Converged Multi Access Networks

A Technical Paper prepared for SCTE•ISBE by

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Table of Contents

Title **Page Number**

List of Figures

Title **Page Number**

Introduction

This paper discusses the benefits of converged multi access networks. The paper considers three main access technologies. They are Cable, Mobility & PON. As these three access technologies evolve, opportunities to evolve the aggregation and edge networks emerge. Newer network architectures offer unprecedented opportunities for Multi Service Operators (MSOs) and Service Providers (SP) in architecting networks, streamlining and simplifying operations, and opportunities to offer new services at reduced cost. Converged multi access networks also offer benefits for subscribers, as their internet experience will be uniform regardless of the access media/type.

The paper discusses key technology evolutions first. These are enablers for the converged multi access network. It presents the components of the converged multi-access network and discusses the converged architecture while contrasting them to today's network build outs. The benefits of converging the network are presented and discussed. Finally, the converged network topology is presented. The paper concludes with the benefits of such an architecture to MSOs/SPs and subscribers.

Key Technology Evolution

Access network technologies are undergoing two key technology evolutions. These are catalysts to evolve the access network to a converged access network. The two technology evolutions are migration from big iron hardware to virtualization and disaggregation, and deep fiber migration of access networks.

The primary goal of the access network evolution is to provide 10 Gbps to the home at reduced latency and cost. There is uniformity in the way different access technologies are approaching solutions. All three, Cable, Mobility & PON are transforming to deep fiber closer to the subscriber neighborhoods.

Before looking into how these key technology evolutions will help transform the access network, let us look at how Cable, PON & Mobile access networks are deployed today and the consequences of those buildouts on overall operations and associated costs.

1. Access Networks Today

Figure 1 shows a typical picture of big iron deployments of access technologies.

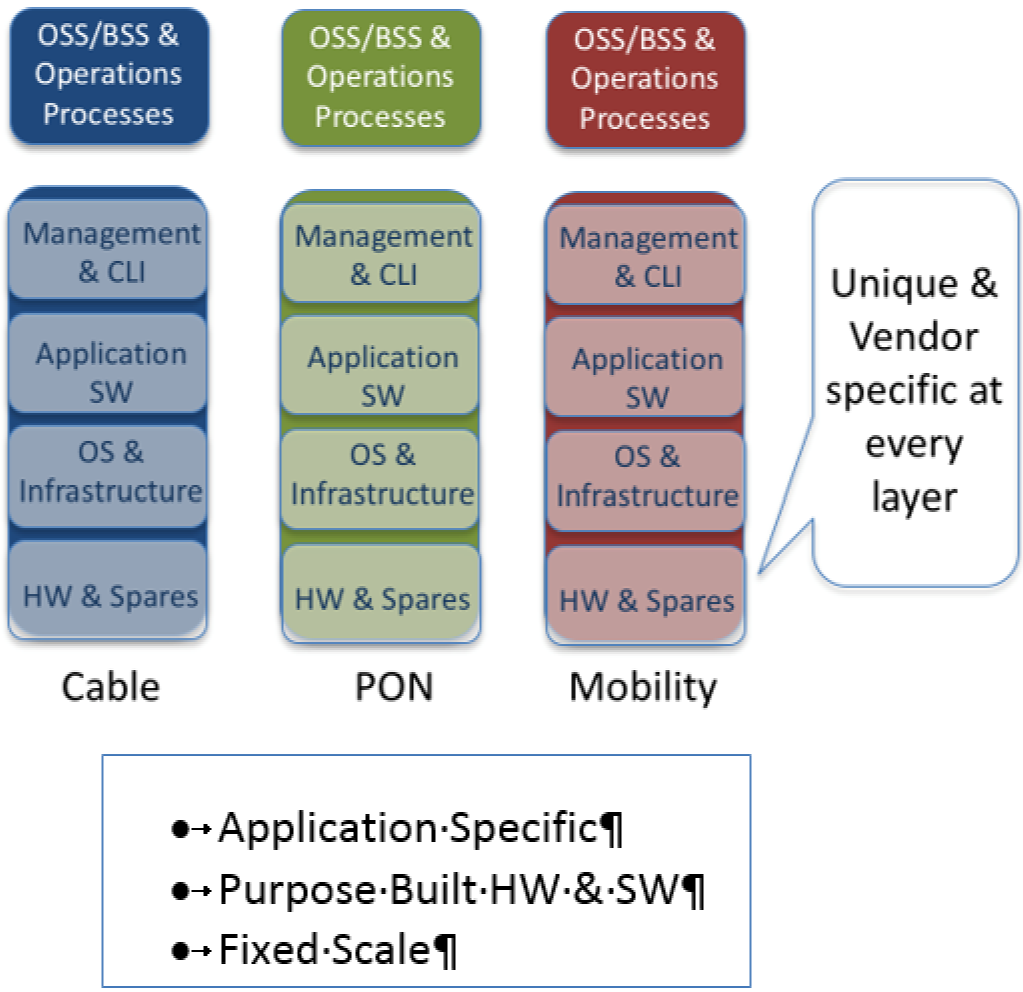

Figure 1 - Access Technology Deployments Today

Access technologies are custom built today. They consist of big iron boxes from network equipment vendors with proprietary hardware, operating systems, application software, management software and command line interface (CLI). Big iron boxes are purpose built and optimized for the access service it provides. As a consequence, operations processes to configure, monitor, upgrade and create new services are unique as they are also tailored to the capabilities and scale of the big iron box. Most operators prefer multiple vendors for the same application. Each vendor has their own unique big iron solution. As the operator manages solution variations from multiple vendors for the same application, it makes every single access technology even more bespoke and further silos the application and its operations processes. As a consequence, the edge and aggregation networks necessary to service the access application also become bespoke.

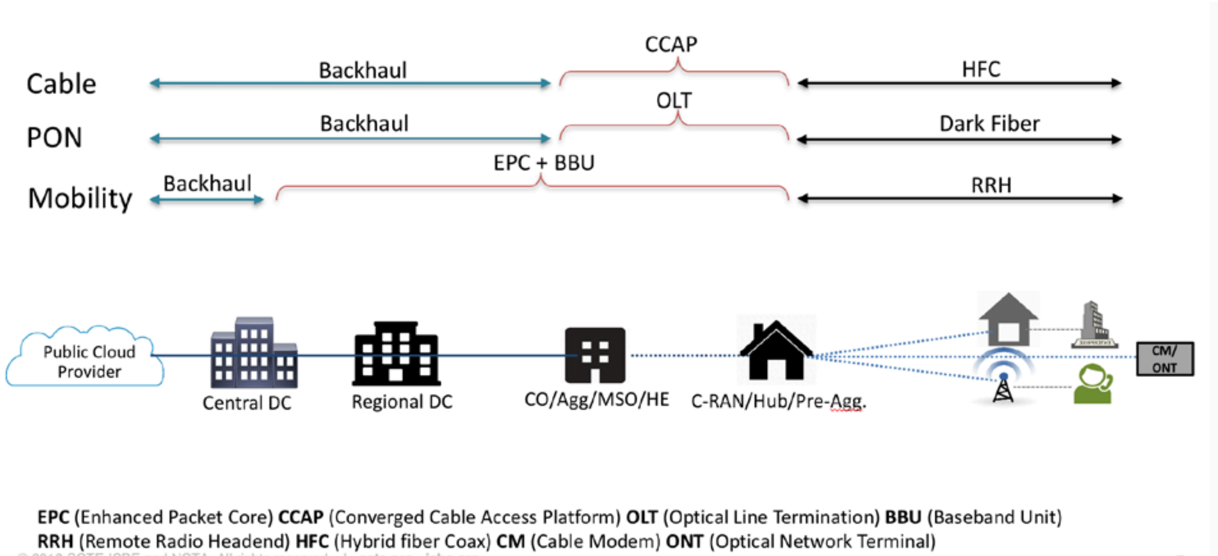

Figure 2 - Today's access network

Figure 2 shows the layout of the CIN today. The CIN is the portion of the network from the Hub/C-RAN to the RPD.

There are several differences in way the fronthaul network is deployed across access technologies.

Firstly, the CIN, is unique per access technology. In Cable access it is a Hybrid Fiber Coax network, while it is a dark or analog fiber network for PON and a 1 or 10 Gbps Ethernet network to the cell tower for Mobility. These networks are largely different in the way they are deployed, managed and operated.

Secondly, the way services are delivered across access technologies varies. For example, Cable operators deploy Converged Cable Access Platform (CCAP) devices. These devices are self-contained units with several network functions bundled together in the sheet metal. They terminate layer 1 coax cables, provide layer 2 DOCSIS capabilities, layer 3 IP routing, subscriber management and an entire stack for video distribution over the Cable network.

PON, on the other hand, disaggregates functions across at least two boxes. The layer 1 of the PON network is terminated in an Online Termination (OLT) and traffic is handed off to an edge router and subscriber management box (not shown).

Mobility also splits functionality into multiple boxes or layers. It terminates the layer 1 over air protocol at the base of the tower and hauls traffic to the Base Band Unit (BBU) and Enhanced Packet Core (EPC). The EPC performs subscriber termination and routing.

Service provisioning on Access technologies varies. Service provisioning in Cable is performed on the CCAP, whereas on PON must be accomplished on two or more devices: the OLT, the subscriber manager and routing devices. For Mobility, service provisioning is done on the EPC and the router behind it.

Thirdly, the location of access technologies in the provider network also varies. Cable operators deploy CCAP devices in hubs or head ends, PON OLTs are also deployed in hubs or head ends but the aggregation router for PON may be deployed deeper in the network. The EPC for mobility is typically much deeper in the network.

The consequence of disparate deployments of access technologies is that operations processes, network growth, subscriber and service additions become very specific to the access type.

It is very difficult to converge operations across multiple access technologies today. Most operators that offer services across multiple access technologies run these in a “ships in the night” model, where one access technology shares nothing with the other in the field network, hub or head end.

Ultimately, traffic does get aggregated at the regional or central data center but that is beyond the scope of the access network, and more in the edge portion of the network.

2. Access Technology Evolution

2.1. Virtualization & Disaggregation

Virtualizing and disaggregating access technologies is well underway. This is illustrated in Figure 3. Large portions of the overall stack, hardware, and software will be common and uniform and will therefore support fungible servicing multiple access applications. Specifically, the underlying hardware (servers and data center switch fabrics), operating system software, application infrastructure and portions of the monitoring, telemetry and automation software will be uniform across access technologies. This creates unprecedented uniformity across these technologies.

Virtualization also enables disaggregation and sharing of network functions. For example, CCAP need not be a single unique bundled instance anymore, as subscriber management and routing can be disaggregated and made common and shared across multiple access technologies.

As large portions of the overall application stack become common, access technologies from multiple vendors will not be disparate anymore. Further, common infrastructure will streamline and simplify operations. An operational component that is specific to the application technology will still exist, however, however this will be a smaller portion of the entire access technology network operation.

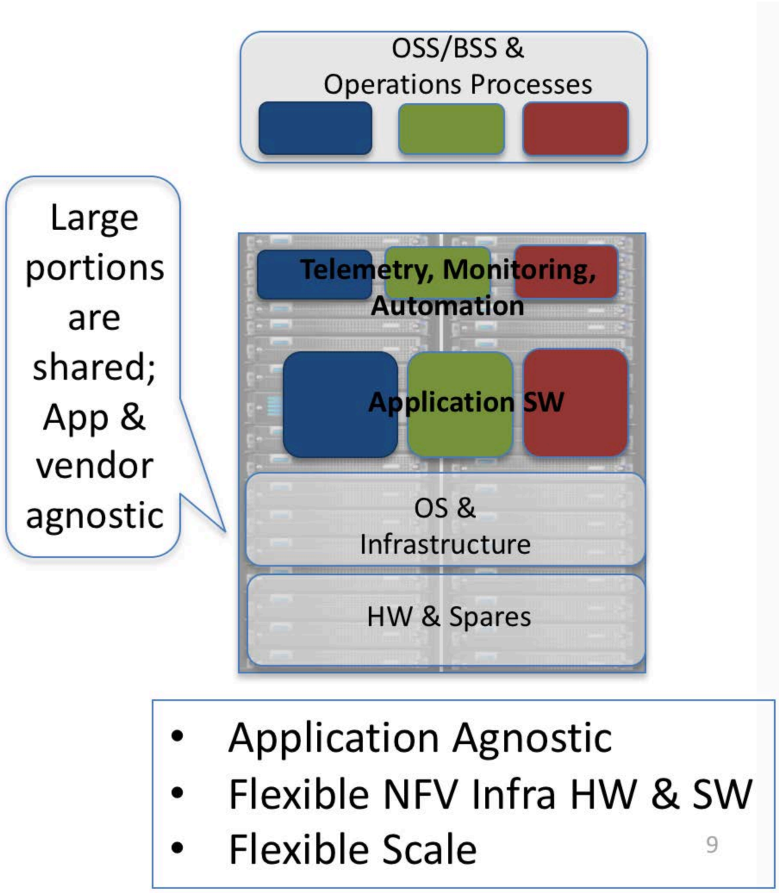

Figure 3 - Virtualization and Disaggregation of Access Technologies

2.2. Deep Fiber Migration

The CIN from the hub/C-RAN to the neighborhood is being converted to digital fiber. This is underway for all three access types, Cable, Mobility & PON. Figure 4 shows a CIN converged across access technologies.

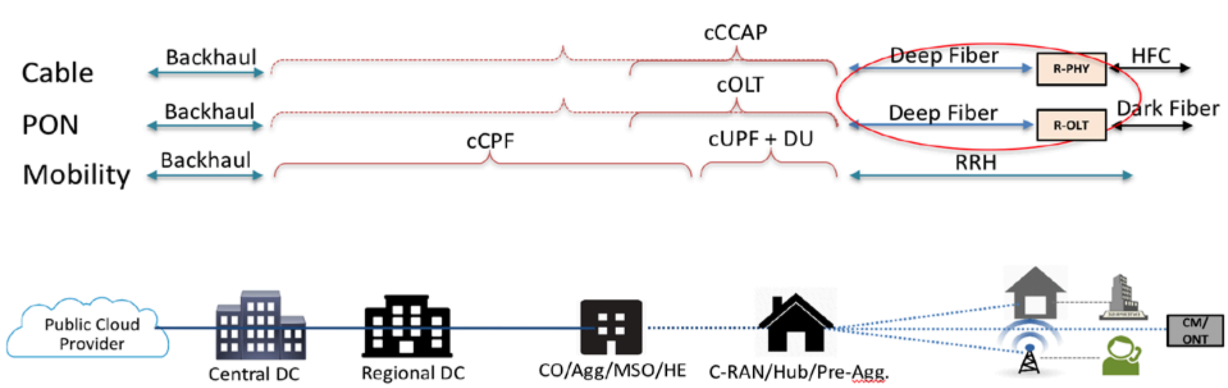

Figure 4 - Converged CIN

Convergence of the CIN for Cable, PON and mobility to 10/100 Gbps deep fiber has big implications on the ability to converge the access networks in the back end.

The deployment and management of the deep fiber portion of the network itself is agnostic of the service that runs on it. Also, it allows access specific service functions such as cCCAP (Cloud CCAP), cOLT (Cloud OLT) and cCPF (Cloud Control Plane Functions for Mobility) and cUPF (Cloud User Plane functions for Mobility) to reside anywhere from the hub to central data center.

Virtualization & disaggregation and the migration to deep fiber are key to architecting the converged multi access network as they eliminate access specific silos.

Advantages of Converged Access Networks

There are six main advantages of converged access networks. These are:

1. Common Multi Access Fronthaul Network (aka. Converged Interconnect Network)
2. Common Access Termination Infrastructure
3. Common IP Services Infrastructure
4. Operational Efficiency & Automation
5. Facilities Optimization
6. Uniform Subscriber Services and Experience

Common Multi Access Fronthaul Network: As shown in Figure 4, a common multi access fronthaul network is a 10/100 Gbps network between the hub and the neighborhood. It displaces a large portion of the access specific network. It is inherently access agnostic and can carry traffic for multiple access technologies simultaneously. This is a big advantage over today’s access specific network as this portion of the fronthaul can be operated as a common portion across access technologies.

A deep fiber fronthaul pushes access specific networks to the neighborhood. Access specific distance limitations are eliminated or minimized. Also, as deep fiber covers the major portion of the distance between the subscriber access equipment and the provider access termination equipment, the latency of the network does not increase.

Consider the example of a cable network. With legacy integrated CMTS (Cable Modem Termination System) deployments, the biggest contributor to latency in the network is between the cable modem and the CMTS in the hub. The legacy HFC network is made up of analog fiber and a coax cable network at about 1000 homes passed. The coax portion of the network is the largest contributor to latency. With deep fiber penetration, the fiber portion of the network goes deeper to about 120 homes passed, reducing the length of the coax network, so latency is not impacted adversely.

With deployment of deep fiber, access specific distance limitations are eliminated. This allows access termination equipment such as a cCCAP device, cOLT and cCPF/cUPF to be located deeper in the network and more importantly co-located. Co-location of access technologies allows deployment upon a common infrastructure.

As multiple access technologies can be co-located due to deep IP fiber migration, operators can offer uniform multi-access services using the same infrastructure and fronthaul network.

Common Access Termination Infrastructure: As access technologies migrate to virtualization and disaggregation, as shown in Figure 3, they can all leverage common data center compute and network infrastructure. Coupled with the fact that multiple access technologies can be co-located due to deep fiber migration, an unprecedented new opportunity arises to offer multi-access services using the same infrastructure and fronthaul network.

Common IP Services: As access technologies decouple from the backend IP services framework due to disaggregation, a common set of IP services can be applied via service chains shared across access technologies.

As an example, consider the CCAP device that incorporates the entire routing stack. A disaggregated CCAP could offload routing, DHCP and any other security services to an IP services chain.

Figure 5 shows a sample Common IP services chains.

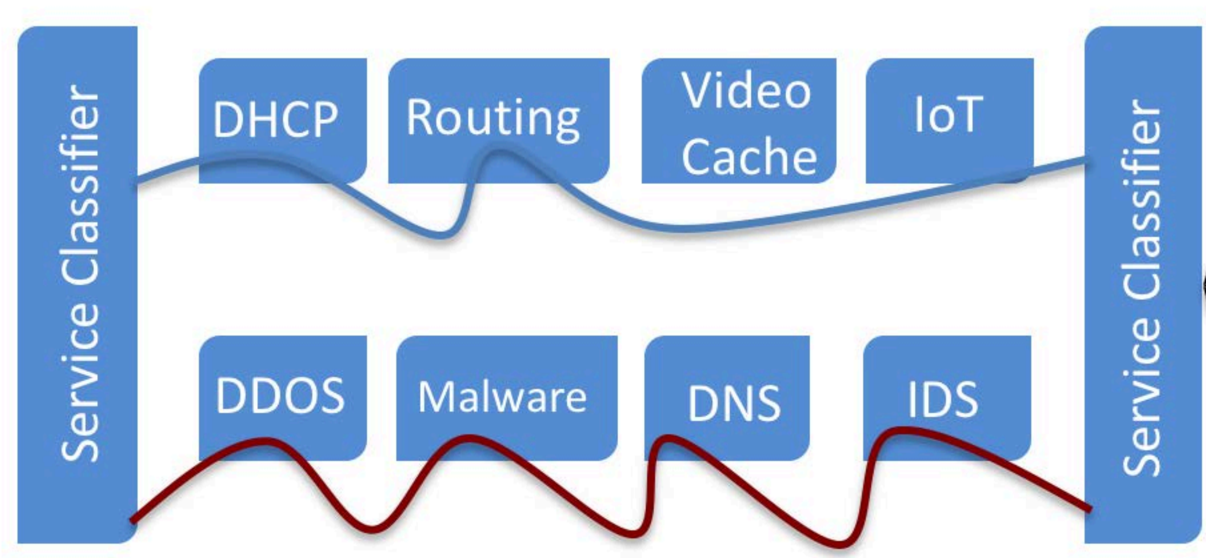

Figure 5 - Common IP Services Chain

A common IP services chain across access technologies creates a uniform experience for subscribers. For the provider, common IP services provide an opportunity for uniform access policy management and application. Common IP services facilitate application of uniform security policies rather than on an access-specific basis. This will improve security of the entire network.

Operational Efficiency & Automation: Several factors contribute to access network operational efficiencies and automation. As illustrated in Figure 6, the converged deep fiber fronthaul network can be operated as a common entity serving multiple access technologies. The common access services infrastructure can also be operated as a common single entity that is access agnostic. Further, the common IP services chain applied to access technologies can also be operated as a common entity.

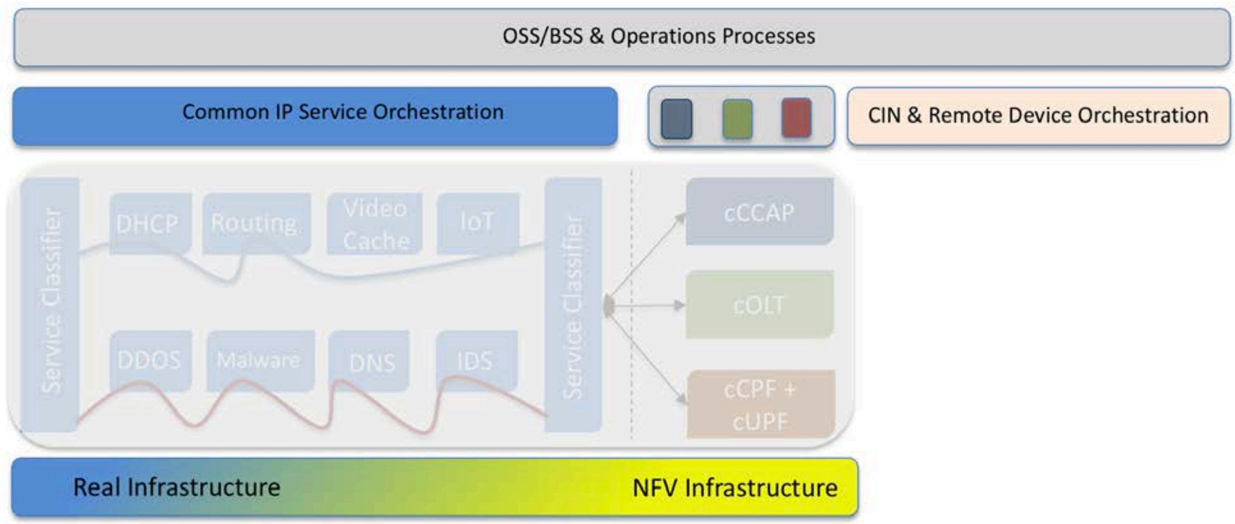

Figure 6 - Operational Efficiency & Automation

The components of the network that are still access specific such as the access technology VNFs and the last few miles of the access network are the only remnants that need access specific operation.

Taken together, most of the access network can be operated as a single common entity. This is an unprecedented opportunity to simplify and streamline operations via automation. Automation can serve to detect and repair faults via fault tolerance built into every layer of the network. Automation can also help with upgrades and application of service policy and in provisioning new services.

Facilities Optimization: A common fronthaul network, disaggregation and virtualization of access technologies and a common IP services network create many new opportunities for facilities optimization.

- Operators can offer multiple access services using the same facilities, leading to better utilization of a facility and better metrics for subscribers/facility or revenue/facility.
- Operators could lease out portions of the facility or co-locate multi-access equipment for better utilization.
- The access network could be leased out to other operators for extending their reach.
- Facility consolidation is yet another advantage, as multiple facilities are not required to host each access network.
- Finally, along with multi-access networks, providers could provide value- added services such as video cache hosting, security and peering deeper in the network.

Uniform Subscriber Services and Experience: As a common IP service chain is applied across access technologies, subscribers will attain a uniform access experience, agnostic of the access used to connect to the internet. Further, if subscriber identity is also unified across access technologies, subscribers will get a uniform experience agnostic of the device they connect to the internet with. This creates new use cases for device to device handoff as subscribers switch from one access network to another via switching access devices.

Multi Access Network Topologies

This section puts all the ideas together to propose topologies of converged multi- access networks. Figure 7 shows the fronthaul multi access network.

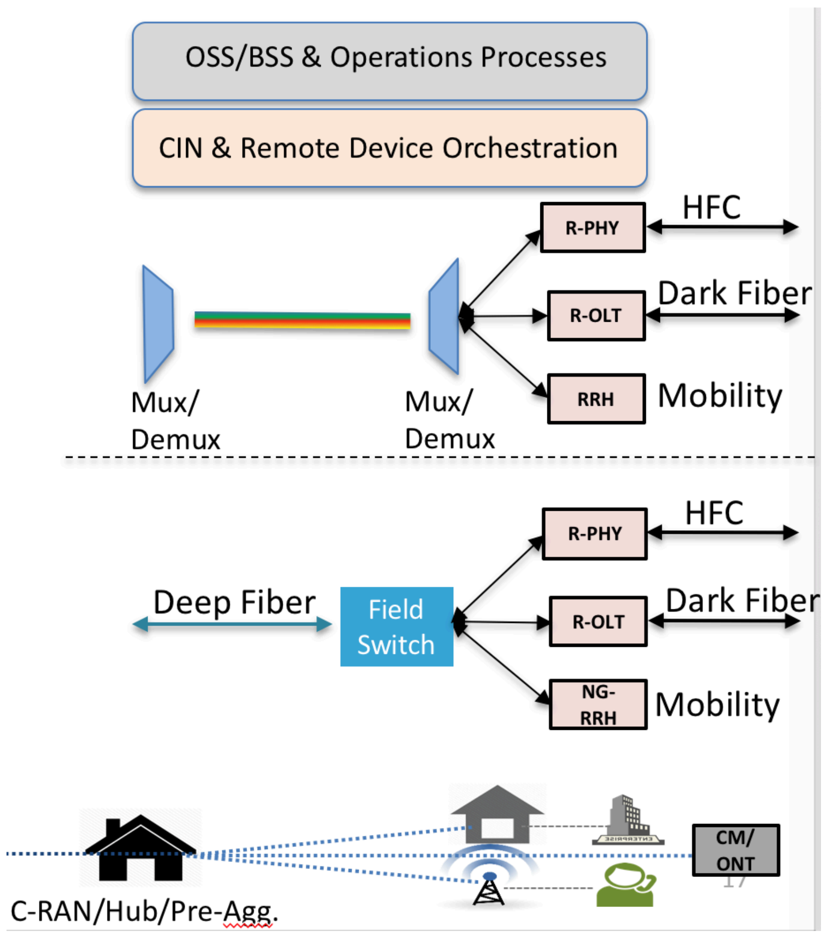

Figure 7 - Fronthaul Multi Access Network

The CIN usually extends from the provider hub to neighborhoods it services. Two topologies are illustrated. The one on the top is a DWDM optical transport topology. In this topology, one pair of mux/demuxes reside in the hub while the other resides in the field. The network is capable of hauling multiple terabits of traffic. Traffic to each of the field access technology devices (such as RPDs and R-OLTs) could be multiplexed on a wavelength or traffic for multiple devices could be multiplexed on the same wavelength. In the latter case, a field switch will be required to de-multiplex traffic for multiple access devices on the same wavelength.

The lower portion of Figure 7 shows a 100 Gbps fiber deep distribution layer from the hub to the field, terminated by a field aggregation switch. Traffic is de-multiplexed by a field aggregation switch to field access devices.

The operator could choose either of these topologies depending on the density of field devices and ultimately the number of subscribers serviced.

As the CIN is access agnostic in both cases, it can be managed via common management software. Thus, a multi access CIN can be managed using the same software layers thereby simplifying and unifying CIN operations.

Figure 8 adds on the converged multi access layer to the outside CIN.

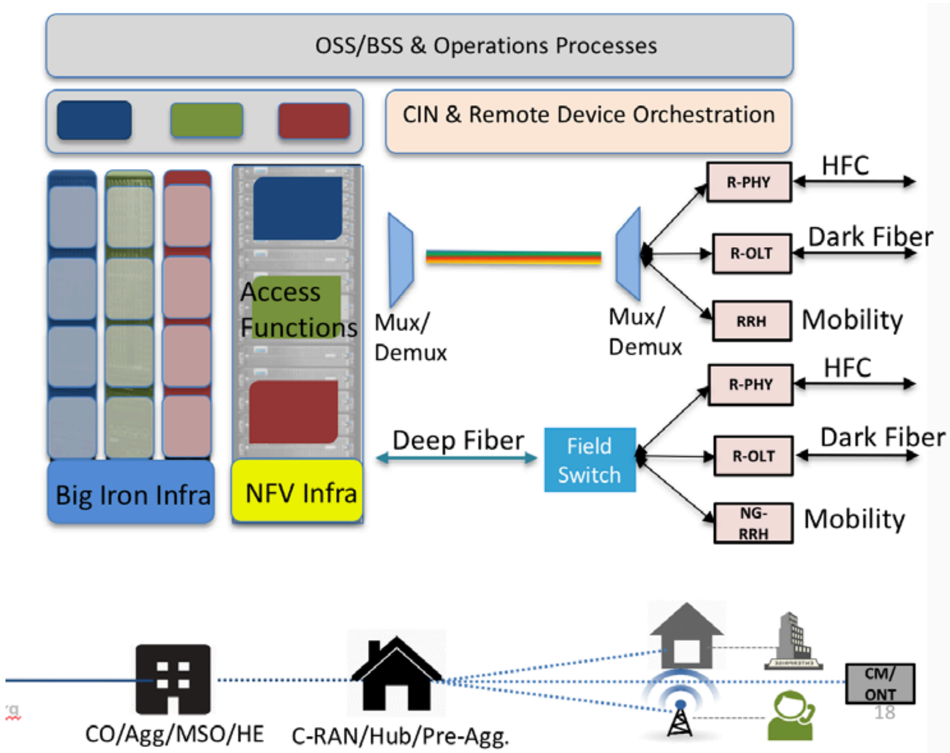

Figure 8 - Converged Multi-Access Layer

Multiple access technologies, such a Cable, Mobility and PON reside on a common virtualized infrastructure attached to the CIN.

It is not required that any operator rip and replace the current revenue generating big iron infrastructure with replace it virtual instances to avail the benefits of a converged CIN. Big iron infrastructure can continue to be deployed and will share the CIN with virtual instances. Although, virtualization provides unique flexibility in scaling an access technology or scaling across access technologies.

There are three variants of the topology with NFV infrastructure. In the first variant, the NFV infrastructure for converged multi access technologies resides in the hub along with the front haul. In the second variant, only the CIN equipment resides in the hub while the NFV infrastructure and multi access CNFs reside in the headend and in the third, the CIN and the data plane CNFs reside in the hub while the control and operations reside more centrally.

As the headend is usually a larger facility than the hub, it can aggregate more subscribers. Aggregation of more subscribers leads to better utilization of the common NFV infrastructure. The choice of variants depends on many factors such as facility power, space and access technology migration to virtualization. Consolidation criteria are unique to every site in the provider network.

Combined real and virtual instances could be managed together with an overall single layer of management software that componentizes application specific portions.

As the NFV infrastructure is common across access technologies, the management layer for the infrastructure is also common across access technologies. There is an access specific component in the management software to manage the corresponding access CNFs and the remote field devices associated with the specific access technology. Provider operations, and OSS & BSS processes extend to cover the NFV infrastructure, unifying management of the CIN, field devices and NFV infrastructure.

Figure 9 shows the complete picture of the converged multi access network by including the IP services network layer. A final convergence on NFV infrastructure is shown. This yields the highest level of convergence and best utilization of infrastructure, though even if portions of the network still have big iron in place a large portion of convergence can be met.

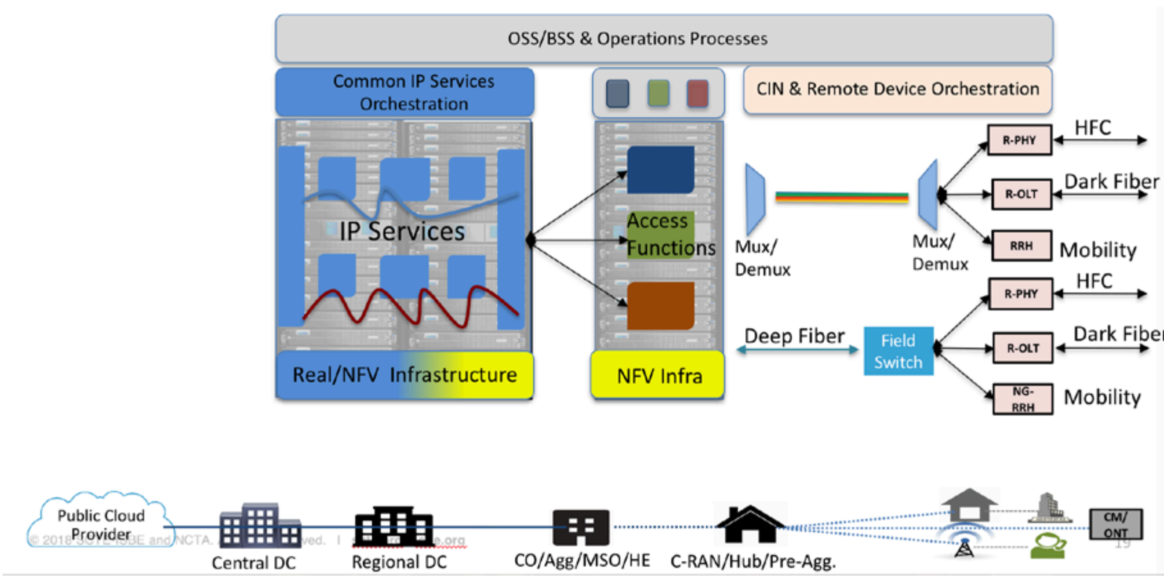

Figure 9 - The Converged Multi-Access Network

As the access layer of the network is now common for all access types and access technologies co-residing at the same location, a single common shared IP services layer can service all access types. Therefore, the entire access network becomes converged and multiple accessed. This simplifies deployments, management and reduces cost to install and operate the network.

The IP services layer could be built using real (purpose built) hardware or virtual instances or a combination of both real and virtual. The IP services layer could be co-located with access workloads or could be deeper in the network anywhere between the central data center to the head end. The deeper in the network the IP services reside, the more subscriber traffic needs to be aggregated and routed. Peering points, video caches and security all move deeper. Note that the IP services layer can be converged regardless of whether the access layer comprises big iron or virtual instances or both.

As the IP services network is common to access technologies, it can be managed as an entity agnostic of access technologies. Combined with the remaining portions of the converged access network, a single

OSS/BSS plane and a common set of operations processes can be applied to manage the entire converged multi- access network.

Conclusion

Access networks Cable, PON & Mobility are evolving because of two underlying technology trends. These are migration of the access technology to virtualization and disaggregation, and rebuilding of the CIN using deep fiber. These technology drivers allow access networks to be built in a common and converged fashion and be co-located.

Once the access technology network and the CIN are converged, the IP services layer can also be converged and can be deployed as an access agnostic network serving multiple access technologies.

As large portions of the access network are common converged and access agnostic, they can be managed and operated using common access agnostic processes enabled by a common converged layer of management software. This is a new opportunity to stream line and simplify operations while providing newer access services.

A converged multi access network creates new unprecedented opportunities for operators. It becomes easier to offer multi-access services, to collaborate and create new opportunities for co-hosting services, as well as to provide new opportunities for facility optimization.

Operators can better monetize the access network by running multiple access types using the same infrastructure.

A converged multi access network also benefits subscribers. The subscriber experience will be uniform across access types, while creating new handoff and access network redundancy opportunities. Subscribers can attain new bundled access services if operators offer multi-access bundled services.

Abbreviations

BBU	Base Band Unit
BNG	Broadband Network Gateway
EPC	Enhanced packet Core
HFC	Hybrid Fiber Coax
CCAP	Converged Cable Access Platform
CIN	Converged Interconnect Network
CM	Cable Modem
CMTS	Cable Modem Termination System
CPF	Control Plane Function
DOCSIS	Data Over Cable Service Interface Specification
DU	Distribution Unit
DWDM	Dense Wavelength Division Multiplexing
FAR	Field Aggregated Router
Gbps	Gigabit per second

HHP	Households Passed
IP	Internet Protocol
OLT	Optical Line Terminal
ONT	Optical Network Terminal
ONU	Optical Network Unit
MSO	Multiple System Operator
PON	Passive Optical Network
UPF	User Plane Function
RRH	Remote Radio Headend
RPHY	Remote - PHY