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Passive Optical Networks: Are MSOs Really Ready?

An Operational Practice prepared for SCTE/ISBE by

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Introduction

This paper discusses the complexity that operators face as they scale Passive Optical Network (PON) deployments within their footprint. To streamline PON builds, operators must understand questions related to the strategic and financial decision making process to act quickly like "where do we go? And how do we measure success?". In parallel, Multi-System Operators (MSOs) must strategize the impact to their workforce to answer questions like, "must we standup a separate team dedicated to PON?" If not, MSOs must arm their impacted teams with training, resources, and Operational Support Systems (OSS) and Business Support Systems (BSS) tools to support PON. Lastly, leadership must also effect change within the culture to meet operational targets despite the complexity introduced through PON.

Within the MSO community, PON is widely regarded to be the incumbent technology for the access network replacing hybrid fiber-coax (HFC). MSOs chose PON because it surpasses the capabilities of HFC and will easily deliver premium services including 1+ Gbps Internet access. Today, MSOs are deploying PON in both Ethernet and Gigabit forms. While MSOs have plans to deploy PON in pockets across their footprints, operators are wrestling with preparedness to take on this additional set of operational responsibilities.[1]

As Telcos have grown their fiber network, they have developed an appreciation of the effort required to operate a physical network. To the detriment of their customers, however, they have also taken steps to reduce operational costs by, for example, having shorter Care center call-in hours.

In contrast, MSOs already have a daily appreciation of the effort, cost and complexity to build, operate and maintain the HFC network. They are now embarking on a journey to add PON in addition to HFC. Despite its targeted deployment, the addition of PON has a broad impact because teams must seamlessly switch between HFC and PON. While there are many similarities between a PON and HFC network, the differences are sufficient to warrant an examination of how tactical aspects of daily operations will change.

Specifically, changes exist in:

- Where to build fiber given targeted neighborhood overbuilds
- How to manage workforce operations of PON that simultaneously manages HFC
- How HFC-specific tools need to evolve to support PON

Currently, these activities are highly specialized and scaled for HFC. But now, they must change. But by how much and in what way?

1. Background

Fiber delivered services for commercial applications have existed since the 1970s and accelerated in use and efficiency in the 1980s. Fast forward to 2005, Verizon announced that it would launch a video service over a fiber optic network. Fast forward again to 2015, the growth of residential homes connected to fiber delivered services has doubled the rate of homes passed by fiber over the prior year (see Figure 1).

[1] We estimate 10-20% of HHP will be PON over the course of the next 10 years.

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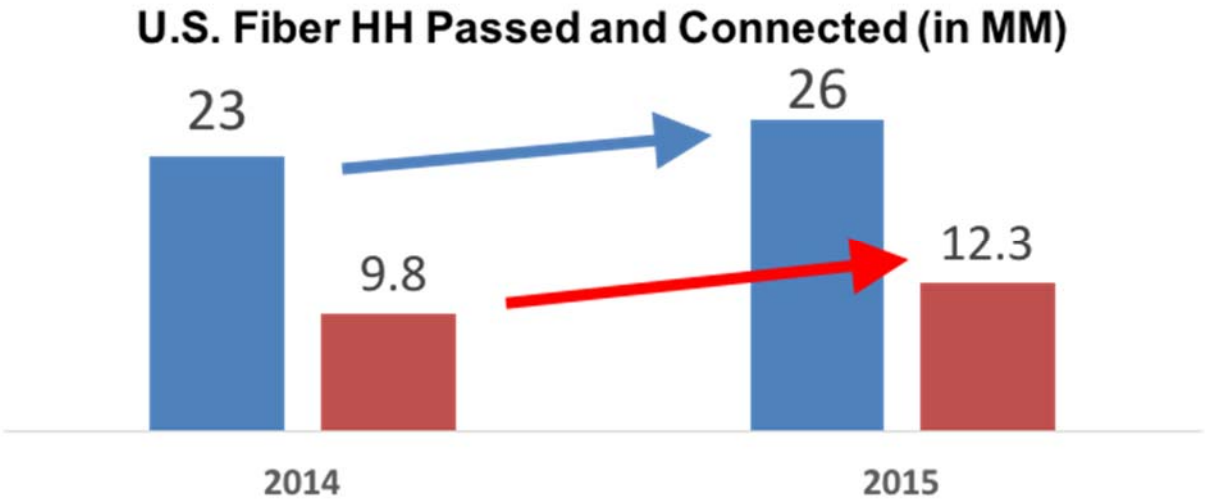

Figure 1 - US Fiber Passings and Connections 2014-2015 (in MM)[2]

This fact can be seen as a significant inflection where the demand is now growing faster than fiber construction. While MSOs plan to deploy PON sparingly, recent growth signals they should increase the rate of PON contruction in order to keep up with demand, to retentain existing customers.

2. Strategic Build Considerations

Operators should be focused on how to execute their PON builds. To maintain competition, they must undertake fiber construction quickly and deliberately. PON builds have many aspects to it, but knowing the following will enable success:

- Where to go
- Committing to a timeline
- Predictable costs
- Future-proofing (aka 'build once and never go back' approach)

In areas where subs are defecting, operators should be ready to deploy PON as quickly as possible and know answers to: overbuild or replace HFC; fiber routes; planned network topology; permitting timeline; construction contractors; capital costs; marketing plan and goals; operations; and training plans.

As shown in Figure 2, Operators must be aggressive in applying capital quickly to build out the PON network in neighborhoods where their customers are being lured away by overbuilders.

[2] Sources: Statistics, FCC, FTTH Council, IBB Consulting

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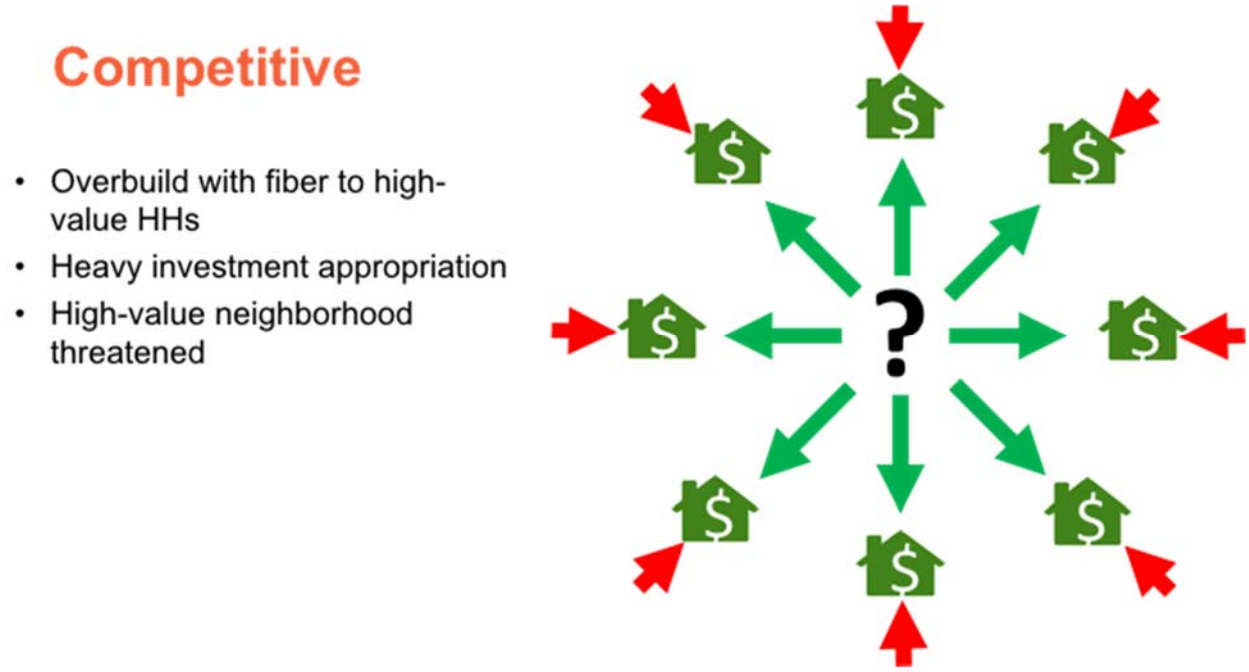

Figure 2 - Build considerations for overbuilt neighborhoods

In areas adjacent to overbuilderss, operators must decide on whether to deploy PON or fiber deep (aka zero or one radio frequency (RF) amplifier between the node and the premise) in hopes of retaining existing customers. If the MSO decides to build PON, the aforementioned questions apply. Alternatively if the MSO decides to build out fiber deep instead of PON, many of the PON build questions still apply and based on the intensity of competition, fiber deep builds may quickly pivot to a PON build.

As shown in Figure 3, Operators must take steps to retain existing customers. Retention tactics may include deployment of PON, or for HFC, fiber deep, DOCSIS 3.1 and Remote PHY deployments. If subscribers are migrating, they are signaling that subscribers have a better value proposition and service offering than they are currently receiving.

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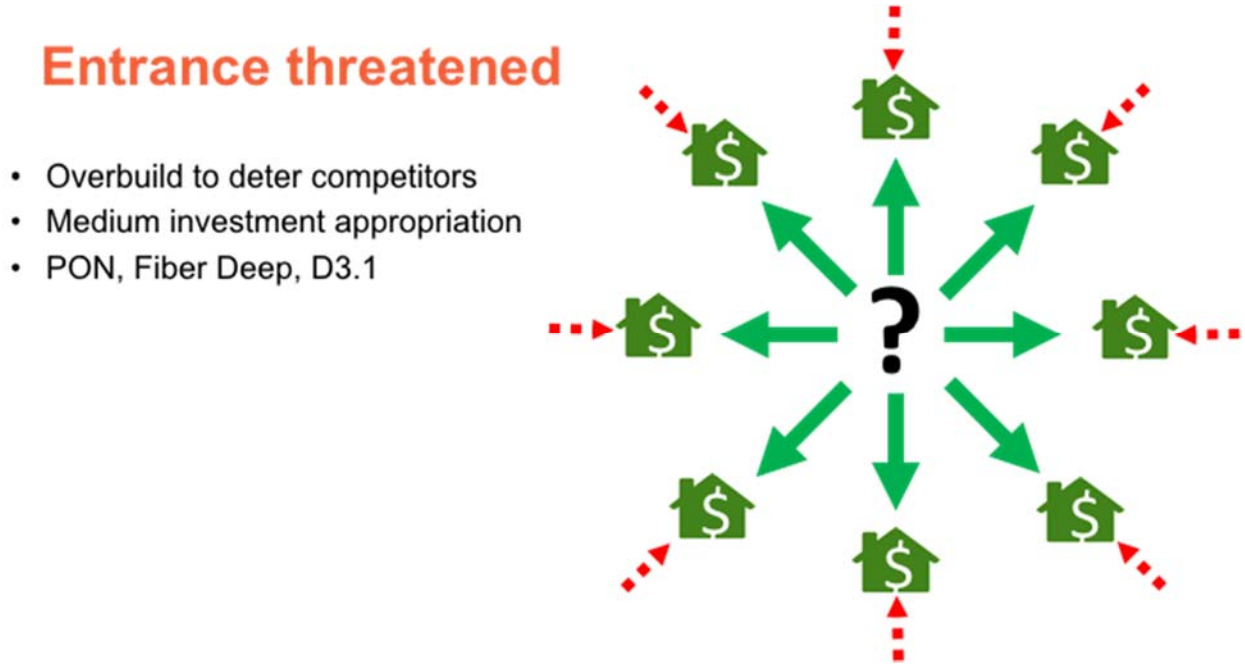

Figure 3 - Build considerations for neighborhoods adjacent to overbuilders

For areas not overbuilt, operators have time to decide what approach to take. Likely offerings include incremental speed upgrades with business-as-usual (BAU) node splits with minimal impact to the outside plant and limited, if any, construction activity. Clearly, operators must factor in available capacity and product offerings requiring that additional capacity. If in areas not yet overbuilt, D3.1 is deployed, operational impacts are mostly BAU.

Figure 4 illustrates a scenario in which operators do not have an urgency to build PON. Within these neighborhoods, targeted upgrades to DOCSIS 3.1 or even fiber deep may be appropriate for pockets of customers.

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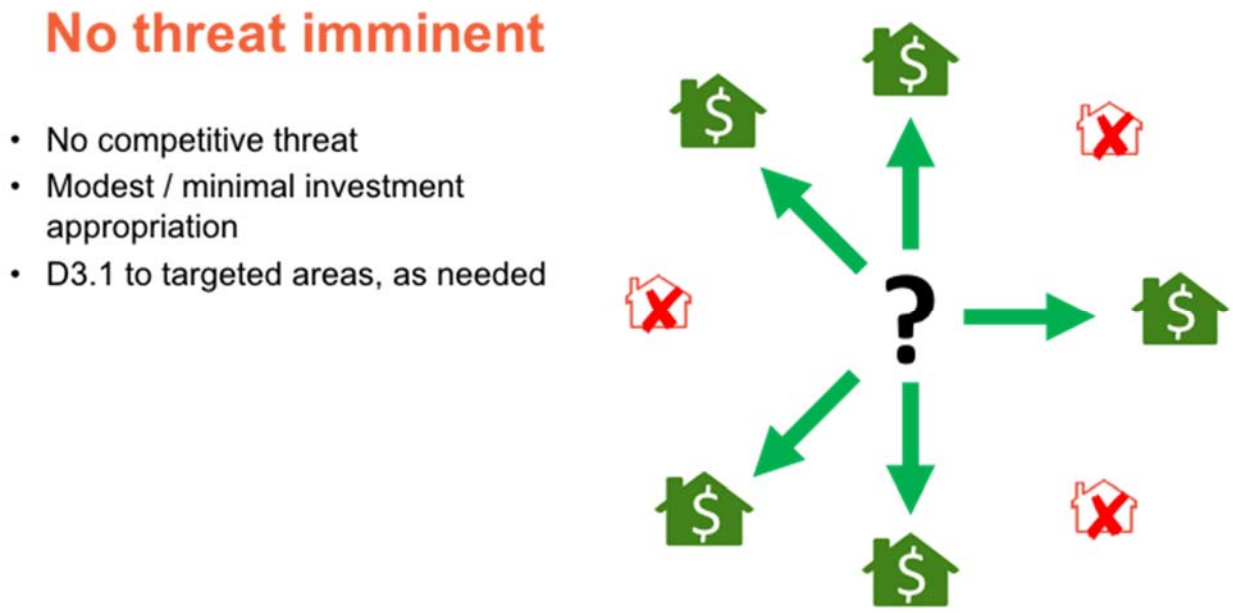

Figure 4 - Build considerations in neighborhoods with high loyalty

In all cases, local Marketing and Government Relations teams should have a keen sense of where the overbuilders are heading. Assessment of where to build PON must take into account customers that may be leaving.

3. Financial Build Considerations

Next, let's consider the financial aspects of PON builds. For planning purposes, operators should have a target cost of PON per household passed (HHP). At the time of this paper's publication, the benchmark for MSOs is approximately $1,000 per HHP which is primarily driven by the labor costs.[3] This figure varies based on the local construction workforce, technology used and, of course, negotiated agreements with the construction contractor. At risk of stating the obvious, larger contracts can give negotiating leverage to the operator to dictate pricing terms. These larger contracts covering multiple geographies help to average out those varying local labor costs.

After setting targets for PON construction, management must have visibility into construction plans to ensure that downstream activities can be executed per plan. Management reporting dashboards should include miles constructed; cost per mile; customer retention; and new subscriber acquisition. A continual review of these operational metrics should compare actuals with plan.

These actual-to-plan metrics must account for both positive and negative performance and must be used by management teams to affect changes. Specifically, if metrics indicate poor performance to plan, what

[3] Source: IBB Consultings

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can be done better? If metrics indicate positive performance to plan, success factors should be fed back into areas where performance is poor. Regular and frequent post mortem reviews should include examination of why the program exceeded (or fell behind) targets. If we've fallen behind, why? Can we make up these deficits? If not, should we adjust forecasts and targets? If we've done well or are ahead of plan, can we (or should we) go faster? Some operators are spending billions of dollars in construction costs, and they need to ensure that they are spending their capital efficiently.

But what operational metrics should be used as an indicator of performance? The answer depends on the organization's management financial objectives. One choice is a simple project return on investment (ROI). Another option are the subscriber penetration and retention metrics interpet a raw number of customers as a measure of success. Another metric is free cash flow which accounts for any debt issued that is directly related to financing construction costs. A metric could be as simple as revenue or profit. Operators have many options from which to choose and in the end are likely to select multiple metrics to report on performance.[4] This is especially true when trialing and deploying early PON builds. Once the builds start generating revenues, they become invaluable in demonstrating which metrics actually start matching their targeted values and prove out the underlying business case.

Irrespective of financial metrics chosen, operators should optimize PON builds against them. And these metrics should be take to the most granular of management levels possible (e.g., franchise). Why? Because management and its discretion and decision-making should reflect how well it is doing compared with other responsibility areas. For example, if franchises are the lowest level of customer management and competition dealings, then each franchise should be accountable for those metrics. Additionally, the granular levels enable benchmarking across the organization to understand differences and, perhaps, how they might be improved.

Operators should also have a strategy for greenfield builds in brand new housing developments and for multi-dwelling unit (MDU) buildings. In these potentially dense residential areas, PON is a cost efficient way to have a high ratio of HHP per mile of fiber construction. Additionally, fiber in residential areas provide the operator with an option to extend it to serve those commercial customers in new and adjacent areas.

Now that we've fully examined the financial and strategic aspects of PON deployments, let's look at the workforce and the additional responsibilities they will assume.

PON Changes the Cable Lifecycle

This section discusses the impact of PON on the cable lifecycle with specific emphasis on the impact to operational teams – both internal- and customer-facing and the challenges each team will need to overcome to achieve success. Internally-facing teams include field service and fulfillment, line maintenance technicians, dispatch, construction, and facilities. Externally-facing teams include Care, Sales, Marketing, and Government and Public Relations (see Figure 5).

[4] A key element to the financial performance is cost which can be measured in various ways. The most direct costs are fiber construction activities which include labor and materials. Additionally, operators must explicitly account for related manpower and activities around expediting permitting, notifying customers of activity in the neighborhood including potential outages, executing construction, and acquiring and retaining customers. Teams impacted include and are not limited to Government and Public Relations, Program Management and Administration, and Marketing and Sales. In addition to their impact, cost of these supporting functions need to account for the hours and effort.

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Figure 5 - Operational teams impacted by PON deployment

While all teams will assume some additional BAU responsibilities, those responsibilities vary in terms of amount (see Figure 6). For teams with a high level of impact, they may have to increase staff or upgrade the skillset of the workforce permanently to account for the additional complexity. This impact requires training to the entire workforce. For teams with medium level of impact, they may have a temporary increase in staff or rely heavily on training to increase the skillset of the workforce. For teams with low level of impact, they may need to temporarily increase their effort by working longer hours or higher contractors on a short-term basis to cover the additional work until it is absorbed by the existing workforce.

Over time, Operators should measure the impact of PON on the operational metrics and 'right size' their teams accordingly. The industry expects a significant reduction of Care calls, trouble visits (aka 'truck rolls') and line maintenance activities over the next 10 years.

Figure 6 - Level of impact on Operational teams by PON deployment

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Table 1 - Summary of PON-related activities by operational team

Function	Impact	Activities	Enablers
Install	High	• Fiber installs	• Training: Processes • Tools
Repair	High	• Fiber repairs	• Training: Processes • Work orders / Dispatch
Construction	High	• As built documentation • Field data acquisition • Status reporting	• Inventory, plant mapping tools
Maintenance	Medium	• Fiber and OLT repair • Drop replacement	• Work orders • Tools • Training
Dispatch	Medium	• Fiber job routing	• Tools
Care	Low	• Troubleshooting	• Training: Line of questioning • Call routing
Marketing	Low	• Upsell of fiber-enabled services • Outage notification	• Status of construction and impacts
Sales	Low	• Sale of fiber-enabled services	• Notification of completed fiber build by neighborhoods
Government Relations	Low	• City / municipal awareness	• 'Leave behind' talking points
Public Relations	Low	• Media awareness	• 'Leave behind' talking points

4. Field Service and Fulfillment

Field Service and Fulfillment teams will have new installation and repair processes, tools and CPE. New procedures and equipment are related to fiber drops to the network access point (NAP) in the cases of both buried and aerial fiber drops (see Figure 7). Drop work includes connecting a fiber drop to the NAP, validating light on a fiber and even replacing it. Mounting of ONUs are also part of technician responsibilities including powering it and installing or changing back-up batteries. In HFC, the ground block at the home has many installation options unlike ONU which needs to be close to power and accessible to both in-home and line technicians. Depending on whether in-home wiring is coax or Ethernet, installation procedures may be different for Ethernet customer premise equipment (CPE). Technicians will also have different home health check parameters. The tools - both physical and OSS –

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will also be different. Technicians will use these new tools to verify status and power levels. Drop buries will continue to be BAU.

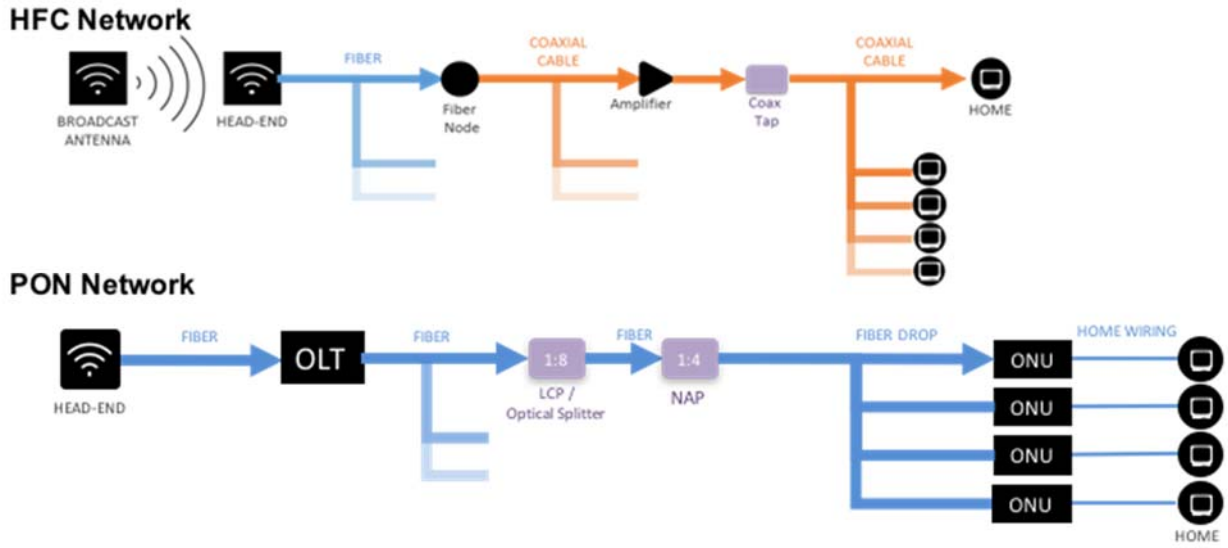

Figure 7 - Side-by-side HFC and PON Network diagram

Repairs include swapping out a malfunctioning PON ONU. It can also include migrating a customer from a combined fiber plus HFC installation to fiber-only installation. This migration scenario may also include in-home Multimedia Over Coax Alliance (MoCA) certification. Another migration scenario is to move a customer from Radio Frequency over Glass (RFoG) to PON by swapping out the RFoG Optical Network Unit (R-ONU) for a GPON- or EPON-ONU. Other repair activities include connector cleaning (aka 'pig tail') at the ONU or NAP; refer to maintenance (RTM) or refer to construction (RTC) for fiber drop replacements; and replacement of an ONU's battery backup for lifeline voice services as required by the Federal Communications Commission (FCC).

5. Line Maintenance

Since the team already works with fiber in HFC plant, Line maintenance will have a moderate set of BAU responsibilities for PON. However, depending on the fiber architecture a mini and strand-mounted Optical Line Terminal (OLT) will be a new device.[5] The OLT requires line maintenance to use new tools to verify home health remotely. Replacement of splitters at the fiber cabinet and replacement of NAPs are likely additional responsibilities.

6. Fulfillment and Day of Job

To coordinate fulfillment and repair activities, dispatch will modify scheduling by having another skillset to map to installation and repair jobs. Dispatch will match PON-trained technicians (and equipment on their vehicles) to the appropriate jobs. While not very different from what they do today, dispatch will have yet another level of scheduling complexity than they do today. Overall, operators will have to

[5] When commercially available, Remote PHY introduces a new device to line maintenance for the HFC network. So OLT for PON and Remote PHY for HFC are new in both types of plant builds.

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decide whether to have their field workforce enabled with both HFC and PON skills and allowance for the time out of quota for PON-specific training. Before training and deployments are complete, Dispatch and Quota tools will need to have PON-specific job and task codes in order to match technicians to jobs. The Day-of-Job team will also need to provide technicans with the location of PON-specific repairs. Service and repair work orders will indicate geographic location of the NAP, fiber cabinet and OLT for efficient completion of jobs – different from BAU.

7. Care

The last customer impacting group is Care. Like Dispatch, Care activities will be similar and likely use an additional set of LOQs. To provide a seamless customer experience, Care tools should have indicators of which customers have PON services. Care will also benefit from diagnostic tools to assess whether they should schedule a technician visit or refer to maintenance. Operators may also want to arm their PON-specific agents with visibility of detailed in-home CPE health (via Technical Report-69 (TR-69) specification), and provide correlation in order to identify when an issue is in the fiber plant to avoid unnecessary truck rolls to the home.

8. Construction

As mentioned earlier, Construction teams are involved in drop buries but may also have the additional set of responsibilities depending on the demarcation point with line maintenance. As a new region begins to deploy fiber, repair jobs will include fiber drop replacements. While this is likely a field service responsibility long-term, Construction may have to temporarily assume this responsibility until Field Service Technicians are trained. Construction may also need to cut in commercial power on the fiber plant for line-mounted OLTs. Additionally, construction may have a role in expanding fiber footprint by installing new cabinets or expanding capacity in existing ones. The most important BAU responsibility is during fiber construction itself. This is accurate and diligent Field Data Acquisition (or FDA). FDA is critical to determine a physical service path of a customer in order to troubleshoot and repair efficiently and accurately. Automating the documentation and loading into OSS tools are key in this respect to minimize dual entry and error. In addition, regulatory and financial report require accurate reporting of fiber (and HFC) miles built and may have tax and fiscal impacts if it is inaccurate.

9. Facilities

Lastly, Facilities will have a new set of optical transceiver equipment. Staff will also configure, install, monitor and manage OLTs in the secondary facilities (i.e., the network hubs or secondary headend). While a new set of responsibilities that are likely to consume more time than currently, this is not greatly different than fiber-based activities and may be a larger percentage of overall work effort and replace HFC-related activities.

10. Other Functions

As discussed earlier in this paper, the PON effort needs support from various groups that will take on new or additional responsibilities. For Government and Public Relations, they will evangelize the benefits of PON to the neighborhoods that they will serve to justify the disruption of daily life during construction. The PON deployment program can support these teams with talking points and a physical marketing piece (aka ‘leave behind’) to articulate those points. Marketing needs to know the deployment plan (i.e., timing, neighborhoods, services) so they can ‘soften’ the ground for sales who will then know when to

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tell prospective and existing subscribers when they can be up and running and with what services beyond what they might be able to receive today over HFC. Support tools will be key to informing when sales and marketing can act. These are likely similar to existing sales tools for commercial fiber builds that notify teams the status of construction activities and their completion.

Operational and Business Support Tools

Underpinning these activities are OSS and BSS tools. When modified or stood up, these tools will enable the success of the workforce. Since these and related tools are highly specialized for existing processes and HFC, Operators goals are to modify how they work in order to support PON which vary from simple to complex. Simple tool modifications can take the form of a new option in a dropdown menu in a user interface. Complex modifications may be as large as replicating a database on which multiple systems are dependent. This section discussions provisioning, network topology, sales and prospecting databases, and technical operations and monitoring.

11. Provisioning

Most operators are stalwart in maintaining the DOCSIS provisioning framework. Given the robust nature and amount of time used in developing it, Operators are justified to keep it. While most operators will implement DOCSIS Provisioning of EPON (DPOE) or DOCSIS Provisioning of GPON (DPOG), MSOs debate the merits of a force fit of DPOx (i.e., DPOE or DPOG) compared to a fiber-base provisioning system used by Telco and fiber overbuilders.[6] CableLabs has proposed an initiative that include provisioning called OnePON which MSOs may migrate to in the future. In either case, MSOs must have a provisioning process and roadmap for PON devices.

12. Network Topology

In fiber to the premise (FTTP) architecture, the physical layer outside plant (OSP) is does not typically carry power along the fiber line between the OLT to the ONU. The significance is that no network component or device in the fiber plant can report back to OSS to determine if there is an impairment or outage. So how does the operator know what to fix (and where to fix it)? A few things need to be known: location, splitters, and port. Locations of NAP, fiber cabinet and OLTs need to be known. If a problem is at any of these locations, a technician needs to know where to go. Splitters with ports exist within the network and mostly in a fiber cabinet. If a problem is in the splitter, the technician will need to know which splitter and port within that splitter to examine. But how will the MSO pinpoint the location of a problem? The next section discusses how correlation will be performed to pinpoint a problem.

13. Technical Operations and Monitoring

The fiber network topology is important in operations and monitoring. For HFC, troubleshooting and provisioning rely on the HFC topology and the accompanying node combining plan. Together, these two items indicate the service path to any subscriber. Additionally, HFC monitoring tools provide indicators of node and amplifier health. With the service path and indicators of health along it, operations can identify where a problem may exist for technicans to investigate.

[6] DPOE / DPOG makes analogies of OLTs and ONUs to CMTSs and Cable Modems

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However, in an all passive PON network, active (powered) devices simply do not exist and cannot provide any telemetry between the OLT and ONU. Therefore, to provide information about the network, end points in the network (i.e., CPE in the home) will have to report back. In addition to the end points, the fiber topology and its passive components must be well documented for each customer. This provides the physical service path for each customers.

With the service path and end points reporting back, OSS tools can perform correlations around outages and service degradations. Working together, OSS can better identify the location(s) where an issue might exist. For example, a customer reporting an outage might be an indicator of a larger issue. Correlation must systematically examine all network components to determine the size of an issue. In this example of a single customer reported issue, Technical Operations must look at other subscribers on the same NAP, splitter, fiber cabinet and OLT to determine if a larger impairment or outage exists (See Figure 8, Figure 9, and Figure 10).

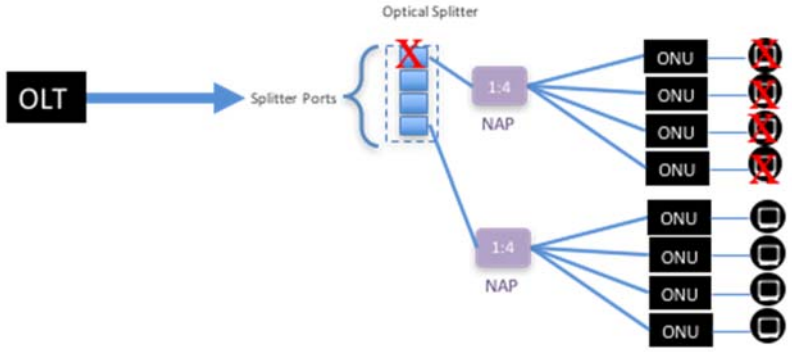

Figure 8 - Optical Splitter Port Outage

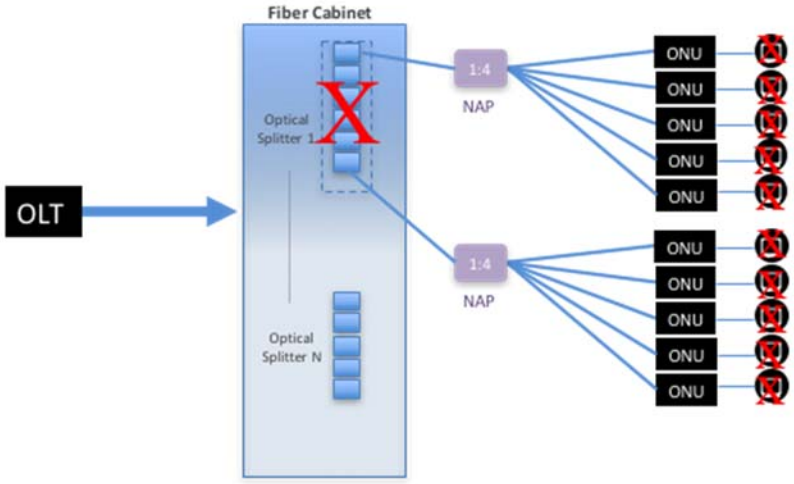

Figure 9 - Optical Splitter Cartridge Outage

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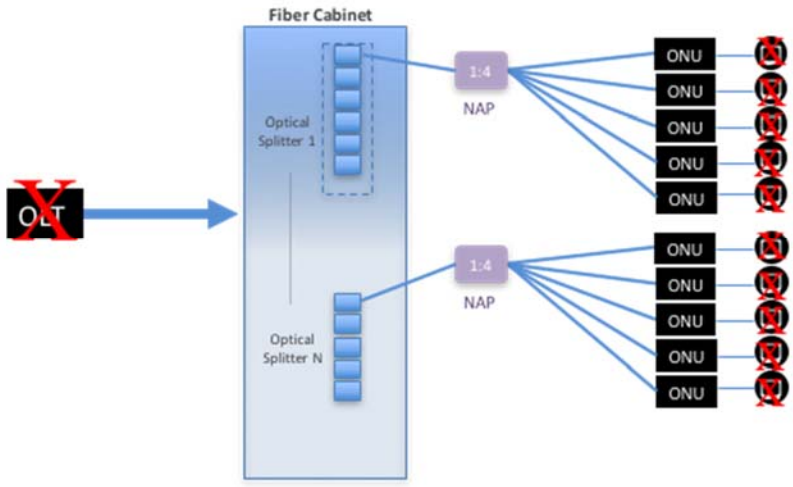

Figure 10 - Optical Line Terminal Outage

When the correlation in a PON network pinpoints the location of an issue, a technician can start at the affected components to further diagnose and repair. Programming correlation into OSS monitoring tools may be even more difficult if a customer is dual wired with HFC and Fiber. The difficulty arises because operations has to both know which services are provided over what network and switch between monitoring tools and repair processes.[7] However, troubleshooting processes are similar and account service codes indicating which services are on what physical layer that require diagnosis and appropriate dispatch.

Culture Change

One final commentary: As operators build out their fiber networks, they are faced with new and additional tasks. Coming from an HFC and legacy MSO world, the workforce may have difficulty in absorbing the new processes and techniques required to operate and manage PON. For telcos, attaching wires into a punchboard and appropriately documenting it has been a standard practice for them. As operators migrate to PON, similar attention to documentation of both physical and optical network components are key to successful operations. MSOs have successfully made large transitions from analog to digital video and are now moving to IP video. Organizations now face the challenge of PON and are up to the task to attain success!

Key Takeaways

PON deployments are complex. To prepare, Operators must:

- Streamline PON builds by examining and acting upon the strategic and financial considerations
- Prepare and train operational teams for the new set of PON-related responsibilities

[7] As of this writing, most MSOs have not built tool that spans both HFC and Fiber for the same subscribers. Dual wiring with HFC and Fiber is only a transition architecture to rapidly deploy 1+ Gigabit service until the operator deploys video over Fiber.

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- Modify and build OSS and BSS tools supporting the workforce activities and processes
- Undergo a cultural shift that re-enforces and rewards meeting performance goals

Abbreviations

BAU	Business As Usual as a part of known operational handling
BSS	Business Support Systems
CMTS	Cable modem termination system
CPE	Customer Premise Equipment
DPOE	DOCSIS Provisioning of EPON
DPOG	DOCSIS Provisioning of GPON
DPOx	Either DPOE or DPOG
D3.1	DOCSIS version 3.1
DOCSIS	Data Over Cable System Interface Specification
EPON	Ethernet Passive Optical Network
FCC	Federal Communications Commission
FDA	Field Data Acquisition
FTTP	Fiber to the premise
Gbps	Gigbits per second
GPON	Gigabit Passive Optical Network
HFC	Hybrid Fiber Coax
HHP	Households passed with outside plant
MDU	Multi-dwelling unit
MoCA	Multimedia over Coax Alliance
MSO	Multi-system operator
NAP	Network access point
OLT	Optical line terminal
ONU	Optical network unit
OSS	Operational Support Systems
PON	Passive optical network
R-ONU	RFoG Optical Networking Unit
RF	Radio frequency
RFoG	Radio Frequency over Glass
RTC	Refer to construction
RTM	Refer to maintenance

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