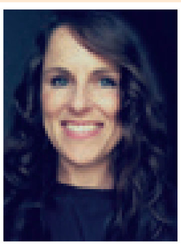
Fibre to the Business

Opportunities and Challenges

By Vanesa Diaz, Market Development Manager EMEA, Corning Optical Communications

Commercial subscribers represent a significant opportunity for CATV operators to grow their revenues quickly, with immediate returns on investment. A large percentage of the commercial market revenue resides with customers who are looking for more bandwidth scalability and flexibility. With today's fibre to the business solutions, MSOs are well-positioned to deliver fibre services to these customers by leveraging their existing assets.



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When it comes to deploying fibre to the business (FTTB), MSOs have traditionally faced two significant challenges. First, many operators find they don't have enough fibre in their networks to dedicate fibre pairs to every potential business customer and still support the growing network demands of residential services. At the same time, running new fibre from the headend or hub to potential business customers can be a cost-prohibitive solution.

Today, there are a number of cost-effective alternatives that are enabling MSOs to deploy fibre to the business using their existing fibre plant. Let's explore three of the most common fibre to the business architectures and their associated link losses.

Home run

The most common FTTB architecture deployed today, the fibre home run uses spare or "dark" fibres to feed each individual business.

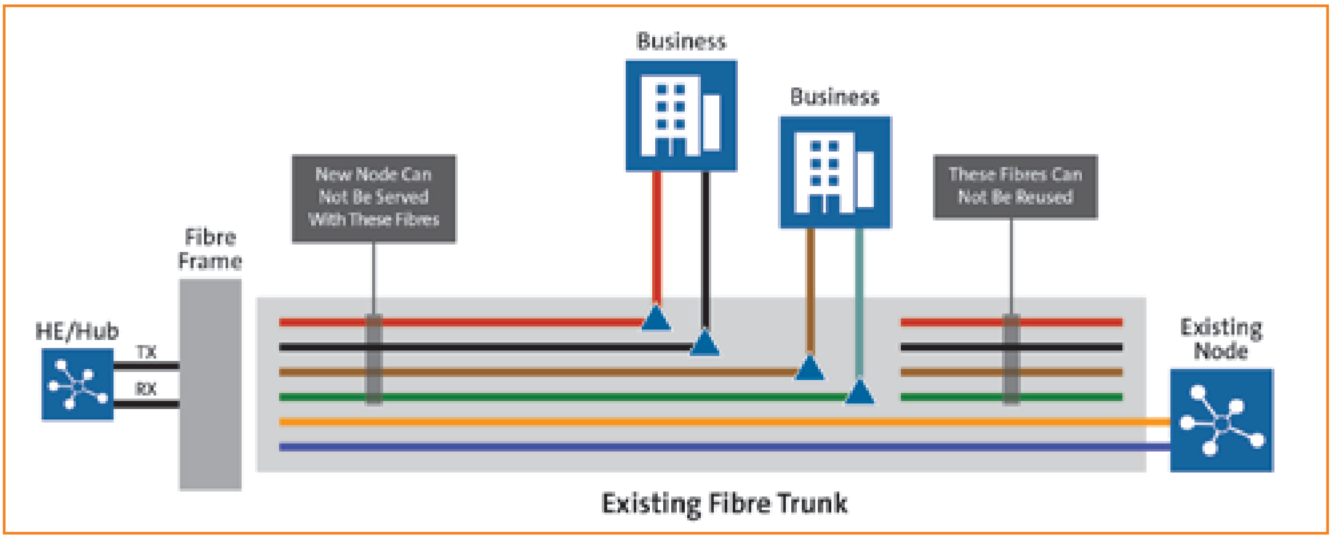

Figure 1: Fibre home run

In Figure 1 above, an existing fibre trunk feeds a residential node and two businesses. In this architecture, two fibres have to be "tapped" from the existing fibre trunk to support the business service. Usually these fibres are tapped from the existing four-six fibres that feed a residential node. In this scenario, the fibres downstream from the tapped fibres cannot be re-used unless a new cable is spliced into the trunk cable.

Let's examine this architecture in greater detail. Figure 2 below shows an area with eight potential business customers as well as a new residential area requiring a fibre node. To deliver service to the businesses and homes, an operator would have to re-enter an existing closure to splice 18 dark fibres in an existing trunk cable. As previously mentioned, many operators find that they don't have enough unused fibres in their trunks for new business customers, mainly because many of the spare fibres installed during upgrades have already been used for splitting/segmenting nodes or extending the plant into new residential areas.

Where spare fibres are available, however, the implementation of coarse wavelength division multiplexing (CWDM) and/or dense wavelength division multiplexing (DWDM) augmentation can be used to increase capacity for business services instead of using dedicated strands.

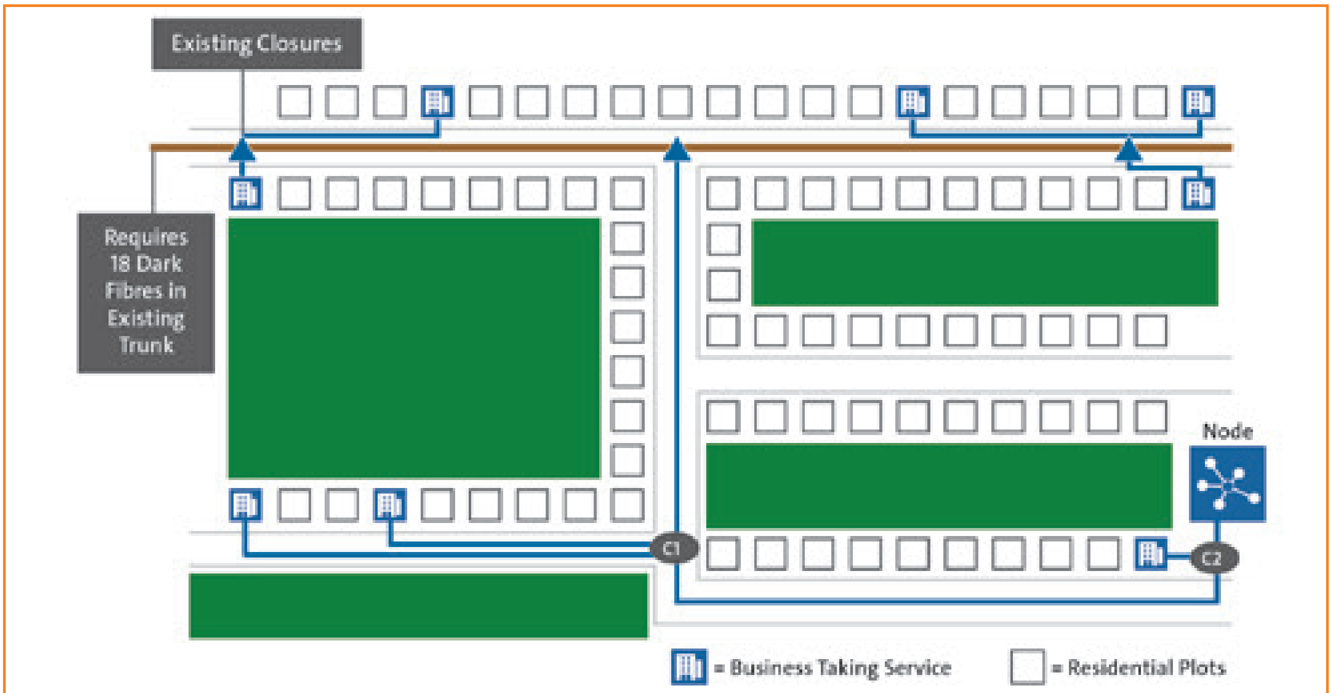

Figure 2: FTTB home run architecture-8 business + residential node example

Video @ 1310 nm		Probability 99.99997%	99.997%	99.87%	97.72%
Margin	dB	4.3	4.5	4.6	4.8
Transmission Budget	dB	12.0	12.0	12.0	12.0
Calculated Loss Budget	dB	7.7	7.55	7.40	7.25

Data Up/Down @ 1550 nm		Probability 99.99997%	99.997%	99.87%	97.72%
Margin	dB	19.5	19.7	19.8	20.0
Transmission Budget	dB	25.0	25.0	25.0	25.0
Calculated Loss Budget	dB	5.5	5.35	5.20	5.05

Adjust Con Loss Here		
Mean Loss per Unit	SD per Unit	Mean + 3 x Sigma
0.3	0.07	0.51

Adjust Dist Here	
Mean Loss per Unit	SD per Unit
Max Dist	20.0 km

Out of Spec

Table 1: Link-loss budget for fibre home run

To analyse the fibre home run link-loss budget side by side with other architectures, we will assume a 20km distance and include the loss in cabled fibre, mated connector pairs and fusion splices. As shown in Table 1 above, the home run link-loss budget is 7.7dB at 1310nm and 5.5dB at 1550nm.

This loss budget also compares two transmission budgets, 12dB for 1310nm video transmission and 25dB for 1550nm data transmission. For this example at 20km, both the data and video have positive margin at a 99.99997% confidence interval.

From a technical perspective, the pros and cons of the fibre home run architecture include:

Pros:

- Excellent network reach of 60km given a 25dB link budget.
- Purely passive system that is protocol-agnostic.

Cons:

- High utilisation of existing fibre plant.
- 18 dark fibres required for eight businesses and a node.

Passive Optical Network (PON)

In the passive optical network (PON), an MSO lights up one or two dark fibres to feed up to 16 or 32 businesses. 1G and 10G EPON tend to be the MSO's PON technologies of choice in accordance with IEEE 802.3av. 10G EPON wavelength utilisation (1575-1580nm downstream and 1260-128nm upstream) allows for coexistence with RF video (1550-1560nm) and GPON/1G EPON (1480-1500nm downstream; 1260-1360nm upstream). With DOCSIS provisioning over EPON (DPoE), the EPON OLT and subscriber ONU perform as a CMTS and cable modem would, using familiar DOCSIS management systems.

Figure 3 below illustrates how an existing fibre trunk feeds a residential node and two businesses using a PON. In this architecture, one fibre is tapped from the existing fibre trunk to support bi-directional traffic for business customers. An optical power splitter is used in the field to split a broadcast signal to multiple businesses. The standard wavelengths used in a PON are 1490nm for downstream data and 1310nm for upstream data. An analogue video signal can be multiplexed in at 1550nm. Two more fibres are needed for the residential

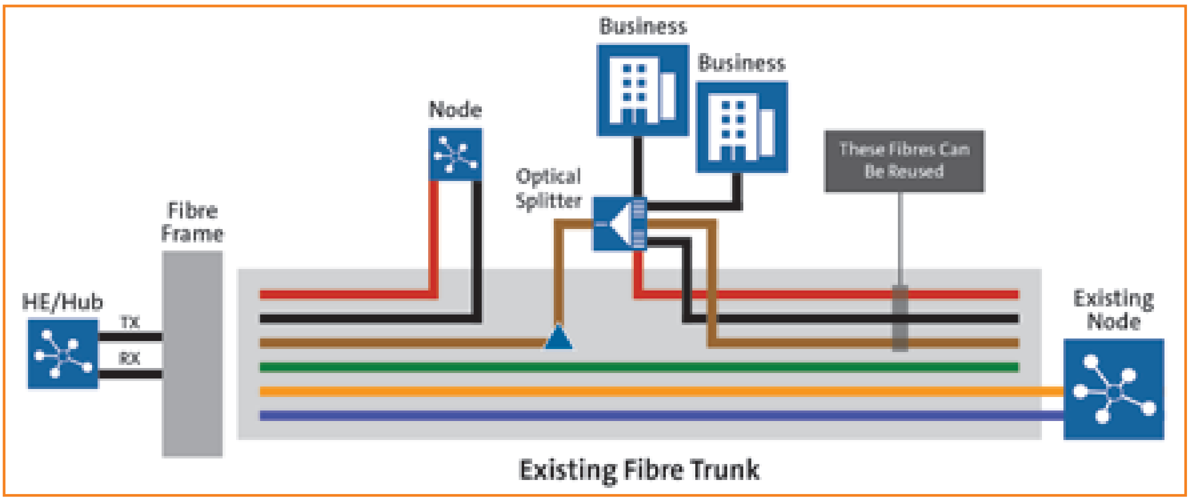

Figure 3: FTTB PON architecture

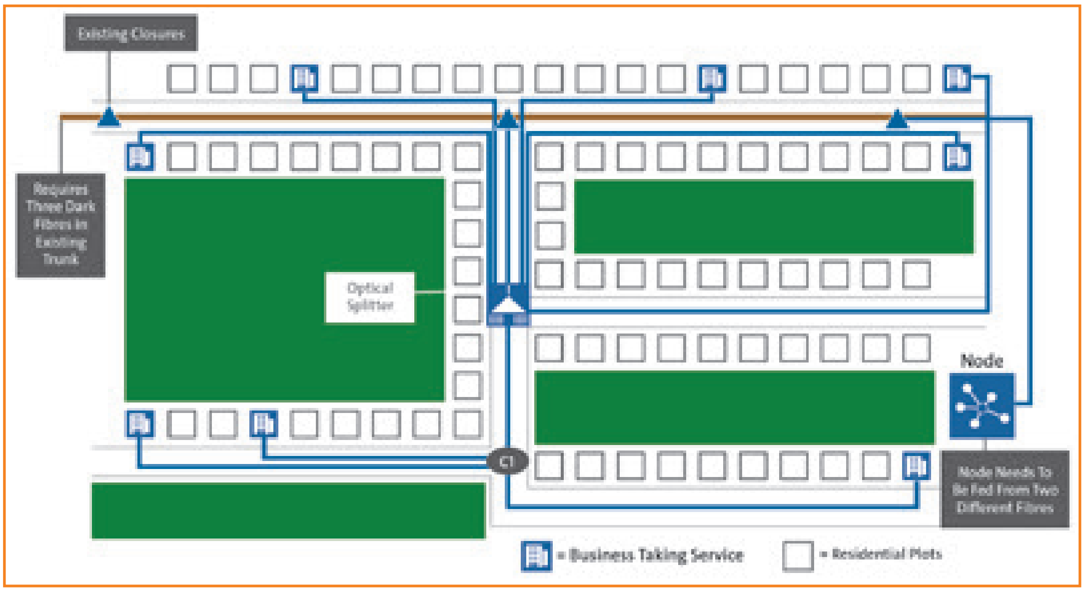

Figure 4: FTTB PON run architecture-8 business + residential node example

node. In this scenario, the fibres downstream from the tapped fibres can be re-used if enough optical power is available.

Using the same scenario as we used in the fibre home run, we will explore how a PON architecture can support up to eight new business customers and a new residential node.

As shown in Figure 4 above, to reach the eight businesses and residential node, the operator now only needs three dark fibres. In this scenario, the operator would have probably split a 1x32 PON into two or four PON networks by using a passive optical splitter in the headend or hub. A field-hardened, passive 1x8 splitter is then deployed in an outside plant terminal. From the terminal, one- or two-fibre drop cables are run to the customer premise. These terminals and drop cables can be pre-terminated with optical connectors to decrease the time and cost of fusion splicing.

Again assuming a 20km distance and taking into account the loss in cabled fibre, connectors, optical splitters (1x8) and fusion splices, Table 2 below shows the PON architecture link-loss budget is 7.7dB at 1310nm (based on a direct fibre connection to the node) and 17.0dB at 1550nm.

This link-loss budget also compares two transmission budgets, 12dB for 1310nm video transmission and 25dB for 1550nm data transmission. For this example at 20km, both the data and video have positive margin at a 99.99997% confidence interval.

The pros and cons of the PON architecture include:

Pros:

- Better utilisation of existing fibre plant, one or two fibres per PON.
- Adding a residential CATV node requires two additional fibre businesses and a node.
- Purely passive system.

Cons:

- Shared bandwidth.
- Distance limited by optical loss and protocol.

		Probability			
Video @ 1310 nm		99.99997%	99.997%	99.87%	97.72%
Margin	dB	4.3	4.5	4.6	4.8
Transmission Budget	dB	12.0	12.0	12.0	12.0
Calculated Loss Budget	dB	7.7	7.55	7.40	7.25
		Probability			
Data Up/Down @ 1550 nm		99.99997%	99.997%	99.87%	97.72%
Margin	dB	8.0	8.4	8.4	9.1
Transmission Budget	dB	25.0	25.0	25.0	25.0
Calculated Loss Budget	dB	17.0	16.62	16.24	15.86

Adjust Con Loss Here		
Mean Loss per Unit	SD per Unit	Mean + 3 x Sigma
0.3	0.07	0.51
Adjust Dist Here		
Mean Loss per Unit	SD per Unit	
Max Dist	20.0 km	

Out of Spec

Table 2: Link budget for PON

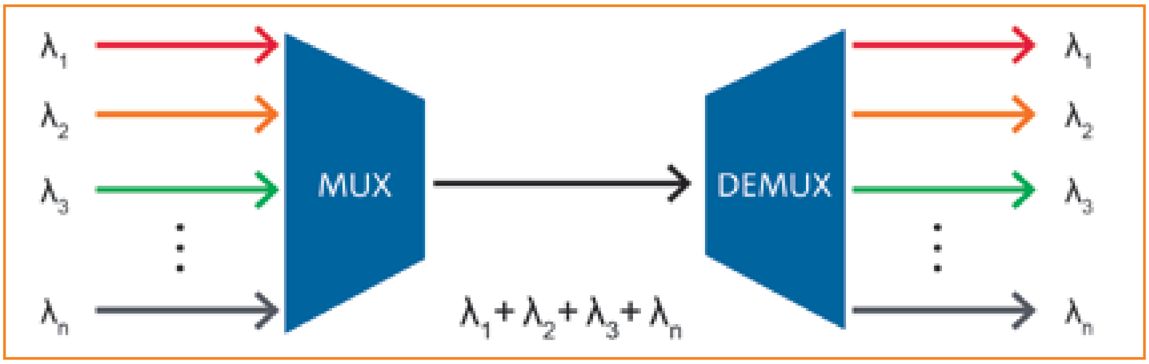

Figure 5: WDM

Wavelength Division Multiplexing (WDM)

The wavelength division multiplexing (WDM) access network is the last architecture that we will analyse. Traditionally used in the long-haul and metro network to transport large amounts of data from point to point, today's operators see WDM as an effective way to deliver fibre to the business.

There are two main types of WDM: dense wavelength division multiplexing (DWDM) and coarse wavelength division multiplexing (CWDM). DWDM platforms use temperature-controlled distributed feedback (DFB) lasers and have very tight channel spacing (50-200GHz). These systems are ideal for networks that require higher wavelength counts (16-64). CWDM systems can use lower-cost, athermal DFB lasers and wider channel spacing (20nm). These platforms are typically found where lower wavelength counts (4-8) are required.

The International Telecommunication Union (ITU) provides recommendations for wavelength planning. The ITU document G.694.1 provides the spectral grids for DWDM applications, while G.694.2 provides the spectral grids for CWDM applications.

In a WDM access network, the operator may use one or two fibres from an existing trunk to deliver individual wavelengths to multiple business customers. In a two-fibre system, as depicted in Figure 6 below, each customer has a specified wavelength that can be used for both transmit and receive traffic. In this system, operators can also transmit and receive 1310nm to new or existing fibre nodes over the same pair of fibres.

The WDM access network uses transmitters and receivers which are tuned to the specified ITU-grid. Individual wavelengths or channels are aggregated onto a single fibre using a passive WDM mux device in the headend or hub. Then a passive WDM demux device, in an outside plant terminal, drops the appropriate wavelength to the subscriber. All other wavelengths are dropped to other subscribers or are passed through and continue onto the network, as shown in Figure 7 opposite. On the return fibre, wavelengths are aggregated onto the network as they pass through each mux device.

WDM mux terminals are a key component in the WDM access network as they provide a safe and reliable environment

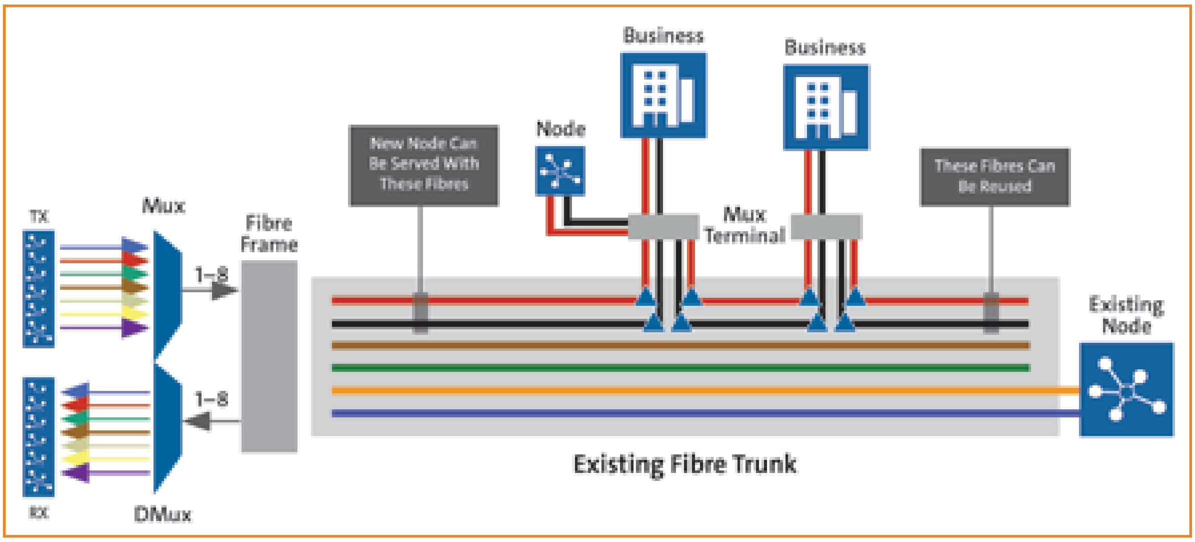

Figure 6: FTTB WDM architecture

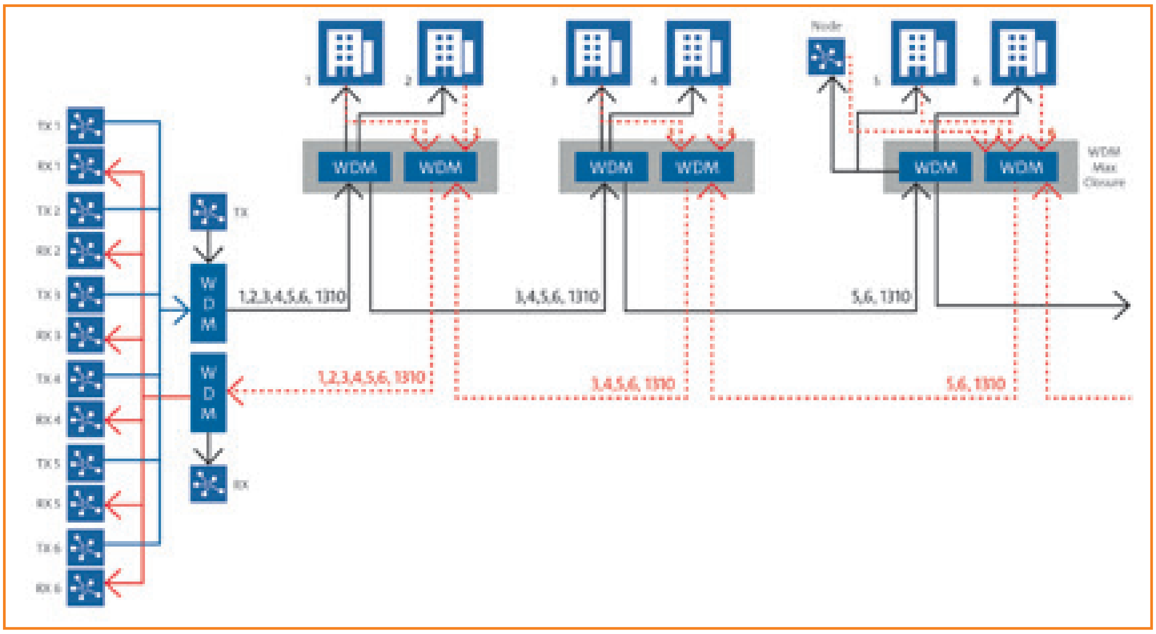

Figure 7: FTTB CWDM 2 fibre architecture

for field-hardened passive devices. Unlike standard splice closures, mux terminals allow for operators to easily install, maintain, add and test WDM mux devices in the field.

An operator could also use a one-fibre WDM architecture, in which two wavelengths are required per customer for upstream and downstream traffic. A one-fibre WDM architecture with eight wavelengths can serve up to four businesses. A disadvantage to the one-fibre architecture is that the operator cannot transmit bidirectional 1310nm traffic to new nodes.

In Figure 8 below, we see the same eight new businesses and the new node, this time only requiring two dark fibres in the existing trunk cable for service.

There are several possible approaches to deploying this type of FTTB network (i.e. bus, star, ring). This analysis uses a star architecture to maximise subscribers and to reduce optical loss. While the link-loss budget still includes cabled fibre, connectors, WDM filters and splices, it's important to remember that the WDM access network gives the operator the flexibility to maximise the link loss for individual channels.

The example shown in Figure 9 overleaf uses a passive CWDM filter, dropping the 1310nm wavelength first with an insertion loss of approximately one dB.

The loss budget also compares two transmission budgets, 12dB for 1310nm video transmission and 25dB for 1550nm

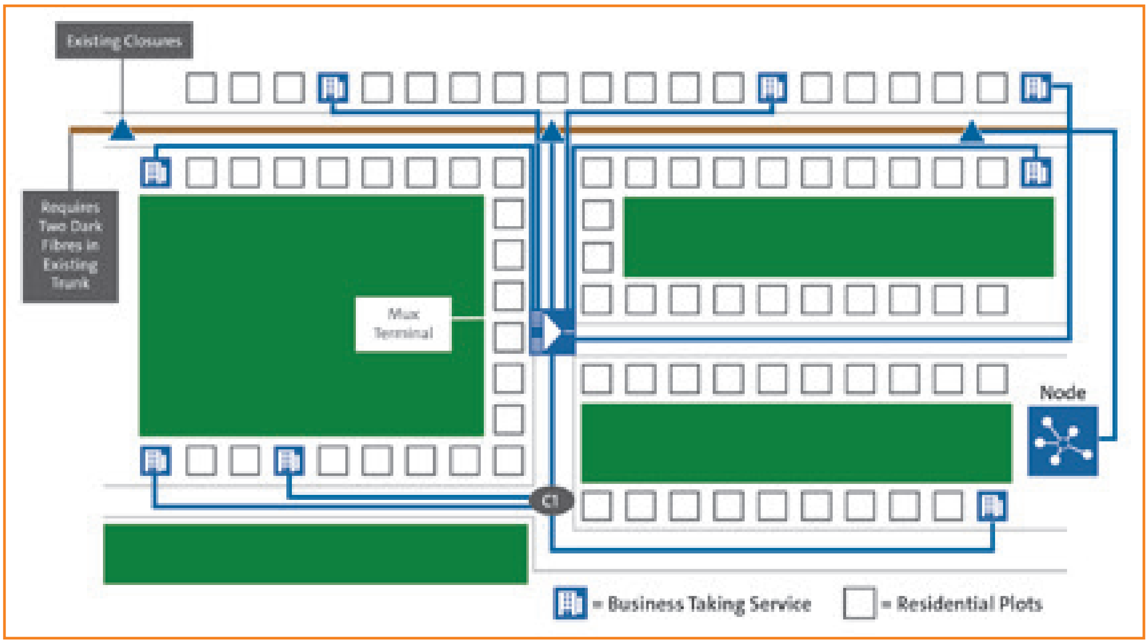

Figure 8: FTTB PON run architecture-8 business + residential node example

Video @ 1310 nm		Probability 99.99997%	99.997%	99.87%	97.72%
Margin	dB	-0.2	0.3	0.7	1.2
Transmission Budget	dB	12.0	12.0	12.0	12.0
Calculated Loss Budget	dB	12.2	11.72	11.27	10.82

Data Up/Down @ 1550 nm		Probability 99.99997%	99.997%	99.87%	97.72%
Margin	dB	9.2	9.7	10.1	10.6
Transmission Budget	dB	25.0	25.0	25.0	25.0
Calculated Loss Budget	dB	15.8	15.32	14.87	14.42

Adjust Con Loss Here		
Mean Loss per Unit	SD per Unit	Mean + 3 x Sigma
0.3	0.07	0.51

Adjust Dist Here	
Mean Loss per Unit	SD per Unit
Max Dist	20.0 km

Out of Spec

Table 3: Link budget for WDM

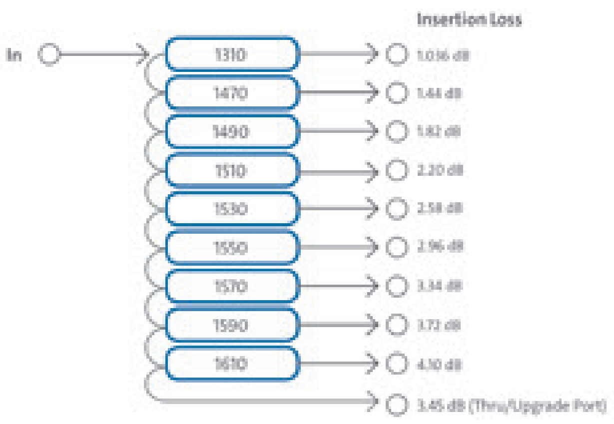

Figure 9: CWDM demux device

data transmission. The link loss for this WDM access network is 12.2dB at 1310nm and 15.8dB at 1550nm, as shown in Table 3.

At 20km, the data has positive margin and the video has -0.2dB margin at a 99.99997% confidence interval.

The pros and cons of the WDM architecture include:

Pros:

- Best utilisation of existing fibre plant.
- Two fibres for data and residential CATV node.
- Purely passive, protocol-agnostic plant.
- Virtually unlimited bandwidth.

Cons:

- Distance limited by optical loss.

Analysing the technical differences of the home run, PON and WDM architectures in this model serving eight businesses and one residential node, we can look at a number of different parameters, as shown in Table 5 opposite.

The summary shows that the fibre home run requires 18 dark fibres (two fibres per business x eight business = 16 fibres + two fibres for the residential node = 18 fibres). The PON architecture requires three fibres (one fibre for the PON and two fibres for the residential node) and incurs the highest loss at 1550nm. In the WDM architecture, two fibres feed all eight business customers and the residential node.

Link-Loss @ 20 km for Eight Businesses and One Node			
	1310 nm Loss (dB) for Residential Node	1550 nm Loss (dB) for Downstream Data	Dark Fibres Required
Fibre Home Run	7.7	5.5	18
PON	7.7	17	3
WDM	12.2	15.8	2

Table 4: Link-loss summary

Eight Businesses + One Node Example					
Architecture	Dist-Given 25 dB Loss Budget	Distance Limitation	Bandwidth: Shared or Dedicated	Protocol	Dark Fibre Requirements
Fibre Home Run	60 km	Power	Dedicated	Any	High
PON (2-Fibres)	20 km	Protocol or Power	Shared	ATM or Ethernet	Med
WDM	35 km	Power	Dedicated	Any	Low

Table 5: Bandwith loss comparison

Table 5 above depicts a general side-by-side technical comparison of the three architectures. Given a link-loss budget of 2dB, the fibre home run boasts the longest reach and the highest utilisation of existing assets. Based on current standards, the PON's reach is typically limited to 20km, whereas WDM can reach 35km. In comparing the bandwidth of these three architectures, the main takeaway is that the PON is a shared bandwidth, while the fibre home run and WDM architectures deliver dedicated bandwidth.

Conclusion

Commercial subscribers represent a significant opportunity for CATV operators to grow their revenues quickly, with immediate returns on investment. A large percentage of the commercial market revenue resides with customers who are looking for more bandwidth scalability and flexibility.

With today's fibre to the business solutions, MSOs are well-positioned to deliver fibre services to these customers by leveraging their existing assets.