Virtual Converged Cable Access Platform Architecture

Gainspeed and Juniper Networks offer a new, cost-effective approach to cable access networks, built on cloud-based architectures and focused on IP service delivery.

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Executive Summary

The challenges facing the cable industry are no secret. If you have any role in managing today's cable infrastructure, you are well aware of the enormous and ever growing cost and complexity of network deployment and maintenance. With demand for bandwidth and services radically growing—especially high-speed data and IP video—multiple service operators (MSOs) are hard-pressed to scale capacity and meet customer demand.

The familiar techniques for capacity management aren't able to efficiently scale to meet the growing demand for bandwidth. Compounding the issue, some evolutionary approaches may put further strain on an already burdened network, requiring additional nodes in the outside plant and more equipment in jam-packed head-end facilities. "New" dense hybrid gear like the Converged Cable Access Platform (CCAP) still requires a large footprint along with associated power and cooling. While it does increase capacity, it does not efficiently scale network performance, increase service velocity, or improve customer experience.

This dilemma, however, provides an opportunity for innovation. By leveraging software-defined networking (SDN) and Network Functions Virtualization (NFV) techniques, a CCAP's processing functions can be distributed to Ethernet-based fiber nodes while the control plane is centralized, thus virtualizing the CCAP platform, while still leveraging the existing operations and billing systems. By implementing Virtual CCAP (V-CCAP) in residential and business markets, cable operators can respond to changing market needs, meet exploding capacity requirements, rapidly deploy new services, and cost-effectively migrate their hybrid fiber coaxial (HFC) networks to a software-driven, all-IP architecture.

Introduction

The cable industry is facing a significant challenge. New and enhanced services are enabling MSOs to grow, but the current access network infrastructure is unable to scale fast enough to meet projected demand. Cable's high-speed data, or Data over Cable System Interface Specifications (DOCSIS) platform in particular, cannot keep pace with existing growth, never mind the additional burden that new services will place on the network.

Competition exacerbates the situation. In select markets, service providers such as AT&T, Verizon, and Google have introduced ultra high-speed services, some offering speeds as much as 6 times faster than prevailing rates, and at lower price points. In light of these threats and constraints, what should MSOs do?

History provides clues. From fiber optics to Gigabit Ethernet to the cloud, the cable industry has a long record of embracing new technology. The industry created its own solutions, such as the hybrid fiber/coax (HFC) architecture and the DOCSIS standard. That combination of new and homegrown technologies enabled "cable TV" operators to adapt competitively and become Internet service providers (ISPs), phone companies, content distribution networks (CDNs), enterprise-class carriers, wireless access providers, and more.

One of the more recent innovations in the cable industry is the CCAP. Designed to merge the cable modem termination system (CMTS) and Edge QAM (EQAM) platforms into one device, CCAP was intended to reduce access platform footprint and increase platform efficiency.However, with bandwidth growth rates continuing to outpace industry expectations, integrated CCAPs are entering the market unable to meet the industry's bandwidth and related challenges.

Today's dilemma gives cable an opportunity to transform itself again. The idea of distributing CCAP has emerged as one such opportunity. By leveraging software-defined networking (SDN) and virtualization technologies, MSOs can turbocharge the CCAP. A distributed and virtualized CCAP will not only enable cable operators to meet skyrocketing capacity requirements, it will also allow them to efficiently migrate their HFC network into a competitive, software-driven, all-IP architecture.

The constraints facing the industry are real. In the first section of this paper, we review the challenges those constraints are imposing on the industry and their existing solutions. In the second section, we introduce the V-CCAP solution—its components, features, and benefits. Whether considering niche or widespread scenarios, MSOs now have at their hands a truly scalable solution, one that at last leverages SDN to centralize the control plane, providing for greater network automation; virtualizes the CCAP hardware platform by distributing its routing features onto the edge/access routing platform, and its DOCSIS PHY and media access control (MAC) features into the Ethernet node; and leverages an all-IP transport vehicle with NFV to deliver new services to end users with greater agility.

Pressures on Current Access Architecture

The HFC network, which was designed for analog video, is unable to support the exploding capacity requirements of narrowcast digital services such as video on demand (VOD), IP video, and high-speed data. In many markets, broadband infrastructure has reached saturation—and at just the wrong moment.

Existing cable modem termination system (CMTS) platforms are proving unable to scale at a time when MSOs need to leverage their infrastructure to deliver high-growth applications such as commercial services (L2VPN and L3VPN), Wi-Fi backhaul, small-cell backhaul, cloud-based virtual customer premise equipment (vCPE), and IP video. The enormous demand for bandwidth and new data services is highlighting several issues and limitations with the legacy analog access network.

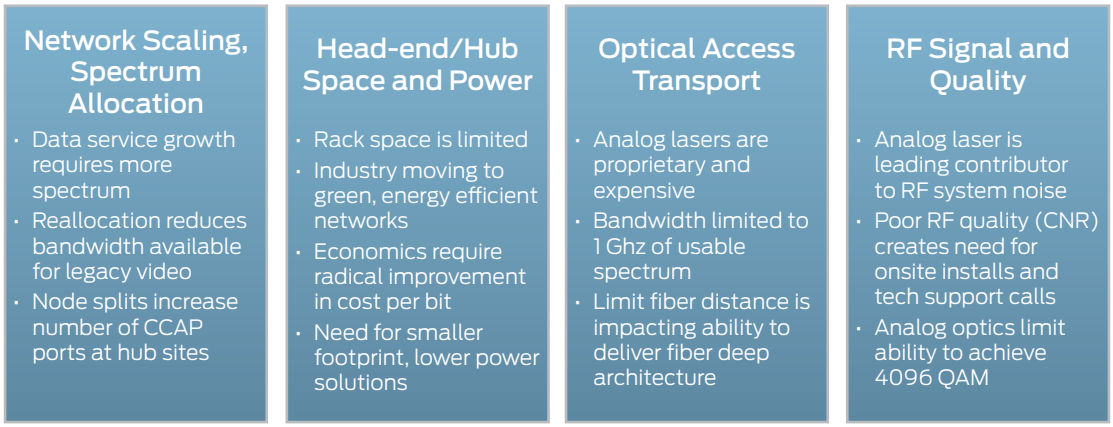


Figure 1. Pressures on current cable architectures

Network Scaling and Spectrum Allocation

To address the nonstop demand growth for bandwidth, cable operators are constantly challenged to scale their network capacity. At present, cable operators have just a few ways of doing this: split nodes, reallocate spectrum, or add spectrum. Each choice has its advantages and operational drawbacks. (See Table 1)

Table 1: Options for Augmenting High-Speed Data Services

Technique	How to do it?	Pros	Cons
Node splits	• Add more CMTS/CCAP ports • Add more optical gear	• Reduce users per service group (SG)	• Time intensive, costly projects • Significant growth in CMTS/CCAP ports • Requires additional fiber or wavelengths for new nodes
Reallocate spectrum	• Convert analog to digital to free up spectrum • Convert MPEG2 to MPEG4 video to free up digital video channels • Add more CMTS/CCAP ports	• More spectrum for DOCSIS	• Less bandwidth available for legacy video services • Significant growth in CMTS/CCAP ports
Add spectrum	• Upgrade HFC plant • Add more CMTS/CCAP ports • Replace optical gear	• Upgrade to 1 GHz or 1.2 GHz	• Time intensive and costly. Requires touching *all* actives in the field. May require replacement of tap face-plates. • Significant growth in CMTS/CCAP ports • Outside plant redesign, may need to reduce fiber distance to balance power, linearity, and bandwidth

One way to increase the bandwidth provided to each customer is to reduce the number of customers being serviced by a given fiber node. While conceptually straightforward, node splits carry a substantial price tag. Not only must operators purchase one or more nodes and cover installation costs, they must also add a corresponding CMTS/CCAP port for each node as well.

A few years ago, operators served close to 2,000 homes passed from a single CMTS port and 2-4 DOCSIS downstream channels. The norm has now dropped to around 500 homes passed. But moving from 500 homes passed per DOCSIS service group (SG) to 150 and eventually down to 50 requires a tenfold capacity increase in CMTS ports, with each port supporting vastly more channels (at minimum, 32). Monolithic CMTS and CCAP systems are limited in their physical density, so operators will be forced to deploy a larger number of them. This requisite expansion of space, power, and cooling in thousands of locations significantly undercuts one of the primary motivations of CCAP.

Another method of increasing data capacity is to reallocate the existing spectrum, shifting video from analog to digital transmission and transitioning to more robust video compression methods to reduce the capacity required by each digital channel. While this makes more bandwidth available for DOCSIS channels, it requires a reduction in video capacity, and more significantly, it requires a substantially greater number of CMTS/CCAP ports in the head-end and hubs.

Finally, cable operators can add capacity simply by adding spectrum. However, there is nothing simple about that. Adding spectrum is a very expensive and complex proposition involving HFC plant upgrades, new optical gear, additional CMTS/CCAP ports, and possibly substantial redesign work of the outside plant.

Head-End/Hub Space and Power

As discussed in the previous section, current approaches to scaling the network all entail adding significant amounts of gear in the head-end and hubs. However, hub space, power, and cooling are at the top of the concerns list for cable network architects and planners. Rack space is limited and many facilities are already at capacity. From a business perspective, operators need to reduce their cost per bit; reducing the operating expenses by head-end and hub efficiencies could make a big difference. Additionally, the industry as a whole is making strides to move to green and more energy-efficient networks. All of these factors point to a need for a solution with a smaller footprint and lower power requirements.

Addressing these issues was one of the primary drivers behind CCAP. However, the market did not stand still while CCAP was being conceived, designed, and introduced. Broadband capacity requirements continue to double every two years driven heavily by IP video consumption. In parallel, quadrature amplitude modulation (QAM) video usage has significantly dropped. Consequently, industry trends have reduced the value of a monolithic CMTS/EQAM platform.

Optical Access Transport

Traditional cable access networks rely on linear analog lasers to transport the radio frequency (RF) spectrum generated in the hub or head-end to the fiber node. Unfortunately, the analog laser, which has long been the workhorse of the cable distribution plant, has reached its performance limit.

Linear analog lasers are expensive, proprietary to the cable industry, and maintenance-intensive. They also are unable to meet the linearity requirements for modulating signals beyond 1 GHz. These limitations are inhibiting growth. Under the existing analog system, many MSOs have been forced to design their networks and manage corresponding real estate investments around the costs and carrier-to-noise ratio (CNR) penalty associated with longer distance lasers.

More than any other element in the system, the analog laser negatively impacts the RF signal, thereby limiting end-to-end service performance and reducing the spectral efficiency of the HFC plant. This makes supporting higher order modulation, such as 4096 QAM, a doubtful proposition. Breaking through this bottleneck is one reason the industry is so enthusiastic about the idea of distributing CCAP via digital Ethernet transport. The winning CCAP combination, however, involves both distribution and virtualization, which conveys numerous additional benefits.

Solution Overview and Benefits

Cable operators are looking for a next-generation platform that not only overcomes existing pressures but also sets them up to win long-term. That means deploying services rapidly and flexibly across the full spectrum, while scaling them in a way that minimizes additional hardware in the head-end and hubs. As noted above, the industry has a history of combining familiar and new technologies. The V-CCAP solution does just that, leveraging IP/MPLS routing, SDN, NFV, and a distributed implementation of CCAP.

V-CCAP Summary

Virtual CCAP appeals to cable operators for several reasons: scale, RF performance, automation, lower cost, less maintenance, and rapid deployment of new IP-based services. Flexible and resilient, the V-CCAP solution addresses the limitations of today's networks in a simple and cost-effective manner, delivering a dramatic price/performance advantage over alternative approaches, transforming the network, and enabling a virtualized, software-driven, all-IP environment.

Consisting of virtual controller, video engine, Ethernet switch, router, and Ethernet-based node, the V-CCAP architecture revolutionizes the cable access network. (See Figure 2.)

V-CCAP is a distributed access architecture. It relocates both the PHY and the DOCSIS MAC to the fiber node. This approach provides a number of benefits with respect to greater network scalability, higher fiber capacity and efficiency, improved RF performance, and reduced maintenance.

But V-CCAP goes beyond simply distributing Layer 1 and Layer 2 to the node. It uses SDN and virtualization techniques to break apart the traditional monolithic CMTS/CCAP and distribute the functions the CMTS/CCAP performs to other parts of the network. It centralizes management and the cable control functions on an off-the-shelf server in the data center

or cloud, places subscriber management and IP/MPLS functions on the edge router that's already a part of the MSO network, and relocates both DOCSIS processing and RF modulation in the fiber node. By reorganizing at the functional level, V-CCAP completely eliminates the physical CMTS/CCAP from the head-end, along with its associated power and cooling demands.

It's worth emphasizing that the V-CCAP architecture pushes cable-specific elements to the perimeter (the data center and the Ethernet node). Everything left in the head-end is equipment that is broadly used across telecommunications and data communications and this offers huge economies of scale.

Also of key significance is the fact that the V-CCAP solution is built on the current MSO network's operational paradigm. It makes use of the existing coax network and CPE, is fully compliant with CCAP operation support systems interface (OSSI), supports all of the same MIBs, and enables zero touch integration into the existing operations and business support systems (OSS/BSS).

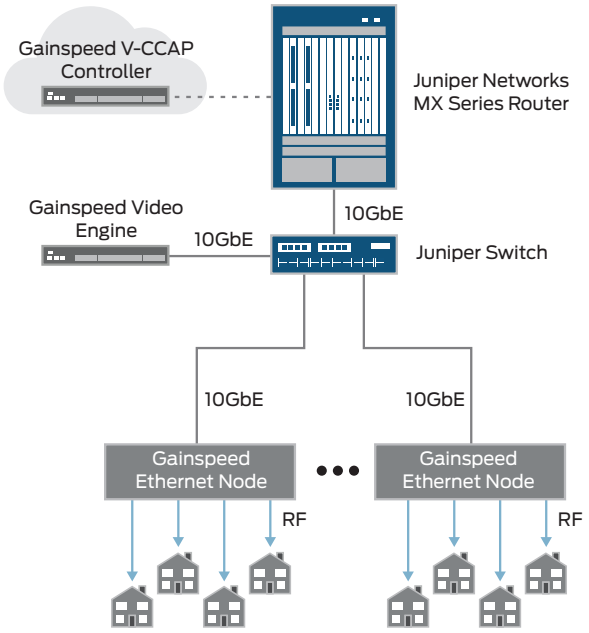
Best-in-Class Benefits

The V-CCAP solution delivers all of the benefits of CCAP—reduction in space, power, and cost—but to a much greater extent and with lower capital and operating expenses. Compared to CCAP, V-CCAP reduces capital investment by 55 percent, operational expenditures (OpEx) by 65 percent, and power usage and rack space by 92 percent, all while providing a 10 times increase in fiber efficiency.

The key benefits V-CCAP provides are:

- **Minimizes the space/power footprint by eliminating the physical CMTS/CCAP**: Rack space in head-ends and hubs is at a premium, with many facilities already near capacity. Each additional piece of equipment not only has a cost associated with its physical space and maintenance, but power and cooling expenses as well. Virtualizing the CCAP literally precludes the need for a physical box and eliminates some of the existing equipment, freeing up space in existing head-end and hub facilities. Additionally, because V-CCAP eliminates analog optics and related distance/capacity issues from the head-end to the node (as will be discussed later), V-CCAP can enable cable operators to eliminate or consolidate hub facilities.
- **Increases HSD capacity and flexibility by delivering "Full Spectrum DOCSIS"**: Pushing DOCSIS processing and RF modulation out to the edge of the access network allows analog optics to be replaced with 10GbE and converts analog fiber nodes into digital, IP-enabled devices (Ethernet nodes) deep in the cable operator's access network. This distributed architecture optimizes spectrum utilization, provides flexible spectrum provisioning, and enables "Full Spectrum DOCSIS" to every Ethernet node and every service group.
- **Eliminates RF combining and optics by extending IP/Ethernet from the head-end to the node:** The RF performance of traditional cable access networks is limited based on factors such as distance, carrier-to-noise ratio (CNR), and ingress noise. By deploying IP/Ethernet to the access network edge, V-CCAP eliminates the distance limitation. By distributing the RF origin out to the node, the V-CCAP architecture is able to deliver a much stronger, cleaner RF signal into the home, reducing truck rolls and improving both service delivery and end-user quality of experience. This architecture will also enable software-based migration to higher order modulations, such as 4096-QAM and orthogonal frequency-division multiplexing (OFDM), with a move to DOCSIS 3.1.
- **Frees capital for IP investment by preserving the existing EQAM infrastructure**: Given the growth in IP video and the corresponding decline in the use of QAM video, there is no need for additional investment in EQAM infrastructure. Through the use of a video engine that converts QAM video to Ethernet, V-CCAP leverages the existing EQAM infrastructure, leaving more budget and technical resources available to support growing IP demands.
- **Accelerates service deployment with zero touch provisioning:** V-CCAP leverages SDN technology to provide greater network automation and dynamic provisioning, along with NFV capabilities, to enable greater network agility and increase the velocity of deploying new services. Both of these capabilities benefit the cable operator by increasing revenue opportunities while reducing the associated operational costs. The customer also benefits by having a broader menu of available services from which to choose and receiving quicker service activation.
- **Provides an elegant migration to an all IP/Ethernet solution**: With the ever increasing demand for data services, and the eventual move to all IP video, V-CCAP enables cable operators to support their current needs and, with software upgrades, lets them easily scale the network to evolve with their services as their strategy and markets require.

In summary, Virtual CCAP produces a future-proof network that is more efficient and cost-effective, less complex, easier to scale and operate, and adaptable to each operator's distinct needs and IP strategy.



- **Improved Scale, Efficiency, and Economics**
  - Reduces space, power and cooling requirements and costs
  - Solves the service group scaling issues
  - Replaces analog optics with 10GbE
  - Delivers "Full Spectrum DOCSIS"
- **Increases Performance and Fiber Utilization**
  - Converts analog fiber node to digital, IP-enabled devices
  - Enables higher order modulation (4096 QAM)
  - Delivers stronger RF signals / higher SNR
- **Simplifies Operations**
  - No chronic maintenance, retuning, analog adjustments
  - Accelerates and eases service deployment
  - Works with existing back-office and EQAM infrastructure
  - Provides elegant migration to an all IP / Ethernet solution

Figure 2. Benefits of V-CCAP architecture

V-CCAP Deployment Scenarios

The V-CCAP solution is applicable across an MSO's entire footprint. This section discusses how V-CCAP's features and capabilities map into residential, multiple dwelling units (MDUs), and business-class customer deployments.

Residential Market

The bread and butter business for cable operators is the residential market segment. One of the biggest issues that MSOs face is the growing bandwidth requirements driven by streaming IP video. Cable operators have kept up with demand by implementing node splits and reducing service group size, but as discussed earlier, this comes with enormous cost and complexity. Every additional node requires CMTS/CCAP ports in the head-end.

Implementing V-CCAP enables DOCSIS bandwidth augmentation at reduced capital and operational costs. By eliminating analog optics from the head-end to the node and using standard 10GbE, operators can leverage their entire available spectrum for DOCSIS 3.0 and 3.1. By leveraging software configurability, MSOs can dynamically make adjustments to accommodate varying line conditions and customer service requirements.

With the use of innovative enabling technologies, the V-CCAP solution seamlessly and transparently integrates into an operator's existing video distribution network. A "video engine" can be used to ingest operator selected RF channels and transform them into Ethernet for transport to the Ethernet nodes, which in turn modulate the signal for delivery to the customer premise. The video engine also supports transparent transport for NTSC/SECAM/PAL analog video programming via circuit emulation. And it uses circuit emulation to support transparent transport for industry-standard, set-top box out-of-band (OOB) control channels.

In addition to supporting data and video applications, the V-CCAP solution uses PacketCable standards to deliver voice services, thus enabling V-CCAP to support "triple play" services with significantly greater data capacity, higher customer satisfaction, and lower CapEx and OpEx than a traditional CCAP/CMTS solution.

Multiple Dwelling Units (MDUs)

Multiple dwelling units (MDUs) are a distinct subset of the residential market and present a lucrative, but highly competitive opportunity for cable operators. MDU owners typically own the building's internal coax cabling and are free to select any voice, video, and data service provider; they are not limited to the cable television provider designated for their geographic area.

Many MDU owners see communication services as a way to differentiate their apartment buildings and condominiums from others. Aware of competitive service offerings, many MDU owners are requesting much more than just "cable TV." Their wish lists include gigabit service speeds, more consistent download and better upload speeds, Ethernet-based services, community Wi-Fi, and more. Thus, MDUs represent a huge market opportunity, but MSOs are under attack on both price and performance.

The capacity, performance, and flexibility of the V-CCAP solution enable cable operators to address the distinct needs of MDUs. V-CCAP cost effectively provides enormous capacity of up to 158 downstream (DS) and 12 upstream (US) channels over the existing HFC infrastructure, and it enables MSOs to meet these aggressive demands at a much lower cost than fiber-to-the-premise (FTTP). Furthermore, V-CCAP is software upgradeable to DOCSIS 3.1. As a result, MSOs can bid more competitively for MDU deals.

V-CCAP's flexibility is also particularly beneficial for the MDU market. V-CCAP virtualizes service groups, enabling operators to differentiate and dynamically scale their service offerings. With this flexibility they can customize channel lineups to IP set-tops, community Wi-Fi, and higher bandwidth. V-CCAP enables the MSO to deliver 1 Gbps services on both fiber-based Ethernet and coaxial cable.

Many MDUs are mixed-use buildings with both residential and commercial tenants. V-CCAP's flexibility and use of SDN/NFV enable the solution to simultaneously provide relevant services for both residential and business customers.

Business Services

Commercial/business services represent a huge market opportunity and the largest growth area for cable operators—more than $140 billion in high-speed data services in the U.S. alone. However, due to the limitations of many MSOs' infrastructure, the market has been largely dominated by traditional telecommunications providers.

However, V-CCAP alters that situation with fiber-level performance and guaranteed services over the existing coax network, enabling MSOs to seamlessly deliver cloud-based services and satisfy the needs of enterprise customers. The V-CCAP infrastructure replaces the analog fiber connection with a 10GbE digital fiber connection and pushes DOCSIS into the outside plant, thus allowing the edge router to take its rightful place as an edge services gateway.

The V-CCAP controller is able to isolate commercial services from residential, and work in combination with an SDN/NFV controller and the edge router to introduce innovative services into the network. These new virtual capabilities allow operators to harness the power of the cloud to deliver new services such as managed security, carrier-grade NAT, caching, and deep packet inspection (DPI), increase business agility and service velocity, and drive revenue and profit growth.

The diagram shown in Figure 3 illustrates the flexibility of the V-CCAP architecture to meet business needs and support a combination of centralized and distributed services. In this example, an end user, which could be a business location, individual subscriber, or device, orders a set of services. Through the use of "service-chains," the SDN/NFV controller creates a data path through the necessary devices, physical or virtual, to implement the requested services. The service-chain may include multiple elements that must act on the data flow, and these elements can be positioned local to the hub site or remotely across the IP/MPLS metro network. As the network grows and changes, simply rearranging software elements can shift where these services are implemented. No service is permanently fixed to a particular location or resource in the network; instead, operators are able to dynamically adapt the system to their particular use case, traffic load or pattern, or policy requirements.

By integrating V-CCAP with an SDN/NFV-enabled network, Cable operators can deploy new and existing IP-based services to their business customers with greater speed, agility, and ease, eliminating the need for costly, manual configuration and reconfiguration of the network.

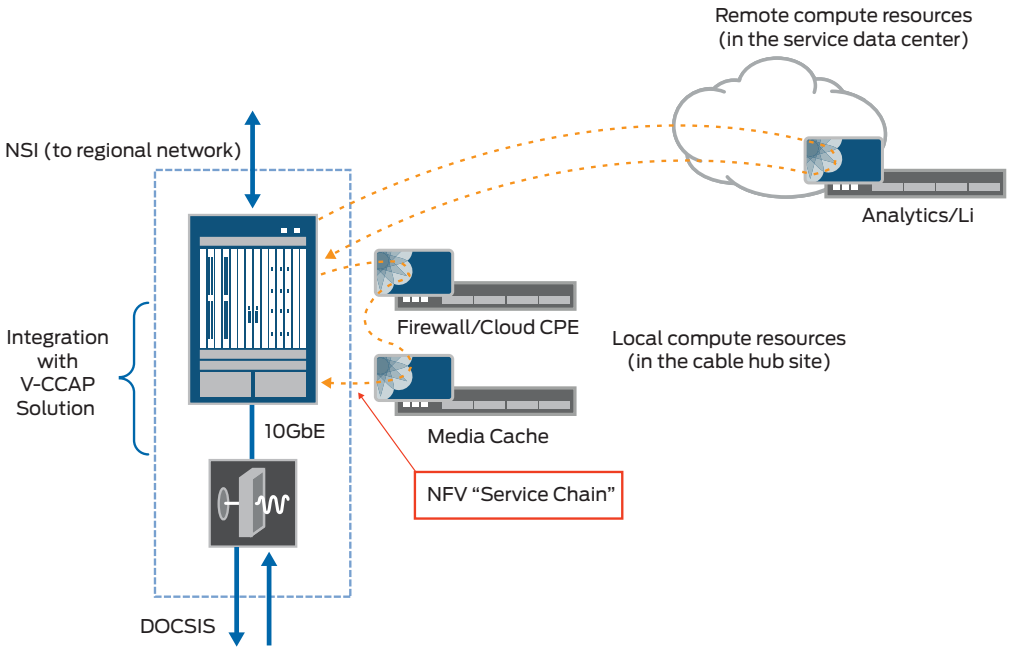


Figure 3. Flexibility of the V-CCAP architecture

Conclusion

It is an exciting time of innovation and growth in the cable industry. The stakes are high, and now more than ever, cable operators need an access network that is simple and efficient to manage, is scalable both in footprint and bandwidth to meet the growing needs of customers, and can easily integrate new, revenue-generating IP-based services.

The V-CCAP architecture redefines how cable networks are built by eliminating the need for today's CMTS/CCAP platform, analog fiber transmitter, and linear fiber optic receiver. By leveraging SDN and NFV technologies, V-CCAP delivers a dramatic price/performance advantage over alternative approaches, distributes head-end processing functionality while centralizing management and control, migrates the fiber network from RF to Ethernet, moves key hardware functions into software, and pushes IP closer to the customer, whether residential or business. The resulting network architecture provides a flexible and resilient all IP-based solution that addresses the limitations of today's cable networks in a simple and cost-effective manner.

V-CCAP thus enables cable operators to respond to changing market needs, meet skyrocketing capacity requirements, rapidly deploy new services, and efficiently migrate their HFC networks to a software-driven, all-IP architecture.

About Gainspeed

Gainspeed Inc. is redefining how cable networks are built. Gainspeed enables cable operators to meet skyrocketing capacity requirements, respond to changing market demands, and rapidly deploy new services all while cost-effectively migrating their networks to a software-driven, all-IP architecture. Additional information can be found at www.gainspeed.com.

About Juniper Networks

Juniper Networks is in the business of network innovation. From devices to data centers, from consumers to cloud providers, Juniper Networks delivers the software, silicon and systems that transform the experience and economics of networking. The company serves customers and partners worldwide. Additional information can be found at www.juniper.net.

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