SOLUTION BRIEF

Gi-LAN and Dynamic Service Function Chaining for Communications Service Providers

Executive Overview

Intel is accelerating adoption of network function virtualization (NFV) with unique capabilities that enable optimal use of data center resources to deliver Communications Service Provider (CSP) services. In Mobile Wireless networks the Gi-LAN allows the introductions of value added service and security functions on the Internet gateway interface. With the need to rapidly introduce differentiating service features, the virtualized Gi-LAN also provides the CSP the ability to reduce cost by running new functions in software. Dynamic service function chaining based on software-defined-networking ensures that relevant traffic runs through appropriate functions in the Gi-LAN for optimal resource utilization. Gi-LAN technology is equally applicable to fixed broadband and cable networks.

This document details those technologies and describes Intel's role in the ecosystem to accelerate the development of solutions that drive adoption of NFV in CSP production deployments.

Introduction

Increasing market pressures, such as skyrocketing mobile traffic, demand for enhanced services, and the search for more cost-effective solutions are driving Communications Service Providers (CSPs) to adopt network function virtualization (NFV). Virtualizing services onto standard, off-the-shelf hardware and taking advantage of software-defined networking (SDN) will increase network flexibility and reduce costs, as well as enable operators to more quickly launch new revenue generating services more efficiently.

A typical CSP has between 2 and 5 million subscribers that access services through the Gi-LAN.[1] The sheer number of active users demands transit requirements in the 100-Gbit range. Mobile traffic is expected to grow at a compound annual growth rate (CAGR) of at least 45 percent,[2] and analysts predict the current USD 2.3 billion NFV market to reach USD 11.6 billion in 2019.[3] CSPs and the industry's ecosystem are evaluating approaches to scale to meet these traffic requirements.

Dynamic Service Function Chaining (SFC) is a technology approach that is being evaluated to efficiently scale to accommodate the increased workloads on the network caused by enormous traffic growth. Dynamic SFC in the Gi-LAN, in coordination with SDN/NFV technologies that are being deployed by CSPs, is an area that is currently immature. However, as the Gi-LAN SFC use cases and capabilities mature, the technology will provide a powerful mechanism for CSPs to realize the benefits of NFV and SDN technologies.

This paper describes the technologies required to enable and mature SFC in support of CSP production deployments.

Market Opportunity

The specific timing and market opportunity for virtualized Gi-LAN differs based on how it is categorized and the remaining lifespan of its current physical network functions. One of the factors influencing timing and prioritization for deployment of virtualized functions for CSPs is based on the end-of-life agreements with suppliers for the physical appliances that support those network functions. The transformation also assumes that the performance and management of the virtualized solution will meet the needs of the leading CSPs.

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Gi-LAN

The 2015 Infonetics4 report provides a good overview of the market opportunity and timing of various CSP network functions and related hardware revenue.

In Figure 1 below, the circled items highlight the functions within this report that are typically part of the Gi-LAN. This data provides rough guidance on the total available market, since some CSP's deploy Deep Packet Inspection (DPI) within the Evolved Packet Core (EPC) gateway and not "all" routers will reside on the Gi-LAN, and other nuances. Therefore, it only provides a high-level perspective for Gi-LAN.

	Worldwide Service Revenue (US$M)			2014-2019
	2014	2015(E)	2019(E)	CAGR
PCRF and DPI Functions	$553	$1,030	$3,153	42%
Mobile Core and EPC Functions	$74	$218	$2,088	95%
IMS Component Functions	$89	$396	$1,719	81%
Security Functions	$37	$79	$421	63%
vRouters	$2.5	$21	$271	156%
Video CDN Functions	$0.0	$9.9	$301	N/A
Other	$1.5	$15	$688	242%
Total VNF Revenue	**$758**	**$1,767**	**$8,642**	**63%**

Figure 1. Gi-LAN market opportunities.

In Figure 2 below, worldwide revenue projections are made for NFV spending through 2019.

	Worldwide Service Revenue (US$M)			2014-2019
	2014	2015(E)	2019(E)	CAGR
NFV	**$951**	**$2,264**	**$11,602**	**65%**
Hardware	**$153**	**$364**	**$1,806**	**64%**
NFVI Servers, Storage, and Switches	$153	$364	$1,806	64%
Software	**$177**	**$1,847**	**$9,409**	**65%**
NFV MANO	$13	$79	$768	125%
VNF	$758	$1,767	$8,642	63%
PCRF and DPI Functions	$553	$1,030	$3,153	42%
Mobile Core and EPC Functions	$74	$218	$2,088	95%
IMS Functions	$89	$396	$1,719	81%
Security Functions	$37	$79	$421	63%
vRouters	$2.5	$21	$271	156%
Video CDN Functions	$0	$10	$301	N/A
Other	$1.5	$15	$688	242%
Software	**$27**	**$53**	**$387**	**71%**
Outsourced Services for NFV Projects	$27	$53	$387	71%

Figure 2. Gi-LAN market revenue projections.

For a typical CSP, Gi-LAN functions include, but are not limited to, the following network functions:

- Header enrichment
- Packet inspection
- Firewall
- Carrier grade NAT
- TCP proxy
- Video optimization
- Content filtering
- Security appliances

As described previously, given the broad scope of network functions and the services that are enabled by the unique capabilities of this network segment, a wide range of suppliers are expected to participate. The more common suppliers used by CSPs for these network functions are listed below.[4] Please keep in mind this is not an exhaustive list.

Video Optimization Vendors

Flash Newtworks, Inc.

Mobixell Networks

Openwave Mobility, Inc.

Skyfire Labs

Vantrix, Inc.

Venturi Wireless

Citrix (ByteMobile)

Core Infrastructure Vendors

Alcatel-Lucent	DPI, Optimization
Cisco	DPI, Optimization
Ericsson AB	DPI, Optimization
Huawei	DPI, Optimization
Nokia Networks	DPI, Optimization

DPI and Bandwidth Mgt Vendors

A10 (NAT)

Allot Communications

Affirmed Networks

Arbor Networks / Tektronix / Danaher

Bivio Networks, Inc.

Citrix (ByteMobile)

Continuous Computing (Radisys Corporation)

F5 Networks

GENBAND

ipoque GmbH

Juniper Networks, Inc.

Procera Networks

Qosmos

Sandvine Incorporated ULC

Tellabs

Volubill

Industry Challenges

As stated previously in this document, static service function chaining is not ideal, and, yet, dynamic SFC is not yet mature enough for broad market adoption.

Static Service Function Chaining Drawbacks

The inflexible nature of today's mostly static Gi-LAN SFC in production deployments limits the CSPs' ability to scale, innovate, and monetize new services. Some of the most common challenges related to today's SFC approaches (see ETSI document RFC 7498) are as follows:

- Topological dependencies
- Configuration complexity
- Constrained high availability
- Consistent ordering of service functions
- Application of service policy
- Transport dependence
- Elastic service delivery
- Traffic selection criteria
- Limited end-to-end service visibility
- Classification and reclassification per service function
- Symmetric traffic flows
- Multi-vendor service functions

These challenges can be summed up in two key areas:

Lack of Flexibility and Standardization

When static Gi-LAN service chains are defined by Access Point Names (APN), the CSP must configure a separate APN (or alias APN) for each unique service chain. Each service function classifier node and APN configuration is unique to the vendor(s) in the network, which results in custom implementations for each CSP. All network topology changes must be manually coordinated with service function chain provisioning (a significant operational consideration). All monitoring is also manual.

Increased Costs

Today's static approach to service chains also drives service costs because of the disparity between cost structure and revenue. For any subscriber attached to a particular APN, that subscriber's mobile packets are steered across all the nodes in that service chain, regardless of whether that subscriber needs all the services in the chain. In other words, the physical infrastructure does not accurately reflect subscriber needs. Another source of cost burden with static service chaining is scalability and reliability. While the mobile gateways may be able to handle significant traffic load increases, typical Gi-LAN functions do not necessarily scale in the same manner. Also, Gi-LANs must be significantly overbuilt in the appliance architecture to cope with site or unduplicated element failure.

Dynamic Service Function Chaining: Key Challenges

In addition to the RFC 7498 challenges listed earlier, implementations of dynamic SFC must surmount fundamental technical issues stemming from basic virtualization and packet processing. Replacing dedicated physical appliances with virtual appliances, packet flow, L2/L3 processing, and L4-L7 manipulation and processing introduces many technical challenges in the following areas:

Packet Flow

- Logical packet flow may not be clear.
- Virtual appliances are not in a fixed physical location.
- Packets may need to traverse some links multiple times.
- Distinguishing between "before" and "after" a service is difficult.
- Operations, administration, and management, as well as troubleshooting tools, do not yet exist.

L2/L3 Processing

- L2/L3 header manipulation prevents the header from being consistent in the chain.
- Control mechanisms for a packet flow are identified by the header.
- Network address translation can modify the IP address.

L4-L7 Processing

- Network services that perform processing and modifications at L4 through L7 are not standardized.
- Network services that terminate flows and initiate new flows are not standardized.
- Metadata types vary across implementations.

Hybrid Environments

As NFV and dynamic SFC evolve, it is quite likely that CSPs will gradually transition from physical appliances to virtualized appliances in networks. Hybrid architectures that mix VNFs with Physical Network Functions (PNF) will be highly complex. However, innovation sparks innovation, and as dynamic SFC matures and gains market traction, new applications will undoubtedly emerge. A historical example is Multiprotocol Label Switching (MPLS), which allowed for label stacking that led to pseudo-wire emulation, virtual private LAN service, and IP virtual private network applications to build hierarchy and abstraction.

Overall NFV and SDN Challenges

To realize dynamic SFC, the fundamental challenges commonly acknowledged for SDN/NFV must be addressed. How and when these challenges and impediments are addressed will impact SFC architectures and deployment methodologies. Industry impediments for SDN/NFV include orchestration, workload placement, network service life cycle management, integration of SDN Controllers, data path performance, optimal path routing, type and use of packet header metadata information, and redundancy and operational issues.

Service Function Chaining

Software-defined programmability for Gi-LAN enables network services to scale efficiently and steer traffic across both the virtual and physical network functions. As shown in Figure 3, from a recent 2015 Service Chaining Operator Survey,[5] Gi-LAN is a focus area for CSPs to use service function chaining in the Gi-LAN.

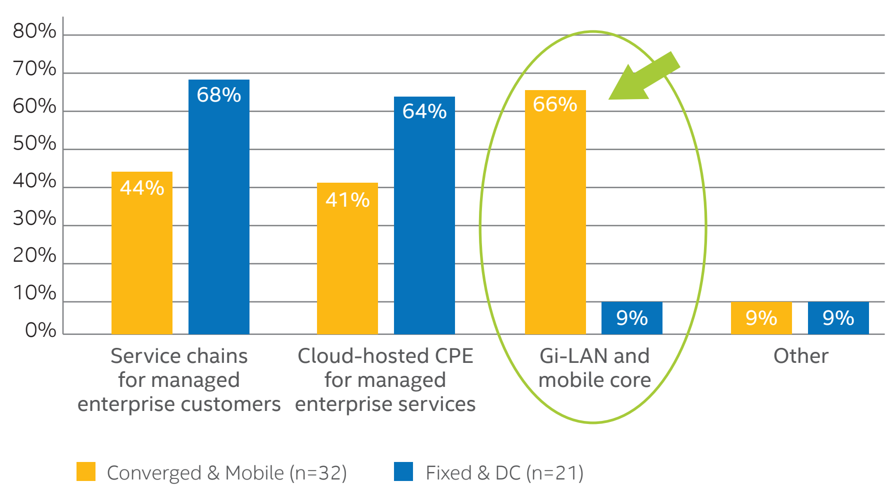

Figure 3. Service chaining survey results.

This same survey also provided some insight on the specific network functions that CSPs prioritize to be used in service chains (see Figure 4). These traffic functions all reside in the Gi-LAN.

Differing options and proprietary approaches on how the service chain is configured and the preference of the communications path between network functions is impacting broad adoption for SFC. As shown in Figure 5, packet headers are the preference for conveying application identification in service chain information.

The most prevalent encapsulation method for packet headers to communicate SFC metadata is network service header. However, at this time, there is no industry consensus on this approach.

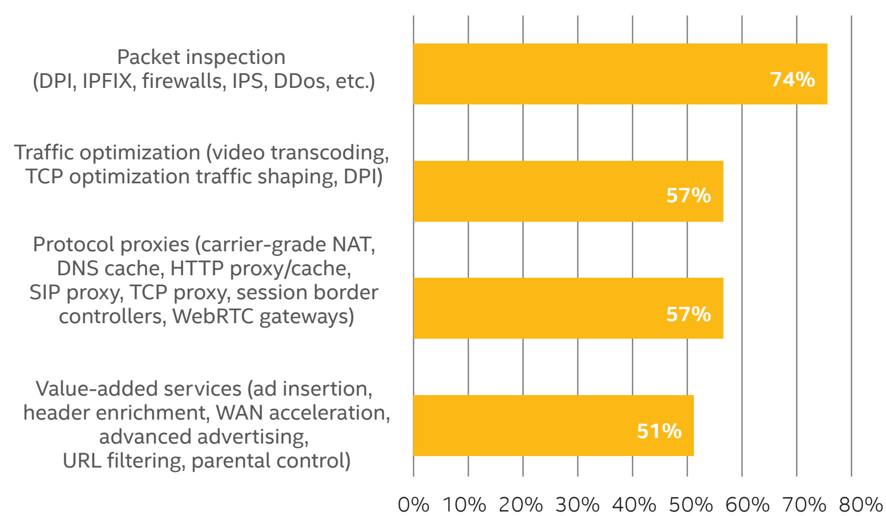

Figure 4. Network function prioritization in service chains.

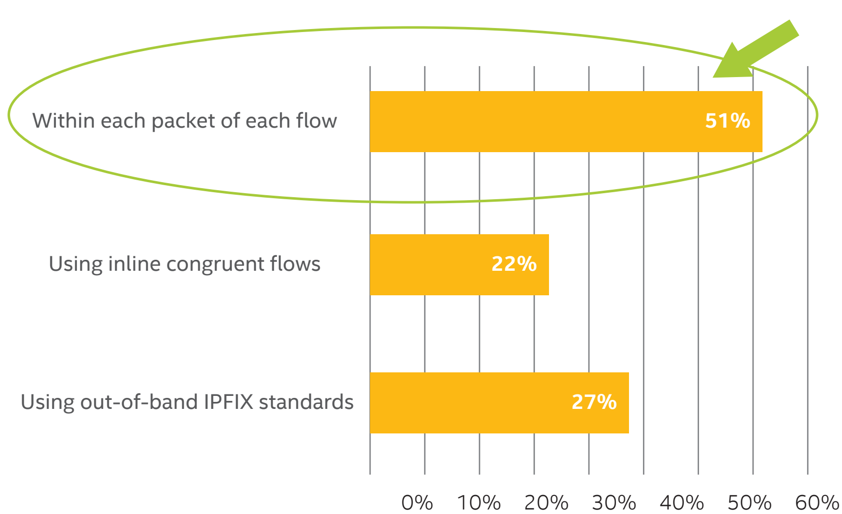

Figure 5. Preference for conveying application identification.

State of the Industry

The industry does not yet have broad adoption of Gi-LAN deployments using dynamic SFC based on SDN/NFV technologies. There are implementations of Gi-LAN dynamic traffic steering used today, but these are generally made-to-order customized solutions that use manual, vendor-specific configurations. However, as mentioned previously, the Gi-LAN network functions are ideal candidates for NFV, which leads to great interest in leveraging SFC for a virtualized Gi-LAN.

A number of Open Source efforts are underway with the intent of driving the industry toward convergence on a more common SDN/NFV methodology that is integrated with the CSP's network.[6] Such a convergence will enable open, interoperable, and interchangeable solutions for broad market adoption. However, currently some of these Open Source solutions are immature and have technological and operational gaps that limit broad market adoption for CSP production deployments.

Some of the technological gaps include the following: metadata format, SFC encapsulation, SFC provisioning, and integration with existing mobile network policy infrastructure. The metadata in the header provides the ability to exchange context information between classifiers and service functions and between one service function and another. The format and encapsulation of this metadata and how it is exchanged is an open topic in standards and industry bodies. An approach gaining interest is the use of Network Service Headers (NSH). The current NSH draft (https://tools.ietf.org/html/draft-ietf-sfc-nsh-04) provides a mechanism to carry shared metadata between network devices and service functions, and between service functions. While NSH is not yet standardized by the Internet Engineering Task Force (IETF), there is industry and open source community support for NSH as a valid data plane encapsulation approach to support dynamic SFC.

While NSH-based SFC is a potential approach, the industry is not unanimous in its support for NSH. Some major ecosystem players resist NSH and make coherent and valid arguments. Even the telecommunications equipment manufacturers that plan to support NSH consider mass market acceptance as being five years away. The greatest benefits provided by NSH are abstraction and, primarily, metadata. For the Gi-LAN use case, where subscriber-specific actions need to be taken, metadata is extremely valuable because it eliminates the need to integrate service functions with the Policy and Charging Control system.

NSH and SDN address some of the more common LAN requirements for SFC; however, the Gi-LAN and mobile networks add complexities. For example, mobile networks have comprehensive policy and charging controls and policy enforcement architecture (for details, refer to the 3GPP Technical Specification 23.228). Dynamic SFC (Figure 6) introduces additional policy controls that need to be coordinated with the existing policy architecture. The 3G Partnership Program (3GPP) is also developing several technical reports and conducting studies to evaluate approaches to better integrate the dynamic SFC provisioning with the existing mobile network policy controls architecture and traffic steering policies. As an example, 3GPP Technical Review 23.718 defines a new interface (called the St Interface) between the Policy and Charging Rules function (PCRF) and a new Service Chain Traffic Controller function (SCTCF).

This interface, among other capabilities, enables the PCRF to interface to the SFC controller functions to provide traffic description filters for more comprehensive and coordinated implementation service function chains in the Gi-LAN.

In summary, across the industry, the benefits of dynamic SFC are widely acknowledged; however, the immaturity of technologies currently prevent the industry from realizing significant value from dynamic SFC for a CSP's Gi-LAN.

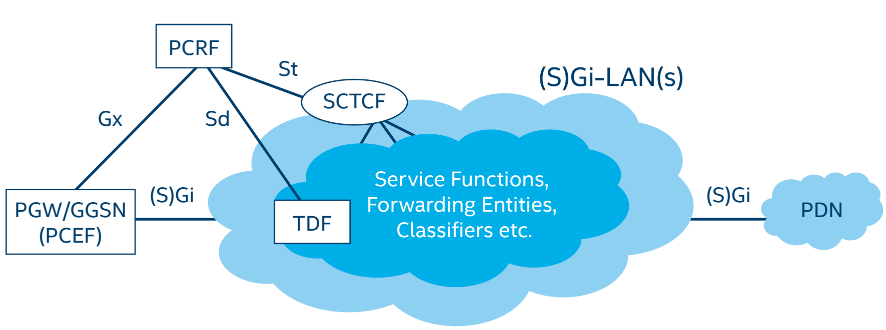

Figure 6. Dynamic service function chaining.

Intel's Role in Addressing Market Pain Points

Broad market adoption of technology innovation requires the technology's business drivers to solve a problem (for example, cost) or enable a new capability (for example, revenue). Intel is driving ecosystem investment to make NFV a reality. Intel is providing core technology and investing in the ecosystem to enable virtualized network functions and routing applications to scale more efficiently to optimally deliver end-to-end services. A common software-defined programmability of virtualized functions and routing between these functions will provide SPs with the ability to scale and steer traffic in a more efficient manner.

For Gi-LAN based on SDN/NFV, performance and dynamic programmability are required to achieve the benefits of SDN/NFV. Intel's core technology, product, and solutions roadmap and ecosystem partnerships will enable the following:

- **Optimal Resource Utilization**. Provide the performance, management, and programmability that will be necessary to accelerate adoption and scale the Gi-LAN virtualized network functions on Intel® architecture-based standard high volume servers (SHVS).
- **Reduce Fragmentation**. Provide common methodology and ecosystem enablers to apply dynamic programmable service functioning chaining to reduce industry fragmentation for CSPs' SDN/NFV environment.

The delivery of end-to-end Service Functions often requires inclusion of both traditional network service functions as well as application-specific features. Service Functions may be delivered within the context of an isolated user group or shared among many users or user groups. Current service function deployment models are relatively static, tightly coupled to network topology and physical resources. The result of that static nature of existing deployments greatly reduces, and in many cases, limits the ability of CSPs to introduce new services and/or service functions. Furthermore, there is a cascading effect: service changes affect other services.

The benefits of NFV increase for CSPs as more functions run on Intel architecture-based standard high volume servers (SHVS). For optimized cost and scaling, this requires not only adequate performance, but also intelligent programmability and management to enable efficient operations.

In addition to cost savings (CapEX/OpEX), the virtualized Gi-LAN with SFC drives new revenue models and new services opportunities for CSPs. The virtualized Gi-LAN solution enables the CSP to increase sales through new services offerings, especially in the mobile and Internet of Things (IoT) markets. The foundational elements of a virtualized Gi-LAN enable CSPs to increase operating income through bandwidth management-type services and improved end user experience.

Using a Gi-LAN SFC design that incorporates Intel® processors helps ensure the solution will have the performance and scalability to run multiple virtualized services on a single system. CSPs can draw from the Intel processor portfolio to offer a full range of Gi-LAN SFC solutions, sized for different numbers of virtual network functions and users. For example, they can create small, medium, and large-scale solutions using the Intel® Atom™ processor C2000, Intel® Xeon® processor D, and Intel® Xeon® processor E5 families.

SDN/NFV for Gi-LAN Network Functions

SDN and NFV promise to revolutionize the industry by driving reduced cost and increased service revenue. However, the transition to NFV will require a number of new, disparate technologies to work collaboratively. The maturity of these technologies is captured in Intel's Network Maturity Model for CSPs.[7]

The Gi-LAN network functions provide a variety of different services; however, most are IP-based and rely on data plane performance. Virtualized data plane performance optimization is an ongoing effort as the capabilities necessary to transition network functions to standard high-value servers continue to evolve. A description of these efforts and pros/cons of different approaches is captured here: https://networkbuilders.intel.com/docs/open-vswitch-enables-sdn-and-nfv-transformation-paper.pdf

Technology Overview

The following sections describe the Gi-LAN and dynamic SFC technologies in more detail. (see Figure 7)

Traditional Gi-LAN

In traditional CSP mobile networks, the Gi-LAN consists of service functions based on rigidly defined physical appliances (a combination of proprietary software and hardware) that forward traffic to each node to inspect, steer, modify, monitor, or report on the mobile data packets. These physical appliances use physical cabling and pre-configured static routing mechanisms. Gi-LAN service functions allow the CSP to innovate, differentiate, and monetize services using unique capabilities provided by these IP networking functions that reside between the mobile packet gateway and the external Internet.

Some of the more common Gi-LAN network service functions include Firewall, TCP Proxy, Network Address Translation, Load Balancing, Content Delivery Optimization (such as Web, video, audio), Deep-Packet Inspection, and Header Enrichment. The underlying capabilities of the Gi-LAN service functions enable CSPs to offer subscriber-facing value-added services that drive additional revenue for CSPs.

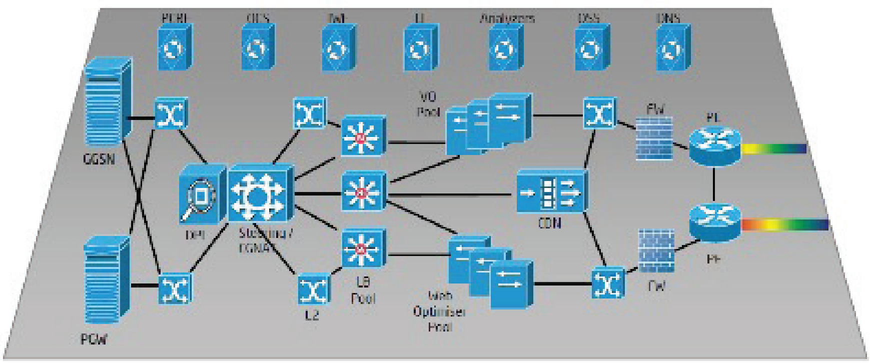

Figure 7. Simple Gi-LAN architecture.

A common approach for today's deployments requires that each network appliance is managed by its own event management system or by an operating system command-line interface. While many SPs implement service steering on the Gi-LAN's network to steer the appropriate traffic to the appropriate set of service nodes, this process has significant drawbacks: manual configuration is error-prone, and service agility is substantially hampered by rigid architectures.

Gi-LAN Service Chains

The preconfigured paths across disparate IP networking functions that lead from the mobile packet gateway through the Gi-LAN to the external packet data network are commonly referred to as service chains. A service chain requires the definition and instantiation of an ordered set of network functions and the subsequent steering of traffic flows through those network functions. Mobile CSPs typically use APNs as an initial means to define separate service chains for different subscriber pools. Within APNs, depending on the functionality of the mobile gateway or traffic decision function, additional preconfigured packet inspection logic can be used to further delineate unique service chains per subscriber session.

The lack of standards oversight for Gi-LANs has resulted in a wide range of Gi-LAN architectural approaches, even within the same mobile network operator group. Typically, mature markets with high average revenue per user exhibit more complex architectures, more diverse service bundles, and more complex traffic optimization and content delivery. The lack of Gi-LAN standards has also led to a broad vendor mix, making the management, maintenance, and evolution of the Gi-LAN operationally difficult.

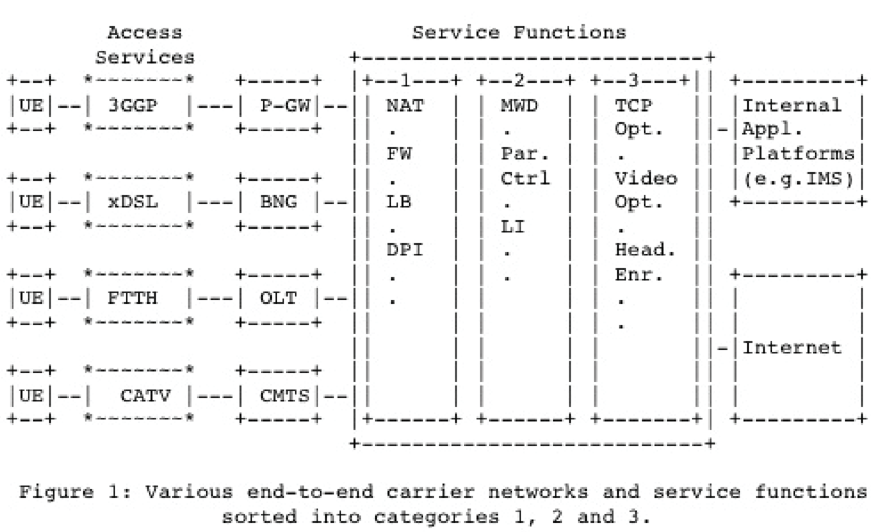

Figure 8. Service function chaining.

Service Function Chaining

IP networks rely on the combination of basic routing and switching along with advanced functions for the delivery of value-added services. For CSPs, the network functions that enable differentiated services typically reside in a LAN segment within a CSP's data center. SFCs define the path and the sequence of the network functions subscriber data flows across the LAN segment. Service function chains ensure a fair distribution of network resources according to agreed service policies, enhance the performance of service delivery, and take care of security and privacy. For Mobile CSPs, the LAN segment is known as the Gi-LAN.

Dynamic Service Function Chaining

IP networks rely on basic routing and forwarding functions, which are not combined with advanced functions for the delivery of value-added services. Historically, network functions are implemented in rigid, inflexible chains, which make it difficult for CSPs to create differentiated service offerings, limit service innovation and agility, and diminish the ability to dynamically adapt services in response to traffic patterns or subscriber growth.

Dynamic SFC enables CSPs to use software to dynamically configure network services without making changes to the network at the hardware level, thereby significantly reducing capital expenditures (CapEx). Dynamic SFC allows more optimal use of network resources and provides more efficient provisioning of new services in a more agile, automated manner.

Figure 9 shows a simple visualization of how SFC works, and Figure 10 illustrates how SFC fits into the NFV architecture.

Three fundamental components combine to enable dynamic SFC:

- **Service Function Classifier**. The Classifier analyzes traffic in real time and enables intelligent traffic steering to optimize the number and sequence (chain) of service functions. This is accomplished by applying policies and inserting into the flow packet headers a SFC header that contains a path ID. The format of this header is not standardized (see "State of the Industry" for further discussion).
- **Service Function Forwarder**. The Forwarder is responsible for forwarding data packets to their designated service function instances by matching the path ID contained in the NSH with the next-hop information provided by the SDN Controller.
- **Service Functions**. These are the individual functions, such as Firewall, Proxy, Network Address Translation, Load Balancing, Content Delivery Optimization, Deep-Packet Inspection, and Header Enrichment.

While the Classifier can be provisioned in several different ways, typically the SDN Controller interfaces with a virtual switch (such as Open vSwitch* (OVS) or other classification function through a communications interface such as OpenFlow* or the OVS Database (OVSDB) management protocol.

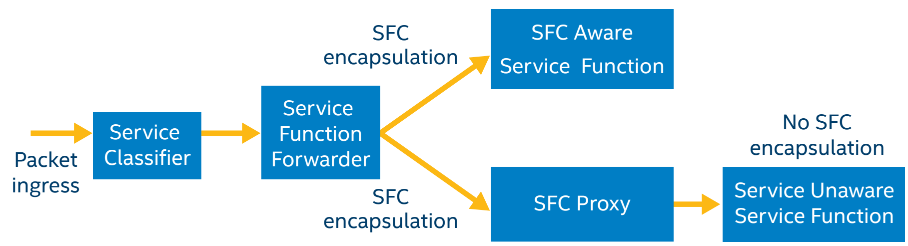

Figure 9. Basics of dynamic service function chaining (SFC).[8]

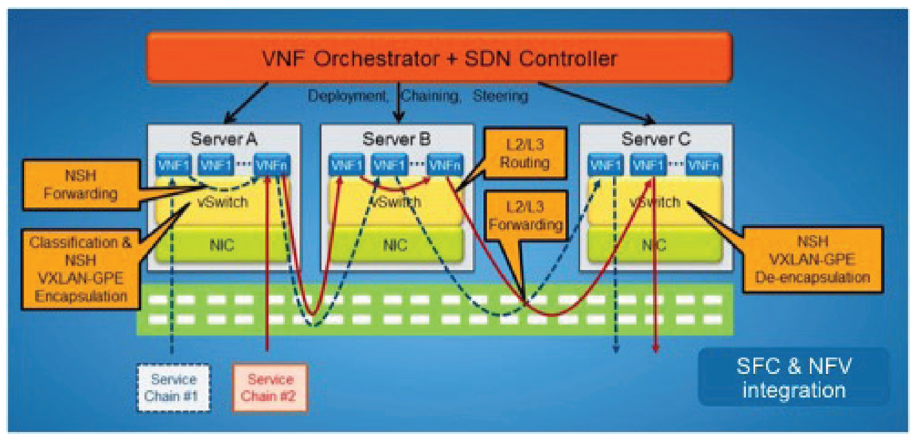

Figure 10. SFC and NFV integration.

Intel® Technologies and Ecosystem Enablers

Intel's differentiation for the enablement of Gi-LAN network functions derives from the unique capabilities of Intel's chipset and platform ingredients to enable efficient resource utilization via optimal performance and programmability. Intel's ecosystem efforts continue to allow the ecosystem to make optimal use of the capabilities with more seamless integration and use of these capabilities by the NFV/SDN architecture.

Virtualized network functions benefit from the ongoing efforts to enable and enhance the horizontal platform. Platform capabilities based on Intel's chipsets supporting open source ingredients (including the Data Plane Development Kit (DPDK) and OVS are leveraged by CSPs to achieve the benefits of NFV. The horizontal platform provides the foundation for a virtualized infrastructure. Capabilities such as CPU/memory virtualization, I/O virtualization, workload isolation and acceleration are the foundation of NFV.[11]

Intel's chipset and platform capabilities enable Gi-LAN network functions to facilitate efficient resource utilization via optimal performance and programmability. Intel continues to work with the ecosystem to enable optimal use of these capabilities with seamless integration by the NFV/SDN architecture.

Purpose-built devices require CSPs and their hardware partners to qualify each version of a device, whether it is produced to offer a distinct service or to accommodate a different number of users. With Gi-LAN based on industry-standard technologies, CSPs can produce, and qualify, fewer variations for their solutions. The virtualized environment allows them to support different services and to scale more easily.

Intel's Chipset and Architecture Capabilities

Specific Intel capabilities that drive optimal performance and security for Gi-LAN type functions are identified in Figure 11 below. Some of these capabilities include Enhanced Platform Awareness (EPA),[12] Intel® Resource Director Technology (RDT), Intel® QuickAssist Technology (Intel® QAT),[13] Intel® Trusted Execution Technology (Intel® TXT), and Intel Advanced Encryption Standards New Instructions (Intel® AES-NI), among others.

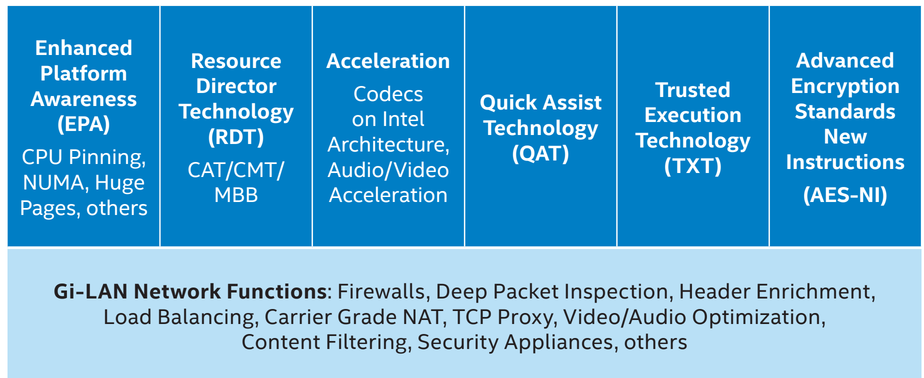

Figure 11. Intel capabilities for Gi-LAN

The table below provides links to more information on these specific capabilities:

Table 2. Links to specific capabilities.

Intel® Resource Director Technology	http://www.intel.com/content/www/us/en/architecture-and-technology/resource-director-technology.html
Intel® QuickAssist Technology	http://www.intel.com/content/dam/www/public/us/en/documents/white-papers/communications-quick-assist-paper.pdf https://01.org/packet-processing/intel®-quickassist-technology-drivers-and-patches
Intel® Trusted Execution Technology	http://www.intel.com/content/www/us/en/architecture-and-technology/trusted-execution-technology/malware-reduction-general-technology.html http://www.intel.com/content/www/us/en/architecture-and-technology/trusted-execution-technology/trusted-execution-technology-security-paper.html http://www.intel.com/content/dam/www/public/us/en/documents/guides/intel-txt-software-development-guide.pdf
Intel® Advanced Encryption Standards New Instructions	https://software.intel.com/en-us/articles/intel-advanced-encryption-standard-instructions-aes-ni http://www.intel.com/content/dam/www/public/us/en/documents/white-papers/aes-ipsec-performance-linux-paper.pdf
Enhanced Platform Awareness	https://software.intel.com/sites/default/files/managed/8e/63/OpenStack_Enhanced_Platform_Awareness.pdf https://networkbuilders.intel.com/docs/openStack_Kilo_wp_v2.pdf
Open vSwitch*	https://networkbuilders.intel.com/docs/open-vswitch-enables-sdn-and-nfv-transformation-paper.pdf
Data Plane Development Kit	http://www.intel.com/content/www/us/en/intelligent-systems/intel-technology/dpdk-packet-processing-ia-overview-presentation.html https://networkbuilders.intel.com/docs/aug_17/Future_Enhancements_to_DPDK_Framework.pdf
Intel® Cloud Integrity Technology	http://www.intelserveredge.com/enhancedsecurityservers/
Hardware Offload	http://www.intel.com/content/www/us/en/ethernet-products/controllers/overview.html

Please note: A separate reference-benchmarking document will detail performance benefits of these capabilities for specific virtualized vIMS network function use cases.

Open Source and Standards

Intel is driving software contributions and broad market capabilities through Open Source communities.

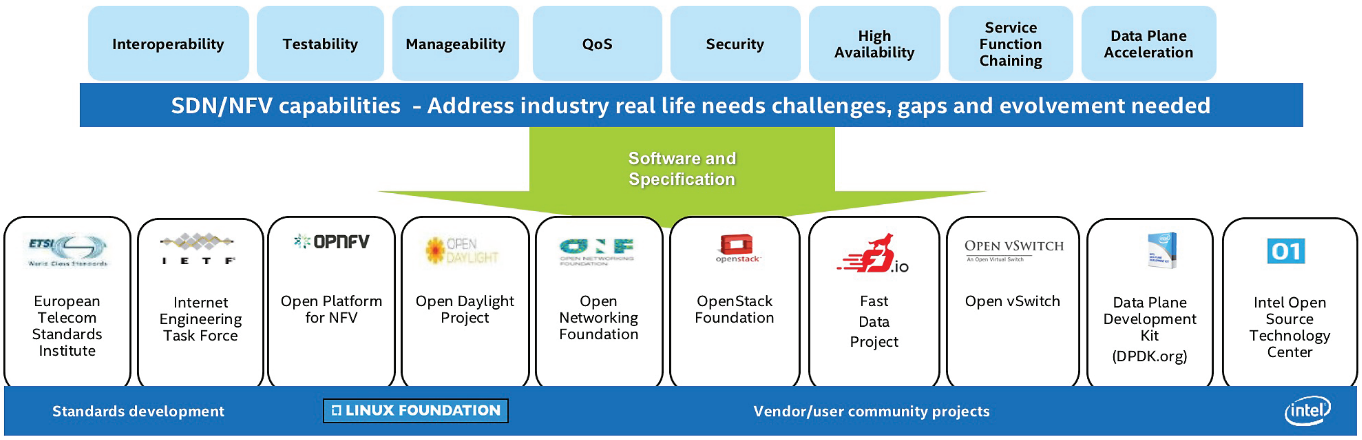

Figure 12. Intel's involvement in open source and standards.

Intel invests in 10 Open Source and standards initiatives shown on Figure 12, from the ETSI-NFV group to Intel's own packet processing project on 01.org.

Contributions are driven both by the market and by specific customer requirements. This includes providing real-life deployment and business needs, targeting performance metrics, closing development gaps, and enabling the management tools needed to ensure service levels.

Intel's contribution is across the entire spectrum, including technical specifications, code development, testing and benchmark tools and reference platforms.

Intel® Open Network Platform Reference Architecture

Intel® Open Network Platform (Intel® ONP) Server is an enablement program with a Reference Architecture integrating Intel's hardware and open source software ingredients for easier ecosystem adoption. One of the key objectives of Intel ONP Server is to align and optimize key Open Community software ingredients for architects and engineers targeting high-performing SDN and NFV solutions. Intel ONP provides a convenient reference platform to evaluate the latest performance contributions for OpenStack,[14] DPDK,[15] and accelerated OVS.[16]

Intel® Network Builders

Intel recognizes that enabling network transformation will require a strong ecosystem of partners. The Intel® Network Builders community (www.networkbuilders.intel.com) has more than 180+ partners developing SDN/NFV solutions on Intel Architecture (see Figure 13). Within this community, there are more than 30 software vendors for critical SDN/NFV use cases, including Gi-LAN. The work of the community extends to proofs of concept, reference architectures, and trials. With the help of its ecosystem partners, Intel remains committed to the development of technology solutions and capabilities that will improve the performance of virtualized network functions for CSPs.

Figure 13. Intel® Network Builders

Next steps

- To learn more about Intel's technology for NFV, attend the courses available in the Intel Network Builders University at https://networkbuilders.intel.com/university.
- To learn more about Intel Network Builder partners for vEPC and other NFV products, visit https://networkbuilders.intel.com/solutionscatalog.
- To build a testbed using the Intel ONP Reference Architecture, download the documentation at https://01.org/packet-processing/intel%C2%AE-onp.
- To get the best security in your NFV systems, specify Intel Cloud Integrity Technology in your infrastructure and VNF procurements.
- To get the highest performance from your NFV systems, specify compatibility with the Data Plane Development Kit in your Infrastructure and VNF procurements.
- To get the highest return on investment from your NFV systems, specify use of Enhanced Platform Awareness in your Orchestration, Infrastructure and VNF procurements.

Additional Info

Related efforts in Intel:

- Solution Blueprints (Intel Internal): vCPE, vIMS, vEPC, Gi-LAN

  https://soco.intel.com/groups/sdnd-platform-solutions-team
- OpenDaylight Contribution and IETF efforts on NSH https://tools.ietf.org/pdf/draft-ietf-sfc-nsh-00.pdf

  https://wiki.opendaylight.org/view/Project_Proposals:Service_function_chaining
- OpenStack EPA contributions https://01.org/sites/default/files/page/openstack-epa_wp_fin.pdf

  https://networkbuilders.intel.com/docs/openStack_Kilo_wp_v2.pdf
- Intel Open Network Platform https://01.org/packet-processing/intel-onp-servers

Intel Network Builders Related Info:

- https://networkbuilders.intel.com/solutionscatalog/qosmos-classifier-258
- https://www.brighttalk.com/webcast/12229/132479

ETSI-Defined Gi-LAN/SFC Proofs of Concept (POCs):

- POC 2: Service Chaining for NW Function Selection in Carrier Networks
- POC 4: Multi-vendor Distributed NFV
- POC 6: Virtualized Mobile Network with Integrated DPI
- POC 7: C-RAN virtualization with dedicated hardware accelerator
- POC 13: SteerFlow: Multi-Layered Traffic Steering for Gi-LAN
- POC 15: Subscriber Aware SGi/Gi-LAN Virtualization
- POC 20: Virtually based content caching in NFV framework
- POC 23: Demonstration E2E orchestration of virtualized LTE core-network functions and SDN-based dynamic service chaining of VNFs using VNF FG
- POC 34: SDN Enabled Virtual EPC Gateway

[1] The "Gi" (Gateway-Internet) LAN interface (referred to as the sGi-LAN in 4G networks) is the reference point defined by the 3rd Generation Partnership Project (3GPP) as the interface between a service provider's mobile packet gateway and an external packet data network (such as the Internet).

[2] Ericsson Mobility Report, June 2015. http://www.ericsson.com/res/docs/2015/ericsson-mobility-report-june-2015.pdf

[3] http://www.fiercewireless.com/tech/story/study-nfv-market-will-hit-116b-2019/2015-07-20

[4] Source: Infonetics

[5] www.qosmos.com%2Fwp-content%2Fuploads%2F2015%2F02%2FService-Chaining-in-Carrier-Networks_WP_Heavy-Reading_Qosmos_Feb2015.pdf

[6] These open source efforts include OpenDaylight*, OpenStack*, and Internet Engineering Task Force (IETF) projects.

[7] http://www.intel.com/content/www/us/en/communications/service-provider-network-maturity-paper.html

[8] Source: https://tools.ietf.org/html/draft-ietf-sfc-nsh-00

[9] http://www.dpdk.org

[10] http://openvsitch.org

[11] http://www.intel.com/content/www/us/en/virtualization/virtualization-technology/intel-virtualization-technology.html

[12] https://software.intel.com/en-us/articles/openstack-enhanced-platform-awareness

[13] https://01.org/packet-processing/intel%C2%AE-quickassist-technology-drivers-and-patches

[14] http://www.openstack.org

[15] http://www.dpdk.org

[16] http://openvswitch.org

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