Thinking Of Moving from DPoE to XGS-PON?

A Few Insights from a Cable Operator's Perspective

A Technical Paper prepared for SCTE by

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1. Introduction

Have you been contemplating implementing XGS-PON in your network but have thus far leveraged Data Over Cable Service Interface Specification (DOCSIS®) provisioning over Ethernet passive optical networking (EPON) (DPoE)?

As cable providers have deep experience in deploying and managing DOCSIS networks, DPoE provides a great method of leveraging DOCSIS knowledge and investments to support fibre to the premises (FTTP) deployments. Despite this advantage, many operators are considering shifting their FTTP technology plans from EPON/DPoE based systems to 10 gigabit symmetrical passive optical network (XGS-PON) for technical or financial reasons.

This paper will explore the key items to consider when making the transition to XGS-PON. Topics that will be explored include technical items such as fiber architecture, provisioning and tools, all the way to cultural and organizational change management (OCM).

As all operator networks and organizations are different, this paper is not intended to provide the answers but instead offer insight and thoughts that operators can take away to help form their own plans.

2. Optical Distribution Network

The optical distribution network (ODN) is the optical transmission medium connecting the optical network terminal (ONT) to the optical line terminal (OLT). It consists of the feeder fiber, drop cables and passive optical splitters fiber. The ODN is a key component of the passive optical network (PON). While the ODN requirements of EPON and XGS-PON are very similar there are several important factors that must be considered before planning a transition from EPON to XGS-PON.

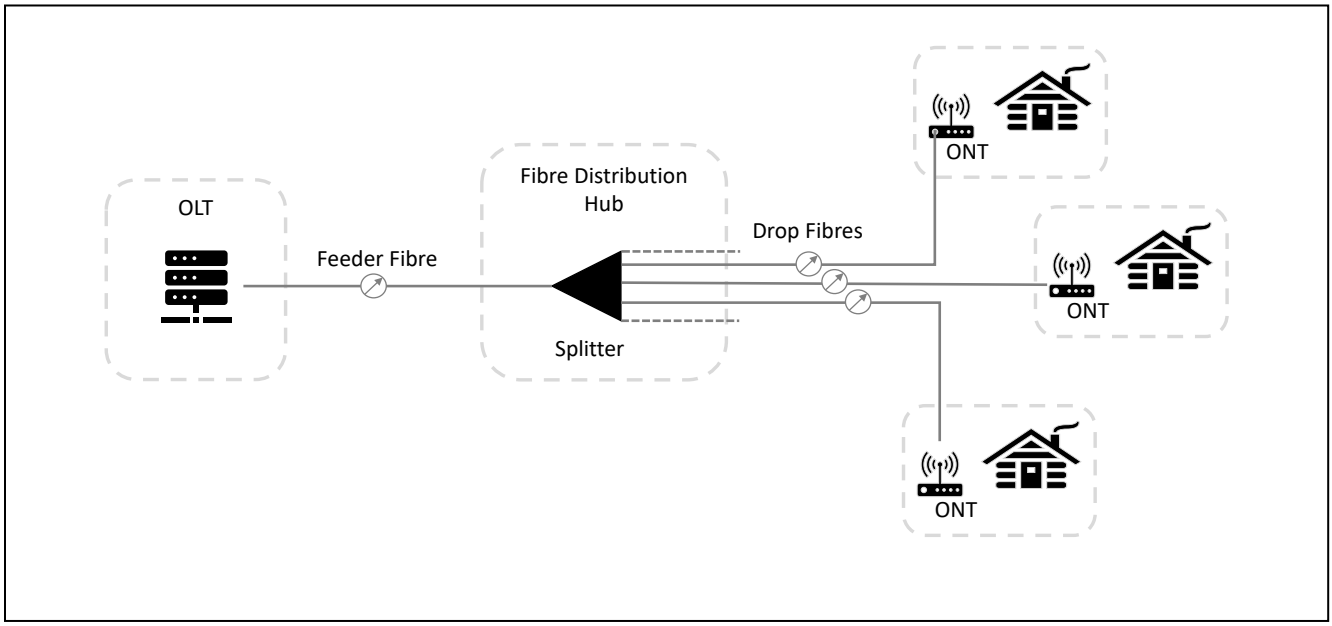

Figure 1 – Simplified PON Optical Distribution Network

2.1. Transmission Characteristics

In the ODN, distances from the OLT to the ONT, and PON capacity are factors in determining the split ratios. The types of customers that will be served on the PON – business and/or residential, and the location of the customers (rural vs urban) may also influence the decision on the split ratios and PON architecture.

Table 1 – EPON and GPON Characteristics

	EPON	10G-EPON	GPON	XGS-PON
Standards	IEEE 802.3ah (2004)	IEEE 802.3av (2009)	ITU-T G.984 (2003)	ITU-T G.987.1 (2016)
Downstream Line Rate	1.25 Gbps	10 Gbps	2.488 Gbps	9.953 Gbps
Upstream Line Rate	1.25 Gbps	10 Gbps	1.244 Gbps	9.953 Gbps
Split Ratio	up to 1:64	up to 1:128	up to 1:64	up to 1:128

EPON/10G EPON and GPON/XGS-PON share transmission characteristics, similar split ratios and optical budgets. As a result, existing EPON/10G EPON ODNs can support XGS-PON services without any modification.

2.2. Wavelength Planning

EPON and GPON technologies use the same wavelengths. 10G EPON and XGS-PON also share the same wavelengths. Therefore, the two technologies cannot share the same physical fiber. Coexistence on the same PON fiber is supported with EPON and 10G EPON, or GPON and XGS-PON. But when migrating from EPON to GPON, or 10G EPON to XGS-PON, then separate PONs and splitters will need to be utilized. When migrating from EPON to XGS-PON, the two technologies can coexist from a wavelength perspective.

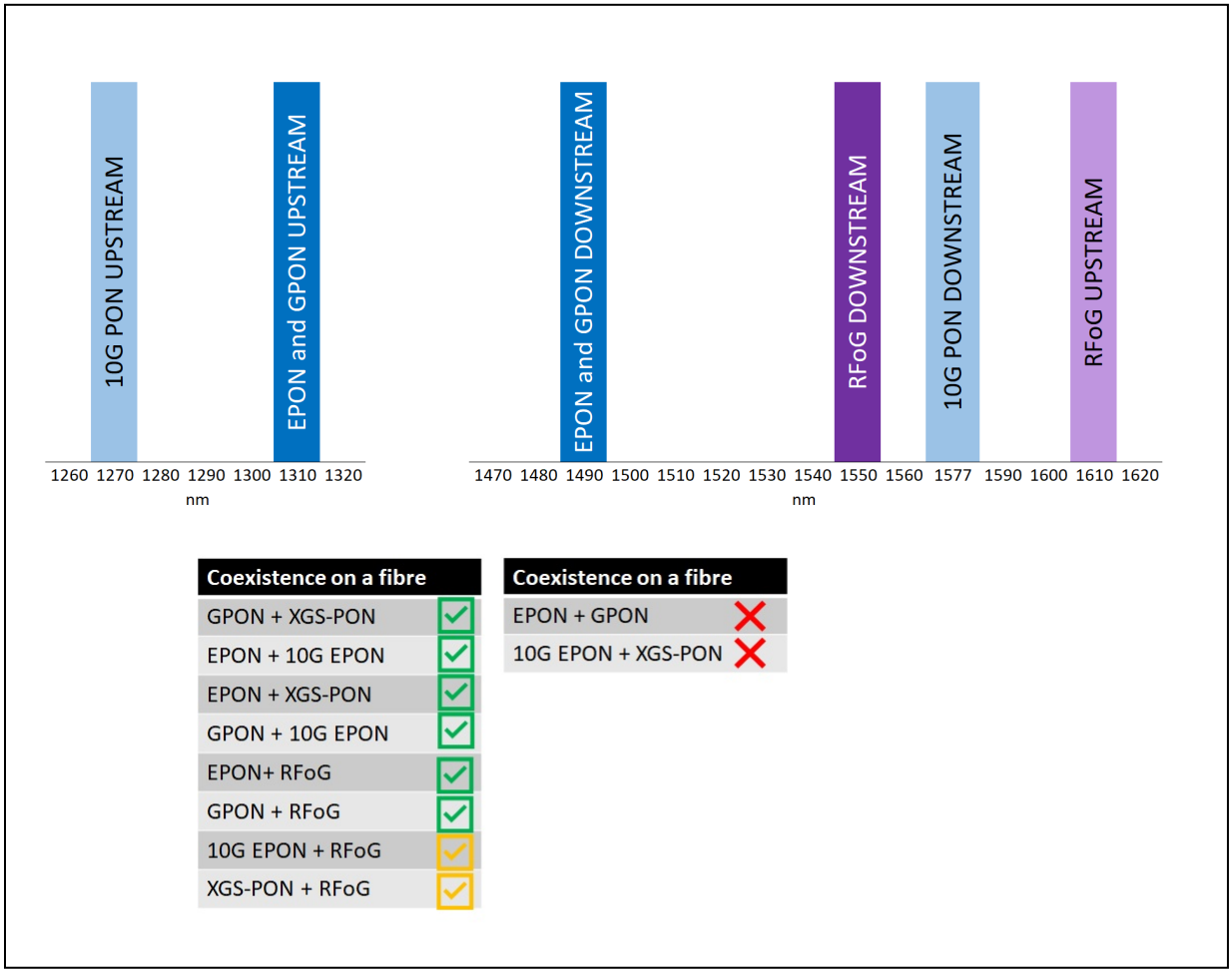

Figure 2 – PON Wavelengths and Coexistence

Radio frequency over glass (RFoG) (ANSI/SCTE 174 2010) may have been used to extend quadrature amplitude modulation (QAM) based services (voice, video and internet) over fiber. For these services, RFoG may be used on its own, with EPON or with GPON. RFoG will also coexist with 10G EPON or XGS-PON but will require wavelength filtering changes due to the proximity of wavelengths used for RFoG and PON. Additionally, operators will need to be cognizant of the RFoG power levels and that the split ratio will need to be kept to 1:32. This could be a limiting factor for PON capacity expansions though, considering that 10G EPON or XGS-PON supports 1:128 split ratios. It should also be noted that if operators use distributed OLT hardware (remote-OLTs) instead of chassis-based OLTs in the hub-site, the analog optics will need to be incorporated into the node housing in the field as well. However due, to RFOG's own wavelengths and optical power characteristics, considerations will not allow coexistence with 10G EPON or XGS-PON. Operators will need to develop a plan to migrate off RFoG especially with PON capacity expansions. Therefore, as ITU and IEEE standards for PON share the same wavelengths this can result in co-existence issues. Operators need to ensure they have a clear wavelength plan defined.

2.3. Distributed vs Centralized Split

Operators will need to consider their PON strategy especially around their current split architecture: centralized or distributed splitting.

In a centralized architecture or single stage splitting, one splitter is fed by one OLT PON port and supports all the drops to the customer premises. In Figure 3, one PON port is split to 32 customer premises at one splitter as an example. There would be a higher concentration of fibers from the splitter as opposed to a distributed split. In a centralized architecture, splitters could be dedicated for each wavelength and PON. Good documentation is required to manage the splitters, homes passed of the PON port and the ONT locations.

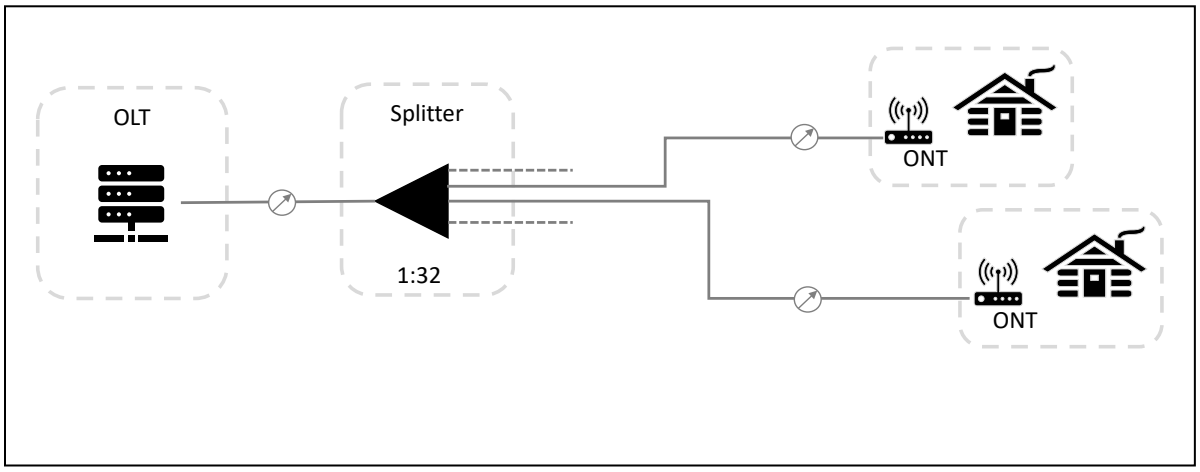

Figure 3 – Centralized Split Example

In distributed and cascaded splits, there are stages of splitters. The splits ratios at the splitters can be any combination as required of the PON. An example distributed split is shown in Figure 4. In this example, one fiber from the OLT PON port would be split 1:4 at the first splitter, and four 1:8 taps would feed a total of 32 customer premise locations. The splitters can be located anywhere in the field. This architecture reduces the fiber counts required near the first stage splitter. Operators will need to take care in planning any PON technology transitions especially if the PONs cannot coexist.

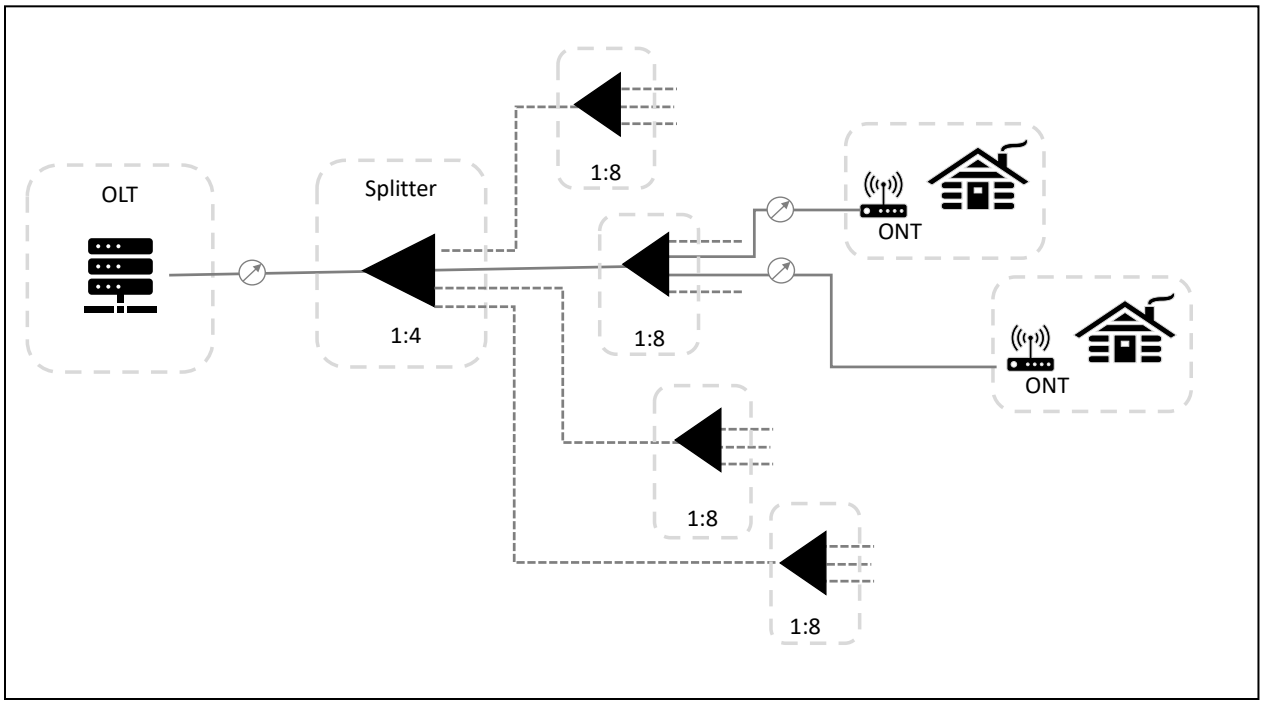

Figure 4 – Distributed Split Example

3. Deployment Model

For PON technology transitions, it will be important to consider the deployment strategies of both new PON customers and of the current PON customer base in an operator's network.

3.1. Greenfield Development

In greenfield deployments, new fiber and PON builds are made to reach new customers. While this is a blank slate, operators will need to determine a wavelength plan of which technologies will be deployed over which fibers and splitters. Proper ODN documentation will be important not only for dependent backend systems, like provisioning, performance and capacity monitoring, but also for operating processes. Good documentation systems will need to be in place to manage the PON capacity and planning. Operators will also need to ensure operating processes and knowledge is in place for the technician dispatch and order fulfillment to understand which customer premise equipment (CPE) to deploy during each customer activation, whether it be the XGS-PON ONT or the EPON ONT.

3.2. Customer Migration from EPON to XGS-PON

Operators should consider their PON strategy and how to manage their current PON customer base and technology: will it be capping the growth of the existing PON technology and fully migrating to the new technology? Or will the existing PON technology also be maintained? When considering migration of existing customers, operators will need a plan. There are additional considerations if it is EPON to XGS-PON transitions, or any other migration where PON coexistence is not possible. The existing PON port and fiber cannot be merely reused without field work. EPON/10G EPON and GPON/XGS-PON will have to be on separate splitters as they cannot coexist on the same fiber since they use the same wavelengths, as shown in Figure 2. Operators may want to think about a customer-by-customer transition plan for a mix of customers on EPON, RFOG and EPON, and XGS-PON. In a centralized architecture, splitters can be dedicated to a PON technology. Migrating existing PON customers would involve moving the drop cable from one splitter to the other likely in the same fiber distribution hub. For the first XGS-PON customer activation, a field technician would activate the new splitter for XGS-PON, and then customer-by-customer be able to transition from EPON to XGS-PON. The drop cable would need to be moved for each customer at the splitter. CPE swaps would be required where an XGS-PON ONT would be installed, and the EPON ONT and RFOG ONU, if applicable, would be removed.

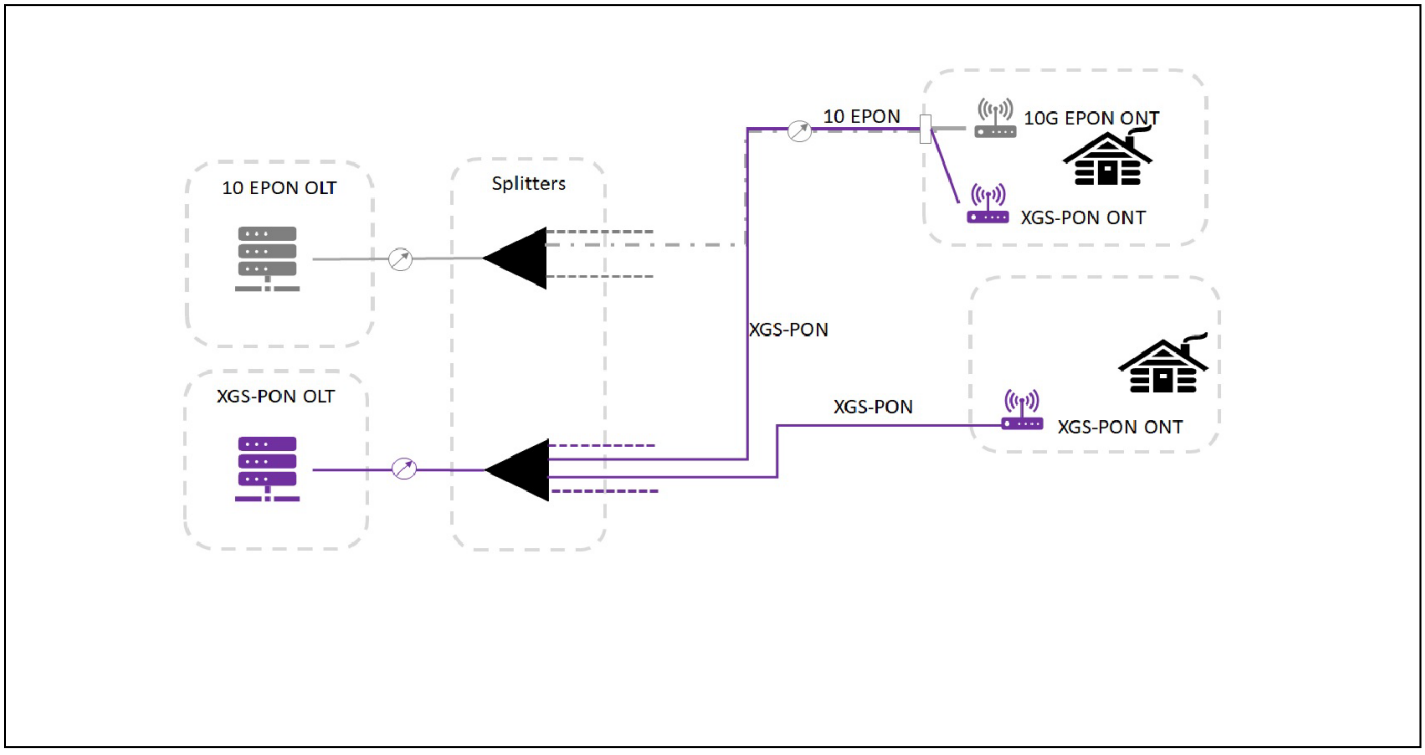

Figure 5 – Customer Migration in a Centralized Split Example

In a distributed architecture, splitters and taps are located in various locations in the field to reach customers. Migrating existing PON customers would involve careful planning. It will not be operationally easy to do these migrations in large batches without risk of impacting customers for longer periods of time, involving many field resources in coordinated efforts, and/or additional fiber builds. Potentially all customers would be switched over when the fiber to the OLT port is moved. If a new splitter and additional fiber builds from the OLT to the splitter and taps is possible, groups of customers migrating at the same time would be fewer. Perhaps providing the customer with the new ONT equipment and asking them to install is an option but operators will need to consider fiber handling and safety procedures. General anticipation of an increase in customer technical support calls may also need to be planned for, as with any new technology launch.

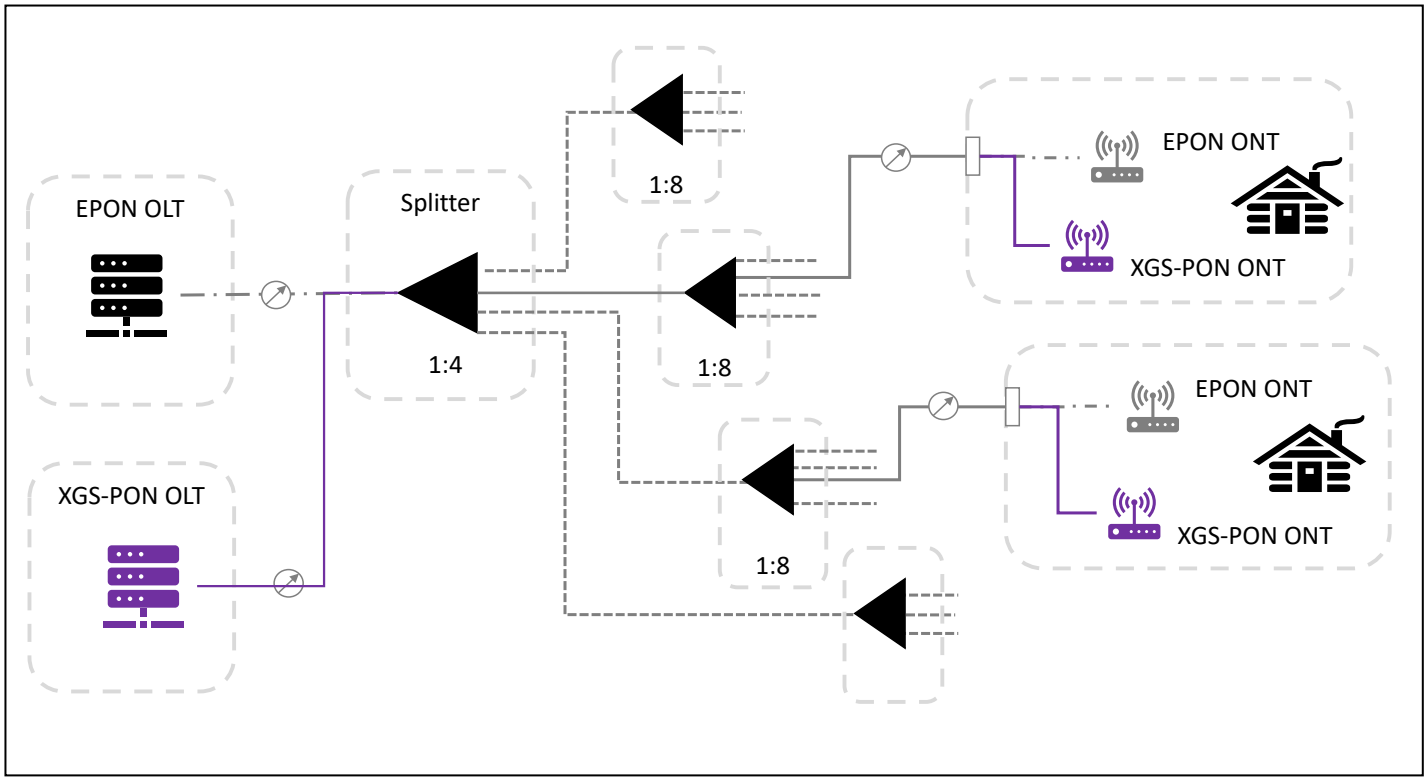

Figure 6 – Customer Migration in a Distributed Split Example

In either split architecture, operators will need to review a plan for capping and growing their PON technologies, and the customer migration strategy for their network scenarios to ensure minimal support requirements.

4. Service Catalog

Operators should review their services to ensure compatibility with the new PON technology. It will be useful to review the entire service catalog in the PON technology transition and determine which are being offered in the new architecture. Re-design and solutioning of each service on XGS-PON may be required. Examples may include speed tiers definitions, IP-only services, and niche services like – hospitality video, elevator service lines, static IPs, lobby cameras, just to name a few. Every service an operator plans to offer will need to be rearchitected and tested prior to launch.

Operators need to have clear plans for all service offerings not just the big three (Voice, Video, Data). Engineering and design teams are not always aware of the work arounds done in the field to support these services (like lobby cameras).

4.1. Services on RFoG

RFoG may have been used with or without an EPON overlay. RFoG allows for quadrature amplitude modulation (QAM) based services to be extended over fiber.

There are several complexities involved with running RFoG. One is with optical beat interference (OBI), when cable modems in an RFoG network transmit simultaneously in the upstream cause interference between the RFoG ONUs, resulting in upstream packet loss. OBI mitigations could include: only using one DOCSIS SC-QAM upstream channel, or specific scheduling at the CMTS capable of detecting OBI issues. A second complexity is with the optical power levels of RFoG and the nearby PON wavelengths. The RFoG optics can overpower those of PON and will result in challenges with RFoG and the 10G PONs. Lastly, RFoG equipment has been difficult to source over time.

Transitioning away from RFoG requires a plan to cap the services being offered on RFoG. The RFoG services will need to be converted to IP services to migrate to PON. So, while the RFoG architecture has served its purpose, as operators transition to all IP-services the need for RFoG is reduced. Migrating from EPON to XGS-PON will be an opportunity to review the transition away from RFoG.

4.2. Speed Tiers

Also required is the decision on which speed tiers to offer on XGS-PON. Each speed tier profile needs to be tested and validated and added in the end-to-end system, from the provisioning system to the billing systems. The operator will need to decide if they want to support all, only some of the current speed tiers offerings, or new tiers on the new PON technology. Servicing tiers over PON allows for potential opportunity to offer higher upstream speeds.

4.3. Specialized Services

There may also be specialized services that operators currently offer that may require re-architecting or review of the solution for XGS-PON. While these services may not be large revenue generating services, their importance should not be discounted and potential redesign should not be overlooked. Example services and their design considerations are listed in Table 2.

Table 2 – Special Services Design Considerations

Special Services	Design Considerations
Layer 3	Which control system to utilize: BNG, PCRF or other policy control system
Static IPs	Determine how to configure the customer
Hospitality Video	Multicast streaming to the hospitality site will be a priority
Elevator Service Lines, Single Play Voice	Plan for a voice-only service option
Lobby Cameras	Ensuring these can be delivered via IPTV in some manner will be essential.
Third Party Internet	Ensuring the TPIA architecture can efficiently deliver the traffic to the hand off location(s) is important.

In some cases, the CPE swap from EPON to XGS-PON in business customers may be more involved. Customer devices such as routers or firewalls may also need a reconfiguration. Operations will need to plan ahead to avoid delays during the migration. For example, some business customers have third party providers who manage their internal networks. Coordination with customers is important to make sure their IT resources are available during the transitions.

5. Transitioning from DPoE to Native Provisioning

Operators need to think about a plan for the transition from DPoE to GPON provisioning. Here are some things to consider.

5.1. Monitoring

DPoE uses a virtual cable modem (vCM) that emulates a response to all DOCSIS MIBs. For DPoE monitoring the vCM is accessed for metrics. In GPON, the metrics are located at the OLT. An operator would need to plan how and what metrics to monitor on a GPON system. With DPoE, operators may not have fully utilized all the PON related monitoring metrics, especially since DPoE was likely utilized to take advantage of DOCSIS features and making the EPON ONT look and feel like a DOCSIS cable modem. There may not have been an urgent need to dig further into PON specific metrics. New and different metrics like optical levels, signal to noise ratios are not required for DOCSIS. As well, whether to capture and use the native GPON metrics from the OLTs and their element management systems, or to utilize the element management systems themselves will needed to be decided.

In transitioning from DPoE to XGS-PON, new monitoring metrics and modifications to the methods used to collect and report on these metrics will need to be considered.

5.2. Provisioning

Provisioning of PON services varies with technologies. DOCSIS provisioning uses cable modem files and configuration files, while DHCP is used to tell the cable modem where to get the configuration files from. GPON provisioning is done on the OLT and the northbound broadband network gateway (BNG). GPON

uses queues for traffic separation or quality of service (QoS), compared to Service Flows used in DOCSIS.

Operators will need to determine how to transition from DOCSIS configuration files which are in the form of type-length-value tuples (TLVs) to GPON configuration. In addition, operators will need to determine a way to differentiate which customers are using which technology and therefore which provisioning system is used – DOCSIS or GPON. A decision will need to be made regarding where each provisioning system will be used, for example at the billing system, or in orchestration or somewhere else. Another decision operators will need to make is whether the operator is building the differentiation decision into their billing system, orchestration, or building a new service to determine this.

5.3. Access CPE Device Management

DPoE systems inherently manage EPON ONT devices via the vCM. The vCM has a management internet protocol (IP) that the DPoE system emulates. In GPON, management of the GPON ONT is done via the OLT and often this is via an element management system (EMS) of the OLT. Any other management systems and any other tools will need to understand how to talk to the EMS when information is required about the ONT itself.

Operators will need to think about how to do policy management, charging, and authentication. policy and charging rules function (PCRF) is responsible making policy decisions and charging rules, which control how subscribers use network resources. The different PON technologies will manage this function differently and operators will require a detailed understanding for integration purposes. An operator will need to decide where this policy is kept, for example: in an element management system, in the BNG via local user database (LUDB), or PCRF.

5.4. Network Architecture

In the PON network architecture, there are a couple of decisions operators may contemplate. With the OLT, there are centralized, chassis-based OLTs typically deployed at a hub site; and distributed OLTs where the OLT is installed in the field like a node. The decision to use one or both may depend on items like the serving area and its distance from the hub site, hub site and current transport architecture, hub site space and power availability etc.

Another consideration is with the broadband network gateway or BNG, which is the traffic aggregator. It is responsible for authenticating subscribers using a LUDB and is the gateway for customer traffic. The BNG could be a layer 3 gateway device that is able to communicate with a PCRF, or operators may decide on a more feature-rich BNG device.

Secondly, operators can decide on whether to use a centralized BNG, or a distributed BNG architecture. A centralized BNG architecture would utilize larger-scale BNGs deployed centrally at hub sites and core locations. A transport network is required to connect to the OLTs. A distributed architecture would use smaller-scale BNG devices, distributed into the regions. These BNGs would be smaller points of failure than a centralized solution. OLTs would likely connect directly to these distributed BNGs. While minimal transport network would be required between the OLT and BNG, additional aggregation points in the core may be required. The design will need to consider expansion and customer scale.

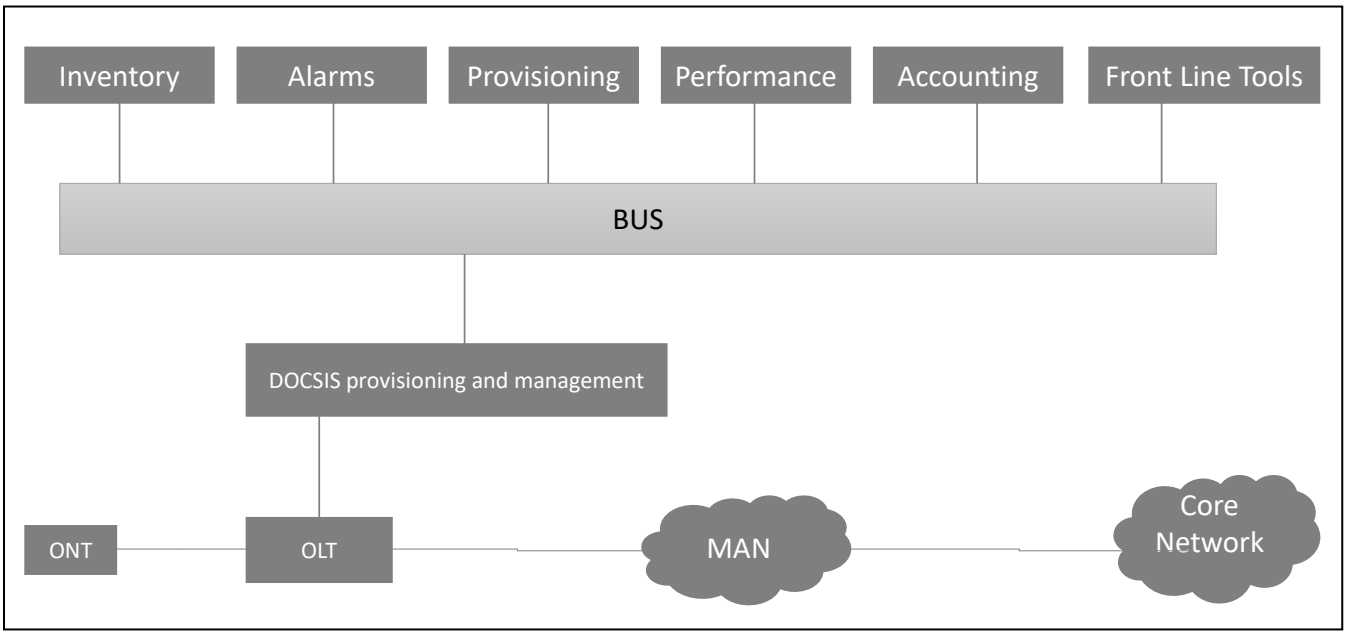

Figure 7 – DPoE Network Block Diagram

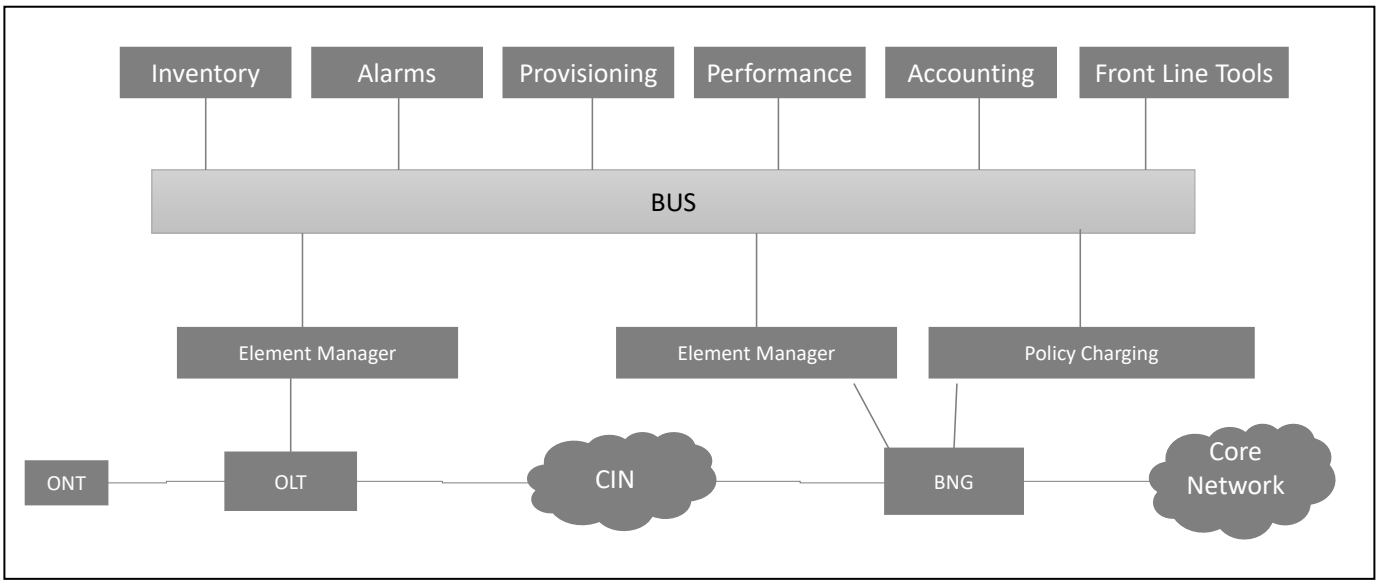

Figure 8 – GPON Network Block Diagram

6. Program and Organizational Change Management

Introducing a new technology and architecture will impact many departments. A clear program objective is very important. Stakeholders aligning at the beginning of the program of the minimum deliverables of the program will reduce confusion and debates and make overall delivery more efficient.

Because there can be so much to learn about a new technology, architecture, and processes, clear roles and accountabilities in the program are beneficial, especially Lead Architects in each domain and knowledgeable end-to-end system primes.

6.1. Development to Production Phases

From the development lab through to the first production launch, there is a lot of testing within and between teams. Establishing and coordinating clear testing schedules will be challenging but is important. An agile approach – using short test cycles and reiteration, works well especially when there are dependencies with other team's test results, configurations and time.

Establishing a production trial period in friendly locations, to test and practice production deployment processes and production networks allow for teams to smoke test the system and identify faults that only show up in true production deployments. The potential for unplanned issues should not be underestimated in making changes of this magnitude. This is also an ideal set up for continued regional training of the technology and operating procedures.

For the initial production deployment phase to ensure first customer deployments runs smoothly, a specialized support team could be formed. The purpose of this group could be to ensure that there is a direct line to all the domains and teams for escalations and quick resolution. This could be especially useful when a technician is at a customer's home and requires assistance and quick resolution. It would not be sustainable to maintain this team for a long period of time, so during this phase it is also a good opportunity to review what escalations and issues are experienced and determine what is required to move out of this phase.

6.2. Organizational Change Management

There are new skills for teams to incorporate into their accountabilities in a transition of PON technology. The support tools and processes are different and will require teams to learn and adapt. Operators should plan and think ahead to prepare all the various teams, like network provisioning teams, field teams, and escalation teams.

With the BNG and the access CPE device management functions in either the BNG and PCRF, LUDB or other policy control systems, operators will need to think about roles and accountabilities including subscriber policy and contracts management, network configurations management and associated functions in the element management system. A review of these functional roles may be required by operators.

In many areas, teams will need to learn new troubleshooting and provisioning skills. While integration into existing tools and systems will occur, teams may need to learn CLI or EMS steps on a fundamental basis to integrate systems and also in exceptional troubleshooting situations. Field teams will need a laptop when it was not previously required. Overall escalation processes and teams may be different due to new accountabilities of the technology.

Training is an important aspect and determining the best timing for the training is equally important. Providing the information too early runs the risk that the knowledge may not be retained. And too long after will not be helpful for initial launches. Establishing a regular cadence of refreshers across departments may also be useful.

There is plenty of change between EPON and GPON technologies affecting many roles across the organization that engaging OCM teams early in the program would be beneficial to assist teams through the transition. Developing a plan on how to manage and get in front of the changes impacting teams will alleviate any frustrations during a period of lots of learnings.

7. Conclusion

It is possible to take a project from concept to production in minimal time, even as the whole company is learning along the way. DPoE is an introductory step towards FTTP and with DOCSIS as a foundation it was mostly seamless to integrate. While deploying XGS-PON is unique compared to DOCSIS systems, operators can rest assured that it is doable to integrate the new technology. The more challenging aspects have to deal with the program and change elements rather than the technology itself. Top three items: picking the right battles, establishing a good execution plan, and make training and communication a top priority.

Operators should concentrate on their program's key deliverables. Establishing these at the onset of the program will help keep everyone moving towards the same objectives. As things inevitably will come up, these principles will help with decision making and determining which issues and initiatives to concentrate on.

Along with the overall delivery objectives, a good execution plan including designating key lead primes in each domain will make things smoother. Having lead architects that are knowledgeable of the end-to-end systems will be crucial. One of the hurdles may be with testing between teams: lab testing, pre-production testing, and field validations before adding customers. Of course, these phases are not a new concept, but keep in mind the scale of testing an entirely new end-to-end architecture, and the domains and teams dependent upon one another. There is not a lot common between DOCSIS and XGS-PON. The back-office systems and operations support systems need to be integrated with the new technology. Allocation of adequate time for each team is not easy. They will be dependent upon each other.

Finally, there is lots to learn with switching technologies, aside from the obvious learning about the new technology, but also potentially new processes and accountabilities that are required. Whether for new teams or seasoned architects, there will be a learning curve. Don't underestimate how much there is to learn and get accustomed to with the shift from EPON to XGS-PON. Everything from field technicians needing to learn new troubleshooting skills, to architects needing to learn the functions of domains like the BNG and PCRF. Training will be required early on to even understand the technology enough to design the network architecture, network design and network components. Training is required to get teams familiar with how to implement the new technology and as deployments span throughout the regions.

Tie this together with great communication and some celebrations along the way. While the technologies are different, it is attainable to make the transition.

Abbreviations

BNG	broadband network gateway
CIN	converged interconnection network
CPE	customer premise equipment
DHCP	dynamic host configuration protocol
DOCSIS	data over cable service interface specification
DPoE	DOCSIS provisioning over EPON
EPON	ethernet passive optical network
FTTP	fiber to the premise
GPON	gigabit passive optical network
IEEE	Institute of Electrical and Electronics Engineers
IP	internet protocol
ITU	International Telecommunication Union
LUDB	local user database
MAN	metro area network
MIB	management information base
OCM	operational change management
ODN	optical distribution network
OLT	optical line terminal
ONT	optical network terminal
ONU	optical network unit
PCRF	policy and charging rules function
PON	passive optical network
QAM	quadrature amplitude modulation
QoS	quality of service
RFoG	radio frequency over glass
SCTE	Society of Cable Telecommunications Engineers
SC-QAM	single channel quadrature amplitude modulation
TLV	type-length-value tuples
TPIA	third party internet access
vCM	virtual cable modem
XGS-PON	10G GPON

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