ASSIA VIRTUALIZATION FOR CONSUMER BROADBAND

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Abstract – Network Functions Virtualization (NFV) and other software virtualization concepts are sweeping the Internet and telecom industries to provide flexibility and innovation in service development and delivery ASSIA systems are vendor independent, run on virtualized infrastructure and are software centric. We are pushing the industry forward with many powerful new innovations; virtualizing the broadband network itself, creating new and powerful Virtual Network Functions (VNFs) and creating new ways of combining VNFs in service function chains to enable functionality vital to operators. This paper describes the many ways in which ASSIA assists operators in their move toward virtualization.

Contents

1. Introduction

Broadband access network and home network speeds are increasing, and the numbers of connected devices are growing along with network usage. The simple operations model of managing one line per home is collapsing. The cloud offers nearly unlimited computing power, allowing new network control and management concepts using Software Defined Networking (SDN) and Network Functions Virtualization (NFV). These enable services to have great agility and innovation.

Network elements (NEs) can be disaggregated, separating the unified capabilities of large multifunction boxes into their constituent functions that can then be virtualized, implemented in software, and re-used. Virtualization also separates data plane functions that must be embedded in the equipment, from control and management plane functions that are not intrinsically part of the equipment and so can be virtualized. Virtual Network Functions (VNFs) typically run on cloud-computing or data center infrastructure as defined by the ETSI ISG on NFV [2]. Alternately, some network functions can run in a user space or common execution environment on the equipment itself, and be implemented by software such as downloadable open source.

1.1. Benefits of NFV

There are many benefits of NFV in addition to general network and operations modernization:

- Flexibility and rapid service creation. Easy upgrade, copy, and backup. Upgrade simply by installing new software on servers instead of cumbersome hardware or custom software/firmware upgrades.
- Flexibly assign and share computing resources.
- A centralized touch point for network and services management.
- Opex reduction.
- Elasticity provided by the infrastructure for capacity expansion and the deployment of new network functions.
- An open platform, enabling Virtual Network Functions (VNFs) to be supplied by open source, operators, vendors, third parties, etc. VNFs from all these sources can be mixed together to create network services, and be re-arranged and re-used.

This paper shows the many areas where ASSIA solutions support virtualization, highlighting ASSIA software for NFV systems. This includes ASSIA's well-known broadband and Wi-Fi diagnostics and optimization products: ASSIA DSL Expresse®, GPON-Expresse and Cloudcheck®. The details of several ASSIA virtual solutions are described: ASSIA Multi-Tenant Expresse supports sharing and open access among wholesale and retail network operators; ASSIA Multi-Link enables Network as a Service (NaaS); Cloudcheck Server, Agent, and the Cloudcheck smartphone app support disaggregated Wi-Fi management using an alternate management path for broadband over Wi-Fi and cellular networks; ASSIA virtual Probe (eProbe) provides a universal interface to manage broadband NEs and the virtual eDSLAM; while other ASSIA VNFs enable many functions including new enhanced video streaming services.

2. The Virtualized Broadband Network and ASSIA Expresse

ASSIA pioneered the Software-Defined Access Network (SDAN) concept [3][4]. SDAN applies a number of virtualization techniques to broadband access, virtualizing the network itself into Network as a Service (NaaS). This section describes ASSIA Multi-Tenant Expresse and ASSIA Multi-Link for virtualization.

ASSIA Multi-Tenant Expresse allows a single physical network to be operated by multiple operators, with each performing operations on their own virtual network slice, nearly indistinguishable from as if they were each operating their own separate physical networks.

ASSIA Multi-Link advantageously bonds and load balances the users traffic over multiple broadband connections (DSL, GPON, cable, Wi-Fi, 4G/5G) enhancing the user's Quality of Experience (QoE) and creating a services-oriented network by combining these separate physical access methods into a seamless virtual access entity.

2.1. Multi-Tenant for FANS and open access

Physical unbundling is neither technically nor economically feasible with any of the deep fiber deployment technologies. Physical unbundling of Fiber-to-the Premises (FTTP), Fiber to the node (FTTN) using Vectored VDSL2, and Fiber to the Distribution Point (FTTdp) using G.fast would all require multiple operators to each run fiber in the outside plant to each of many small nodes, install all these small nodes, deploy equipment at each of these small nodes and maintain that equipment. Much of this fiber and equipment would be redundant and underutilized and thus the costs would be prohibitive.

The existence of multi-operator environments therefore must depend on virtual unbundling. Plain vanilla resale is insufficient; a vibrant ecosystem supporting innovative service offerings from multiple operators depends on an open virtualized platform that fosters competitive innovation and services differentiation, to drive economic growth of broadband services at a lower cost and with improved operations.

The Broadband Forum is currently specifying Fixed-Access Network Sharing (FANS) [5] for future virtual unbundling. ASSIA Multi-Tenant Expresse is an ideal platform to host centralized management system of FANS, being rapidly implementable and capable of working with today's network deployments [6]. Multi-Tenant Expresse has already been used by multiple operators with great success to provide flexible virtual services to resellers for broadband access over today's networks.

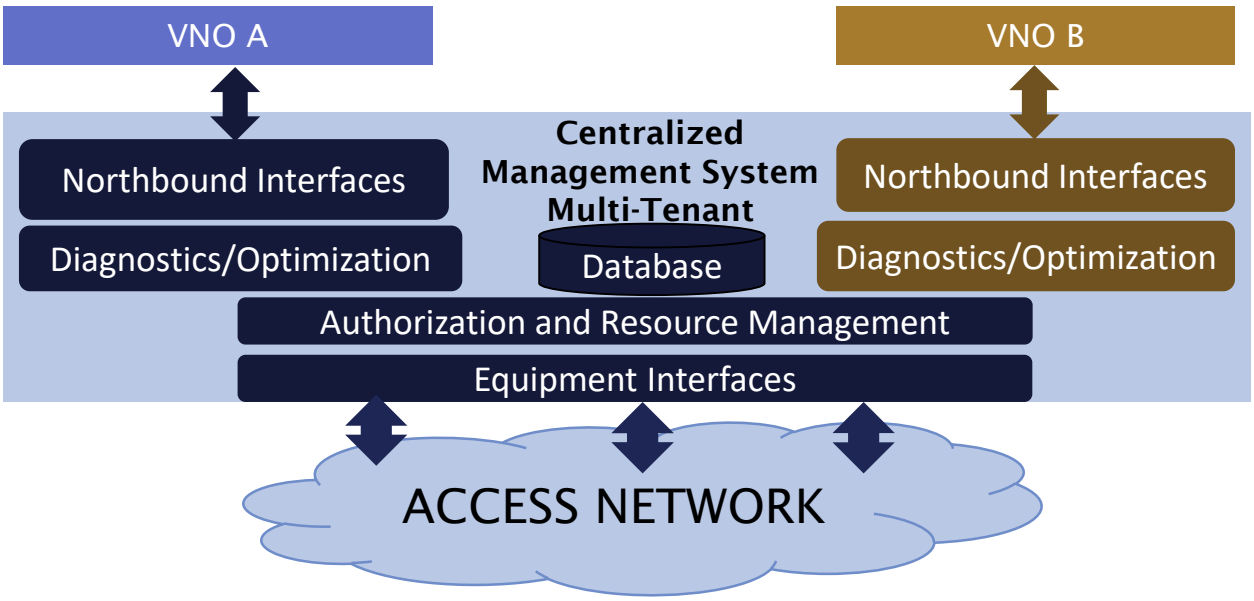

Figure 1. ASSIA Multi-Tenant Expresse.

As shown in Figure 1, Northbound Interfaces (NBIs) link the ASSIA Multi-Tenant Centralized Management System with Virtual Network Operators (VNOs) management systems, while Southbound Interfaces (SBIs) link it with network equipment and systems. Each VNO logically sees their own slice of the network.

ASSIA Multi-Tenant performs centralized functions, automatically provides performance and diagnostics data from network elements to VNOs, and allows centralized control and configuration of network elements. Within ASSIA Multi-Tenant there is an authorization engine and request management function to enforce policies and avoid potential conflicts or discrepancies in resource sharing or line settings among VNOs. ASSIA Multi-Tenant readily provides for multi-tenancy, performs authorization functions, and performs resource allocation with arbitrage between the various requests and parties as determined by configurable policies.

Cross-operator fault correlation and performance optimizations can be performed by ASSIA Multi-Tenant in conjunction with ASSIA's DSL Expresse® and GPON-Expresse broadband optimization products. For example, Dynamic Spectrum Management can jointly optimize all operators' DSLs, often resulting in 2x to 3x performance improvements.

2.2. ASSIA Multi-Link for broadband NaaS

ASSIA Multi-Link leverages the multiple broadband pipes that often connect to many end locations; DSL, 4G/5G, Wi-Fi access, etc. by bonding them into a virtualized pipe. Each of these multiple physical pipes usually carries multiple services or flows and at any given time many links are underutilized, allowing Multi-Link to load balancing across all links and services to greatly increase perceived service levels. Load balancing, SDN, and virtualization techniques are all used by ASSIA Multi-Link to aggregate or otherwise combine these broadband connections.

The broadband network itself can be virtualized. In addition to virtualizing network management and optimization with DSL Expresse®, GPON-Expresse and Cloudcheck® and with the use of ASSUA's multi-tenant capabilities, ASSIA's Multi-Link solution virtualizes the broadband access network itself into a Network as a Service (NaaS) platform.

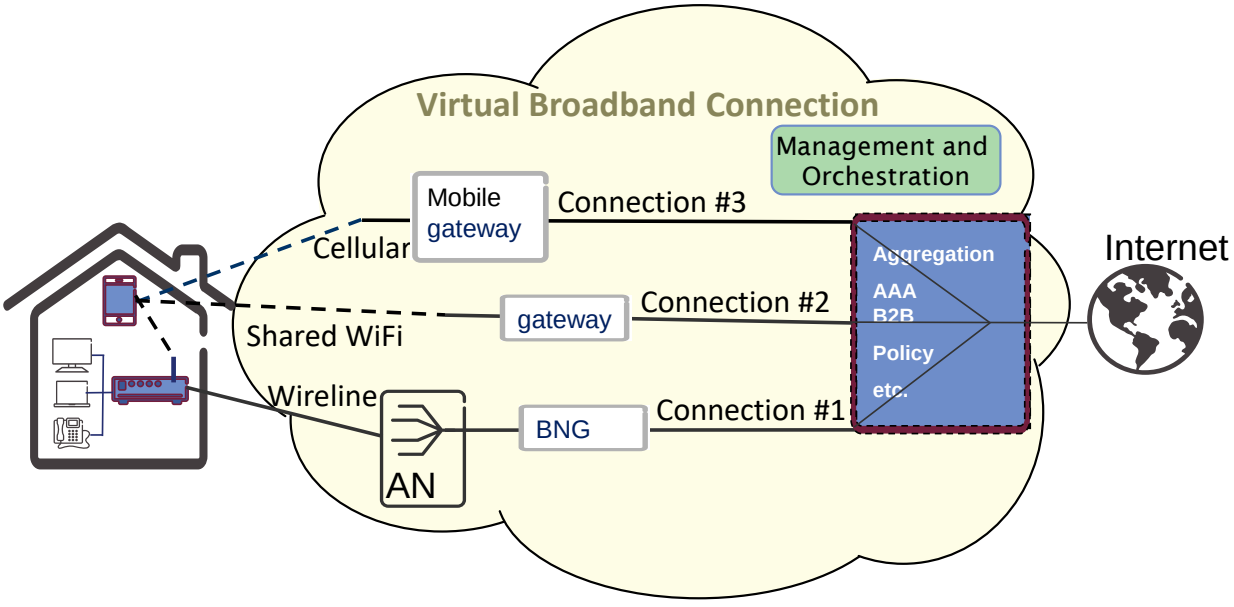

Figure 2. ASSIA Multi-Link creating Network as a Service (NaaS).

ASSIA Multi-Link uses IP-layer link bonding with sophisticated load balancing algorithms to optimize delivery of a range of services over multiple links with different bandwidths and QoS. Adaptation in real time is also possible with the use of SDN flow tables determined by a virtualized controller. The Multi-Link solution advantageously combines multiple residential Internet connections for improved customer QoE. Multi-Link facilitates roaming between wireline broadband, Wi-Fi, and cellular networks. Multi-link can also initiate broadband access over LTE, before broadband wireline is provisioned, and then seamlessly use LTE as a backup access method for load balancing in times of high usage after the wireline access starts running.

3. Home Networking, Wi-Fi, and ASSIA Cloudcheck

3.1. Disaggregated Wi-Fi management

With more connected devices and more bandwidth available to the home, subscribers demand a high quality broadband experience in the home and Wi-Fi is one of the major components supporting that experience. Wi-Fi may be the most problematic of all links to the customer, and problems with Wi-Fi may typically be seen by the customer as failure of the broadband service to deliver its overall promise.

Wi-Fi performance, and thus the user experience can often suffer due to many environmental factors, such as congestion, noise, and interference and the user is typically not able to differentiate between these problems caused by Wi-Fi, and other problems in the access network, or in the underlying applications. Today operators lack effective tools to efficiently assess subscriber Wi-Fi QoE, and diagnose and resolve Wi-Fi related issues or to differentiate Wi-Fi related degradations from other causes of poor customer experience. At the same time, subscribers cannot easily resolve Wi-Fi issues without having to call their service provider. This inability to diagnose and address Wi-Fi problems translates into high operating costs for the service provider caused by ineffective or lengthy support calls, expensive “truck rolls” for on-site service, and replacement of CPE. Because of the lack of effective tools, operator’s attempts to resolve issues are often ineffective resulting in return calls and visits, and high levels of customer dissatisfaction.

Wi-Fi problems can be addressed with enhanced diagnostics, fault and performance monitoring, troubleshooting, re-configuration, and optimization. Some of this can be done by remote management over TR-069, however, the TR-069 data model is limited, and methods of accessing it are built into box firmware so improvements and additions to these functionalities are slow and vendor dependent. Further, TR-069 performs all data gathering and analysis at a remote server and has a slow and cumbersome optimization loop.

ASSIA Cloudcheck brings the benefits of disaggregation to Wi-Fi management. Functions now running on Wi-Fi Access Point (AP) boxes are virtualized; some functions run in the cloud as Virtual Network Functions (VNFs), while other functions are implemented in the Cloudcheck software agent running the box itself.

The Cloudcheck Agent runs in an execution environment or user space on the customer’s Wi-Fi AP (Access Point), this is called “equipment slicing.” The Cloudcheck agent performs local data collection and local optimizations while communicating with the Cloudcheck server.

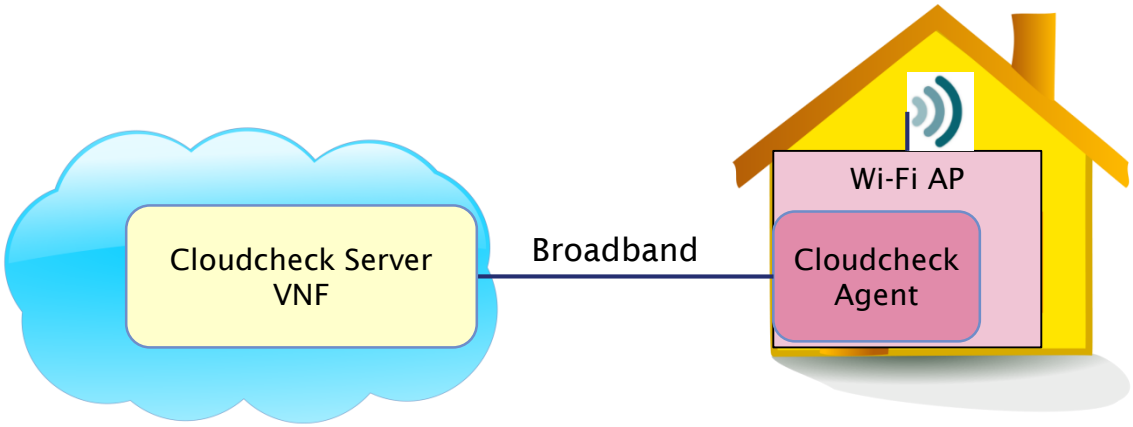

Figure 3. ASSIA Cloudcheck disaggregates Wi-Fi management.

The Cloudcheck Optimization Server is fully virtualized to run as a VNF in an NFV system. Cloudcheck Server stores long-term historical data, performs network-wide management by coordinating among multiple APs, performs complex processing such as implementation of expert systems, etc. Cloudcheck Server applies machine learning and deep analytics to evaluate historical and real-time conditions of the Wi-Fi environments and to makes automatic, contextual-based optimizations. Cloudcheck Server runs advanced algorithms and implements to provide real-time, historical, and predictive analysis. Real-time subscriber Quality-of-Experience (QoE) to the user device is determined with "Real-Q technology." Cloudcheck Server thus provides a wealth of Wi-Fi information and diagnostics capabilities to operators, while also optimizing the Wi-Fi configurations with instructions sent to the Cloudcheck Agent in the AP.

There is a need for real-time reaction to alleviate problems before the customer generates a complaint. For example, a Wi-Fi channel may experience high interference, then the channel or band should be changed immediately to address the issue as it occurs. The ASSIA Cloudcheck Agent provides real-time reaction to the Wi-Fi environment and executes self-healing policies to optimize the network for best possible user experience. The Agent also performs real-time data collection, and makes Wi-Fi throughput measurements without installing software on other user devices. The Cloudcheck Agent aggregates diagnostics and speed test data and presents this data to Cloudcheck Server for in-depth long-term analyses.

ASSIA Cloudcheck Agent is easily installed with a simple software download into data memory or non-volatile flash. Placing a versatile agent on the AP itself aligns with the industry-wide move toward virtualized software solutions to enable rapid upgrades to functionality, to leverage open source solutions, and enable open systems which encourages innovation. With its ability to coordinate with the Cloudcheck server, the Cloudcheck agent virtualizes Wi-Fi management at the customer's premises while remaining compatible with current AP designs and architectures. Cloudcheck is also being deployed in partnerships with AP vendors.

ASSIA Cloudcheck is gaining the capability to use the standardized User Services Platform (USP) protocols across the broadband connection to allow further disaggregation. USP is also known as TR-069 Issue 2, and will allow operators to manage IoT services.

3.2. Customer smartphone diagnostic app

Customer empowerment represents the next phase of delivering a flawless customer experience by providing subscribers with new capabilities to optimize their broadband service based on how,

where, and when they use the service. With customer empowerment, service providers enhance the broadband experience by letting the customer personalize the service according to his needs.

The ASSIA Cloudcheck® app empowers customers via an appealing Smartphone interface. Cloudcheck app contains a speed test for measuring true broadband and Wi-Fi throughput, the SweetSpots tool for Wi-Fi signal strength measurements and Smartifi to manage the Wi-Fi network and automatically optimize Wi-Fi performance. Cloudcheck app increases customer satisfaction and lowers operations costs by enabling self-install and self-help. Cloudcheck app also interfaces to the Cloudcheck Agent and the Cloudcheck optimization server to further diagnose and optimize the customer's Wi-Fi.

3.3. Alternate management path

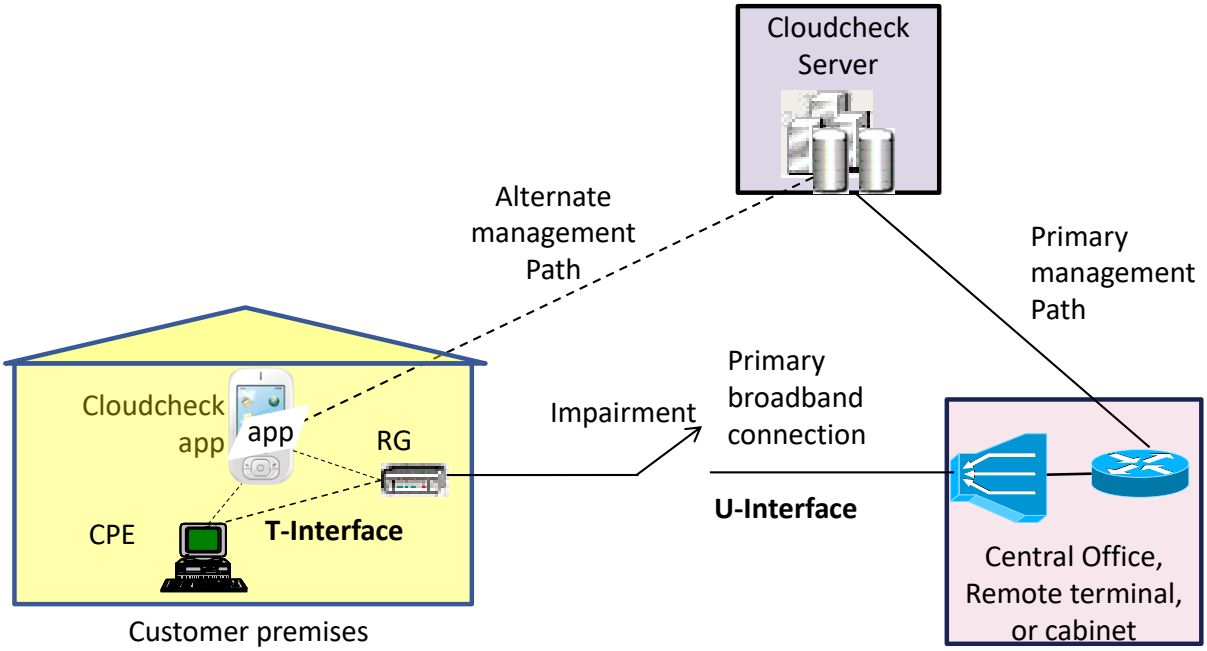

Figure 4. ASSIA Cloudcheck creates an alternate management path.

As shown in the figure above, ASSIA Cloudcheck® can create an alternate management path, as specified by the Broadband Forum [7], to remotely manage the broadband CPE when the CPE's primary management path is unavailable. The alternate management path is for diagnosing a faulty broadband connection, initial installation of the Residential Gateway (RG), etc. An alternate management path is established by the Cloudcheck app in a smartphone connecting to the RG via Wi-Fi, while also connecting the smartphone to the Cloudcheck Server over a cellular data network. The Cloudcheck alternate management path has many uses:

- Remediate a broadband line failure, by pulling data from the RG and re-configuring or re-booting the RG software.
- Remote initial configuration of the broadband CPE to initialize the broadband line, enabling self-install.
- Remote troubleshooting. Detailed diagnostics analysis using historical data is performed by the Cloudcheck Server.

- Automated self-help systems or call center personnel instruct users to download the Cloudcheck app to their smartphone.
- After remediation, the Cloudcheck app can run speed tests to show the user that the broadband line is running properly.

3.4. ASSIA eCheck

ASSIA eCheck provides a fair and accurate reporting of the customer's entire broadband access connection by simultaneously measuring Internet speeds of the customer's fixed-access connections and their Wi-Fi connections. eCheck combines broadband line data from ASSIA Expresse with in-home network data from ASSIA Cloudcheck Server and Cloudcheck Agent, to create comprehensive customer centric reports of broadband Internet access performance.

eCheck reports cover everything from basic throughput to specific devices, applications, and flows. Traffic demand and available capacity are determined. Impact on perceived QoE is determined end-to-end and per link. Reports can be organized in numerous ways for use by an operator, or can be provided to regulators, ISP's, and consumers. Traffic-management detection is possible and is unbiased. eCheck uses Cloudcheck Real-Q technology for real-time, historical, predictive QoE analysis

eCheck is fully virtualizable into a cloud-based NFV system and can be integrated with complementary VNFs into virtual Network Services.

4. ASSIA-provided Virtual Network Functions (VNFs)

Virtual Network Functions (VNFs), vFunctions, and microservices are all names for agile software-implemented functional modules that can be used together in an NFV system, as defined by ETSI ISG NFV [2]. ASSIA has been writing advanced network software for many years, these already run on virtualized platforms, and are readily implemented as VNFs in any NFV system. ASSIA software is developed in a modular architecture; so that ASSIA software easily works within NFV systems as each ASSIA functional module directly becomes a VNF.

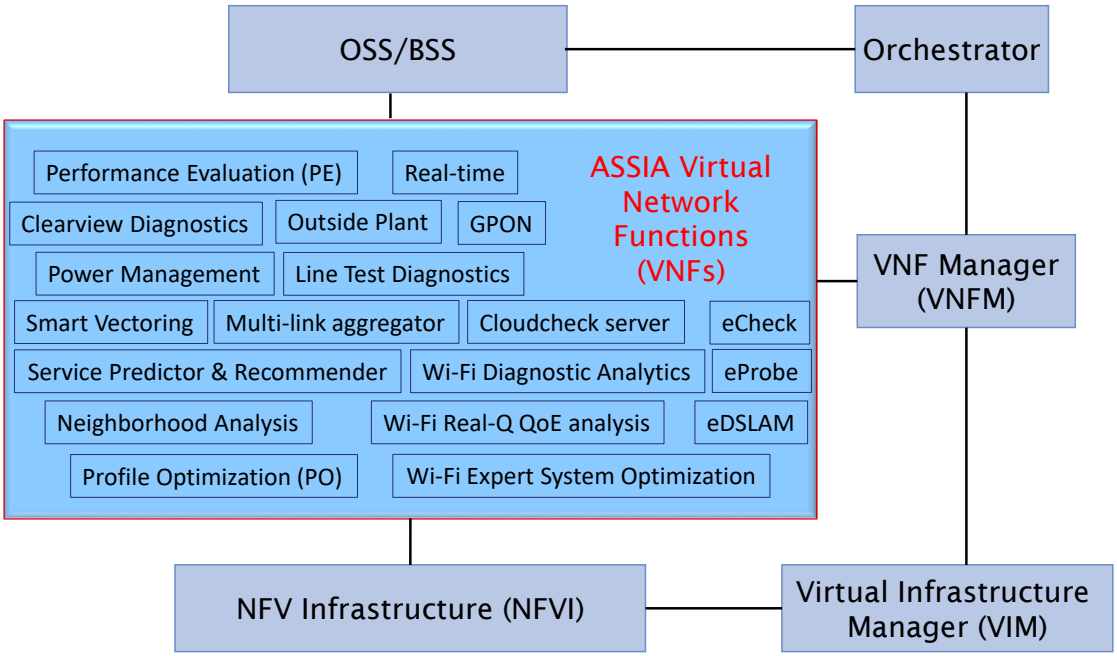

Figure 5. ASSIA VNFs function within an NFV system.

Figure 5 shows a number of ASSIA systems serving as VNFs with an NFV system. VNFs work in the NFV system by running on the NFV Infrastructure (NFVI), while being managed by OSS/BSS and Management and Orchestration (MANO) systems including the Virtual Infrastructure Manager (VIM), VNF Manager (VNFM), and Orchestrator. ASSIA VNFs currently run on virtual platforms and are ready to run on any NFV system, including VMware, Open Platform NFV (OPNFV), OSM, Open-O and CORD.

The Central Office Re-architected as a Datacenter (CORD) project aims toward efficient and effective virtualization of telecom networks. CORD gave impetus to further efforts in the Broadband Forum to define cloud infrastructure in the Central Office (Cloud CO). ASSIA VNFs, and eProbe in particular, can strongly assist in implementing CORD and Cloud CO.

As defined by ETSI ISG NFV [2], a Service Function Chain (SFC) uses multiple VNFs to form a Network Services (NS). In this way, ASSIA VNFs can be used as building blocks in the creation of many services, with ASSIA VNFs being combined, re-used and used with VNFs from other sources.

4.1. ASSIA eProbe and eDSLAM

The ASSIA virtual Expresse Probe (eProbe) is a particularly useful VNF that can support many network services. eProbe is a virtual software system that collects, analyzes, collates and stores broadband and Wi-Fi status, test, diagnostics, and performance data from broadband Network Elements (NEs) and CPE. ASSIA eProbe has adapters for collecting data from all popular DSL, GPON, and Wi-Fi equipment, to gather a rich set of network data. eProbe is far more agile and much lower cost than deploying dedicated hardware probes. eProbe further collates, analyzes, and stores a comprehensive history of many metrics which are time-stamped and easily cross-correlated. eProbe can enable many related VNFs to easily work with many broadband NEs via the protocol-agnostic and vendor-agnostic eProbe NBI.

ASSIA eProbe has the following components:

- Equipment adapters – Perform multi-protocol collection from all popular broadband NEs, collecting test, diagnostics and status data, performance data, per-line spectral data, transceiver data, and inventory identification.
- Data processing - Normalizes collected metrics for storage and presentation, aggregates statistics, normalizes counters.
- Northbound Interface (NBI) translation – Translates data from NEs and CPE into a common format for transmission across the eProbe NBI.
- Historical database - Stores data across long time periods, allowing in-depth big data analytics.
- Policy management – Operator-configurable data collection policy and tuning.
- Scheduler - Schedules incoming NBI data requests to Southbound equipment messages, manage resources, optimize when and how to collect data, balances loads on the equipment.

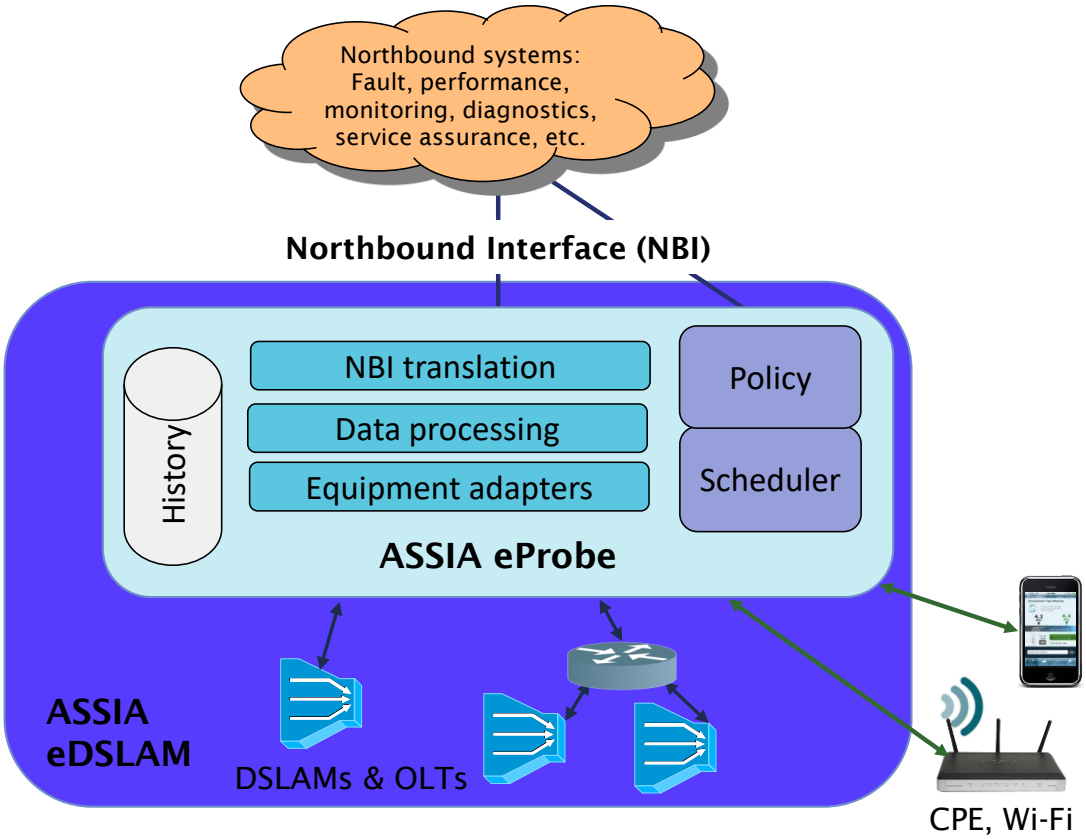

Figure 6. ASSIA eProbe and eDSLAM.

The ASSIA eProbe is used in a service function chain with ASSIA to create the "eDSLAM" to abstract broadband diagnostics, control and management. eDSLAM makes any and all ANs (past, current, and future) look uniform in terms of physical-layer management. ASSIA eProbe provides the interface that imports data from access nodes, and is also extended to transmit control signals to those access nodes. The eDSLAM imports the universal data and control interface provided by eProbe into an abstraction layer, so that all types of access nodes can be managed uniformly by an operator. eDSLAM and Multi-Tenant can be combined to present multiple virtual slices of DSLAMs to multiple operators. eProbe and eDSLAM are VNFs that run in an operator's NFV system. Further, DSLAMs, Optical Line Terminals (OLTs), and Cable-Modem Termination Systems (CMTS) can all be collectively referred to as "Access Nodes (ANs)," and ASSIA's eDSLAM is readily extendable to create any type of "eAN."

5. Use Cases

In addition to the NFV use cases previously described, some use cases enabled by ASSIA include:

- End-to-End service diagnostics and optimization
  - Implemented by a network service chain of ASSIA VNFs and other VNFs for all network and service elements.
- User-requested bandwidth-on-demand (Dynamic Rate Allocation)
  - Implemented by chaining ASSIA Expresse for broadband with ASSIA Cloudcheck for Wi-Fi.
- Operations chaining for customer care or for field service

- Implemented as a network service chain combining ASSIA Expresse and Cloudcheck diagnostics with customer care analytics and operator's OSS VNFs.

- Video Streaming
  - Video streaming is described in some detail:

5.1. Video streaming use case

In this case a consumer requests a video stream from a video service provider, and the network operator provides a premium level streaming service. Here, systems are virtualized and work together in a service function chain to satisfy the consumer.

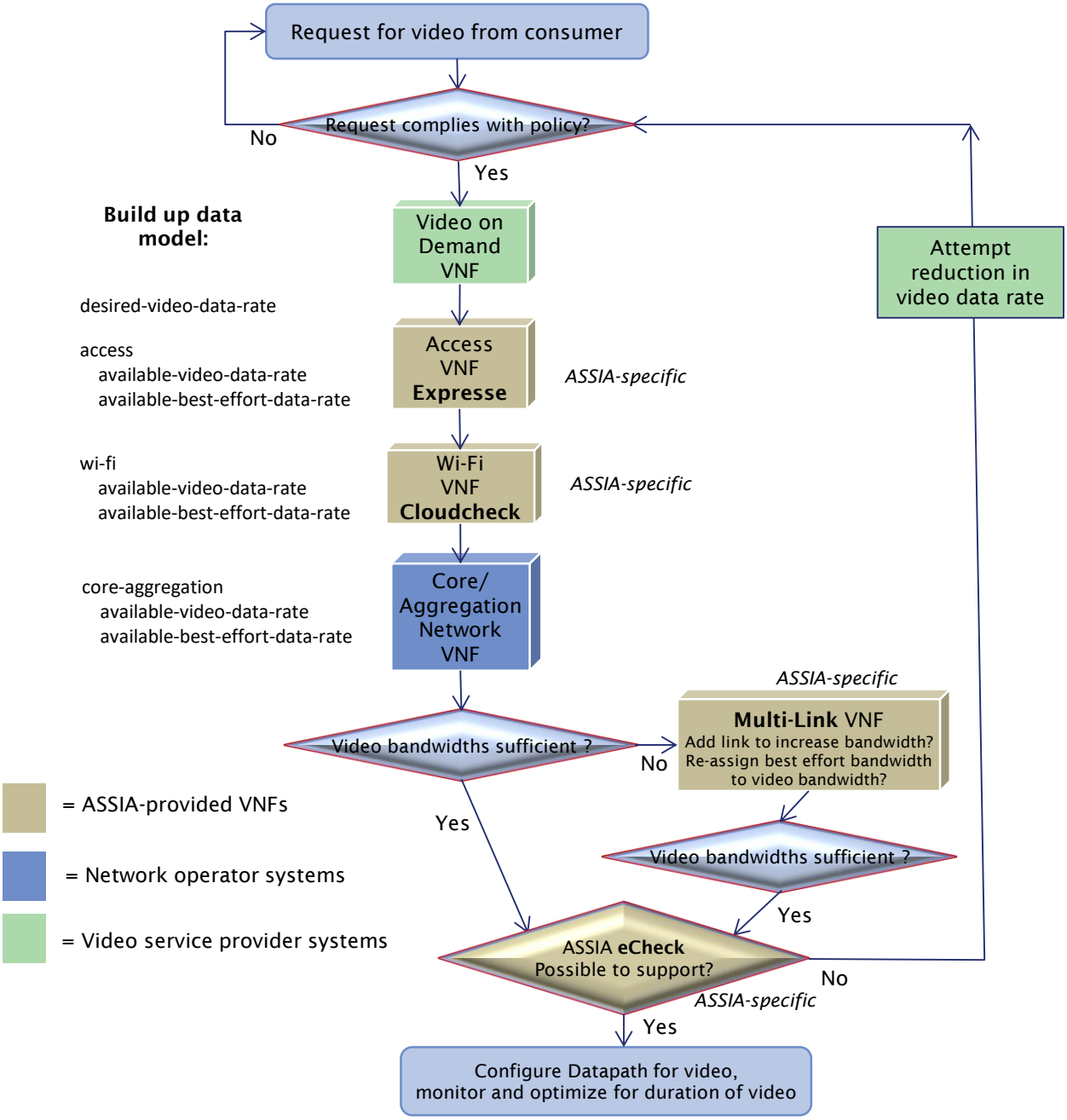

Figure 7. ASSIA VNFs enabling enhanced video streaming.

As shown in Figure 7, ASSIA-provided VNFs are a crucial part of providing enhanced video service and work in conjunction with network operator systems and video service provider systems. The service function chain essentially builds up a data model by gathering data on each link and combining these to optimize end-to-end service delivery and assurance.

6. Summary

ASSIA DSL Expresse performs diagnostics and optimization of broadband access, and ASSIA Cloudcheck diagnoses and addresses Wi-Fi problems. ASSIA is a software company, and all ASSIA systems are virtualized so they work in an NFV ecosystem. This paper showed how these and other ASSIA virtual systems can fulfill many use cases: with Multi-Link to enable NaaS, Multi-Tenant enabling network sharing, powerful disaggregated Wi-Fi management, customer diagnostics, enabling an alternate management path for broadband via a cellular connection, eCheck, the virtual Probe (eProbe), eDSLAM, etc. Combinations of ASSIA VNFs and other VNFs can satisfy many use cases and service needs, with video streaming service showcased here.

ASSIA VNFs are easily plugged into an operator's NFV system, to streamline operations, allow flexibility, and offer all the benefits provided by NFV.

7. References

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