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OpenBNG Solutions from Intel

Intel's portfolio of end-to-end programmable solutions enables a wide range of Open Broadband Network Gateway (OpenBNG) deployment models, architectures, types and locations

Authors

Petr Kastovsky
Product Marketing Engineer
Switch and Fabric Group

Paul Mannion
Broadband Segment Director
Network and Edge Solutions Group

Babu Peddu
Product Marketing Manager
Switch and Fabric Group

Executive Summary

Because the broadband network gateway (BNG) is the focal point for traffic aggregation in any fixed broadband network, it can be a choke point in the face of ever-increasing internet traffic. Service providers need to deploy smarter, faster and less expensive BNG solutions to grow their businesses. But traditional proprietary black-box fixed-broadband equipment limits operators' ability to innovate. Intel is working with the ecosystem to provide a portfolio of solutions that support an open and disaggregated BNG platform that can drive operators' innovation and cost reduction.

Intel's end-to-end OpenBNG portfolio supports all types of BNG locations, service types and resiliency models, as well as provides the high bandwidth necessary for today's heavily used networks. Through collaboration with the industry, Intel's OpenBNG solutions are fully programmable, interoperable, modular and flexible, using state-of-the-art processors, switches and accelerators like Intel® FPGAs and Intel® Infrastructure Processing Units (Intel® IPUs) all connected with open, industry-standard interfaces, software development kits (SDKs) and application programming interfaces (APIs).

Intel is committed to continuing to work with the ecosystem to develop OpenBNG solutions that support service providers' ability to deploy networks that feature intelligence, high performance, enhanced visibility and control.

Contributor

Bert Klaps, Senior Systems Engineer,
Programmable Solutions Group

Acronyms

API	application programming interface
BNG	broadband network gateway
CUPS	Control and User Plane Separation
FiBr	Fiber Broadband
FPGA	field-programmable gate array
HQoS	hierarchical quality of service
IFP	Intelligent Fabric Processor
IPU	Infrastructure Processing Unit
RFI	request for information
SDK	software development kit
TCO	total cost of ownership
TIP	Telecom Infrastructure Project
vBNG	virtualized BNG

Fixed Broadband Challenges

Monolithic, black-box fixed-broadband equipment is composed of proprietary hardware, software and legacy operations support system (OSS) interfaces. Because this equipment lacks open and programmable hardware, it prevents extensibility to new use cases. This inflexible environment has many disadvantages:

- Limits fixed-broadband service providers' ability to innovate.

- Creates lock-in and prevents a vendor-agnostic approach.

- Is slow to deploy, complex to maintain and difficult to integrate with other network components, such as OSS and business support system (BSS) functions.

- Lacks fully open application programming interfaces (APIs), which prevents interoperability.

- Leads to high total cost of ownership (TCO).

But extensibility, agility, flexibility and lower costs are exactly what fixed-broadband service providers need to thrive in today's marketplace. Network traffic is steadily increasing, driven by more at-home workers and students. High-resolution multimedia streaming, high-resolution video calls, AR/VR, online gaming, metaverses, digitization of industries such as healthcare, the Internet of Things (IOT) and the intelligent edge all drive high-bandwidth needs. It is predicted that at the end of 2030 there will be 1.6 billion fixed broadband subscribers worldwide compared to 1.27 billion in Q4 2021, up by 26%.[1]

CapEx is predicted to outpace revenue growth in many markets over the coming years[2], so the fixed-broadband industry needs improved solutions that enable a broad range of use cases and business models, reduce the OpEx of networks and drive further innovation. Lack of an efficient, high-speed broadband connection can negatively impact economic growth, household incomes, educational performance, healthcare access and the ability to work from home.

A Closer Look at the BNG

The broadband network gateway (BNG) is the key network component in broadband access. It is the network node where the subscriber's policy is administered. It is the first IP-aware node and is both subscriber- and service-aware. It provisions the necessary quality of service for each service (such as voice, video, data and high-priority data) that the communications service provider offers to the broadband subscriber. Due to its strategic nature, the BNG is often protected by 1:1 redundancy. It normally resides in an edge location where space and power budgets are not as extendable as in a more centralized location.

The BNG must be an efficient, scalable, flexible and high-throughput device. With today's growing network usage, it is increasingly important that the underpinning architecture take these requirements into account.

OpenBNG Community: Encouraging the Development of an Open, Disaggregated BNG Platform

Recognizing the challenges facing fixed-broadband service providers, Meta (formerly known as Facebook) spearheaded the Telecom Infra Project (TIP), with the goal of disaggregating all of the network (RAN, packet core, access point, mobile, backhaul and more).[3] As part of the TIP, the Fixed Broadband (FiBr) Project Group aims to transform the BNG to accomplish the following:

- Accelerate the development and deployment of modern and secure technologies based on open and standard interfaces.

- Improve supply chain diversity, unlocking new business opportunities for suppliers and increasing choice for operators.

- Encourage the development of carrier-grade products that can be commercialized, based on operator requirements.

Openness is a key pillar of network transformation—open hardware with a programmable silicon as well as open standards and open software interfaces. Other important aspects of network transformation include interoperability, modularity of software, simplicity of management, flexibility and sustainability of the ecosystem (see Figure 1). With a network with these characteristics, each operator can choose its own components that are best suited for its use cases and customers, while the ecosystem can continue to evolve and provide differentiation and new revenue possibilities.
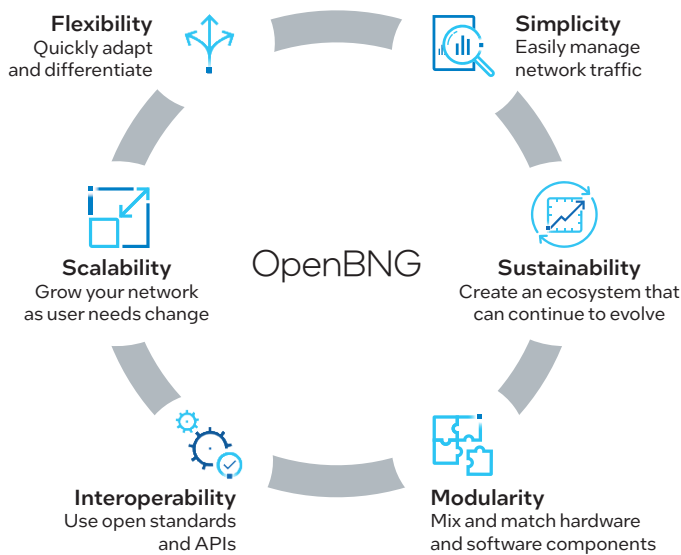

Figure 1. Key characteristics of OpenBNG.

To turn the vision illustrated in Figure 1 into reality, the FiBr Project Group, including five TIP founding operators (Telefónica, Telecom Italia, Vodafone, British Telecom and Deutsche Telekom), began work in 2020 on the OpenBNG project. After publishing a white paper in 2020, the FiBr Project Group finalized a list of 1,800 technical requirements in June 2021. Examples of technical requirements include support for time synchronization; varying network speeds up to 400 GbE; deep buffers; complex hierarchical schedulers; resources to handle tens of thousands of subscribers and hundreds of thousands of queues; millions of counters; and multiple layers of hierarchical quality of service (HQoS). Once the requirements list was completed, the FiBr Project Group conducted a request for information (RFI), which received 15,000 responses from the ecosystem.

A Closer Look at the OpenBNG RFI

The OpenBNG RFI enabled the FiBr Project Group to understand operator demand, supplier products and solution maturity. This information, in turn, can help align and refine supplier and operator roadmaps and define next steps for the OpenBNG project. The RFI helped the FiBr Project Group discover that the ecosystem landscape includes several silicon suppliers, including Intel, and that there is a diversity of silicon solutions.

Cloud BNG
Apply cloud principles to the BNG to achieve business goals.

The application of cloud technologies—that is, cloudification—to the fixed access network can provide telecom operators with a new platform approach and the opportunity to reduce costs while increasing opportunities at the network edge. Cloud BNG uses NFV and cloud principles like microservices and containerization to achieve the same software-defined networking advantages that have been previously gained through core network transformation.

Cloud BNG—also referred to as virtualized BNG (vBNG)—uses CUPS to implement a disaggregated BNG solution that allows independent and fine-grained scaling of user plane and control plane functions. Other open-source components used in Cloud BNG include OpenStack, Docker and Kubernetes.

Cloud BNG enables operators to introduce new services and meet capacity and flexibility requirements for increasing traffic while simultaneously reducing their capital outlay and reducing operational costs. For more information on a real-world case study, read the Deploying an Agile, Cost-Efficient Cloud BNG blog.

Additionally, it became clear that software suppliers have a variety of backgrounds. Some are experts in BNG and broadband remote access server (BRAS). Others focus on routing using Internet Protocol Multi-Protocol Label Switching (IP/MPLS). Still others are cloud-native players, specializing in microservices and containerization. Across the globally diverse suppliers, support exists for stand-alone BNG (full functionality and service-only) and for CUPS-based BNG.

After sifting through the RFI responses, the FiBr Project Group created a shortlist of suppliers that had solutions that were open and disaggregated (hardware and software are decoupled), are compliant with the OpenBNG technical requirements list and are ready for testing. While there is still much to do, the RFI has proved that the FiBr Project Group can begin testing and validating many OpenBNG supplier products, and it is exciting to see suppliers realize their roadmap objectives and help build a stronger OpenBNG ecosystem.

View the OpenBNG RFI Results Announcement video for more information on the shortlist and on emerging entrants to the market that are considered "companies to watch."

Intel's OpenBNG Portfolio

Intel has collaborated with ecosystem players, including telco operators (the end users of OpenBNG solutions), as well as hardware manufacturers and software vendors. The result of this collaboration, as defined in the "Open BNG Technical Requirements", is an end-to-end portfolio of Intel technology-based OpenBNG solutions that support different architectures, types, locations and resiliency models (see Figure 2).
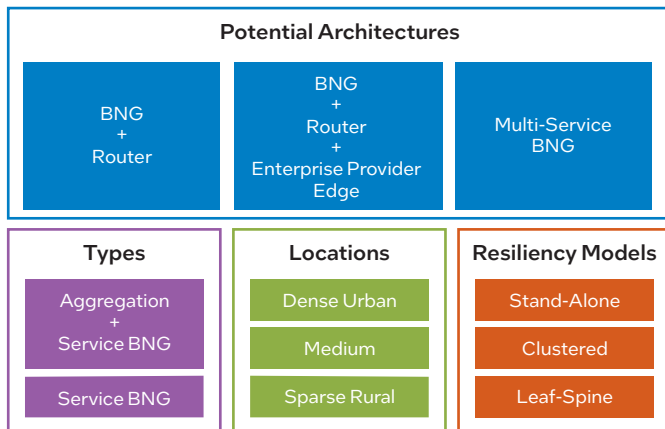
Intel Technology-based OpenBNG Solutions Support

Potential Architectures		
BNG + Router	BNG + Router + Enterprise Provider Edge	Multi-Service BNG

Types	Locations	Resiliency Models
Aggregation + Service BNG	Dense Urban	Stand-Alone
Service BNG	Medium	Clustered
	Sparse Rural	Leaf-Spine

Figure 2. Intel's OpenBNG Portfolio supports different architectures, types, locations and resiliency models.

Key Features and Components

Intel's OpenBNG portfolio is built on Intel technologies (see Figure 3). These various components can be combined in different configurations using industry-standard protocols and tools like the P4 programming language, Data Plane Development Kit (DPDK), Infrastructure Programmer Development Kit (IPDK) and more.

Intel OpenBNG Components

Integrated Photonics

Optical Modules
High-bandwidth connectivity at 100 GB, 400 GB and beyond

intel. Si PHOTONiCS

Ethernet

Switch
P4-programmable scale-out fabric with uncompromising performance

intel. TOFiNO

IPUs and Network Adapters
Programmable infrastructure acceleration for demanding data movement

intel. IPU   intel. eTHeRNeT

Compute
Improved Density, Power and Cost

CPUs and XPUs
Fabric-enabled endpoints aligned to accelerators and software pipelines

intel. XEON   intel. STRATiX 10   intel. AGILEX

Industry Standards

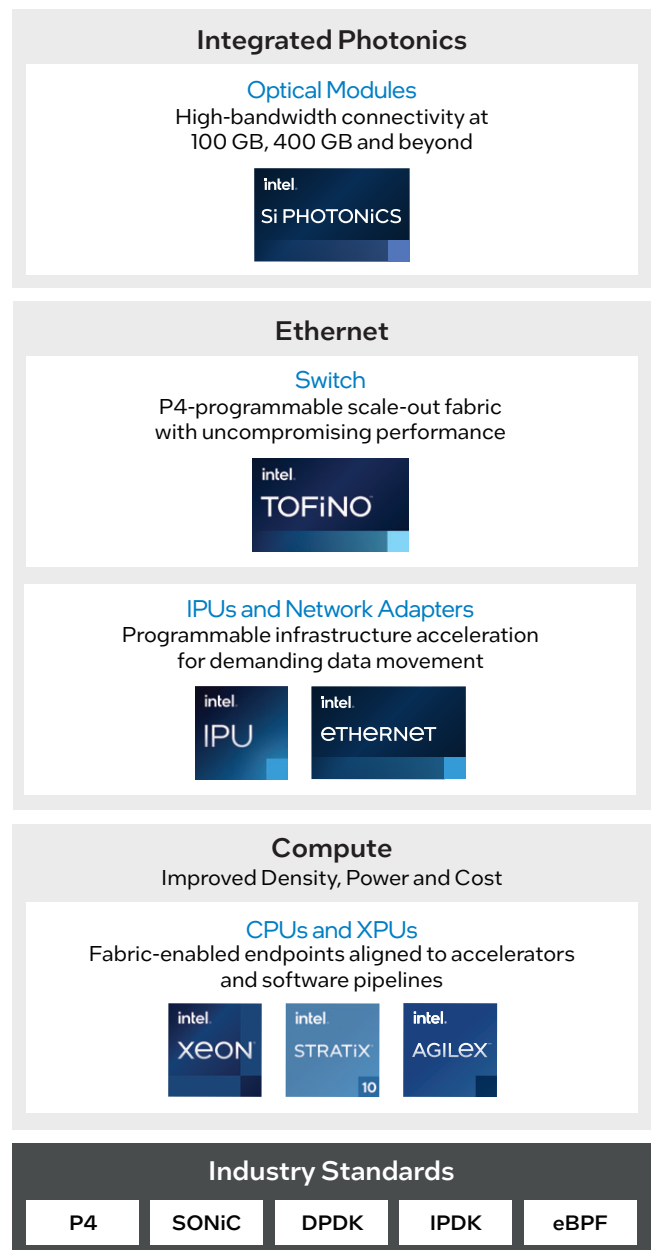| P4 | SONiC | DPDK | IPDK | eBPF |

Figure 3. From fully programmable Intel® Tofino™ IFPs to CPUs to accelerators to optical modules, Intel technology enables a broad portfolio of networking platforms.

Overview of Available OpenBNG Solutions from Intel

Intel offers two reference user plane solutions for OpenBNG. Both are based on a CUPS architecture with support for a common control plane (see Figure 4). The control plane agent receives the commands from the CUPS controller and programs the underlying user plane forwarding tables and quality of service engines.

Operators can choose which user plane solution best fits their BNG location and use case. The server software-based solution is suitable for all locations, both centralized and at the edge, while the server switch-based solution is ideal for high-density, low-power and space-constrained locations. Table 1 provides a more detailed comparison of the two options, and they are described fully in the following sections.
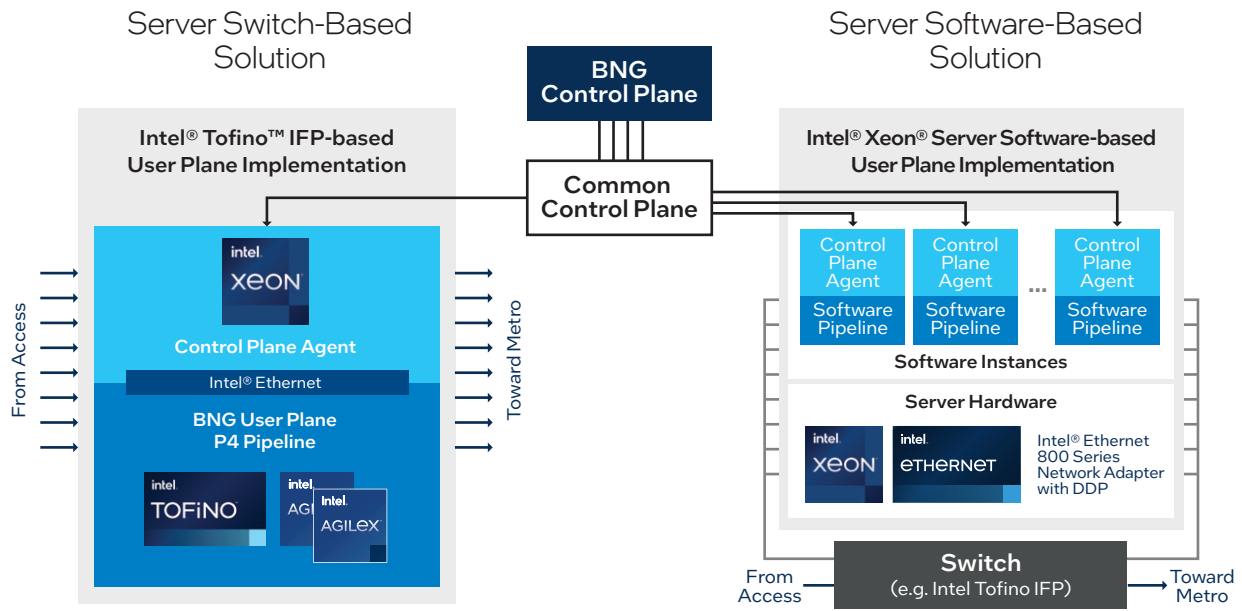
Figure 4. Heterogeneous CUPS user plane implementations.

Table 1. Comparison of Server Switch-Based and Server Software-Based OpenBNG Solutions from Intel

	Server Switch-Based Solution	Server Software-Based Solution
Deployment Location	High-density or space/power-constrained sites	All locations
Aggregate Throughput (Uplink + Downlink)	2.4 Tbps per server switch (Intel® Tofino™ IFP+ 2x Intel® FPGAs)	~700 Gbps[a] per 2-socket server with 36 cores
Pay-as-you-Grow Capability	Coarse-grained scaling	Fine-grained scaling suitable for distributed edge footprint and throughput
Space and Power Consumption	Highly optimized user plane	Efficient use of Intel's P and C state power management technologies
Refresh Cycle	7–10 years	3–7 years[b]
Processing Latency	Low microseconds	Low milliseconds
Hardware Availability	Selected supported hardware platforms	Universally available from many server OEMs' virtualized solutions
User Plane Technologies	Implemented using open standards-based P4 and register transfer language (FPGA)	Implemented using Intel's DPDK and Vector Packet Processor (VPP) open-source, I/O-optimized SDKs
Port Aggregation Capability	Integrated	External switch required
Extensibility	Fully programmable, requiring software-like development skills (e.g., P4 and APIs) and techniques (e.g., continuous integration/continuous delivery pipelines)	Cloud-like using continuous integration/continuous delivery software upgrade practices
Solution Availability	Trials in 2022	Deployed today world-wide

[a] 512-byte packet size.

[b] Typical data center server: up to 5 years of service; extended life servers: up to 7 years of service (such as Intel® Xeon® Gold 6338N processor).

Server Software-Based Solution

This solution creates a virtualized BNG (vBNG) on a typical commercial-off-the-shelf (COTS) server. The vBNG is usually located in a central office or metro point of presence (PoP) cloud. The vBNG makes it possible to deploy a high-performance BNG workload on a general-purpose server equipped with an Intel Xeon Scalable processor such as the Intel Xeon Gold 6338N processor. Intel has developed the Intel® Select Solution for Forwarding Plane, which enables OpenBNG and takes advantage of containerized user plane technologies enabled in Docker and Kubernetes. As shown in Figure 5, this Intel Select Solution provides a reference pipeline for a CUPS-enabled vBNG solution that efficiently uses the I/O and compute resources of an Intel processor-based server.

The solution relies on open-source software development kit (SDKs) and standard hardware, such as DPDK-accelerated virtual switches, and can run on a variety of operating systems like Ubuntu, Red Hat Enterprise Linux, VMware vSphere and Canonical. The latest release of the Intel Select Solution uses a 2-socket standard server with 3rd Generation Intel Xeon Scalable processors with four Intel® Ethernet Network Adapters (E810-2CQDA2, 200 Gbps). The Intel Ethernet 800 Series Network Adapter features advanced Dynamic Device Personalization (DDP) for full pipeline programmability.
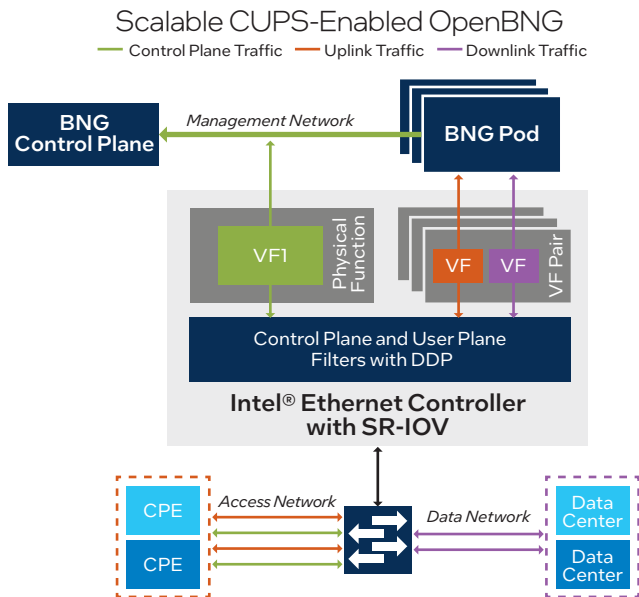

Figure 5. Scalable CUPS-enabled OpenBNG using a server software-based architecture.

As demonstrated in Figure 6, the vBNG performance scales linearly with the number of user plane instances deployed. Each instance requires two cores, and when 32x2 = 64 cores are used for the BNG user plane, throughput speeds in excess of 650 Gbps are achievable across the two sockets, with 0.001% packet loss.[4]
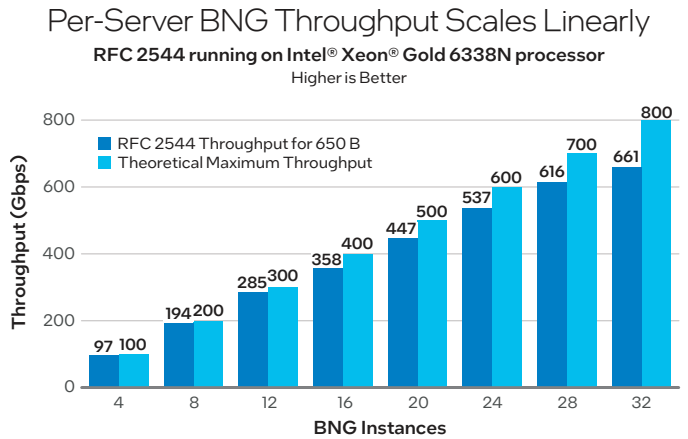

Figure 6. Linear scaling of vBNG throughput.[4]

Business Benefits of the Server Software-Based OpenBNG Solution

OpenBNG solutions based on Intel® processor-based servers are based on COTS components and open software that can perform traditional BNG functions. This open architecture offers a range of benefits to network owners and operators:

- Lowers OpEx and accelerates time to market.
- Achieve the scalability and flexibility required for multiple scenarios and use cases.
- Reduces TCO.

Several operators are already using Intel's server-based OpenBNG architecture in production. For more information on this solution, use the following resources:

- Re-Architecting the Broadband Network Gateway (BNG) in a Network Functions Virtualization (NFV) and Cloud Native World white paper
- Path to Cloud-Native Broadband Network Gateway (BNG) with Kubernetes case study
- Benu Networks Pushes its Cloud BNG to 100 Tbps Throughput on Intel Technology technical solutions blog
- Deploying an Agile, Cost-Efficient Cloud BNG blog (Hrvatski Telekom)

Next-Generation OpenBNG: Server Switch-Based Solution with Intel® Tofino™ Expandable Architecture

When compared to traditional black-box proprietary solutions, operators can benefit from programmability, intelligence, performance and visibility/control by taking advantage of Intel® Tofino™ Expandable Architecture.

This new offering lets network owners and operators take advantage of the P4 programmability of Intel® Intelligent Fabric Processor (Intel® Tofino™ IFP) for packet processing, while employing the power of Intel Xeon processors and the acceleration capabilities of Intel FPGAs and/or Intel IPUs to extend and augment Intel Tofino IFP functionality (see Figure 7). Intel Tofino Expandable Architecture increases table and buffer capacity by two orders of magnitude[5]—compared to a stand-alone data center-focused switch application-specific integrated circuit (ASIC)—and supports network transformation through the ability to add new types of network functions.

Massive performance and scale, flexibility, open standards and reduced TCO are all critical factors in today's constantly growing and evolving networks. Intel Tofino Expandable Architecture can help provide all of these—today and into the future.
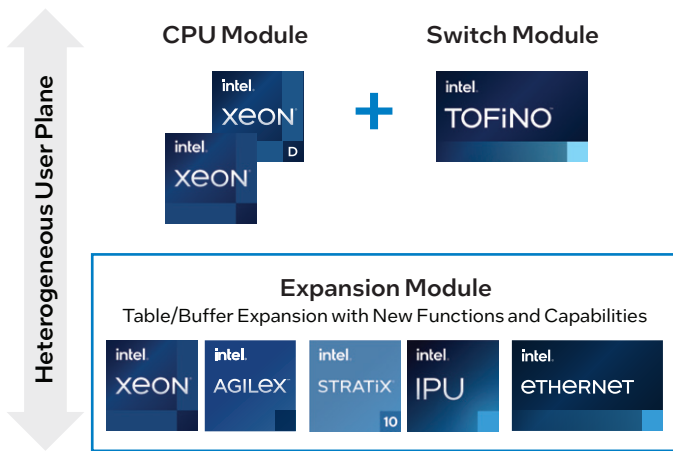

Figure 7. High-level view of Intel® Tofino™ Expandable Architecture.

Overview of Server Switch-Based OpenBNG

Intel's next-gen OpenBNG solution uses a server switch architecture. This implementation form factor combines Intel CPUs, FPGAs/IPUs and IFPs into a single rack-mount system. As an integrated platform, a server switch has a small footprint. (Note that other implementation form factors are possible, depending on specific deployment needs.)

Figure 8 illustrates an example architecture using Intel Tofino Expandable Architecture for OpenBNG. The Intel FPGA module handles HQoS, while the Intel Tofino IFP handles all the rest of the upstream and downstream user plane functions (such as classification, routing, access control lists (ACLs), multicast and lawful intercept).
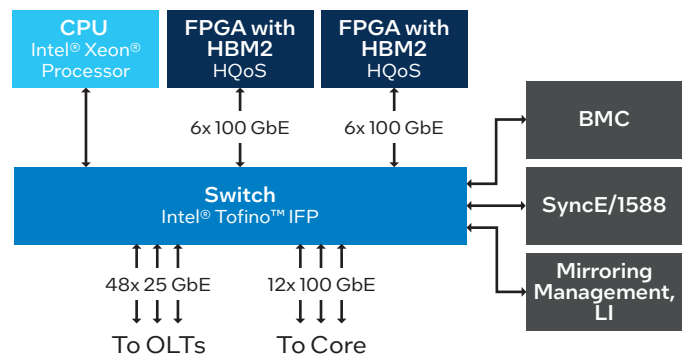

Figure 8. Example Intel® Tofino™ Expandable Architecture for OpenBNG.

An Intel Tofino IFP provides up to four pipes in the first and second generation and up to eight pipes in the third generation, with multiple stages per pipe. It is possible to run the BNG program in some pipes and run counter pool programs on other pipes, as well as focus the programs in each pipe on a specific aspect of the BNG pipeline. Within each pipe, it is possible to dedicate several stages to counters only. Table 2 provides details on how to best match memory to throughput, depending on the requirements.

Table 2. Memory versus Throughput Optimization on Intel® Tofino™ IFPs

Workload Focus	Pipe Usage	Throughput	Memory
Maximize Front-Panel Port Capacity	All pipes with the same program	All pipes with full front-panel port capacity	1 pipe of memory (1 ingress and egress pipe pass)
Maximize Lookup Memory	All pipes with different programs	1 pipe with full front-panel port capacity	All pipes of memory

HQoS Capabilities

HQoS is a crucial aspect of the BNG; it helps ensure that various subscriber groups receive the user experience that they expect (and pay for). The server switch-based OpenBNG architecture supports one to four Intel FPGAs, and the bandwidth and number of queues scale linearly. Each Intel® Stratix® 10 FPGA offers the following capabilities for reliable HQoS (see Figure 9):

- Up to 6x 100 Gbps @ 256-byte packet size
- Up to 160,000 queues
- 3–7 scheduling layers, with a default configuration of 5 layers
- 8 GB or 16 GB of HBM2 memory for traffic buffering, depending on the specific FPGA used
- QDR-IV, eSRAM memory for queue management tables
- Congestion control
- Fine shaping granularity, supporting a combination of low-bandwidth services (e.g., voice) and high-bandwidth broadband services
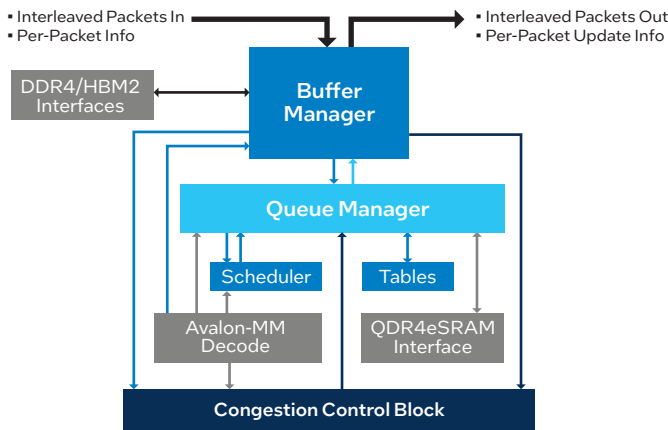

Figure 9. Carrier-grade HQoS reference design on the Intel® Stratix® 10 FPGA.

Business Benefits of the Server Switch-Based OpenBNG Solution

Using an OpenBNG solution based on Intel® Intelligent Fabric provides the following key business benefits:

- **Intelligence.** Take advantage of intelligent packet processing and P4 programmability to customize networks as user and business needs change.
- **Performance.** Achieve up to 25.6 Tbps switching throughput, with 112G/56G SerDes for high speed and easy migration. Intel Tofino IFPs provide power-optimized configurations for power-constrained environments, while Intel FPGAs enable expandable table and buffer sizes.
- **Visibility and control.** Enhanced congestion control, real-time in-band network telemetry and diagnostics with Intel® Deep Insight Network Analytics Software are just some of the manageability advantages available with Intel Intelligent Fabric.

Join the OpenBNG Intel Tofino Expandable Architecture Ecosystem

Several hardware suppliers already offer server switches featuring Intel Tofino Expandable Architecture. Operators are participating in proofs of concept and more projects are planned for the near future. If you are interested in finding out how to join these efforts, contact your Intel representative.

Conclusion

The need for a flexible architecture that offers more bandwidth and lower latency is continuing to grow. To achieve this, networks need to get faster and smarter. Intel has worked with the ecosystem, including TIP and various suppliers and operators, to develop a broad, end-to-end portfolio of fully programmable, interoperable and modular components that can enable a wide range of OpenBNG scenarios.

Intel's OpenBNG solutions—featuring disaggregation of hardware and software, open standards and modularity—bring business benefits to operators, including the following:

- Acceleration of innovation.
- Flexibility to adapt to new use cases and scenarios.
- Ability to upgrade hardware without changing the software.
- Open APIs and a wide range of suppliers, with the freedom to select the right hardware and software.
- Increased average revenue per user.
- Reduced TCO through the use of off-the-shelf hardware and software.

Intel's vision, technology and deep ecosystem experience and relationships can help build the next generation of programmable networks that help operators rapidly innovate, adapt and differentiate.

Learn More

You may find the following resources helpful:

Intel® Technologies
- Intel® Tofino™ Expandable Architecture
- Intel® Tofino™ Intelligent Fabric Processors (Intel® Tofino™ IFPs)
- Intel® Xeon® Scalable processors
- Intel® Ethernet Technology
- Intel® FPGAs
- Intel® Infrastructure Processing Units (Intel® IPUs)
- Intel® Silicon Photonics

Other Resources
- OpenBNG webinar
- P4 open source programming language
- SONiC operating system
- Press Release of Vodafone and partners in world first multi-vendor test of new broadband standard

For more information, contact your Intel representative and visit **intel.com/fabric**.

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[1] Point-Topic, "Global Fixed Broadband Take-up Forecasts by Technology for up to 2030: Fibre Rules," https://www.point-topic.com/post/global-fixed-broadband-2030

[2] Dell'Oro Group, April 2021. "Telecom CapEx 2020" blog.

[3] For more information on the TIP, visit the 2016 news release and the TIP home page.

[4] Testing by Intel as of 7/28/2021. vBNG Server: Intel® Server System M50CYP Family, 2x Intel® Xeon® Gold 6338N processor (32 cores, 2.2 GHz), 16x 32 GB DDR4, Solidigm D3-S4510 SSD (480 GB), 4x Intel® Ethernet Network Adapter E810-2CQDA2. Software: Red Hat Enterprise Linux 8.2, vBNG 20.11, Docker v20.10.5 build 55c4c88, DPDK-v20.11, BIOS = SE5C6200.86B.0020.P24.2104020811, microcode = 0xd0002c1, P-state disabled, Intel® Hyper-Threading Technology = ON, C-states disabled, Intel® Turbo Boost Technology = OFF, SR-IOV and Vtd enabled. For additional configuration details and discussion, read the white paper, "Re-Architecting the Broadband Network Gateway (BNG) in a Network Functions Virtualization (NFV) and Cloud Native World."

[5] A typical data center-focused switch offers hundreds of Mbits of table memory https://www.intel.com/content/dam/www/central-libraries/us/en/documents/tofino-product-family-brochure.pdf and hundreds of Mbytes of buffer capacity https://www.linleygroup.com/mpr/article.php?id=12304 Intel® Stratix® 10 MX FPGA comes with 8 GBytes or 16 GBytes of HBM2 memory https://cdrdv2.intel.com/v1/dl/getContent/652451 offering 50-100x more memory capacity.