Final Report:

Using the ACCC Analysys Network Model

for

Modeling Fibre to the Premise

Prepared for Optus

By

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Version 0.97, 8 October 2009

Executive Summary

Current industry wisdom would lead one to expect that a fibre based access infrastructure will deliver a lower cost structure overall for the delivery of rich multimedia services than that offered by an equivalent copper access network under similar greenfields deployment conditions. This paper investigates the use of the network cost model developed by Analysys Mason Consultants for the ACCC to demonstrate the cost of fibre to the premise (FTTP) across the Australian market. The question that is being addressed is whether the Analysys model can provide a cost model for FTTP and what changes are required to the model to deliver a satisfactory outcome?

The model has been analyzed to address this question and it is shown that the model can deliver a cost model for a point to point (P2P) fibre to the premise access architecture. However, this basic change on its own does not lead to a cost optimized P2P fibre access deployment. In order to determine a more optimized cost structure for this architecture, the values of several parameters need to be adjusted. The resulting cost model provides a reasonable approximation to the costs likely to be encountered for a wide scale FTTP deployment across Australia. Unfortunately, without actually changing the underlying structure of the Model, it is not possible to fully optimize the outcome. There remain fundamental constraints within the Model which limit an optimized outcome.

It is also recognized that the P2P FTTP architecture is not necessarily the lowest cost option for all segments of the market. Passive Optical Networking (PON) is considered to offer a lower cost structure, especially for small business and residential customers. However, the ability of the Analysys model to implement a PON FTTP architecture has been shown to be impossible without majot structural change. An approach was defined to test this possibility with the optical splitters located at the Pillars contained in the copper access model. However, the Model could not adapt to this configuration or reduce the feeder cable fibre count to reflect the optical splitting associated with this configuration. Hence the use of the Analysys Model to develop a cost structure for a PON based access network is considered to be inappropriate.

Overall, it is evident that the Analysys models are not designed to deliver an optimal FTTP outcome. However, the model does provide some useful guidance as to the cost benefits of deploying a fibre based access infrastructure as compared to a copper one. The initial results indicate capital expenditure savings of several billion dollars over that for the equivalent copper implementation, and the service delivery capability will be greatly enhanced. Given more time to understand the intricacies of the Model, it may be possible to achieve a workable cost model for the P2P FTTP case and gain considerable insight from such a model, providing at the same time that its fundamental limitations are acknowledged and understood.

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1. Introduction

Optus has requested a comparison of the cost of a fibre to the premise (FTTP) based network verses the current copper network cost structure, as delivered by the cost models being used by the ACCC. The ACCC commissioned Analysys Mason in the UK to prepare a network cost model for Australia based on a forward looking view of technology as might be deployed on a replacement basis.

The Analysys Model, as prepared for the ACCC (referred to as the Analysys Model) provides a useful baseline for the costing of a network to serve Australia. The base model is constructed around a traditional copper access model, assuming a green-fields[1] deployment, with a forward looking view of costs. A variant is also provided which delivers a Next Generation Network (NGN) based on a fibre to the node (FTTN) access architecture. In this case, copper is still deployed between the access node located in the street and the customer premise.

In terms of this study, the Analysys model provides the baseline cost for a copper access network, in either configuration – Copper to the Premise (CTTP) or Fibre to the Node (FTTN). It has been proposed that this copper based model can be modified to deliver a cost model for a Fibre to the Premise (FTTP) access deployment. The validity of this approach is explored in the body of this paper, along with the results of some initial investigations. In addition, the modifications required to achieve this change are described and the limitations to using this approach are identified.

2. Access Network Architectures

The basic access network architectures which are discussed in this paper are described below. The following description attempts to identify both the similarities and the differences between these architectures. The issues identified in this section will be referred to below, in the more detailed discussion of the use of the Analysys Model where some of these architectures are actually used.

2.1.Copper to the Premise

The Copper to the premise access architecture has been in existence for almost 100 years. Over time, it has evolved to what we find today. In urban areas, the architecture today is as illustrated in Figure 1 and it is this architecture which is essentially represented within the Analysys Model. The copper cable spans downstream from the local exchange to the street based pillar. There are typically many pillars per exchange serving area. Each pillar provides service to up to about 400 premises.

Each premise is connected to the pillar via a single pair of copper wires. The pair of copper wires is typically contained within a 2 pair copper cable sheath from the premise termination point to the Distribution Point (DP). From the DP the pair of copper wires is aggregated into a multi-pair copper cable for carriage up stream to the appropriate pillar serving the DP cluster.

[1] Green-fields in this context refers to the deployment of a new access network with minimal use of existing assets, except those relating to the existing Telstra exchange sites and associated copper centres.

The upstream cable from the DP to the Pillar is typically 100pairs in a non-tapered network, but could be 10, 30 or 50 pairs in a tapered network configuration.

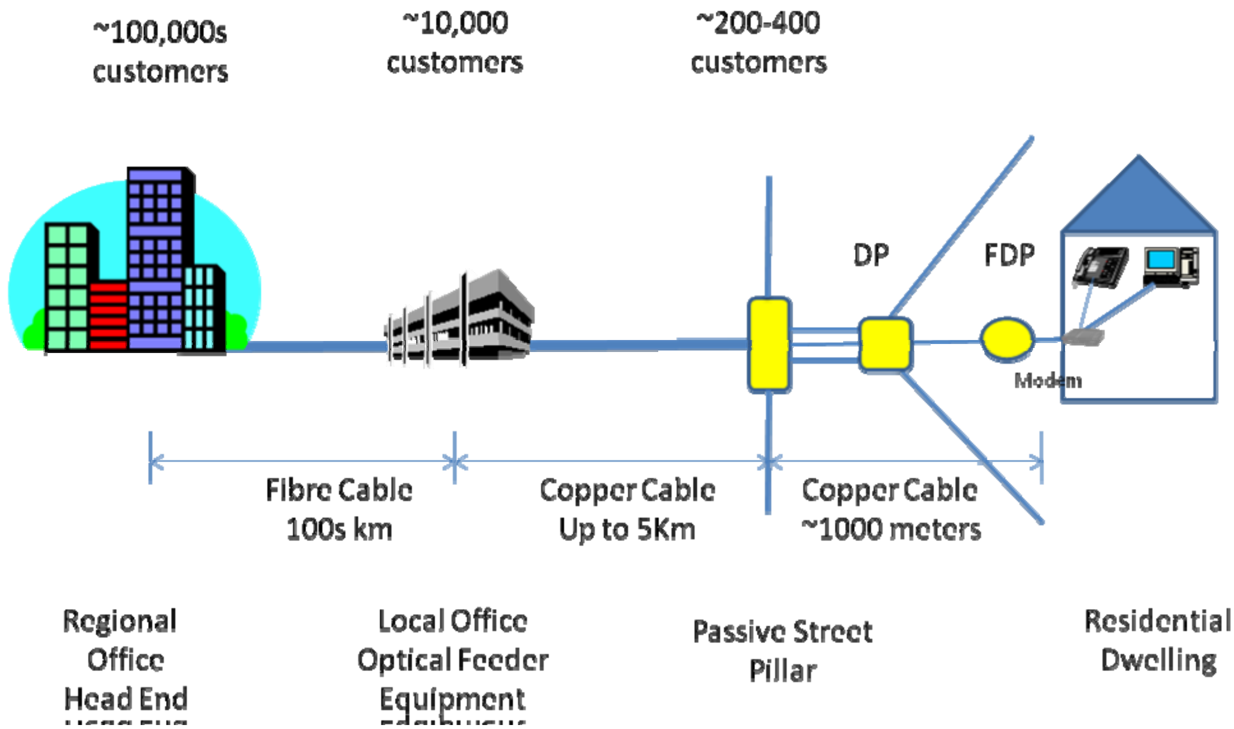

Figure 1: The basic Copper to the Premise architecture.

At the DP, the pairs of copper wire for a maximum of 4 premises are separated out to provide drop leads to the closest premises. Each drop lead will be laid in the trench following the road to the point adjacent to the best entry point for the premise and then will be laid into the premise. The Final Distribution Point (FDP) is the point closest to the best entry point for each premise.

2.2.Fibre–to-the-Node (FTTN)

The first incremental introduction of fibre into the copper access network comes with the fibre to the node (FTTN) based access architecture as illustrated in Figure 2. This architecture is being widely deployed around the world as a first step towards FTTP. This architecture has fibre deployed in the feeder of the access network as illustrated in Figure 2, but uses the existing copper twisted pair cable network to deliver the service into the customer's premise.

The FTTN architecture can also be referred to as fibre-to-the-cabinet (FTTC) when the opto-electrical conversion is deployed in a street side cabinet, typically serving some 100-600 consumer premises (see Figure 2). In this configuration, the remaining copper cable network will typically have an average length of around 1Km, with 99% of copper pairs less than about 2.5Km.

It can also be referred to as Fibre-to-the-Kerb (FTTK) where the opto-electrical conversion is deployed in much smaller street side cabinets, each servicing typically less than 100 premises. In this latter case, the copper cable network typically has an average length of around 300-500m and 99% of copper pairs are less than 1Km in length (see Figure 3).

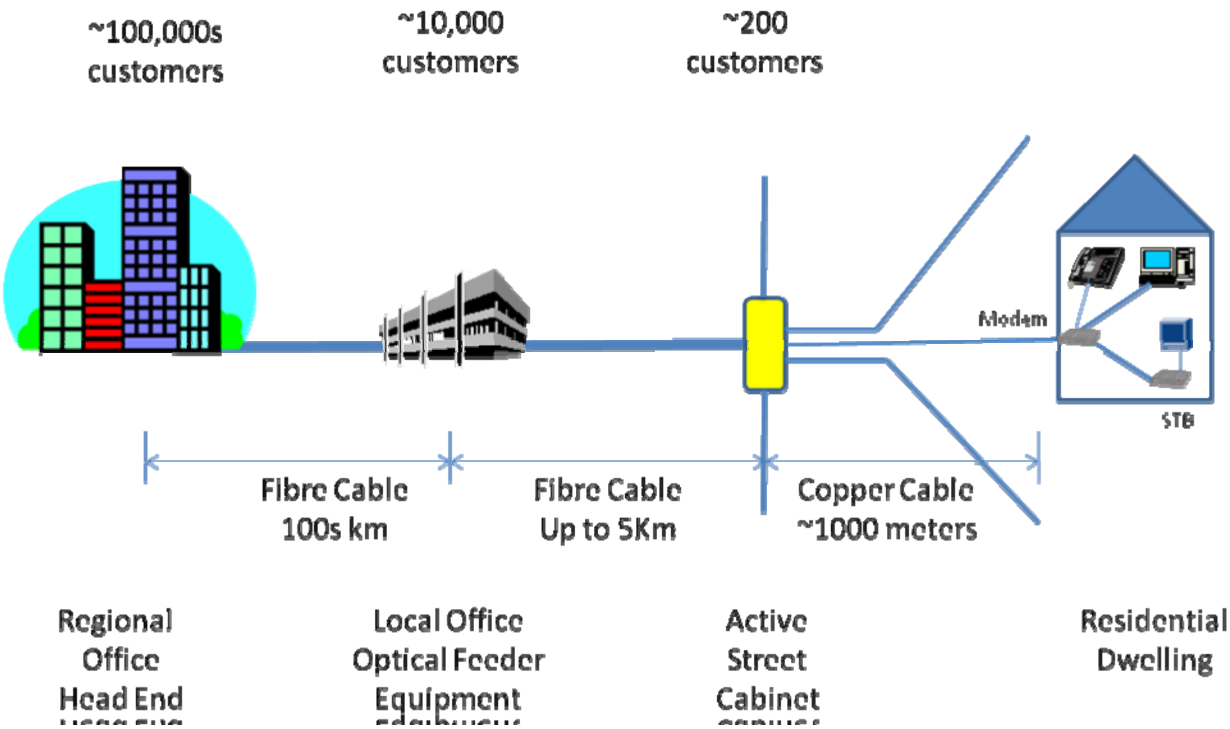

Figure 2: Typical Fibre-to-the-Cabinet architecture.

In both of the FTTN configurations, the technology used for the opto-electrical conversion in the street side cabinets is usually based on some form of Digital Subscriber Line (DSL) technology. In the FTTC configuration the most common DSL technology for deployment is ADSL2+ today, although VSDL2 can also be deployed on shorter copper lines. The ADSL2+ technology will achieve downstream line synchronization rates of about 20Mbps on average and better than 10Mbps for better than 99% of access lines. The upstream line synchronization rates will be around 1Mbps on average and better than 0.5Mbps for more than 99% of access lines. All of these figures, refer to the line termination point on the outside of the consumer premise and may be degraded by in premise wiring and modem characteristics. In the case of FTTK deployments, the most commonly deployed DSL technology is VDSL2, with downstream line synchronization rates of more than 50Mbps and upstream line synchronization rates of more than 10 Mbps. A typical FTTK deployment would be configured to achieve better than 20 Mbps downstream and 5Mbps upstream line synchronization rates for better than 99% of lines within the required coverage area.

FTTN is used as a progressive architecture towards FTTP, by an incumbent service provider that has a widely deployed copper cable network already established, and where demand for widespread take-up of high capacity broadband services is uncertain. It is predicted that as time goes by, new DSL technologies will evolve to improve the performance achieved by the FTTN solutions[2]. Typically the best performance improvements will be evident with copper loops of less than 1Km in length, so the FTTK approach offers more future proofing than the FTTC approach.

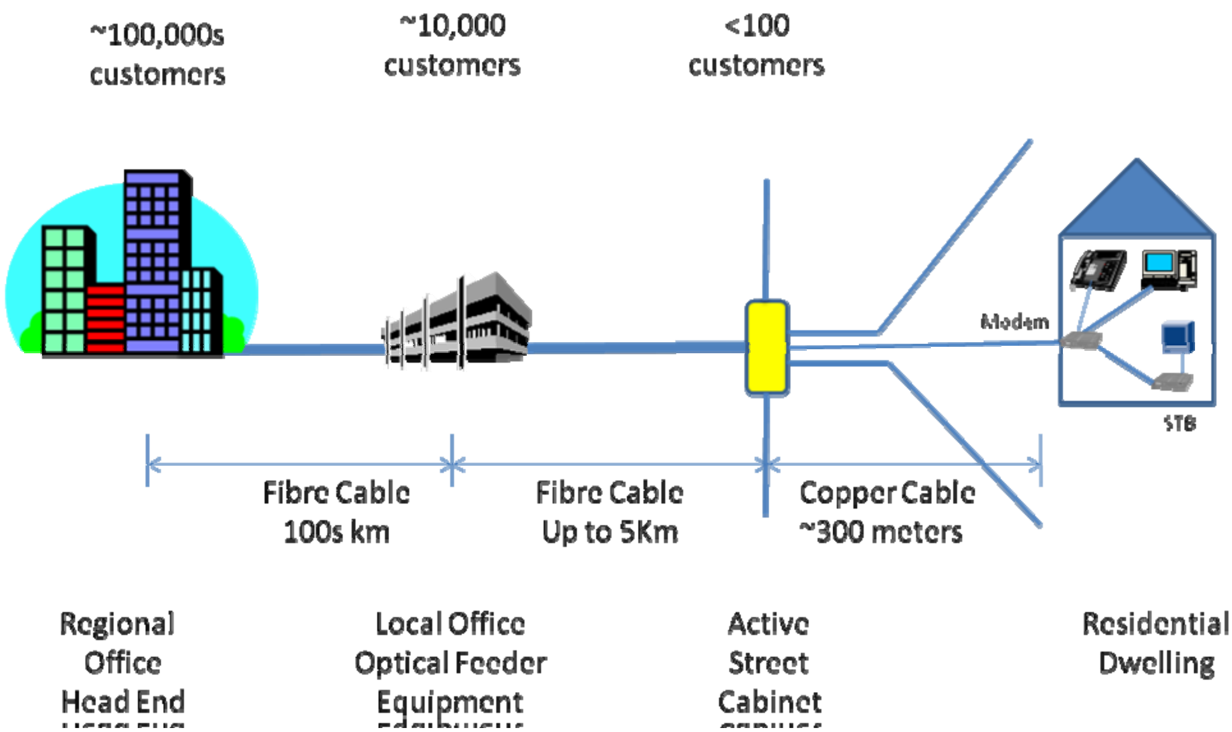

Figure 3: Typical Fibre-to-the-Kerb architecture.

2.3.Fibre-to-the-Premise (FTTP)

FTTP in this report is used to define the generic provision of fibre optic based technology to provide a telecommunication capability all the way into the consumer's premise, with the optical to electrical conversion being implemented on the consumer premise. FTTP is used independent of whether the consumer is a business or residential consumer. The total set of FTTP solutions can be subdivided into two subsets based on type of customer, such that:

- Fibre-to-the-business (FTTB) refers to the provision of fibre based access solutions into premises occupied primarily for business purposes, and
- Fibre-to-the-home (FTTH) refers to the provision of fibre based access solutions into premises occupied primarily for residential purposes.

The other key discrimination factor between FTTP access solutions is the differences in architecture which can be used for implementation. These include two primary categories as follows:

- Active Ethernet Over Fibre (AEF),

[2] Cioffi, J.M. Jagannathan, S. Mohseni, M. and Ginis, G. CuPON: The Copper Alternative to PON 100Gb/s DSL Networks, IEEE Coms Mag. June 2007, pp132-139.

- Passive Optical Networking (PON).

The AEF implementation involves point to point (P2P) fibres deployed from some central location out to each individual premise being provided with service, as illustrated in Figure 4. Each individual fibre pair (typical configuration, although single fibre feed can also be used) will be fed via an Optical Line Terminal (OLT) located at the central location which acts as a point of aggregation and is often referred to as the Central Office (CO). At the consumer premise, the fibre will be terminated in an Optical Network Terminal (ONT) which is dedicated to each premise. In this configuration, the fibre pair is dedicated to a single consumer premise and there is no sharing of the fibre resource. This includes the dedicated use of optical to electrical and electrical to optical conversion at each end of the dedicated pair of optical fibres.

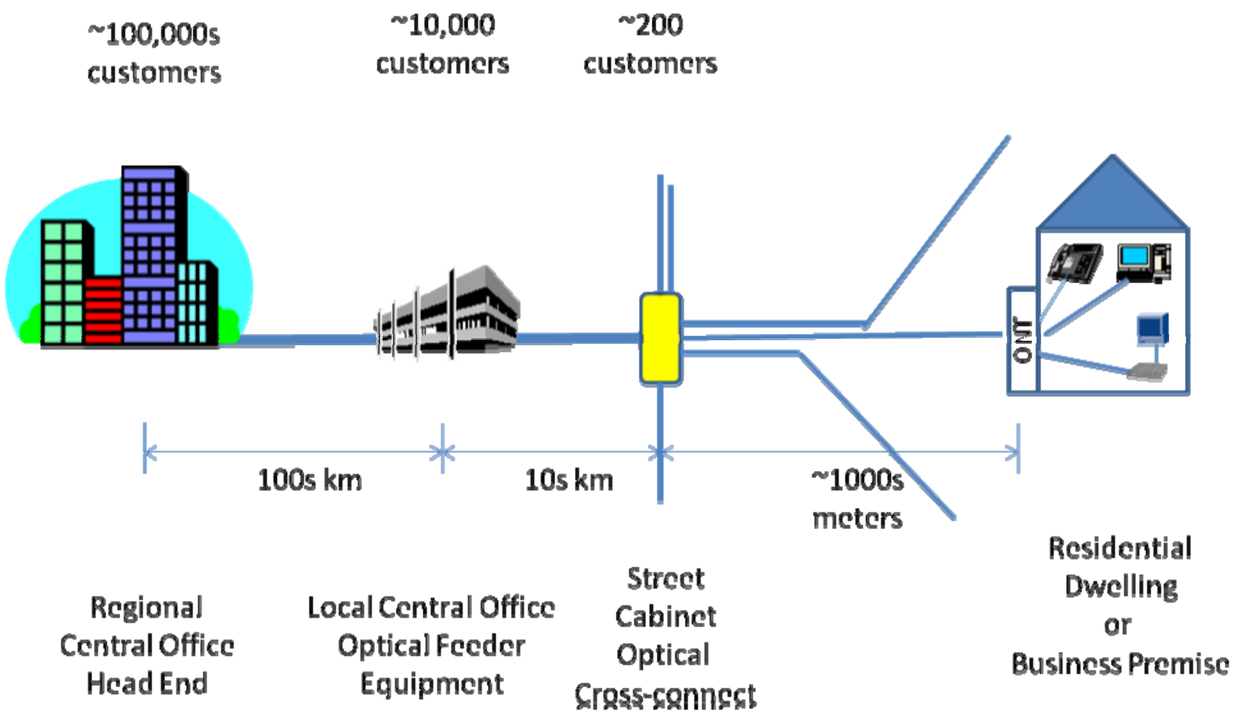

Figure 4: Typical Active Ethernet over Fibre (AEF) using a point-to-point fibre architecture.

In a multi-tenant premise, the AEF architecture can be used to deliver service to multiple consumers, located in the same physical premise (such as a high rise building) over a single pair of fibres. In this case, the ONT is used to provide individual ports for each consumer within the multi-tenant premise. In this case the bandwidth derived from the fibre access is shared across the number of ports configured, and can result in contention for the available resource depending on how the OLT-ONT circuit is configured. In the New Zealand context, multi-tenant residential buildings are not common and so this form of shared infrastructure architecture is not specifically considered in the cost models.

In comparison, Passive Optical Networking (PON) deliberately involves the sharing of the deployed fibre resource across a defined number of consumer premises, as illustrated in Figure 5. The feeder part of the access fibre is shared across 32-64 (typical) consumers, while the short distribution component only is dedicated to each consumer. Passive optical splitters are deployed in the route to the customer to enable the splitting and combining of the optical capacity between the consumers. A two level splitting architecture is often used to enable the minimization of the fibre deployed in the distribution architecture. It is assumed that the splitter architecture will have a maximum utilization of about 80%, as it is very difficult to achieve much better than this in practical deployments.

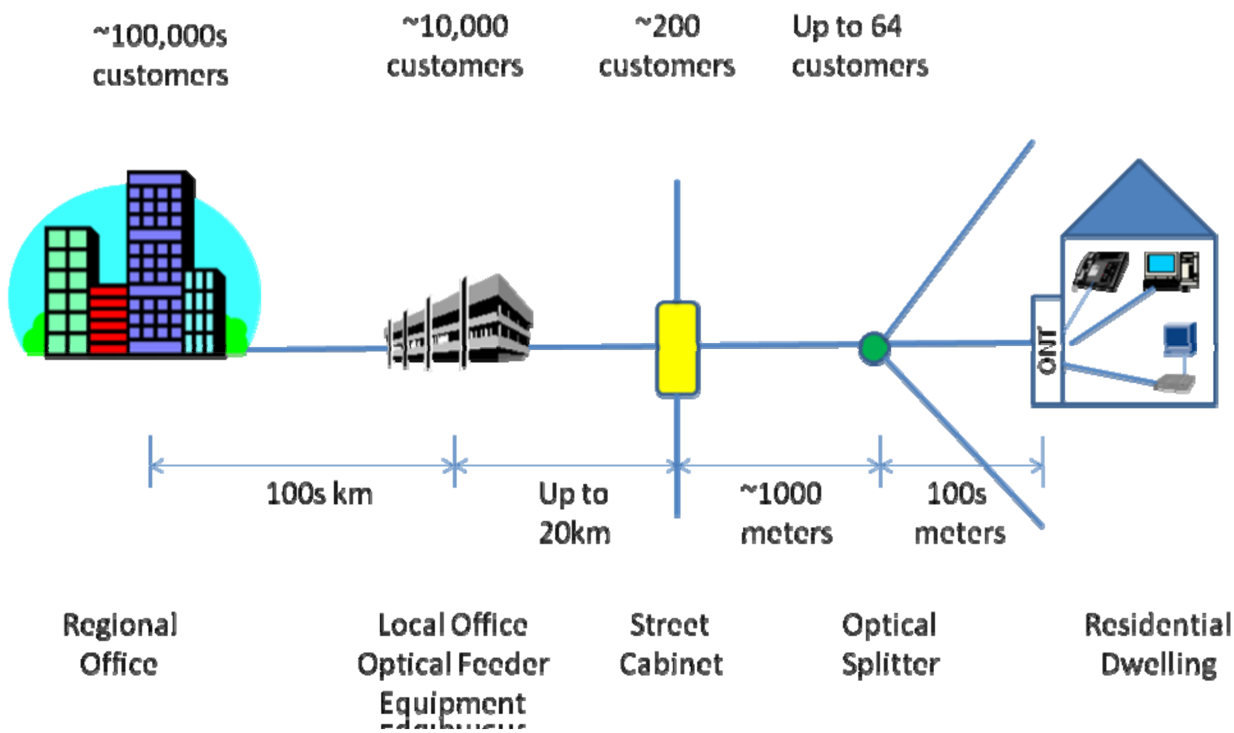

Figure 5: Typical Passive Optical Network Configuration using the G-PON technology.

PON comes in many forms and is continuing to evolve. The primary PON architectures available today and likely to be available in the future include:

- Broadband Passive Optical Network (B-PON),
- Ethernet Passive Optical Network (E-PON),
- Gigabit Passive Optical Network (G-PON),
- Next Generation Passive Optical Network (NG-PON)
- Wavelength Division Multiplex Passive Optical Network (WDM – PON).

Of these, the G-PON architecture is being most widely deployed today with 32 or 64:1 splitting, being most common. Most recent cost studies involving PON use this architecture. In the future, the NG-PON architecture will become more prevalent and in the longer term (during the next decade) the WDM-PON architecture is likely to increase in popularity.

The PON architecture is best suited to the residential consumer environment and so is frequently used for deployments of FTTH. On the other hand, the AEF architecture is more frequently deployed for business applications or FTTB. The AEF architecture is also widely used for the provision of service into multi-tenant high rise residential dwellings, as mentioned above.

FTTP today is deployed widely into business premises using the AEF configuration. Coverage of business premises in high density areas such as the CBDs of cities is widely available. Coverage is progressively moving out into the suburbs to provide service to business premises in less densely populated areas, again typically using the AEF configuration. In some countries such as Singapore and Hong Kong, there has also been increasing deployment of the AEF FTTP architecture into high rise residential apartment buildings.

On the other hand, PON based FTTP is increasingly being deployed to deliver service to residential premises in new residential sub-divisions. This is often referred to as “greenfields” FTTH deployment. To date, there has been much less deployment of FTTH to replace existing copper cable networks, in what is often referred to as “brownfields” deployment situations. The big difference between “greenfields” and “brownfields” deployment is that in the case of “greenfields” deployment, the ground is developed with other services such as roads, footpaths, sewage and utilities, so burial is a relatively simple process and hence low cost. In some situations, a greenfields developer will provide the trench at zero cost as part of the development. However, the greenfields situation is a very small part of a major rollout of FTTP, so is not normally a critical component of any cost modeling exercise. In the case of this exercise, it is assumed that no other form of telecommunications infrastructure exists, so a “greenfields like” deployment approach is modeled.

3. Demand Stimulus

The primary difference between a copper access model and fibre access model is the ability of the fibre access model to deliver higher capacity data capability. Fibre optic cable has an almost unlimited ability to deliver broadband data capacity, over very long distances, as compared to copper cable which has a limited bandwidth, which can only be enhanced through the reduction of the copper cable length. As illustrated in the previous section, short lengths of copper cable can support 100Mbps downstream over lengths of cable less than 300m. In comparison, fibre optic cable can support multi Gbps services over several 10s of kilometers. However, whether the capability of fibre is required or not depends on customer demand. If a customer only wants a simple telephone connection, then copper cable provides a low cost solution and in fact the fibre based equivalent is relatively high cost. On the other hand, if the customer requires multi Megabits per second of data and telephony and video, then any copper based solution will struggle to deliver the required bandwidth at any cost, while the fibre based access will deliver this capability at relatively low cost. Hence the choice of access technology is dependent more on customer demand for services as compared to any other parameter.

The Analysys Model has essentially been developed to support telephony and a relatively low performance broadband data capability. Hence these customer requirements can be largely satisfied through the deployment of copper in the access network. Improved performance is achieved through the use of FTTP as described above. However, within the demand based constraints applied within the Analysys model, copper remains the predominant access medium.

Although the Analysys model is designed to deliver a copper based access network infrastructure, it does have the provision built in to deliver fibre access to customers that have sufficient demand to warrant this approach for access. The transition from copper access to fibre access is driven entirely by customer demand. If a specific customer premise has a requirement for demand above a prescribed limit then that customer will be provided with a point-to-point fibre connection over the access network as compared to the predominant copper access. This applies for either the traditional copper network or the NGN based network models.

Based on the demand stimulation premise, and the related guidance provided in the user manuals, this approach to driving fibre into the access network has been investigated. It has been found that it is possible to change the threshold for demand so that all premises have sufficient demand to automatically drive the provision of fibre into the access network, as compared to copper. The trigger point has to be set to 1 demand unit for the demand per premise and this transition occurs. The model then delivers a full fibre-to-the premise access implementation, along with an upgrade of the core network components to cater for the incremental demand driven by this transition.

This approach has been tested and after several subsequent adjustments to model parameter values, the Model has been found to operate correctly on a near universal basis. As expected, all practical cost models have their limitations, and so the demand stimulation approach did not function properly initially, when all access circuits are stimulated with demand above the threshold simultaneously. Some parameters in the model did exceed their prescribed bounds and the model did produce some strange results. However, once the range of parameter values were adjusted, the approach did work well and the integrity of the model was maintained.

Once adjusted in this manner, the model produces a cost structure for a fibre to the premise (FTTP) implementation which is based on a point-to-point (P2P) fibre in the access architecture. This is certainly one of several valid access network architectures. However, as indicated in more detail below, it is not necessarily the cost optimum access network architecture. Furthermore, inspection of the model inputs suggests that many parameters of the resulting access architecture will not be optimized for wide scale fibre deployment. Many of the parameters will remain optimized for a copper based architecture, so that the costs delivered through the use of this approach is unlikely to deliver a cost optimized network implementation for FTTP and this has proved to be the case in practice.

The description which follows, attempts to identify many of the changes that have been found to be required to optimize the cost structure of the model. This includes limitations with the basic point to point architecture as compared to another alternative involving the use of a Passive Optical Network (PON)architecture.

4. Point-to-point (P2P) Ethernet over Fibre Access Architecture

As discussed above, the simple demand stimulation approach to the development of a FTTP based network cost model using the Analysys model does deliver a P2P fibre access network. The P2P fibre architecture is one of several valid fibre architectures, but is not expected to be the lowest cost alternative. This less than optimum outcome is expected to arise for the following reasons:

- The Analysys models are based on a set of starting assumptions that are not necessarily optimum for the deployment of a cost optimized fibre access network,
- Many of the inherent network cost parameters are optimized for copper deployment as compared to wide scale fibre deployment.

4.1.The Optimum P2P FTTP Access Architecture

Ideally the P2P access architecture to support FTTP would be as illustrated in Figure 6. In this diagram, the following trench, duct and fibre assumptions would apply:

- The lead in to any premise should be made using a 4 fibre cable blown through a 4mm outside diameter (OD) tube which is fitted into a 16mm OD duct.
- The 4mm tube needs to be continuous and air tight from the nearest DP through the FDP to the premise termination point (using airtight tube joints where required).
- The 4 fibre cable is blown from the DP via the FDP through to the premise termination point as a single run.
- DPs should located at a maximum of 250m separation, so that the maximum DP to FDP length should be 125m which is straightforward with current tube blowing technology (in rural areas blowing distances of up to 1km would be possible and it is proposed that the DP separation could be increased to a maximum of 1km in these areas).
- The number of premises connected per DP should be in the range of 12 to 24 premises in urban areas and could reduce to as low as 2 in rural areas (the optimal value will depend on premise density across all demographics.
- This allocation of premises per DP requires a maximum of 24 by 4mm micro tubes within the duct serving the DP to FDP link. A typical value would probably be 12 to 18 micro tubes.
- A 16mm Y or T duct connector would need to be deployed at each FDP to serve the customer premises connected at the FDP in order to separate the lead-in from the transverse duct route.
- The appropriate number of 4mm tubes need to be separated at each DP to serve the number of customer premises connected to each DP, via the associated FDPs (16mm ducts each containing one 4mm micro tube form the FDP to the customer premise termination point link.
- The 4mm micro tubes would need to be managed at the DP pit, as would the associated fibre joints between the main transverse cable and the lead-in cables (one fibre pair per lead-in connected for most premises – two of the fibres only in the lead-in cable used).
- The Pillar is assumed to aggregate services from a maximum of 400 customer premises, and provides the second level of fibre aggregation.
- The DP to pillar cable will need to accommodate a maximum of 800 fibres plus about 10% spares. Hence a maximum of 864 fibres will be aggregated at the pillar, both upstream and downstream
- Many DP to pillar cables will accommodate less fibres, as the pillar will often serve more than one contiguous area adjacent to the pillar. In addition, in order to drop off premise tubes at

each DP, there needs to be an additional 1-4 by 12mm tubes which each accommodate 6 by 4mm micro tubes.

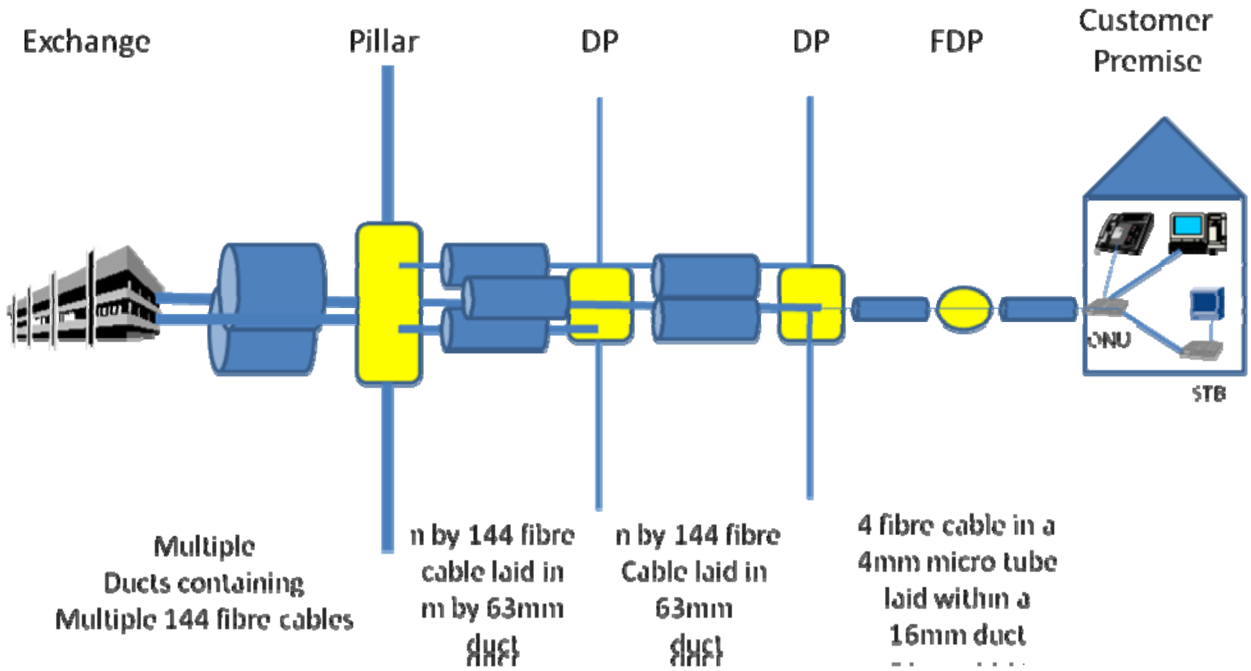

Figure 6: An optimized point to point fibre to the premise passive access architecture.

- Typical DP to pillar duct configurations could include:
    - 63mm OD with 6 by 12mm tubes each containing a single 144 fibre cable,
    - 63mm OD with 5 by 12mm tubes each containing a single 144 fibre cable and 1 by 12mm tube containing 6 by 4mm tubes,
    - 63mm OD with 4 by 12mm tubes each containing a single 144 fibre cable and 2 by 12mm tubes each containing 6 by 4mm tubes,
    - 50mm OD with 3 by 12mm tubes each containing a single 144 fibre cable and 2 by 12mm tubes each containing 6 by 4mm tubes,
    - 40mm OD with 2 by 12mm tubes each containing a single 144 fibre cable and 2 by 12mm tubes each containing 6 by 4mm tubes,
    - 32mm OD with 1 by 12mm tube containing a single 144 fibre cable and 2 by 12mm tubes each containing 5 by 4mm tubes.
- Other configurations could be provided for special situations such as business parks and CBD installations.
- Each Pillar to RAU, LPGS, Exchange would then consist of multiples of the above cable configurations or could use larger diameter ducts with each duct containing multiple 864 fibre cables to accommodate the ”daisy chaining” of pillars – up to 3 by 864 fibre cables per 100mm ID duct is feasible.

- All of the above single duct per trench configurations can be deployed using directional drilling technology. Two ducts per trench can also be deployed using this technology when the individual ducts are 63mm or less in diameter.
- With more than 2 ducts per trench, open trenching is required with a substantial increase in trenching cost.

If this architecture could be properly represented by the Analysys Model, then we could expect an reasonably well optimized cost structure for the FTTP deployment. Unfortunately as discussed below, the Analysys Model can only approximate this architecture.

It should be noted that the architecture described in this section is based on the use of industry best practice technology, such as that offered by such global suppliers as Draka[3]

4.2.The Analysys Model Based FTTP Access Architecture

The above describes an optimized fibre deployment architecture for a P2P fibre access network. However, the Analysys Model does not enable this architecture to be implemented without substantial changes to the structure of the model. The best approximation to the above, which is possible within the constraints of the model, has the following characteristics:

- The lead in to any premise consists of a 6 fibre cable which can be provided with a cost structure as if it were housed in a 4mm outside diameter (OD) tube which is fitted into a 16mm OD duct.
- DPs are located at a maximum of 250m separation.
- The number of premises connected per DP is limited to a maximum of 4.
- This allocation of premises per DP requires a maximum of 4 (6 is the nearest standard configuration) by 4mm micro tubes within the duct serving the DP to FDP link.
- The appropriate number of 4mm tubes need to be separated at each DP to serve the number of customer premises connected to each DP, via the associated FDPs (16mm ducts each containing one 4mm micro tube form the FDP to the customer premise termination point link.
- The Pillar is assumed to aggregate services from a maximum of 400 customer premises, and provides the second level of fibre aggregation.
- The DP to pillar cable will need to accommodate a maximum of 800 fibres plus about 10% spares. Hence a maximum of 864 fibres (or 6 by 144 fibres) will be aggregated at the pillar, both upstream and downstream.
- Many DP to pillar cables will accommodate less fibres, as the pillar will often serve more than one contiguous area adjacent to the pillar. In addition, in order to drop off premise tubes at each DP, there needs to be an additional 1 by 12mm tubes which each accommodate 6 by 4mm micro tubes.
- Typical DP to pillar duct configurations could include:
    - o 63mm OD with 5 by 12mm tubes each containing a single 144 fibre cable and 1 by 12mm tube containing 6 by 4mm micro tubes,

[3] Draka, Draka XS Net Value Innovation for Next Generation Access Networks, Product Catalogue, 2009.

  - 63mm OD with 4 by 12mm tubes each containing a single 144 fibre cable and 1 by 12mm tubes each containing 6 by 4mm micro tubes,
  - 50mm OD with 3 by 12mm tubes each containing a single 144 fibre cable and 1 by 12mm tubes each containing 6 by 4mm micro tubes,
  - 40mm OD with 2 by 12mm tubes each containing a single 144 fibre cable and 2 by 12mm tubes each containing 6 by 4mm micro tubes,
  - 32mm OD with 1 by 12mm tube containing a single 144 fibre cable and 1 by 12mm tubes each containing 6 by 4mm micro tubes.
- In the Analysys model, the standard unit of fibre capacity becomes the 144 fibre cable housed within a single 12mm tube, so that there are 72 pairs of fibre maximum per duct, with multiples of this number of fibres in the larger duct configurations as used in the model.
- Other configurations could be provided for special situations such as business parks and CBD installations.
- Each Pillar to RAU, LPGS, Exchange would then consist of multiples of the above cable configurations.

The deployment of ducts within trenches will use the same trench cost per duct size as that used in the copper model. It is acknowledged that the cost structure used in the copper model is less than optimum, but if these figures are changed in the fibre model they should also be changed in the copper model. Without doing both the comparison would be invalid, so it is proposed to use the same trenching costs for both models and to base this on the current Analysys figures.

4.3.Other Assumptions

The Analysys models are built on the core assumption that the existing Telstra exchange locations and numbers are used within the models. As indicated in a separate paper[4] this assumption does not lead to an optimum fibre deployment model, but again changing this assumption would require substantial structural change to the model which is beyond the scope of this exercise. Hence this assumption is retained as per the Analysys copper model.

The Analysys models then define a network of nodes around which the copper access network is optimized. The P2P fibre network would automatically assume the same nodes unless modified to do otherwise. Hence we end up with a set of inherent assumptions around which the P2P fibre access network will be implemented including:

- Existing RAUs, LPGS and Exchanges are used for active access equipment,
- The existing copper based pillar and trench architecture is used for the distribution fibre (consistent with the description in section 4.2),
- All demand for a single customer is satisfied by a single pair of fibres (consistent with the description in section 4.2).

[4] Milner Consulting Limited, FTTP Cost Study – Public Version, As prepared for the New Zealand treasury, February 2009.

It should be noted that a pair of fibres has been provided per premise in the above architecture descriptions. For many applications of fibre access today, it is possible to use a single fibre strand per premise. Coarse wavelength division multiplexing is used to provide the go and return paths over the single fibre strand. However, not all technology choices are best suited to using this approach – either today or expected to be so in the future. Hence it is considered to be prudent to deploy a pair of fibres per premise in order to be certain that technology choices are not constrained in any way in the future.

All of these assumptions dictate much of the architecture associated with the P2P fibre implementation defined by the Analysys Model. These assumptions avoid structural change to the model, but may not result in a cost structure as low as might be achieved if a pure green-fields approach was to be used.

4.4.Unit Cost Changes

There are many parameters within the existing model which assumes a copper based access network architecture. Most of the resulting unit cost elements are required as part of a P2P fibre access deployment, but many of the parameters would have different values in a fibre implementation. The following describes the changes that are required to the unit costs with a transition from a copper optimized access network to a fibre one, which is optimized within the constraints of the basic Analysys Model.

4.4.1. Trench unit costs

The trenching costs will be similar for both technologies. The same length of trench is required to serve the same customer demographic and the costs for trenching should be very similar. The only advantage offered by the fibre deployment is that more fibres can be accommodated in a smaller duct space than is the case for copper. This should automatically adjust itself in the model through the mapping of duct costs to trench costs as illustrated in more detail below. However, in practice, this mapping did require some careful interpretation and special manipulation in order for the Model to produce a robust outcome.

Currently the trenching costs within the copper model are based on a basic cost of AUD30 per meter. This base trench cost is considered to be low as an average value across all of urban Australia, but is common to both models, so will not be changed for comparison purposes. This base figure increases in some relationship with the number of ducts deployed in the trench. This is essentially a correct assumption, except that the cost structure is quite different to what I would expect. It is certainly not optimum relative to my understanding of trenching costs. However, again, it is proposed that the cost structure for trenching as provided by Analysys be used consistently for both the copper and fibre access models.

4.4.2. Duct Unit Cost

The cost of duct to house the majority of copper cables in the Analysys model are as listed in Table 1 below. The costs for the duct are substantial especially for the larger duct capacities. However, it should be noted that the dominant duct configurations in use within the model are those labeled Duct 1-8. It is understood that the duct handling costs are included within the figures provided in Table 1.

Duct Type	Duct (AUD)
Duct 28	400
Duct 24	360
Duct 20	300
Duct 16	240
Duct 12	180
Duct 8	120
Duct 6	89
Duct 4	74
Duct 2	58
Duct 1	29

Table 1: Duct costs within the Analysys Model.

Fibre cable is typically deployed in a managed duct system to enable the easy blowing of fibre cables and jointing of the cables. Some typical duct costs are:

- Duct containing 5 by 10mm tubes including fittings AUD7.90 per m
- Duct containing 5 by 12mm and 7 by 6mm tubes plus fittings: AUD10.02 per m

In both cases the total handling cost for the duct is AUD1.15 per meter.

The difference in duct cost appears to be very substantial. As the cost of deployed duct represents more than 60% of the total capital expenditure cost for the network, then this change will have a substantial impact on the overall cost of the access network in favor of fibre deployment.

In order to match the duct cost structure to that which is used in the copper cost model, the duct cost model which has been used in the Analysys Model for the fibre access network is as follows:

No. of 144 fibre cables	No. of 4mm micro tubes	No. of 12mm tubes	No. and type of ducts	Installed cost of duct (AUD per meter)
1	6	2	1 by32mm	8.15
2	6	3	1 by 40mm	9.15
3	6	4	1 by 50mm	10.15
4	6	5	1 by 63mm	11.15
5	6	6	1 by 63mm	11.15
6	6	7	1 by 63mm plus 1 by 32mm	19.30
7	6	8	1 by 63mm plus 1	19.30

			by 32mm	
8	6	9	1 by 63mm plus 1 by 40mm	20.30
9	6	10	1 by 63mm plus 1 by 50mm	21.30
10	6	11	2 by 63mm	22.30
11	6	12	2 by 63mm	22.30
12	6	13	2 by 63mm plus 1 by 32mm	30.45
13	6	14	2 by 63mm plus 1 by 32mm	30.45
14	6	15	2 by 63mm plus 1 by 40mm	31.45
15	6	16	2 by 63mm plus 1 by 50mm	32.45
16	6	17	3 by 63mm	33.45
17	6	18	3 by 63mm	33.45
18	6	19	3 by 63mm plus 1 by 32mm	41.60
19	6	20	3 by 63mm plus 1 by 32mm	41.60
20	6	21	3 by 63mm plus 1 by 40mm	42.60
21	6	22	3 by 63mm plus 1 by 50mm	43.60
22	6	23	4 by 63mm	44.60
23	6	24	4 by 63mm	44.60
24	6	25	4 by 63mm plus 1 by 32 mm	52.75

25	6	26	4 by 63mm plus 1 by 32mm	52.75
26	6	27	4 by 63mm plus 1 by 40mm	53.75
27	6	28	4 by 63mm plus 1 by 50mm	54.75
28	6	29	5 by 63mm	55.75

Table 2: Duct cost profile as used in the modified Analysys Model.

4.4.3. Combined trench and duct unit costs

Although the comparisons are not perfect, the copper cable deployed in the Analysys Model will be contained in ducts which when buried will have a unit cost of between AUD60 and AUD 641 per meter deployed, as shown in Table 3.

	Urban deployment: trenched duct			
Duct Type	**Provision of trench (AUD)**	**Installation of guard wire (AUD)**	**Duct (AUD)**	**TOTAL (AUD)**
Duct 28	240	1.35	400	641
Duct 24	240	1.35	360	601
Duct 20	240	1.35	300	541
Duct 16	120	1.35	240	361
Duct 12	120	1.35	180	301
Duct 8	60	1.35	120	181
Duct 6	60	1.35	89	150
Duct 4	30	1.35	74	105
Duct 2	30	1.35	58	89
Duct 1	30	1.35	29	60

Table 1: Trench and Duct costs for a copper based access network from the Analysys model.

In comparison the unit cost for the roughly equivalent buried fibre duct will be around AUD 40-312 per meter as shown in Table 4. This is a substantial reduction in unit cost by around 30-60%. If this unit cost reduction is achieved across the entire access network, it represents a saving of more than AUD5B.

	Urban deployment: trenched duct			
Duct Type	**Provision of trench (AUD)**	**Installation of guard wire (AUD)**	**Duct (AUD)**	**TOTAL (AUD)**
Duct 28	240	1.35	55.75	297.10
Duct 24	240	1.35	52.75	294.10
Duct 20	240	1.35	42.60	283.95
Duct 16	120	1.35	33.45	154.90
Duct 12	120	1.35	30.45	151.80
Duct 8	60	1.35	20.30	81.65
Duct 6	60	1.35	19.30	80.65
Duct 4	30	1.35	11.15	42.50

Duct 2	30	1.35	9.15	40.50
Duct 1	30	1.35	8.15	39.50

Table 4: The Deployed duct costs for a fibre based access network.

In practice most of the cost in the access network is related to the smaller Duct values, where the savings is least. Even so this change alone would suggest a cost saving as indicated in Table 5 below. The actual savings are likely to be less than that indicated in Table 5, as the distribution of duct usage will be biased to the lower values in the case of fibre deployment and other cost impacts will counter those indicated in this table.

Duct Type	**Total Copper Access Capex (AUD billions)**	**Percent Savings for Fibre deployment**	**Actual Savings from Fibre Deployment (AUD billions)**	**Fibre Duct Deployment Cost AUD billions**
Duct 1	9.221	34	3.135	6.086
Duct 2	6.947	55	3.821	3.126
Duct 4	2.735	59.5	1.624	1.111
Duct 6	0.570	45	0.256	0.314
Duct 8	0.070	54	0.0377	0.0323
Duct 12	0.0098	48.5	0.0047	0.0051
Duct 16	0.0012	54	0.0006	0.0006
Duct 20				
Duct 24				
Duct 28				
TOTAL	19.554		8,879	10.675

Table 5: Predicted cost reductions for the deployed duct network for the fibre access network relative to the copper access network.

4.4.4. Fibre Cable Unit Cost

In the Analysys Model, the 100pr copper cable is priced by Analysys at AUD4.19 per meter. The roughly equivalent fibre optic cable is a 216 fibre single mode cable which is priced at AUD5.48 per meter. This comparison is highlighted in Tables 6 and 7 respectively. Although the copper cable has a slightly lower unit cost relative to the fibre cable, the capacity of a pair of fibres is considerably greater than that for the equivalent pair of copper wires. This particularly applies for the provision of multiple services, where the single pair of fibre strands can support any services that can be contemplated for any premise. On the other hand, a single pair of copper wires can only be used for a relatively narrow range of services and in the Analysys Model several pairs of copper wire are used to deliver multiple services, so that the unit cost of copper relative to fibre is considerably in favor of the fibre for the delivery of rich multimedia services.

Copper Cable Type (pairs)	Cable Unit Cost (AUD per m)	Hauling Cost (AUD per m)	Delivery and Handling (AUD per m)	Total Deployed Unit Cost (AUD per m)
2	0.17	1.73	0.03	2
10	0.63	3.00	0.13	4
30	1.50	3.00	0.30	5
50	2.27	3.00	0.45	6
100	4.19	3.00	0.84	8
200	7.45	3.38	1.49	12
400	13.96	4.14	2.79	21
800	26.98	5.66	5.40	38
1200	40.00	7.18	8.00	55

Table 6: Deployed copper cable unit costs .

Fibre Cable Type (No. Single Mode fibres)	Cable Unit Cost (AUD per m)	Hauling Cost (AUD per m)	Delivery and Handling (AUD per m)	Total Deployed Unit Cost (AUD per m)
6	1.28	0.20	1.15	2.63
12	1.57	0.20	1.15	2.92
24	2.09	0.20	1.15	3.44
48	2.79	0.20	1.15	4.14
96	3.49	0.20	1.15	4.48
144	4.36	0.20	1.15	5.71
216	5.45	0.20	1.15	6.8

Table 7: Deployed fibre cable unit costs.

As indicated in Section 4.4.2 above, most of the fibre network is deployed using multiples of 144 fibre cables, plus 6 fibre cables for final drop lead. The unit cost for 144 fibre cable installed in a 12mm tube is AUD5.71 per meter. This implies that the cost of a pair of fibres from the DP upstream is AUD0.079 per meter. The cost for a deployed pair of fibres downstream from the DP to the premise termination point is AUD3.20 per meter.

In the fibre to the premise models, it is assumed that all services required for any premise can be delivered over a single pair of fibres. In practice, for some business premises two pairs of fibres will often be used to deliver diverse access, but it is not clear how the Analysys model deals with this market requirement, if at all. It is also true that some fibre deployment approaches can be achieved using a single strand of fibre per premise. As this is not universally applicable, 2 fibre strands per premise has been used consistently throughout the discussion which follows. This is the most conservative approach.

A 100pr copper cable requires a minimum of a 25mm inside diameter sub-duct to enable successful hauling. In comparison a 144 fibre cable can be blown through a 12 mm diameter tube and a 96 fibre cable can be blown through a 10mm tube. Hence a typical 100mm inside diameter duct can accommodate many more fibres strands, than it can copper wires. These features reduce the overall cost of trenching and duct deployment for the fibre architecture.

Fibre cable is much lighter than that for copper and hence the deployment of fibre cable is undertaken using different procedures. Copper cable is typically hauled through a duct using a hauling wire. For copper cables of about 100 pairs and over, the maximum hauling distance is about 200m, so that pits need to be deployed at about this separation or less. The Analysys Model typically uses a maximum of 100m separation. The cost for hauling copper cable through a duct is estimated by Analysys to be around AUD3 per meter. On the other hand, fibre cable of almost any capacity can be blown through ducts using forced air over ranges up to around 1km in length. The cost per meter to do this is about AUD0.20, which is substantially less than that for copper. The fibre blowing does require some special equipment, but the capital cost of such equipment is very low when distributed over a very large deployment, as would be the case for Australia.

As mentioned above, a further saving can be made through the need for fewer pits for jointing of fibre cables, as the blowing technique can be used over distances of up to 1km. However, the full value of this attribute can only be fully realized in rural areas. In most urban areas pit placement is determined by the need to joint cables to feed along streets. This tends to limit the average pit separation to about 250m. The urban deployment uses this figure as the maximum separation between DPs.

Not all costs associated with fibre cable are reduced relative to those for copper cable. There are two areas where copper cable has lower unit costs than that for fibre and these are:

- The jointing of fibre optic cables,
- The termination of fibre optic cables.

Whereas a copper wire costs around AUD2 per joint, the equivalent joint for fibre optic cable is AUD20 per joint. This looks to be a significant unit cost increase. However, as there is only one joint per 100m typically for copper cable and 1 joint per 250m or more of fibre cable, the contribution of joints to the cost per meter of cable deployed is relative small for either case.

Similarly, the cost of terminating a pair of copper wires on an MDF is only around AUD2, whereas the cost per pair for fibre optic cable terminated on an Optical Fibre Distribution Frame (OFDF) is around AUD40. Again, the termination only occurs every kilometer or more of cable, so the contribution to the unit cost per pair meter for either technology is very low.

Overall the jointing and termination costs for fibre do not contribute greatly to the unit cost of deploying fibre cable relative to that for deploying copper cable.

4.5.Optical Network Unit

There is no question that the cost of deploying an optical network unit at any customer premise is significantly higher than that to deploy an analogue telephone on the end of a pair of copper wires. However, in today's market, the need for a simple analogue telephone only at most premises has been superseded long ago. Most premises require various forms of data service as well as telephony and increasingly video services are delivered over the same access infrastructure. In this case, the unit costs for termination equipment for either copper or fibre begin to become more balanced. A simple DSL modem, terminated on copper, together with appropriate customer cabling and filtering, costs about AUD100-200 per premise. A more sophisticated Residential Gateway that supports high speed Internet, analogue telephony adapter (ATA) and video ports plus the associated cabling will cost around AUD 300-500. This latter figure is quite comparable with that which can be expected for an Optical Network Unit (ONU) which supports a similar array of end user services.

It is important to recognize that the unit costs for copper and fibre terminal equipment are only comparable when one also considers a comparable set of end user services. Furthermore, the fibre solution is only really comparable when the services required by the customer involve a rich mix of multimedia services as compared to a single service such as analogue telephony.

It should be noted that the Analysys Model ignores the terminal equipment costs. It simply assumes that the network terminates on a terminal block located at the customer premise. This approach has also been taken for the fibre network to enable comparison with the copper network model. For the fibre lead-in, the terminal box is assumed to cost AUD20 and there is an additional AUD20 to terminate the fibres. However, it needs to be noted that there is an additional cost associated with the ONU for any practical deployment.

4.6.Operational Cost Reductions

Many studies have been undertaken comparing the cost of maintaining fibre on a pair kilometer basis as compared to copper on a pair kilometer basis. Many of these studies have compared brownfields copper deployments relative to greenfields fibre deployment. In this case the operational savings due to lower fault incidences is considerable, being in the order of 30-40% unit cost reduction for fibre relative to copper. This is because aging copper is highly susceptible to corrosion of joints and reduced insulation integrity due to water ingress. However, this is not a fair comparison, when both the copper and fibre infrastructures are deployed on a Greenfields forward looking basis, as is the case with the Analysys models.

When both greenfields copper and fibre are compared on an operational cost basis, the following factors need to be considered:

- The probability of a fault caused by a digging error is equal for both technologies,
- The cost of jointing a broken fibre cable is higher than that for the equivalent copper cable,
- The cost of repairing a ducted fibre optic cable system is typically less than that for the equivalent copper cable system due to the use of innovative duct management technology,

- Fibre cable and joints are not as prone to water damage or other environmental impacts as those for copper cable,
- Managed duct systems for fibre cable enable less disruption to the longitudinal fibre cables than that for copper cables as premises are connected and disconnected to and from the network,
- Fibre optic cables are not susceptible to induced electrical noise.

All of these factors mean that a FTTP access network offers lower operational costs to that for an equivalent copper access network. The actual cost savings will vary widely depending on underground plant management regimes applying in given locations. However, one could expect a minimum of 10% reduction in annual maintenance costs per kilometer of deployed fibre pair as compared to a kilometer of deployed copper pair. A more typical figure would be in the range of 20% unit cost savings. To date, the Analysys Model has not been modified to reflect these operational cost reductions. This would require a significant additional effort, which time did not permit.

4.7.Overall Cost Impact

A full analysis of the likely cost savings through the deployment of a P2P FTTP network has yet to be completed. However, the reduction in duct cost alone is expected to reduce the cost of the access network by more than AUD 5B relative to that for copper as applied in the Analysys model. Further work is required to confirm the exact amount of capital cost reduction. Preliminary results from the Model suggest that the overall capital cost reduction lies in this same range for the P2P fibre access network model.

In addition, as indicated above, the operational cost savings are also expected to be in the range of 10-20% per pair kilometer as compared to the copper equivalent. This factor has not been investigated using the Analysys Model to date.

5. Passive Optical Networking (PON)

5.1.Overview

Industry best practice identifies PON as having about 15% cost reduction relative to Point-to-point fibre architectures. The trade-off is that the PON architectures that are currently economic to deploy involve some compromise in terms of end user capacity that can be delivered. A standard G-PON architecture with 2.5Gbps downstream and 1.2Gbps upstream and using a 32:1 splitter delivers a maximum dedicated bandwidth to each premise served of around 70Mbos on the downstream and 30Mbps on the upstream. Of course the peak bandwidth is effectively much higher, but this cannot be used in a sustained manner by any single user.

In order to deliver higher dedicated bandwidths per premises served, either the splitter ratio must be reduced or the peak bandwidths must be increased. Reducing the splitter ratio, results in an increase in cost per premise served. On the other hand a new version of PON called Next Generation PON (NG-PON) is now being standardized which will deliver peak bandwidths of 10Gbps downstream and 2.5Gbps upstream. This would enable downstream services per premise served of over 100Mbps and upstream of over 50Mbps while still using a 32:1 splitter.

In practice, the bandwidths offered by PON solutions are adequate to meet the needs of most residential customers and most small business (<6 employees) customers. As these customers have a low willingness to pay, the cost reductions which can be achieved using these technologies for these segments of the market can be very worthwhile. On the other hand, the constraints offered by PON technologies which are available now and are likely to be available over the next 10 years at affordable prices, means that there also needs to be P2P fibre solutions available for medium to large business and government premises. Hence the optimum fibre deployment solution involves a hybrid model, involving both P2P for medium/large business and PON for residential and small business. This is a preferred approach by many commentators.

Unfortunately the Analysys model developed for the ACCC is not well suited to PON deployment. The ability to manipulate the model to deliver a satisfactory PON outcome has shown itself to be very challenging. This is because the model does not inherently have a means of sharing physical access infrastructure across multiple premises. The only way in which this might be achieved, is to make each pillar in the access architecture equal to a 32:1 optical splitter. This dramatically changes the basic access architecture delivered by the model, and has proven to cause the model to fail. Certainly, such a radical change to the model has been shown to drive a set of consequential impacts which does destroy the integrity of the model.

The ability of the Analysys model to incorporate a hybrid PON and P2P access model is impossible. Once into the access topology component of the model, the distinction between medium/large business premises and small business/residential premises is no longer evident. The model treats all premises equally, simply based on their demand for services. Hence the distinction between these customer segments and their specific network architecture requirements in a hybrid architecture appears to be impossible to replicate in the Analysys model as it currently exists.

Hence, if a hybrid model outcome is required, the only way it could be achieved is to blend the outputs of two separate models, one which deploys P2P only and one which deploys PON only. This of course assumes that the individual P2P and PON models can actually be made to function correctly. Even then the resulting answers would only be approximations as the blending of the two model outputs is by no means a trivial exercise and is subject to some considerable approximations.

5.2.PON Assumptions

In the discussion which follows, it was assumed that the optical splitters could be located at the pillar locations in the Analysys model. As indicated above, the actual pillar locations may well change so that any one pillar in the new model only accommodates one splitter, or about 32 customers, as compared to the nominal 300-400 customers accommodated within the current model for the pillars.

Further, it was assumed that the PON terminal equipment is located at RAUs, LPGS and exchange locations. In most cases it would be possible to bypass any RAUs or LPGS and only install PON equipment in exchange buildings, but it is not clear whether the model in its current form will enable this outcome.

Obviously, the trade-off here is a reduced number of active nodes in the access network, but with a commensurate increase in the number of passive pillar nodes.

5.3.Unit cost changes

The basic unit cost changes for PON are very similar to that for the P2P case. Again the use of fibre essentially reduces the volume of duct required and the fibre can be blown into the tubes as compared to being hauled through the duct as with copper cables. These factors do produce a substantial reduction in cost, even when countered by the higher jointing and termination costs for fibre optic cable.

5.4.PON Specific Cost Reductions

In addition to the above, PON has some additional cost reduction factors. A major factor which further reduces the cost of the PON solution is the need for less fibre optic cable in the feeder component of the access architecture. Every premises requires an individual fibre connection from the premise to the optical splitter (usually this consists of a pair of fibres, but in some configurations could be a single fibre). Beyond the splitter in the feeder section of the fibre plant, there only needs to be around one fibre pair per thirty premises (or less if a higher splitting ratio is used).

The second key area in which the costs of a PON solution differs from that of a P2P fibre solution is that related to the Optical Terminal Equipment. In the PON case, each port on the terminal equipment is used to serve the total number of premises connected to a single optical splitter. Hence if the splitter is used to feed 32 customers, then the port cost is also spread over the same number of customers. Typically today, a PON port would cost around AUD1000 as compared to a P2P Ethernet port at around AUD300 per port. However, the cost per premise ends up being around AUD30 for the PON case as compared to remaining at AUD300 for the P2P case, or a 10:1 unit cost improvement for PON.

The final area in which there is a potential cost difference between the P2P fibre deployment and the PON fibre deployment is with the Optical Network Unit located at the customer premises. The cost of these units varies considerably, depending on the functionality provided in the unit. A basic unit which supplies a simple Ethernet bit-stream service only may cost as little as AUD300 deployed. However, most units deployed today include as minimum 2-3 analogue voice ports and at least one video port as well as at least 4 Ethernet ports. In addition, the unit can be deployed with back-up battery power should the mains fail. All of these features can more than double the cost of the PON ONU. Hence the cost is likely to lie in the range of AUD300-600 installed.

5.5.Operational Cost Reductions

The operational costs for a PON deployment are similar to those for a P2P fibre deployment. The only change is related to the number of fibres deployed, which can reduce the costs by a percent or two relative to the P2P fibre access network case.

5.6.Overall Impact on Cost for a PON Deployment

As indicated in the introduction, the best industry wisdom is that a PON deployment has a capital cost which is around 15% less than that for a P2P fibre deployment over the same area and with the same number of connected premises. The operational costs are also expected to be marginally less than that for the P2P deployment. The actual number that will result from the use of the Analysys model is very difficult to predict. Unfortunately, the Analysys model in its current form is certainly not optimal for the modeling a PON deployment, without considerable modification. Hence it is very hard to predict what reduction of cost relative to the P2P approach will be achieved using the Analysys Model.

6. Impact of Fibre Access on Core Network

The core network should simply scale to meet the increased traffic demand that would be expected to result from the deployment of a fibre based access infrastructure. In practice this would occur over time as new services are introduced and customers take up the new services. Hence the expansion of the capacity of the core network would normally be enhanced in a timely manner to cater for this increase in demand.

The Analysys model for the core network should in theory also expand its capacity to meet the new demand for customer services over the fibre access network. Certainly, the NGN core network should only be used in conjunction with the fibre based access deployments (either P2P or PON) as this network design has more capability to expand and also supports the voice over IP required to deliver telephony services to end users over fibre. However, even in the NGN case, the Analysys core network model is heavily reliant on SDH capability, which is not particularly cost effective when predominantly Ethernet based services are being delivered end to end. Hence it is uncertain as to whether the Analysys core network model will scale well in practice. Even if it does scale relative to the increased demand, there is still an issue as to whether it will have a cost structure optimized for use with a fibre access network. The costs are likely to be considerably higher than that which could be achieved with a core network design optimized for use with a fibre access network.

7. Overall Impact of Fibre Access on Cost

It will be evident from the above discussion, that there are both pros and cons in terms of costs for a fibre to the premise based access network deployment. If for example, the customer demand for services was limited to simple telephony only, then deploying a fibre based access network to satisfy this demand alone would not be economical relative to the deployment of a simple copper based access network to satisfy this same demand. On the other hand, if it is assumed that customers will continue to demand much more than plain telephony then the deployment of a fibre to the premise based access network will be the lowest cost approach to satisfy this demand, especially if we are working from a greenfields deployment perspective. The critical issue here is that the fibre access infrastructure needs to satisfy a rich media content and application demand from customers. Otherwise, the inherent capability in the fibre network is wasted and the opto-electrical conversion costs required to carry the traffic over the fibre tends to drive the absolute cost of service delivery.

Given that there is sufficient forecast demand from customers for the purchase of rich media content and applications, then the deployment of fibre to the premise offers the lowest cost solution for the delivery of these services, especially if a new infrastructure of some kind must be deployed – ie. We are working from a Greenfields situation. Today, the cost of fibre cable of equivalent number of pairs to copper cable is roughly equal. Any advantage in unit cost which copper might have today is being rapidly eroded away as the cost of copper increases on world markets and the cost of fibre decreases. Given that a trench must be deployed for either technology this is not a differentiator. On the other hand, the cost of ducts within the trench and the cost of deploying the fibre in the ducts is considerably less than that for the equivalent copper cable. The costs associated with jointing and terminating copper cable is lower than that for fibre cable, but the cost contribution of these activities per meter is low. Furthermore, in an optimized fibre access network deployment, the need for joints per unit length is less. Modern fibre duct management systems reduce this need even further.

The cost of terminal equipment at the customer premise is slightly higher than that for copper based terminal equipment, especially where lower functionality is required. However, where similarly high levels of functionality are required from the copper or fibre terminal equipment, the cost tends to move more in favor of the fibre based solution. Where, considerable functionality is required at the customer premise such as with medium to large businesses, there is no debate about which is the more cost effective solution – the fibre access wins hands down. Hence the relative cost of terminals depends a lot on what services are being delivered to the premise and if we assume that customers will continue to demand more functionality, then the cost will continue to swing in favor of fibre to the premise.

The cost for core network equipment is similar to that for the customer terminal equipment except that the economies of scale and scope are much more prevalent. Hence the costs in the core network today are very similar for either fibre or copper based access solutions, assuming that the core network is optimized for the types of services that are being delivered to customers over the access network. A core network that is optimized for the delivery of telephony, over a copper network will not scale well to deliver rich multi-media services over either a copper or fibre access network. On the other hand, a core network which optimized for the support of rich multimedia services over either a copper or fibre access network will be roughly equal for either access technology. As the take-up of rich multi-media services increases the benefits of having fibre in the access network will increase and the cost advantage will reflect into the core network as well as the access network.

All of the above has been focused on capital costs for deployment and enhancement of network capability. The operational picture is slightly different. Many large service providers such as Verizon have partly justified the move to deploy fibre to the premise on the basis of reduced operational costs relative to those for a copper based access network. Part of the operational savings in some of these models is based on the difference in fault profiles between aging copper plant and new fibre plant, but even when this factor is eliminated from the analysis, the operational cost savings arising from the deployment of a fibre based access network are significant, being in the order of 10% per annum or more.

The remaining question is whether the use of the Analysys model to model fibre to the premise deployment will demonstrate all of the above dynamics? This is highly uncertain. Certainly, in theory, the Analysys model should be access type agnostic. The model simply deploys trenches and ducts to optimally provide connections to clusters of premises. This basic requirement is common to both access technologies. However, to some extent the model pre-determines the way in which duct is deployed in the trenches and then how the cable is deployed within the duct. Unfortunately, this is different for each of the technologies in detail, although the basic concept is similar for each case.

This is where the model has the potential to start diverging from the optimal deployment in the case of fibre as compared to copper. Then there are many details contained within the model which are optimized for a copper access deployment but which are not optimal for a fibre access deployment. However, it has been demonstrated that for a P2P fibre access architecture, the differences are small, so long as the individual cost parameters can be suitably adjusted. Hence the Analysys models are able to provide a reasonable estimate of the cost to deploy an equivalent P2P FTTP access network.

In the case of the PON based fibre access architecture, there are more significant architectural challenges. It is not possible to use the Analysys Model to develop a cost structure for a PON based access network.

8. Sensitivity to Errors

Any model of the complexity of that prepared by Analysys is subject to many sources of error and approximation. It is not that the model is wrong, but rather the results are subject to the many assumptions and approximations contained within the model. Throughout the analysis presented above, these issues have been encountered and new assumptions and approximations have had to made in order to get the model to deliver a reasonable representation of a P2P fibre to the premise access architecture and associated cost structure. Hence the accuracy of the resulting model outcomes must also be limited by these inherent assumptions and approximations. In the case of the PON based FTTP architecture, it is considered impossible to use the existing model to provide a reasonable assessment of the resulting costs due to these limitations.

In fact, it is clear from this exercise that the original copper based model is subject to these same considerations. Although the architecture chosen by Analysys is better optimized for copper deployment than fibre deployment, it is still subject to similar constraints. For example, the way in which trenching and duct installation is done in the model is certainly an approximation to that which would apply in practice. This approximation is required in order to support the algorithms used in the model. However, they are still approximations and so are subject to considerable variation in terms of real costs verses modeled costs. As this part of the model represents about 40% of the total model costs, any error at this level can have a big impact on the outcomes derived from the model.

The major assumptions that give concern in the Analysys copper model are:

- The cost of trenching being a single number averaged over the entire Australian access network which is a massive approximation, as soil conditions vary greatly throughout Australia, and hence so will the costs of trenching.
- The cost of trenching is a function of the number of ducts deployed in a trench, as indicated by Analysys, but the cost profile is much more non-linear than that indicated by Analysys. Typically, one or two ducts (depending on diameter) can be deployed by directional drilling or similar low

cost approaches (typically AUD40-100 per meter depending on ground conditions), whereas for 4 or more ducts a much higher open trenching cost must be used (typically AUD150-600 per meter depending on ground conditions). Once an open trench has to be dug, the cost per duct for deployment becomes almost linear again. This actual trench cost profile is not well approximated by the Analysys copper access network model.

- The cost per duct deployed appears to be substantially higher than modern technology would suggest. Again the approximations used in the model make the exact issues with this parameter difficult to determine, but the approximation used in the copper model is certainly not industry best practice.

The critical issue for the modeling outcomes is that any errors in the above parameters have a big impact on the overall model outcomes. Even an AUD10 error in the cost of trenching has a roughly billion dollar impact on the overall cost structure generated by the model. Hence the model must be considered to be highly subject to these types of errors. In reality it is likely that the errors related to the above three factors could amount to several 10s of dollars variation in the cost of duct deployed, which could impact the model outcomes by as much as few billion dollars.

In order to make a useful comparison between the model being used to cost a copper access network verses a fibre access network, it was decided that we should work with the copper cost model as presented by Analysys – errors, approximations, assumptions and all. This then provides a known baseline for comparison. The point to point FTTP cost model then uses the basic structure of the baseline model, but with the changes as identified in the above description, keeping as many of the original Analysys assumptions and approximations intact.

Furthermore, in order to use the Analysys model for to generate the fibre network costs, additional approximations have been made. Otherwise major structural changes to the Analysys model would have been required, and we wished to work with parameter changes only. Hence the resulting fibre access network costs are also subject to error.

The difference in cost between the fibre and the copper models are reasonably valid, as we are comparing against a common baseline. However, the absolute cost results need to be treated with considerable care. Firstly the fibre access network costs are not optimized, due to the limitations of the structure of the Analysys cost model and its ability to properly model an optimized fibre access network. Secondly, the fibre access network model contains most of the same approximations and assumptions, as are present in the copper access network model. Hence it is prone to the same errors as are present in the copper baseline model.

In summary, it is entirely valid to use the results of this modeling exercise on a comparative basis relative to the Analysys copper baseline model. The results achieved are certainly indicative of what could be achieved in deploying a fibre access network, as compared to a copper access network under the same set of assumptions. However, given this, it is essential to understand that in absolute terms, both models are subject to considerable error, due to the assumptions and approximations inherent within the baseline model, combined with those introduced specific to the fibre access model. This is not really the fault of the designers of the model, but rather is an inherent feature of any such cost model – **such models are simply not accurate in absolute terms**.

In absolute terms the error bounds should be expected to be in the order of plus or minus 20%. If this order of error bound is really achieved with the Analysys model, it would be a very good outcome for such a complex and comprehensive cost model. On the other hand, the comparative cost figures for the copper and fibre models are likely to have tighter error bounds, perhaps something in the region of plus or minus 10-15%. Still not perfect, but better than that for the absolute cost outcomes. It is essential to treat the results of this investigation in the light of this context.

9. Conclusions

This paper attempts to describe the changes that are required to implement a fibre to the premise based access infrastructure, as compared to a copper based access network. It is fully expected that the fibre based access infrastructure will deliver a lower cost structure overall for the delivery of rich multimedia services, than that offered by an equivalent copper access network, under similar greenfield deployment conditions. This would also align with current best industry wisdom.

However, the additional factor involved in this study is the use of the model prepared by Analysys Mason for the ACCC. This model was designed for the delivery of all services to the premises over copper cable and it has been optimized for this scenario. Getting such a model to deliver similarly optimized results for the deployment of FTTP presents some special challenges. It has been found that this model can deliver an estimate of the costs for FTTP deployment under specifically defined conditions.

As expected the Analysys model is able to model the deployment of a P2P fibre based access infrastructure. This fibre access architecture has the greatest commonality with a copper architecture and hence has the highest probability of success. Even so it is necessary to change a range of unit cost parameters for various items contained within the model in order to get a roughly optimized result. The preliminary results obtained from the modified Model suggest that the P2P based fibre access network offers some billions of dollars of capital investment reduction over that for the equivalent copper access network.

On the other hand, the ability of the model to deliver an outcome for the PON based fibre access architecture has proven to be futile. An approach was proposed to achieve this outcome, but it did not prove to be tractable.

Overall, it is evident that the Analysys models are not designed to deliver an optimal FTTP outcome. However, the model may provide some useful guidance as to the cost benefits of deploying a fibre based access infrastructure as compared to a copper one. However, further work is required to refine the preliminary results and gain confidence in the actual savings which can be achieved following optimization of the model for FTTP.