HEAVY READING

White Paper

Bringing Disaggregation to Transport Networks

Prepared by

Sterling Perrin
Senior Analyst, Heavy Reading
www.heavyreading.com

On behalf of

FUJITSU

www.fujitsu.com

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Introduction

Telecommunications networking equipment has long been driven by trends in convergence – taking functions that once resided in separate devices and combining them in a single system. Operator benefits of converging functions in a single system include capex savings from fewer boxes, ease of manageability and opex savings due to reduced central office footprint and from the simplified management of the network and elements.

Examples of this functional convergence (or aggregation) abound. The multiservice provisioning platform (MSPP) transformed the Sonet/SDH market in the early 2000s by combining OC-3, OC-12, OC-48 and OC-192 multiplexers in a single system and allowing operators to mix match various OC-X cards based on their needs. MSPPs also added a low level of Ethernet switching and transport within the same system.

Packet-optical transport systems (P-OTS) advanced the convergence trend by greatly increasing the level of Ethernet switching that could be combined with Sonet/SDH multiplexing within a single system. Through integrated high-capacity Ethernet switching, operators were able to eliminate a number of individual Ethernet switches from COs, thus saving on capex/opex. In addition, many P-OTS products also integrated wavelength-division multiplexing (WDM) transponders and ROADMs.

Key to the success of functional integration/aggregation in telecom network equipment has been a unified element management system (EMS)/network management system (NMS) to manage the network elements. The unified EMS/NMS has historically been provided by the equipment vendor (MSPP, P-OTS or element type) and was used to manage all of that vendor's network elements. Without such a unified system, manageability and the resulting opex savings of element convergence would be impossible. The significant downside of the convergence in networking, historically, is that the unified EMS/NMS has been built by the equipment supplier and proprietary.

The separate but complementary technology trends of software-defined networking (SDN) and network functions virtualization (NFV) are driving unprecedented change across the telecom industry and leading operators to rethink how element convergence is achieved. SDN and NFV are, in fact, opening up the benefits of *disaggregation* in networking, and operators and suppliers are already applying disaggregation to transport networks – in essence, a reversal of the trend of element convergence and functional aggregation that has occurred over the past 15 years.

In this white paper, Heavy Reading outlines the drivers for disaggregation in telecom networks and makes the case for why disaggregation in networks makes sense today, including for transport networks.

Why Now? Disaggregation Drivers

Cloud services delivery is transforming the way operators architect their transport networks. Scaling capacity to accommodate the growth in bits remains critical, of course, but it's not simply about putting in bigger and bigger pipes.

The cloud model is based on sharing storage and computing resources across wide geographies. In order for these resources to be shared efficiently, however, the communications network has to be both dynamic and flexible – a dramatic change from the static-pipes communications model of the enterprise networking past.

As they architect their transport networks for cloud delivery, operators view the following as key requirements and challenges:

- Enabling flexible and dynamic optical layers
- Scaling capacity for increased traffic loads
- Enabling interoperability between different network layers/domains
- Ensuring end-to-end network and service reliability
- Reducing overall latency

Operators globally realize that the old way of doing things is no longer viable in the new era of networking. Deploying bigger and bigger static pipes provides capacity but lacks efficiency and results in networks that cost far more than the revenue generated by those networks can support.

It should not be particularly surprising that network operators are seeking to adapt their networks to the cloud by adopting many of the technologies that have enabled the cloud – particularly in areas of virtualization, use of x86-based commodity hardware, software-based automation, use of open source and systems, and separation of control planes from forwarding planes (a key tenet of SDN). Disaggregation in networks, the focus of this paper, results from the application of these technologies.

Proof of the new operator thinking abounds. The ETSI NFV ISG was formed in 2012 by several of the world's largest Tier 1 network operators, including AT&T, Deutsche Telekom, Verizon and Telefónica, specifically to apply the IT principles of virtualization to telecom hardware, and industry acceptance has been rapid. Membership of the group has grown to more than 270 individual companies, including 38 of the world's major service providers.

In 2013, NTT launched its commercial Enterprise Cloud services using OpenFlow-based SDN, making it the first telecom provider in the world to employ SDN in its global network.

Also in 2013, AT&T announced its ambitious Software-Defined Network Architecture (also called Domain 2.0), a transformative initiative in which AT&T is moving its network architecture from a hardware-centric to software-centric environment. It is among the boldest moves into SDN and NFV announced by any Tier 1 operator. Using SDN and NFV, AT&T aims to dramatically cut the time it takes to bring new services and applications to market. The operator's goal is to virtualize 75 percent of its network by 2020.

Key Benefits of Disaggregation

What Is Disaggregation?

Initially applied in IT, disaggregation is the decoupling of the components of an integrated system from each other, yielding the benefit of allowing users to select the mix of both hardware and software pieces that best meets their needs.

HP recently defined disaggregation in the context of data center networks as "separating the currently integrated hardware and software components of network switches. With this decoupling, IT can independently select networking switch hardware and the network operating system that best fit their needs"* – buying their switch hardware from one vendor and the operating system from another supplier.

Disaggregation is enabled by SDN, virtualization and open systems, and like the enabling technologies, the concept has quickly moved from the IT origins into telecom networks. AT&T, in particular, has embraced disaggregation as a key pillar for the future of its networks, as evidenced in the following statement from John Donovan, Senior Executive Vice President, AT&T Technology and Operations:

> "Disaggregation is a big deal. It means we don't just clone a hardware device completely in software and continue running it as before. Instead, we break out the different subsystems in each device. We then optimize each of those subsystems. We upgrade some and discard others. That's what we're doing with the GPON OLT, as well as other pieces like the Broadband Network Gateway and the Ethernet Aggregation Switch."†

Benefits of Disaggregation

Efficient scaling is one of the main benefits of disaggregation and, as noted earlier, is one of the key operator network requirements for the cloud era. The building block approach to hardware allows for a low initial spend for year-one deployments with the ability to grow incrementally as traffic increases and more capacity is required.

Many converged telecom systems, by contrast, are able to handle future traffic volumes on day one, but also require a large up-front payment for that capacity even when the capacity may not be needed for several years. This is particularly true for equipment with central, terabit scale switching fabrics, as the fabric is part of the initial installation, even though transponders may be added over time.

It is important to note that "building block" scaling alone, as described above, does not fully define or distinguish disaggregation as many equipment suppliers have pursued building block system architectures with their closed, proprietary systems in recent years.

Thus, another key defining characteristic and benefit of disaggregated systems is the ability to share functions across different resources – including the use of x86-based commercial-off-the-shelf (COTS) hardware. With disaggregated telecom equipment, some functions will always run on purpose-built hardware, but other functions may

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* "Network Disaggregation: It's about customers, not boxes," Ahmad Zamer, April 21, 2015

† "Hitting the Open Road: Software-Accelerating Our Network with Open Source," John Donovan, June 17, 2015

be broken out to run on commodity servers – a concept that is totally new to telecom. The value here comes when networking functions can share space on servers that are already housed in data centers performing other functions (IT or other).

The efficient use of capacity also translates into operator opex savings in the more efficient use of data center space and power consumption.

Last, but certainly not least, is the rapid development, deployment and flexibility enabled by disaggregation. Like efficient scalability, network and service flexibility is one of the key operator network requirements for the cloud. Disaggregation allows for rapid deployment of features and functions when needed and in the amount that is needed. Key to this value proposition is the separation of the hardware development cycle (which is typically annual and fixed) from the software cycle (which, as Web scale companies have shown the world, is very fast).

Heavy Reading believes that the true value of software and hardware separation comes when systems are open and operators can choose their hardware and software components independently, and openness is, we believe, the direction in which network operators are driving their suppliers to move.

Role of Software in Disaggregation

Software runs on hardware, and although hardware in telecom networks should not be trivialized, disaggregation architectures are enabled by new software innovations. There are two main software components to network element disaggregation: SDN and NFV. Each is described in more detail below.

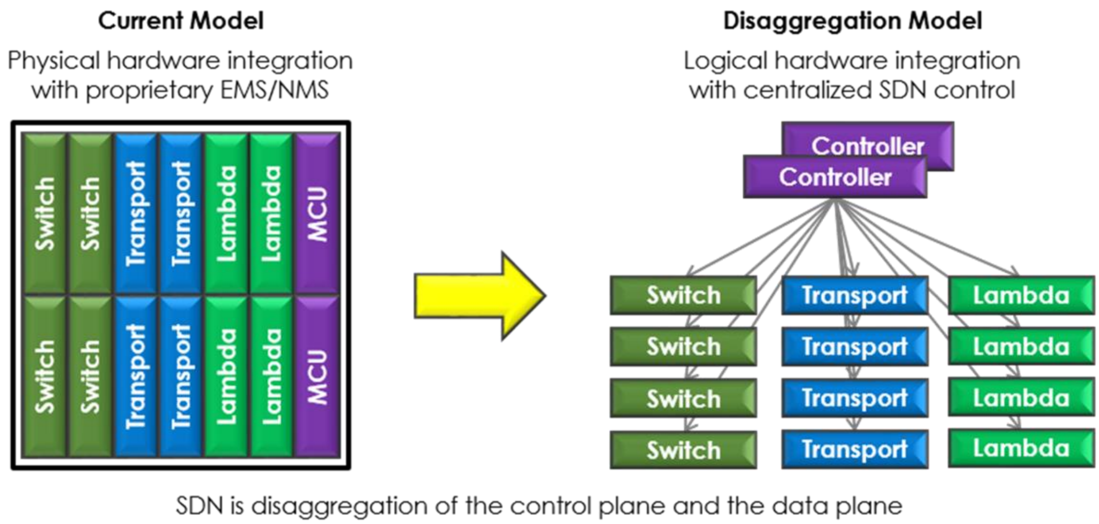
SDN Control & Disaggregation

SDN decouples the control plane from the forwarding or data plane and allows for network programmability via software. Definitions of SDN vary widely by operator or other source, but Heavy Reading believes that SDN for carrier networks – or wide-area network (WAN) SDN – contains the following elements:

- Software programmability
- Multi-element (or global) network view
- Application-centric capabilities
- Network-layer abstraction (control/applications/network)
- Software openness

The global network view and network programmability provided by SDN control are critical for controlling functions that are distributed across multiple hardware elements as if they were one integrated system. **Figure 1** depicts the migration of a packet-optical transport element from the physically integration architecture of today's P-OTSs to a future disaggregated architecture.

Figure 1: Hardware Disaggregation Using SDN Control



Source: Fujitsu and Heavy Reading, 2015

To be clear, little is accomplished under the SDN-controlled hardware disaggregation model if the SDN control protocols and network management systems remain proprietary and closed. For this reason, tremendous attention is being paid to defining standards around SDN control and network management in SDN-based networks.

The ONF plays a critical role as steward of the OpenFlow protocol for SDN control, but it is far from alone in SDN standards. A host of IETF standards exist and are being built upon for SDN, including Forwarding and Control Element Separation (FORCES), Interface to the Routing System (I2RS) and Path Computation Element Protocol (PCEP). In addition, the IETF's Netconf network configuration protocol and Yang data modeling language have risen to prominence for standardized network management systems.

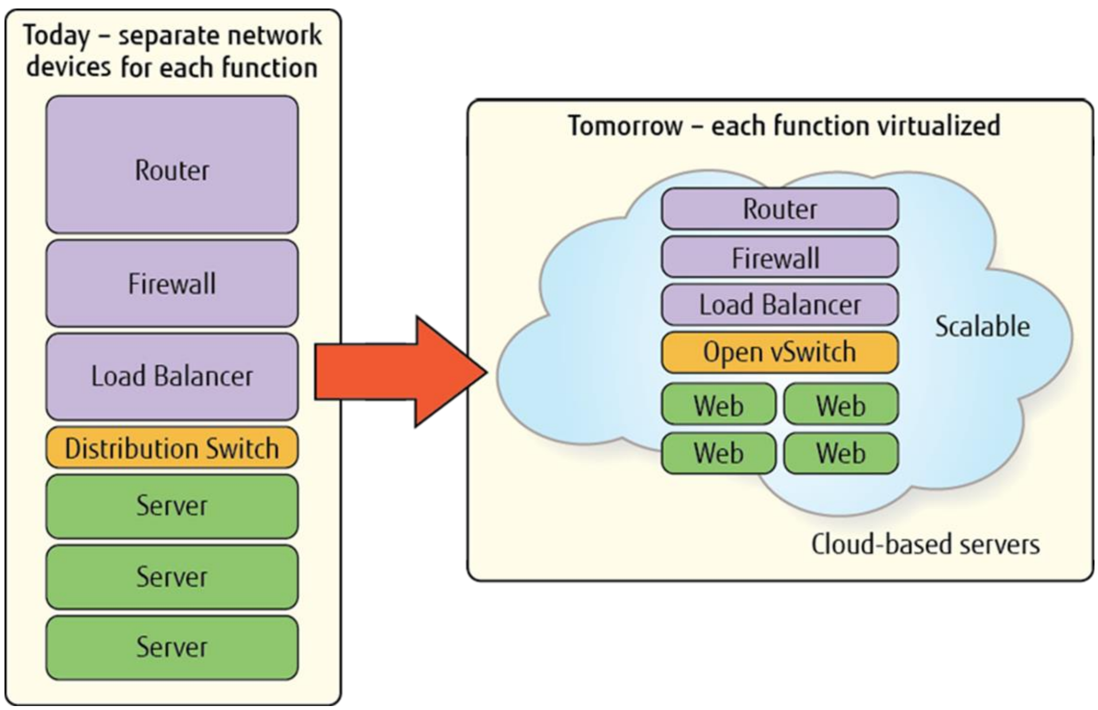
Other significant groups fostering SDN openness and standardization include the Linux Foundation's open source OpenDaylight Project and the ON.Lab open source SDN group. Still more *ad hoc* groups continue to be formed to fill voids as they emerge.

NFV Applicability in Disaggregation

SDN, as described above, provides disaggregation of the hardware functions in the network. NFV provides disaggregation of the software functions by moving network functions from dedicated hardware to software functions that reside on shared infrastructure. In NFV, the shared infrastructure is based on commodity storage, servers and switches that use x86 processors.

The two technology trends play a complementary role in driving the network evolution. In fact, Heavy Reading survey research consistently shows that the majority of operators view SDN and NFV as complementary and interlinked, and are rolling them out together on the same timelines. **Figure 2** depicts a sampling of functions that are moving from specialized hardware devices to virtualized functions implemented in software on commodity hardware using NFV.

Figure 2: Network Function Disaggregation Using NFV



Source: Fujitsu, 2015

This is just a small sampling of possible functions that can be virtualized. AT&T, for example, as identified 200 functions that it intends to virtualize.

While SDN standards work is diffuse and expanding, NFV specification is largely centralized under the ETSI NFV Industry Specification Group (ISG). Now in Phase 2 of its existence, the NFV ISG continues to work on driving consensus around operator requirements for NFV, identifying existing applicable standards, developing new technical requirements and addressing the technical challenges that operators face in NFV.

Early Examples of Disaggregation in Networks

AT&T vBNG & vOLT Examples

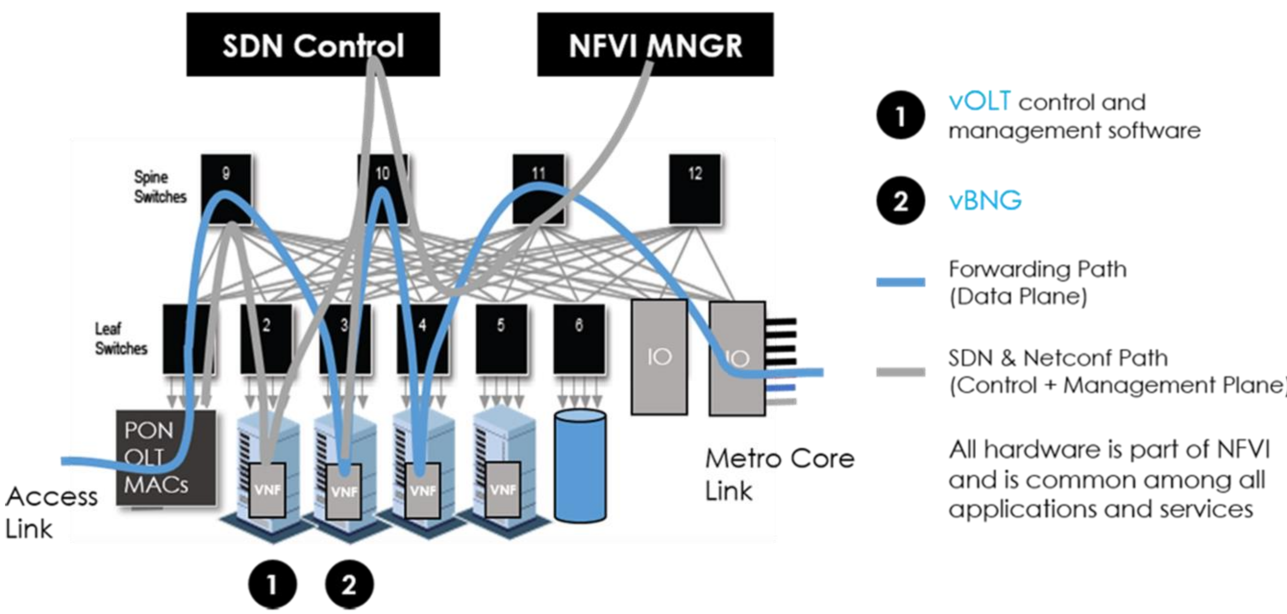
AT&T is perhaps the strongest operator proponent of disaggregation in network equipment and is far along in proof-of-concept (PoC) development. So far, AT&T has talked publicly about using SDN and NFV to disaggregate two types of network elements: gateway routers that connect data center infrastructure to the WAN; and gigabit passive optical network (GPON) access equipment. While the gateway router disassembly was presented conceptually, the GPON virtual optical line terminal (OLT) is further along and has been demonstrated.

Keynoting at Light Reading's Carrier SDN Networks event in May 2015, Tom Anschutz, Distinguished Member, Technical Staff at AT&T, proposed using SDN and NFV to disassemble gateway routers and GPON OLTs into a set of disaggregating functions, and then embed those functions into the data center infrastructure itself, such that the standalone elements themselves could be physically removed from the data center.

On routers, the physical ports cannot be removed, but AT&T proposed standalone input/output (I/O) shelves for this function. On OLTs, AT&T concluded that everything but the MACs can be virtualized and moved to NFVI using standard fabric switches, storage and servers. PON MACs would move to standalone hardware.

Figure 3 shows a data center network with disaggregated vOLT and vBNG functions.

Figure 3: vOLT & vBNG Implementation in NFV Infrastructure



Source: AT&T, Carrier SDN Networks, May 2015

For the vOLT, AT&T has developed a 180Gbit/s capacity OLT I/O blade in a pizza-box form factor that fits into a data center rack, just like a server, and has been demonstrating the prototype in events throughout 2015.

Other Operator Interest in Disaggregation

Verizon is another operator that sees potential in disaggregation, particularly in addressing future scalability limitations being caused by power-hungry coherent optics. Verizon Director of Optical Transport Planning Glenn Wellbrock said that heavy power consumption by digital signal processors (DSPs), along with other chips used in ultra-high-speed transmission, is causing a radical rethink in how future transmission systems are designed.

Functional disaggregation is one potential solution to the impending power dissipation challenge because it distributes the power burden across multiple chassis and racks; yet from a software perspective, it still behaves as a single integrated system.

There are some caveats to the disaggregation approach, however, in Verizon's view. First, it may not be the only solution to the power density challenge, as advances in photonic integration (and particularly silicon photonics) could reduce power to manageable levels. Second, Verizon is not yet comfortable with a multi-vendor architecture for disaggregation for several reasons, and early work would likely proceed under a single vendor architecture.

TELUS is a second operator that sees both merits and some challenges in moving to functional disaggregation. For TELUS, disaggregation is part of SDN and NFV, and it will proceed as an extension of these priorities (particularly NFV). According to Rob Keates, manager IP/optics standards at TELUS, functional disaggregation is a viable solution to many of the problems posed by the highly-integrated "God Box" elements of the past, including high costs and complexity, slow time to market for upgrades and potential vendor lock-in.

Keates sees the greatest near-term appeal for functional disaggregation at the edge of the network, where traffic is more point-to-point in nature. By contrast, according to Keates, functional disaggregation of core nodes, where mesh connectivity is required, could lead to inefficiencies that outweigh the benefits. In any case, the "white box" component of functional integration is a key piece of the value proposition for TELUS.

Fujitsu 1FINITY™ Architecture

While some suppliers, including Cumulus Networks and HP, are starting to promote disaggregation of data center network equipment, disaggregation in the carrier WAN is revolutionary. Fujitsu is the first telecom equipment supplier, of which we are aware, that has taken disaggregation outside of the data center and applied it to the transport network.

In August 2015, the vendor introduced the 1FINITY architecture, incorporating SDN, NFV and disaggregation, spanning packet-optical and access equipment initially, and other types of network equipment in the future. Consistent with the principles of disaggregation discussed in this paper, Fujitsu has introduced a "system on a blade" architecture in which modular blades can stand alone for specific functionality or be combined with other blades for broader system functionality. For example, a WDM blade can operate in standalone fashion or be combined with a packet-switching blade for packet-optical applications.

Software innovation is key, as software logically re-aggregates the modular functions and presents a consolidated northbound interface to operator operations/business support systems (OSS/BSS). Also in line with the principles of software openness in SDN, all blades are Linux OS-based, with open application programming interfaces (APIs).

Challenges to Disaggregation

This paper has described the drivers for and benefits of disaggregation in telecom network equipment and has provided some early examples of innovation in this area. However, the analysis would not be complete without identifying some of the challenges operators and suppliers face in moving from today's integrated and proprietary network architectures to an open and disaggregated architecture of the future.

As with other telecom technology transitions, maintaining the required performance and features is key. Operators cannot adopt new technologies if doing so means, for instance, lowering the reliability of their network or services from five nines to four nines or eliminating features that customers or network operations teams expect.

For one example, carrier Ethernet transport adoption was slower than many suppliers had hoped because performance and management features could not match those of legacy Sonet/SDH networks. Once features and standards matured, a massive and rapid migration away from Sonet/SDH to carrier Ethernet transport began.

Another transition challenge that operators face in moving to disaggregation architectures is one of timing. While network teams plan for future architectures, the product teams within those operators have service and feature requirements that must be met today. Competition does not allow operators to skip a cycle of important feature upgrades while waiting for the next generation to come, and so the transition from old to new must also be managed with today's needs in mind.

A final challenge disaggregation faces is integration with legacy network elements and management systems. Heavy Reading operator survey data shows that the top three challenges to widespread adoption of SDN/NFV are compatibility of new systems with the existing installed base, standardization and integration of SDN/NFV hardware and software components (including the existing systems).

These challenges point to a hybrid world in which new disaggregated elements and systems will need to communicate and co-exist with physical systems and legacy management systems for many years to come.

Conclusions & Future Directions

The concept of disaggregation has quickly moved from its IT origins into telecom networks. Virtualization, SDN and NFV are opening up the benefits of functional disaggregation in networking and operators are taking note. Most recently, we are starting to see these concepts applied to carrier transmission networks – specifically, in packet-optical transport and in optical access.

Benefits of bringing functional disaggregation to telecom transport networks include:

- Efficient scaling, including the ability to precisely match capacity/performance requirements on day 1 deployments and the ability to rapidly add capacity and functions to meet new requirements as they emerge
- The ability to share functions across resources, including the use of x86-based COTS servers and storage, combined with purpose-built hardware
- Reduced power and footprint
- Increased flexibility, resulting from the combination of highly-modular architectures, the use of COTS hardware, and software openness – including the use of open standards and open source

While a migration from today's purpose-built and integrated transport networks to future transport networks based on SDN, NFV, virtualization and functional disaggregation will not be without its challenges, we are already seeing early operator interest in driving this architecture forward. Equipment suppliers must begin to deliver this open and disaggregated architecture of the future or be left behind.