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Demystifying WDM access architectures

How to design effective FTTB systems for flexibility and growth

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More content, more bandwidth, more speed… today's cable operator hears those words every day. As voice, video and data technologies evolve, and the demand for bandwidth steadily grows, there is significant pressure on operators to increase the capability of their hybrid fiber/coax (HFC) networks rapidly and in the most cost-effective manner possible. An exciting and innovative solution to address such challenges is the use of pre-connectorized, field-hardened, wavelength division multiplexing (WDM) terminals and drop cables in the access network.

WDM has traditionally been a powerful tool to move large amounts of aggregate traffic from point to point in long haul and metro networks, making the most efficient use of existing fiber assets. Today, more operators are leveraging this same technology in the access space to support the growing bandwidth requirements for residential and commercial customers [i.e. fiber-to-the-business (FTTB)], while avoiding the need to overbuild the network. MSOs are now using WDM to split fiber nodes (node segmentation) in order to provide more bandwidth and more services to the home, and at the same time provide secure and reliable fiber connections for use in commercial services, all on the existing network.

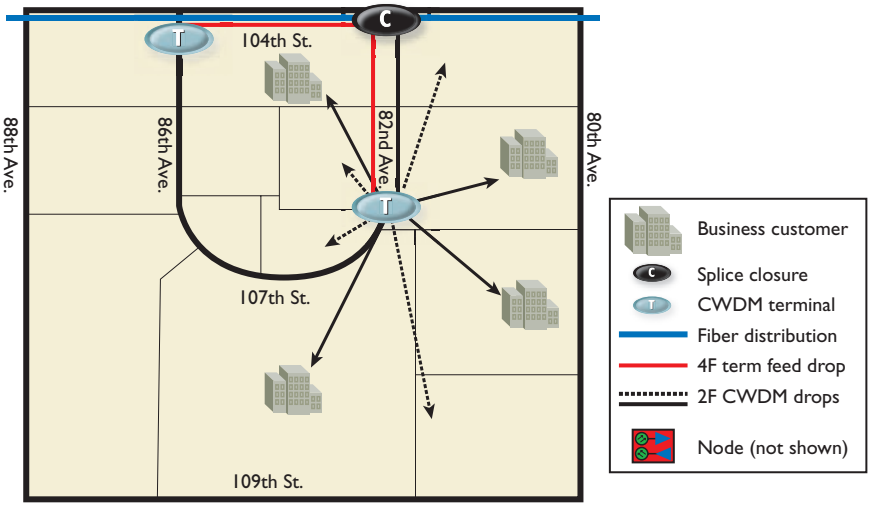

Figure 1: Detached star example.

What does this mean to cable operators?

- Increased bandwidth capability for residential services;
- More revenue from high-paying commercial services;
- The ability to rapidly turn up new customers;
- The competitive advantage of being the first to offer affordable fiber connectivity;
- Eliminating the need for expensive new construction.

This article explores some of the key considerations for overlaying WDM access applications onto existing HFC fiber networks. Its aim is to demystify the complexities of designing, installing and growing a WDM access system by explaining the advantages of using pre-connectorized "plug-and-play" solutions.

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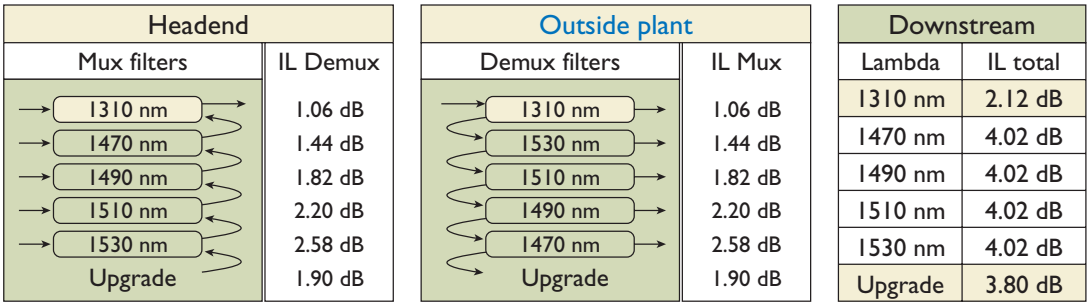

Figure 2: Fiber wavelength pairing.

Generic CWDM deployment

Many MSO engineering and construction managers have already discovered the benefits of employing CWDM (coarse WDM) to expand their overall system capabilities. This added capacity can be used in applications such as improving core residential services, servicing lucrative commercial services contracts, offering wireless connection services to data centers, backhauling wireless networks (including cellular and Wi-Fi), and providing dedicated fiber connections to government, medical and educational organizations.

Still, WDM access architectures are relatively new and thus lack standardization in their deployment. As a result, operators are faced with a lot of uncertainty on how to best design and deploy WDM over their HFC networks.

Specific concerns about WDM access architectures include:

- Significant plant engineering is required to design the system;
- Splicing WDM components in existing closures significantly increases the risk of collateral damage to existing links;
- Extensive training required for personnel to ensure products installed correctly;
- Testing and troubleshooting options are severely limited;
- Difficulty in managing many local fiber access points simultaneously;
- Management of existing nodes during system changes and additions;
- Management of existing FTTB customers during system changes and additions;
- Demanding commercial services customer service requirements (time to activate, options for effective path protection, service level agreements, etc.).

Fortunately, there are some basic engineering and design options that allow operators to leverage the virtues of CWDM without compromising existing systems, limiting future upgrade potential, or otherwise creating a network management nightmare.

Basic FTTB system planning

As cable operators enter the commercial services market, it is often difficult to accurately forecast the location, take rates and growth patterns of FTTB customers. This makes network planning both important and necessary.

Key elements to successful network planning are:

Forecasting demand

- Detailing existing network capability
- Understanding commercial services
- Customer-specific requirements
- Having a robust business plan.

Benefits of pre-connectorized outside plant FTTB WDM access solutions

Systems based on pre-connectorized outside plant solutions typically provide the most cost-effective means of installing and operating a WDM access network. Factory-terminated outside plant WDM terminals and optical drop cables offer the best overall performance in terms of ease-of-use and customer turn-up time, while meeting the same requirements as traditional hard-spliced systems. Equally as important, these types of WDM systems allow for easy installation, provide significant flexibility, and allow for scalable and cost-effective growth.

Pre-connectorized, plug-and-play solutions enhance the value of using CWDM for commercial services and node splitting applications. Specific benefits include:

- Reduce overall OSP passives deployment costs by 20 percent or more.
- Allow for pay-as-you-grow approach (passive and drop cables).
- Lower installation time by 50 percent to 80 percent over hard-spliced solutions.
- Provides readily accessible network test points.
- Best utilization of existing fiber infrastructure.
- Most flexible for growth.
- Ease and speed of installation.
- No special tools or training required.

While standard hard-spliced approaches are currently the most common method of deploying WDM in cable TV access networks, operators are quickly realizing that such products are very complex to deploy. The time needed to design the network and deploy these individual devices is significant, especially for

systems already having some existing devices operating at other wavelengths. Furthermore, this approach often limits overall operator revenue opportunities since new customers cannot be added efficiently and cost-effectively, or in some cases at all. Until recently, hard-splicing WDM components in the field was considered a necessary evil for deploying WDM, but now that has changed with readily available pre-connectorized plug-and-play solutions.

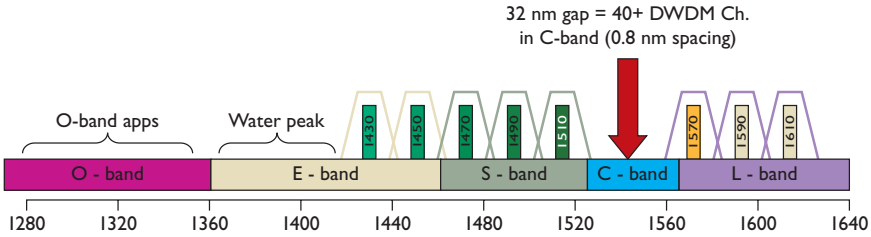

Figure 3: ITU CWDM channel plan.

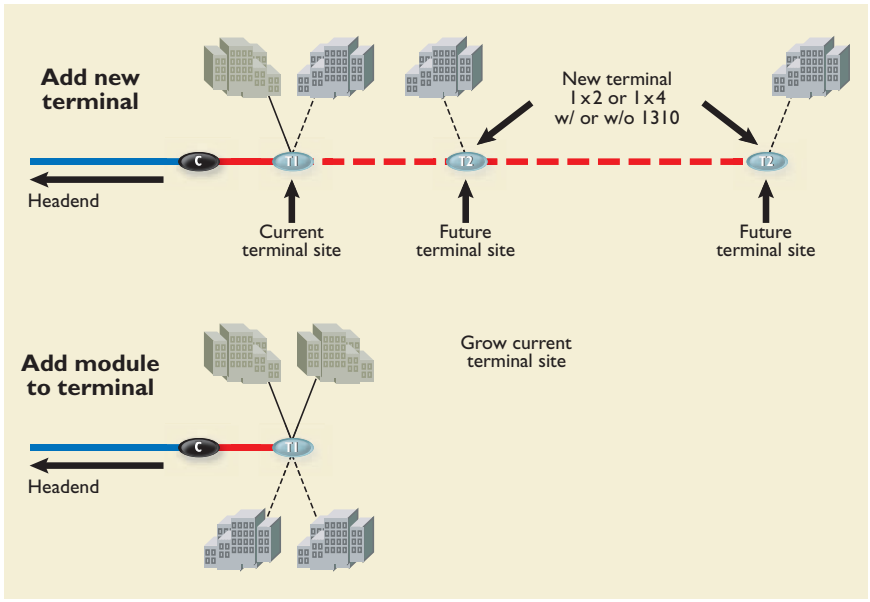

Figure 4: Growing FTTB detached star topology.

FTTB WDM access topologies

The types of topologies most commonly cited and employed in network designs are the star, bus, ring and mesh. However, actual systems may vary significantly from one to another based on the unique requirements of the operator, customer demographics and service offerings. For reasons given in the following sections, the detached star is generally recognized as the most practical WDM access topology for cable networks.

In a WDM detached-star topology, the outside plant WDM filters are centralized in one or more optical terminals (passive closures containing WDM filter sets) as shown in Figure 1. The WDM terminals are connected to the network at an existing splice closure via pre-connectorized cables, allowing the physical location of each terminal in the network to be optimized based on expected customer opportunities. Pre-connectorized drop cables, usually containing two or more fibers, are then deployed from the WDM terminal to each customer. Fibers for multiple customers within the same local area or in the same building (i.e., multi-tenant units) may be contained within a single cable sheath, and then split out at a local network access point (NAP) nearer to a customer cluster, if desired.

In WDM applications, the detached-star topology offers several advantages in terms of cost, flexibility, serviceability and ease of deployment. First, it reduces the need to access the main distribution fibers and existing closure once the detached WDM terminal is installed, which requires only four splices. The system operator can then manage the drop portion of the FTTB access network to each customer premises or video node from the WDM terminal, thereby minimizing the risk to the other networks in the same distribution system (cable). Second, growth is easily facilitated by attaching additional factory-made multiplexer/ demultiplexer (mux/demux) wavelength filter modules to existing modules located within the field terminal, and at the hub or headend, without the need to interrupt services to active nodes or customers out of the same terminal.

This ability to support growth in an easy and methodical manner minimizes the time and cost associated with engineering the network for changes and eliminates field fusion splicing when adding new wavelengths. Therefore, additional revenue opportunities can be quickly and easily pursued, which readily translates to an improved return on investment.

The following section addresses some other key considerations associated with deploying WDM in cable networks.

Wavelength and attenuation planning

Filter pairing and 1310 nm loss budget.

The ease of wavelength planning is another advantage of modular pre-connectorized WDM solutions. It allows the designer to balance channel insertion loss for the various wavelengths, including 1310 nm. Figure 2 shows schematically how "filter pairing" is done to balance the performance of the individual CWDM channels, in addition to minimizing the passive component insertion loss at 1310 nm. In cases where fibers being used for WDM applications also carry 1310 nm node traffic, the 1310 nm loss budget must be carefully managed.

Hybrid CWDM-DWDM systems

In situations where the need for additional capacity beyond CWDM alone is needed to support future network traffic growth, there is a cost-effective and easily managed alternative to going to pure DWDM (dense WDM). This method employs a wavelength bypass scheme to allow CWDM wavelengths to be used initially, and then DWDM wavelengths added later to support additional channel capacity. The result is a hybrid CWDM/DWDM configuration capable of supporting up to 48 WDM channels (8 CWDM and 40 DWDM). The key benefit to this type of system growth strategy (vs. pure DWDM) is that costly DWDM component purchases can be significantly delayed until the additional capacity is actually needed, thereby keeping per-channel costs to an absolute minimum. Properly planned CWDM systems based on pre-connectorized solutions allow for DWDM channels to be easily integrated without interrupting service to existing CWDM applications. See Figure 3.

Managing FTTB growth

The discussions up to this point highlight some of the key issues that must be considered when looking to deploy WDM FTTB access architectures. As it is often difficult to forecast which businesses will take services and when, operators must allow for a multitude of growth scenarios. In cases where customers and/or nodes will be added incrementally over time, the provider must carefully consider all options to ensure the flexibility to grow the system in the long-term. In using a hard-spliced approach, options are limited to adding unused (dark) filters at first install, which increases system complexity and first-installed costs, or to require planned breaks in services to existing customers to manage subsequent additions. The latter can be problematic with commercial services customers where "level of service" agreements are in place. Such issues are much more easily managed with a modular detached-star topology as presented earlier. Figure 4 shows how system growth can be accomplished incrementally with a modular CWDM in a "pay-as-you-grow" approach.

Summary

For cable operators considering deploying WDM to increase network capacity, there are a number of important considerations to take into account. Proper design and planning are critical in order to ensure that operators build a network that offers the best return on investment and provides sufficient growth potential in an easy and scalable manner. To that end, modular pre-connectorized CWDM access solutions for the outside plant offer several advantages over alternatives in terms of design, installation, flexibility, ease of maintenance and testing. ■

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