



EXECUTIVE SUMMARY

ADVA has issued two announcements leading up to MWC 2019: the launch of the Ensemble Controller for consolidated network management and programmatic software-defined-networking (SDN) control and the launch of the Ensemble Activator, a network operating system (NOS) for white-box switching. When combined with ADVA's ongoing engagements in artificial intelligence (AI), machine learning (ML) and analytics, the announcements point toward a bigger strategic evolution at ADVA.

ADVA is an industry consolidator. With the announcement of the Ensemble Controller, ADVA is consolidating the leading aspects of its software portfolio, including the FSP Network Manager, into a unified SDN controller platform to simplify operations, deliver open northbound interfaces for network orchestration and enable an easy path to closed-loop automation.

ADVA is a leader in the migration toward open, disaggregated, and virtualized networks. As a member of the Telecom Infra Project (TIP) Open Optical Packet Transport Project Group (OOTP), ADVA is playing a leading role in commercializing the Voyager open transport solution. ADVA is also collaborating with the TIP disaggregated cell site gateway (DCSG) project for 5G transport evolution. As selected by Verizon and Colt, Ensemble Connector is a network operating system and virtual function hosting environment running on white-box uCPE hardware at the edge of the network. ADVA's experience with Voyager, DCSG and Ensemble Connector led to the launch of Ensemble Activator.

ADVA is embracing ML and analytics for increased networking intelligence and closed-loop automation. ADVA is utilizing ML and analytics to enhance and automate areas where it has extensive domain expertise, such as network synchronization to enable predictive analysis of GNSS receiver performance and early warning of potential failures. ADVA is leveraging open-source initiatives and frameworks, such as TensorFlow, and contributing to ETSI ENI and the TIP AI/ML project groups with emphasis on predictive maintenance, path optimization and network security.

Key Points

- ADVA is consolidating its network management and SDN controller functions with the launch of **Ensemble Controller**
- ADVA is announcing a carrier-grade white-box switching NOS with the launch of **Ensemble Activator**
- The Ensemble Activator initial use-case is **TIP's DCSG** for 5G transport evolution
- ADVA is a leader in open, disaggregated networking:
 - **Major open optical line system deployments**
 - **Proven SDN interoperability**
 - **Pioneering NFV with early commercial uCPE roll-out**
- ADVA is combining **deep domain expertise with ML and analytics** to enhance and automate network operations and life-cycle management

INTRODUCTION

It is no secret that major changes are happening in the way we design, build and manage communication networks. Insatiable bandwidth demand and the migration of workloads and applications to the cloud have unleashed powerful economic and technological forces on the information and communication technology industry. Global IP traffic is expected to continue to grow 26% annually through 2022¹. Global cloud IP traffic is forecasted to increase even faster at 27% annually through 2021². By 2020, 80% of traffic is expected to originate from cloud applications and services³.

Two visible industry responses to these forces are the migration toward software defined networking (SDN) and network function virtualization (NFV). Two concepts remain at the heart of the SDN transformation: open application programming interfaces (APIs) to abstract the network and unified data modeling of network elements, such as switches and optical gear, to create logical topology and hierarchy. With NFV we seek to create virtualized instances of new and well-known functions such as virtual evolved packet core (vEPC) or virtual broadband network gateways (vBNG) that can run on general-purpose computing hardware.

As ADVA invested in SDN and NFV for real-world network deployments, it realized that it takes more than an open API and a virtual function to make a reliable, economical network. Over the past several years ADVA has invested in practical, operationally-focused solutions born from its deep domain expertise in optical networking, Ethernet switching and distributed edge virtualization. The launch of Ensemble Controller, Ensemble Activator and ongoing investments in ML and analytics for increased intelligence and closed-loop automation are the most recent reflections of ADVA's strategic focus on delivering the software, infrastructure and tools to facilitate the migration and mass commercialization of SDN and NFV.

OPEN, DISAGGREGATED, PROGRAMMABLE INFRASTRUCTURE

ADVA is embracing disaggregation, open networking and SDN control beyond industry collaboration and formal participation in open-source development communities. Open line systems (OLS) offer freedom from single vendor lock-in and the opportunity to take advantage of different technological lifecycles. The ADVA FSP 3000 supports a disaggregated OLS deployment model that is leveraged by Microsoft Azure in its metro-distributed data center architecture. The solution utilizes INPHI ColorZ QSFP28, PAM-4, 100 Gb/s, 100 GHz pluggable transceivers installed directly into data center routers/switches. The innovative OLS based on the ADVA SmartAmp™ eliminates the manual complexities often associated with direct detect transmission, such as PAM-4, by automatically measuring transmission performance and adjusting network settings throughout the deployment life cycle.

¹ 2018 Cisco Visual Networking Index.

² 2018 Cisco Global Cloud Index.

³ Nokia Bell Labs Traffic Forecast 2017–2020.



Figure 1. ADVA FSP3000 SmartAmp™ DCI Open Line System

ADVA has also been a leading vendor and contributor to the Facebook TIP Open Optical Packet Transport (OOPT) project group where ADVA has taken the lead with long-term partners Celstica and Cumulus on commercialization of Voyager, an open white-box transponder, packet switching and routing solution. Telia Carrier recently used Voyager on a 1,000 km link in Northern Europe where it delivered a 200 Gb/s single wavelength via 16QAM modulation. In addition, Vodafone has announced that it plans to proceed with additional field testing of Voyager in 2019.

ADVA is also leading the way toward disaggregated 600 Gb/s single-wavelength DWDM solutions. The high-density, compact, modular, 1RU, ADVA FSP 3000 TeraFlex™ platform supports three hardware sleds with each sled supporting up to 12 x 100 G client interfaces and 2 x 600 Gb/s line-side interfaces for a total system capacity of 3.6 Tb/s client and 3.6 Tb/s line-side. In November 2018, Tencent trialed the ADVA TeraFlex™ solution by plugging it into its OPC-4 open-line system.

For efficient control of open and disaggregated multi-vendor networks, ADVA supports SDN control via native YANG modeling, NETCONF/RESTCONF protocols and open APIs on its platforms. This allows seamless integration with standard interfaces into northbound umbrella SDN controllers and is already commercially deployed and showcased in various proof-of-concept installations, for example, in the Telia Company R&D lab in Stockholm as part of the European industry consortium Celtic-Plus project SENDATE. The ADVA SDN control architecture has been engineered to work with all open-source and commercial SDN controllers, helping to decouple the complexities of managing photonic transmission systems while enabling greater network automation and optimization.

Beyond disaggregated, programmable infrastructure, ADVA also provides network management and a full range of à la carte services, including installation, commissioning, maintenance and monitoring.

THE ADVA ENSEMBLE SOFTWARE SUITE AND NETWORK VIRTUALIZATION

As early as in 2014, ADVA recognized the relevance of NFV and started to complement its portfolio of Carrier Ethernet hardware appliances with NFV based solutions, creating a white-box-based alternative for Carrier Ethernet demarcation and opening the network edge for hosting of virtual network functions (VNFs). Seeing a need to make VNF deployment easier for on-premises universal customer premises equipment/software-defined wide area network (uCPE/SD-WAN) devices, ADVA developed and launched the Ensemble Connector. Ensemble Connector is a high-performance virtual hosting and virtualization networking software platform that runs on white-box Intel and ARM based computing appliances. Ensemble Connector supports zero-touch-provisioning (ZTP) for easy installation and overcomes the

complexities of deploying OpenStack in a distributed CSP network. Both Verizon and Colt have selected ADVA Ensemble Connector for their uCPE/SD-WAN deployments.

With early customer engagements, ADVA identified a need for managing and orchestrating the network function virtualization infrastructure (NFVI) and developed Ensemble Orchestrator and Ensemble Virtualization Director. Ensemble Orchestrator provides ETSI MANO compliant orchestration to facilitate on-boarding and full life-cycle management of a broad range of VNFs. Ensemble Virtualization Director supports operational teams with a comprehensive performance and fault management dashboard. Ensemble Virtualization Director provides advanced network management and automated deployment of NFV based services including ZTP for uCPE/SD-WAN devices and services at the edge of the network.

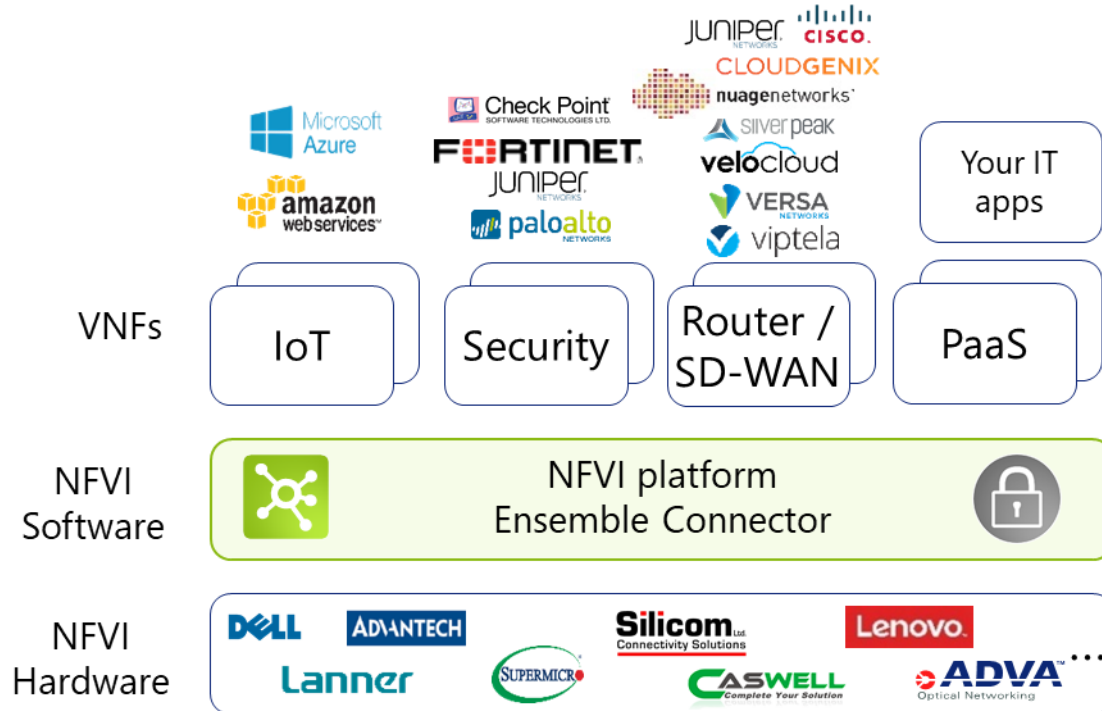


Figure 2. Ensemble NFVI with Ensemble Harmony Ecosystem

INTRODUCING ADVA ENSEMBLE CONTROLLER

The ADVA FSP Network Manager (FSP NM) is deployed across more 750 customers and manages more than 100,000 networking devices globally. Likewise, with the acquisition of MRV in 2017 ADVA added the widely deployed Pro-Vision® Lifecycle Service Orchestration (LSO) platform to its portfolio. Pro-Vision® is well-known for its easy and intuitive Web-based user interface and sophisticated design attributes that include the ability to launch remote packet generation and measurement functions with participating optical and Carrier Ethernet infrastructure.

With the launch of Ensemble Controller, ADVA is consolidating its network management and SDN control solutions and leveraging the best attributes of FSP NM and Pro-Vision LSO and Management software.

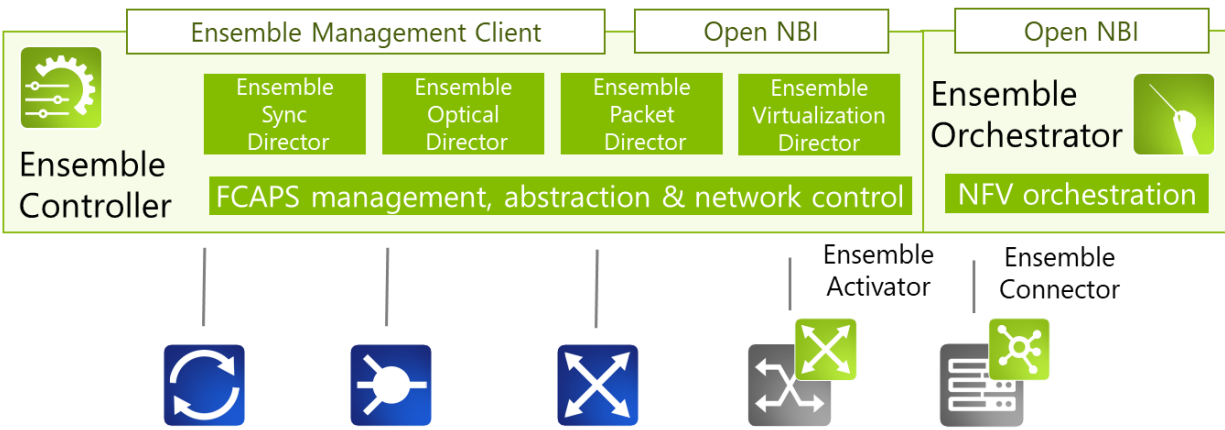


Figure 3. ADVA Ensemble Suite with Launch of Ensemble Controller

By combining legacy management with SDN domain control that supports multiple southbound interfaces and open northbound interfaces (NBI), ADVA is easing the migration to SDN and NFV for network operators. CSPs can retain access to existing FCAPS (fault, configuration, accounting, performance, and security) management functions while introducing end-to-end orchestration via the open Ensemble Controller northbound RESTCONF APIs. The single-domain controller also supports hierarchical control and interoperates with multidomain controllers, including Juniper NorthStar Controller, NEC/NetCracker, Nokia Network Services Platform and Sedona Systems. The modular architecture is extensible and can be tailored to individual customer deployments with service-specific applications such as Ensemble Packet Director, Ensemble Optical Director and Ensemble Synch Director for controlling precise network timing, which is critical in 4G and 5G mobile networking applications. In collaboration with the Ensemble Virtualization Director and the newly launched Ensemble Activator NOS, Ensemble Controller supports open, programmatic control of both virtual and physical infrastructure.

INTRODUCING ENSEMBLE ACTIVATOR

The success of disaggregated switching inside the data center has triggered interest in the potential scale, flexibility and efficiency benefits of running network operating systems on bare-metal switches in the wide area network (WAN) as well. The Vodafone-initiated TIP OOPT DCSG project is targeting 5G networks. With Orange, Telefonica and TIM Brazil having also joined the DCSG activity, this open community is focused on defining next-generation mobile infrastructure that is open, disaggregated, interoperable and supplier neutral.

ADVA is contributing in the project with its experience from carrier-grade transport networks as well as virtualization of network functions but importantly with its most recent addition to the Ensemble software solution suite. Ensemble Activator, a carrier-grade network operating system, is combining manageability with a rich set of networking protocols. In conjunction with its partner, EdgeCore Networks, ADVA is leading efforts at commercialization of the technology. ADVA began shipping an early version of Ensemble Activator NOS with its FSP 150-Z4806 edge data center aggregation and switching product in Q4-2018.

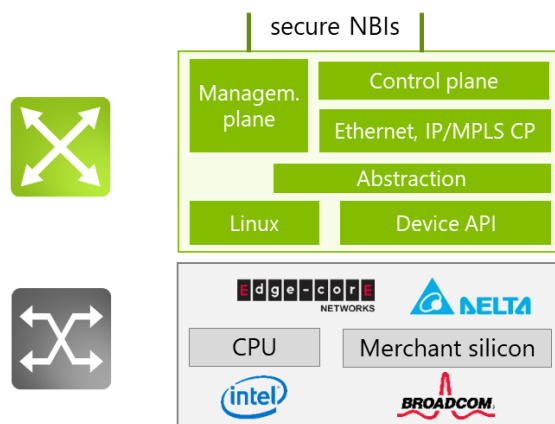


Figure 4. Ensemble Activator Network Operating System Stack

Ensemble Activator is a result of ADVA’s domain expertise and years of experience in deploying optical, Carrier Ethernet and IP/MPLS networks. The NOS is based on Open Network Linux operating system and supports the Open Networking Install Environment (ONIE) framework for zero-touch provisioning. ONIE is common for bare-metal switches where the boot loader initiates connectivity to a configuration server that downloads the latest NOS software and auto-configures the unit. The NOS includes a comprehensive set of Ethernet and IP OAM service activation features. Streaming telemetry with gRPC/gNMI is supported. Advanced IEEE 1588v2 synchronization enables precision timing for packet networks, a precursor for 4G/5G mobile transport. To facilitate SDN migration and control, Ensemble Activator is modeled in YANG and supports the NETCONF configuration protocol. Networking technologies including VLAN, VxLAN, IP/MPLS and EVPN are supported. The NOS is specifically targeted at the multi-layer service edge where it is married with diverse bare-metal hardware supporting a range of interfaces and capacities. The product is initially optimized for the Broadcom DNX family of merchant silicon switches and has been implemented on products from EdgeCore and Delta.

INTELLIGENCE FOR CLOSED-LOOP AUTOMATION

While Ensemble Controller is enabling service providers to offload operational teams from manual tasks, ADVA is complementing SDN control with increased networking intelligence to unlock the full potential of programmatic networking. Network operations teams still rely heavily on manual data collection, analysis and decision making. However, the ability to stream recurring performance data from diverse networking resources combined with cost-effective storage and analysis with machine learning and big-data analytics tools is beginning to enhance human performance by identifying anomalies faster, spotting issues before they become outages and unlocking opportunities to maximize networking performance and improve the quality of the user experience. Although still early in the evolution toward closed-loop automation and autonomous networking, intelligence will combine with network automation to handle many of the manual provisioning, troubleshooting and path optimization activities of today.

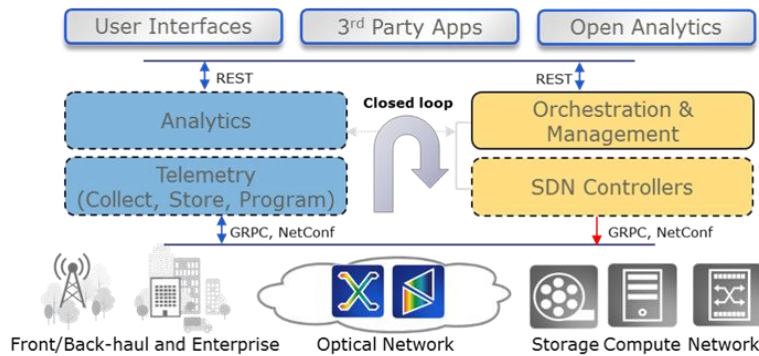


Figure 5. ADVA Closed-Loop Automation Framework

ADVA is embracing ML and analytics for increased intelligence and combining its extensive domain expertise in areas such as network synchronization where predictive analytics can be applied to GNSS receiver performance to identify potential synchronization issues and resolve them before a timing failure occurs. Leveraging open-source initiatives and frameworks such as TensorFlow as well as contributing to ETSI ENI and the TIP AI/ML project group, ADVA is applying ML and analytics in three key areas: predictive maintenance, path optimization and networking security. Danish Rafique, senior manager AI & ML at ADVA, authored a tutorial on the application of ML and analytics to networking in the OSA “Journal of Optical Communication Networking” in October 2018.⁴ It provides a solid application and use-case perspective. One of the distinguishing contributions of the tutorial is a detailed description of the network management architecture that illustrates how ML can be integrated into existing network software stacks.

CONCLUSION

The evolution toward closed-loop automation requires the introduction of three main technologies into the service provider network: disaggregated programmable infrastructure, open interfaces for simplified integration and real-time control and increased intelligence derived from deep domain expertise and advanced ML and analytics techniques. With Ensemble Activator and Ensemble Controller, ADVA is augmenting the first and second key technologies and enabling service providers to implement a programmable, software-defined network with open control. In parallel, ADVA is proactively developing initial ML/analytics use-cases for improved operational efficiency while also validating the technology and building the trust of service providers. Individually all three technologies have value; however, when combined they have the potential to facilitate mass commercial adoption of SDN and NFV and usher in an era of disruptive change in service provider networking and value creation.

⁴ Danish Rafique and Luis Velasco, “Machine Learning for Network Automation,” J. Opt Com Netwk. 10, Oct. 2018.

Analyst Biography: **Tim Doiron** is Principal Analyst at ACG Research, leading the firm's Intelligent Networking practice. Doiron's work is focused on network innovations and transformations in the areas of packet optical networking, data center inter-connect, transport/multi-layer software-defined networking, network orchestration, mobile anyhaul and enterprise services virtualization with network function virtualization and vCPE/SD-WAN. Tim has ongoing collaborations in areas of open source software, network programmability, visibility, telemetry and automation.

Tim has more than 25 years of networking and telecommunications experience across business and technical organizations. He has served in executive and managerial roles: VP/general manager, VP of product management, director of marketing, product manager, business development and software engineering manager at vendor and service provider companies Coriant, Tellabs, ARRIS, Cadant, Ericsson and AT&T. Tim has extensive experience bringing new products to market.

Tim is a frequent speaker at industry conferences and has authored numerous articles. He holds a Master of Business Administration, Webster University; a Master of Science in electrical engineering, Virginia Polytechnic Institute and State University; and a Bachelor of Science degree in electrical engineering, Southern Illinois University. Doiron also holds eight patents and is a member of IEEE and the Optical Society (OSA). He is an active member of the Electrical and Computer Engineering Industrial Advisory Board at Southern Illinois University where he serves as an advisor to the department chair.

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