White Paper

Wireline Networks
Virtualized Broadband Network Gateway (vBNG)

Super-Charging Your Broadband Services with a Cloud-Native, Disaggregated Broadband Network Gateway

BENU NETWORKS

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Introduction

Consumer expectations and demands placed on Internet service providers (ISPs) are constantly shifting. Buying behavior and criteria have drastically changed in recent years; gone are the days when triple-play deals created great value to consumers and helped drive average revenue per user (ARPU) growth for service providers.

Today's residential subscribers are moving from triple-play bundles to single-play broadband access, which adds pressure for ISPs to create personalized, cutting-edge offerings that continue to impress consumers. Additionally, with the recent shift to working from home, enterprise-grade demands are being made on home networks. Residential consumers need the same high quality, reliable, and secure connectivity that they would expect from an enterprise network. And enterprises need cost-effective solutions to measure employee productivity and mitigate the onslaught of phishing and malware attacks being directed at distributed workforces.

Providing these capabilities can prove difficult to achieve for most ISPs, which largely depend on, specialized hardware to manage subscriber sessions. The need to reduce operational and capital expenses adds an additional layer of complexity for ISPs to manage. Carriers are now deciding which path to take for their next-generation broadband network gateways (BNGs)—the traditional legacy, proprietary, and largely hardware-based approach or a new, open, largely cloud software-based approach using commercial off-the-shelf (COTS) hardware. With cloud-native software BNG architectures coming to the fore, carriers can start to achieve the economics and new services velocity that hyper-scalers enjoy.

The investor Marc Andreessen famously said, "Software is eating the world," and various manifestations of that thought are illustrated in Figure 1. For example, the traditional cell phone was a hardware device that had very little application software and minimal software upgradability, as opposed to enhanced smartphones, like the iPhone, which delivers functionality almost entirely as software. As a result, an individual iPhone can evolve over the course of years and expand its capabilities. Similarly, in cars, traditional car makers provided a hardware device with limited upgrades, whereas Tesla has taken a different approach, turning the car into a software-based computer that receives major upgrades and continues to evolve over time. The music industry has also evolved, from the radio to software-based platforms like Spotify that evolve continuously and tailor services to the individual user.

The above examples are designed to be more future-ready than their hardware-based forebears because software is so flexible. This software flexibility also enables more personalization, setting the stage for superior customer satisfaction and loyalty. Innovative carriers understand this transformation and are driving toward a software-based fixed access network that offers future readiness and the foundation for business innovation.

A Next-Generation BNG For Connectivity and Service Delivery

A BNG establishes and manages subscriber sessions by acting as the authentication point through which subscribers can connect to an ISP's broadband network. The BNG aggregates subscriber traffic from the access network and routes it to the ISP core network and the Internet. All traffic from the Internet passes through the BNG on its way back to the subscriber. Implementing a software-based, cloud-native BNG can help operators gain flexibility and provide an additional breadth of offerings, but it needs to be designed to support rapidly emerging converged network standards, use open and interoperable interfaces, and scale dynamically as needs change.

Traditional Hardware-Centric	New Software-Centric Approach
Traditional car • Constrained flexibility • Limited features • Replace for new capabilities	**Intelligent car** • Ultimate flexibility • Broad array of advanced features • Upgrade for new capabilities
Traditional cell phone • Limited to hardware capability • Limited evolution over time • Closed system	**Smart Phone** • Software based • Massive evolution via major software upgrades • Open to thousands of apps
Traditional radio • No evolution over time • No personalization • Limited user experience	**Music streaming service** • Evolves, unbound by hardware limitations • Highly personalized • Customer loyalty
Hardware-based BNG • Limited to chipset capabilities • Limited services • Closed system	**Benu software-based BNG or hybrid** • Built to evolve, achieving future-readiness • Add-on services: teleworker, SD-SASE, etc. • Open system • Third-party service chaining for "any service" support

Figure 1. Hardware-based BNGs are limited to what the hardware supports. Software BNGs are future-ready for services or edge computing that will be required as 5G-like services come to fixed networks. A hybrid software BNG with hardware acceleration is another option that provides flexibility along with low-cost bandwidth scaling.

The Benu Networks Virtual Broadband Network Gateway (vBNG) offers advanced subscriber management, dynamic routing capabilities, advanced services, and a robust set of analytics that empower ISPs to become more agile and scalable to meet current consumer demands. Its cloud-native, disaggregated architecture offers advantages to operators as they look to the future and plan to deliver new, exciting services on top of the broadband connectivity they deliver to subscribers.

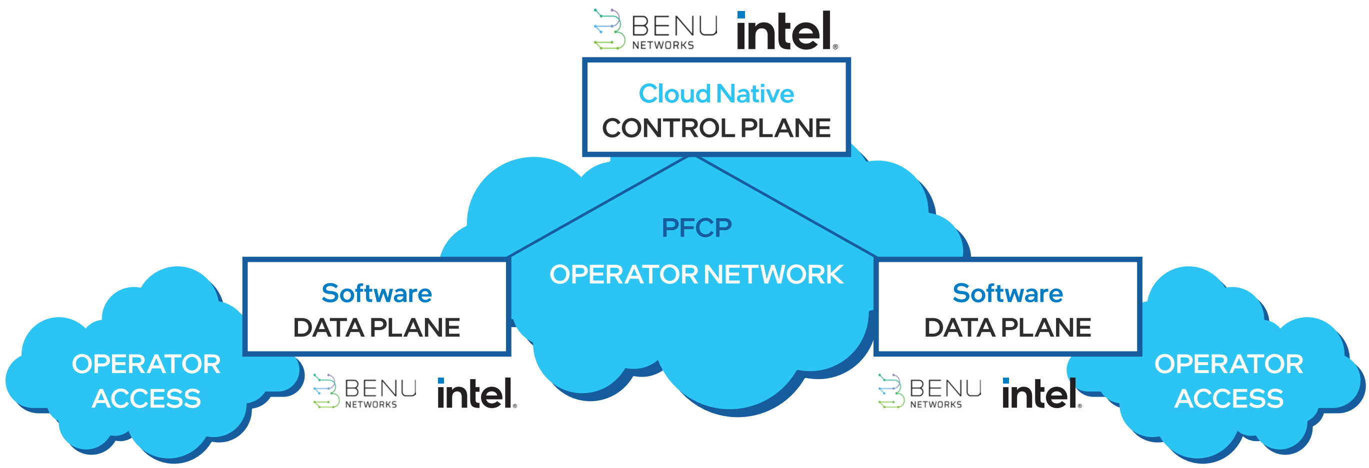

Figure 2. The Benu vBNG supports control and user plane separation (CUPS). In addition, Benu and third-party services can be layered on top to differentiate the broadband service, drive increased revenue, and increase customer loyalty.

The containerized Benu vBNG helps service providers reinvigorate their offerings and rapidly achieve agility, service delivery, and cost efficiency. Here's how:

Agility, Flexibility, and Scale

- Cloud-native design offers speed, adaptability, easy scale-out for growth, and true in-service upgrades.
- Separation of the control and data planes enhances flexibility and interoperability, as shown in Figure 2.
  - Mix and match user planes as needed, such as one control plane communicating with both new and existing user planes in the existing aggregation or Central Office location.
  - New user planes can easily be added to the access edge or at the aggregation data center on an as-needed basis.
  - Using this approach, the user planes can be deployed to match the service they are enabling (for example, Internet, Industrial IoT, enterprise security), enabling the path to fixed access slicing.

Future-Ready Design for Services and 5G

- Designed for network convergence and equipped for 5G wireless and wireline convergence.
  - Traditionally fixed and mobile networks have been two separate entities within service provider networks; these are coming together with the 3GPP and BBF collaborating on convergence standards.
  - Figure 3 shows how the BNG evolves to be an AGF and UPF with the same access network functions, hierarchical QoS, and provider edge core routing functions, but with 5G control plane interfaces (N1 and N2) to the 5G AMF and SMF.
- The solution is software-based, providing the ability to support any service in the future, in contrast to hardware-based BNGs that are limited by the hardware ASICs inside them.

Reduce Network Cost and Increase Network Efficiency

- Offers the ability to reduce costs and increase efficiency by moving the BNG closer to the subscriber edge. Layered-on CDN services can shift closer to the subscriber as well and reduce overall network cost significantly, given that 50 percent of broadband traffic is from CDNs in many carrier networks.
- CUPS architecture helps operators dynamically apply CPU resources, resulting in better efficiency and cost-effectiveness. The user plane from mobile/5G and fixed line can be combined to increase cost efficiency.
- With the Benu vBNG, cost-effective low-scale BNGs can be deployed at the edge, making it easier to reduce network traffic to the data center, support services that require extending the subscriber LAN to the BNG, deliver low latency, provide user-centric services, and reduce overall cost.

Reinvigorate Offerings and Expand Revenue Streams

- The Benu vBNG offers user-aware services that can be layered on top, such as Teleworker SD-SASE, a combination of SD-LAN, SD-WAN, and SASE for enterprise workforces and other types of IP Services; third-party solutions can also be service-function-chained into the solution (see Figure 2).
- Since these services can run in the access edge or aggregation point, service providers can optimize delivery for the best user experience; with low latency and high bandwidth, service providers can provide a consistent user experience across 5G, fixed line, and Wi-Fi access.

Better User Experience

- Operators can regain the ability to surpass subscriber expectations with cutting-edge services and high-speed connectivity that can be rapidly activated to reduce churn.
- Moving the vBNG closer to the edge offers lower latency and higher network speeds for optimal user experience.
- The Benu vBNG makes it possible for operators to offer subscribers control of their bandwidth, set policies by device (IoT management), and more.

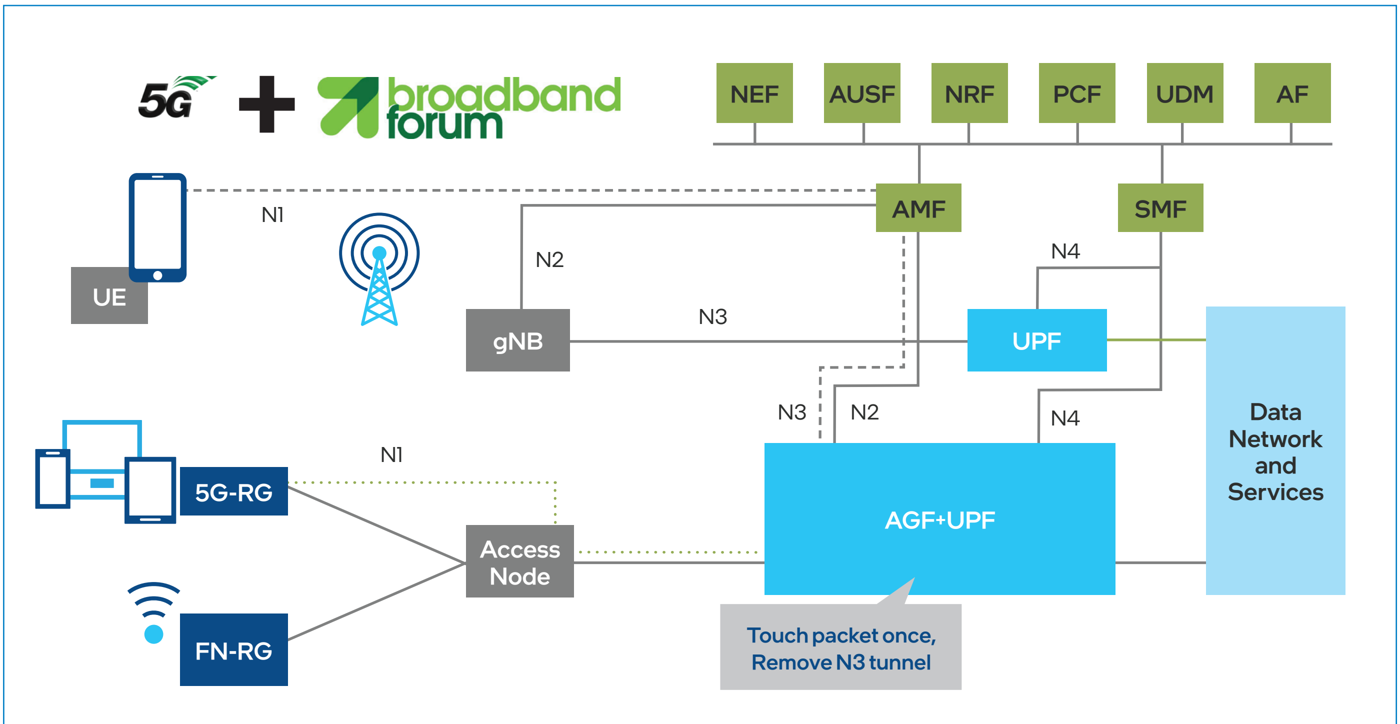

Figure 3. 3GPP and Broadband Forum (BBF) have collaborated to define the evolution of the BNG to a 5G AGF for Wired Wireless Convergence (WWC). By integrating a UPF with the AGF, there is no need for the N3 interface overhead (and its GTP tunnels), and touching the packet only once reduces costs and packet latency.

Deployment Architecture

The Benu vBNG can be deployed in a variety of ways, including software-only (the primary focus of this paper), using hardware-offload, and using a hybrid mix of software and hardware. The software-only, container network function deployment for both the control and user planes is the most flexible option, as shown in Figure 4. This approach enables ISPs to provide network functions in a cloud data center environment that can scale up and down as needed.

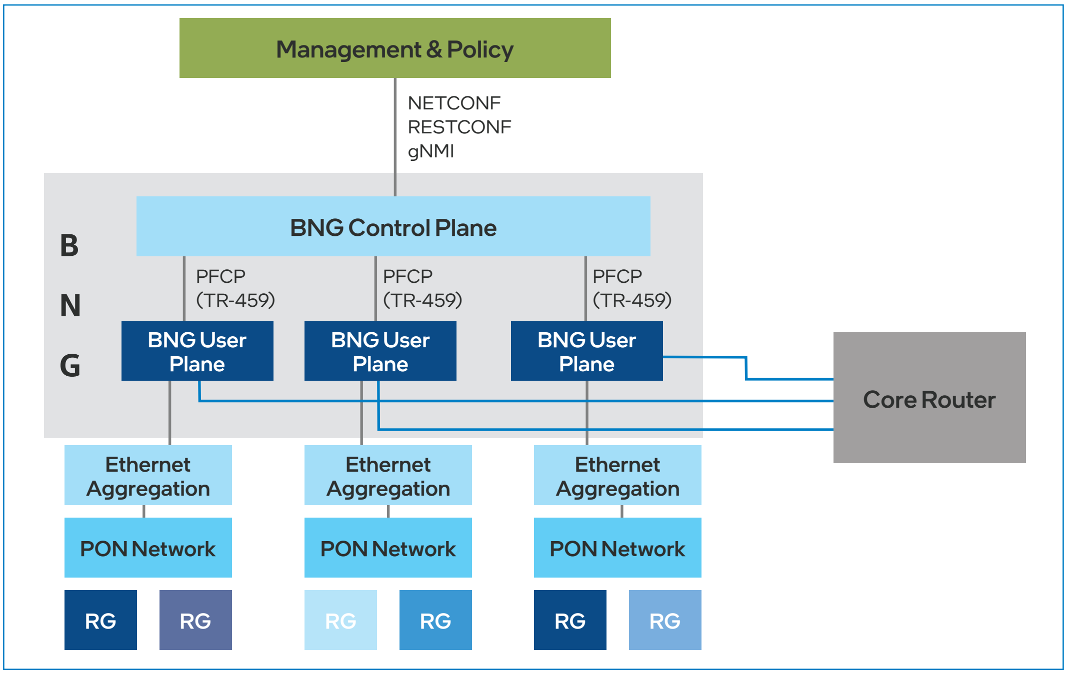

Figure 4. Cloud-native containerized network functions with disaggregation of user plane and control plane. Standards-based PFCP or ONF's Tassen is used between the control and user planes, which could be physically near, or far from each other.

The Benu vBNG software user plane can be deployed as two core containers and in configurations as large as multi-socket 40+ cores containers. The user plane is smart enough to recognize its available interfaces, memory, and available CPUs, and it adjusts its capacity to optimize efficiency and performance. Distribution of functional cores within the user plane is adjusted based on the vBNG functions that are enabled, such as Network Address Translation (NAT), Hierarchical QoS (H-QoS), Security, Analytics, and Debugging to optimize user-plane throughput and latency.

A software-only model fully implements all the packet processing functions of the user plane, including H-QoS in software, where user-plane data cores schedule packets out of queues based on the priority and bandwidth allocation for the services for each subscriber.

Achieving Performance—Benu and Intel Technology Collaboration

Benu Networks and Intel have co-engineered a solution that increases throughput and optimizes overall performance of the user-plane dedicated data cores. Through this collaboration, the vBNG software user plane has seen tremendous increases in throughput per core from both software and hardware improvements. Benu has achieved outstanding cloud-native performance using the combination of Intel® Xeon® Scalable processors and the Data Plane Development Kit (DPDK).

Benu vBNG takes advantage of Intel Dynamic Device Personalization (DDP) technology (which is built into the Intel Ethernet Controller E810), as illustrated in Figure 5. DDP enables deep inspection of packet headers and sophisticated load balancing to optimize utilization of the available Intel Xeon processor user-plane data cores.

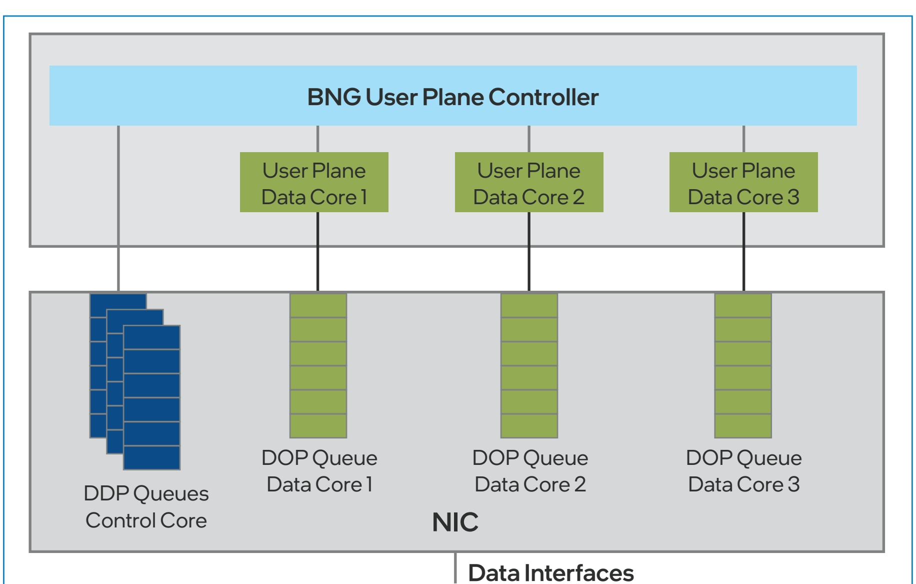

Figure 5. Utilizing Intel Dynamic Device Personalization (DDP) for load balancing and user plane and control plane performance optimization.

Further enhancements have been made in the BNG pipeline using DPDK libraries, processor cache alignments, and non-uniform memory access (NUMA)-aware design, as shown in Figures 6 and 7. This approach has allowed many new services and features to be implemented in the pipeline without impacting performance and latency, as illustrated in Figure 8.

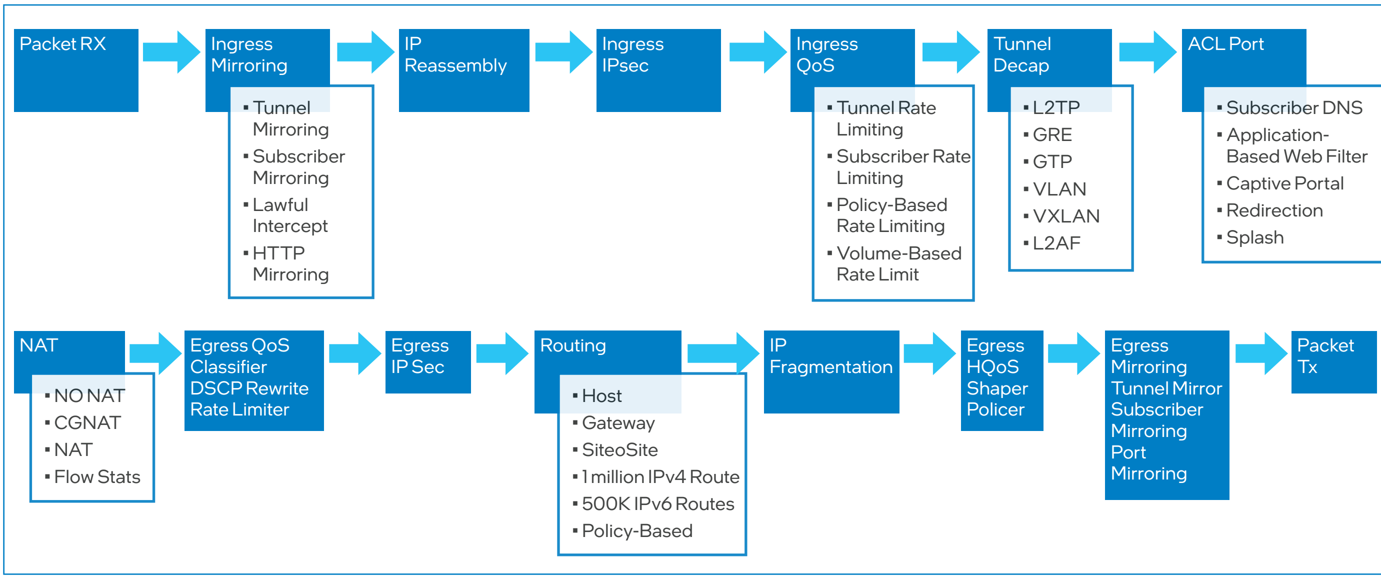

Figure 6. Upstream pipeline in Benu BNG.

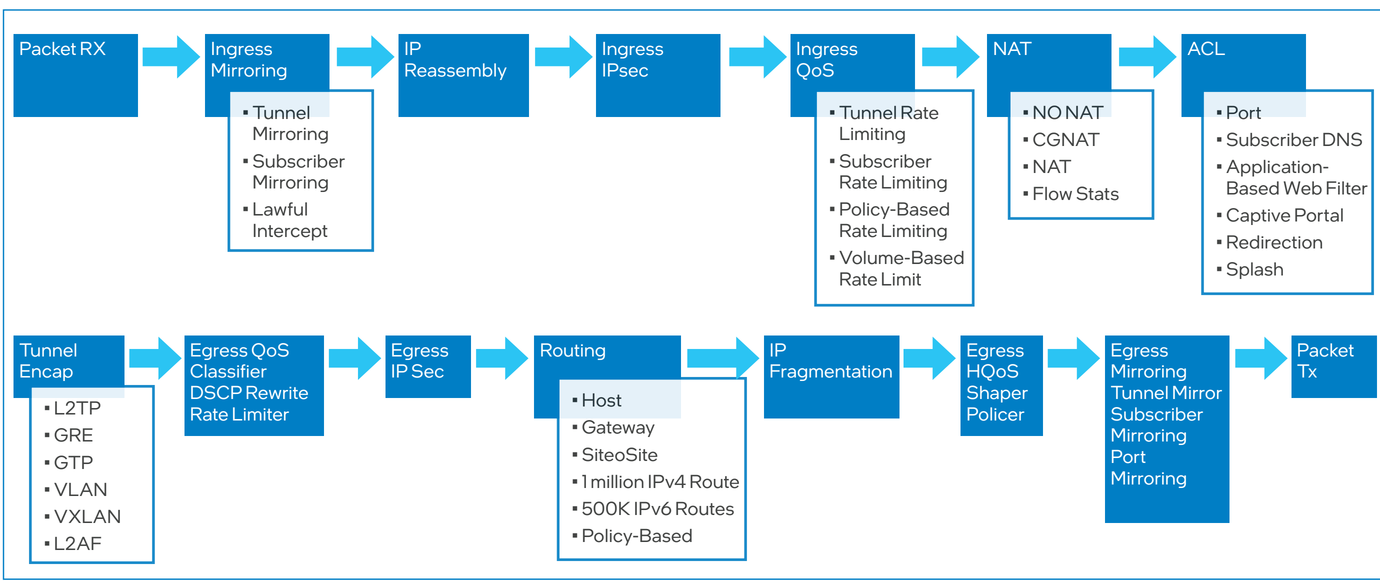

Figure 7. Downstream pipeline in Benu BNG.

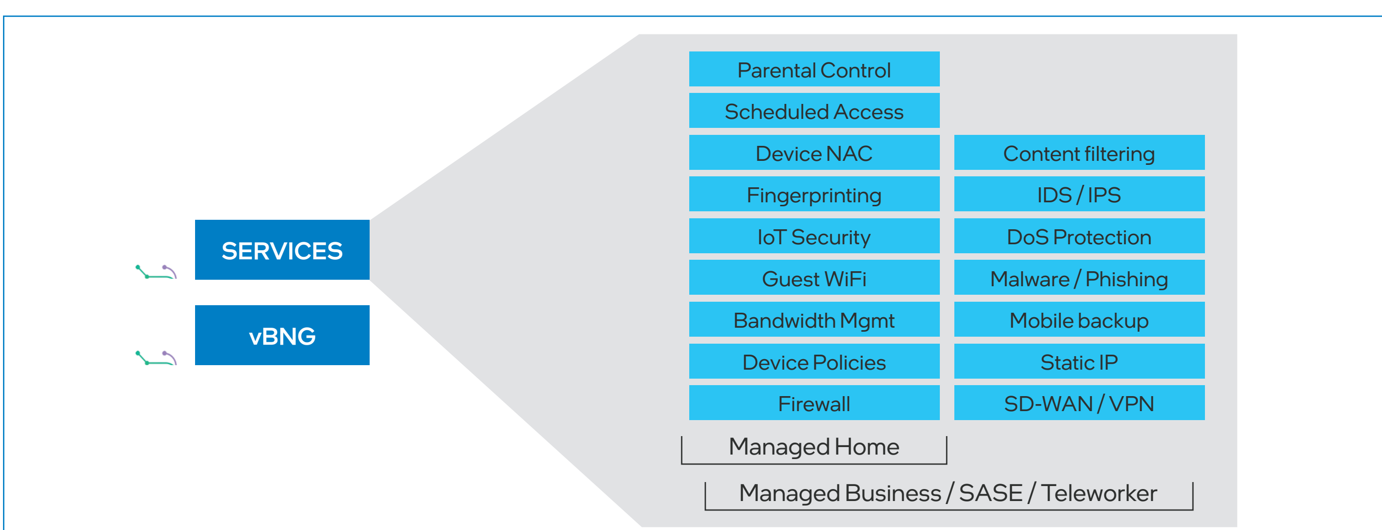

Figure 8. Layering on revenue-generating services for homes, teleworkers, and businesses.

Performance Testing

Performance testing was conducted to gauge per-core packet performance of the software vBNG pipeline with services in a real-world scenario, using the setup shown in Figure 9. The adoption of DDP on the Intel Ethernet Controller E810 allows Benu to better scale performance with Intel Xeon processor cores.

Traffic Profile Description:

- Ixia was used to simulate 40,000 Point-to-Point Protocol over Ethernet (PPPoE) clients and upstream/downstream traffic for the clients. Clients were attached at a rate of 2000 per second.
- All results were captured at IXIA as packet per second rates with less than 0.001 percent drops reported.
- Testing was performed with IMIX and different packet sizes of 64, 128, 256, 512, 1024, and 1500 bytes.
- The upstream to downstream traffic ratio was set to 1:9.
- The IMIX pattern used for the test was 40 percent 65-byte packets and 60 percent 1400-byte packets. This ratio resulted in an average IMIX packet size of 866 bytes.
- Web security filtering, including malware and phishing protection, was enabled throughout the system for the onboarded subscribers.
- Link-group was configured between the vBNG and next-hop router. BGP (Border Gateway Protocol) distributed the routes on the vBNG; 4000 ACL rules were enabled on the vBNG.

BNG User Plane Size

- Five vCPUs were used for the vBNG user plane to handle all subscriber traffic running as bare metal containers.
- Two vCPUs were used for the data plane controller to handle subscriber control plane traffic, configuration, and stats collections.

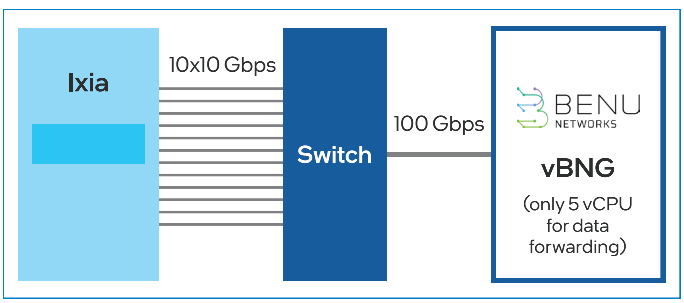

Figure 9. Test setup used Ixia test tools with a variety of packet sizes. The Benu vBNG was configured with QoS, BGP, 4K ACL rules, and web security including malware/phishing protection.

Results

Tests were conducted with a variety of configurations, access protocols, and traffic mixes. Benu has advanced its leadership tremendously during the past six years of development and testing of the SD-Edge platform, enabling optimized performance on Intel technology. Testing has varied the configuration, features, access protocols, and traffic mix. The results shown in Figure 10 are for five virtual user plane cores with PPPoE as the access protocol.[1] For additional test results, please contact Benu Networks.

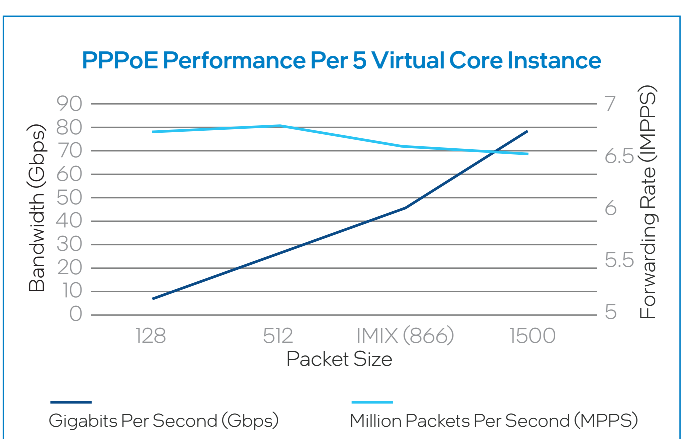

Figure 10. Bandwidth and forwarding rates were measured for a variety of packet sizes. Forwarding rate was nearly constant, as desired, even with larger packet sizes. Bandwidth varied due to packet size differences, and the most indicative result for a BNG deployment was the IMIX result showing nearly 50Gbps for every five virtual (2.5 physical cores). Thus, a 20-core platform with 40 vCPUs would theoretically support almost 400 Gbps, given sufficient I/O on the server.[1]

20-core platform: nearly 400 Gbps performance[1]

Table 1. Hardware and software system components.

Hardware	Server	Dell R740
	CPU	Intel Xeon Platinum 8180 processor
	Number of CPUs	2
	Number of cores used	4 cores (8 virtual cores with Intel Hyper-Threading Technology enabled)
Software	BIOS Profile	DDR4 @ 2666 MT/s, 512 GB
	vBNG	Ubuntu 18.04.2 LTS (bionic)
	HostOS	19.0.5
	DPDK version	Docker 20 based
	Container package	19.0.5

Summary

The vBNG virtualizes integral network functionality, empowering service providers to seamlessly transition to a cloud-based, 5G-ready network. Benu Networks' technology simplifies network optimization, helping service providers rapidly scale their offerings, manage their networks, and safeguard the service experience, as illustrated in Figure 11. By disaggregating legacy network structures and eliminating hardware dependencies, service providers can modernize their networks, reduce costs, and improve the customer experience.

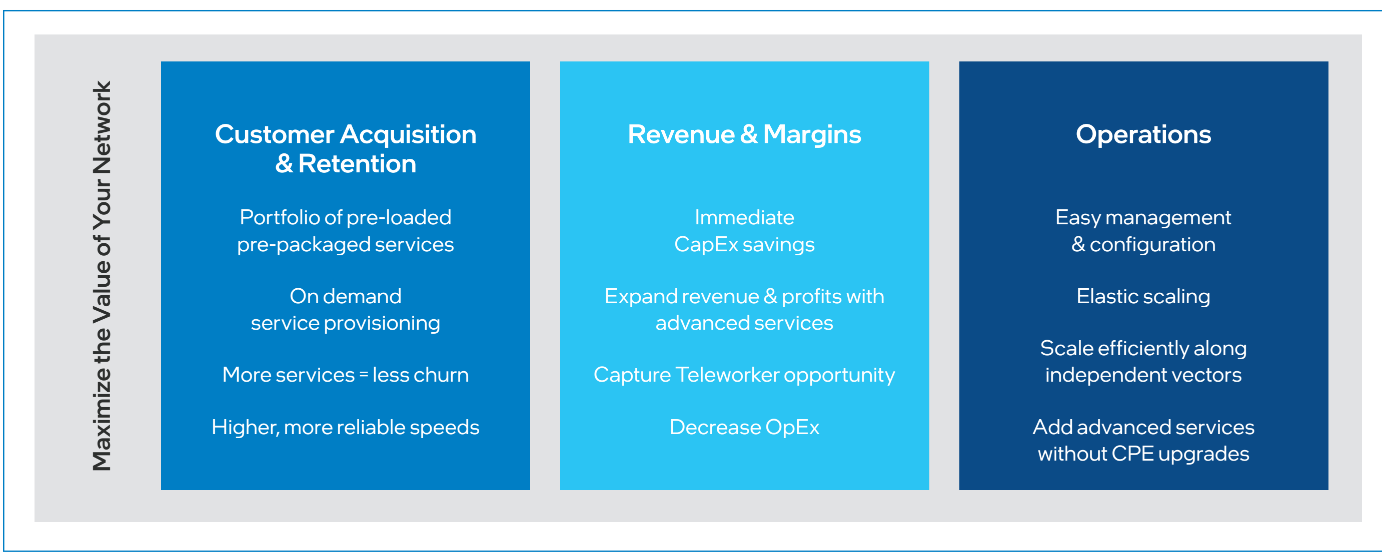

Figure 11. Operators are choosing Benu's SD-Edge vBNG because it provides exceptional performance, low capex and operational costs, flexible deployment models (big/small, CUPS or integrated, elastic scaling), is fully disaggregated from hardware dependencies, and natively supports advanced services like Teleworker SASE, IoT, Gaming or other network slices. It meets today's requirements and can scale for future demands.

Benu's vBNG user plane pipeline uses many of the Intel technologies that have helped improve overall per core throughput and reduce latency in high-throughput environments. DDP support on the Network Interface Card, when available, is used for load balancing PPPoE and Internet Protocol over Ethernet (IPoE) traffic within the user plane cores so that all available cores are highly utilized. The optimized H-QoS DPDK library, Intel Hyper-Threading Technology, and cache alignment of data structures helps improve core usage, overall performance, and system latency. Furthermore, flexibility to add services to the vBNG pipeline when the user packet is already open, enables differentiated revenue-generating services with minimal impact on overall cost. These services can be implemented as network slices and include the following:

- Teleworker SD-SASE solution
- Business Site SD-SASE
- Managed Home Networks (MHN), including IoT and gaming
- Multi-Dwelling Unit (MDU) solutions

The Benu vBNG not only provides the robust infrastructure required for today's fastest broadband networks, but also a strong ROI for any carrier's business.

Acronym Glossary

3GPP: 3rd Generation Partnership Project

AGF: Access Gateway Function

AMF: Access and Mobility Management Function

ARPU: Average Revenue per User

ASIC: Application-Specific Integrated Circuit

BBF: Broadband Forum

BGP: Border Gateway Protocol

BNG: Broadband Network Gateway

CDN: Content Delivery Network

COTS: Commercial Off-the-Shelf

CPE: Consumer Premises Equipment

CPU: Central Processing Unit

CUPS: Control and User Plane Separation

DPDK: Data Plane Development Kit

GPRS: General Packet Radio Service

GTP: GPRS Tunnelling Protocol

H-QoS: Hierarchical Quality of Service

IoT: Internet of Things

ISP: Internet Service Provider

LAN: Local Area Network

MDU: Multi-Dwelling Unit

MHN: Managed Home Networks

NAT: Network Address Translation

NIC: Network Interface Card

NUMA: Non-Uniform Memory Access

ONF: Open Networking Foundation

PFCP: Packet Forwarding Control Protocol

QoS: Quality of Service

ROI: Return on Investment

SASE: Secure Access Service Edge

SD-LAN: Software-Defined Local Area Network

SD-SASE: Software-Defined Secure Access Service Edge

SD-WAN: Software-Defined Wide Area Network

SMF: Session Management Function

UPF: User Plane Function

vBNG: virtual Broadband Network Gateway

vCPU: virtual Centralized Processing Unit

WWC: Wired Wireless Convergence

[1] Benu release: Benu-MEGApp-REL-8.2.0.2
Date of Test - March 2, 2021
Place of Test - Benu Networks lab located in Burlington, MA

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