A Virtual Broadband Network Gateway (vBNG) Approach for Cable Operators in a Distributed Access Environment

A Technical Paper prepared for SCTE•ISBE by

Jason Combs
Principal Architect
Comcast
1800 Arch St Philadelphia, PA 19103
609-706-9190
jason_combs@cable.comcast.com

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1. Introduction

For as long as the Multiple System Operator (MSO) community has built and operated networks, we have been looking for better ways to segment it, and to optimize the work needed to update and maintain it. In addition, serious efforts emerged over the last several years to add other access media to the mix, such as passive optical networks (PONs) and wireless technologies. Among these efforts is network function virtualization (NFV) and software defined networking (SDN), which have captured the attention of the MSOs and of the networking world at large. How does the MSO community take advantage of these concepts to fulfill both today's needs as well as the desire for an easier, quicker deployment of access network technology going forward into the future? In this paper, we will explore:

- Challenges faced by MSOs in deploying new types of access technologies alongside the current (virtual/"v") CMTS
- A method for abstracting service activation to allow for common control of dissimilar access technologies
- A flexible virtual broadband network gateway (vBNG) structure that matches MSO service formats to operate non-DOCSIS access technologies (e.g. PON)
- Advantages of this NFV and SDN approach compared to a traditional hardware BNG

2. The challenges of today's access network

The traditional cable operator's access network is centered around the DOCSIS technology that we all know and love. The business support systems (BSS) and the operations support systems (OSS) that are employed are equally centered around supporting the protocols defined by the DOCSIS protocols. CableLabs and we, as a community, have done an excellent job of extending those systems to support our business needs, as our customers and the Internet as a whole evolved from basic data services into voice, IP video, and commercial services.

The focus on a single technology with a single provisioning and operating model led to development of Cable Modem Termination Systems (CMTS) and Optical Line Terminators (OLT) that are fully integrated, as shown in the blue and orange boxes in Figure 1. These systems are typically developed by a single vendor to support all of the service, routing, reporting, and physical functions. The Distributed Access Architecture (DAA) separated the physical generation of the signal, but otherwise remained as integrated as the original CMTS systems. Likewise, the virtual CMTS (vCMTS) has given us a peek into the future by allowing the CMTS functions to live in a server environment, with all of the technology used to accomplish that, but still retains the unified structure seen in prior iterations of the CMTS.

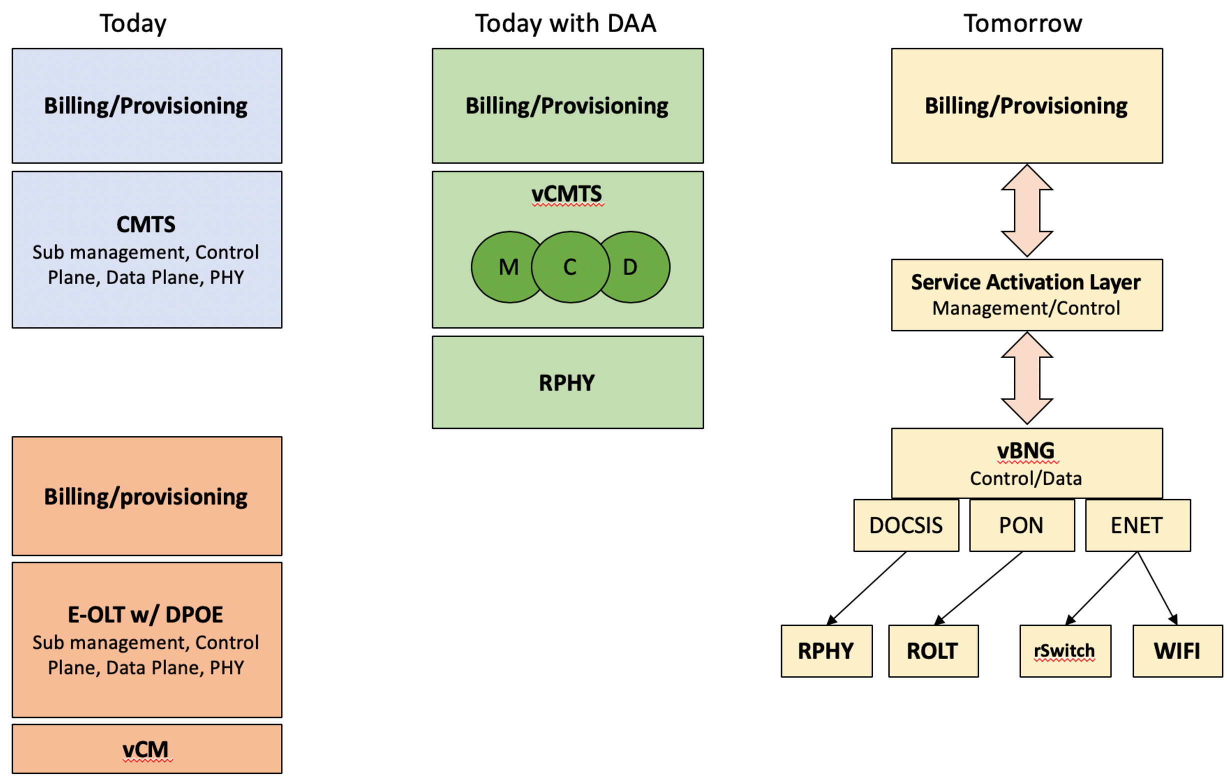

Figure 1 – Evolution of the Access Network

The challenge with this integrated structure begins to clearly show itself once we consider providing our services through other access technologies. The expansion into other access technologies is happening for a number of reasons including demand for multi dwelling unit solutions, changes in physical construction costs, and the desire to compete in the Wi-Fi and wireless arenas. Although more distinctly seen now, these issues have been lurking in the shadows all along. The DOCSIS service, provisioning, and operational models do not mesh well when combined with the wireless, fiber, and ethernet technologies that allow us to expand our network in non-traditional directions. On the other side of the coin, the BSS and OSS systems that have grown up in reaction to the DOCSIS architecture force us to attempt to have other access technologies mimic that architecture to avoid major back office changes. The following paragraphs provide a brief synopsis of five admittedly intertwined priorities that are difficult to achieve with the current structure.

- *Swift integration of new access technologies*. Beyond the need to develop a technology for our physical network, new technologies typically also come with a full system design and integration. All of these system components require time to develop, and often duplicate the same functions from other systems. Most introductions of new vendors cause us to start this cycle again, representing a high barrier to entry and ultimately fewer options for technology partners.
- *Consistent services provisioning*. It is cumbersome to develop and maintain separate BSS systems, in whole or in part, for every technology that we deploy. The problem is a compounding one. It is a massive effort to deploy new authentication and service definition systems, and once they exist, they are difficult to maintain while assuring that service definitions remain aligned

with the existing DOCSIS systems. The way around this problem is to create a translation system, such as the virtual cable modem introduced by DOCSIS Provisioning of EPON (DPoE). This, too, needs to be maintained and updated with the latest changes, and can easily fall behind. Workaround remedies add time to any process and represent custom work for the MSO community.

- *Service consistency*. DOCSIS provides a robust set of service features, which are implemented in its service flows with extensive classifiers, subscriber management filters, and frame accounting with Simple Network Management Protocol (SNMP) and IP detail records (IPDR). Other access technologies have similarly robust features that are simply different from what we typically use. Aligning these methods can cause hardware and feature control issues that limit our choices. The worst-case scenario is the network could look and act differently for one customer than it does for another.
- *Testing velocity.* Swift testing is an inherent challenge with any additional development. What exacerbates it is the unnecessary replication of the same function within multiple systems. Rather than testing the unique functions, much time is spent retesting different implementations of the same function.
- *Operational model differences*. With different systems come different interpretations of specifications and different interface models. This is aggravated by specifications created by organizations with very different goals, that apply to other access technologies. They also create additional work, to translate from one system to another.

3. A method of network abstraction

There is no simple or fast solution to the challenges stated in the previous section. A new system organizational abstraction is needed to make significant progress in resolving these issues. The existing system needs to be broken into distinct components that can evolve in isolation from each other. In kind, these components need to be linked by extensible application programming interfaces (APIs) that can be modified to meet the needs of the future. With this isolation and extensibility, we remove the need to replicate functions that are common to all of the access technologies and give ourselves the flexibility to integrate any technology quickly. Figure 2 below represents the proposed network abstraction.

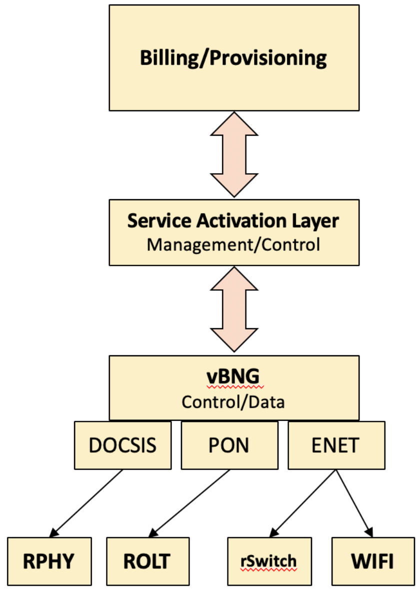

Figure 2 – Functional components of this network abstraction

This architecture focuses on three major areas of providing services through a scaled access system:

The billing and provisioning systems manage the customer entitlements and interactions with us as cable operators. It is necessary to break away from the tight DOCSIS integration that our back-office systems are built on. Much of the goal of this architecture is to enable that transition. The change itself is a massive amount of work that is not directly addressed within this paper.

The service activation layer receives the entitlements from the BSS and creates the detailed service description for a particular customer device.

The vBNG implements the service description provided by the service activation layer and manages the moment by moment experience of the customer. This layer can be broken down further, which we will explore in the following sections. We can add a fourth area to this list of three areas to include the operations and data gathering systems. This has been explored by prior papers in detail, for example, in the SCTE paper "The Future of Operations: Building a Data-Driven Strategy" [1] and will not be explored here.

3.1. Service Activation Layer

The service activation layer exists to create a means of defining the customer's access network services that is abstracted away from both the BSS system and the access technologies that those services ride on. There are several aspects to this component that are necessary to be able to provide this function as illustrated in Figure 3.

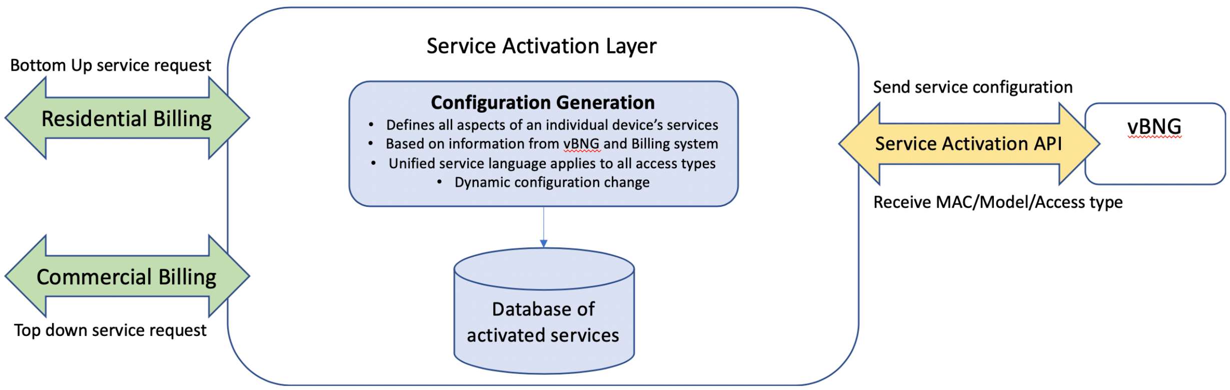

Figure 3 – Interfaces and functions of the Service Activation Layer

- *Service Entitlement flexibility*. Many access networks, such as DOCSIS, use a bottom up provisioning methodology where the end device requests service. However, there are examples of top down access networks, such as commercial ethernet and residential ethernet, where the end device does not include this capability. It is important to have an API that allows for both methods of entitlement and configuration.
- *Unified Access Service Descriptors*. These descriptors are imagined to be in the form of a YANG data model to communicate the services to the vBNG deterministically. They would be formed via a configuration generator that takes the access device type and model along with the customer's entitlements into account. With a common vBNG data plane and a desire to have consistent services, it is imagined that the YANG model for the customer's services would be largely common between access types. The Virtual Provisioning Interfaces Technical Report [2] produced by CableLabs has defined a YANG model that may be a good fit for this language.
- *Access/Customer Premise specific configuration modifiers*. While the majority of the service definitions will be common, there will certainly be access-specific configurations that would be of interest. For example, a PON system may want to be able to configure optical parameters that do not apply to other access technologies. Access-specific extensions of the universal YANG model would cover this case.
- *Database of activated services*. With millions of devices in our networks, it is often difficult to have a definitive knowledge of the exact service configuration the customer device is operating upon when a problem is discovered. The service activation layer should record the exact configuration given for each device to aid in troubleshooting and to add traceability.
- *Push/Pull of configuration*. In the same vein as supporting both bottom up and top down provisioning, this is the mechanism for providing the YANG model configuration to the vBNG. This also enables the ability to change customer device configuration dynamically.

Introducing the service activation layer gives us several capabilities and advantages that help us overcome the problems defined earlier in this paper.

- It abstracts billing and provisioning away from the configuration of the network.
- It presents a consistent service provisioning mechanism for all access networks and all services running through them.
- It brings consistency to service definitions across all access technologies, making their implementation also consistent, within the vBNG
- It eases the application of dynamic services to existing devices and allows for modification of existing services.

3.2. The virtual Broadband Network Gateway structure

Many of the issues discussed here can be resolved with a proper vBNG implementation. There are a number of options, in terms of how the vBNG can be laid out, and which components are included. Let us start with a description of the basic components in this method.

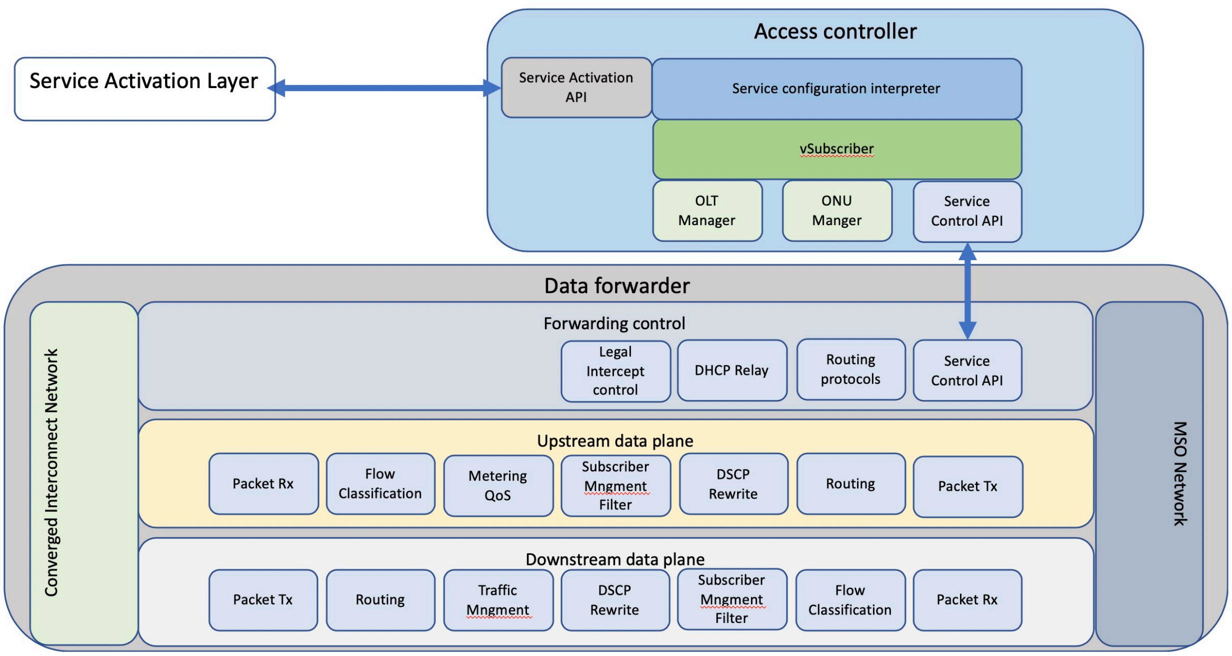

Figure 4 – vBNG structure (OLT example)

Access controller. This sets up the access network itself and the services that flow through it. To accomplish this task there are several steps that are necessary. A service configuration interpreter translates the YANG model produced by the service activation layer into access-specific configurations used by the vSubscriber data construct. The access manager, displayed as an "OLT" or "ONU Manager" in the diagram, is responsible for configuring all remote access components. A service control API then sends the necessary configuration information to the data forwarder, which is where components common to all access networks are configured.

Data forwarder. This provides frame processing and basic subscriber services. Certain functions can be enabled or disabled, such as a traffic manager, for access networks that do not have a built-in means of doing so. On a per customer basis, features like subscriber management filtering and DSCP rewrite can be enabled or disabled based on the services defined via the service activation layer. To aid in effective use of network and processor resources, the data forwarder can be implemented as a single unit or can be separated out for greater flexibility. The first logical separation is the network control, which includes the functions necessary to connect to the MSO network as well as typical services such as DHCP relay, routing protocols, and legal intercept controls. The upstream data plane is the next separation and provides data forwarding services from the customer into the network. Upstream traffic typically has a lower volume expectation. Finally, the downstream data plane provides data forwarding services from the network to the customer. In this case, all access networks would utilize the traffic manager function to shape traffic going downstream. Downstream traffic typically has a higher volume expectation.

These components give us several advantages, no matter how they are laid out in a virtualized system.

- The data forwarder includes common code for all access networks. This is a major facilitator of service consistency, as all customers are served by the same implementation for many of functions provided. From a development perspective this allows us to develop once but use the code many times. Adding new routing protocols, for example, only requires the single implementation to be tested. There is also no need to test the common code extensively when a new access network is developed.
- The Service control API is well defined between the access controller and the data forwarder. This allows for easy and unambiguous integration with new access controllers.
- New development for a new access technology is primarily limited to the access specific functionality such as the access controller, the remote access element, and interoperability with in-home equipment.

4. Advantages of an NFV and SDN approach compared to a traditional BNG

The traditional BNG is the staple of many telecommunication companies' network and has proven to be a solid solution for their access needs. So, why not use the same thing? The answer lies in flexibility. Just as with traditional CMTS deployments, a network operator must choose and size the BNG appropriately for both their current and future needs. Inevitably, when the network capacity or business needs surpass that BNG's capabilities, the operator must upgrade or add more BNGs -- or worse, do both.

Flexibility and reuse are where NFV and SDN shine. This is exemplified by allowing the system to expand functionality naturally into new access networks, while also allowing each of the components to continue to evolve -- to remain the best they can be, without requiring that the entire system be recreated. In terms of capacity, the system relies on generic processing hardware to do its job.

The first advantage with this approach is the ability to directly add capacity by adding more compute power, without touching the rest of the system. Secondly, when using generic hardware, the system can be laid out in different ways to fit the most effective technology, in terms of cost and efficiency.

There are several ways in which these components can be laid out in a virtualized system to optimize the available technology.

The first decision for optimization is whether one instance of the vBNG will handle one service group or many service groups. A single service group vBNG gives you the greatest control and isolation at the expense of more wasted processing cycles, while a multiple service group vBNG gives you more efficient processor utilization at the expense of more complex control and isolation.

The other area of opportunity is whether and how to separate the components of the vBNG to more efficiently assign processing resources. Separating the access controller from the data forwarder is attractive as the access controller and the data forwarder have very different functional and service assurance metrics. This separation would allow for a considerable amount of processor utilization optimization. Perhaps this would give us the ability to have the access controller live higher up in the cloud. Another way to optimize the component separation is to divide the upstream and downstream data planes. This would allow us to take advantage of inherent differences in upstream and downstream utilization. The upstream data plane has significantly less usage, even with symmetric access technologies, and can be multiplexed more effectively, while the downstream data plane has significantly more usage and needs more network and processor resources to be assigned.

Details of these approaches are a subject of considerable discussion in and of themselves. Intel has published an architectural study that dives deep into the factors of these decisions [3] that may be interesting to the reader of this paper.

5. Conclusion

The protocols defined in the DOCSIS specifications have led us down a path that has centered our back office and access networks around those protocols. This has been very good to us, but it is time to integrate other access technologies into our portfolios. The NFV and SDN evolution gives us an opportunity to refactor the way that we build and run our networks to support both the network of today and the multi-technology network of tomorrow.

In light of this goal, this paper has described an access network abstraction which defines a clear demarcation of system functions between the BSS and OSS, service activation, and network access. This architecture should allow us to:

- Deploy new technology quickly.
- Provision access networks in a unified way.
- Have consistent services.
- Minimize testing.
- Enjoy one operational model.
- Evolve each component of our network without interfering with the others.

We must not only produce a network that solves the problems that we can foresee, but one that allows us to continue to adapt well into the future.

Abbreviations

vBNG	virtual broadband network gateway
MSO	multiple system operator
NFV	network function virtualization
SDN	software defined networking
PON	passive optical network

CMTS	cable modem termination system
vCMTS	virtual cable modem termination system
DOCSIS	data over cable service interface specification
BSS	business support system
OSS	operational support system
DAA	distributed access architecture
DPoE	DOCSIS provisioning of EPON
vCM	virtual cable modem
ENET	ethernet
RPHY	remote PHY
ROLT	remote optical line terminator
SNMP	simple network management protocol
IPDR	IP data records
API	application programming interface
YANG	yet another next generation
OLT	optical line terminator
ONU	optical network unit
DSCP	differentiated services code point
rSwitch	Remote Switch or field deployed switch
SCTE	Society of Cable Telecommunications Engineers

Bibliography & References

[1] SCTE paper "The Future of Operations: Building a Data-Driven Strategy"

[2] Virtual Provisioning Interfaces Technical Report - CableLabs

[3] https://www.intel.com/content/dam/www/public/us/en/documents/platform-briefs/broadband-network-gateway-architecture-study.pdf

