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Broadband evolution for cloud-connected living

Differentiated residential broadband services in the era of the cloud and the Internet of Things

White paper

Smart connected devices in our home and on our person are playing an increasingly important role in our daily life. Reliable and ubiquitous broadband services are indispensable in this new era of cloud-connected living and the Internet of Things.

In addition to satisfying demand for more capacity, better coverage and greater connectivity, broadband providers realize they must also rethink their value proposition as consumer needs evolve. In this context several innovative technologies have emerged with the capability to seamlessly enhance the broadband service experience with value-added, on-net cloud services.

This paper discusses the key trends and technologies that are shaping the evolution of residential broadband, and their role in ensuring profitable growth and competitive differentiation.

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Navigating a changing landscape

We are entering a new era of connected living that is characterized by smartphones, smart homes and smart TVs that rely heavily on cloud-resident content and applications. Average broadband speeds have tripled over the past five years, and streaming video now accounts for over 70 percent of North American downstream traffic in the peak evening hours on fixed access networks.

Smart devices in our home and on our person are playing an increasingly important role in our cloud-connected lifestyle, and the average broadband home easily contains a dozen connected devices. Smart homes add a whole category of additional devices that require cloud connectivity for home security and automation, smart energy management, climate control and digital healthcare. Nokia Bell Labs estimates that by the end of 2017, 3.9 billion people will be online and 70 billion things will be connected to the internet.

With so many people and devices relying on the cloud, broadband access has become indispensable. Consumers expect fast, reliable and seamless broadband services to stay connected, whether at home or on the move. While millennials have embraced the cloud, Netflix, social media and everything digital, they have no patience for technical issues and simply expect things to work. And even the most savvy broadband users can use some help in setting up their smart home and protecting themselves against the countless security threats, internet scams and technology pitfalls.

As consumer needs evolve and more user value shifts to the cloud, broadband providers must rethink their business strategy and value proposition. While reliable and affordable high-speed internet (HSI) access is the staple of any broadband service offering, ultimately it has a commodity business model that doesn't inspire consumer loyalty. Because nearly all broadband traffic flows off-net to the internet cloud, there is both a missed revenue opportunity and an added cost.

By enhancing their offering with differentiated, value-added on-net services, broadband providers can become more relevant to their subscribers and improve returns on their network investments. With a presence in the home, as the trusted gateway to the internet, and with a local support and services infrastructure, broadband service providers are uniquely positioned to meet evolving consumer needs with on-net cloud services in ways most web scale providers can't.
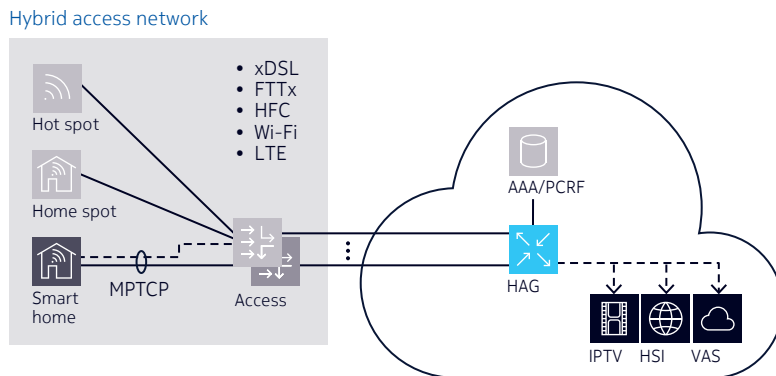
Reliable and ubiquitous broadband

Consumers in the cloud era want to enjoy broadband content not only at home, but also when visiting a neighbor or friend's home, a local bar or a coffee shop. Reliable and ubiquitous broadband access is a must-have for cloud-connected living. And as IP video usage increases and video resolution improves to high and ultra-high definition quality, the primary challenge for broadband providers is addressing demand for more capacity and expanded broadband service reach while improving reliability and lowering service costs.

Expanding broadband capacity to the home

Bringing more capacity to the home requires investments in faster wireline access technologies such as G.fast, TWDM-PON, Ethernet PON (EPON) and converged cable access platforms (CCAP). Wireless access services such as 4G/LTE and Carrier Wi-Fi may enhance coverage where wireline access technologies fall short due to local loop throughput limitations. By enhancing the broadband network gateway (Broadband Forum TR-101) to a hybrid access gateway (HAG) with multipath TCP (Broadband Forum TR-348, section 5.4.3) support (see Figure 1), wireline and wireless access capacity can be combined to optimize reach for high-bandwidth services such as 4K (ultra-HD) video. Moreover, leveraging diverse physical access media provides redundancy for single points of failure, improving service availability for smart home security applications, home offices and small businesses.

Figure 1. Expand access capacity and reach

Hybrid access network

- xDSL
- FTTx
- HFC
- Wi-Fi
- LTE

Hot spot
Home spot
Smart home
MPTCP
Access
AAA/PCRF
HAG
IPTV   HSI   VAS

The next step is to bring the benefits of faster broadband access to the digital home. This is achieved through gigabit home networking technologies such as concurrent dual-band Wi-Fi 802.11b/g/n and 802.11ac. Providing managed Gigabit Wi-Fi® services in the home is important for several reasons. According to ABI Research, about 80 percent of all traffic originates or terminates indoors[1], and the vast majority of broadband connectivity issues in the

1   ABI Research press release, Jan. 11, 2016.
     https://www.abiresearch.com/press/abi-research-anticipates-building-mobile-data-traf/

home are caused by poor Wi-Fi reachability. Managed Wi-Fi services help prevent and troubleshoot connectivity issues, and avoid potential problems that may arise when consumers operate their own wireless router.

Broadband home spots and hot spots

Offering managed Wi-Fi in the home also enables the introduction of home spots, which provides visiting guests an easy and safe way to use broadband services without needing to obtain the security credentials of their host. Similarly, the broadband access provider can deploy smart carrier Wi-Fi technology to extend the home spot concept to hot spots such as restaurants, bars and other public venues to let subscribers access their home network and cloud services without needing to communicate service set identifiers (SSIDs) and passwords, or pay mobile data roaming fees (see Figure 2).

Figure 2. Roaming broadband usage at home spots and hot spots
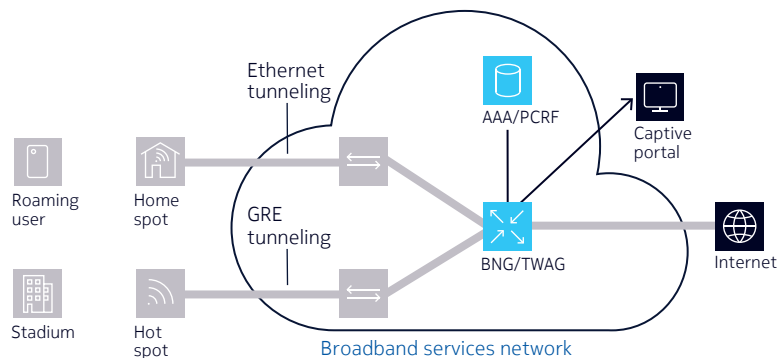
A trusted wireless access gateway (TWAG) enables subscribers to access broadband services at home spots or hot spots such as restaurants or stadiums without requiring any provisioning. The TWAG function can be provided stand-alone or integrated in the BNG. Ethernet frames from home spots are tunneled over IP to support transparent operation of the existing access network, and may use various encapsulation methods such as soft-GRE (Generic Route Encapsulation) or soft-Layer 2 Tunneling Protocol, version 3 (L2TPv3) to enable zero-touch provisioning at the TWAG. Native Ethernet traffic from hot spots typically uses GRE (v4/v6) or GRE over IPsec tunneling techniques using a VLAN for each SSID.

Home services and hot spot services can be deployed using nationwide open SSIDs in combination with a captive portal or by using closed SSIDs. With an open SSID, the AAA function does a first authentication and subsequently redirects the user to a captive portal to accept the service conditions. The closed SSID model works with a dynamic session database (Policy and Charging Rules Function [PCRF]). Both home spots and hot spots broadcast the SSID, with the AAA function selecting the appropriate EAP-PEAP or EAP-SIM authentication method.

Scaling IP video and live TV delivery

A key challenge is avoiding network congestion during prime time when IP video consumption peaks and can seriously stress network resources, especially at the BNG and internet peering points where bandwidth is shared among many users. Content delivery network (CDN) technology addresses this issue by caching popular video content closer to viewers at the network edge (see Figure 3).

Figure 3. Scaling delivery of IP video and live TV services with Nokia Velocix
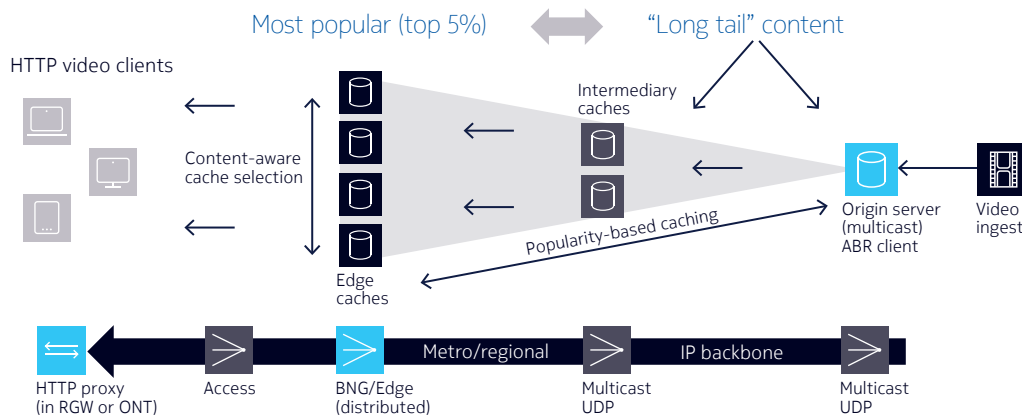
An on-net CDN improves delivery quality and lowers transport costs for unicast IP video delivery. State-of-the-art CDN solutions such as the [Nokia Velocix Media Delivery Platform](#) also support multicast-assisted Adaptive Bit Rate (mABR) technology to enable scalable live TV streaming to HTTP clients. This technology leverages NORM (NACK-Oriented Reliable Multicast, defined in RFC 5740 and RFC 5401) and FLUTE (File Delivery over Unidirectional Transport, defined in RFC 6726) and consumes 2 to 10x less capacity in the access network compared to unicast video delivery.

Smart homes and the Internet of Things

The average family home in developed markets easily contains up to a dozen connected devices, such as computers and laptops, smartphones and tablets, smart TVs, media players and game consoles. The Internet of Things (IoT) emerges as digital homes become smart homes with a plethora of additional networked devices and appliances to enable home security and automation, smart energy management and climate control, digital healthcare, and so on.

Market forecasts for the smart home market predict global revenues will amount to nearly USD 17 billion in 2017, with an annual growth rate of 33 percent over the next 5 years. By 2021 this would result in a market volume of USD 79 billion with a household penetration of 15.6 percent.[2]

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2   www.statista.com/outlook/279/100/smart-home/worldwide#)

Connected device management

Smart digital homes offer many potential benefits, but consumers struggle with the many options and the resulting complexity of managing a home network with dozens of connected smart devices. By enhancing the BNG with virtual Residential Gateway capabilities, broadband providers can augment their service offerings with network-enhanced services and device management for the smart digital home (see Figure 4).

Figure 4. Smart digital homes and smart connected devices
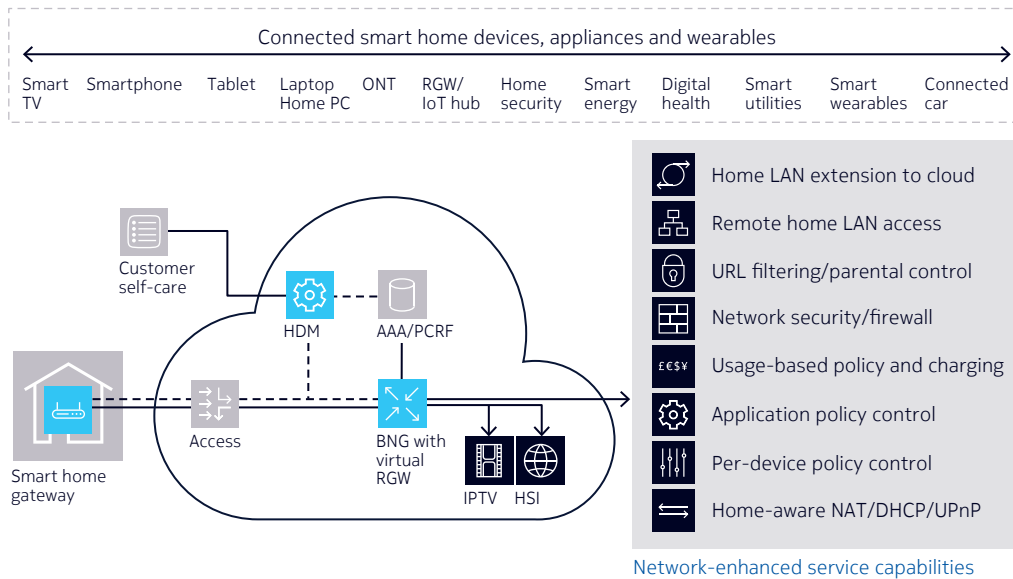
The first challenge is managing the digital home network and gaining visibility and control as more devices are connected, compete for available bandwidth, and add to management complexity. The home network is typically aggregated behind a single IP address on an Ethernet port of a residential gateway or network terminal provided by the broadband service provider. Consumers often operate a separate wireless router behind the broadband modem to extend connectivity in the home, in combination with optional smart hubs for smart home solutions. However, do-it-yourself home management can easily overwhelm the average broadband consumer, which leads to more customer support issues and increased customer care costs.

The broadband provider can enable a plug-and-play smart home experience with user self-management capabilities by introducing a smart home gateway with web-based home device management (HDM). Smart home gateways typically combine a residential gateway and a smart home hub or adapter with multi-standard Wi-Fi and IoT support protocols such as the ZigBee® Wireless Standard, Z-Wave and Bluetooth® Low Energy (BLE), which together cover the vast majority of IoT devices.

The Nokia 7368 ISAM ONT G-240WZ-A smart home gateway also integrates a Gigabit passive optical network (GPON) optical network terminal (ONT) and on-board POTS, USB 3.0 and Gigabit Ethernet interfaces to provide a one-box solution for the home that can save service providers and consumers considerable time and effort to make correct and compatible choices themselves.

Home device management provided by the Nokia Connected Device Platform (CDP) encompasses services that make it easier for consumers to successfully install, operate and maintain their home network without requiring a technician to come to their house. The Nokia CDP can be used to install home devices, monitor their operation and troubleshoot issues, including Wi-Fi connectivity. This makes the broadband service experience simpler and more user friendly while saving on customer care and support costs.

Virtual residential gateway and network-enhanced services

The virtual residential gateway (vRGW) architecture defined in Broadband Forum standard TR-317 is a key enabler for reducing the complexity of the home network and introducing network-enhanced services that address device-specific application needs. Device awareness adds a much-needed level of control granularity and differentiation because it enables subscribers to personalize their broadband service for individual users and devices that share the home network.

A vRGW (vG or virtual Gateway in TR-317 terminology) is a logical network element that is instantiated on a physical or virtualized network platform and either decoupled from or integrated with the BNG. A vRGW instance can be associated to a single home or multiple homes (multi-dwelling units).

Network traffic to and from the physical residential gateway in the subscriber home is bridged to an associated vRGW instance via a logical subscriber link (a software tunnel) that is established in overlay of the IP over Ethernet (IPoE) or Point-to-Point Protocol over Ethernet (PPPoE) subscriber session. This allows moving Layer 3-Layer 7 RGW functions such as IP routing, DHCP/DNS, firewall and Network Address Translation (NAT) to the virtual RGW in the network cloud, which reduces functional dependencies on the home gateway while enabling a seamless integration of network-enhanced services.

Even more important than the benefits of moving some functions out of the home gateway are:

• Reduced complexity in the home network and better visibility on connected host devices

• Reduced life-cycle management because fewer hardware variants of home gateways are needed

• Increased service velocity because new services can be introduced on a network-wide scale without needing to touch the installed base of residential gateway devices.

Nokia Bell Labs estimates that virtual residential gateways can reduce the cost of service fulfilment, assurance and life-cycle management up to 40 percent and result in 5-13 percent higher gross profit margins[3].

Device-awareness and application policy control

Application policy control applies Layer 4-Layer 7 deep packet inspection (DPI) capabilities in the data path to enhance, assure and protect the user experience of specific types of applications. Combining device awareness with application policy control enables further differentiation of the broadband experience for individual subscriber host devices. Application policy control can be implemented as an enhanced function of the BNG or as a VNF in overlay (see Figure 5).

Figure 5. Application policy control
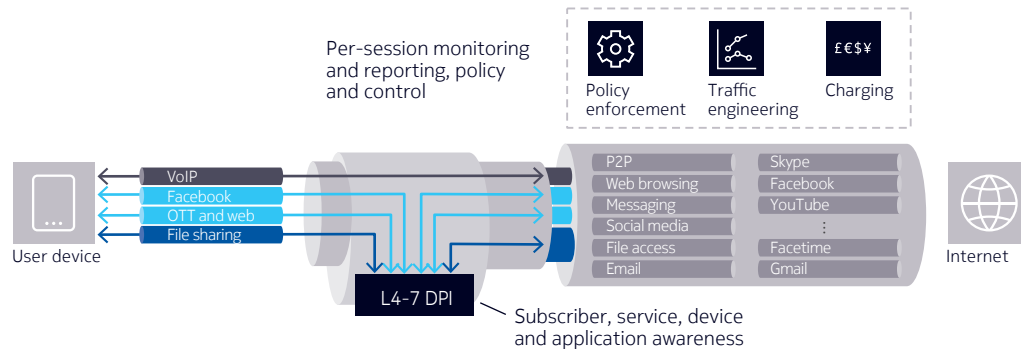
Device and application policies can be applied selectively at different levels of granularity to broadband traffic pertaining to:

- An entire subscriber home

- Specific connected host devices such as a smart TV, tablet or personal computer

- Application groups such as peer-to-peer file transfer, web browsing or social media

- Individual applications such as Skype, YouTube or Facebook.

Device and application policies can be provisioned in various ways. The broadband service provider may provision them as part of a value-added service selection, for example, to zero-rate video traffic that is part of a TV Everywhere subscription; enabling usage monitoring for volume-capped internet services, or filtering black-listed URLs as part of a parental-controlled or legally safe internet service. Alternatively, broadband consumers may customize their broadband experience by setting appropriate device and application policies through the use of a self-service web portal.

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3   Nokia, "The case for a virtualized residential gateway", Page 3, financial white paper, 2016.
     http://resources.alcatel-lucent.com/asset/190361

Application policy control also enables advanced control features such as HTTP header enrichment to automatically authenticate broadband subscribers with connected cloud solution partners. Another use is to establish a two-way communication with the consumer by means of in-browser notifications or HTTP redirection to captive web portals, for example to alert users on data cap limits, copyright issues, perceived security risks or service promotions.

The Nokia implementation of application policy control is called Application Assurance and is part of the Nokia Service Routing Operating System (SR OS). It implements all the previously mentioned use cases in addition to stateful Layer 7 firewall and traffic analytics to measure the volume and performance of applications.

Network-based security services are more effective than security software on user devices because they protect all devices using the internet service and are less easily compromised. The services can stop volume attacks in the network to avoid a consumer's uplink becoming congested or losing connectivity. Moreover, misconfigured security software on consumer devices often causes unintended broadband connectivity issues.

Adding value with on-net cloud services

Traditional broadband services are similar to a ferry service transporting user traffic from the home to the internet. Consumers pay to get to the internet in the fastest and most economical manner because the cloud is the final destination that delivers the experience and value they look for. As more user value is going off-net and over-the-top (OTT), the challenge is to sustain profitable growth.

When introducing on-net cloud services, the traditional broadband service model becomes more like that of a cruise ship. Like the ferry, it provides transport to off-net destinations, but it also offers a value-added service experience to on-net consumers. On-net cloud services contribute revenues that would otherwise be going OTT and are less costly to facilitate because they don't incur off-net peering and transport costs. Moreover, a compelling on-net service experience can become a competitive differentiator that attracts consumers and makes them stay.

Home LAN extensions

Home LAN extension is a valuable on-net service enabler with various applications. "Home anchoring" seamlessly extends the home LAN to other locations such as Wi-Fi home spots and hot spots. Home anchoring is enabled through home LAN extension in combination with a vRGW, and enables a roaming user to securely connect from a home spot to the home LAN.

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Home LAN extensions can be combined with dynamic traffic steering and service function chaining (SFC) to seamlessly integrate on-net cloud and data center services in the home network environment (see Figure 6).

Figure 6. Home LAN extension to home spots and on-net cloud infrastructure
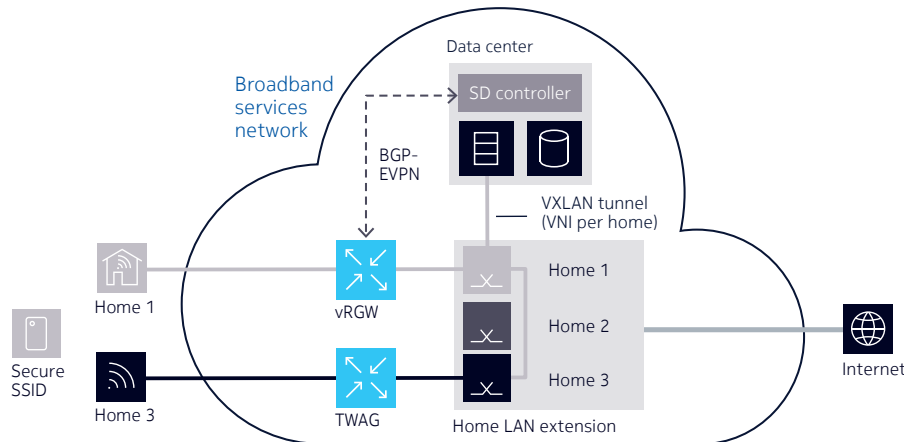
Using home LAN extensions with dynamic traffic steering to Virtual Extensible LAN (VXLAN) tunnels makes cloud services and resources appear as if they reside locally on the home LAN. This enables Digital Living Network Alliance (DLNA)-capable home devices to connect with DLNA servers in the cloud, access Server Message Block (SMB)-based file storage in the cloud as a Network Attached Storage (NAS) medium, or enable cloud-based media streaming with Apple® AirPlay® through Bonjour/mDNS.

Due to their closer proximity to end users, on-net cloud services benefit from lower transport cost (less network hops) and better performance (lower latency) compared to cloud services delivered from off-net data centers. On-net cloud traffic can be managed separately from internet traffic, and due to device-awareness and the home LAN extension concept, there is typically no need for additional apps or for software clients to be installed on the user device to use the service.

Traffic steering and service function chaining

The introduction of on-net data centers introduces a new cloud services edge with myriad ways for developing differentiated opt-in services by inserting various value-added service functions in the user data path. The two key concepts that enable this are traffic steering and SFC as defined in Broadband Forum TR-345, section 6.1.2. A service function chain defines an ordered set of abstract service functions and ordering constraints that must be applied to the user traffic as a result of service classification.

Service functions can act at various layers of the OSI protocol stack, and can be realized as a virtualized element or embedded in a physical network element. They typically enable L4-7 processing-intensive, opt-in service capabilities such as firewalls, application policy control and filtering, TCP load-balancing and carrier-grade NAT (CG-NAT).

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Figure 7. Traffic steering and service function chaining
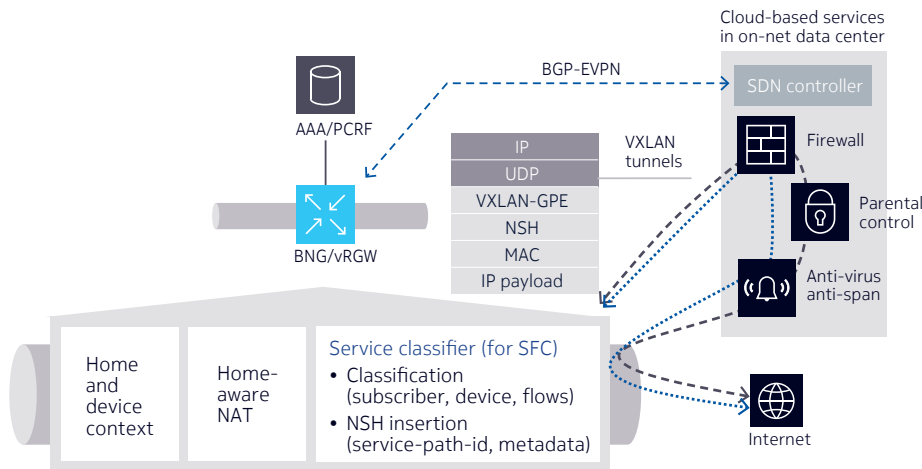
When specific devices or device groups subscribe to an opt-in service, the vRGW instance acting as the service classification function (SCF) inserts the appropriate classification and Network Service Header (NSH) information, and dynamically steers their traffic in the appropriate VXLAN tunnel to the on-net data center. The NSH includes a specification of the service path, which is used to direct the user's service traffic to the appropriate virtual machines that implement the service functions specified in the service chain.

After the user flow has traversed all functions in the service chain, the vRGW reinserts the rendered traffic into the data path and forwards it.

Managed and hosted on-net cloud services

While broadband service providers need to get cloud savvy, build out their on-net data center infrastructure and acquire the tools for zero-touch service delivery, they can leverage the strategic advantages of being a trusted gateway to the internet to build a better and safer user experience for cloud services. Managed on-net cloud services are all about adding value to broadband services where you can, and facilitating OTT cloud services where you must:

- The simplest and easiest services are on-net cloud services such as network-attached storage, which provides a better alternative to Dropbox™ or Google Drive™.

- On-net compute services are an alternative to owning and maintaining a desktop PC. They are a residential variant of Amazon Web Services™ that enable broadband subscribers to remotely access a virtual machine in an on-net data center and use it as a personal cloud computer.

- Smart home solutions and support services offer a better alternative for do-it-yourself and cloud-based solutions. They typically require physical devices that need to be installed in the home and connected by a broadband service. Broadband service providers can leverage their existing presence in the home, in combination with local support and installation services.
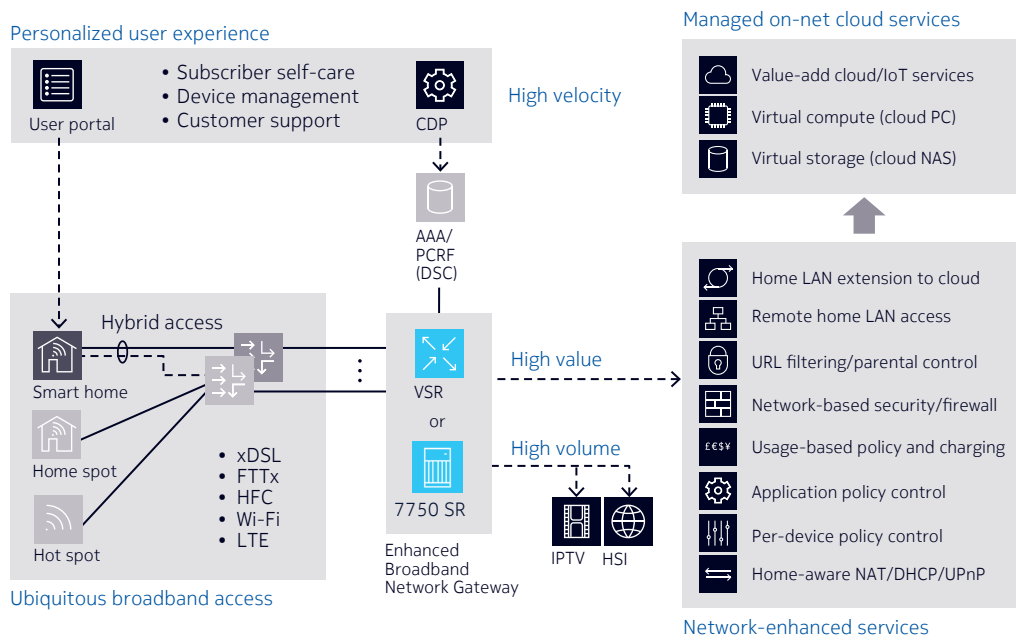
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Broadband service providers can partner with cloud technology providers such as Apple, Microsoft, Google or Amazon to create these on-net services, and collaborate with cloud application providers by hosting complementary services on-net. On-net hosted application solutions reduce delivery costs while improving application performance. For consumers, it adds a level of convenience, trust and recourse when a cloud service is actively supported and endorsed by their broadband provider. The objective is to make the broadband network the first and foremost destination while providing a safe and satisfying experience when visiting off-net destinations in the internet cloud.

Conclusion

In this era of connected living, broadband services are indispensable to connect our smart homes, smartphones and smart cars to the cloud. Broadband networks need to evolve and be enhanced with the necessary device- and application-aware service capabilities that enable consumers and service providers to manage a plethora of consumer devices as part of the Internet of Things.

Nokia offers the key technologies, solution components and operational expertise needed to evolve current triple play and quad play broadband service offerings to value-added, network-enhanced services and on-net cloud applications that are essential for cloud-connected living (see Figure 8).

Figure 8. Nokia solution for residential broadband evolution

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The cornerstone of the solution is the Broadband Network Gateway with several enhancements that are supported on specialized hardware such as the Nokia 7750 Service Router (SR) family and/or the Nokia Virtualized Service Router (VSR).

Through various functional enhancements, this solution can help you:

- Optimize reach, coverage and capacity for high-bandwidth services by leveraging a hybrid access strategy that uses fixed, wireless and 5G fixed-wireless access technologies in combination with multipath TCP
- Offer consumers reliable and ubiquitous access for their smart homes and smart devices to the cloud, and keep them connected at home spots and public Wi-Fi hot spots
- Optimize cost and performance of IPTV and HSI, and differentiate with managed on-net services that are device-aware, network-centric and cloud-enabled
- Enable consumers to customize their broadband experience from anywhere with comprehensive home network management, and dynamic and granular self-service control capabilities.

The result is a cost-efficient, high-velocity service delivery and support model that makes cloud-connected broadband services a reliable, responsive and effortless consumer experience.

References and resources

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Acronyms

AA	Application Assurance
AAA	Authentication, Authorization and Accounting
ABR	Adaptive Bit Rate
API	application programming interface
BGP	Border Gateway Protocol
BNG	broadband network gateway
CDN	content delivery network
DHCP	Dynamic Host Configuration Protocol
DNS	Domain Name System
DPI	deep packet inspection
DSL	digital subscriber line
EAP-PEAP	Extensible Authentication Protocol-Protected Extensible Authentication Protocol
EVPN	Ethernet virtual private network
FTTx	fiber to the anyplace
GRE	Generic Route Encapsulation
HAG	hybrid access gateway
HDM	home device management
HFC	hybrid fiber-coax
HSI	high-speed Internet
IETF	Internet Engineering Task Force
IoT	Internet of Things
IPTV	Internet Protocol television
L2TP	Layer-2 Tunneling Protocol
LAN	local area network
LTE	long term evolution
MAC	media access control
MPLS	Multiprotocol Label Switching
MPTCP	multipath TCP
NAS	Network Attached Storage
NAT	Network Address Translation

NFV	network functions virtualization
NSH	Network Service Header
ONT	optical network terminal
OSI	Open Standards Interconnection
OTT	over-the-top
P2P	peer-to-peer
PCRF	Policy and Charging Rules Function
POTS	plain old telephony service
PPPoE	Point-to-Point Protocol over Ethernet
RGW	residential gateway
SDN	software-defined networking
SFC	service function chaining
SSID	service set identifier
TCP	Transmission Control Protocol
TWAG	trusted wireless access gateway
TWDM-PON	time and wavelength division multiplexed passive optical network
UDP	User Datagram Protocol
UPnP	Universal Plug and Play
VAS	value-added services
VLAN	virtual LAN
VNF	virtualized network function
VoIP	Voice over IP
vRGW	virtual residential gateway
VXLAN	Virtual Extensible Local Area Network
VXLAN-GPE	VXLAN-Generic Protocol Extension
xDSL	any digital subscriber line

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