies or small-scale field trials—the only dependable data is gathered by experience. Desk studies necessarily require some averaging assumptions. Although actual costs should sit within the bounds of these estimates, real costs will inevitably differ in some instances.[79]
- Costs are likely to vary by geography—the cost differential between home-run and shared topologies depends on duct availability, density of premises, and costs of trenching. For example, Cisco estimates that if ducts are unavailable, the premium for home-run may be as low as 2 percent. If ducts availability is limited—the case for most incumbents—the premium may range from 5 to 25 percent.[80]

Implementation Study modelling suggests a fully national home-run topology would require a $2.6 billion investment premium over a shared configuration. This is discussed in more detail in Section 4.3.

There is a policy choice for Government about the level of investment it is prepared to make for a fully future-proof network. In practice, it may not be necessary to deploy home-run topology everywhere to obtain the long-term performance and competitive benefits. We therefore modelled, as our reference case, a mix of 50 percent home-run and 50 percent shared topology within the fibre footprint. This mix represents a $0.9 billion (4 percent) premium over a fully shared access network. The ultimate percentage deployed over a home-run topology should be determined after NBN Co has trialled different architectures as proposed in Chapter 10.

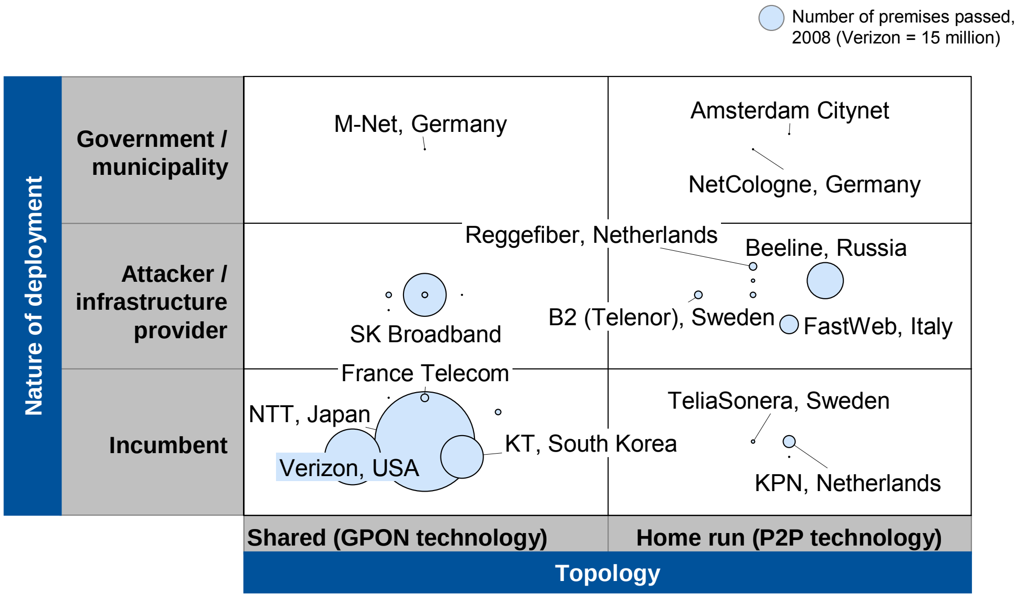
Although it is not a fully future-proof solution, this compromise delivers long-term benefits in the areas most likely to experience future active-layer competition. We consider a premium of this magnitude should be acceptable to Government, given the long-term benefits of home-run topology. A willingness to pay a premium for a future-proof topology is consistent with Government's willingness to pay a premium to deploy fibre-to-the-premises, instead of cheaper but less future-proof solutions such as HFC or FTTN.

Highlight. Geospatial modelling indicates a home-run topology covering 50 percent of the fibre footprint adds approximately 5 percent to the overall fibre access network investment, relative to full shared topology. These costs will need to be refined based on trials to be conducted by NBN Co.

79 New Zealand Treasury 2009, *Fibre-to-the-premises cost study: Prepared for the Treasury*, report prepared by M Milner, Milner Consulting Limited, Wellington

80 Cisco 2009, *FTTH technology considerations*

Exhibit 4–7. Fibre topologies deployed in other countries



SOURCE: Yankee Group; Idate; Japanese Ministry of Internal Affairs; company websites

Assessing precedents and experiences in other network deployments

Australia has the opportunity to learn from the many fibre deployments now underway around the world. Incumbents, infrastructure providers and Governments are funding fibre deployments in many countries. Exhibit 4–7 shows some patterns are emerging.

Shared topologies are usually the first choice for incumbents, for a number of reasons. First, access to their existing ducts is critical for reducing overall costs. Shared topologies employ less fibre in the feeder network and increase the percentage of the physical network that can fit cheaply inside existing infrastructure. Second, commercial incentives can lead some incumbents to limit competition and to avoid physical unbundling. Both these factors favour a shared topology. However, neither of these reasons need apply to NBN co, which owns no ducts and has been established with an open-access mandate. Even if it obtains duct space from Telstra, this will come at a price.

Highlight. Shared topologies are generally favoured by incumbent network owners because they use less duct space and restrict passive-layer unbundling. However, these factors do not apply to NBN Co, which owns no existing ducts and has an open-access mandate.

‘Public’ networks, including municipalities, and attacker network providers have generally favoured home-run topologies. This trend is driven by the benefits of home-run topology identified above. Most publicly-funded networks require open access at all layers of the network. Home-run topology inherently supports this requirement, including the ability to offer dark fibre to multiple providers. The superior performance of home-run topology makes it more attractive to attackers seeking to compete against incumbent networks, particularly in the enterprise market.

> *Any infrastructure directly or indirectly funded by public money should be designed to withstand the test of time. This points to a home-run solution.*
>
> Yankee Group (2009)[81]

History contains warnings against shared networks, with some being redesigned at significant cost. For example, pair gain systems were installed in many copper networks in the 1990s to extend the reach of copper lines and increase the efficiency of provisioning new telephone services. However, when DSL technology emerged these systems were incapable of transmitting the signal. Pair gain systems consist of active multiplexors that combine multiple voice signals for transmission over a single copper pair, before being split in the field into individual lines for each connection. Telstra installed up to 1.2 million pair gain lines in Australia, which has prevented many homes from receiving broadband.[82] Although some of these lines have since been remediated, pair gains restrict many households to slow dial-up Internet, even in 2010. Telstra has indicated the cost of replacing all pair-gain systems could reach $2 billion.[83]

A second example is provided by the British Telecom deployment of a small shared optical network in Milton Keynes in the 1980s. The deployment comprised shared fibre-to-the-cabinet based on TPON technology. However, the network could not support broadband services or local loop unbundling, and was eventually mostly overlaid with copper.[84] This example is analogous to GPON technology installed on a shared topology, and highlights the risk of shared networks preventing the delivery of new services or technologies.

Investing sensibly to create a future-proof topology

The decision of topology for the NBN requires careful consideration of the trade-offs. Although home-run topology provides the NBN with un-matched performance and competitive benefits in the long term, it will likely require additional investment upfront. However, the magnitude of this investment is uncertain prior to deployment. Adding to

[81] Yankee Group 2009, *GPON or P2P: Choosing an FTTH architecture*

[82] David Quility, quoted in Australia, Senate 2008, *Debates,* 11 November, viewed 18 February 2010, <http://www.aph.gov.au/hansard/senate/commttee/S11509.pdf>

[83] Lundy, K (Senator for Australian Capital Territory) 2003, *$2 billion: The cost of Telstra’s neglect,* media release, 27 March, Canberra

[84] Blondeel, Y 2007, ‘Prospects for the roll-out of alternative technologies across Europe’, presentation to the Ofcom regulatory challenges posed by next-generation access networks seminar, Brussels, 27 March

this uncertainty, the cost premium and competitive benefits of home-run differ by geography. The optimal topology is therefore likely to differ by region.

The amount Government is willing to invest for a future-proof network is a policy decision requiring careful consideration. Given the importance of this decision, it should only be made once a real view of costs is available through initial deployments.

The Implementation Study modelled a mix of 50 percent home-run and 50 percent shared topology with detailed geospatial modelling and network costings. We believe that this mix is achievable within the initial expenditure estimate for the NBN access network.

However, given the limitations of desk-based modelling, we cannot definitively recommend the optimal proportion of home-run deployment. Instead, we propose a review of topology options in the early stages of roll-out to support long-term flexibility and competitive outcomes. We detail this process in Chapter 10. NBN Co should anticipate this review, and plan to deploy a network that supports physical unbundling over a significant proportion of the network.

Recommendation 36. That NBN Co be required to deploy fibre topologies that support the ongoing needs of multiple stakeholders, including:

1. Service providers who may seek access to Layer 1 services, anticipating the likelihood of future unbundling requirements;
2. High bandwidth, dedicated class-of-service requirements for enterprise and government users, and for mobile base-stations and other users.

Advice. That NBN Co Board ensure the company conducts trials, in anticipation of the independent review discussed in Chapter 10 of the Implementation Study report, of options for a fibre topology that will support physical unbundling over a significant proportion of the fibre footprint.

Managing physical deployment of the network

The NBN is likely to require a mixed physical deployment, involving both underground and aerial fibre cabling. The mix of deployment methods is unlikely to impact the ability of the network to meet its performance requirements. However, this is an important issue for many stakeholders—for example, some local councils, given the aesthetic impact of different deployment choices.

The factors influencing the optimal mix of physical deployment are availability and access to existing assets, cost, ongoing maintenance, network redundancy and community impacts. Given the subtle and local nature of these factors, NBN Co is best positioned to balance these factors.

Highlight. The NBN is likely to require a mixed physical deployment with both duct and aerial components. The optimal deployment can only be determined area by area—NBN Co should make its decision based on cost and other factors.

Whichever deployment method is chosen, NBN Co should secure enduring rights of access to required infrastructure.

NBN Co should also ensure the assets used to physically deploy the NBN will support an enduring open-access network. The creation or acquisition of assets which could be shared in future—for example, new ducts—should prepare for growth and the prospect of open access at a future date.

Recommendation 37. That NBN Co be required to ensure that the assets used to physically deploy the network support an enduring open-access network; specifically for:

1. New trenches and ducts: to be over-provisioned to ensure sufficient space for future expansion or alternative use; detailed records of the location of ducts to be maintained;
2. Existing ducts: perpetual or long-term (with firm options to renew) indefeasible rights of use to be sought to ensure renegotiation of leases cannot put the future network, or commerciality of NBN Co, at risk; short-term leases to be avoided;
3. Existing overhead poles: long-term rights of use, ease of access and longevity of assets to be ensured; rights and obligations for future repairs and maintenance to be set out; political and community risks to network security and longevity to be considered.

As the largest cost driver for the NBN, the cost of physical deployment is a critical factor. Low cost options may emerge—for example, deployment in sewers or gas pipes.[85] These options should be assessed on the basis of total lifetime costs and utilised where commercially attractive.

Advice. That NBN Co Board consider the lifetime cost of assets used to physically deploy the network rather than only upfront capital cost.

4.2.2 DEPLOYING ACTIVE EQUIPMENT TO DELIVER 100 MBPS

The actual speed available in the access network will depend on the active components installed to light the fibre. The active technology used for NBN Layer 2 services is likely to combine GPON and Ethernet point-to-point (EP2P). Both are capable of delivering 100 Mbps if properly configured.

Technology decisions should be within the mandate of NBN Co. As we discuss earlier, it is important to clearly distinguish between the choice of topology and technology. While in some cases the topology will define technology choice (e.g. shared topologies require PON technology), the factors influencing each decision should differ due to the

[85] Bingeman, M 2009, ‘Sewer skills a fit for cabling’, *Australian,* 13 October, p. 33

significant differences in lifespan between active and passive network components (Exhibit 4–4).

Although both GPON and EP2P technologies can meet the performance requirements in the short term, the technologies differ along a number of dimensions. We now focus on the major differences between these technologies, and the implications for the NBN.

Assessing the options for active technologies

Both Ethernet point-to-point and GPON technology can deliver 100 Mbps in the access network, if properly specified. The technologies differ on a number of dimensions (Exhibit 4–8). However, on one key dimension—upfront cost—the technologies do not differ significantly. We discuss capital cost differences in 4.2. The major differences between GPON and EP2P are in performance and ongoing operational cost.

EP2P provides superior speed to GPON technology, due to the dedicated fibre used for each connection. This also allows EP2P to offer full symmetry of speeds (i.e. equivalent download and upload speed), whereas GPON, backed by ITU Standard G.984, is limited

Exhibit 4–8. Assessment of GPON and Ethernet point-to-point technologies

Decision factors	Technology options: GPON		Ethernet point-to-point	
Speed	✓	Meets NBN performance requirements, with upgrade path to faster speeds	✓✓	Current and future speeds are superior
Security	?	Potential security issues due to shared medium—upstream traffic is not encrypted	✓	Dedicated fibre provides logical security between fibre exchange and user premises
Exchange operations	✓	Efficient use of exchange space due to fewer fibres	?	Fibre management is more challenging, but standard systems are available
Power consumption	✓	GPON uses less power—passive splitters in field improve power consumption per connection	✘	EP2P is less energy efficient—however, difference is equivalent to each user driving a single commute per year

SOURCE: Implementation Study

to a 2:1 ratio of download to upload speed.[86] This lack of symmetry may impact the ability of GPON to support some services in the future—e.g. multiple high-definition video-conferencing channels. Although current GPON speeds are more than sufficient for current market demand, EP2P will always deliver faster speeds as new services evolve.

A standard GPON configuration (2.5 Gbps over a 32:1 split) will result in slightly lower theoretical dedicated speed for every connection (76 Mbps) than the required 100 Mbps. However, dynamic bandwidth allocation allows some connections to receive greater than 100 Mbps. GPON is therefore capable of delivering 100 Mbps, when it is demanded by end users.

EP2P security is also superior to GPON. The dedicated fibre means data is not shared across any connections in the access network. However, GPON broadcasts bits to every connection below the splitter, where it is then decoded by the appropriate equipment. While downstream traffic is encrypted, upstream traffic is not. A 2007 Stanford University study outlines three potential security concerns: denial of service attacks; eavesdropping; and masquerading of an ONT (e.g. continuously transmitting upstream to block transmission of information from other ONTs).[87] However, GPON vendors downplay the significance of these risks.[88] As GPON deployments become more widespread, standards and technology to ensure the security of these networks are likely to emerge. Outputs from industry conferences and workshops indicate this process is already underway.[89] As we discuss in Chapter 2, NBN Co should coordinate with the major security and law enforcement agencies on issues relating to the security of their data over the NBN.

GPON offers improved efficiency of exchange operations. It requires the management of fewer fibres within the exchange, and therefore requires less exchange space. However, fibre management systems are available for EP2P which assist in the efficient management of multiple fibres in the exchange.[90]

GPON is also a more power-efficient technology. This feature makes it cheaper and more environmentally friendly to operate than EP2P. This aspect of the technology is often referred to as its definitive benefit over EP2P, however, the magnitude of this difference should be qualified. EP2P consumes roughly 12 W per user, compared to approximately 7 W per user for GPON.[91] This difference over 12 months is comparable to the power a user would consume driving a single daily commute.

86 Heavy Reading 2009, *FTTH review & five-year forecast: The road to PON and next-gen PON*

87 Gutierrez, D, Cho, J & Kazovsky, L 2007, 'TDM-PON security issues: Upstream encryption is needed', paper presented to the Optical Fiber Communication and the National Fiber Optic Engineers Conference, Anaheim, CA, 25-29 March

88 Wierand, K 2008, 'EP2P and GPON battle for hearts and minds', *Telecommunications,* 8 January, viewed 12 February 2010, <http://www.telecomengine.com/article.asp?HH_ID=AR_3850>

89 Telecom Italia Group 2009, 'Next generation access network (in-security): Security proposal for NGN standardisation', presentation to the 4th ETSI Security Workshop, Sophia Antipolis, France, 13-14 January

90 Industry interviews

91 Ibid.

Balancing policy objectives and practical constraints

Both GPON and EP2P technologies can meet the requirements of the NBN, despite the differences in performance and efficiency. Although EP2P provides superior performance in terms of speed and security, the operating efficiency of GPON technology makes it an attractive option in the near term.

Three factors should mitigate any government concerns about the potential speed delivered by GPON (in standard configuration):

- GPON is capable of delivering 100 Mbps when demanded by end users. Lower splitter configurations would allow all users to receive dedicated speeds at this level, if required. If only a limited number of users require the top speed, dynamic bandwidth allocation can provide the excess capacity to those users with the highest demand;
- Demand for top speeds on the network is likely to evolve slowly over time. Although trends indicate demand for 100 Mbps and higher will be inevitable, it will take some time for a range of services that consume this level of bandwidth to become widespread;
- GPON has an upgrade path to deliver much higher speeds in the future. 10GPON and WDM PON are forecast to provide higher upload and download speeds within the next few years.[92]

As we discuss in the previous subsection, WDM PON is likely to deliver improvements to GPON performance in addition to speed. For example, it may allow service providers to access 'unbundled' wavelengths in the access network. The Implementation Study does not discount the potential for this technology to emerge. However as outlined earlier, we note the uncertainty around its development.

> *The risk of trying to pick WDM-PON technology developments now would be analogous to installing a leading edge ADSL 1 technology that foreclosed a later installation of VDSL2*
>
> Telecom New Zealand Limited[93]

> **Advice.** That the NBN Co Board consider that the NBN is likely to require a mix of Ethernet point-to-point (EP2P) and GPON technology; that EP2P can provide superior performance to GPON in terms of speed and security; and that there is potential for strong demand for EP2P services by SMEs and premium residential users (not just large enterprises) over time, and hence the company should provision sufficient fibre accordingly.

92 Heavy Reading 2009, *FTTH review & five-year forecast: The road to PON and next-gen PON*
93 Telecom New Zealand 2009, *Submission to New Zealand Ultra-Fast Broadband consultation*

4.2.3 SPECIFYING WHOLESALE SERVICES TO SUBSTANTIATE THE NBN PROMISE

Once a network capable of delivering 100 Mbps is in place, the NBN wholesale services will determine the end-user experience. In Chapter 3 we discuss the wholesale service offers at different layers of the network stack. Exhibit 4–9 presents the options for wholesale services within the fibre footprint, and what should be included in the NBN services roadmap over time. In this subsection we discuss the dimensions on which these services must be specified.

Defining service specifications of core NBN Co services

The core offer in the NBN fibre network will be a Layer 2 Ethernet bitstream. This must be defined along 3 dimensions, also discussed in the Reference Architecture:

- **Point of interconnect.** As this is an 'access' product, the default point of interconnect is at the fibre exchange, where the OLT terminates the optical link. Note that in some cases, a transit product may be required to allow retailers to access the service at reasonable cost; this is discussed in Chapter 6.
- **Point of termination.** The NBN fibre network is intended to be open access. It is therefore important that access seekers are able to connect CPE with minimal investment. This is the case today for PSTN and DSL services, where multiple jacks are usually available inside the house. The NBN layer 2 service should provide access at a point inside the house, by means of a patch panel connected to an external or internal ONT.

Exhibit 4–9. Wholesale services to be specified in NBN service roadmap

Core service in initial phases

OSI layer	Service	Timing of offer: During build	Timing of offer: Post roll-out	Criteria for offer
Active L2–3	L3 IP bitstream	✘	?	Failure of Layer 2 market
	RF broadcast	See Chapter 2 for recommendation		
	ATA voice	✓	✓	
	L2 Ethernet bitstream	✓	✓	
Passive L0–1	Dark fibre unbundling	✘	✓	Feasibility of active competition
	Duct/pole access	✘	?	If infrastructure competition necessary

SOURCE: Implementation Study

- **Data link specifications.** Definition of service specifications lies within NBN Co's mandate. We deal with considerations for bitstream services in the following sections. However, it is worth noting that service providers will purchase links on a premises-by-premises basis, but potentially share those links with other operators. NBN Co will need to address the method of bandwidth allocation between operators and services.

> **Recommendation 38.** That the network access point at end-user premises (i.e. the ONT) be required to provide a sufficient number of physical ports to enable multiple providers to offer services to each premises; that NBN Co ensure physical access to this point within the premises, at a location reasonably requested by the user (e.g. within close proximity to existing copper lead-in); this requirement includes: 1. If the ONT is installed externally, an internal patch panel providing open access to service providers on an equivalent basis; or 2. If the ONT is installed internally; that NBN Co be permitted to contract with retail service providers to implement these network access point requirements.

Delivering a superfast experience to all users

Within the portfolio of NBN active bitstream services, there will be some lowest price and performance—or entry-level—services that will be attractive for many consumers. These services are important because they define the minimum service experience. They also form a reference point in the market for performance, pricing, and value of the NBN. If this service offers relatively poor performance, then so will the NBN in the perception of these users. It is therefore imperative that Government provide guidance on the required specifications for these services.

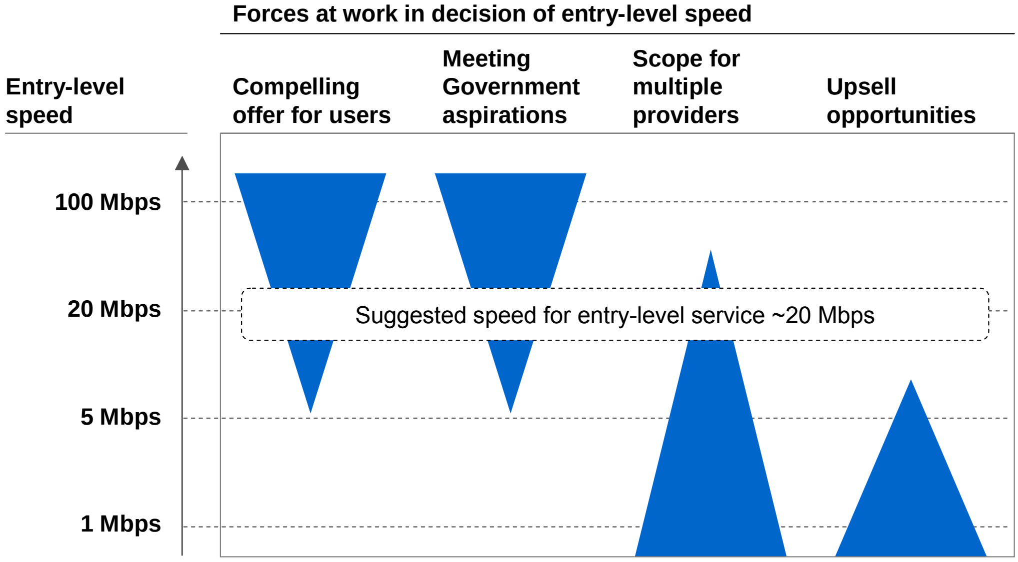
Entry-level services should be defined in two respects:

- What is the required performance of the entry-level bitstream product for broadband use?
- What legacy services should be offered, either as independent pure-play entry-level offers or as a bundle?

> **Highlight.** The performance of the entry-level broadband service will define the initial NBN experience for a majority of end users. It will also form a reference point in the market for performance, pricing and value of the NBN.

We first consider the specifications of the entry-level data product. Several tradeoffs impact this decision, as Exhibit 4–10 shows. We propose that these tradeoffs are best balanced with an entry-level service in the range of 20 Mbps.

Exhibit 4–10. Optimal speed of the entry-level broadband service



SOURCE: Implementation Study

We propose four principles to inform the appropriate performance level of the entry-level product:

- **The entry-level experience must be compelling at copper-substitution prices.** With ADSL2+ now available almost nationally, delivering speeds exceeding 10 Mbps in many areas, a basic offering of 10 Mbps or less is unlikely to gain traction. Some ISPs have average customer speeds today in the order of 12–13 Mbps, with some delivering speeds over 15 Mbps. As a result, we believe 20 Mbps is a minimum to provide a step-change in user experience relative to copper.

> *Our ADSL customers currently receive average speeds of 12–13 Mbps, with some over 15 Mbps*
>
> CEO of Australian ISP

- **The headline offer must substantiate the aspiration.** It is likely that headline entry-level retail offers will be compared against the NBN performance requirement of 100 Mbps. Consultation with industry stakeholders and experts indicates that 10 Mbps would be at the minimum range of an offer befitting Government's objective. By comparison, entry-level fibre offers of providers in other markets are generally at least 15–20 Mbps.[94]

[94] For example, Verizon FiOS offers 15 Mbps download and 5 Mbps upload (Verizon 2010, *Verizon FiOS Internet,* viewed 16 February 2010, <http://www22.verizon.com/Residential/FiOSInternet/Plans/Plans.htm>)

- **There should be scope for multiple service providers in all premises.** Chapter 9 discusses the role of the NBN in levelling the retail playing field. The implication for this section is that meaningful bandwidth should remain for other providers following the purchase of an entry-level product.[95]
- **Upsell based on speed should not be assumed.** Price differentiation is an important mechanism for network businesses to optimise revenues and demand. However, upselling on the basis of speed has proven difficult for ISPs in the DSL market, and it is a source of great market uncertainty. In addition, our revenue modelling (Section 4.5) indicates NBN Co should achieve sustainable long-run revenue with only moderate assumptions about price increases and upsell over time.

Recommendation 39. That an entry-level wholesale bitstream service for NBN Co's fibre network be defined that would be the minimum acceptable service for residential broadband use, specifically:

1. That this bitstream service enable a significant improvement over typical experiences on other fixed networks, and offer at least a 20 Mbps peak download speed within the fibre access network;
2. That this entry-level speed be reviewed over time to ensure it continues to deliver sufficient performance relative to other fixed broadband networks;
3. That exceptions for a lower-speed entry-level service be considered for commercial reasons where most end users will take retail services using at least a 20 Mbps wholesale bitstream service.

In current xDSL broadband networks, speeds are typically quoted as peak data rates. This reflects the effect that the length of the copper loops have on achievable speeds—the further any premises are from an exchange, the lower the experienced speeds. In a fibre access network, the data rates achieved do not decline in proportion to distance from the fibre exchange: all premises within the maximum coverage distance receive identical rates.

For this reason, at least in the early stages of NBN services, the peak data rates offered in the access portion of the network will be equivalent to committed data rates. This means that if a customer purchases a 20 Mbps service, that customer will be able to access sustained data rates of 20 Mbps over their access link.

There are two factors that may cause the data rates actually experienced by the end user to fall below this rate. The first is contention in the backhaul network. Although the access network (from the fibre exchange to the customer premises) is not a contended link, in the backhaul network the data from many end users is combined onto a link which is provisioned at lower capacity than the combination of the individual access

[95] While it is true that a 'best efforts', contended product could be defined at full line speed while still accommodating the entry of other service providers, we are assuming that in practice a consumer will seek complementary rather than substitutive experiences.

links. As a result, a user may achieve less than 20 Mbps speeds when downloading data. This issue is particularly prevalent when accessing data from overseas, due to contention on the submarine cables, particularly to the USA.

The second limiting factor is the potential over time for multiple retailers to share the pipe, or for a single retailer to offer multiple services down a given portion of the bandwidth. For example, if a retailer purchases a 20 Mbps connection and offers both an IPTV service requiring a high Quality of service connection, as well as a best-efforts Internet service over the same connection, the actual experience of the end user on the Internet service will vary greatly according to whether the IPTV service is being used.

We therefore recommended specifying offerings over the fibre network in terms of a peak data rate, rather than a committed data rate, even though in the near term a 20 Mbps peak data rate link will offer a similar experience to a committed information rate link of the same specification.

Acknowledging other factors influencing the user experience

We have focused on download speed as the factor that will define the NBN experience for most users, because this is the reference point for average broadband usage. However, additional factors affect end-user experience—in particular, upload speed and network speeds upstream of NBN Co's point of interconnect.

Upload speed can have a significant impact on the user experience. However, for average broadband users, it is less of a defining factor than download speed, once above a reasonable threshold. For example, typical Internet users download (e.g. video) more data and more often than they upload (e.g. email, outbound file sharing). As such, we believe government can afford to be less prescriptive about minimum upload specifications. In addition, upload speeds provide a useful mechanism to differentiate users, as they clearly enable or prevent certain types of services—e.g. video-conferencing requires high upload speeds. Section 4.5 discusses the importance of mechanisms such as these in optimising revenue for the network.

Regardless of the speeds enabled in the access network, performance bottlenecks in other parts of the network affect the speed that end users experience. For example, limited capacity in international links and the speed of the servers hosting the content will affect users' experience with Internet services—for example, YouTube—over the NBN. These bottlenecks are outside the control of NBN Co, but mean that users are unlikely to experience 100 Mbps for most services in the near term. These potential bottlenecks should be resolved adequately by market forces as more users demand superfast speeds.

> **Highlight**. The actual broadband speeds experienced by end users will be impacted by bottlenecks upstream in the network, such as limited capacity in international transport links and the speed of content-hosting servers. These bottlenecks are outside the control of NBN Co, but will be resolved by market forces over time.

Delivering non-Ethernet services

The NBN also has the ability to offer non-Ethernet based services (i.e. no requirement for an Ethernet port at the ONT). The main services for consideration are emulation of PSTN-voice and RF-video overlay. We discuss RF overlay in Section 3.3. We also discuss the continuation of fixed-voice services in Chapter 2.

An important decision for an NBN fixed-voice service is whether it is bundled with the entry-level bitstream service. Double-play (voice and broadband) users are clearly more valuable to the NBN than voice only or broadband only users. However at present, there are significant segments of customers who take only one of those retail products. In the case of broadband-only customers, naked DSL products have grown rapidly in recent years—approximately 80 percent compound annual growth rate between 2006 and 2009.[96]

We therefore propose that NBN voice and data services be sold in a modular fashion. That is, an ATA voice service[97] would be sold separately to data as a pure-play product. The two services could be bundled if requested by an end user, but at the same time could be sold as standalone offers.

Advice. That the NBN Co Board ensure the company offers an ATA voice service as a pure-play service, once access has been purchased, separate to the data service. This would be most relevant if and when the copper network is deactivated, or to do a whole-of-business migration deal with a service provider who has some voice-only customers.

Providing services with sufficient technical specifications

NBN Co should create a broadband platform which anticipates the greatest range of potential services. This is a challenge in the context of the wholesale open-access Layer 2 services being offered on the network, as we describe below. Today, Ethernet bitstream wholesale services are used to deliver best-effort Internet connections, and cater for a range of basic services. NBN Co will have to enable higher levels of performance, through quality of service (QoS) parameters.

The challenge lies in anticipating the implementation of standards. Although protocols for providing end-to-end QoS across multiple networks are well advanced, such protocols have not yet been deployed at scale to support commercial services. Most implementations of QoS-dependent services on telecommunications networks are still reliant on multiprotocol label switching (MPLS), or similar

> *Support for IP multicast within a Layer 2 bitstream wholesale product set is technically feasible*
>
> Juniper Networks[98]

96 J.P. Morgan 2009, *Australian Telecom Sector in FY09*

97 Analogue Telephone Adapter

98 Juniper Networks 2009, *Submission to New Zealand Ultra-Fast Broadband consultation*

solutions which employ control planes within the same Layer 2 environment. However, there is good reason to believe that these carrier-grade Ethernet standards should be widely implemented over coming years.

NBN Co will need to strive to employ the best standards available, and be open to modifying its wholesale services accordingly. Active equipment should be purchased which supports the greatest number of standards paths, and aligns with the largest global ecosystem.

> **Recommendation 40**. That NBN Co be required to offer wholesale services that support the implementation of carrier-grade QoS functionality, allowing retail service providers to deliver premium services from within their network to end users:
>
> 1. Initially, this means ensuring that the appropriate specifications are adopted through consultation with industry and potential customers;
> 2. Over time, this may require offering services that are higher in the network stack, as has already been considered for IPTV, where IGMP functionality is being considered, and/or extending the geographic extent of the Layer 2 network (i.e. further upstream); such decisions to expand the scope of NBN Co operations should not be taken lightly, and should be based on demonstrated inability of NBN wholesale services to enable services that are feasible within other networks internationally and for which there is demand.

Enabling services for enterprise and Government use

Enterprise and Government customers typically purchase point-to-point connections as part of a managed services relationship with a major ICT services provider, or a sophisticated carrier such as Telstra, Optus, or AAPT. The exact specifications vary depending on the solutions being implemented for that customer, but these links typically have a number of requirements.

First, high-end enterprise and Government users generally require very high, symmetrical speeds—at least 1 Gbps. This is 50 times faster than the suggested minimum speed for residential users on the NBN (20 Mbps). Second, they require redundancy via physically diverse paths. Third, the connections must provide security of transmission. Finally, these users need a range of options for class of service.

High-end services to these customers are typically delivered using Ethernet point-to-point technology over dedicated fibres. NBN Co should anticipate this demand in its network design and service specification. Over time, these services are likely to become increasingly attractive to a range of users, due to the ubiquity of the NBN and competitive offers it will enable.

Specifically, the increased availability and affordability of high-bandwidth point-to-point services is likely to increase the demand from small and medium enterprises. These services have typically been out of reach for users of this scale, but it is reasonable to expect some latent demand in the market. One example would be a small graphic design company that requires a high-speed symmetrical service to quickly transfer large data files and images. NBN Co should anticipate increased demand of this nature, and provision its network and services accordingly.

Advice. That NBN Co Board encourage the company to undertake consultation with enterprise service providers to determine the appropriate specifications to serve the enterprise market, including implications for the mix of fibre topology.

4.3 Meeting fibre coverage objectives within Government's expenditure estimate

The Government's stated objective is to deliver a fibre-to-the-premises access network that covers 90 percent of Australian premises. The majority of the $43 billion initial expenditure estimate comprised $23.3 billion plus contingency and out-turning to build the FTTP access network. Under most plausible scenarios, the network can be built to at least 90 percent of premises within that expenditure estimate. Some significant uncertainties remain about the cost of access to existing infrastructure (including deals with existing infrastructure owners), the exact network topology NBN Co will deploy and some of the civil engineering costs. Many of these will not be resolved until NBN Co begins construction.

This section addresses the cost of building a fibre-to-the-premises access network, in three subsections:

4.3.1 Estimating the cost of the 90+ percent fibre access network

4.3.2 Estimating unit costs from prior deployments and industry expertise

4.3.3 Using detailed geospatial modelling.

4.3.1 ESTIMATING THE COST OF THE 90+ PERCENT FIBRE ACCESS NETWORK

We built a detailed model to estimate the cost of building the fibre access network, to inform policy choices such as the extent of the fibre footprint and to build the business case in Chapter 7.

The unit cost assumptions used in the modelling are based on significant consultation with vendors and civil engineers and have been refined based on field surveys with network construction specialists. Distances are based on detailed geospatial modelling taken down to a per premises level. The accuracy of the overall cost analysis will be even greater once deployment commences and better information is available about the state of existing infrastructure, and the actual costs experienced. Further work is required on the part of the NBN Co to test and validate assumed unit costs, particularly once the network architecture and product design is finalised.

We do not assume a deal with network or infrastructure owners in the modelling. Where existing infrastructure is used by the NBN, it is costed on the basis of current commercial rates. There is a compelling economic benefit for NBN Co and Telstra to reach an agreement to reuse existing infrastructure, including ducts and exchange space, and a deal could significantly reduce overall network costs for the NBN Co.

The modelling takes into account the existing stock of premises as well as projected growth. It is expected that the stock of premises will grow at a rate of approximately 1.25 percent p.a. over the life of the network. We break this growth rate down into 0.75 percent for greenfields premises and 0.5 percent for brownfields subdivisions and developments.

Drivers of construction cost for the fibre access network

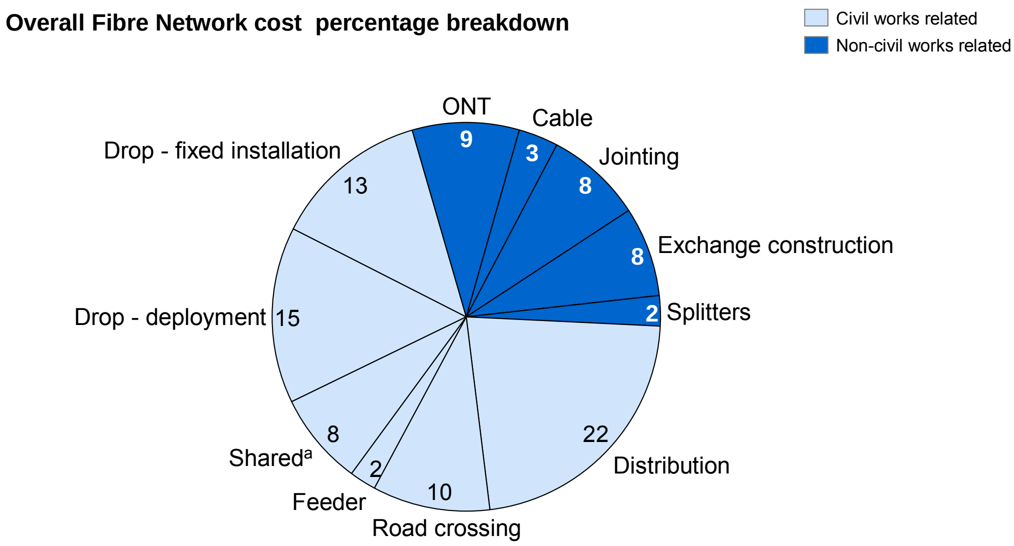
We modelled a GPON network with a home-run fibre topology for fifty percent of the fibre footprint. The network modelled is provisioned to allow redundant home-run fibre links to businesses and high value customers wherever required in the access network. The following are the major elements of the GPON access network:

- **Exchange**—the central office where the active electronics (OLT and other actives) are situated;
- **Feeder network**—the fibre connecting the exchange to the splitter cabinet;
- **Splitter cabinet and splitters—**a cabinet in the field through which the feeder fibre passes and can be split into multiple distribution fibres;
- **Distribution network**—the fibre from the splitter cabinet through to the drop point;
- **Drop and CPE**—the fibre lead-in from the drop point to the ONT in the premises and associated installation activities allowing connectivity to the network

The majority (approximately 70 percent) of the deployment cost is civil works related (Exhibit 4–11). These costs are for deploying the fibre through the distribution and road-crossings, feeder and drop as well as customer premises installation costs. The actual cost of the fibre itself is rather small. If 'pre-connecterised' cabling is used then the cable cost would rise as jointing and splicing costs are transferred from the field to the factory.

As civil works make up the majority of the costs, distance is a critical variable in the overall cost estimation. We describe our approach to distance estimation through geospatial modelling in Section 4.3.3.

Exhibit 4–11. Fibre access network cost breakdown



a. Feeder and distribution share the same trench
SOURCE: Implementation Study

Fibre access network cost curve

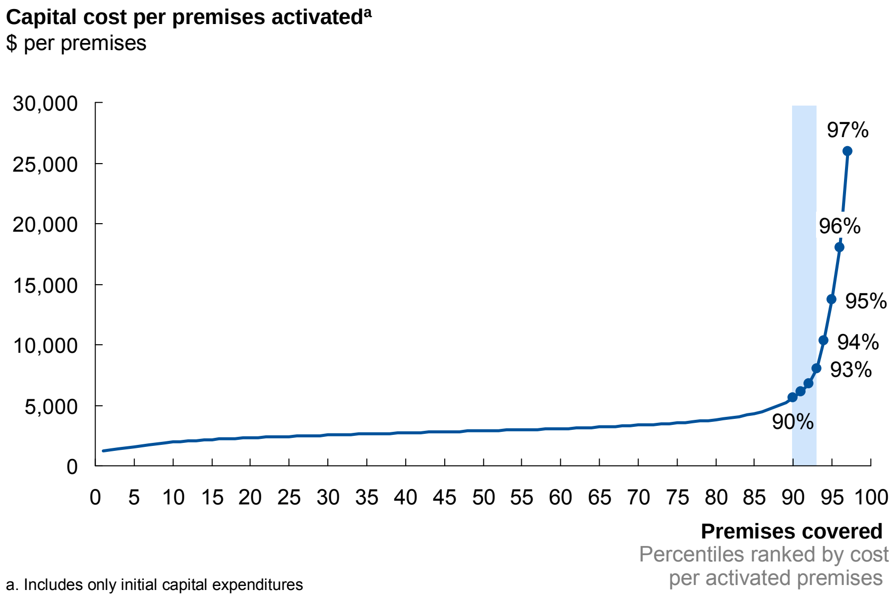
Fibre access network costs can be expressed as a cumulative and marginal cost curve ranging from zero to one hundred percent coverage of premises in Australia. The primary driver of difference in cost-to-serve at the premises level is the required deployment distance per premises. As would be expected, this is highly correlated to density.

The cost curve (Exhibit 4–12), when viewed on a marginal level, allows an understanding of where it becomes dramatically more expensive to serve additional premises and thereby avoid distortion due to the use of average costs. The marginal curve further allows an understanding of policy choices such as uniform pricing and the potential for pre-emptive cherry-picking of areas with attractive economics. On a cumulative level it allows the assessment of how coverage choices translate into overall network costs.

The marginal cost curve:

- Is modelled on the basis of a 100 percent shared deployment;
- Includes all the costs of the fibre access network from the exchange to the premises;
- Excludes costs associated with other elements of the overall project such as backhaul, operating and business support systems and overhead costs. The fibre cost curve provides an indicative only cost of the access network at different coverage levels.

Exhibit 4–12. Fibre-to-the-premises cost curve



a. Includes only initial capital expenditures
SOURCE: Implementation Study

Note that our reference case for the business case modelling assumes a 50% home-run topology which is not included in the above cost curve due to its distortive effect. A marginal cost curve should not be used as a basis for making policy choices concerning fibre topology but only as a guide to where cost to serve begins to accelerate to an unacceptable degree.

The cost curve demonstrates that the incremental cost to connect premises accelerates very sharply after the 93rd percentile. The implication of this spike in cost per premises—particularly for the mix of technologies deployed in the NBN—is discussed in Chapter 5. To give an indication of the acceleration in costs, Exhibit 4–13 shows the cost per percentile beyond 90 percent of premises passed, as a multiple of the 50th percentile costs as well as an acceleration rate, which is the rate of change compared to the previous percentile.

The actual roll-out will not be able to deploy to exactly 90 or 93 percent of the cheapest premises in Australia (as suggested by the above curve) due to the fact that premises of a certain density percentile are not all contiguous. The Mesh Block curve presents marginal costs that are too high and too low at both extremes of the curve. Premises which comprise the first 20 percent of the curve are indeed cheap to connect on an individual basis (they mostly comprise dense MDUs in urban areas). These premises are not contiguous, but rather represent distinct pockets spread across different suburbs and cities. Building a network that covered only the most dense of these premises would incur significantly greater fixed costs per premises (as well as being logistically impractical), so that a cost curve drawn for the first 20 percent of premises alone is considerably more expensive than the above curve suggests.

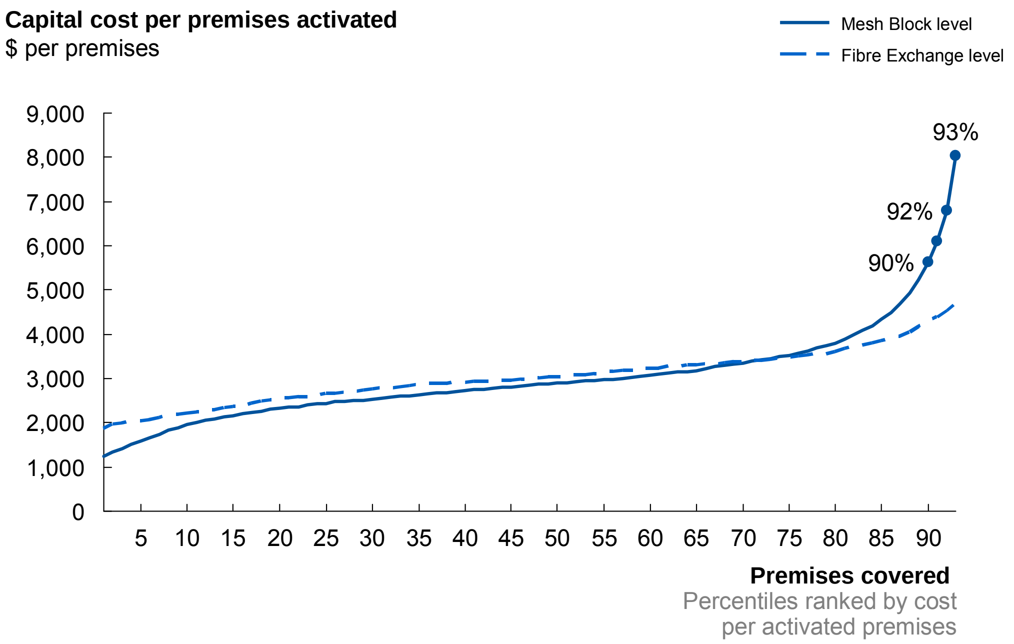
Exhibit 4–13. Breakdown of upper percentiles from FTTP cost curve

Percentile	Cost as multiple of the 50th percentile	Acceleration rate
90	1.9	7%
91	2.1	8%
92	2.3	11%
93	2.8	19%
94	3.6	28%
95	4.7	33%
96	6.2	31%
97	8.9	44%

Source: Implementation Study

The cost curve below (Exhibit 4–14) demonstrates the curve on a Mesh Block and fibre exchange level up to the 93rd percentile. The fibre curve (dashed line) produces a much flatter curve and is more representative of marginal roll-out costs incurred in deploying the network to contiguous areas.

Exhibit 4–14. Fibre-to-the-premises cost curve (93 percent coverage)



SOURCE: Implementation Study

Implications of uniform pricing

The slope of the cost curve has important implications for the ability of NBN Co to establish a uniform wholesale price across all areas within the fibre access network. In Chapter 1 we discuss the desirability of geographically uniform prices within (but not across) access technologies, to drive a network effect through widespread take-up of services. The Implementation Study believes that the combination of the slope of the cost curve, ability to price transit backhaul separately and freedom to vary migration incentives is sufficient to enable uniform wholesale access pricing. Major issues concerning uniform pricing are set out in Exhibit 4–15.

Exhibit 4–15. Implications of the fibre access cost curve for uniform pricing

Uniform pricing within the fibre access network

Historically, wholesale fixed-line access prices have been set by the regulator in a band structure, with exchanges falling within a particular band receiving uniform pricing. The Government has expressed its preference for the pricing of the basic NBN access service to reflect principles of geographical uniformity. We anticipate that NBN Co's Special Access Undertaking to the ACCC will reflect this policy aspiration.

The Implementation Study believes establishing affordable, uniform wholesale access prices across the fibre network is desirable for two reasons: first, it can help enable Government's aspiration to deliver affordable broadband to all Australians by reducing the degree of retail price variability in the market. Second, it can help drive take-up of NBN services which is an important driver of commerciality. This uniformity should be limited to the access portion of the network however, and should only apply within—not across—access technologies, due to fundamental differences in performance.

Uniform pricing does present some challenges:

- **Price levels that compromise NBN Co's business case:** If uniform prices are set too low this risks NBN Co capturing insufficient revenue per customer to generate a return on the capital invested over time. If prices are set too high, revenue may also suffer due to low take-up of services.
- **Risk of cherry-picking by competing network operators.** Given the marginal cost to deploy fibre varies by geography, competing network builders have an incentive to enter in only the lowest-cost areas. By contrast, NBN Co is required to deploy in all areas within the fibre footprint. An average national price set by NBN Co could therefore magnify the incentive for competing providers by allowing them to overbuild the NBN at lower cost in targeted areas and offer lower priced services.

Is uniform pricing viable within the fibre access network?

The ability of the NBN to overcome the challenges of uniform pricing depends strongly on the shape of the fibre access cost curve up to the point where fibre deployment ends—which the Implementation Study recommends taking as the point where the curve begins to accelerate dramatically (approximately the 93rd percentile). Exhibit 4–12 demonstrates the way marginal cost to deploy fibre across premises varies by geography. Based on the shape of this curve we believe uniform pricing is viable within the fibre access network, for four reasons discussed below.

1. Ensuring use of a uniform price does not inhibit take-up

Setting a uniform price establishes an implicit cross-subsidy from users in low cost areas (who receive a price higher than they otherwise would) to users in high-cost areas (who receive a price lower than their cost to serve would imply). Essentially, the uniform wholesale price point must be sufficiently high that it generates an acceptable return relative to the *average* cost per premises activated across the curve (assuming take-up rates are roughly uniform across the curve—if take-up is lower in outer areas then this will be a conservative assumption since average cost per premises will be lower).

Therefore, if the cost curve rose very steeply at, say, the 75th percentile, this would present a significant challenge for setting a uniform price, since the average cost of deployment would be very high, leading to an unsustainably high uniform price point.

2. Confronting the risk of cherry-picking low-cost areas

As discussed above, the low end of the cost curve is only accurate in the context of a national deployment, where adjacent, more expensive areas are also served to create a contiguous network. It is not possible to build a network that serves only the lowest-cost percentiles at the costs depicted above. Therefore, for an alternative market entrant targeting the least expensive premises, their cost curve at the low end would reflect higher costs than those represented in Exhibit 4–12. Costs would more closely resemble the flatter fibre-exchange curve in Exhibit 4–14 and consequently the opportunity for 'cherry-picking' is not as great as it may initially appear. For a longer discussion of measures to ensure any overbuilding of the access network is consistent with Government's objectives for the NBN, see Section 10.2.

3. Separating transit and access pricing

The cost curve shown above is for the fibre access network only. In areas that lack competitive providers of backhaul today, NBN Co will also provide transit backhaul to connect Fibre exchanges to the core of the network (see Chapter 6). This transit backhaul will primarily be deployed outside metropolitan areas, which will add cost disproportionately to serving premises on the right hand side of the cost curve shown above.

The Implementation Study believes NBN Co should be permitted to charge separately for this transit backhaul component, which will remove one of the major drivers of cost difference between geographies, and therefore improve the viability of uniform access pricing.

In Chapter 6 we discuss a separate mechanism to ensure the affordability of transit services. It is important to note that this additional cost to serve remote premises may not automatically be passed on to consumers through higher retail prices. If the additional cost is not significant, service providers may cross-subsidise these customers via a uniform retail price structure to allow them the simplicity of a national rate card.

4. Excluding migration incentives from uniformity requirements

Some service providers may require incentives to migrate their customers onto the NBN.

In Section 4.4 we discuss the need for NBN Co to have flexibility regarding the nature and extent of these incentives, as long as they are offered on an equivalent basis. Competitive dynamics and retailer economics are likely to differ between geographies—any migration incentives offered by NBN Co should reflect this reality and have the flexibility to vary by geography and over time, without distorting long-term equivalence or uniformity of access prices.

Source: Implementation Study

We discuss the other considerations for national uniform pricing—within access technologies—in Chapter 2.

4.3.2 ESTIMATING UNIT COSTS FROM PRIOR DEPLOYMENTS AND INDUSTRY EXPERTISE

A bottom-up approach has been used in the modelling which draws on granular estimates of network elements. Estimates are the result of extensive consultation with industry vendors, network operators, technical consultants and internal analysis. Field surveys with two major civil engineering companies have been undertaken to ascertain the likely costs of civil works in the network build across regions with different geographical characteristics. A leading industry contractor was retained to advise on cost assumptions.

The Implementation Study has specifically avoided using high-level benchmarks such as cost/premises from international roll-outs as a basis for calculating overall costs. We avoid this approach because:

- Cost differences between localised (typically urban) and national roll-outs
- Costs faced by incumbents (with significant ability to cheaply re-use existing infrastructure) are different to those faced by over-builders
- Differences in labour prices between countries
- Incentives to over/understate costs in markets where prices are set as a function of the regulated asset base
- Fibre take-up percentages (the driver of headline cost per activated premises numbers) are different

Deployment mix as a driver of network deployment costs

Other than distance, the major driver of overall costs is the mix of deployment methodologies employed in the roll-out.

In the distribution network there is the possibility of pursuing a significant variety of deployment methods due to the reduced the risk of large-scale end-user disconnections if the distribution cable is cut.

The more conventional methods of deployment are underground through a ducted telecommunications conduit (either existing or newly constructed) or aerial deployment. Some less widely used deployment methods include placing fibre through the sewerage network, gas pipelines, electrical ducts or other available infrastructure. Although less conventional, these methods have been used for several international roll-outs.

The possibility of using the sewer network in particular has received significant attention. The Implementation Study has not been able to accurately assess the likely costs involved in such a deployment due to the paucity of available data. On this basis, a sewer based deployment has not been modelled although it is acknowledged that the technology to allow such a fibre deployment is still in its infancy and is rapidly developing.

The use of alternative undergrounded infrastructure such as gas pipelines or electrical conduits, while possible on an ad-hoc basis where available and practical, would be less preferred to form a significant part of a large-scale national roll-out. As such these methods have not been modelled.

The model assumes that the deployment will follow the existing road network and utilise only aerial infrastructure or underground telecommunications conduit (either new conduit built by the NBN Co or existing Telstra ducts). In spite of this assumption, there is the real possibility that alternative deployment methods, where feasible, could reduce the overall costs of the network.

Advice.: That NBN Co Board investigate the appropriateness, feasibility and cost of using alternative passive infrastructure to lay fibre in the network build.

Density as a driver of costs per metre

An important consideration in ascertaining realistic cost inputs is the impact of premises density on unit costs (Exhibit 4–16). As premises density changes the cost to pass premises also changes. High density areas tend to have larger, busier road networks and a higher percentage of concrete between the premises boundary and the road, making trenching more expensive. High density areas also have significant existing infrastructure which often necessitates expensive drilling under the surface of the road, further increasing costs. Several other differences including premises frontage and changing average span between poles contribute to different unit costs in areas with different density characteristics. These differences have been taken into account in the overall cost modelling.

Exhibit 4–16. Impact of density on unit costs

Density and its impact on unit costs

Analysis has shown that the cost per metre in very high density places can be sharply higher than the cost per metre in lower density areas. Our cost modelling includes differential costs/metre for high and low density areas, for both new trenching and aerial deployments.

New trenching. Field surveys conducted in NSW and Victoria establish that the trenching methodology deployed is highly correlated to density. Above a certain threshold the footway at a surface level changes from mostly grass to mostly concrete and becomes sufficiently crowded with other infrastructure so as to rule out a surface trenching method. This step-change in costs is factored into the model.

Aerial. Geospatial analysis based on pole data in NSW reveals that pole distances begin to lengthen as premises density declines. This is consistent with average premises frontage analysis which also increases as density declines. As aerial cost per metre is a function of distance between poles, the change in pole distances has been factored into the model.

Source: Implementation Study

Exhibit 4–17. Trenching techniques

Trenching techniques
Directional Drilling. Uses a machine to bore through the ground at a typical depth of 0.8–1.2 metres. It is most appropriate where there is significant obstruction caused by existing utilities at a surface level, where deployment across a road is required or where council regulations require complete reinstatement of a sidewalk after open trenching.
Open trenching. Uses a chain-digger or other equipment at surface level to trench and then re-compact to fill the trench once the conduit has been laid. Open trenching is most suitable where there is ample room at a surface level to dig without impacting other infrastructure. The costs of open trenching are largely dependent on the level of re-compacting that is required after digging.
Mole-plough trenching. Uses a mechanical digger in soft-soil. It is the cheapest method but is only available in soft-soil in areas that are completely unobstructed.
Micro-trenching. Involves cutting a narrow trench along a street curb or footway. This method is generally considered inappropriate in Australia due to possible water damage to bitumen or asphalt after the micro-trench has been cut.
Other novel methods not commonly used in Australia. Includes micro/open trenching hybrids and mechanised shallow trenching methods using advanced mechanised installation machines from Europe or America.
Source: Implementation Study

Distribution

The distribution network can be deployed aerially or underground and runs from the splitter cabinet to the drop point (either a pole or a pit). If the distribution shares the same route as the feeder then the distribution fibres are placed underground in the same conduit as the feeder.

Where the distribution is deployed underground in a new trench, the overall cost comprises:

- Labour and equipment for the trench—typically a function of the trenching method and soil type;
- Installation of the conduit—typically 50–100 mm in diameter and guard-wire;
- Capital and labour for purchasing and installing a pit system;
- Road crossings to access premises on the other side of the single-sided deployment.

The cost per metre of deploying underground in a new trench depends on the mix of different trenching techniques used (Exhibit 4–17) and ranges from $60–150 per metre.

> **Advice.** That NBN Co Board ensure the company investigates innovative trenching methods not currently used in Australia to assess their potential to bring down the costs of the deployment.

Where distribution is deployed aerially, the cost comprises:

- Pole make-ready including costs associated with load-testing (checking if the pole has the necessary structural integrity to support fibre) and pole framing (clamping, screwing, drilling etc);
- Re-configuration, pole reinforcement or replacement, where needed;
- Hauling for fibre installation.

Aerial is typically a substantially cheaper deployment method than new underground trenching. Although it may have a shorter life than underground cable and involve higher operating costs, aerial deployment is almost always cheaper if good quality pole infrastructure exists. The capital cost of aerial installation is estimated to be in the range of $20–$30 per metre throughout the network.

Cost estimates assume that the deployment will be aerial wherever possible. Detail on the assumed maximum aerial percentage is below (Exhibit 4–18).

Exhibit 4–18. Availability of aerial deployment

55 percent availability of aerial deployment

The estimated maximum extent of an aerial deployment is 55 percent of cumulative total distribution distance, based on:

- A theoretical maximum aerial deployment of 72 percent—which is the number of premises now receiving electricity aerially (according to Electricity Supply Australia)
- A conservative assumption that approximately 7 percent of total poles in Australia are structurally incapable of supporting fibre. This estimate is the result of extensive consultation with utilities. We have not sought independent engineering advice to confirm this or the assertions of different utility companies as to the usability of their pole infrastructure. We assume NBN Co will do so during network planning.
- All other poles are generally available for the fibre deployment, although field trials show approximately 5 percent of poles are likely to be incapable of supporting fibre due to the presence impeding infrastructure. This 5 percent are assumed to be randomly distributed throughout different distribution networks. As a result, the need to deploy underground decreases the aerial percentage by 10 percent (as the loss of one pole requires an underground deployment covering twice the span).

It further assumes:

- Community acceptance of an aerial fibre roll-out
- NBN Co does not deploy any poles of its own. As access to existing poles is mandated, NBN Co deploys fibre on all poles where it is technically feasible

Source: Implementation Study

There remains significant uncertainty as to the 55 percent of the distribution deployment that is assumed to be achievable with aerial fibre due to:

- Community resistance that is inherent in an aerial roll-out;
- Uncertainty as to the proportion of pole network infrastructure that is structurally incapable of supporting fibre (could be less or greater than 7 percent);
- Uncertainty as to the proportion of poles that are unsuitable for deployment due to impeding infrastructure (could be less or greater than 5 percent);
- Some utilities may be unwilling to cooperate with NBN Co and there are the practical challenges of seeking access under the relevant access regime.

Some of this risk can be reduced with appropriate powers and immunities legislation, which is discussed in Chapter 7.

Feeder

The feeder network, due to the risk of large-scale end user disconnections is assumed to be deployed underground to allow greater network security. A large proportion of the total trenched distance of feeder is overlapping with the distribution network and we assume trenches are shared.

The Implementation Study assumes that the most attractive fifty percent of fibre exchange service areas have a home-run fibre topology with a dedicated fibre running from the exchange to the premises. The remainder are served with a shared topology.

Fibre exchanges, street cabinets and splitters

Exchanges are deployed to serve a maximum of 30,000 premises. This assumption is in-keeping with the current number of premises served per Telstra exchange and is not a recommendation as to the actual size per fibre exchange. The modelled network covers a maximum radial distance of 10 km from the exchange.

It is not assumed that the NBN Co utilises existing exchanges. All exchanges, as part of a new build, incorporate costs associated with site acquisition, external structure, electrical and air conditioning, site make-ready, power backup and costs associated with leasing land. To calculate land lease costs and how these vary according to geographic characteristic, exchanges have been divided into high density and low density categories to reflect higher costs per square metre in urban locations. It is assumed that the minimum land areas available for leasing per exchange will significantly exceed the actual space requirement of the NBN and this has been taken into account in the modelling.

All exchanges are equipped with an OLT. The OLT specifications may vary according to the number of premises served at the exchange. We have provisioned with OLT chassis with 2.5 Gbps line cards. On a per premises basis the OLT cost per user is expected to be less than $100. Optical distribution frames to facilitate fibre management are assumed to be deployed at every exchange.

The modelling assumes that where a shared topology is used, the feeder fibres will be split at street cabinets which have been placed in the network to serve 250 premises. The cabinets are capable of supporting nine splitters and a maximum of 288 premises. A cabinet per 250 premises should not be read as a recommendation. It may be preferable to have more aggregated cabinets if a shared topology is to be successfully unbundled at the active layer in the future. Cabinet costs, although significant, equate to approximately $30 per premises. The modelling assumes that 1:32 splitters are employed at the cabinet level.

Drop

The drop incorporates the fibre lead-in to the premises and the fixed installation cost involved in installing the ONT. The Implementation Study assumes that customer premises are activated on a demand driven basis and not when passed. This leads to lower overall costs and greater capital efficiency (Exhibit 4–19).

The deployment costs of the drop vary according to whether the installation is aerial or underground. Typically the drop method will be aligned with the distribution method—i.e. an aerial distribution will lead to an aerial drop and an underground distribution will lead to an underground drop. Exceptions to this are made for premises which are passed by an aerial distribution but have an underground lead-in. This percentage was assessed as roughly 10% of premises.

Exhibit 4–19. Benefits of demand-driven activations

Benefits of demand driven activations
Connecting end users on a demand driven basis reduces capital costs, results in higher capital efficiency and is more practical than a policy of simultaneous ‘pass and connect’ in advance of the customer taking up the service.
Costs are reduced through capital costs forgone for those premises who choose ultimately not to connect to the fibre network due to wireless substitution or use of competing infrastructure. If the premises were activated when passed with an outside ONT deployed, it is estimated that this would result in additional costs exceeding $3 billion. If the drop fibre were only made to the premises and no ONT installation occurred (i.e. the fibre was just curled up) then the additional cost would exceed $1 billion. A policy of pass and connect further increases the operational leverage of the company making its financial performance more sensitive to take-up rates.
Practical legal considerations suggest that issues of consent could be problematic when installing the lead-in to premises when passing.
Based on these factors the Implementation Study has assumed that the drop will be deployed only on a demand driven basis.
Source: Implementation Study

Where the lead-in is deployed underground, the model assesses two different cost segments: pit to property boundary and property boundary to premises boundary. Both segments are assumed to have different unit costs. Within segments costs differ according to high density and low density categorisation. It is assumed that pit to property boundary will typically be deployed in a ducted conduit and property boundary to premises boundary will be direct buried to minimise overall costs. The underground lead-in is assumed to have a fixed cost per premises based on high density or low density categorisation. This approach is consistent with current market practices where lead ins are typically costed on a fixed basis per lead-in.

Aerial lead-ins are significantly cheaper than underground lead-ins. Savings are achieved as the pole from which the cable is deployed has already been made-ready in the course of the distribution deployment. Aerial costs are made up of hauling and cabling.

Collaboration with utilities will be important in achieving a widespread aerial roll-out (Exhibit 4–20).

Exhibit 4–20. Collaborating with Utilities in network roll-out

Collaborating with Utilities

The NBN deployment could benefit from collaboration with electricity distribution network service providers in several ways. Direct cost savings could be derived from coordinating the fibre deployment with utilities' own network upgrades, fibre deployments, undergrounding initiatives or smart-metre roll-outs. Further cost savings could accrue from cooperation with utilities to achieve minimal disruption to existing infrastructure from the distribution roll-out. Finally, collaboration could provide other benefits including premises access rights through shared infrastructure where this may be problematic to achieve, such as for MDUs.

However, several significant hurdles stand in the way of effective collaboration, notably negotiating, contracting and coordinating roll-out schedules with the numerous electricity distributors, each of which has exclusive distribution rights for a franchise area. Therefore the Implementation Study has not assumed any significant savings from coordination with utilities.

Smart meters are currently being installed throughout Australia, driven by a desire to achieve more efficient energy consumption (specifically peak-load management) requiring two-way communication. In 2007, the Council of Australian Governments mandated the deployment of smart meters in areas where the benefits outweigh the costs.[a]

Installing smart meters requires access to customer premises by a skilled electrician. This truck-roll could be coupled with the installation of an ONT to avoid the cost and disturbance of multiple visits. It may also be possible for the ONT and smart meter to collocate which could reduce overall costs. Moreover, in the same enclosure, power could be provided to the ONT directly out of a power outlet adjacent to the smart meter, which would reduce the need to enter the premises. However, there are five main issues that would need to be resolved for the NBN roll-out.

- Timing. The deployment of smart meters and the NBN FTTP network are on different schedules. Smart meters are quicker to install and COAG has mandated smart meter roll-outs where the benefits outweigh the costs. For example, Victoria has already commenced with their deployment of smart meters, which is scheduled to be finished by 2013[b].
- Demand for fibre. Although all distributors expressed interest in fibre as a communications platform, they are already trialling alternatives such as mesh radio and WiMAX[c]. These other

technologies are more than sufficient for the current bandwidth needs of smart meters.

- Acquisition of customers. Smart meters will be deployed to all customer premises in a certain area where benefits outweigh the costs, without customers requesting an upgrade. This is significantly different to the NBN where service providers will have the option to transfer customers to the fibre network. Therefore the deployment of the NBN and smart meters are not aligned well in terms of network cut-over timing.
- Location of ONT. It will be difficult to place the ONT and smart meter in adjacent positions. The positioning of the ONT at the premises will most likely be determined by the easiest path for the drop cable. It will be unlikely that the drop fibre will be easily aligned with the location of the electricity entry point, where the smart meter is located. Furthermore, an outdoor ONT is more expensive than an indoor ONT (~$200 more)[d]. This extra cost combined with the potential extra costs in deploying will likely outweigh the benefit of sharing an enclosure.
- International precedents. There has been no large-scale international FTTP deployment identified in which a network owner has successfully collaborated with electricity utilities during the deployment of smart meters on a large scale.

These hurdles may be overcome in specific situations. NBN Co should investigate collaborating with utilities during smart meter roll-out where commercially attractive to do so.

Fibre deployment may become cheaper if the deployment is coordinated with utilities' own capital works programs and costs are shared. Recently, many electricity utilities have embarked on major network upgrades as their assets are ageing and they strive to cope with increasing demand.[e] This combined with pressure to underground aerial cabling has led to increasing deployment of power cables underground.

Clearly to achieve successful collaboration, timing and deployment issues will need to be resolved. NBN Co and the utilities are typically on different schedules and this makes the resolution of such issues problematic. Moreover, it is typically much slower to deploy underground power cables, which may slow down the deployment of the NBN should the company choose to pursue this path for fibre deployment. Nevertheless, the size of potential cost savings is significant and justifies serious investigation of all possibilities for coordination.

The costs and speed of the aerial build will be influenced significantly by the commercial terms that NBN Co negotiates with utilities for infrastructure access. While access to pole infrastructure is mandated under access regulations, access is expected to be attained through private negotiations. Effective cooperation with utilities will clearly be important.

a. Council of Australian Governments 2007, *Council of Australian Governments' Meeting 13 April 2007*, viewed 8 December 2009 <http://www.coag.gov.au/coag_meeting_outcomes/2007-04-13/index.cfm>

b. Ibid

c. Interviews with Energy Australia

d. Industry interviews

e. Australian Energy Regulator 2009, *State of the Energy Market Report 2009*, Melbourne

Source: Implementation Study

Multi-dwelling Units

We assume that flats or offices are internally wired with fibre when they are passed to allow the customer to connect on demand. Internal wiring includes the lead-in to the building's main distribution frame from the drop point and the installation of the communications riser to each floor in the building. We have also included costs associated with surveying the building, designing the installation and consulting with strata corporations.

Customer premises installation

The installation of the ONT can vary based on various network design choices. We assume the most cost efficient method is employed and the ONTs are installed on the inside of the premises (Exhibit 4–21).

Exhibit 4–21. Location of the ONT

ONT location

It is assumed that the NBN will deploy ONTs on the inside of premises. Indoor ONTs offer significant cost savings over outdoor ONTs. Consequently, the majority of FTTP roll-outs internationally have involved indoor installation.

In addition, indoor placement improves customer experience and accelerates commoditisation of the ONT, thereby providing greater opportunities for future competition at the active layer.

Total cost of an indoor ONT and its installation are significantly lower compared to an outdoor ONT. There are three major cost components which differ between indoor and outdoor ONTs.

- The cost of the device and enclosure is approximately $200 more for an outdoor ONT[a] than an inside one. A strong, sealed, weatherproof enclosure with glands and seals is required for outdoor ONTs to protect them from the elements.
- Providing power to an outdoor ONT is much more complex than an indoor ONT, which plugs directly into a general purpose outlet (GPO). Most premises do not have a free GPO outside. Therefore an electrician would need to enter the premises to run the power cable between the ONT and the closest free power socket. This is a significant cost as it could take well over an hour of skilled labour to run electricity to the ONT.
- The connection between the ONT and CPE also becomes more complicated for an outdoor ONT. CPE can plug directly into an indoor ONT, but an outdoor ONT requires individual cables to be run through the wall for each port on the ONT. Therefore it is possible that four Cat 6 cables may have to be run through the wall for an outdoor ONT as opposed to one 'ruggedised' fibre cable for an indoor ONT, again increasing the installation time and cost.

It is estimated that the overall cost per premises of an outdoor ONT would be approximately $300 higher than an inside one.

Customer experience is typically better during the roll-out. An indoor ONT takes less time to place and less wiring is needed. It requires a customer to be at home during the installation, but an outdoor ONT typically requires internal access as well, so that electrical wiring can be done.

International experience shows most ONT faults can be rectified with remote testing, but outdoor ONTs do have an advantage for future maintenance as technicians can access the unit without entering the building. This advantage is not perceived to be significant as most faults are likely to be caused by CPE and connections within the premises rather than the ONT itself. These faults would require internal access to the building, regardless of location of the ONT.

Competition is more likely to be encouraged at the active layer by deploying indoor ONTs. There is a greater chance that indoor ONTs will be commoditised due to their simpler and cheaper form, making it easier for competitors to compete at an active layer.

Replacing indoor ONTs, which are physically similar to wireless routers today, will be a simple process for customers compared to replacing an outdoor ONT mounted to an external wall. Moreover, indoor ONTs are cheaper, making it easier for the customer to upgrade their ONT if they wish to customise or replace it.

FTTP networks are being deployed throughout the world, but very few deployments involve outdoor ONTs. There are strong reasons to believe that the placement of ONTs on the inside of premises is preferable.

a. Industry interviews

Source: Implementation Study

We assume the installation of a network interface device (NID) which is the termination point for the drop cable at the premises. The NID is a small, weatherproof enclosure, usually mounted on the exterior of the premises. The drop cable enters the NID at one end and a 'ruggedised', bendable cable is connected to the other end. The cable must be 'ruggedised' to protect the fibre when passing through the wall.

There is an option to either splice at the NID and wall socket or use pre-connectorised cable. Where it is easy to accurately measure the cable distance, pre-connectorised cables should be used to reduce installation times. This can be aided by the use of a 'library' of different cable lengths stored in the truck.

After the NID, the ruggedised cable enters the exterior wall of the premises and is run through the wall cavity until it reaches the back of a wall socket within the premises. The length of the cable run between the NID and the wall socket can differ greatly, based on their relative locations and on the structure of the building. Consequently, deploying this cable is typically a complicated and expensive step and may require a team of two.

The wall socket is then installed inside the premises, preferably close to an existing power outlet. A patch cable is used to directly connect the wall socket to the ONT, without any need for splicing. The ONT is then plugged into the existing power outlet in the same room.

The total fixed installation and materials cost (excluding lead-in installation) is estimated to be approximately $500 per premises. The Verizon experience suggests that this cost can be brought down over time with experience and the adoption of best practices.

Some premises will require rewiring or new CPE within the home. Exhibit 4–22 explains these migration costs, which the end user or the retail service provider would bear. We modelled a migration incentive of $300 per premises connected, which NBN Co would provide to the service provider to assist with migration and help drive take-up. This is modelled as an offset against the revenue as NBN Co receives from service providers. It is assumed that apart from the one-off migration payment, the service provider will fully absorb migration costs. The amount of equipment and level of service an individual end-user demands will ultimately determine the precise cost of new CPE or rewiring.

Exhibit 4–22. Migration costs

Migration costs
Migration costs are defined here as the additional network costs on the customer-side, beyond the indoor ONT. The two major components of migration costs are rewiring premises and provisioning and installing new customer-premises equipment (CPE). **Rewiring premises.** Most premises are currently wired with a twisted copper pair, which supports both Internet and voice services. This copper network within the premises will need to be connected to the ONT if customers wish to continue using existing devices, such as telephones and fax machines, which are currently connected to a their POTS outlet. This will generally require a copper connection from the ONT to the existing copper wiring. These two points may not be close together and could be as far away as 20m in some MDUs. After rewiring the premises would then be disconnected from Telstra's copper network and the signal to the existing devices would be carried over fibre. In addition to voice customers, broadband or IPTV subscribers may require premises rewiring to connect the ONT to CPE as the existing copper network cannot be used. For broadband subscribers, rewiring with Cat 6 cable is required if their existing PC or router is not located near the ONT. However, if customers are satisfied with wireless services, no rewiring is required as a wireless router can be plugged directly into an ONT. Likewise, the customer may request IPTV, which would require Cat 6 cable connected between the ONT and each set top box (STB) for each television. Wiring each CPE could range from 5 metres to over 20 metres for larger premises, which would take 0.5–2 hours for a skilled labourer.[a] **Provisioning and installation of CPE.** Voice, broadband and IPTV are the three main services likely to be provided over the NBN and each will require different types of CPE. However, if people have a combination of services, devices can be consolidated to a certain extent. For example, some home gateways can support both wireless Internet connectivity and IPTV. Voice customers have the ability to continue using existing handsets if the POTS port on their ONT is connected to the existing copper network within the premises. Also, VoIP handsets, which are becoming more common, can be plugged directly into the ONT.[b] Therefore no CPE should need to be replaced for voice subscribers. Broadband subscribers, however, will need a router to connect their ONT to a computer. Alternatively, a wireless router can also be plugged into the ONT to support several computers and WiFi-capable devices throughout the premises. Current prices for basic routers or wireless routers are approximately $100[c]. IPTV also requires distinct CPE, typically in the form of a stand alone STB for each television. Some existing STBs, including in-built STBs, may be capable of supporting IPTV. But in general, users will need a new STB which currently cost approximately $100[d].

a. Industry interviews

b. Pyramid Research 2009, APAC fixed communications demand

c. Based on CNET Australia reviews of various routers. CNET Australia 2010, *CNET,* viewed 1 February 2010, <http://www.cnet.com.au>

d. Based on a CNET Australia review of various set-top boxes. CNET Australia 2010, *CNET,* viewed 1 February 2010, http://www.cnet.com.au

Source: Implementation Study

4.3.3 USING DETAILED GEOSPATIAL MODELLING

Ensuring a high level of accuracy with granular geospatial modelling

Distances and density of premises are the primary drivers of civil works costs, which comprise 70 percent of overall costs. We have used detailed geospatial modelling to accurately measure these factors. The importance of geospatial modelling is summarised in Exhibit 4–23.

Defining and aggregating premises

Understanding the extent to which fibre can be economically deployed across Australia requires detailed, granular analysis. We use the Geocoded National Address File (G-NAF) which has spatial information (latitudes and longitudes) for every premises in Australia. We used, on the advice of DBCDE, premises which either Australia Post or the Australian Electoral Commission recognise as a current address. The approach we used to filter the G-NAF dataset is described in Exhibit 4–24.

Exhibit 4–23. Importance of geospatial monitoring

The importance of geospatial modelling

Geospatial modelling applies spatial analysis tools and techniques to spatial information, including the latitude and longitude of individual premises, the location of the road network, and the location of existing infrastructure especially Telstra exchanges.[a]

Geospatial modelling is required to avoid using radial distances, which in some cases are a good approximation, but do not accurately reflect the likely path a network would use. It is best illustrated with examples of the algorithms used in our modelling:

- **Clustering algorithms and implicit Voronoi.** These algorithms are used to group large numbers of objects together in a logical group to minimise overall distance. This has been used to group premises which are served by a street cabinet and to group Mesh Blocks which are served by an exchange.
- **Dijkstra algorithm.** This algorithm calculates the lowest cost to travel over a road network. This has been used to estimate the deployment of the feeder and distribution network, and to optimise reuse of the same route to reduce trenching costs wherever possible.
- **Travelling salesman.** This calculates the optimal sequence to visit a number of locations to minimise overall cost. This has been used to estimate the distance required to build a backhaul network featuring fully redundant rings.

The geospatial modelling is detailed and rigorous. We modelled every address and street in Australia, down to the level of counting the number of fibres that pass through each street.

a. We used commercially available datasets, including the Geocoded National Address File (G-NAFs) for the location of premises, StreetPro for the road network, Exchange Info for the Telstra Exchanges and existing exchange boundaries, and ABS Mesh Blocks.

Source: Implementation Study

Analysing 10.7 million premises requires some aggregation into logical groups. We do not use Exchange Service Areas (ESAs), which are the premises served by an existing copper exchange, because:

- The exchange area boundaries were drawn a long time ago, and in many areas population densities have changed; and
- We are conscious of the 'tyranny of averages'. There are many ESAs where the average density is too low to justify a fibre roll-out, but taking a more granular approach with smaller units of analysis reveals a town with sufficient density and scale to support a fibre roll-out, and outlying areas which will be served with an alternative technology.

We have used the Australian Bureau of Statistics (ABS) Mesh Blocks as our basic unit of analysis. The Mesh Blocks are based on the 2006 Census of Population and Housing, and group residential dwellings using street boundaries. Mesh Blocks, except for empty ones, contain relatively uniform numbers of premises and therefore help in understanding how population density varies across Australia. Mesh Blocks contain additional information including a categorisation by type of use (residential, commercial, agricultural, etc).

Mesh Blocks only contain residential dwellings, not business addresses. Therefore we used G-NAF addresses to locate premises, and map these to Mesh Blocks in order to group premises into granular units for analysis.

> *The ABS has developed Mesh Blocks as a new micro-level geographical unit for statistics. There are 314,369 spatial Mesh Blocks covering Australia with most residential Mesh Blocks containing approximately 30 to 60 dwellings. Mesh Blocks have been designed to be small enough to aggregate accurately to a wide range of spatial units and thus enable a ready comparison of statistics between geographical areas, and large enough to protect against accidental disclosure.*
>
> Australian Bureau of Statistics (2008)

Modelling a realistic fibre network

To estimate the distances involved in an FTTP deployment, the Implementation Study modelled a realistic, but theoretical network. Network design and the specific premises to be served with different technologies is a decision for NBN Co. Our modelling is for the purposes of cost estimation. NBN Co will no doubt make different decisions about its deployment as it plans its roll-out, and surveys street by street. Nonetheless, our modelling provides a strong platform for cost estimates and the business case.

Exhibit 4–24. Applying a filter to national address files to calculate total premises

Premises filtering

G-NAF is the authoritative Geocoded National Address File that combines address data contributed by a number of sources. According to the G-NAF product description supplied by the PSMA:

> *G-NAF uses existing and recognised address sources including the state and territory Government land records, as well as address data from Australia Post and the Australian Electoral Commission. Through a rigorous process involving textual address comparison, matching and geospatial validation, both national consistency and national coverage are achieved at levels not previously obtainable.*
>
> *G-NAF is an exercise in collaboration. The concept of a national index of addresses has been evolving since 1995. Some 15 significant organisations have and continue to contribute and support the initiative. The G-NAF data contributors include:*
>
> – *The mapping agencies and land registries of each of the Commonwealth, state and territory governments;*
>
> – *Australia Post; and*
>
> – *The Electoral Council of Australia and the Australian Electoral Commission.*

For many addresses, the 3 different sources are not completely aligned. PSMA provides a Reliability field for each record which indicates to what degree the sources are aligned. The Implementation Study has filtered the addresses by :

1. Removing jurisdiction only addresses (retaining AusPost and AEC records);
2. Removing retired addresses;
3. Removing alias addresses;
4. Removing parent records where there are three or more premises at a single location; and
5. Removing data error duplicates.

Based on the November 2009 G-NAF data, the filtering results in 10.7 million addresses

Source: PSMA Australia Limited; DBCDE; Implementation Study

Our modelling has passed through two iterations.

Determining the fibre footprint

An initial round of modelling was conducted to place exchanges, street cabinets, feeder and distribution. Two fibre footprints, covering 90 percent and 93 percent of premises respectively, were created using:

- The total road distance, premises density and the number of MDUs (which were calculated for every Mesh Block) and
- Deployed road distance, which we calculated for more than 20,000 Mesh Blocks (around 10 percent of non-empty Mesh Blocks).

Deployed road distances were estimated (as a ratio of total road distance controlling for premises density) and combined with the proportion of MDUs and the premises density to rank each Mesh Block into percentiles.

Calculating distances and the number of exchanges

Once the footprints were established, we clustered the Mesh Blocks within a fibre footprint to place exchanges subject to three rules:

- Fibre exchanges typically do not serve more than 30,000 premises. This is a conservative assumption we adopted, to ensure network integrity and to enable modelling of a home-run as well as a shared topology. Many international FTTP networks have used the new deployment as an opportunity to reduce the number of exchanges relative to a copper network, and NBN Co may wish to do so;
- The radial distance from OLT to ONT cannot exceed 10 km, based on industry conventions for GPON with a 1:32 split to guarantee against performance degradation;
- Where a fibre exchange can collocate with an existing copper exchange, this location is preferred.

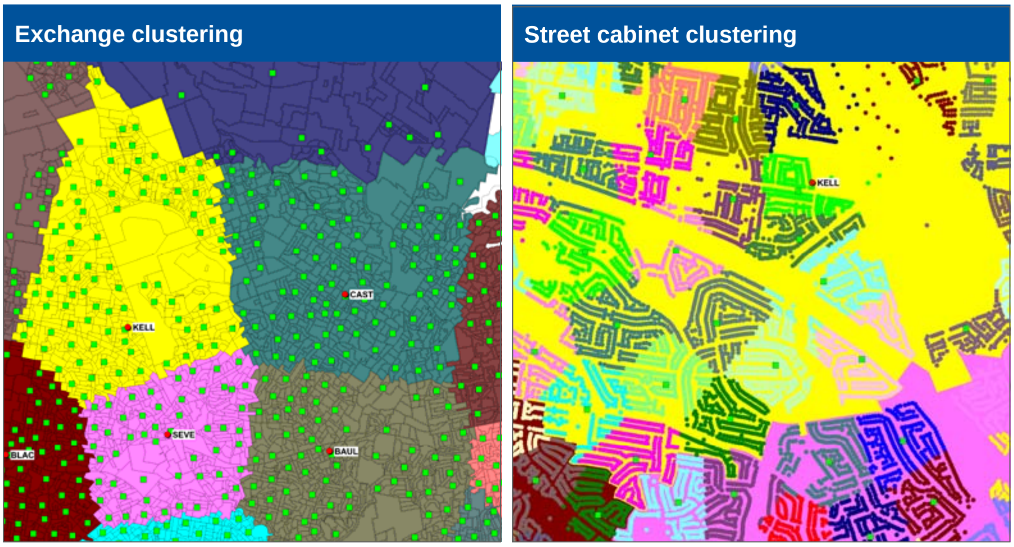
Once exchanges are created, premises are clustered around splitter cabinets to form cabinet zones with a maximum 250 premises per cabinet. Again, this is a conservative assumption as splitter cabinets are available in larger sizes which may reduce costs and facilitate unbundling.

The left hand side of Exhibit 4–25 shows the exchanges (red dots) and the bright colours show which Mesh Blocks are clustered to each exchange. The right hand side zooms in to show the street cabinets (green squares) and the individual premises (coloured dots) which cluster to each street cabinet.

Finally, we modelled the feeder network (from exchange to street cabinet), using a lowest cost algorithm and the distribution network (vertex to vertex) for every street and premises within each of the two fibre footprints.

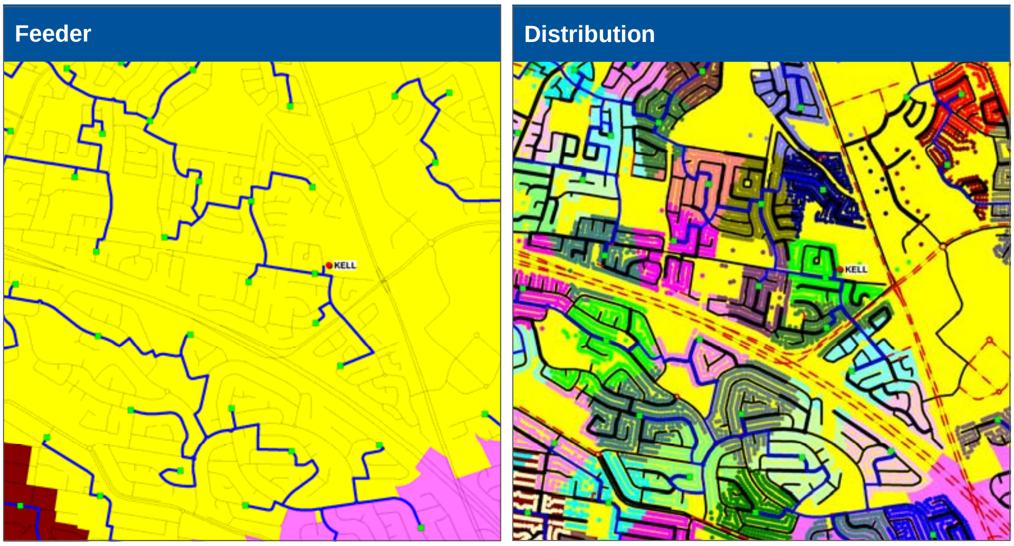
The left hand side of Exhibit 4–26 shows the feeder network, in blue, connecting the exchanges (red dots) to street cabinets (green dots), and shows the way the feeder network minimises total cost by sharing the same trenches where possible. The road network is represented by pale grey lines. The right hand side shows the distribution cable in black—the thinnest lines represent 1–12 distributions fibres; the medium lines represent 12–48 fibres and the thickest lines represent 48–312 fibres. Roads with red dashed lines do not have any distribution fibre.

Exhibit 4–25. Clustering premises to form cabinet zones



SOURCE: Implementation Study

Exhibit 4–26. Modelling the feeder and distribution network



SOURCE: Implementation Study

Combining sophisticated algorithms with practical overlays

Using Mesh Blocks overcomes the 'tyranny of averages', but some practical overlays are required to ensure the fibre footprint generated represents a realistic network design. The first potential issue is a 'Swiss cheese' network, where the road distance per premises for a Mesh Block is just above the cut-off used for the fibre footprint (e.g. it lies in the 94th percentile) but it is adjacent to Mesh Blocks which are attractive to serve. In this case, the cost to serve with fibre may actually be relatively low, especially if a Mesh Block has a relatively large geographic area, but most of the premises are adjacent to the fibre network boundary.

The second potential issue is the minimum scale required for a fibre exchange and the distance of that exchange to backhaul. Mesh Blocks can have a low road distance per premises (de-facto qualifying them for fibre) and be located far away from other premises that fall within the fibre footprint or from other exchanges for backhaul purposes. Both these facts can make the premises unsuitable for fibre coverage on the basis of cost to serve.

These potential issues have been addressed with the practical overlays described in Exhibit 4–27 below. It is important to highlight that while these overlays alter the fibre footprint, none affect more than 1.5 percent of premises.

Exhibit 4–27. Practical overlays applied to geospatial modelling

Possible issue	Overlay	Description
Swiss Cheese	Smoothing algorithm	A weighted average covered road distance is calculated for all Mesh Blocks. The weighted average is based on the average percentile of all adjacent Mesh Blocks. Any Mesh Block which previously would have fallen out of the fibre footprint, but would now fall within based on its weighted average is included in the fibre network.
	Hole filtering	Any Mesh Block not included in the initial fibre footprint, but wholly contained with a contiguous fibre footprint, is also included in the fibre network. These Mesh Blocks typically do not contain premises (e.g. parkland, cemeteries), but some have 1-2 premises (e.g. a caretaker's office).
Isolated Mesh Blocks	Crossing holes	If the network needs to cross an empty Mesh Block to connect premises to their exchange then this distance is included within the overall network.
Isolated exchanges	Shaving algorithm	Fibre exchanges that are not proximate to other fibre exchanges within the fibre footprint, so the cost of providing backhaul is absolutely prohibitive, are removed from the fibre footprint.

Source: Implementation Study

Clearly, the company has significant degrees of freedom to optimise its network relative to our modeling:

- Our modeling leaves approximately 100,000 premises within 100m of a fibre coverage zone and 200,000 premises within 500m. Often this is a result of Mesh Block boundaries being drawn down the middle of a street, leaving the 'last good street in town' outside the fibre footprint. In practice some of these will be included in the footprint, and potentially some premises within our footprint will be excluded for practical reasons or to strike a different balance between the cost of backhaul and the cost of the access network.
- NBN Co's network design could have fewer exchanges serving more premises per exchange and larger street cabinets serving more premises per cabinet, both of which have the potential to reduce overall costs.

4.4 Achieving take-up of services on fibre

The NBN will deliver a step-change improvement in fixed-line performance capability for households, businesses, and institutions. Understanding how quickly users respond to this improvement by adopting fibre services requires evaluation of four factors. We address these factors in turn:

4.4.1 Understanding the shift from fixed lines

4.4.2 Understanding demand for superfast fixed-line broadband services

4.4.3 Establishing the case for RSPs to migrate traffic to the NBN

4.4.4 Expecting fibre to emerge as the predominant fixed-line infrastructure.

Each of these subsections describe the elements of the Implementation Study's approach to modelling take-up of fibre services, a summary of which is provided at the end of this section in Exhibit 4–40. The approach to revenue modelling is described in Section 4.5.

4.4.1 UNDERSTANDING THE SHIFT FROM FIXED LINES

Although a ubiquitous part of the communications landscape over the 20th century, fixed-line markets are in decline. Customers worldwide are leaving their copper-enabled PSTN services in favour of mobile and VoIP services, and DSL take-up is not yet sufficient to maintain fixed-line penetration. However, this trend of fixed-line abandonment is not yet severe in Australia when compared to other developed countries. Fixed-voice penetration in Australia stood at 87 percent of households in 2009,[99] compared to US and European figures in the range of 50 to 60 percent.[100] From this high starting point, significant declines in fixed-line penetration are likely on the existing copper network, irrespective of a fibre overbuild.

The NBN will be Australia's future fixed-line network and will offer a step-change in performance relative to copper. In assessing the likely future demand for fixed-line products, it is helpful to examine the major drivers of fixed-line penetration and how demand dynamics will be altered by the NBN.

The Implementation Study believes that fixed-line demand for NBN services is likely to be strong and will underpin a revival in fixed-line demand across Australia. This review of the market is laid out in three parts:

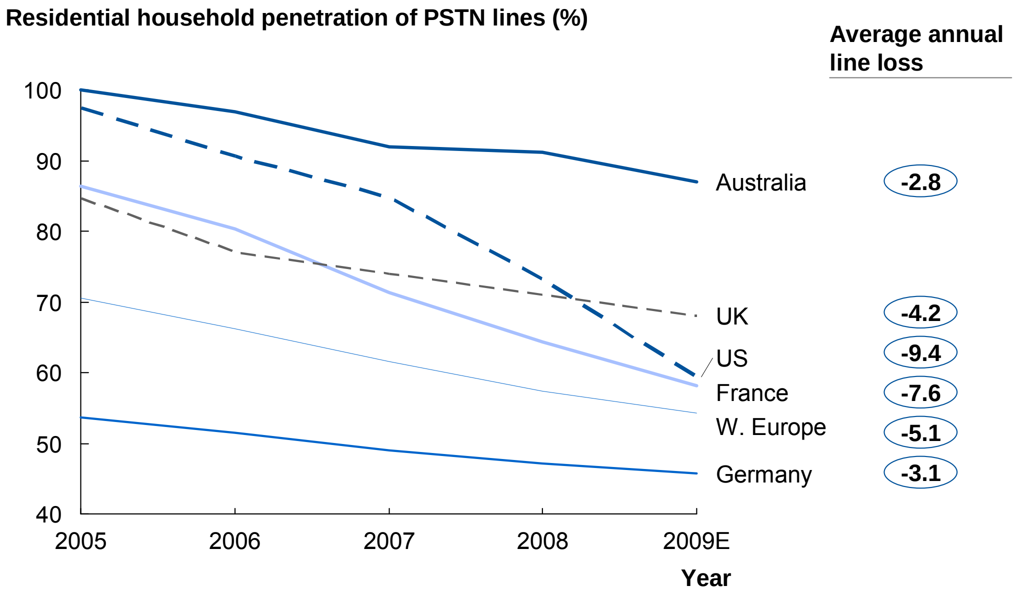
- Transition to a broadband-centric fixed-line market

99 Telsyte 2009, *Home Speed Home: Australian Consumer Digital Home Study;* Note that ACMA figures put this number as high as 90 percent based on Roy Morgan data (ACMA 2009, *Communications report 2008-9*)

100 Pyramid Research 2009, *Residential and business fixed forecasting database*

- Increasing role of mobile broadband
- Continued strength of fixed broadband over time

Exhibit 4–28. Fixed-voice line loss in major markets



SOURCE: ACMA; Pyramid Research; Telsyte Research; Implementation Study

Broadband replacing voice as anchor fixed-line service

The fixed-line relationship will soon be based primarily on broadband services, as fixed-voice services decline in relevance. Historically, voice has been the anchor product for the fixed-line. PSTN penetration stood above 90 percent at its peak, with Internet penetration growing from nothing to over 70 percent today. Broadband customers are still largely a subset of voice customers, but PSTN voice penetration is falling while broadband penetration continues to grow.

Global trends show the decreasing relevance of PSTN. Fixed-voice line loss averaged over 5 percent per year in Western European countries since 2005 and over 9 percent in the US market (Exhibit 4–28).[101] This has been driven largely by substitution to mobile as attacker brands capture share. This trend is now gathering pace in the Australian market, where fixed-voice penetration has declined an average of nearly 3 percent per year since 2005.[102]

101 Ibid

102 Ibid; ACMA 2009, *Communications report 2008-09;* ACMA 2008; *Communications infrastructure services and availability in Australia 2008*; ACMA 2007; *Communications infrastructure services and availability in Australia 2006-7*

There is reason to believe that an increasing number of Australians are poised to leave their fixed-voice lines:

- **Increasingly attractive mobile pricing.** Australians cite price as the most important reason they prefer their fixed line to a mobile phone,[103] with 37 percent saying they would consider replacing their fixed-line if mobile prices were lower.[104] Current mobile prices are declining, particularly as attacker brands (e.g. Vodafone, Virgin) gain share. The price of a mobile call has fallen over 10 percent per year on average since 2005.[105] Mobile calls are also becoming less expensive relative to fixed lines. The mobile price premium, on a per-minute basis, fell from 50 percent premium to approximately 5 percent between 2005 and 2007.[106] As mobile voice prices continue to decline, fixed-voice line loss is likely to accelerate.
- **Mobile 'network effect' and high fixed-to-mobile rates.** Fixed-to-mobile calling rates—increasingly important in a mobile world—are also high in Australia. Major carriers charge up to 80 cents per minute for a fixed-to-mobile call,[107] compared to a small flat fee for fixed-to-fixed calls.[108] As more calls are made to mobiles, customers will have an added incentive to leave their fixed-voice lines for less expensive mobile-to-mobile calling.
- **Widespread acceptance of VoIP as a substitute.** VoIP has a growing presence in Australia, particularly among SMEs. In 2009, an estimated 2.5 million Australians used VoIP at home, up from 1.8 million in 2008. Twenty percent of SMEs report using VoIP, up from 17 percent the year prior.[109] This is good news for fixed-broadband penetration—these services will likely be an important part of the fixed-line relationship and even more so as niche technologies move into the mainstream (e.g. video conferencing). However, as these services will increasingly run 'over the top' of fast broadband connections, rather than on a dedicated managed carrier network, they are hard for carriers to monetise.

Customers who have abandoned PSTN services are unlikely to re-subscribe to a PSTN service. Unlike broadband—where a fixed-line product may offer a noticeably different quality of service to mobile—mobile voice services are effective substitutes for fixed-voice lines. Only 20 percent of customers surveyed felt their fixed-voice lines offered a

103 ACMA, *Telecommunications today report*, vol. 5, *Consumer choice and preference in adopting services*, Canberra

104 Ibid

105 Merrill Lynch 2009, *Global wireless matrix*

106 ACMA 2008, *Fixed-mobile convergence and fixed-mobile substitution in Australia*, Canberra

107 Telstra 2010, *Home phones & plans*, viewed 1 February 2010, <http://www.telstra.com.au/homephone/>; Optus 2010, *Personal plans*, viewed 1 February 2010 <http://personal.optus.com.au/>

108 Ibid

109 ACMA 2009, *Communications report: 2008-09*

more reliable service or a better connection than their mobile phones.[110] Moreover, the services offered on fixed-voice lines are unlikely to evolve over time, creating limited opportunity to win back lost customers.

It is clear that broadband will be the core of a compelling fixed-line proposition in the future even as fixed-voice declines.

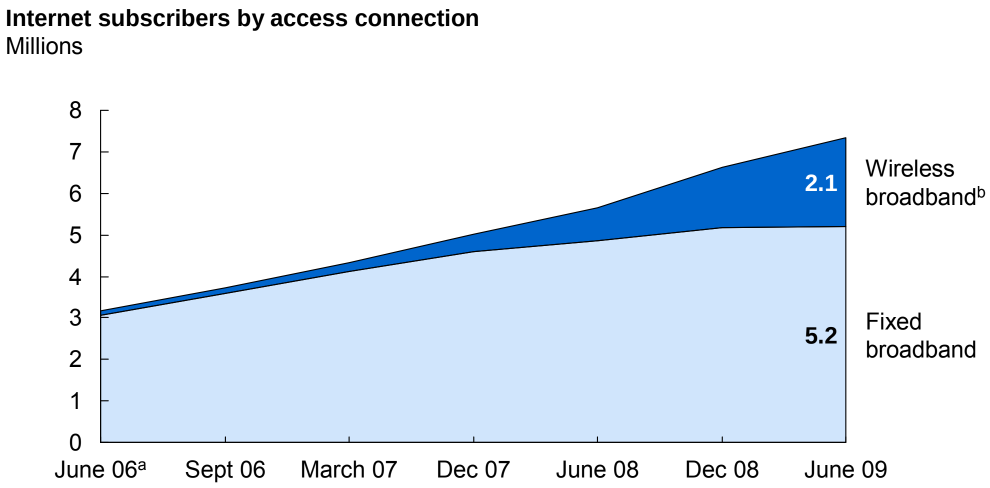
Increasing role of mobile broadband

Mobile broadband has grown dramatically over the past three years (Exhibit 4–29). The market added 664,000 mobile broadband subscribers in the six months to June 2009. Over this same period, the fixed broadband market grew by only 80,000 lines, leading to widespread concern over the future prospects for the fixed-line broadband market.[111]

It is likely that the market momentum and investment by carriers in advertising will result in continued strong mobile share of broadband growth in the short-term. However, this growth is not as threatening to the fixed-line market over the medium to long-term as headline statistics suggest.

The Implementation Study believes that the confluence of several unique and temporary factors has resulted in the rapid growth of wireless broadband that can be seen in

Exhibit 4–29. Growth in wireless broadband accounts over time



a. ABS data reported for all available periods
b. Wireless data includes both mobile broadband and fixed wireless, as ABS did not split data prior to 2009. In June 2009 fixed wireless accounted for 160,000 of the 2.1 million subscribers. Fixed broadband included 90,000 satellite subscribers
SOURCE: ABS

110 ACMA 2007, *Telecommunications today,* vol. 1, *Consumer attitudes to take-up and use*, Canberra
111 White, D 2010, ‘Mobile may challenge NBN’, *Australian Financial Review*, 11 January, p. 48

Exhibit 4–29. The drivers of this growth are likely to weaken over the medium to long term as fibre connectivity becomes ubiquitous.

Coexistence of mobile and fixed broadband

Rather than substituting for fixed-line broadband connections, as has been widely assumed have assumed, most mobile broadband connections are for users who also have a fixed-line connection at home. This suggests that mobile broadband is a complement rather than just a substitute for fixed broadband.

Moreover, research in multiple markets consistently suggests that between 70 and 90 percent of mobile subscriptions are not substitutive. Less than a third of Australian broadband households today are mobile only, according to Telsyte research.[112] That number is estimated at between 20[113] and 25[114] percent in the US, 24 percent in the UK,[115] and 9 percent in France.[116]

This suggests that less than 200,000 of the nearly 664,000 mobile broadband accounts added in the six months to June 2009 were added by mobile-only users. The 470,000 remaining were complementary—purchased not by people replacing their fixed broadband accounts but supplementing them.

> **Highlight.** Mobile broadband growth does not directly substitute fixed-line services; they are complementary in many cases, and address different user bases.

Weakening drivers of mobile broadband growth

These effects together mean that mobile and fixed broadband services can coexist. There is good reason to believe that mobile broadband growth will slow, as recent growth has been supported by a number of temporary factors (Exhibit 4–30):

112 Telsyte 2009, *Home speed home: Australian consumer digital home study*

113 McKinsey & Company 2009, *North American Wireless Panel Survey*; the Wireless Panel is a proprietary McKinsey survey of mobile phone subscribers conducted annually since 2003. It includes more than 30,000 responses from all North American wireless carriers from postpaid and prepaid customer segments and from business and consumer users

114 Centers for Disease Control 2009, *Wireless substitution: Early release of estimates from the National Health Interview Survey, January – June 2009*, report prepared by S Blumbert and J Luke, National Center for Health Statistics, Hyattsville, MD

115 McKinsey & Company 2008, *European Telecom Consumer Insights Survey;* European equivalent of the North American Wireless Panel, surveying over 30,000 European mobile phone users

116 Ibid

Exhibit 4–30. Drivers of mobile growth that are likely to weaken

Current growth drivers	Factors that suggest a future slowdown
Recent drops in mobile broadband pricing	Mobile broadband pricing fell significantly in the past year.[a] For the first time, mobile broadband is competitive with comparable DSL offers on price.[a] For example, Telstra recently dropped the price on its 3 GB per month bundled mobile broadband plan by 40 percent, to $30—less than many entry-level DSL plans.[b] Growth in mobile broadband subscriptions corresponds directly with these price drops. Telstra's first major mobile broadband price cut in November 2007 coincided with a doubling in net adds, from under 100,000 in the period prior to the cut to more than 200,000 in the period following. Telstra did not sustain that growth during a period of stable pricing: net adds dropped to under 150,000 in second-half 2008—a period in which it offered no major price cuts. When Telstra cut prices again in first-half 2009, net adds spiked, to just under 250,000[c]. As the market matures, continuing dramatic price reductions are unlikely and mobile broadband growth rates will likely moderate.
Poor fixed broadband offers	Australian fixed-line broadband services are slow, expensive and usage-constrained when compared with international peers. Among OECD countries, services are third slowest, prices seventh highest and usage 'caps' are the norm.[d] Usage caps are standard for fixed-line connections in only four other OECD countries. The quality of fixed-line broadband offers is set to improve dramatically once fibre is introduced. The NBN roll-out, combined with increased competition amongst service providers, will deliver significantly better fixed broadband services. Mobile broadband is likely to look much less attractive compared to fixed-broadband as applications requiring high-bandwidth became more widely used.
Strong adoption of remote working in business market	International data suggests that a large percentage of mobile broadband subscriptions are held by business customers, for whom connectivity is highly valuable and mobility commands a premium.[e] As the business market reaches saturation, overall growth will slow.

a. For example, Internode's introductory $30 per month 5 GB bundled plan (Whirlpool 2010, *Internode*, viewed 30 January 2010, <http://bc.whirlpool.net.au/bc/isp-9/internode.htm>)

b. Telstra 2010, *Wireless Broadband: Latest Offer*, viewed 15 February 2010, <http://www.bigpond.com/Internet/plans/wireless/latest-offer/?cid=bph-access-3>

c. Goldman Sachs JB Were 2009, *Telecommunications Services*

d. OECD 2010, *Broadband Portal,* viewed 20 January 2010, <http://www.oecd.org/sti/ict/broadband>

e. IDC 2007, Australia wireless and mobile broadband 2006–2010 Forecast and Analysis: Two Princes

Source: Implementation Study

Taken together, these factors suggest that mobile growth should moderate once fibre services become ubiquitous.

Continued strength of fixed broadband over time

Fixed broadband is likely to enjoy significant market share in the long-term. The major factor supporting fixed broadband will be an increasing performance advantage over wireless broadband platforms which will only widen as bandwidth hungry applications emerge.

There are several reasons why this advantage will be significant in the future:

- **Fibre offers higher performance through intrinsic physical properties.** Fibre offers end users an uncontended physical platform for the transmission of bandwidth that is only constrained by the power of the active electronics employed. Wireless services are contended and users' rates of speed are affected by the number of other users competing for available bandwidth. Overall wireless capacity is constrained by available spectrum.
- **Mobile will have trouble meeting increased demand.** AT&T's difficulty in delivering mobile data over its 3G network is instructive. AT&T's mobile network has struggled to meet rapidly increasing demand for data and has led to the company encouraging customers to switch their iPhones to WiFi wherever possible (Exhibit 4–31).[118] Increasingly fixed-line Internet is becoming an enabler of wireless data.

> *At the end of the day from a physics perspective, you're just not going to be able to beat a fixed-line connection when you're comparing it to fibre-to-the-home solutions. … The bandwidth requirements are going to exceed that of what mobile is going to be able to deliver.*
>
> Chris Chapman, ACMA Chairman[117]

- **Users will require fixed-line connections to support emerging services.** Proposed products such as 3D HDTV require sustained data rates of up to 60 Mbps. While next-generation wireless technologies such as LTE are theoretically capable of delivering peak speeds in this range to some subscribers, they cannot deliver these speeds during busy hours or over sustained periods. Therefore very high bandwidth applications will not work on wireless products. Further, LTE will likely continue to face serious contention issues, although it represents a significant improvement over today's 3G HSPA technologies.

117 Ramli, D 2010, 'IDC, ACMA: Wireless broadband won't hurt NBN', *ARN*, 13 January, viewed 30 January 2010, <http://www.arnnet.com.au/article/332325/idc_acma_wireless_broadband_won_t_hurt_nbn/>

118 Wortham, J 2009, 'AT&T to Urge Customers to Use Less Wireless Data', *New York Times,* 9 December, p. B6

Exhibit 4–31. AT&T's challenge in meeting increased demand for mobile data

Case study: AT&T mobile network challenge	
New devices driving increased data usage	■ In the second quarter of 2009 nearly 60 percent of AT&T's wireless subscribers bought an integrated device ■ Wireless packet data over their network has increased more than 18 times in the last two and a half years driven by customers taking unlimited data packages.[a]
Customer dissatisfaction due to poor network performance	■ The result is dropped calls, spotty service, delayed text and voice messages and glacial download speeds as AT&T's cellular network has strained to meet the demand[b] ■ Customers are beginning to express dissatisfaction over dropped calls and the inability to connect to the 3G network[c]
AT&T encouraging use of Wi-Fi networks	■ AT&T encourages users to switch iPhones to Wi-Fi networks wherever possible, signing deals with retailers (e.g. McDonalds) for free access ■ Significant amounts of mobile data are being transitioned to fixed-line networks with traffic backhauled this way rising from 8 percent to 24 percent of total traffic in the year to November (2009) [d]

a. AT&T CTO John Donovan, quoted in Reardon, M 2009, 'AT&T's CTO defends wireless network', *CNET*, 8 October, viewed 15 February 2010 <http://reviews.cnet.com/8301-12261_7-10371298-10356022.html>

b. Wortham 2009, 'Customers angered as iPhones overload AT&T', *New York Times,* 2 September, p. B1

c. Reardon 2009, 'Is the iPhone hurting AT&T's brand?', *CNET,* 2 October, viewed 15 February 2010, <http://news.cnet.com/8301-30686_3-10365952-266.html>

d. Burrows 2009, 'AT&T mulls plans to deal with iPhone data demand', *BusinessWeek*, 21 December

Source: Implementation Study

- **For comparable prices, mobile operators are unlikely to deliver competitive products with current network constructs.** The recent pattern of providing mobile broadband to a greater number of customers at increasingly lower prices has been driven by temporary forces which are likely unsustainable going forward. Excess capacity in recently expanded networks (e.g. Telstra's GigE investments to 85 percent of base stations) has allowed Telstra and Optus to offer highly competitive pricing over expanded capacity.[119] Similar excess capacity among major telecommunications provider in Europe (e.g. Telekom Austria) led to comparable price cuts and corresponding high take-up of mobile broadband.[120] This will likely not be possible in the future as adding excess capacity will be difficult and expensive as the demands for mobile capacity per subscriber continues to increase. LTE will not solve this problem, as investment needs are similar to those of current mobile solutions. The current attractive pricing structures are unlikely to

[119] Goldman Sachs JB Were 2009, *Telecommunication services*

[120] J.P. Morgan 2008, *The power of mobile broadband;* Note that data are for the European market, and based on the expected cost of future investment, not historical capex

be able to move much lower while sustaining the continued investment that is required to satisfy user demands.

There is potential for the NBN to enable improved wireless speeds as mobile providers install micro or picocells. New retail offers may lead customers to use their FTTP service as 'household backhaul' when in the home—as AT&T encourages iPhone users to do today. Mobile operators are also likely to NBN backhaul services from the NBN to increase their cell density. Although these outcomes would improve the performance of mobile broadband, they increase usage of the network and revenue, respectively, for NBN Co.

4.4.2 UNDERSTANDING DEMAND FOR SUPERFAST FIXED-LINE BROADBAND SERVICES

As explained above, demand for fixed-line services is expected to remain strong with mobile services being complementary rather than substituting for fixed-line demand over time. A key question is then how fast mass-market consumers will shift their fixed services across to fibre from their existing copper or HFC based services. Predicting this is difficult: take-up rates of previous Internet technologies have traditionally been hard to estimate prospectively and there are no domestic examples of widespread fibre deployments from which to learn.

There is no single method to predict how end-user take-up of fibre services will progress in Australia—the best method is to triangulate from different sets of observations. At the same time, care must be taken in understanding the applicability of each of these given the array of unseen factors that influence take-up. This section will look at three sets of observations: historical rates of technology adoption in Australia, international fibre roll-outs and market research.

Using analogies from the adoption of other technology platforms in Australia

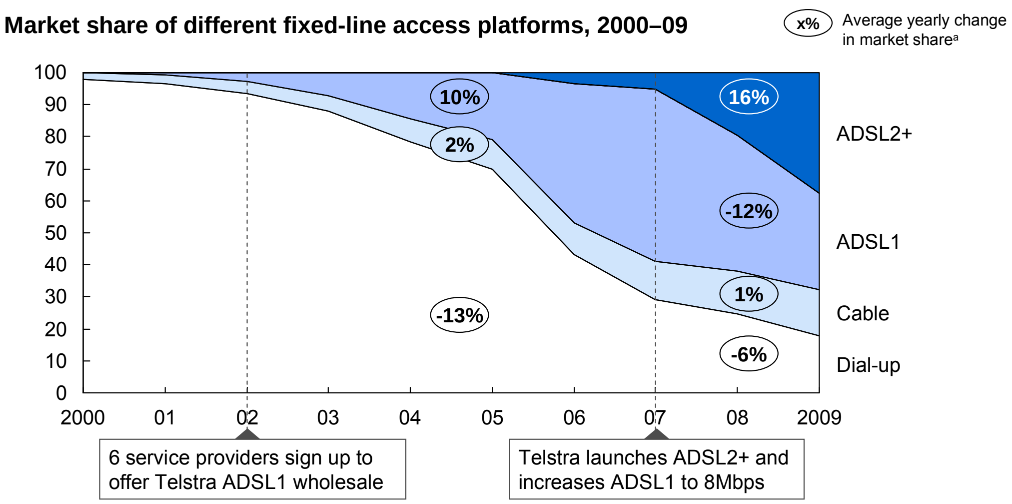
Previous transitions between technologies demonstrate that, with the right incentives, rates of take-up can be very high. For example, in 2005 2G phones were 96 percent of the total mobile phone market, while 3G phones comprised 4 percent. Since then, the market share of 3G phones has increased at 13 percent per annum on average, reaching a market share of 57 percent in 2009.[121] This has been heavily driven by the improved value proposition of 3G phones to end users and the incentive of mobile operators to move users to higher revenue 3G products.

[121] World Cellular Information Service 2010, *Annual total subscriptions Jan 1995 to Jan 2010*

Another recent technology transition in Australia is the migration of broadband customers from 'off-net' to 'on-net'. In this transition, retail service providers moved customers from resale products using Telstra DSLAM to services using their own DSLAM infrastructure. Retailers were incentivised to migrate customers to capture greater retail margins for these products. As a result, migration has been fast. Optus, for example, moved approximately 26 percent of its 'off-net' customers per annum to 'on-net'.[122] Prior to its acquisition of WestNet, iiNet transferred over 15 percent of its 'off-net' customers per year to 'on-net'.[123] Like migration to fibre, the 'off-net' to 'on-net' transition involved choices by retailers. However, unlike fibre, there was relatively limited customer interaction in the move to 'on-net'.

A more directly comparable case to the roll-out of fibre is the adoption of broadband in Australia (Exhibit 4–32). Market share losses for dial-up averaged 13 percent per annum between 2002 and 2007, while the market share increase for ADSL1 was 10 percent per annum over the same period, recently surpassed by the market share increase for ADSL2+ of 16 percent per annum between 2007 and 2009.

Exhibit 4–32. Transitions between fixed-line Internet technologies in Australia



a. Yearly market share calculated as subscribers for specific platform divided by total market subscribers; Yearly change in market share calculated as market share minus previous yearly market share; Calculations are done for years 2002–07, and 2007–09

SOURCE: ABS 2009, *Internet Activity, Australia, June 2009;* cat. no. 8153.0; Screen Digest 2009, *Australia: Broadband Connections by Technology (Annual and Forecast)*; BuddeComm 2009, *Australia – Broadband – ADSL2+ Providers*, ZDNet 2002, 'Telstra downplays broadband demand', *ZDNet,* 25 November; Telstra, *Six Customers Sign Up To Wholesale ADSL Offering,* media release, Sydney, 6 December 2001; Telstra, *BigPond marks 10th Anniversary with launch of national High Speed Broadband*, media release,10 November 2006

122 Screen Digest 2010, *Internet Service Providers (ISPs): quarterly & annual subscribers*

123 Ibid

Learning about take-up from overseas fibre deployments

Many other countries are currently rolling out fibre to meet the growing demands for speed and content (Exhibit 4–33). A good way to compare take-up across markets is to measure new connections as a percentage of homes passed. Since many countries are still only part way through their fibre deployments, only a small percentage of a country's population may be able to connect to fibre at any given time. Overall connections to fibre will therefore under-represent actual take-up and should be read very carefully in making comparisons across markets at different stages of roll-out.

The nine countries for which we present data are at varying stages of roll-out. As would be expected, penetration (the percentage of homes activated as a percentage of those passed) varies significantly. The take-up rate of premises connecting to the network (Exhibit 4–34) shows a significant range across countries. Values range from 2 percent per annum in Italy to 28 percent per annum in Norway. Most countries experience growth between 6 and 12 percent per annum. These countries can be divided into two broad groups. Japan, South Korea and the United States which represent well established, major roll-outs with more than 10 million homes passed. The others (Italy, France, Denmark, Sweden, the Netherlands and Norway) are less well advanced with fewer overall premises passed and are therefore less reliable for forecasting likely take-up in Australia.

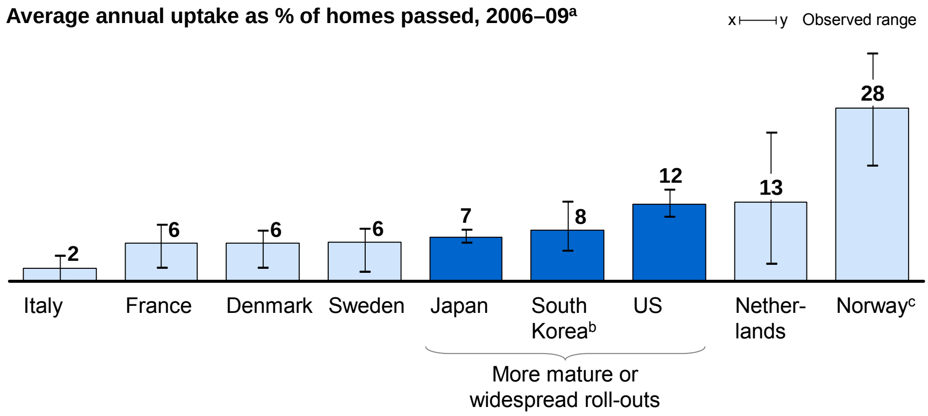
Exhibit 4–33. Fibre roll-outs in selected countries, 2009

Country	Type	Homes activated Millions	Homes passed Millions	Penetration % homes passed	Homes passed % total homes	Penetration % all homes
Japan	FTTH	15.0s	46.8	32	93	30
South Korea	FTTB/N	7.3	~18.0	39	92	36
US	FTTH	4.4	15.2	29	15	4
Sweden	FTTH	0.4	1.0	43	23	10
Italy	FTTB	0.3	2.2	15	10	2
Netherlands	FTTH	0.2	0.8	28	8	2
Norway	FTTH	0.2	0.3	68	13	9
France	FTTH	0.2	~5.5	4	18	1
Denmark	FTTH	0.1	0.7	15	20	3

Note: All figures are for June 2009, except Japan and US. Japan homes passed figure is from September 2008 (most recent available). Other Japan and US figures are from March 2009

Source: Japanese Ministry of Internal Affairs and Communications, IDATE, RVA LLC, Analysys Mason

Exhibit 4–34. Recent average annual fibre take-up rates in other countries



a. Calculated as incremental new activations for the year, divided by average cumulative number of homes passed for the year. For Italy, France, Denmark, Sweden, the Netherlands and Norway, numbers are based on Australian financial years. Numbers for FY09 for these countries are extrapolated by doubling first half numbers for homes activated and homes passed
b. Average incremental uptake as a percent of household sites (a conservative estimate) because homes passed data not available
c. Norway data from 2007 only once >100,000 homes passed

SOURCE: IDATE *"FTTH European Panorama"* December 2008; RVA LLC *"Fibre to the Home: North American Market Update for the FTTH Council"* April 2009; Japanese Ministry of Internal Affairs and Communications *"Japan Monthly Statistics: Information and Communication Service Subscribers and Contracts"*; Analysys Mason *"Fixed broadband: connections and penetration"* October 2009

The less widespread roll-outs show considerable variability. Norway has had a high take-up rate because of a very selective roll-out where fibre is only built to communities where take-up is guaranteed to be high.[124] By contrast, Italy has had low take-up due in part to legal issues over churning customers between Fastweb (an attacker retail service provider which led fibre deployment in Italy) and the incumbent Telecom Italia.[125] France's take-up is diluted by a rapid build-out of nearly 4.5 million premises between June 2007 and December 2008.[126]

The more well established or widespread roll-outs show a more consistent picture. Japan, South Korea and the US had average annual take-up rates of 7–12 percent of homes passed over the last four years. In the United States, fibre penetration, as a percent of homes passed, increased from 16 percent in 2006 to 29 percent in 2009. This was despite competition from cable and price premiums for fibre compared to cable and DSL. In Japan and South Korea, fibre is now available to more than 85 percent of premises and penetration of fibre has grown at a consistent rate over the past five years.

There are three important lessons from these widespread roll-outs for the Australian context:

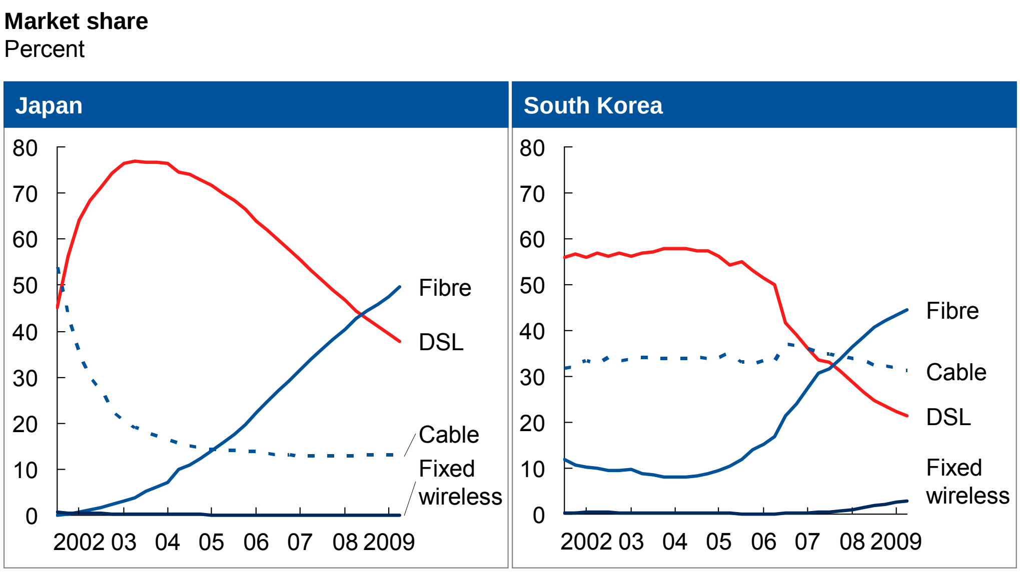
124 Anderson, N 2009, 'Norwegian ISP: dig your own fiber trench, save $400', *Ars Technica*, 11 May, viewed 8 December 2009, <http://arstechnica.com/tech-policy/news/2009/05/norwegian-isp-dig-your-own-fiber-trench-save-400.ars>

125 Reuters 2008, 'T.Italia, Fastweb agree to settle disputes', *Reuters*, 21 June, viewed 13 December 2009,<http://www.reuters.com/article/idUSL214039720080621>

126 iDATE 2009, 'FTTH European Panorama', presentation to the FTTH Council Europe Conference, Copenhagen, 11 February

- **Fibre can displace DSL.** Japan and South Korea have both shown that fibre can take significant share off DSL (Exhibit 4-35). Fibre penetration has reached between 30 and 40 percent of premises passed and now accounts for almost 50 percent of the broadband market in both countries. Fibre has displaced DSL as the most popular broadband access platform and its number of users is rising;
- **Fibre take-up has not yet reached a plateau.** Despite moderately high levels of penetration in countries like Japan and South Korea, fibre take-up rates have been fairly consistent in recent years and overall market share is continuing its upward trajectory in both countries;
- **Cable can maintain share.** In some countries, cable has managed to hold share against fibre (Exhibit 4–35). In these countries, incumbents deployed fibre to counter the threat of triple-play services on cable. Many cable operators have since responded by upgrading their networks to a new standard (DOCSIS 3.0) that can deliver higher broadband speeds with a relatively small capital outlay. In Australia, both Telstra and Optus have announced upgrades to their cable networks to DOCSIS 3.0, with Telstra's cable users in Melbourne being the first to be offered higher speeds. It is reasonable to assume, then, that in the absence of any agreements with current providers, the main source of fixed-line competition for fibre will be cable networks.

Exhibit 4–35. HFC, DSL and fibre broadband market shares in Japan and South Korea



SOURCE: Analysys Mason 2009, *Fixed broadband: connections and penetration*

Exhibit 4–36. Comparison of Australian NBN roll-out with other geographies

Network	Non-incum-bent led	Open access	Wholesale-only	Selective roll-out	Governme-nt support	Lack of strong cable/ VDSL competition[a]
NBN	✓	✓	✓	✗	✓	✓
Japan	✗	✓	✗	✗	✓	✗
South Korea	✗	✓	✗	✗	✓	✗
Norway	✓	✗	✗	✓	✗	✗
Sweden	✓	✓	✓	✓	✓	✓
Netherlands	✗	✓	✗	✓	✓	✗
US (Verizon)	✗	✗	✗	✓	✗	✗
Denmark	✗	✓	✗	✗	✗	✗
Italy (Fastweb)	✗	✗	✗	✓	✗	✓
France	✓	✗	✗	✓	✗	✗

Other factors that will influence relative uptake rates

- Relative prices
- Enabling of competition in uncontested exchanges
- Degree of backhaul constraints
- Competitive-ness of wireless offering

a. In Australia, cable covers <25% of premises and is not presently fully DOCSIS 3.0 capable

SOURCE: IDATE 2008, *FTTH European Panorama: Detailed FTTx Projects*; Verizon 2009, *FiOS website*; OECD 2009, *Broadband Portal*; Japanese Ministry of Internal Affairs and Communications 2008, *ICT Policy in Japan*; IDATE 2009, *FTTx Watch*; National IT and Telecom Agency 2009, *FTTH the situation in Denmark from a regulatory perspective*; Fastweb 2009, 'Fastweb FTTH: A 10-years success story', market presentation

Projected demand for fibre services in Australia can be informed by international comparisons. However, Australia's starting point and context are different in important ways (Exhibit 4–36).

In reviewing these differences, there are several characteristics of the Australian situation which will favour rapid take-up:

- **Lack of high-speed competition in Australia**. In most other countries, fibre has been rolled out to compete with cable operators who own networks spanning a larger proportion of the population. In Australia, only about 25 percent of premises have access to cable infrastructure and the speeds that will be available on fibre are a step-change from ADSL speeds. Furthermore, approximately 40 percent of premises are in non-competitive exchange areas where there is no DSLAM infrastructure owned by a party other than Telstra.
- **Wholesale-only, open-access rather than built by the incumbent**. Incumbent-led programs encounter conflicting incentives. Incumbents incur capital costs to build a fibre network and connect customers from which they hope to benefit from new customers added to the network and from higher ARPUs as well as reduced attrition of their existing customer base and operating cost savings from transitioning existing customers off expensive legacy networks to fibre. In practice it is difficult to realise the benefits from all of these objectives simultaneously. This typically leads incumbents to introduce fibre as an initial premium product to their highest value customers and to manage the transition of lower value customers more slowly.

The exception is in markets like the US where cable operators have competed aggressively by offering integrated triple-play offers. Such competition accelerates the rate at which customers churn off legacy networks and increases the incentive to pre-emptively transfer customers to fibre. With the NBN as a wholesale-only and open-access network, carriers will compete aggressively to win customers on fibre.

- **Priced for affordability and take-up, not as a premium product.** NBN Co should have an obligation to price for affordability and take-up in the near term. The lack of consumer willingness to pay premiums for higher speeds before the widespread emergence of applications to take advantage of this capacity has been correctly identified as a concern by analysts and stakeholders. On the NBN, wholesale prices should be set so that consumers can be offered superior speeds at comparable prices to current plans and this should facilitate the development of the aforementioned applications ecosystem.
- **The ability of NBN Co to offer financial incentives to retailers.** Incentives, if offered by NBN Co, will help drive take-up. Subject to regulatory restrictions, these could take a number of forms—e.g. introductory offers or term discounts—and are discussed later in this section.
- **Further evolution of services and content.** As bandwidth-hungry content and applications become more prevalent every year, it makes the proposition of superfast broadband more compelling to end users. This suggests that the NBN can expect stronger fundamental consumer demand than earlier roll-outs in other markets many of which faced a less bandwidth-hungry set of end users.
- **Community support and awareness.** NBN will be perceived by Australians as a large-scale, nation-building program. Its high profile and the pride associated with this build are not present to the same degree in many other countries. This may help with awareness and take-up in early years.

The main disadvantage NBN will face compared to many other countries is the ubiquity of roll-out. NBN is committed to delivering broadband to all Australian premises, a constraint that does not allow a selective, commercially-targeted roll-out like the one in Norway.

There are also several execution risks which may affect fibre take-up. Smooth migration and effective marketing are critical to the success of fibre. Take-up will also depend on having a desirable product, which requires users recognising the value of higher speeds. This will depend on the availability of quality video content and other bandwidth hungry applications. With the major pay TV operator half-owned by Telstra, a lack of competing video content over fibre is a particular risk for NBN take-up. Effective management of download caps will also be critical to consumers’ perception of value.

Competition with other fixed-line technologies like VDSL may also affect NBN take-up. Currently, TransACT offers VDSL in medium-density areas in Canberra. It is possible that other Internet service providers could invest in the infrastructure required to roll out similar services in other parts of the country. Uniform pricing for NBN Co may give these Internet service providers the opportunity to do so.

> **Highlight.** Observations of fibre take-up rates in other countries, as well as comparisons with the adoption of new technologies in Australia, suggest that take-up rates in the range of approximately 6-12 percent of homes passed per annum can be achieved and sustained.

Deriving insights from market research

To enable applications like streaming video, consumers will require higher download speeds. The speeds required for these services to operate effectively are at the limits of what ADSL technologies can currently deliver. Coupled with the fact (discussed in Section 3.1) that speed deteriorates rapidly with distance from the exchange for ADSL, it is clear that current technology is inadequate in meeting projected levels of demand for streaming video.

Market research shows that most Australians value access to a superfast broadband service. A recent Telsyte study[127] reports that approximately 80 percent of Australians are willing to pay more for a superfast broadband service. The study notes that Government services and high-definition video-on-demand are the primary reasons for this interest.

While there are potential pitfalls in relying on today's consumer preferences expressed through market research, there can be little doubt that consumers value a physical platform that is future proof and facilitative of both existing and new multi-media services. Market research confirms the overall conclusion of the Implementation Study that there is strong demand for superfast broadband services which will increase as an applications ecosystem emerges to take advantage of the high available bandwidth per user.

4.4.3 ESTABLISHING THE CASE FOR RSPS TO MIGRATE TRAFFIC TO THE NBN

As a wholesale-only company, NBN Co will have no direct relationships with end users—retailers will act as intermediaries, purchasing products from the NBN and selling them directly to end users. Therefore, while end-user demand will be essential in creating a pull for fibre, take-up will also depend on retailers seeing an economic reason to push fibre products. This section looks at how NBN Co can effectively incentivise retailers to move to fibre.

127 Telsyte 2009, *Home speed home: Australian consumer digital home study*

Economic rationale for retailers

In choosing an access platform with which to serve customers, retailers will look to maximise profitability. Five factors will influence a retailer's decision to migrate customers. The importance of each factor for retailers will differ between fibre and copper.

- **Average revenue per user.** It is expected that fibre based services will command a price premium over DSL based on perceived value to users. In Japan, the United States and the Netherlands, fibre has managed to maintain a consistently higher price than DSL. Furthermore, it is reasonable to expect that the emergence of a newer, faster technology will lead to price declines on services offered over legacy platforms—reducing margins for existing providers using ULL.
- **Wholesale access price.** Obviously, retailers will compare copper and fibre wholesale costs. The cost of Telstra's ULL and wholesale offers will become critical inputs into any decision, although there are uncertainties around those prices. The ACCC may not decide to raise prices on ULL, although price rises are possible if fixed network costs were to be spread over fewer users. Equally, Telstra may choose to price under the regulated price cap for ULL services. Despite the uncertainties around the relevant copper prices, it is likely that fibre will have a higher wholesale access price compared to the ULL price on copper.
- **Retailer cost to serve.** These costs may include billing, customer service and marketing. Together with the first two factors, this determines the margin for a retail product. A fibre offer will require lower investment by a retailer in active equipment and may incur lower backhaul charges (if the retailer is using NBN's transit backhaul) and exchange access fees compared to DSL. It is reasonable to expect that NBN Co services will reduce retailers' physical costs to serve.
- **Churn.** With the introduction of a new technology, the churn rate on copper should increase to take into account the additional churn of customers switching to fibre. The additional churn decreases the lifetime value of a customer on copper and increases the relative value of a customer on fibre.[128]
- **Set-up or acquisition costs.** The retailer may incur costs of changes to internal wiring at a customer's house. This is likely to be a significant upfront capital expenditure which may be offset by migration payments from the NBN Co. Leaving the customer on the legacy network incurs zero costs for the retailer.

NBN Co will be responsible for setting wholesale access prices for its products within the policy and regulatory framework specified by Government. For the purposes of modelling, the Implementation Study has calculated that many retailers will have a

128 Gupta, S. et al. 2006, 'Modelling Customer Lifetime Value', *Journal of Service Research*, vol. 9, no. 2, pp. 139-155

positive business case for using fibre at a wholesale price of approximately $30-35 per month.

We illustrate some indicative pricing scenarios in Exhibit 4–37. These scenarios show the range of prices at which retailers should be indifferent between their legacy copper platforms and the fibre platform. They show that the margin impacts from an increase in wholesale prices for fibre can be more than offset by lower churn, higher ARPU and the lower retailer costs to serve. Some of the factors involved in this modelling may only become apparent to retailers over the longer term (e.g. churn).

The other benefit of a retailer choosing fibre is that it will open up infrastructure based competition for premises that are in non-competitive exchange areas.

Creating the right incentives for migration

To encourage migration to fibre, NBN Co can provide targeted incentives over and above the implicit incentive found in the positive business case for retailers. Effective migration incentives would increase the rates of migration and provide higher early cash flow to NBN Co.

Exhibit 4–37. Price scenarios at which retailers will be indifferent between copper and fibre

	Retailers offering a resale product[a]	Retailers offering broadband on a ULL platform @ $16 per month[b]	Retailers offering broadband on a ULL platform @ $23.60 per month[b]
Wholesale access price on copper	$30–35	$16	$23.60
Indicative benefits from using fibre (retailer cost to serve savings, avoidance of copper ARPU erosion, avoidance of additional churn on copper)	$2–14	$12–24	$12–24
Indifference price for retailers to switch to fibre[c]	**$32–49**	**$28–40**	**$36–48**

a. Although retailers offer ADSL using their own DSLAMs, some retailers resell a Telstra wholesale product

b. Current ULL price in Band 2 is $16 per month. ACCC is considering increasing prices in areas deemed to be part of Zone A to $23.60 per month

c. Price at which fibre becomes at least as attractive to a retailer as copper long-term

Source: Implementation Study

Exhibit 4–38. Typical telecommunications market incentives

Incentive	Description
Cash transfers	Cash transaction for each customer migrated to fibre
Installation	Installation provided for each customer migrated to fibre. This could include, for example, basic internal wiring
Discounts	Price discounts based on volume of connections transferred
Term Contracts	Contract arrangements that lock in price levels for given time horizons
Custom products	Provide unique solutions through product mix
Expiring offers	Incentive offers that expire at set dates in the future
Introductory offers	Special offers for new customers, for example 50 Mbps for the price of 20 Mbps for the first year

Source: Implementation Study

Exhibit 4–38 shows typical incentive mechanisms. Government should allow NBN Co broad flexibility to employ such incentives to encourage take-up through service providers, within the constraints of equivalence. These incentive mechanisms could include one-off fibre connection cash transfers, free installation or discounts on price over set terms.

NBN Co should consider the following when determining incentive schemes:

- **Broad Equivalence.** NBN Co's value transfer should not distort the power of retailers within the market. Its incentive schemes should provide broad equivalence on price and terms.
- **Economic efficiency.** NBN Co should use cost-impact analysis to construct economically efficient incentive schemes.
- **Transparency.** NBN Co's incentive arrangements with service providers should be transparent, with all providers able to understand the types of incentives offered to them, and others.

Recommendation 41. That NBN Co be permitted to provide one-off incentives to service providers to encourage migration of their customers onto the network; that these incentives be transparent and offered on a broadly equivalent basis within geographic areas at a point in time; that uniformity of incentives across geographic areas or time not be required.

4.4.4 EXPECTING FIBRE TO EMERGE AS THE PREDOMINANT FIXED-LINE INFRASTRUCTURE

A major factor which will influence the ultimate degree of fibre penetration is the economic viability of legacy networks, particularly copper, as user numbers decrease. Although there is significant uncertainty surrounding future regulatory changes and the long term economics of the copper network, the Implementation Study believes that as fibre penetration increases, the economics of Telstra's copper network will deteriorate. This could eventually lead to an economically-rational decision to shut down the copper and migrate the remaining customers to fibre, absent of any agreement upfront.

Copper network economics

Understanding the future of Telstra's copper network requires examining its economics as its users and revenues decline. Generally, an owner of an asset will shut down that asset if cash flows are expected to be negative. Historical costs, while influencing the depreciation schedule, are sunk and largely irrelevant for any such decision-making. Direct cash costs include maintenance, power and utilities, other network support costs and should include any realisable opportunity costs of keeping legacy infrastructure.

> **Highlight.** Direct cash costs, rather than sunk costs, is the appropriate measure of costs to consider in any future shutdown decisions for legacy networks.

Assessing the copper network's direct cash costs is difficult. Most telecommunications operators are integrated companies that do not report the costs of operating only the copper network, and it is difficult to analyse Telstra's cost structure outside-in. Even in countries that have undertaken functional separation (e.g. the UK with BT Openreach), it is not entirely clear how much of the network support costs are directly borne by the separated entity as opposed to an accounting allocation of group-level costs.

Evidence suggests, however, that a meaningful proportion of the costs of operating the network are fixed and that, as a result, the average unit costs of operating a line will increase as the number of subscribers decrease. AT&T in a submission to the FCC states that customers who leave their network raise the average unit costs for their other customers.[130]

> *Due to the high fixed costs of providing POTS, every customer who abandons this service raises the average cost-per-line to serve the remaining customers.*
>
> AT&T[129]

[129] AT&T 2009, *Comments on NBP public notice #25: AT&T Inc. comments on the transition from the legacy circuit-switched network to broadband,* submission to the FCC, GN Docket No. 09-47; GN Docket No. 09-51; GN Docket No. 09-137

[130] Ibid

Highlight. The copper network's costs have a fixed component. As a result, the average cost of operating the network per user will increase as the number of users falls.

Deterioration of copper economics with the introduction of fibre

As users move off copper onto fibre the average costs per subscriber left on the copper will increase and Telstra's overall economics will deteriorate. For many exchange areas, once the user base falls below a threshold, it may be economically rational to shut down the network in that area.

A separated Telstra will behave differently to an integrated company. An integrated Telstra will optimise across the entire business, which could involve absorbing losses in its wholesale units to retain higher profits in its retail unit. However, if Telstra were separated and faced an 'equivalence of inputs' condition, then Telstra's retail division would face the same economic choices as other retailers. It would evaluate the relative merits of the copper and fibre networks and consider the migration incentives on offer from NBN Co.

In either case, Telstra may choose to migrate customers who value high speed to ensure their retention. In addition, the wholesale network division will face a difficult predicament as volume falls and unit costs rise—leading to an uncomfortable choice between reducing price to stem share losses despite rising costs, or raising prices to maintain profitability on shrinking volume.

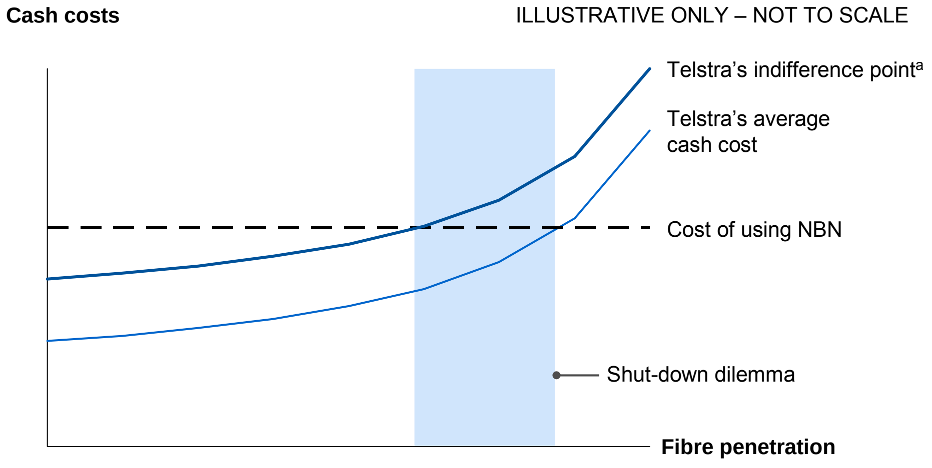
Exhibit 4–39 shows the economic choices for Telstra's retail unit (or an integrated entity) if a proportion of Telstra's copper operating costs are fixed. As fibre penetration increases, the costs to Telstra will increase. As is the case with other retailers, Telstra's retail division will have an indifference point that is higher than the pure cash cost analysis would otherwise indicate because of the differences between fibre and copper in average revenues per user, churn and retailer costs to serve (discussed above). The indifference point line determines when the retail division would choose to move its customers to fibre, assuming copper access prices increase as network costs increase.

Highlight. As users move off copper onto fibre, any fixed costs on copper will be spread over fewer users, increasing the average cost per user and, at some point, potentially making the copper uneconomic to run. This effect will be more pronounced if Telstra's wholesale and retail divisions are separated and make decisions independently.

Several countries have started thinking about closing portions of legacy infrastructure due to the roll-out of next-generation access.[131] In recent years, Telstra shut down its CDMA network and migrated all its traffic to other technologies. Other industries also exhibit deteriorating economics when the number of customers decreases.

[131] European Regulators Group 2009, *Report on Next Generation Access – Economic Analysis and Regulatory Principles*, Brussels

Exhibit 4–39. Deterioration of copper's economics as fibre penetration increases



a. Assumes there are churn, ARPU and retailer costs to serve differences between copper and fibre once fibre is rolled out
SOURCE: Implementation Study

There is, however, considerable uncertainty in predicting the long-term economics of copper and Telstra's decisions about its future. After all, no country has yet closed down its copper infrastructure due to the roll-out of a fibre network. The main uncertainties are:

- **Total cost per user.** The higher the overall costs on copper, the more likely the network is to become uneconomic to run. Conversely, if costs are low per user, then the network is less likely to be shut down.
- **Long term variability of costs.** The greater the percentage of overall costs that are variable over the medium to long-term, the less the average cost per user will increase as user volumes decline.
- **Actions Telstra could take.** For example, an integrated company may decide to suffer losses on the copper network to preserve retail market share.
- **Take-up of fibre.** Take-up of fibre may plateau before the costs have deteriorated enough to warrant shutdown. However, experiences in countries with high penetration of fibre, such as Japan and South Korea, suggest that this plateau may not in fact occur.

Nevertheless, on balance, it is likely the economics of copper will deteriorate over the long term, making it more probable fibre will emerge as the predominant fixed-line infrastructure.

Exhibit 4–40. Fibre take-up modelling in the business case

Approach to modelling take-up of fibre

The take-up modelling is based on a combination of the level of consumer 'pull' for fibre-based services and a compelling business case existing for a retailer to migrate services to copper (through a combination of wholesale pricing and one-off migration incentives). The modelling is based on individual activation curves for cohorts that are aggregated into an overall activation profile.

Activation curves by cohort

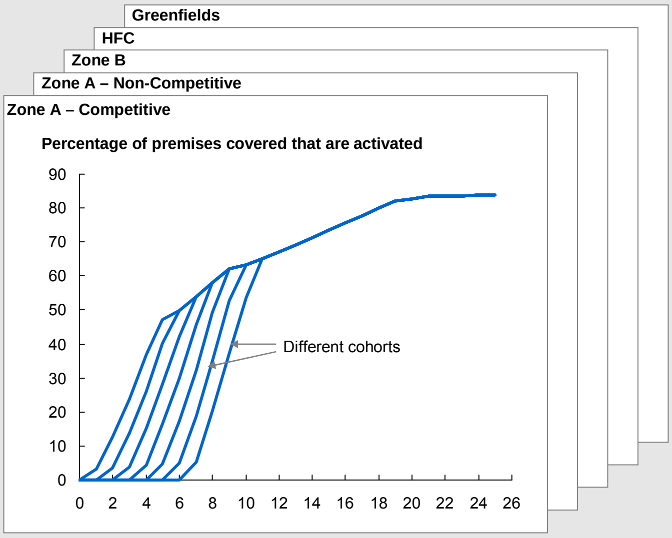
Take-up in the fibre footprint is based on cohorts. A cohort is defined by two characteristics:

- **Geography.** The fibre footprint is split into 4 broad regions for the purposes of modelling: areas with HFC, Zone A competitive, Zone A non-competitive, Zone B. Greenfields premises across each region are modelled as a separate category. The zones correspond to ACCC definitions[a]. A particular area is considered competitive if there are retailers other than Telstra with DSLAM infrastructure in that area. The modelling treats these regions differently. In HFC cohorts, a greater ability of HFC to hold share relative to fibre is modelled. A user in a Zone A non-competitive region is expected to move to fibre more quickly than a customer in a Zone A competitive region due to strong expected activity from ISP attackers. Greenfields premises are treated as a specific case with much faster activation and higher than average penetration. By 2018, Greenfields will account for 11 percent of premises and by 2035, they will account for 28 percent.
- **Year covered.** The take-up effect starts only when a home is covered, and premises covered in later years are expected to move to fibre faster than those covered at the beginning of the rollout.

Within a cohort, take-up is differentiated by two factors:

- **Product.** A voice-only customer is less likely to want to move to fibre in the early years;
- **Retail Service Provider.** Consistent with the modelling assuming no deal for migration of customers, Telstra customers are modelled as moving more slowly to fibre.

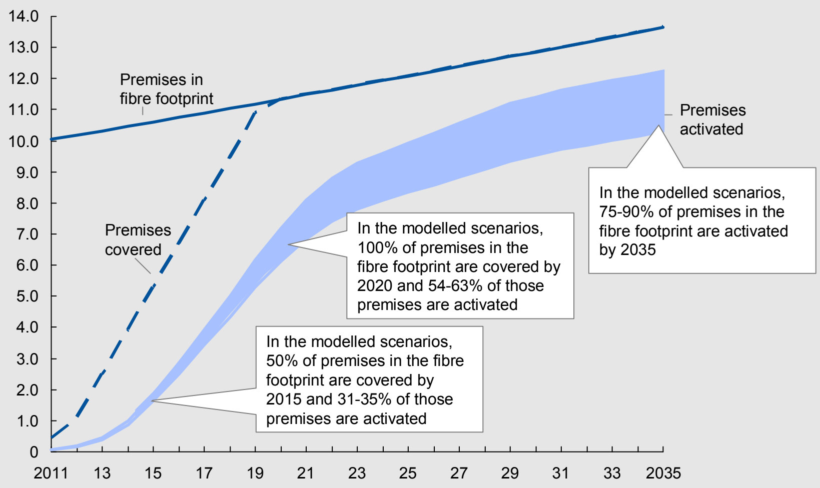
Activation curves by cohort



SOURCE: Implementation Study

Aggregate fibre take-up scenarios

Premises, Millions



SOURCE: Implementation Study

The activation curve is then built up for each cohort. In general, take-up in the early years after an area is covered is modelled to be at the higher end of the 6 to 12 percent range observed in other fibre deployments. This slows, however, once penetration exceeds approximately 60 percent of the cohort. If, however, the copper network were shut down earlier, then there could be an uplift in penetration. The tail of the activation curve is based on the terminal penetration of fibre, which is driven by the combined demand for services over fibre (e.g. 70 to 90 percent for fixed-line broadband).

Aggregate modelling of take-up

Activations for each cohort are aggregated to yield overall coverage and activation (see Chart below), which then drive revenues. There are three features to note in the scenarios represented by the chart:

- Total premises to be covered by fibre in 2018/19 is modelled to be 93 percent of 12.1 million, including 1.3 million new premises from 2010. New premises growth is modelled at 1.25 percent of existing premises;
- All premises are covered by 2018/19. After that, all growth in premises covered is from new premises;
- Activation is shown as a range based on the market demand scenarios of 70 to 90 percent penetration of fixed-line broadband.

a. ACCC, *Draft pricing principles and indicative prices for LCS, WLR, PSTN OTA, ULLS, LSS*, August 2009

4.5 Creating a robust revenue model for the NBN fibre network

One of the most important commercial decisions facing a network operator such as NBN Co is setting price. This will require balancing a range of considerations—take-up, other objectives such as usage, regulation, and financial performance—in a constantly evolving landscape. Although pricing is a matter for NBN Co subject to the applicable regulatory regime, this section provides guidance on major issues to be considered in setting price, now and in the future, and how revenue scenarios may play out for the business.

Three subsections follow:

4.5.1 Managing pricing over time

4.5.2 Implementing a price architecture consistent with policy objectives

4.5.3 Achieving a sustainable revenue profile within the fibre footprint.

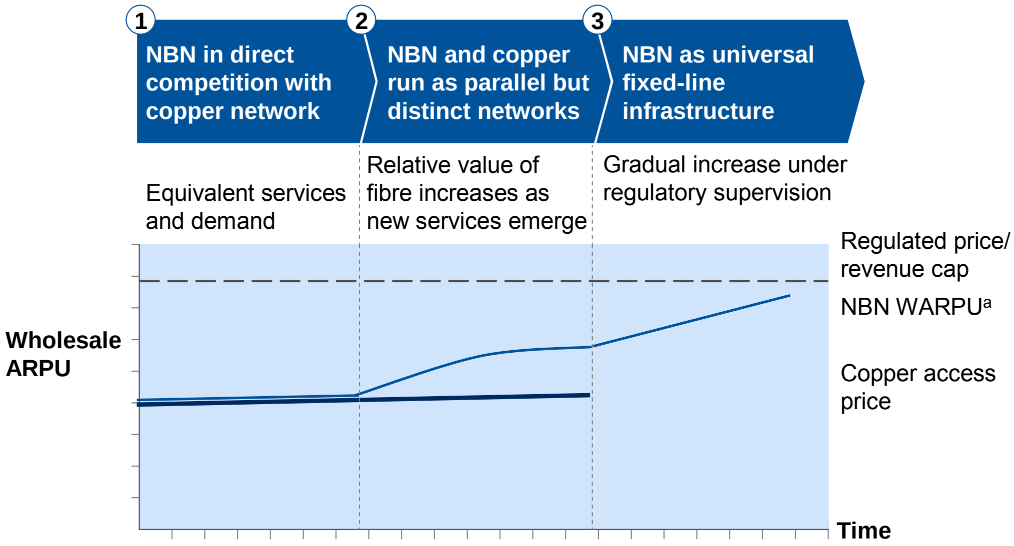
4.5.1 MANAGING PRICING OVER TIME

Pricing of NBN services must reflect the needs of numerous stakeholder groups: Government, the ACCC (on behalf of end users) and customers. These groups have a range of objectives. Government has objectives of take-up and long-term commercial viability of NBN Co, amongst others. The ACCC is concerned with the long-term interests of end users. Customers of the NBN currently operate on a separate platform and will need incentives to move onto the NBN.

Pricing is likely to evolve over a number of phases to balance the needs of these stakeholders. Exhibit 4–41 presents one view of this evolution. The timing of these phases is uncertain. However, this framework highlights the changes that are likely to occur over the life of the NBN. We discuss these phases in three parts:

- Setting initial price levels;
- Pragmatically increasing average prices over time;
- Managing pricing within a regulated revenue cap.

Exhibit 4–41. Conceptual phases of pricing for NBN services



a. Wholesale average revenue per user
SOURCE: Implementation Study

Setting initial price levels

The objective of pricing in the initial phases of the NBN is to drive take-up on the network. Prices for NBN services will therefore be initially constrained by offers on competing networks—in particular, the copper network.

The previous section outlined a methodology to estimate the indifference price for service providers. Indifference pricing refers to the level at which NBN wholesale prices represent parity with copper access prices in terms of customer lifetime value. At these prices, service providers have equal incentive to offer services on either network. The Implementation Study has modelled initial prices for NBN services referencing this methodology. The findings of our revenue modelling are presented later in this Section.

Gradually increasing prices over time

The relative value of fibre is likely to increase over time as new services and uses emerge. As it does, NBN revenues should increase to provide a fair return on the network investment. An increase in revenues over time would likely correspond to an increase in user value. A plausible revenue trajectory over time is presented in Exhibit 4–41. This trajectory could be achieved in two ways: a change in demand for new or higher-priced services; or a price increase on basic services (within the ongoing affordability requirement).

First, changes in demand could drive increased revenue on the NBN. The emergence of new or improved retail services could require users to upgrade to higher speed and/or quality services. These services will likely command higher prices. Demand for higher-priced services will drive an increase in average revenue per user. However, the extent of this revenue opportunity is uncertain.

Second, prices could improve returns over time via regulatory review. There are precedents for this approach in other countries. Singapore, for example, has scheduled a number of pricing review points, at which wholesale prices can be altered, depending on demand.[132]

However, any price increases should not come at the expense of network penetration, given the ongoing requirement for affordability and take-up of NBN services.

Advice. That NBN Co Board consider real price increases for NBN services to achieve reasonable return; that any price increases should ensure entry-level services continue to uphold the NBN requirement for take-up and affordability.

The revenue trajectory has implications for NBN Co and any pricing agreed with the ACCC. Given the uncertainty of future demand, NBN Co may need flexibility to introduce price increases to achieve an adequate return on investment over time. Price increases should be negotiated between NBN Co and the ACCC as part of the special access undertaking, to ensure entry-level prices continue to uphold the affordability requirement outlined in Chapter 2. NBN Co should ensure that its special access undertaking specifies a mechanism and timing for reviewing and setting prices, with a view to long-term cost recovery.

Advice. That NBN Co Board establish a mechanism and timing for reviewing and setting prices of NBN Co services as part of the pricing regime negotiated with the ACCC.

Pricing over the long-run within a regulatory framework

The NBN will eventually emerge as a monopoly provider of some network services. As it does, its revenue and prices may face increased regulatory scrutiny. The ACCC is charged with regulating industries and providers to ensure the long-term interests of end users. Subject to any negotiated pricing regime such as a special access undertaking, regulation of NBN prices and services could occur in a number of ways—e.g. price caps for specific services or an overall regulated return.

[132] Infocomm Development Authority of Singapore 2009, *Industry briefing to FBOs*, Singapore

The ACCC and other national regulators typically regulate prices on the basis of cost. However, it is difficult to reasonably allocate the cost of individual services offered on next-generation networks. This is because a high proportion of cost is fixed upfront, and there is little or no marginal cost of providing different or additional services.

> *With next-generation access a greater proportion of costs will be fixed upfront capital costs which are common across shared services…There will be no sound cost-oriented basis for allocating overall access costs across services.*
>
> Brian Williamson, Director Plum Consulting (2009)[133]

Regulation of NBN services is likely, but the nature and timing of that regulation is uncertain. Successful navigation of the path to regulation has two requirements. First, Government, ACCC and NBN Co must constructively engage on areas likely to be regulated. Second, NBN Co should ensure the costs of building and operating the network are recorded transparently at a sufficient level of granularity (Chapter 10). Government and the ACCC should clearly state to NBN Co their expectations in this regard.

Advice. That NBN Co Board consult with the ACCC and Government on current and likely future pricing regulation; that NBN Co Board ensure costs of building and operating the network are recorded at a level of granularity consistent with likely regulatory requirements.

4.5.2 IMPLEMENTING A PRICE ARCHITECTURE CONSISTENT WITH POLICY OBJECTIVES

Price architecture refers to the components and features of pricing for NBN services and how they come together. NBN Co must be allowed flexibility to develop this architecture to achieve commercial success. Pricing decisions are dynamic and challenging. They are best left to the company, within its regulatory and policy constraints.

To balance these obligations and constraints, the NBN price architecture should:

- Provide commercial flexibility to NBN Co;
- Encourage use of the network;
- Permit multiple retailers to deliver services to premises;
- Anticipate the possibility of future separation.

133 Williamson, B 2009, 'The regulation of next-generation access networks and the draft Commission Recommendation', paper presented to the Network for Economic Research on Electronic Communications conference, Madrid, 11-12 September

Providing commercial flexibility to NBN Co

Pricing flexibility is important to network and telecommunications companies. It allows them to adapt to market conditions, create new revenue streams, even spur demand. Such pricing decisions are challenging and dynamic—prescriptive advice today will not serve NBN Co as conditions change.

Telecommunication companies use a range of pricing mechanisms to optimise revenue. Typical elements of a commercial price architecture include:

- **Price differentiation** that involves varying prices by type or quantity of service or user;
- **Commercial terms and charges,** including contractual terms, volume discounts and operational charges (e.g. connection fees);
- **Bundling of services** that involves grouping services (e.g. voice and data services) at a discount to the sum of their individual prices;
- **Fixed access charges** for every connection to the NBN, similar to existing PSTN line rental charges.

NBN Co should have flexibility to adopt commercial pricing mechanisms, within the constraints of its other policy objectives. The remainder of this subsection highlights the policy objectives that will restrict the flexibility of NBN Co to use some of these mechanisms.

> **Recommendation 42.** That Government not constrain the commercial flexibility of NBN Co to design and update a price architecture, within the requirements of regulation and its obligations for affordability and take-up of services; that Government support NBN Co's adoption of price mechanisms such as price differentiation (except where it is based on geographic location) and differentiated commercial terms and charges that are consistent with equivalence

Price differentiation

A considerable body of literature exists regarding price differentiation of services on communications networks. There is broad agreement that some level of price differentiation in telecommunication and other high-fixed-cost industries (e.g. airlines) is appropriate to achieve social benefits, while helping in the pursuit of a commercial return.

> *Price discrimination by firms with market power is often viewed as unfair. From the point of view of social surplus, however, the judgement… may be quite different. Roughly speaking, welfare goes up if total output is increased.*
>
> Mitchell and Vogelsang (1991)[134]

The alternative to differential pricing—in other words, to price all NBN connections at a single price—would be inefficient. A single price that provides a fair return on investment would be too

134 Mitchell, B and Vogelsang, E 1991, *Telecommunications Pricing: Theory and Practice,* University of Cambridge Press, Cambridge

high for many users, and therefore constrain take-up and usage. On the other hand, a single price that maximised take-up would be unlikely to provide the NBN with any reasonable return.

Some price differentiation of NBN services is therefore appropriate. Exhibit 4–42 outlines the options for differentiating prices of NBN services. NBN Co should consider the use of these options where commercially viable, within the policy mandate outlined in this report. Price differentiation levers that should be constrained in the context of policy objectives are addressed further below in this subsection. It is important to distinguish between price differentiation for services and NBN Co's equivalence obligation. NBN Co should be permitted to define services that are specific to categories of end users such as businesses, schools and mobile transmission sites. Equivalence demands that each of these services, with the same conditions, be available on a wholesale basis to retail service providers. Therefore, differentiating wholesale services by end-user category for retailers to use to deliver services to end users does not contravene equivalence.

Advice. That NBN Co Board consider reasonable differentiation of prices between discrete categories of end users and customer types:

1. Categories of end users. Different prices could apply between business users (i.e. those with an ABN) and residential users;
2. Customer types. Different price levels or structures could apply between retail service providers, e.g. ISPs serving individual premises, and commercial operators, e.g. mobile carriers serving multiple users from a single connection.

Commercial terms

Commercial terms typically include volume-based discounts, long-term contracts and revenue-sharing. There are also a number of one-off or ancillary charges that may be associated with NBN services—e.g. connection fees, port charges, exchange racks.

As a commercial company with an objective to eventually attract private funding, NBN Co should be permitted to pursue a range of actions that improve return on investment by providing revenue assurance and/or a reduction of risk. It should also have flexibility to charge for ancillary services, so long as these charges transparently reflect costs and are in line with industry practice.

Commercial charges levied by NBN Co should only be limited where they violate principles of equivalence, or other requirements within the NBN wholesale mandate (e.g. driving take-up of NBN services). For example, discounted rates for a long-term contract that guarantees a large volume of customers each year would favour bigger retailers. These terms would in effect violate the principle of equivalence, even if it were offered on the same terms to all providers. Many providers do not have the scale to take-up such an offer.

Exhibit 4–42. Options for price differentiation of NBN services

Options for price differentiation	Examples
Service specifications	■ **Download speed**. Prices increase with download speed. This is a primary mechanism of differentiation in most markets ■ **Upload speed**. Prices increase with upload speed. It is useful to differentiate services that have symmetrical bandwidth requirements, e.g. video-conference services ■ **Quality of service**. Prices vary depending on QoS or Class of Service, to differentiate premium products (e.g. IPTV) ■ **Multicast capability**. Premium charge if capability is required. Useful to capture additional revenue from video providers ■ **Contention**. Prices vary with contention ratio in aggregated bitstream. Not relevant for uncontended last-mile NBN service, but appropriate to differentiate backhaul and other aggregated services
Usage characteristics	■ **Total usage**. Wholesale charge per unit of data used at retail level. Can be difficult to measure ■ **Usage tiers**. Wholesale prices vary by download cap ■ **Peak/off-peak usage**. Wholesale prices vary by time of day ■ **Source of usage**. Usage charges depend on origin of data (e.g. higher price for data routed from international vs. domestic servers)
Characteristics of end user or customer	■ **Type of end user**. Different price for business versus residential end users. Singapore's NBN provides a precedent ■ **Type of customer.** Different prices for single-premises service providers (e.g. ISPs) versus multi-user network providers (e.g. mobile carriers)

Source: Implementation Study

Advice. That NBN Co Board offer a range of commercial terms and additional charges, as long as the offers are:

1. Equivalent and do not distort competitive outcomes;
2. Transparently calculated and reflect reasonable recovery of costs for providing that service, e.g. cost of connecting customers.

Encouraging use of the network

NBN Co should set prices to maximise take-up of network services. While an important attraction of the network will be the superfast speeds it offers, the issue of whether NBN Co should employ download caps has been a subject of debate.

The Implementation study believes that usage-based wholesale pricing that replicates Australia's existing retail download caps risks constraining use of NBN services. One could legitimately question the value of superfast speeds if download caps remain. Current caps are outliers in the developed world and have kept Australia's broadband penetration lower than their potential. Moreover, for retail providers to maintain today's margins, they would likely pass on usage-based wholesale charges to customers. Both caps and higher prices per unit of data would constrain growth in data demand and undermine NBN take-up objectives.

Charging higher prices for usage will hamper the growth of services which demonstrate the NBN's superiority over other networks. Releasing usage constraints will allow service providers to offer high-bandwidth services (e.g. e-health, IPTV) which will provide much better experiences than either slower fixed broadband solutions (e.g. DSL) or mobile broadband. However, at current usage caps, use of these services will be constrained. The equivalent of one hour of television usage every day via IPTV will result in monthly downloads of approximately 150 gigabytes, compared with today's high-end retail DSL plans which typically offer no more than 80 GB per month at best.

The differentiation with respect to mobile broadband is even more stark. Due to capacity constraints, mobile broadband is likely to require download caps for the majority of users in the future.

Advice. That NBN Co Board avoid usage-based wholesale pricing for uncontended services in the long term, once the network is profitable and/or cost recovery is assured; that if usage-based pricing mechanisms are implemented for a transition period, they should:

1. Not constrain reasonable use of cloud-based services;
2. Only differentiate between consumption of sufficiently distinct products or services—e.g. at a level corresponding to considerable usage of IPTV per day;
3. Be of a similar magnitude to those implemented in comparable economies around the world.

Ensuring sufficient competition in the home

Government seeks to stimulate competition in fixed-line products through the NBN. This goal is explicitly non-revenue maximising for NBN Co. A purely commercial approach would attempt to diminish competition in services provided to the home, by extracting maximum value from a single service provider that could 'lock up' an entire connection. To ensure this competition exists, NBN Co should not bundle its wholesale services, at a discount to the sum of individual price points. This mechanism would favour larger providers, and prevent the emergence of a level retail playing field.

Bundling should be avoided by NBN Co in its wholesale pricing. There are about 5.5 million voice-only connections in Australia, and 0.7 million broadband-only DSL connections. This latter figure increased by 30 percent between 2008 and 2009.[135] Bundling voice and data products together limits the ability of these consumers to choose the service that best meets their needs.

Pricing a bundle of wholesale services (e.g. voice and data) at a discount to the price charged for each service creates an advantage for large retailers. It reduces competition after the first service provider has secured access to a household. It also limits the flexibility of customers to choose only the retail products that suit their needs and to diversify these purchases across retailers.

We also recommend against two other types of bundling. First, bundling could occur across services—for example, a last-mile bitstream service bundled with backhaul. This could also reduce retail competition, by reducing both pricing transparency as well as the flexibility of service providers to specify products that suit their needs. Second, physical components of the wholesale services necessary to reach end users could be bundled. For example, if individual charges are levied for access to the ports of the ONT, service providers should not be able to acquire multiple ports at a discount.

Advice. That NBN Co Board ensures general pricing for NBN services is transparent and modular—e.g. bundling services at a discount should be avoided, unless a discount is applied to certain legacy services or an entry-level offer.

Adjusting in future given the possibility of future separation

Elements of NBN Co price architecture implemented in the short term can assist the long-term development of the industry. In Chapters 9 and 10 we discuss the importance of active-layer competition and the possibility of longer-term separation of NBN Co into passive and active network providers. The pricing of NBN services can smooth the transition to both of these end-states.

Separation of active and passive network services would require a division of revenue into these components. Should Government seek separation in the future, NBN would need to adapt its price architecture to facilitate the separation and maximise value from it at the appropriate time.

A fixed access charge for NBN services would provide a simple and transparent means of separating price into active and passive components. This access charge serves a dual purpose for an eventual transition. First, it is transparent, signalling to retailers a base price which helps them price their own products efficiently. It also allows future NBN investors

> *In future, there is no reason why the cost of line maintenance need not be apportioned more equally between voice (and) data…Alternatively, consumers could pay separately for their connectivity and for their applications*
>
> Cable and Wireless (2009)[136]

[135] J.P. Morgan 2009, *Australian Telecom Sector in FY09*

[136] Cable&Wireless 2009, *Response to Ofcom's consultation document: Next generation networks*

greater transparency about post-separation cash flows. Second, it provides NBN Co with anchor point for an eventual passive access price that would likely be negotiated with the ACCC once active competition is introduced.

Levying a fixed access charge also has an ancillary benefit. A fixed monthly charge would provide an efficient way to recover a portion of the fixed investment, while allowing flexibility for some value-based, variable pricing.

> **Advice.** That NBN Co Board consider that a fixed access charge is appropriate to ease future separation on the condition that it:
>
> 1. Is set at a level that does not constrain take-up of NBN services;
>
> 2. Does not bundle additional services.

Illustrating a price architecture consistent with policy objectives

For the purpose of the business case modelling, we have developed a proposed price architecture that balances NBN Co's objectives and stated policies. Details of the actual price architecture is a matter for the NBN Co and will likely be the subject of a Special Access Undertaking to the ACCC. The illustrative price architecture is shown in Exhibit 4–43 below.

4.5.3 ACHIEVING A SUSTAINABLE REVENUE PROFILE WITHIN THE FIBRE FOOTPRINT

The revenue profile from the NBN fibre network is inherently uncertain. Different revenue profiles, combined with different roll-out cost scenarios, create different rates of return. In Chapter 7 we bring cost and revenue for the NBN together to present an integrated business case. However, under all scenarios, NBN Co is expected to achieve significant operating margins due to its low operating cost profile.

NBN Co should have a commercial mandate to set prices to drive take-up. Prices have yet to be determined by the company. For the purposes of developing a business case for the NBN, we have estimated a range of revenue outcomes. This subsection outlines the approach to estimating revenue in the fibre access network, and discusses a range of potential revenue outcomes.

Estimating revenue in the fibre access network

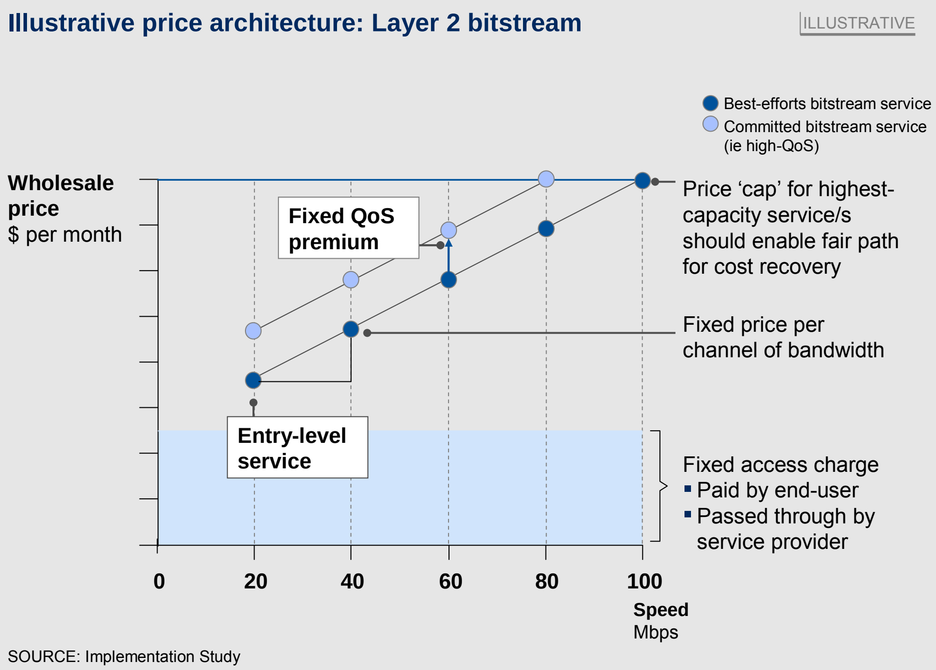
We have taken a conservative approach to modelling NBN fibre-access revenue, given the challenge of estimating the number of variables at play. The scope of our modelling comprises:

Exhibit 4–43. Illustrative price architecture

Example price architecture that balances commercial and policy objectives

Here we illustrate a price architecture that balances the objectives and constraints outlined in this section. It provides context for the recommendations and advice outlined in this section. This architecture would apply to a Layer 2 bitstream service in the access network only (i.e. any transit service would be priced separately); and contains some specific assumptions:

- A fixed access charge is levied to end users for connection to the network, and is passed through by the first service provider
- Bandwidth is the scarce resource that, once at capacity, will drive the requirement for network upgrades. Therefore, speed is used as the primary discrimination lever
- The price of the entry-level broadband service (20 Mbps in this example) would be referenced to copper access prices to drive migration
- The price point for the top-speed/capacity service (i.e. 100 Mbps) is set to ensure average wholesale revenue per user provides a fair return on network investment
- Straight-line discrimination between speed channels is used to avoid arbitrage (with no bundling of channels)—i.e. every subsequent channel is sold to providers on an equivalent basis
- Fixed premium for QoS grades within each speed band; providing a linear approach consistent with best-efforts service



Source: Implementation Study

- A focus on mass-market services—i.e. broadband and voice (PSTN emulation). High-bandwidth and non-premises services such as enterprise-grade point-to-point and backhaul to mobile base-stations, respectively, are not included;

- Conservative assumptions regarding new services—i.e. the only non-Internet services assumed to be adopted by service providers are voice and IPTV. Any additional wholesale services purchased by ASPs will therefore be upside to the business case detailed in this report;
- Awareness of practical challenges of mass-migration—i.e. the migration of users onto the network, even once demand for services delivered on fibre exists, will not happen immediately.

For the avoidance of doubt, this section focuses on the fibre access network only. Revenue from transit or non-fibre services is not included.

Drivers of revenue

Revenue is a product of the number of fibre connections (or penetration) and the average wholesale revenue per connection (WARPU). Penetration depends on:

- **Fixed-to-mobile substitution.** The addressable market for NBN services is determined by the number of premises willing to take a fixed-line connection. Loss of fixed-voice lines and rapid growth of mobile broadband have raised concerns this market is contracting. Although these effects are likely to continue in the short term, the performance of fibre will drive a resurgence in fixed-line broadband. We discuss these trends are discussed in detail earlier in this chapter.
- **Demand for services delivered on fibre.** Take-up of fibre is driven by the demand for services delivered over it. Predicting user demand is difficult given the lack of fast alternatives in Australia. We discuss relevant analogies earlier in this section and note the range of likely take-up rates based on international experience.
- **Speed of migration.** Underlying demand for services delivered on fibre does not translate immediately into take-up. Migration onto the network takes some time once fibre is made available to a given 'cohort' of users. This delay is driven by two factors: inertia of end users, and operational limitations associated with migrating large numbers of users onto a new network. For the NBN, the need for installation of equipment at end-user premises affects both factors through inconveniencing end users and presenting operational challenges. The combination of the demand for services and the speed of migration provide the rate of take-up, referred to earlier in this section.

The average wholesale revenue per connection is driven by:

- **Initial price levels.** NBN Co should price to maximise affordability and take-up. Given conservative assumptions of minimal upfront fibre premium, wholesale prices should encourage service providers to generate adequate margins while pricing for mass-market adoption. We outline a methodology to estimate the 'indifference price' earlier in this section; and apply this methodology to model prices of NBN Co services.

- **Price growth over time.** Real prices of NBN Co services may need to increase over time to allow a fair return on network investment. We assume real growth of between 0 and 2 percent per year across the range of services modelled—lower for voice, higher for services such as IPTV.
- **Changes to product mix.** Demand for services will change over time, driving a change in the average revenue per connection. For example, the gradual emergence of IPTV as a service would increase average revenue. Alternatively, once passive-layer unbundling is introduced, NBN Co will only receive passive revenue from lines that are unbundled by access seekers. We assume modest penetration of IPTV—10 percent of connections by 2022. We also model the introduction of active competition in 2022—capturing 20 percent share of lines within four years.

Once these factors are estimated, total revenue within the fibre access network is driven by the number of premises within the footprint. When the fibre roll-out is complete, growth in premises will drive continued growth in revenue.

Price levels and approach

NBN Co has a mandate to set prices for its services within the applicable regulatory regime. The Implementation Study is not recommending prices that should be set for services. However, assumptions have been made to construct the revenue component of the overall business case. These assumptions are outlined below.

The modelled price architecture is similar to the example presented in Exhibit 4–43. It has a fixed component and modular add-ons for individual services. That is, an access charge applies to every connection. Individual charges for broadband, voice and other services (e.g. IPTV) are applied on top of that charge, depending on demand.

Wholesale prices modelled are consistent with the ‘indifference’ pricing approach discussed earlier in this section. This methodology estimates the wholesale prices that give service providers an equivalent customer lifetime value compared to the copper network. It indicates blended average wholesale prices in the range of $30–$40 per month, depending on the wholesale access (ULL) price on the copper network.

We also assume that price differentiation allows NBN Co to charge some users higher prices. For example, some users are likely to pay more for higher speeds (Exhibit 4–43). However, NBN Co could achieve this upsell in a number of ways. Our focus is on the revenue impact rather than a particular method of service differentiation (e.g. download versus upload speeds). We assume an average upsell of $5 per month per connection, in addition to the charge for basic broadband access. This would represent ‘premium’ segments paying more—e.g. $15 extra across one-third of the user base.

Major sensitivities

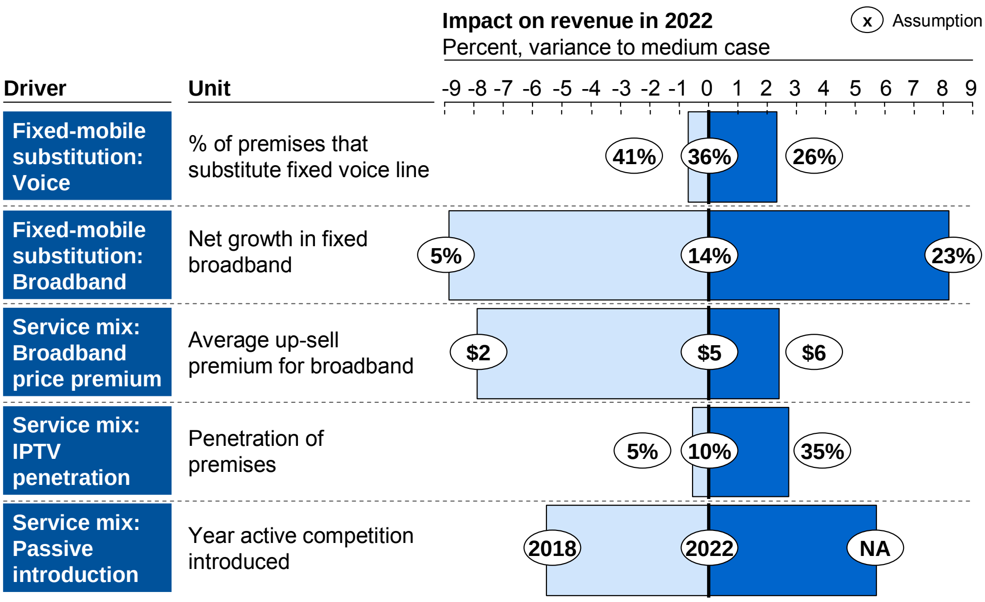
Estimating revenue on the NBN requires consideration of each of the factors discussed in this section. Exhibit 4–44 demonstrates the sensitivity of revenue to these variables, in percentage terms. Fixed broadband penetration and pricing have the biggest revenue impact.

Preparing for a range of revenue outcomes

Given the degree of uncertainty and number of variables at play, a range of revenue scenarios is analysed. Exhibit 4–45 outlines these scenarios, which are integrated with cost scenarios in Chapter 7 to inform the overall business case. We focus on four scenarios that differ along the two dimensions with greatest revenue impact: fixed-broadband penetration and wholesale pricing.

The ULL price affects the wholesale fibre prices that will encourage service providers to switch to the NBN. There is uncertainty regarding the ULL price that will be charged in the market going forward. The current price is $16 per month in Band 2 locations (the de-facto reference point for ULL pricing), but the ACCC has published a position paper stating its intention to raise the price to $23.60 in Zone A locations.[137] As discussed in Section 4.5, this directly impacts service providers' cost-to-serve, and therefore the price at which they would be willing to switch to the NBN.

Exhibit 4–44. Revenue sensitivity of major variables



SOURCE: Implementation Study

137 Australian Competition and Consumer Commission 2009, *Draft pricing principles and indicative prices for LCS, WLR, PSTN OTA, ULLS and LSS*, Canberra

Exhibit 4–45. Revenue sensitivities modelled for business case

Revenue scenario	Fixed broadband demand (percent)	Reference price[a]	Revenue 2022, $b[b]
■ Higher demand	90	$23.60	4.8
■ Mid-case demand, higher price	80	$23.60	4.4
■ Mid-case demand, lower price[c]	80	$16	4.2
■ Lower demand[c]	70	$16	3.9

a. ULL price on copper (per month)

b. Real dollars (including a 1 percent per annum real price increase); includes existing premises, greenfield and brownfield developments

c. Includes a 'glide path' back to scenario 2 price trajectory after 10 years

Source: Implementation Study

This difference is reflected in the NBN wholesale prices modelled under each scenario. Exhibit 4–46 outlines the wholesale prices modelled for common packages of services, under each scenario. To re-iterate, this is an indicative price architecture only, to illustrate the principles described and for business case modelling. NBN Co, as a commercial entity, should retain flexibility to design and update a price architecture. For example, NBN Co may decide to not offer a basic broadband service without voice—creating an entry-level service of $30-$35 depending on the ULL scenario in our modelled architecture. Furthermore, these prices do not factor in migration incentives. A voice-only service, with a wholesale price of $25 per month would need some migration incentives to retailers to cater to low-ARPU voice-only subscribers. In both scenarios, as shown in Exhibit 4–46 the wholesale prices modelled for a basic service package (e.g. basic double-play), as well as weighted ARPU, fall within the ranges that should encourage service providers to switch to copper (Exhibit 4–37).

The second dimension modelled in the revenue sensitivities is peak penetration of fixed broadband. We discuss the drivers of this metric in Section 4.5, and have modelled a range of potential outcomes. Each is broadly consistent with the trends discussed in that section. Exhibit 4–47 presents the three fixed-broadband penetration scenarios used in the business-case sensitivities. Note these do not represent Implementation Study forecasts of the likely outcome, but are scenarios developed for the purposes of modelling. To be clear, these scenarios represent penetration of fixed broadband, which is likely to be shared between fibre, copper and HFC platforms.

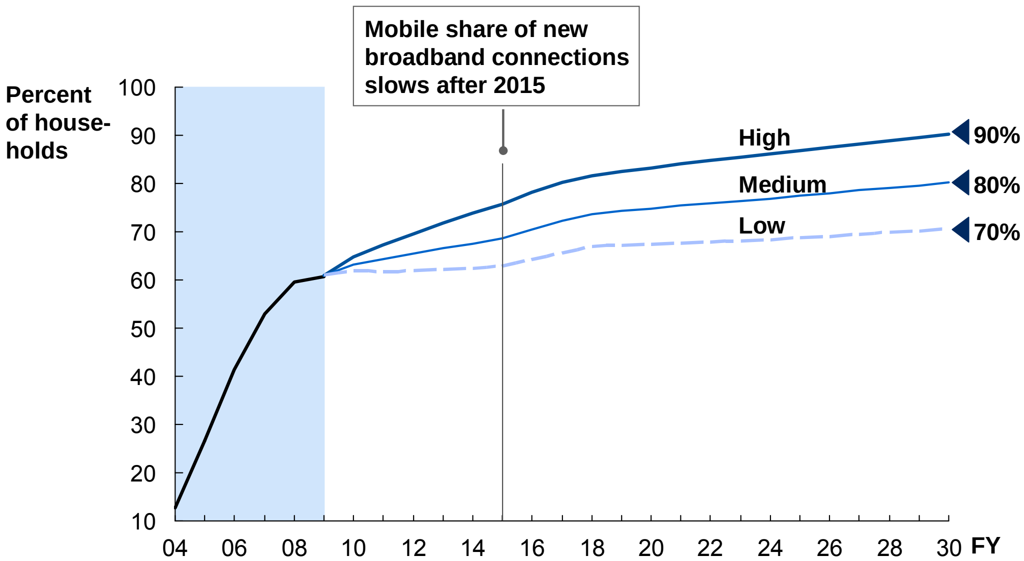
Exhibit 4–46. Example NBN wholesale prices modelled under two scenarios

Wholesale service	Wholesale price per month ($16 ULL)	Wholesale price per month ($23.60 ULL)
Basic broadband only	25	30
Voice only	25	30
Double play (basic broadband, voice)	30	35
Triple-play (basic broadband, voice, IPTV)	33	38
Premium broadband double-play	45	50
Small business[a]	60	60
Blended WARPU (2011)	33	38

a. Assumes business customers demand voice and fast broadband and some form of higher service options
Source: Implementation Study

In Chapter 7 these scenarios are integrated with potential cost outcomes, to present overall business-case sensitivities for the NBN.

Exhibit 4–47. Fixed-line broadband penetration scenarios



SOURCE: Pyramid; J.P. Morgan; Implementation Study