MODERNIZING THE CABLE NETWORK INFRASTRUCTURE

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EXECUTIVE SUMMARY

Market forces are driving cable operators to transform their networks and infrastructures to enable them to increase the velocity and breadth of service offerings and to reduce capital expenditures and operating costs. Key technologies are now mature enough for network introductions that will underpin their digital transformation.

The Distributed Access Architecture (DAA) paves the way for operators to modernize their networks by moving cable-specific equipment to the network edge, unlocking the possibility to virtualize the network elements in the headends, which leads to the eventual consolidation of the headends and hubs. The access network is digitized and becomes more intelligent, enabling it to play a key role in driving a customer's digital experience and in supporting future services. The analog network that has connected the headends to the access network gets a significant makeover, becoming digital and eventually IP based and making it a significant asset for future revenue generation from services, such as 5G. Other technologies, such as FDX, will further propel operators toward the future as upstream bandwidth capacity increases to 10 Gb/s and beyond.

This transformation is far-reaching in scope. Operators should plan carefully and work with vendors that have the expertise to meet the breadth and depth of their needs. In this paper we provide a framework for the transformation and discuss its benefits and future revenue-generation opportunities, which are significant and if done correctly will set operators on a firm competitive path for decades to come.

KEY FINDINGS

- Digital transformation is a must for cable operators to remain competitive.
- DAA is a major enabler. Moving cable-specific elements to the node opens the way for the digitization and eventual consolidation of the headends and hubs. This will enable operators to benefit from industry-wide best practices on software-based service delivery.
- Digitization of the access network, including the access nodes, and the interconnect network opens operators to significant opportunities to improve the customers' experiences offer new services, including 5G backhaul.
- The transformation is of unprecedented magnitude, should be planned carefully and undertaken with trusted vendor partners.

INTRODUCTION

Cable operators are faced with an intense competitive environment; existing and emerging competitors are threatening their businesses while at the same time the behaviors and expectations of customers are changing drastically. Cable operators are increasingly seeking new revenue sources with a focus on the business market, and many are offering wireless services. This is leading operators to accept that their networks and operating environments are no longer suited for the needs of the marketplace today. Consequently, they are embarking on a far-reaching transformation of their networks and businesses to meet the needs of a changing and highly competitive market and to grow their top-line revenue. Essentially, they are seeking to become digital service providers that can offer the services and digital experiences that their customers demand.

A major element of this transformation is the network that delivers their video, data and telephony services. This network is for the most part analog, rigid, and difficult to scale. It also restricts them to limited talent and to a small number of vendors, thus leading to higher costs.

By transforming their networks, operators can unlock near term and long term revenue opportunities.

DRIVERS FOR THE CABLE OPERATOR NETWORK TRANSFORMATION

Today, cable operators are at a crossroad. Their traditional business is declining, and their plants are increasingly obsolete. They need to reinvent their business and infrastructure or be relegated to irrelevance in the future.

Declining legacy business but new opportunities within reach

Cable operators continue to lose video subscribers on a quarterly basis. In 4Q 2018, top US cable operators lost 243 thousand video subscribers and over 900 thousand subscribers in 2018.

Figure 1. Video Subscriber Trends for Major US MSOs (Source: Company Data)

This decline is driven by changing customer behavior and expectations and by developing competitive dynamics; it is driving cable operators to seek new revenue opportunities and to evolve their infrastructure and business model, as their business is shifting away from legacy services and as their legacy infrastructure is no longer suited for the delivery models the market demands.

Cable operators are well-positioned to offer the services the market needs today and in the future provided they evolve their plant and their operating environment to better align with the requirements of the new services.

Data consumption growing exponentially but revenue per bit declining

Operators are experiencing an exponential growth in bandwidth utilization on their broadband networks. This is largely driven by a significant increase in video streaming. Internet video accounted for 55% of global data traffic in 2017 and is projected to be 71% of data traffic in 2022[1]; this growth will be partly due to the increasing quality of the video from standard to HD and more recently to UHD. Additionally, use of other data-intensive applications is growing: IoT, augmented reality and others. This rise has led operators to continuously increase their network capacity to stay ahead of demand. Comcast has upgraded its entire footprint to DOCSIS 3.1 to deliver gigabit speeds; 90% of Cox customers have access to gigabit speeds, and 99% will have the GIgablast service by the end of 2019[2]. Charter has gigabit connections across almost all of its 41 state service area[3].

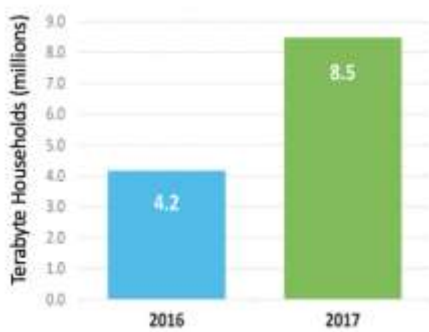

Figure 2. Internet Households Exceeding Terabit Doubled in 2017 (Source: Cisco VNI 2017–2022)

[1] https://www.cisco.com/c/m/en_us/solutions/service-provider/vni-forecast-highlights.html.

[2] BTR 12/18/2018.

[3] BTR 12/17/2018.

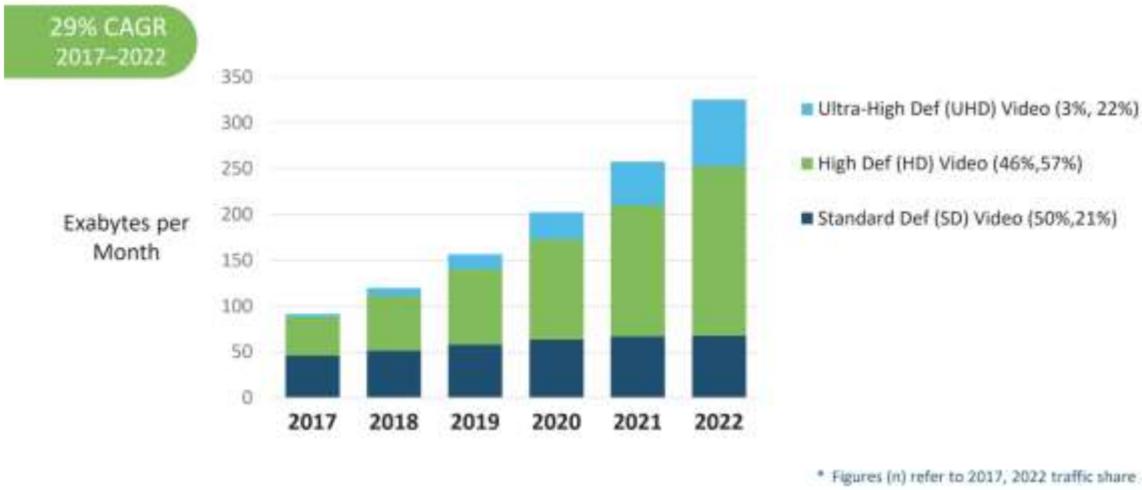

Figure 3. Higher Bit Video Gains Traction (Source: Cisco VNI)

This continuing capacity increase is leading to constraints in the headends. Capacity growth is mostly being met by node splits, which increase the number of nodes in the outside plant (essentially reducing the number of subscribers served by each node) and result in more bandwidth per subscriber because the node capacity is split among a smaller number of subscribers. However, the additional nodes need more headend equipment, which requires space, powering and cooling. In some markets, cable operators are running out of space in the headends, which sometimes leads them to lease new properties at high prices and also increases their power and maintenance costs.

At the same time that bandwidth consumption is growing revenue per bit is going down. Operators are not reaping the benefit of capacity expansion through average revenue per user (ARPU) increase and must seek new revenue sources to make up for the shortfall.

Return path limitations

The current cable plant is limited to 42 MHz in most cases, which constrains the upstream bandwidth to 100 Mb/s, a significant limitation given the proliferation of services that are upstream bandwidth intensive.

Revenue is increasingly generated from new services

Cable operators are generating revenue from new sources. For example, Comcast generated 13% of its revenue from business services in 4Q 2018, compared to 8.5% in 1Q 2014. At the same time, mobile services are becoming a major source of revenue for major MSOs; some operators are offering streaming services to counter the threat from vMVPDs (for example, Charter's Spectrum TV Essentials). Most operators are either offering or planning to offer SD-WAN and other software-defined services to business customers, for example, IoT.

These services require capacity, flexibility, and an operating environment for which current plants are ill-equipped, but with the right architecture and operating changes, operators can evolve to become a competitive player in the market.

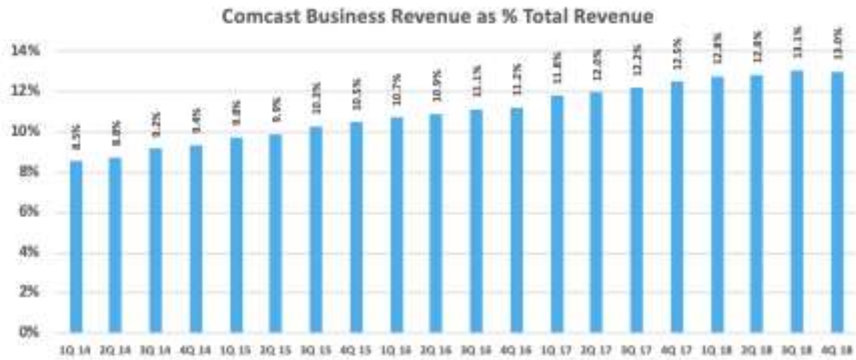

Figure 4. Comcast Business Revenue as Percentage of Total

Spectrum capacity constraints

Due to growing demand, some operators are exhausting the capacity of their 750/860MHz and even 1 GHz spectrum, leading them to contemplate increasing spectrum to 1.2 GHz and beyond.

Rigid, esoteric plant

The cable legacy plant is largely hardware based and relies on analog technology, which is rigid, requires specialized technicians that have become increasingly hard to find, and depends on expensive special-purpose equipment from select vendors.

Constrained scalability

Current cable operators plants lack elastic scalability. Due to the long cycles associated with hardware, operators need to forecast demand well in advance and deploy equipment, which has to be powered, cooled and maintained, long before demand materializes, putting operators at a competitive disadvantage and increasing their operating cost. This scenario is in contrast to the software world that enables capacity to scale elastically with demand.

Legacy operating environment

The cable plant was designed for services that were based on analog technology. Although the infrastructure was adequate for those services, it is rigid and only operates under a predefined set of rules. As legacy plants evolved, operators added disparate systems and software patches over the existing plant to meet the requirements of new services. This strategy is no longer adequate for current services and business environments, which require flexibility, high throughput downstream and upstream, ability to perform predictive analytics, and the capability to offer a differentiated digital experience with self-service tools.

FRAMEWORK FOR NETWORK TRANSFORMATION

It is clear that the cable plant is hampering operators' competitive leadership and needs to be transformed. Their networks need to be both backward and forward compatible: Support all existing services and at the same time enable operators to offer new services to replace declining revenue from the maturing business.

Transformation must address three major areas: The headends and hubs, the interconnect network, and the access nodes. Operations and business support systems will eventually need to evolve as well. Although the amplifier cascade that exists today between the optical node and the customer's location needs to change and to be reduced (and in some cases to be completely removed), this change will happen gradually over the long term for some operators.

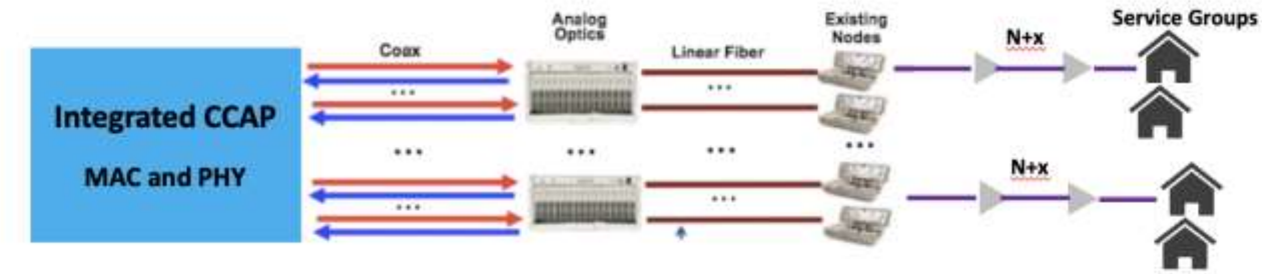

Figure 5. Cable Network Architecture of Today

Although Fiber to the Home (FTTH) is an alternative to deliver high capacity to the home—a good solution for green field areas—for the majority of the cable systems, the cost of FTTH is significant. To address the need for increased capacity, the industry has developed a new architecture and different specifications that meet operators' needs in terms of backward and forward compatibility and will set them on the right competitive path going forward. This architecture is akin to building a fiber network. It enables operators to densify the access network to significantly increase bandwidth capacity and to selectively bring fiber to the subscriber that wants it rather than incur the cost and complexity of building FTTH irrespective of demand.

Distributed Access Architecture (DAA)

The DAA was developed by CableLabs and the cable industry to modernize the cable access network; it enables moving functions and elements that have been an integral part of the CCAP to the access network. This enables the headend environment to be virtualized over the long term and leads to significant benefits for cable operators.

A prerequisite for DAA is DOCSIS 3.1, which enables a higher modulation from the traditional maximum of 256 QAM modulation to 1,024 (even 4,096) and results in throughput up to 10 Gb/s downstream and 1 Gb/s upstream. DOCSIS 3.1 capacity can increase to 10 Gb/s symmetrical with Full Duplex DOCSIS (FDX).

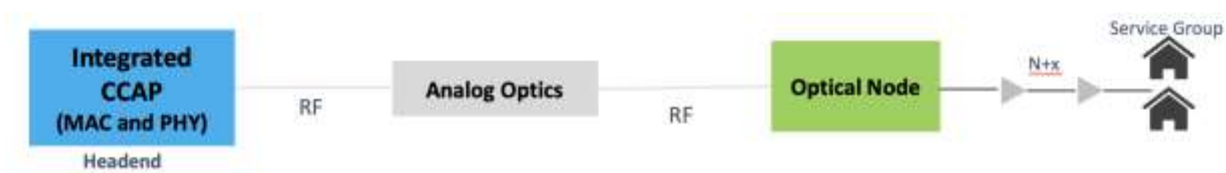

Figure 6. Legacy Network Infrastructure (simplified)

There are two main variants of DAA:

- **Remote PHY or R-PHY:** The physical layer (PHY) is moved from the CCAP to the fiber node. A Remote PHY Device (RPD) is added to the node to handle the PHY capability. R-PHY is based on the MHAV2 CableLabs specifications.

Figure 7. Remote-PHY

- **Remote MACPHY or R-MACPHY:** The Media Access Control (MAC) and the PHY layers are moved to the fiber node. A Remote MACPHY Device is added to the node, which handles the MAC and PHY capabilities. The specifications for R-MACPHY are under development at CableLabs.

Figure 8. Remote-MACPHY

Today, R-PHY is gaining market traction, particularly in North America, because it is based on largely completed CableLabs standards, while standards for R-MACPHY are still in development. Cable operators worldwide are assessing which DAA version is best suited to their needs, based on a number of factors.

R-PHY eliminates many of the inefficiencies of analog optics. Moving the PHY layer to the access network significantly reduces the noise typically introduced in the network by analog transmitters and receivers, thereby resulting in improved signal quality. Furthermore, R-PHY enables the operator to increase capacity in the access network (by splitting nodes) without having to add capacity in the headends and hubs; this combined with the higher modulation inherent to DOCSIS 3.1 leads to significant downstream capacity increases, bringing the plant to the downstream capacity range of FTTH at a fraction of the cost of deploying FTTH. Increased upstream capacity will be made possible by FDX.

Moving the PHY layer to the access node enables operators to add capacity without having to add dedicated headend equipment, which leads to reduced rack space as well as power and cooling costs. Moving the PHY layer from the CCAP makes it possible to virtualize the remaining elements of the CCAP (the CCAP core) and move them to a data center, thus reclaiming significant space in the headends and opening the way for headend and hub consolidation.

Virtualizing the CCAP also enables the operator to use applications that draw on network abstraction and orchestration capabilities to automate the configuration and management of thousands of RPDs in the access network, which results in significantly reduced time and cost of migration. Similar efficiencies and virtualization advantages can be reaped with R-MACPHY.

Full Duplex DOCSIS

Full Duplex DOCSIS 3.1 is an extension of the DOCSIS 3.1 specifications that will enable symmetric multi-gigabit speeds over the existing HFC infrastructure. FDX will significantly increase the upstream capacity by adding six upstream OFDMA channels. It boosts network capacity to 10 Gb/s in the upstream and 10 Gb/s in the downstream. The enhanced upstream capacity paves the way for a host of new services. FDX is slated for deployment starting in 2020. However, FDX capable equipment, particularly access nodes, is available today from some vendors.

Other Initiatives

In addition to DAA and FDX, there are many initiatives under consideration:

- **Extended spectrum DOCSIS (also referred to as DOCSIS 4.0):** Goes beyond DOCSIS 3.1 and FDX to enable symmetrical broadband speeds of 30 Gb/s or even 60 Gb/s[4]. This effort is still in the development stage and far from proven.
- **N+0:** Refers to the number of amplifiers between the node and the customer. The concept of N+0 is to eliminate all analog between the node and the customer and results in the most distributed network possible for an MSO, because beyond N+0 node splits are no longer an option to increase capacity/bandwidth per subscriber. N+0 is considered a prerequisite for FDX, and some operators, notably Comcast, have committed to it. However, this approach is very costly and beyond the reach of some operators. Vendors are working on approaches to deliver FDX without requiring N+0 in the access network. N+0 is also cost prohibitive in some areas where bandwidth demand is less significant, such as rural areas.
- **10G initiative:** Is the industry vision for delivering 10 gigabit networks, a powerful, capital efficient technology platform that will ramp up from 1 gigabit offerings today to speeds of 10 gigabits per second and beyond[5].

TRANSFORMING THE CABLE NETWORK

Cable network transformation should proceed along three main prongs and should be complemented by the modernization of the OSS/BSS environment.

[4] https://www.lightreading.com/cable/docsis/here-comes-docsis-40/d/d-id/743285.

[5] https://www.cablelabs.com/news/10g-next-great-leap-broadband.

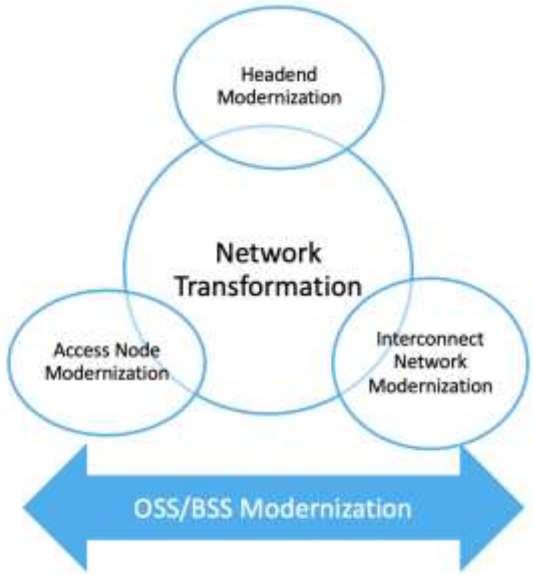

Figure 9. Cable Operator Network Transformation

Headend modernization

Modernization of the headend (and hubs) starts by moving the PHY layer (or the MAC and PHY layers) to the access network, which turns what was once an analog infrastructure to a digital one, thus distributing the functionality for better control, management, analytics, and an improved user experience. The modernized headend should support all the existing services: static multicast, dynamic multicast, broadcast video, linear video, switched digital video, and video on demand. The new systems should also support out of band signaling (OOB) for communicating with the access network.

In planning to modernize the headend, the operator should consider the best path to upgrade to DOCSIS 3.1 and what migration options are available from the CMTS vendor or vendors. Some operators may have a combination of DOCSIS 3.0 and DOCSIS 2.0 network elements that need to be upgraded to 3.1[6]. DOCSIS 3.1 is backward compatible with DOCSIS 3.0. An important consideration for operators is whether to invest in additional hardware and software for the upgrade or whether to seize the opportunity to virtualize the CCAP. Once the PHY layer is moved out of the CCAP, the remaining CCAP core can be virtualized. The same is true in the R-MACPHY case where only a software- based controller will remain in the headend (or ultimately the data center).

There are multiple solutions on the market that replace the massive CCAP Core chassis (or the CCAP controller) with servers and switching equipment. Cisco recently introduced a cloud-native version of the CCAP Core, the Cloud Native Broadband Router (cnBR). A software-based CCAP can now be moved to a data center or to consolidated headends, freeing significant space in crowded headends and hubs. It is less expensive in terms of capex and opex and paves the way for innovative services and capabilities, because it enables operators to develop and deploy new services that best meet their subscriber needs.

[6] https://www.arris.com/globalassets/resources/white-papers/preparing-for-docsis-3-1.pdf.

For operators that are not ready to move to R-PHY or that have made recent investments in their outside plant and are waiting for profit/break-even but understand the need to optimize operations (for example, headend or hub site consolidation), an R-PHY shelf solution enables them to keep the access network intact (which means keeping the analog nodes intact) and concentrate the RPDs in the R-PHY shelf. The R-PHY shelf essentially becomes a digital extension of the main headend and removes the need for dedicated equipment in hub sites, thus reducing the number of management interfaces and overhead for overall service operation.

Digitizing the headend by removing the PHY (or MACPHY) layer is the first step; the ultimate goal is to virtualize the headend, which becomes possible once the PHY is moved[7].

Modernization of the interconnect network

Traditionally, headends and hubs were connected to the access network by an analog DWDM network. Now that PHY layer is moved to an RPD in the access node, a digital fiber network with optical IP switching is needed to connect the CCAP cores (which contain the MAC processing) to the RPDs and to also connect the CCAP core to the video core and other systems. Such a network is referred to as Converged Interconnect Network (CIN). Similar considerations exist in the case of R-MACPHY.

The CIN provides a common multi-access fronthaul network and a common-access termination infrastructure, which replaces the overlay networks and creates a seamless and intelligent system, enabling operators to bring all services into a single management plane. The CIN has multiple benefits:

- Replaces analog fiber, which is difficult to maintain and requires expertise that is increasingly rare, with industry-standard digital optics such as 10 Gb or 100 Gb. Digital optics technologies are mature, widely available, and present the benefit of a declining price curve.
- Provides a common IP services infrastructure to deliver all services, which brings uniformity to the services and to the subscriber experience and opens the operator to a host of new revenue-generating opportunities.
- Common service delivery infrastructure leads to operational efficiencies and to facilities optimization.
- Common IP infrastructure opens the door for automation.

In designing the CIN, the operator has a number of design requirements and considerations:

- Distributed or centralized? Bridged or routed?
- Single layer of spine-leaf?
- Full mesh or point to point? Although point to point may be less complex in the near term, it will need remapping in the future when more CCAP cores are added.
- Which technologies need to be converged, for example, RF, IP?
- Amount of backhaul capacity needed.

Operators also need to satisfy operating requirements:

- Nonblocking network architecture.

[7] This solution is also suitable for small hub sites and multi-dwelling units.

- Support for 1588/PTP for 5G backhaul.

Digitizing the interconnect network is a major undertaking for operators and needs careful planning. However, if operators build out the CIN properly as a Layer 3 network, they can operate it like a Layer 2 transport and gradually turn on Layer 3 services when they are ready to offer and support them. This provides them with an on-demand option where capabilities are enabled as needed versus the traditional way of physically building out capacity when needed. Some vendors (for example Cisco) are already offering such licensing models. Furthermore, as the future network fabric, the CIN will bring together all the disparate domains and will enable the capabilities that will allow operators to automate, manage and maintain end-to-end network processes.

Modernization of the access network

Digitization of the access network primarily revolves around upgrading the fiber nodes. The legacy nodes are based on analog technology. Their capability is limited to supporting the legacy services; they are operationally expensive due to the time it takes to install and maintain them, and they require specialized skills. Legacy nodes lack intelligence and do not have self-diagnostics capabilities. They are typically pinged every few minutes to make sure they are operational, which means that failures take a few minutes to be detected, at best, and then need a truck roll to diagnose the problem and eventually repair it.

Operators meet growing demand for bandwidth by splitting nodes, meaning that they add nodes, which reduces the size of the service groups and increases the bandwidth available for each subscriber in the service group. This is leading to a proliferation of analog nodes, which are time consuming to install and suffer from the shortcomings already mentioned. Furthermore, the increased bandwidth consumption does not lead to a higher ARPU; therefore, operators need to find more cost-effective ways to meet the growing demand while deploying infrastructure that enables them to offer new revenue-generating service.

Digitizing the access network is the right path to meet the bandwidth demand and to enable future service opportunities. As operators increase the number of access nodes, rather than adding analog nodes, they should deploy nodes that are R-PHY (or R-MACPHY) ready and that are also ready to support FDX even if they do not deploy these technologies in the immediate future. Such nodes are on the market today and have been interoperability tested with CCAPs from multiple vendors (Cisco released such a node in late 2018). The nodes can operate in a traditional fashion (with an integrated CCAP), and the RPD, as well as the FDX module, can be added at a later time when the operator is ready for an R-PHY migration or when it is ready for FDX. In addition to putting the operator on a path toward DAA, R-PHY nodes, if they are also intelligent[8], bring significant advantages: they offer optimization beyond that of standard nodes because they enable operators to power down unused ports, they enable operators to do remote device management, and to remediate faults before they escalate into outages.

Operators that are reducing the size of their service groups by increasing the number of nodes should use this opportunity to use intelligent nodes that are forward upgradable, rather than continue to iterate on the current nodes, which may address their short-term needs, but limit future possibilities.

[8] Older nodes which are upgraded to R-PHY and lack compute capabilities do not deliver these advantages.

CONSIDERATIONS WHEN MIGRATING TO DAA

The migration to DAA has profound implications and and should be carefully planned. The operator should create a network evolution plan that takes into consideration the existing network architecture and the service needs over the next five years. Some of the criteria to consider:

- The version of DOCSIS it is currently running.
- How the new architecture will support all existing services and the service roadmap.
- How the transition will align with any planned expansion (for example, from 860 MHs to 1.2 GHz).
- Support for OOB, analog video, VOD, etc.
- Amount of available power in the access network.
- Management of the RPDs or MPDs.
- Design of the CIN.
- OSS/BSS: The operator should assess its existing OSS/BSS capabilities, including DOCSIS provisioning systems, fault tolerance and security management systems, and ensure that the vendor's solutions for DAA provide all the needed capabilities.
- Changes in RF Network Alignment Process: Because the analog links are replaced with digital ones, the legacy analog sweep systems and field tools no longer work. The operator needs new tools for RF network alignment and for upstream quality assessment and should train technicians on the new tools.
- Skillset of existing staff. Given that the new plant will be digital and will be software based, new expertise will be required, which can be obtained by a combination of retraining and hiring.
- Methods and procedures should be revised for the digital age.

Because of the complexity and far-reaching aspect of the transformation, it is crucial that the operator works with a vendor that has end-to-end solutions that address all major areas of network transformation and the breadth and depth of expertise to support it throughout the migration. A vendor whose capabilities are limited to some parts of the network transformation do not offer holistic solutions, which may result in technological silos, repeating the integration mistakes from the past with their complex system overlays.

BENEFITS OF NETWORK TRANSFORMATION

The benefits of the network transformation are significant in the short and the long term.

Capacity expansion combined with energy and space optimization

One of the short-term drivers of DAA is capacity expansion. By moving the PHY layer or the MAC and PHY layers from the headend to the node and by reducing the size of service groups, the operator can offer more bandwidth to customers without the added hardware, power and cooling in the headends and hubs.

Outside plant modernization

Evolving to an all-digital, fiber-based infrastructure and eliminating the combiners and analog optics: The analog fiber network connecting hubs to nodes is replaced by a less-expensive, higher quality 10 Gbps or 100 Gbps Ethernet network, and digital fiber is pushed closer to the customer. Digitizing the cable access and standardizing on Ethernet enables operators to more efficiently use network resources, offer new services, and optimize across devices. Digital fiber will become the fabric on which every service and device interact, eliminating customized overlays or manual provisioning. This results in improved reliability and leads to better customer experiences.

Migration to centralized data centers

Once the CCAP is virtualized it can be moved to centralized data centers or consolidated headends, thus further alleviating the headends. A virtualized CCAP no longer requires a dedicated location for management (hypothetically). Because it will be cloud based it can be spun up and on demand when and where services are needed.

Benefits of the CIN

The migration to a digital interconnect network to replace the analog network will be a game changer for operators. Some of the benefits resulting from the digitization of the interconnect network:

Longer distances, more density and lower costs

- Digital fiber enables operators to more than double the distance between the headends and the access network, leading operators to rethink their network architectures and opening the possibility to centralize the CCAP cores and other network elements in data centers and to consolidate the hubs.
- Digital fiber is less prone to degradation and failure, which reduces operating costs and improves customers' experiences. It is less expensive because it benefits from broad industry adoption.
- With digital fiber, operators can leverage standard-based interconnectivity and economies of scale.

Additional benefits if the interconnect network is IP based

If the digital fiber is also an IP network (or Metro Ethernet or EPON/GPON network), there are additional strategic benefits[9]:

- The same IP network can be used to deliver residential and business services.
- The IP network provides a pathway to offer FTTH services. Unlike the traditional approach of building the entire fiber network ahead of demand, the digital CIN brings the fiber very close to the subscriber (at the node). From there, the operator can drop fiber to the customer that wants to subscribe to FTTH, which makes it more cost effective, because it is success-based spending.
- The IP network can be used to backhaul 4G and 5G data, leading to new revenue opportunities.

5G opportunity enabled by FDX

FDX enables symmetrical multi-gigabit speeds over existing HFC infrastructure[10]. In addition to the expected benefits of upstream bandwidth, FDX enables cable operators to play a unique role in 5G, which, particularly in the millimeter wave, will be a small-cell deployment. It is conceivable that customers will have small-cell types of devices in their homes or offices that will be backhauled over the HFC network to the nearest node and from there over the high-throughput, nonblocking, IP based interconnect network.

[9] https://blogs.cisco.com/sp/using-segment-routing-to-unlock-the-full-potential-of-the-rphy-converged-interconnect-network.

[10] https://www.mobileworldlive.com/featured-content/top-three/cablelabs-sees-5g-benefits-in-full-duplex-docsis-spec/.

Cable operators have boots on the street and access to customers' premises, which gives them a distinct advantage because these microcells need to be installed, powered, and backhauled.

Automation

Virtualizing the infrastructure enables operators to have a single orchestration layer that abstracts the complexity underneath. Using SDN and NFV principles enables operators to automate network operations and to significantly improve resiliency.

Automating operations and service delivery infrastructures becomes increasingly valuable as automation becomes more pervasive across systems and solutions. This is when data from various systems can be aggregated for meaningful insight, and value can be generated when services and solutions are integrated to provide a seamless experience and end-to-end visibility across services and systems. This means that solutions should be based on open source code, follow specifications to the extent possible, have open APIs, and have an underlying end-to-end digital fabric. Vendors with end-to-end solutions are in a better position to deliver on end-to-end automation and the resulting operational efficiencies and improved user experience.

As operators embark on their network transformation journey, they should avoid replicating the piecemeal approach of yesterday, which resulted in silos and incompatible systems and solutions.

As they introduce automation in their operating environments, operators should also carefully plan for the entire automation cycle and make it an integral part of their network transformation initiatives at every step, because these capabilities cannot be retrofitted once plans are in place.

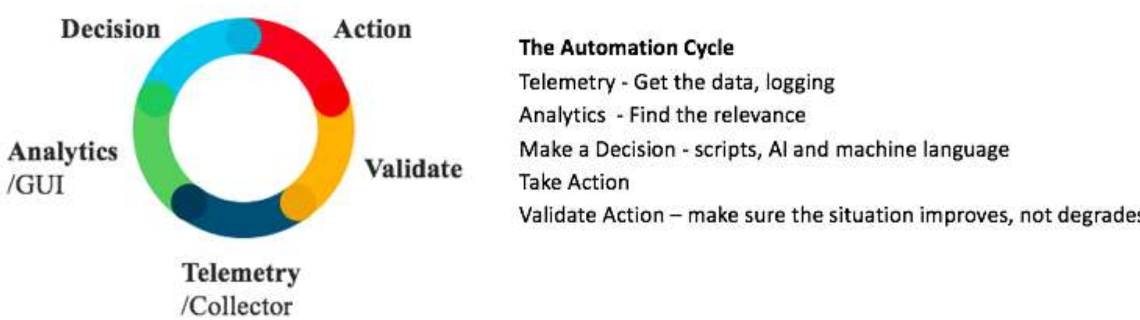

Figure 10. The Automation Cycle (Source: Cisco)

An example of automation is node management. Traditionally, analog nodes did not require software, but most DAA nodes do. When a DAA node is installed, it needs to determine the appropriate version of software to install (it may not have the latest version preloaded) and also to keep track of the version of software installed. In the legacy environment, node association with a CMTS was 1:1. This is no longer true in the DAA environment, because a node can connect to a number of IP reachable network elements.

These are only examples of the level of complexity introduced by DAA, which becomes exacerbated as the number of nodes increases with reduced service group sizes. Therefore, the manual tools of yesterday are no longer suitable, and automation becomes de rigueur.

Vendors have stepped up to provide the automation tools for node management. Examples include Cisco's Smart PHY that enables cables operators to easily install RPDs and to automatically capture intelligence ad telemetry information in their access networks. However, even these solutions should be considered as part of a holistic approach to automation.

Service Velocity

The digitization of the cable infrastructure and virtualization of key network elements enables operators to reap the benefits that today gives the advantages to the likes of FAANG. If operators deploy microservices-based systems to replace existing legacy, they will be able to adopt the software agility principles that benefits Internet companies. Rather than the long development and deployment cycles that characterize their businesses, they will be able to innovate at Internet speeds, which means introducing new services and modifying existing ones over weeks rather than months and years. This will lead to better customer satisfaction and possibly to a competitive advantage.

Capacity Elasticity

Because of their rigid structure, cable operators today are forced to add capacity ahead of demand. They typically add hardware racks then populate them with cards as demand materializes. These racks take a lot of space and need to be powered and cooled even when utilization is low. Their current capacity scaling is essentially stepwise (with significant capital expense associated with the investment), while demand growth is typically linear. A software-based infrastructure provides them with a linear scaling capability in the CCAP. Innovative licensing models, such as Infinite Broadband Unlocked from Cisco, enable them to further align investment with customers' demands. Some vendors are even taking this flexibility further, enabling operators to use/move licenses geographically based on where demand is. Such flexible licensing schemes are the beginning of how business models will be transformed by virtualization and a harbinger for more to come.

Digital Customer Experience

Today, customers expect a superior digital experience from their service provider. They value the ability to manage their services through a number of touch-points and want self-service capabilities. The hardware-based systems of cable providers combined with a largely analog plant fall far short of meeting customers' needs. The digitized environment will enable cable operators to offer the digital experience customers have come to expect.

New Services

In addition to the services already discussed, the digital plant opens significant, new opportunities for cable operators. Instead of the rigid, proprietary infrastructure of yesterday, the new environment opens them to industry-wide standards that have an underlying software foundation, complemented by gigabit capacity. New network elements such as the virtualized CCAP core will become composable, much like a cloud-native EPC, enabling cable operators to offer mobile services, among others. New virtualized platforms, such as Comcast's ActiveCore℠, are already enabling operators to offer revenue-generating business services, such as SD-WAN.

Fault Prevention

Most cable repairs are reactive rather than proactive, particularly in the outside plant (OSP) because it is very expensive to dispatch a technician to diagnose problems in the OSP. The old adage of cable operators learning about outages from their customers still rings true in many cases. Operators need better capabilities to monitor their networks to detect deterioration and repair it before it escalates into an outage. As cable operators serve more business customers, reliability of their networks becomes even more essential. The new infrastructure enables the automation and intelligence capabilities for automated diagnostics and error prevention.

Less Reliance on Cable-Specific Hardware and Skillset

Cable operators' networks rely on a number of cable-specific components and technologies. Their analog transmission capabilities require specialized skills, such as people who know how tune lasers, something akin to an art. It behooves them to migrate to a more mainstream technology that can be sourced from a larger pool of vendors, which reduces cost, and which can be operated by people with more common and easier to find skills.

Better Analytics

Data are the most important assets in any organization. Operators can use data to better understand customers' behavior and trends, gain network visibility, anticipate failures and correct them, and create new services based on a deeper understanding of their customers' needs and behavior patterns. Rigid networks do not provide operators with the data they need. The new digital infrastructure enables them to collect data in the access nodes, very close to the customers; this gives them very valuable insight about utilization patterns and informs their service evolution plans.

Operational Expenses Savings

As previously discussed, cable operators need to plan ahead for capacity, which results in added operating costs and ties up real estate unnecessarily in the headend. They also have inefficiencies in the access network. Because they cannot monitor utilization of the node, operators turn on all the ports in the node, which results in unnecessary power consumption. With better ability to monitor utilization in the node, they can turn on the ports as needed and modify their configurations at different times of the day based on changing demand. This leads to better cost efficiencies.

CONCLUSION

Market forces are pressuring cable operators to modernize their infrastructures to a degree they have not seen in decades. This is because their plans are no longer suitable for the demands of the market. A major framework that underlies their transformation is DAA, which enables them to unbundle the CCAP, thereby moving cable-specific equipment to the access node and opening them to the possibility of virtualizing network elements in the headends and hubs. The access network is also digitized with the nodes (which will host the RPDs and MPDs), becoming intelligent and automatable. The interconnect network is transformed from an analog, rigid network to a digital one, which eventually will become a powerful IP network underlying their connectivity and building the foundation for future services. Other technologies are being developed, for example FDX, that will further increase the capacity of the network and unlock a host of future revenue-generation opportunities.

As they embark on this transformation, cable operators should carefully assess their short-term and long-term needs and take stock of their capabilities. They should look for solutions that bring their infrastructure in line with the broader industry, that are based on open-source software, and that are aligned with existing industry standards to the extent possible. They should also work with vendors and partners that have the breadth of solutions and depth of expertise and capabilities to address their evolving needs.

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