The Fiber Plant Decision Tree: How Deep Is Fiber Deep?

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Introduction

Over the past several years, cable operators have seen their networks transform into an advanced platform for transmission of data services for both residential and business customers. In order to accommodate the growth of services and transmission speeds, CATV operators have been deploying fiber deeper into the network.

When CATV operators adopted fiber for widespread use in their networks, it was common for one node to serve a cascade of several trunk amplifiers, with each amplifier feeding dozens of line extenders before the RF signals would finally arrive at a customer. That architecture could involve thousands of homes per node. Today, most nodes serve about 500 homes and do so via line-extender amplifiers only.

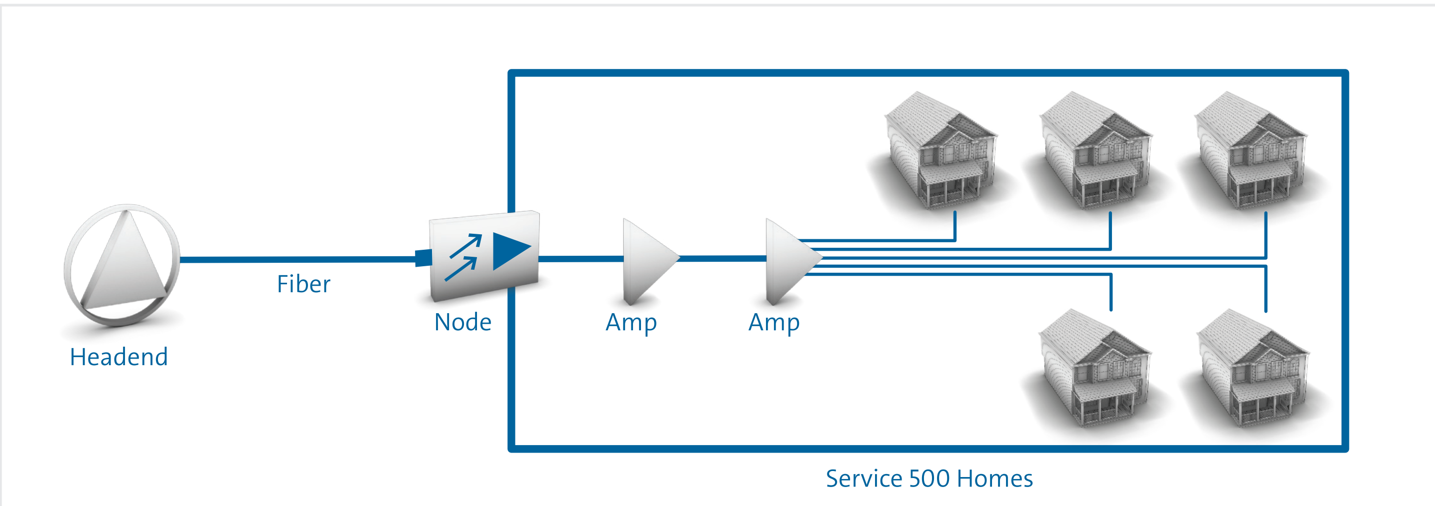

Figure 1 – Hybrid Fiber-Coaxial (HFC) Network 500 Homes Per Node

Migration continues as nodes are being subdivided into smaller service groups, typically feeding 125 or fewer homes each. These smaller numbers enable operators to deliver Gigabit services along with legacy video services.

For the longer-term future, fiber-to-the-home (FTTH) options demand smaller service groups, typically 32 or 64 homes each.

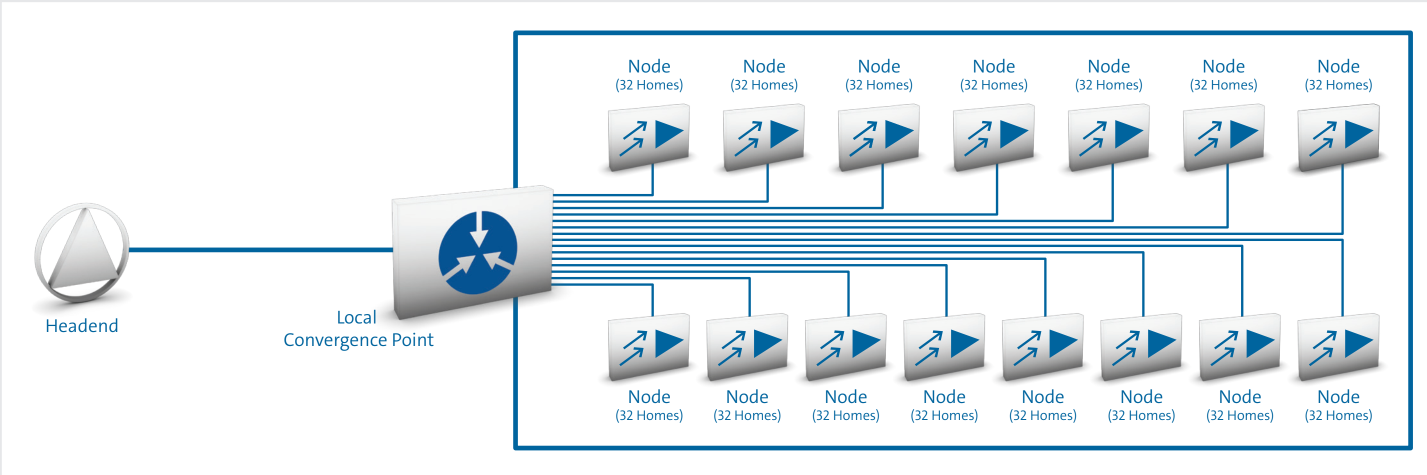

Figure 2 – HFC 32 Homes Per Node

All of these architectures have one thing in common: the need for optical fiber between the headend and service group.

How Many Fibers?

The fiber count required for a service group depends on the initial system design and forecasting how network demands will exhaust the existing fibers.

Let us consider a typical node+3 HFC system, designed for 500 homes per node in the early 2000s (Figure 3). Since fiber optic cable was bundled in buffer tubes of six fibers per tube, many systems were designed for six fibers per node, which made sense: matching the node fiber count to the buffer tubes made for easier splicing and organizing of the fibers back in the headend. In this scenario, each node requires one fiber for downstream and one fiber for upstream, leaving four fibers for spares. Business services can require two fibers for an upstream- and downstream-dedicated fiber service to a business location. With residential and business services, fiber exhaust can happen very quickly – leaving the operator with limited options.

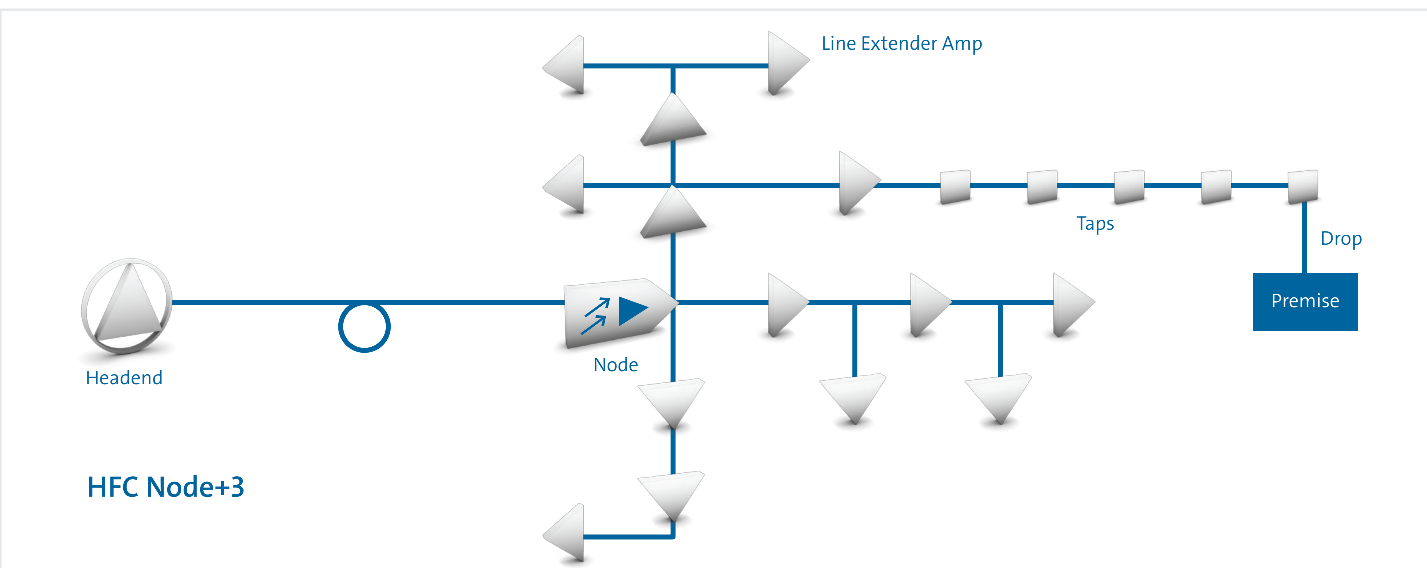

Figure 3 – HFC Node+3 Network

For example, often a node split is needed and no fibers are available for the required 1x4 split.

One solution is to deploy coarse wavelength division multiplexing (CWDM) or dense wavelength division multiplexing (DWDM) techniques. In these deployments, a single spare fiber with four distinct wavelengths could be used to feed four nodes. With passive analog techniques, this method can then split the service group from 500 homes per node down to 125 homes per node.

For CATV operators considering a node+0 design or a FTTH passive optical network (PON), the service groups would need to be divided even further.

To illustrate how this works, let us take the above node+3 system and migrate it to a node+0 network ... then finally to a FTTH PON. We will analyze how each of these deployments affects the access part of the network and the transport part of the network.

Access Plant Development

The access network can be broken down into three distinct sections: headend to distribution point, distribution point to node/OLT, and node/OLT to premise.

Type of Network	Headend to Distribution Point/OLT	Distribution Point to Node/Splitter	Node/Splitter to Premise
Coax	Fiber, DWDM, or CWDM	Fiber – discrete wavelengths to node	Fiber to node, coax to premise
Fiber	Fiber, DWDM, or CWDM to OLT	PON fiber to splitters	PON fiber – one per premise

Previously, operators only had one option when they lacked the fiber count necessary to feed the aggregation point – overlay more cables from the headend out. Now they have more options.

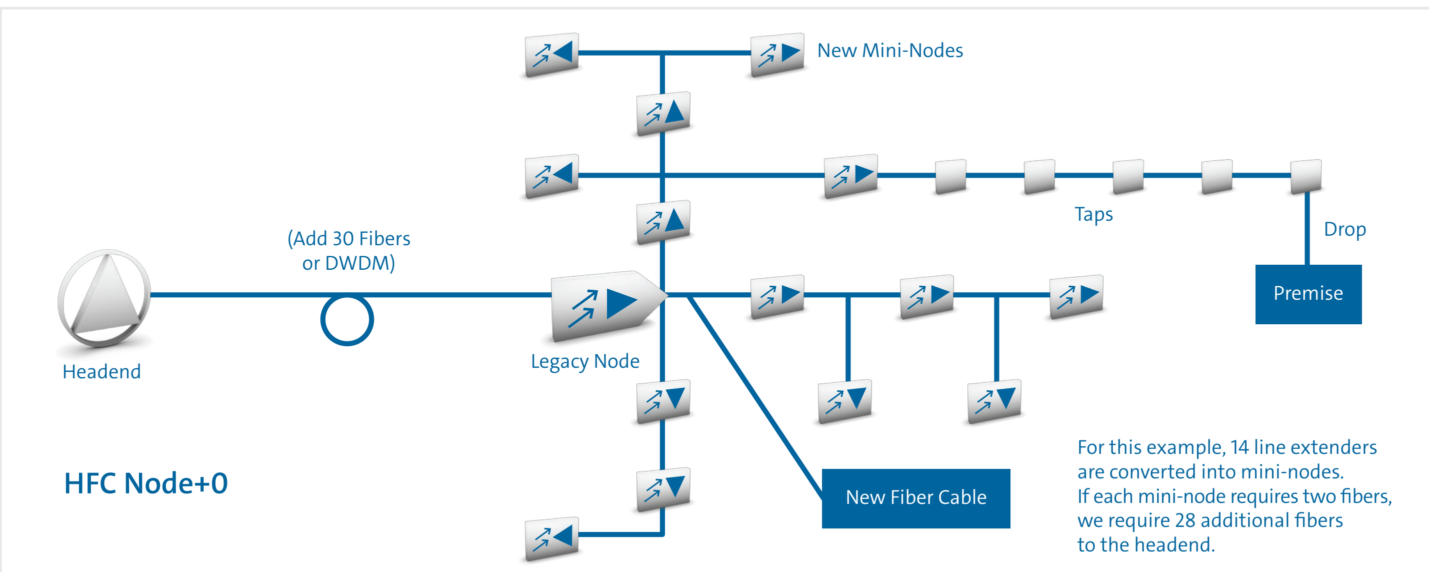

Figure 4 – HFC Node+0 Network

Let us examine what happens when we convert a node+3 system into a node+0 system (Figure 4). Each former line extender location becomes a new mini-node location. The mini-nodes now feed a smaller service group and the line extenders are removed. If we run a minimum of two fibers per node, then 28 fibers are needed. If we want to reduce the fiber count from the legacy node back to the headend, we would need to deploy a DWDM system with 28 wavelengths.

What if we create a PON from the former node location instead? Figure 5 shows that the neighborhoods previously served by a line extender are now served by a splitter location instead. If we run a minimum of two fibers per splitter location, 24 fibers are needed. By relocating the OLT to this distribution point (legacy node location), we can reduce the necessary fiber count back to the headend.

If we compare the diagrams for these two network options, the required fiber counts are very similar, but the total sheath distance of necessary fiber optic cable is different because the FTTH network requires installation of new cable beyond the mini-node/splitter location.

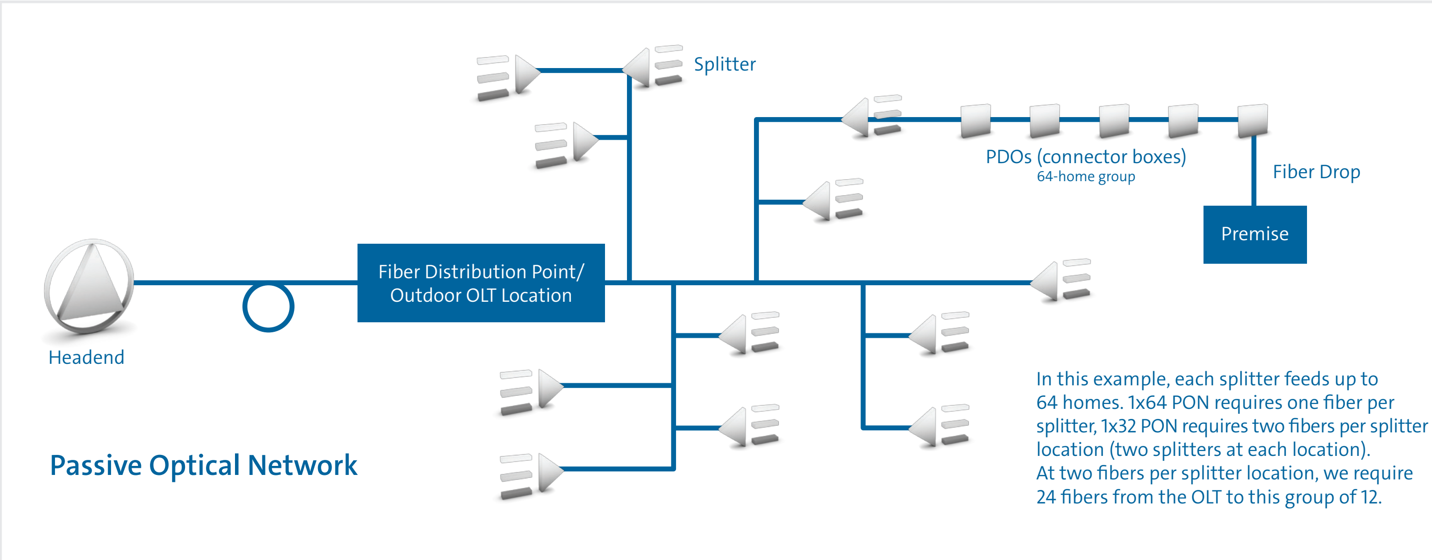

Figure 5 – Passive Optical Network

Another important consideration is fiber availability for business services. In a primarily residential network, many business services can ride the same coax network or PON used to serve homes. A business might demand its own dedicated fiber for security purposes or for an unusually high-bandwidth demand. A different architecture might be required, such as a ring-for-route protection. For this reason, no matter what the required count for serving residential requirements, there should be extra fibers installed for future business services. How many? That depends on the commercial density of the particular geographic area.

When it comes to cellular networks and the emergence of 5G, both of which traditionally use fiber, a coax network or PON could accommodate the required bandwidth with very small cell sizes. Some radio access networks (RAN) work with dark fiber, connecting several radio heads to a common controller. Bottom line: extra fiber strands should be planned to accommodate any future requirements.

The Transport Plant – Getting to the Access Network

Now that we have an idea of the access network choices, and a list of technologies available to help deliver what we desire, let us go deeper into the capabilities of each of them and calculate the fiber counts we will need in the transport part of the network.

First, suppose we just pull new cable for everything. The design is fairly simple: we count the premises we wish to serve and get an idea of the neighborhood splitter placements for a PON, or node placements for a node+0 style architecture.

For a PON, each splitter feeds 32 homes (or perhaps 64). Due to the short distances involved, loss from the splitter to the premise is not significant. For coax, on the other hand, distance is critical. Coax cable loss limits how far we can go from the node. A rural area might require many more node locations than an urban one. When we have our splitter count or node count, we can then know what the fiber design will look like back to each distribution point. The number of splitters plus the number of business services spares equals the number of fibers back to the headend.

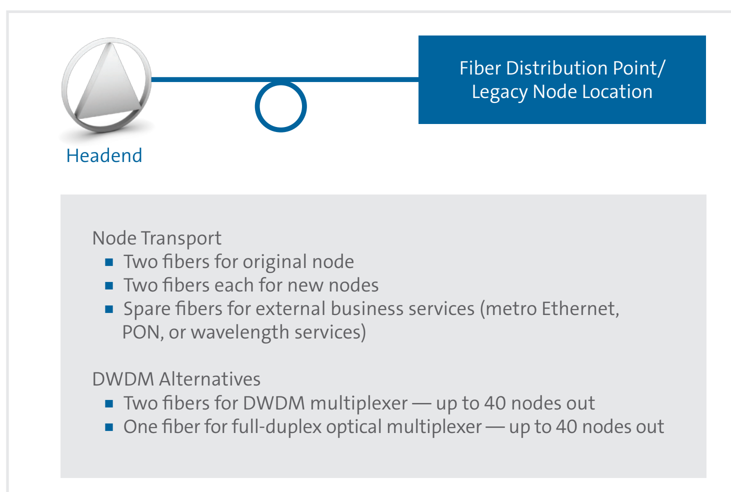

Figure 6 – Node+0 Transport

Between the splitters and the distribution point, or between the node and the distribution point, we have a conventional fiber network.

Conventional CWDM typically can accommodate up to eight wavelengths per distribution point. That could mean service for up to two 4x4 nodes. That might have been adequate a few years ago, but now we probably require 15 or more nodes to feed a node+0 overlay.

Conventional DWDM has more wavelength choices, typically 40. We can use 40 wavelengths (20 upstream and 20 downstream) to feed 20 nodes. Each wavelength has a channelized splitter and colored laser. Note: 48-channel DWDM solutions are available to support the MSO industry.

So, in the case of transport servicing a node+0 coax network (Figure 6), the maximum number of nodes per distribution point times two equals the number of wavelengths of DWDM we will require.

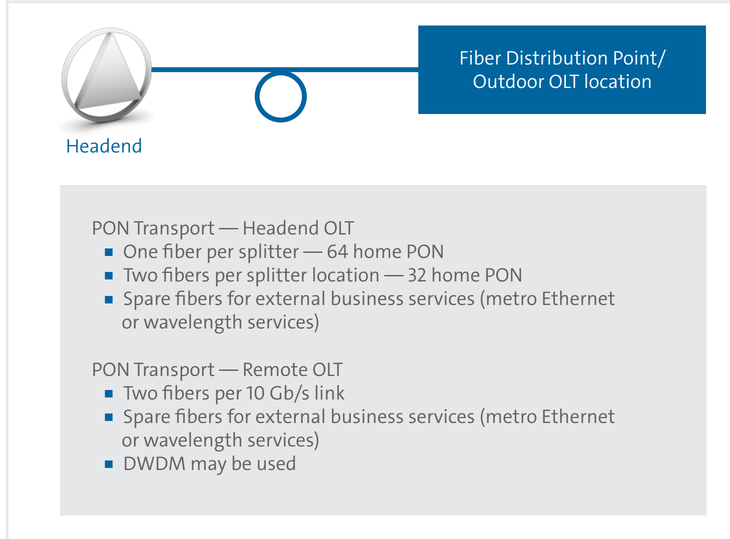

Figure 7 – PON Transport

For a PON (Figure 7), there is no DWDM option beyond the OLT, because each PON already uses multiple wavelengths. To feed the remote OLT from the headend, a single pair of fibers carrying a 100 Gb/s signal might be enough. Conventional DWDM is reasonable to consider if there is not enough fiber available from the headend to a remote OLT in the field. The remote OLTs need not be colocated with the DWDM device, however, minimizing the number of remote OLTs is a good idea, since each remote OLT requires real estate and power in addition to the equipment itself.

The Decision Tree – How Many Fibers Do We Require?

In order to use the decision tree, we require the following inputs:

- Number of Service Groups per Distribution Point
  - For an HFC network, count the number of mini-nodes to be fed.
  - For a PON, count the number of splitter locations to be fed.
- Distance and Equipment Limitations
  - Make sure the loss-budget distance from the headend to the distribution point is within the capabilities of the network equipment used. If not, an active location (DWDM for HFC or remote OLT for PON) must be included in the design.
  - For a remote OLT, each input trunk feed from the headend will have sufficient bandwidth to service a maximum number of service groups (splitters). For example, one operator might decide that a 100 Gb/s feed could support 10 service groups at 10 Gb/s with oversubscription. Another might decide that the same 100 Gb/s feed could serve 40 groups with 10 Gb/s.
- Business Services
  - Determine the number of business-services fibers desired for the area covered by the distribution point.

Node+0 HFC Network

Considering an HFC network to be converted from node+3 to node+0, we obtain the number of nodes by counting the number of existing line-extender amplifiers. Then, looking at the HFC Transport Fiber Count Decision Tree (Figure 8), we take this count as "N." If the plant feeding the legacy node has two spare fibers, "F" becomes two. For our example involving 14-line extenders, we start with F = 2 and N = 14.

If we take this example through the decision tree, we decide to employ DWDM.

Our DWDM system will need to feed the 14 new nodes at a minimum. It should also feed the old legacy node, which would free up an additional pair of fibers, and have capacity for future business-services requirements.

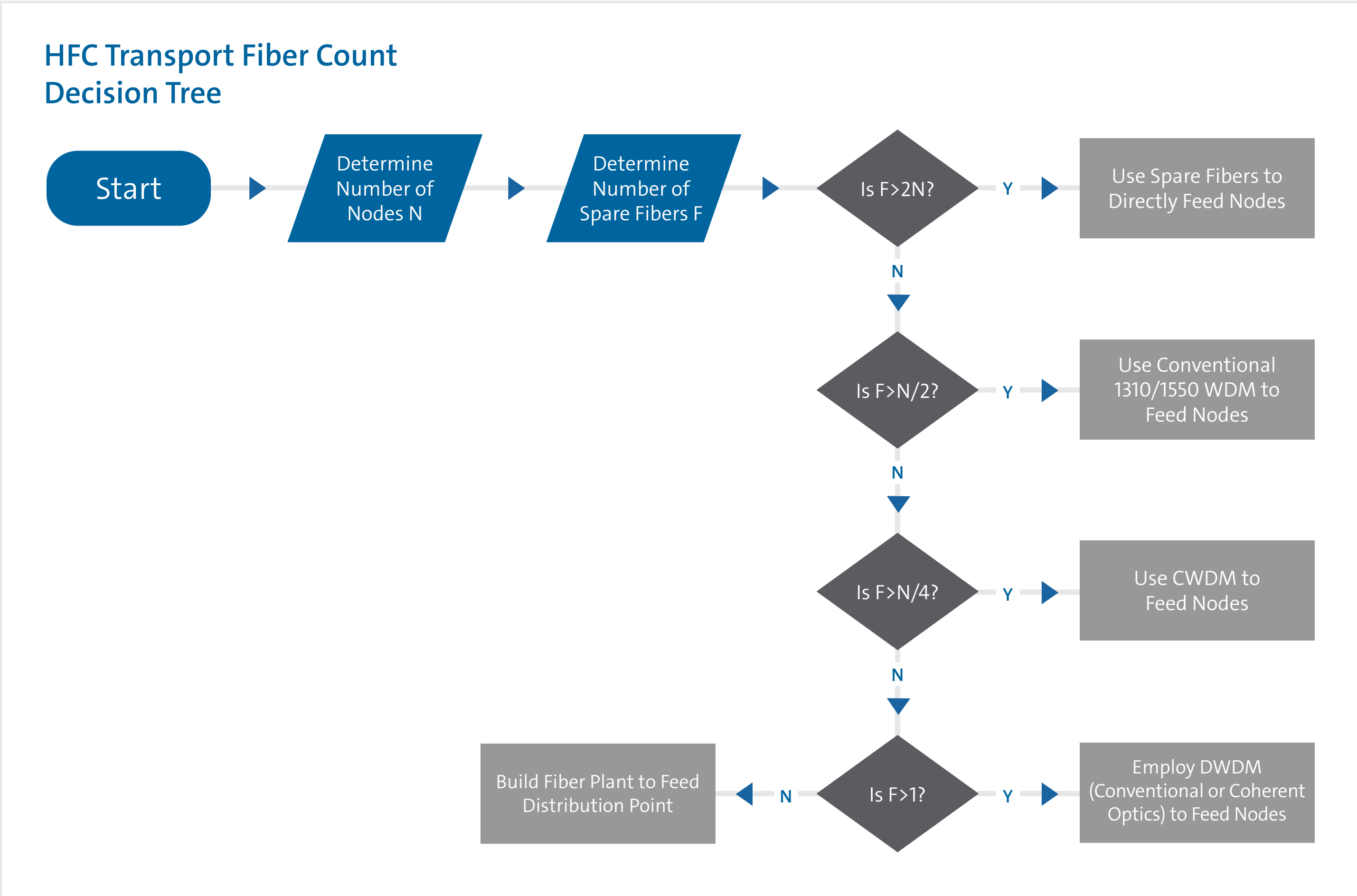

Figure 8 – HFC Transport Decision Tree

PON

If we decided instead to build a PON, we would require a very large number of fibers to construct a true PON from the headend out to the splitter locations. Fourteen spare fibers are necessary to feed 14 splitters (or 28 spare fibers, if there were two splitters per location). Suppose our plant only has two spare fibers. Then S = 14 and F = 2.

For example, by going through the PON decision tree (Figure 9) with these numbers, we decide that we require a remote OLT. Further, we determine that the remote OLT needs two 100 Gb/s feeds to deliver service to the 28 32-home splitters contemplated. We decide to employ passive DWDM to feed the remote OLT, and we have plenty of capacity for two 100 Gb/s feeds, plus room for many more.

As with the HFC example, we should also make certain that wavelengths are available for future business services.

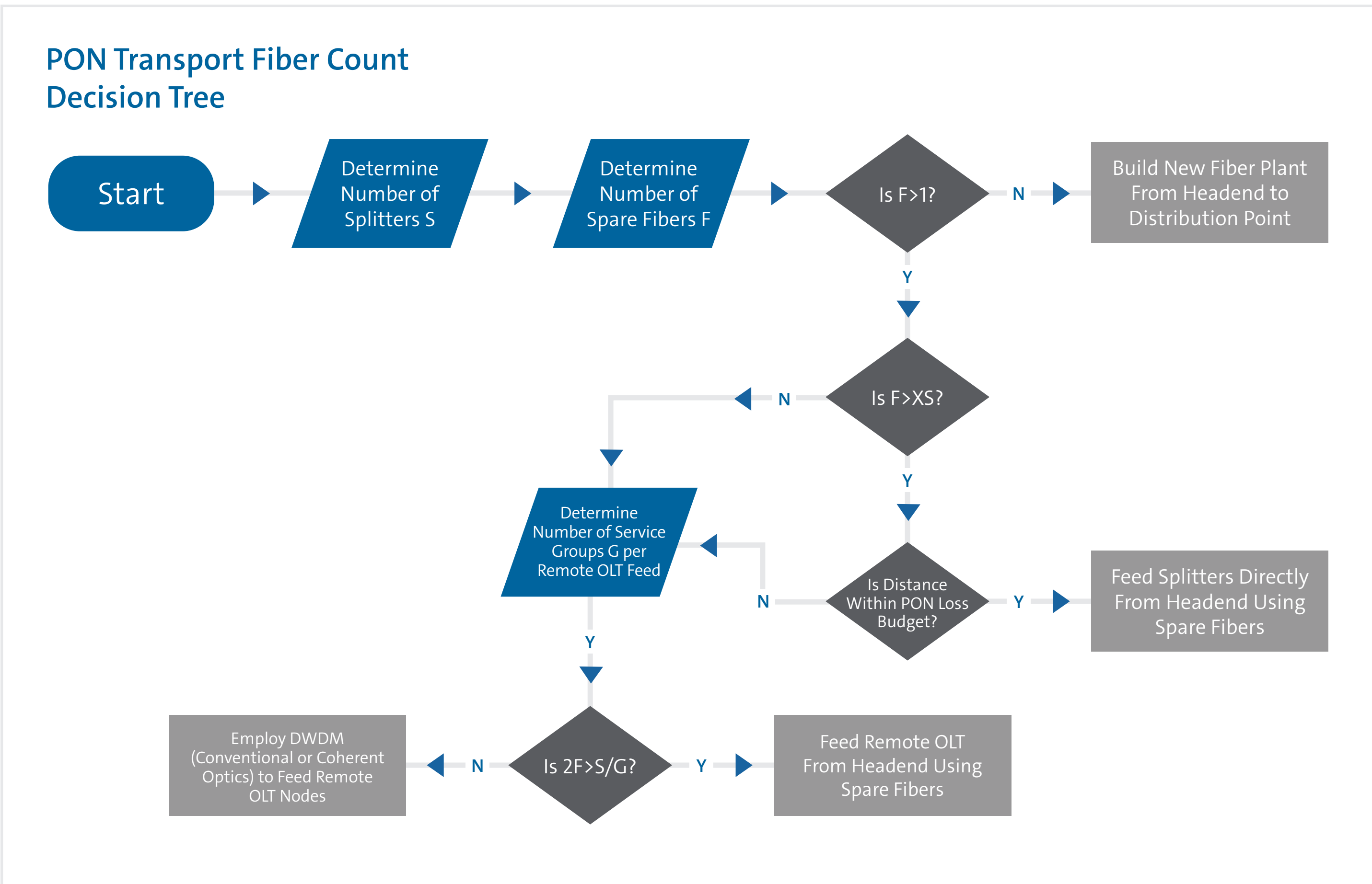

Figure 9 – PON Decision Tree

Conclusion

The architecture required to build advanced networks is remarkably similar between PON/FTTH and HFC node+0. We can build significant "transport" plant to feed these fiber distribution clusters, or we can make prudent use of active and passive solutions, including remote OLTs and DWDM, in order to keep the construction of new fiber optic cables to a minimum.

By analyzing the financial and technical implications of the various options, an operator can decide the best choice for the particular situation and be prepared for bandwidth demands that the future will bring.

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