ERICSSON

VIRTUAL HOME GATEWAY

Monetizing Residential Services and Implementation Models

Rev PA3

CONTENTS

Glossary

A list of acronyms used in this document,

- 3GPP — 3rd Generation Partnership Project
- 6RD — IPv6 Rapid Deployment
- AAA — Authentication, authorization, accounting
- ADSL — Asymmetric Digital Subscriber Line
- AN — Access Node
- AP — Access Point
- ASP — Application Service Provider
- BCG — Broadband Cloud Gateway
- BGF — Border Gateway Function
- BNG — Broadband Network Gateway
- CDN — Content Delivery Network
- CGNAT — Carrier Grade Network Address Translation
- CLIPS — Connection Less Internet Protocol services
- CPE — Customer Premise Equipment
- DHCPv4/v6 — Dynamic Host Configuration Protocol v4/v6
- DoS — Denial of Service
- DPI — Deep packet Inspection
- DSLAM — Digital Subscriber Line Access Multiplexer
- DS-Lite — Dual-Stack Lite
- EFS — Evolved Flow Switch
- GPON — Gigabit Passive Optical Network
- HGW — Home Gateway
- IGMP — Internet Group Management Protocol
- IPoE — Internet Protocol over Ethernet
- ISP — Internet Service Provider
- L4-L7 — Layer 4 to Layer 7 protocol stack
- LAN — Local Area Network
- LI — Lawful Intercept
- M2M — Machine to Machine
- MAC — Media Access Control
- MSAN — Multi-Service Access Node
- NAPT — Network Address Port Translation
- NAT — Network Address Translation
- NAT44 — Network Address Translation IPv4 to IPv4
- NAT64 — Network Address Translation IPv6 to IPv4
- O&M — Operations and Maintenance
- OLT — Optical Line Termination
- OTT — Over The Top
- PC — Policy Control
- PGW — Packet Gateway
- QoS — Quality of Service
- RAN — Radio Access Network

• RIP	Routing Information Protocol
• SDN	Software Defined Network
• SCCF	Service Chaining Control Function
• SSR	Smart Services Router
• STB	Set Top Box
• TCO	Total Cost of Ownership
• uPnP	Universal Plug and Play
• URL	Uniform Resource Locator
• vHGW	Virtual Home Gateway
• VLAN	Virtual Local Area Network
• VoIP	Voice over Internet Protocol
• VM	Virtual Machine
• VNI	Virtual Network Identifier
• VR	Virtual Router
• VXLAN	Virtual Extensible Local Area Network
• WAN	Wide Area Network
• xDSL	x Digital Subscriber Line

Introduction

Home Gateways have been the central element of Residential broadband services for several years for the Operators. Home Gateways connect the WAN side network to the Home LAN network and provide the operational demarcation point between the Home network (Home LAN) and the WAN. Thus it supports at least one WAN-side interface and one or more LAN interfaces that connect to the host devices at the residence. From an evolution perspective, what started off as a simple modem has been growing in complexity with support for a variety of interfaces, routing and bridging functions and a variety of personalized subscriber services delivered to homes. Throughout this evolution, the home gateway has held its place as a service delivery and service demarcation device at the residence and supported such mass-deployment functions as auto-configuration, remote firmware update and remote management. However with the increasing number of new services delivered to the home user over multiple devices, Home Gateways have also been growing in functional complexity. The ubiquitous spread of broadband, increase in last mile bandwidth and most importantly, the increase in the number of connected devices have resulted in a slew of requirements in terms of new features, new interface types, higher speeds, advanced functionalities and new services. The increasing complexity and Operations and Management overhead this brings to the Operators have fuelled the trend to virtualize some of the complex home-gateway functions; thereby, simplifying the operational aspects of the Home Gateways for the Network Operator.

Home Gateways

Home Gateways provide a plethora of functions for the Home use. Most home gateways today support several of the following functionalities:

- Gigabit Ethernet capability
- Integrated 802.11n AP, backward compatible with 802.11b/g
- Integrated VoIP function support (G.711 and G.729)
- Local Bridge
- Basic routing (static, Ripv1, Ripv2) support – Ipv4 and IPv6-ready
- IGMP v1/v2/v3 snooping support for IPTV service
- DHCP Server/Relay
- UPnP
- CDN

- NAT/NAPT, Firewall
- BGF
- Security (with stateful packet inspection, DoS protection, etc)
- QoS
- Remote Management Functions

New services such as Home automation, Home Security, Smart metering and energy control services require additional functions. Such new functions cause an ever-increasing upward pressure on the overall cost of the Home Gateways, which include cost of the device, installation, operation and maintenance plus field upgrades when required to add new capabilities. Complexity in home network gateways means a costly point of failure for broadband services. The Hardware-Software combinations in the millions of installed Home Gateways are an impediment to Time to Market; new services to be introduced need to take into account the home gateway device legacy, model, version and functions supported which means it is hard for operators to quickly roll out new services on a network-wide basis.

Now all this has to be viewed in the context that in bundled services, Home Gateways are often offered free, thus getting subsidized by the expected future revenue potential. Putting together, these factors have provided the key drivers for the operators to reduce the overall cost of Home Gateway by moving some of the complex functions into a central location through a virtualization approach. This serves to remove service introduction bottlenecks, and increase the agility of home services delivery.

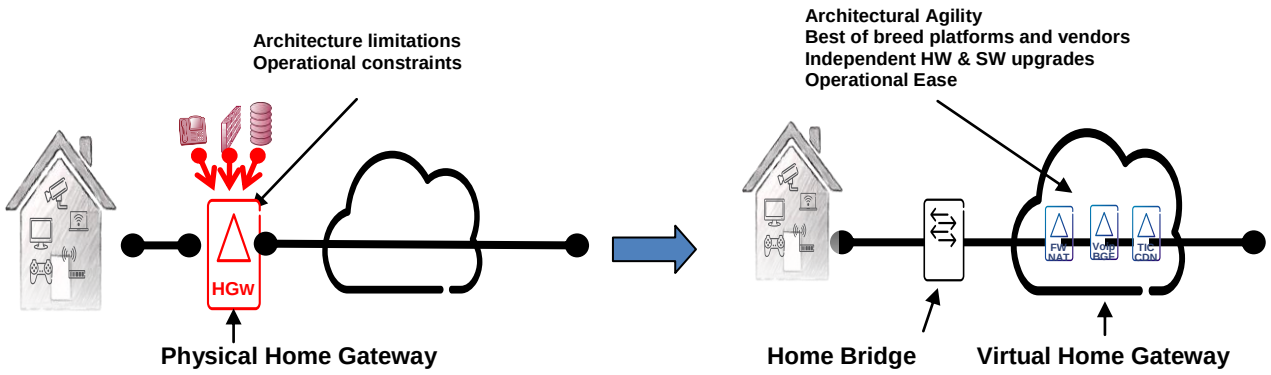
Virtual Home Gateways

Virtual Home Gateway (vHGW) is the home gateway component that is located remotely at the network, providing a remote virtual termination point for the Home LAN. With its unique centralized awareness of subscriber, home devices, network status and services contracted, Virtual Home Gateways turn the home broadband triple-play connectivity of the operators into a multi-play access opportunity. Virtual Home Gateways are applicable to DHCP based IPoE architectures.

Virtual Home Gateways (vHGW) have been under discussion for several years now. Lately, the momentum has been increasing as virtualization and cloud based services begin to take hold, making the virtualization of HGW a central technology for residential service delivery. Virtual Home Gateways (vHGW) are also viewed as a highly effective solution for new services based on Machine to Machine communications such as Smart Metering, Home Security, Health Care, Smart appliance and the emerging smart home services.

Virtual Home Gateway approach moves the complexity out of the HGWs into the network. Complex Home Gateway functions are moved to be co-resident with the Broadband Network Gateway Function. Thus functions such as NAT, DHCP, Firewall, CDN, UPnP, BGF are all removed from the Physical Gateway and become network resident virtualized functions but associated intelligently with each subscriber context. Physical Home Gateway in this case becomes a simple bridge (Home

Bridge), removing the architectural limitations associated with extending complex services over it and the resultant operational constraints. Operator will be able to configure some parameters remotely through a management interface on the Home Bridge.



Evolution from Physical to Virtual Home Gateway

Virtualizing the above functions at a central gateway location also helps in central provisioning and scaling the services. In addition, It facilitates enhanced agility for new service introduction, flexibility in implementing service changes, independent hardware and software upgrades and ease of troubleshooting in case of service failures.

Virtual Home gateway Transformation

How can broadband operators benefit from this vHGW transformation?

Let's start with the Smart or Connected Homes. A few years ago, a single subscriber premise gateway had to aggregate a small number of devices, such as computers and a printer. In contrast, in addition to several computers and printers, today's Smart or Connected Homes may have as many as twenty or more powerful smart devices, such as several high-definition SmartTVs, smart set top boxes, several high-definition multiplayer gaming consoles, multiple tablets, multiple smartphones, cloud-based network attached storage, and one telephone or several voice applications in the iPod/ iPad/ iPhone), even smart thermostat and smart home security system which may include high-definition home closed-circuit TVs.

Subscriber behavior patterns have changed as well. Being surrounded with so many smart devices has inevitably increased the usage of productivity applications as well as entertainment applications. Many parents have struggled to balance this usage.

While the proliferation of these new devices and shift in behavior patterns pose new challenges, broadband operators can benefit immensely by providing different levels of services, either for value-added or revenue enhancing purposes. Deployment of vHGW provides a new foundation for the broadband operator to participate actively in the value chain, such as:

- Aggregation points for thermostat, utility meters and home security system.
- Operator hosted portal for parental control service based on time of day per device, metered device usage, metered application usage, website tracking and even provide the higher bandwidth for VPN and cloud traffic.
- Centralized virus suppression and website reporting that monitor activities within the home networks and alert of any rogue devices or usage.
- Tiered services based on the number of devices and provide service assurance based on device characteristics. For example:
  - Tie tiered bandwidth service to a fixed number of devices. Offer granular and personalized services per device as additional services.

- Small bandwidth with constant bit rate service for telephone or any voice applications running on iPods, tablets and smart phones
- Constant bit rate and high-bandwidth service for high-definition multi-player gaming consoles
- High-priority for VPN and cloud traffics from computers and tablets.
- High-bandwidth for video traffic coming from smartTVs, closed circuit TVs, and any video applications from computers and tablets.

Monetization with Virtual Home Gateway

The benefits of the Virtualized Home Gateway Approaches to the top line revenue increase are tremendous. Some of them are:

- Granular Parental Control of any Home device
- Mobile Devices are always visible thus facilitating control over offload and Mobility between 3GPP and WiFi.
- Ease of introduction of new functionalities such as IPv6
- Personal Profile is now centrally manageable and thus enabling remote home/ visited home services
- Inter-home smart devices can be connected and be opened up to facilitate innovative 3rd party service provider applications (home security, home healthcare, utilities
- Cloud services such as network PVR can be easily extended into the Home LAN

From the Operators perspective, Virtual Home Gateway turns their broadband home access presence into a substantial service monetization opportunity. By enabling Cloud services into Home LAN, vHGW paves the way for extending cloud based services to their subscribers.

The virtual Home Gateway function would terminate the L2 home devices sessions and provide a path to the embedded services. These services can now be extended to the subscribers with service awareness, differentiated based on a combination of criteria such as Subscriber Contract, End Device Capability, Home User Category, Network Load and Fixed-Mobile convergence status. Perhaps more importantly, by enabling end-device visibility, virtual Home Gateways provide service visibility into Residential devices, in quite a similar way as 3GPP Mobile networks do for, 3GPP Mobile devices. This is important for the much-desired operator objective of participation in the OTT value chain. It can also facilitate unified control of Fixed WiFi and 3GPP devices.

VIRTUAL HOME GATEWAY- A TCO VIEW

Immediate benefits of implementing the Virtual Home Gateway concept include capital and operational expenditure savings.

Capital expenditure savings

Virtualized Home Gateways can considerably reduce capital expenditure due to less expensive home gateway devices to deploy. Gateways only need to provide bridging capabilities with VLANs and basic multicast and QoS features. A bridged device is far less complex than a routed device, and hence bears less cost.

In addition, existing deployed home gateways can be reconfigured to support bridged mode for vHGW compatibility. So no swap out of existing home gateway devices is required when transitioning to a vHGW deployment.

Operational expenditure savings

There will be significant operational savings from reduced handling of calls at the call center. An example of such comes from a major North American operator who recorded statistics of around 50-60% of calls to its call center that were due to customer configuration errors. By reducing the home gateway device to a simple bridge, it is estimated that a significant number of these calls would also be reduced accordingly.

Since new services can be enabled remotely at the Virtual Home Gateway function resident at a the centralized network location, Home Bridge devices do not need to be changed out when new services are deployed, resulting in reduced truck rolls. An example of this is when there is a requirement to support IPv6. All legacy home gateways deployed in the field may not support IPv6 and may not be software upgradeable, hence to upgrade them would mean field replacement – typically done by sending a new unit to the subscriber and requiring the subscriber to return the old unit. This clearly is an expensive and time consuming procedure. In the case of the vHGW scenario, the home gateway behaves simply as a layer 2 Bridge and therefore is not required to support IPv6.

In supporting IPv6, there also comes a complex requirement on these gateways. This situation requires one or more of complex implementation approaches such as NAT at the home gateway + dual NAT or CGNAT, DS-Lite or 6RD + tunneling. However with the introduction of the vHGW the situation will be greatly simplified - no NAT in the home gateway, no dual-NAT, no CGNAT, no vX/vY tunneling and no need for DS-Lite, 6RD, NAT44, and NAT64 in the BNG. Overall, the network architecture is greatly simplified making operational management much easier and far less prone to errors.

SERVICE WHOLESALING WITH VIRTUAL HOME GATEWAY

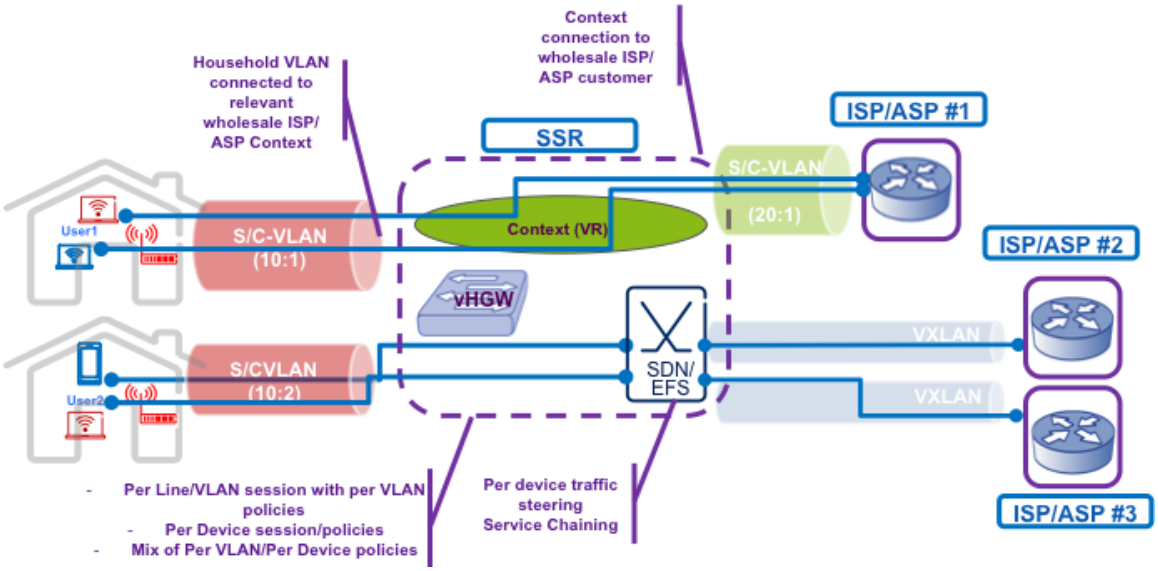
In the case where the household chooses to obtain its services from another service provider other than the network provider providing physical connectivity, wholesaling of services would be

required. One way to achieve this is to use individual Contexts (virtual routers) within the vHGW, which would be connected to each wholesale ISP/ASP customer.

The network provider or owner of the vHGW would terminate the devices from a household in a Context based on the ISP/ASP provider that the household has subscribed to. All the subscriber traffic in this Context is then steered to the relevant wholesale ISP/ASP. The wholesale ISP/ASP would in this instance supply the bridged home gateway to the household.

Another possible scenario is where different services within a household are obtained from different ISP/ASP's. In this case, the network provider or owner of the vHGW would terminate the individual device sessions, and then steer the session traffic to the relevant wholesale ISP/ASP. In this case there could be additional considerations to be taken into account such as definition of trust boundaries, service demarcation and SLA monitoring points.

Once device sessions are terminated at the vHGW, various methods to steer these individual sessions could be used, including the use of SDN, where an SDN switch (such as Ericsson's Flow Switch) could switch the subscriber sessions to the relevant wholesale ISP/ASP. In any case, SDN with EFS can simultaneously support both approaches – all household devices/services to a single ISP/ASP or different household services from different ISP/ASPs.



Wholesale service by household (User 1) and by device (User 2)

The figure above depicts an example of the two scenarios of per household and per device traffic steering of subscribers to the wholesale ISP/ASP customer, together with different examples for backhaul connection to the wholesale ISP/ASP customer. The Ericsson SSR router can function both as a vHGW and as an SDN EFS.

VIRTUAL HOME GATEWAY - ERICSSON SOLUTION

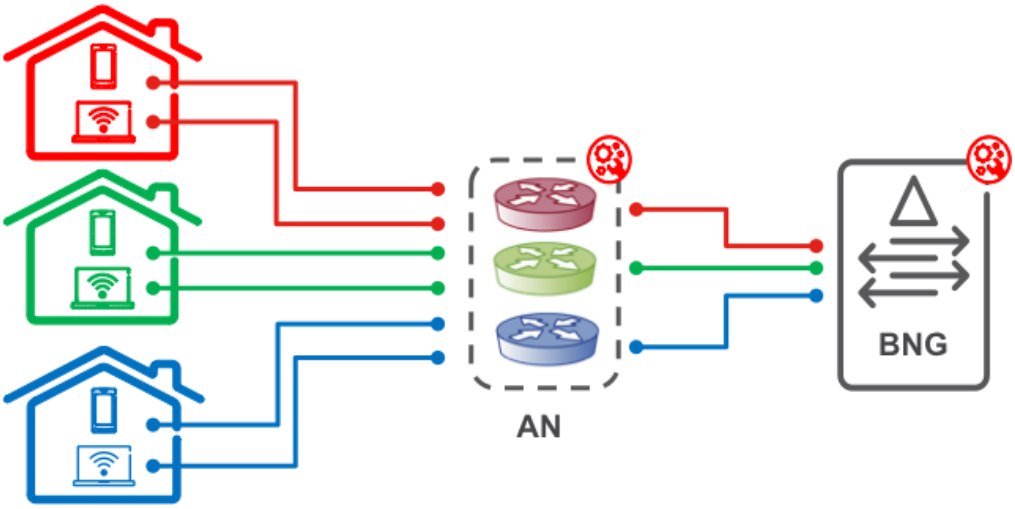
VIRTUAL HOME GATEWAY PLACEMENT

Having covered the benefits of moving the intelligence from the physical Home GW located to customer premise to the network, there are several locations that can be considered to implement the vHGW.

ACCESS NODE BASED VHGW

Placing the Virtual Home GW on the Access Node (DSLAM, MSAN, OLT) that has been positioned by some vendors as a time to market solution to implement vHGW, however it has the following challenges:

- Functional duplication of the subscriber related functions between AN and BNG
- Operational complexity of having provisioning/ QoS spread
- Limited platform flexibility (NAT, Security, Content Filtering typically not available on AN)
- Access agnostic challenge – ANs have different capabilities depending on the access type (xDSL, GPON, Cable)

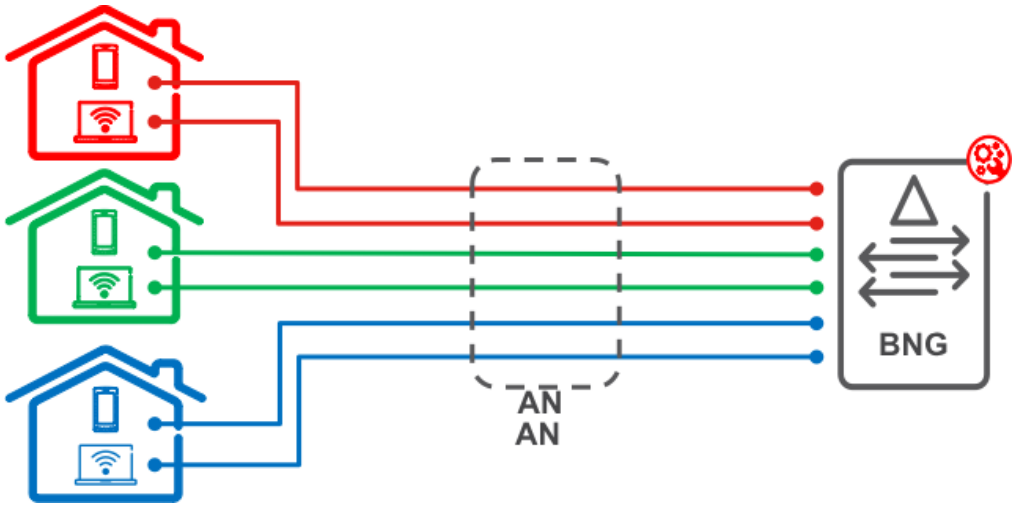


BNG BASED VHGW

For networks with high performance BNGs, the natural placement for the IP session management could be on the BNG itself. Having the BNG as a single control point for Virtual Home GW has the following benefits:

- Access agnostic (xDSL, Fiber, Cable)

- Homogeneous per user device / per line policies
- High Touch subscriber features like QoS / policies, LI, Accounting, Quota (time/volume), CGNAT

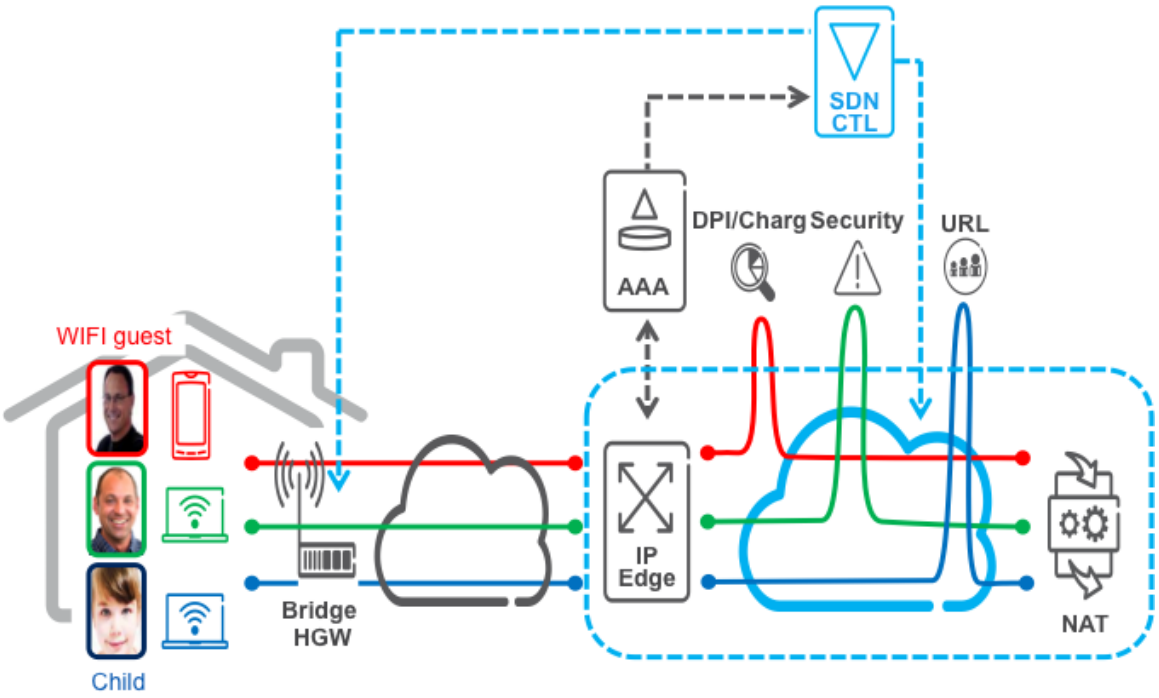


Moreover, the BNG can potentially be used to leverage L4-L7 Applications that are already implemented on the platform like DPI, Content Filtering and CDN/TIC.

CLOUD BASED VHGW

Even though the IP session management typically resides on the BNG, it is possible to leverage a Cloud infrastructure to virtualize the different L4-L7 functions (CGNAT, DPI, Security, CDN/TIC) instead of having them co-located in the BNG.

In that scenario a service chaining function is required in the network to apply the right chain of virtualized applications to a specific user/device.



SDN Controller can also be used to control the bridge Home GW to implement granular forwarding and QoS policies between device in the home or on the upstream.

The benefits of implementing virtualized apps versus physical apps are:

- Elastic capacity provided by the Cloud infrastructure (on demand spawning of new VM based on load
- Better usage resource on shared commodity hardware
- Operation savings through network automation provided by the Cloud Management
- Mix and match of vendors for Applications
- Dynamic flow offload (aka dynamic service chaining)

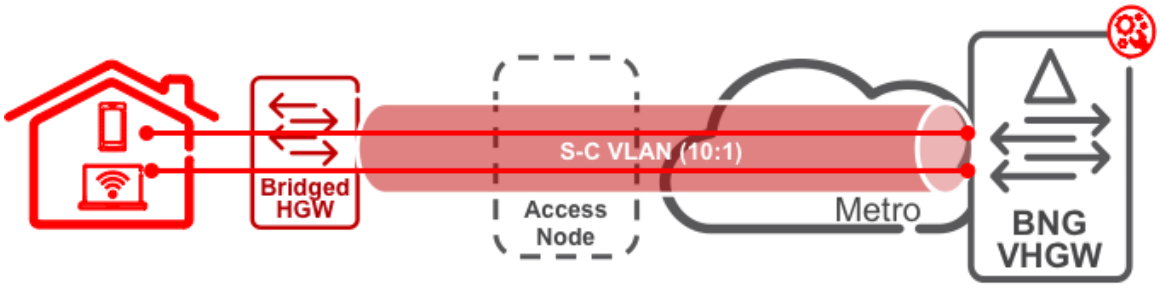
These benefits have to be balanced with the performance and reliability gains obtained by running these apps on dedicated optimized hardware.

VIRTUAL HOME GATEWAY -IMPLEMENTATION

ACCESS IMPLEMENTATION

In order to get direct visibility to the different home devices, the physical HGW is configured as a transparent L2 bridged CPE (Bridged HGW). In the future this bridged HGW could be remotely managed from a centralized SDN Controller to enable granular forwarding rules inside the home.

The Home network is identified by a unique SVLAN/CVLAN combination



Each Device at home gets a separate IPoE session. On the BNG this could be a CLIPS session with per session Authentication/Accounting and policies (QoS, LI).

The CLIPS session is triggered by DHCPv4 or DHCPv6 packet from the home device (laptop, Tablet, smartphone, STB), each home device getting a unique IP address. The Radius AAA Server provides the IP-Session level control with per IP session accounting (Traffic acct, IP address assigned, MAC@).

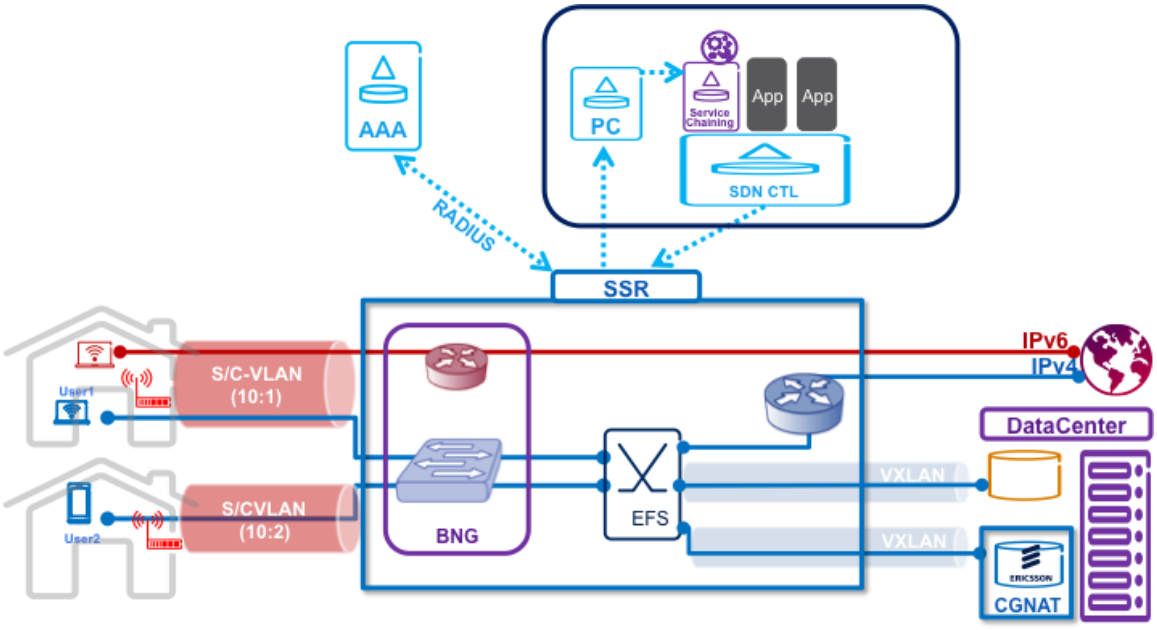
The different home devices are identified by their MAC address (IP address can overlap between homes). This enables a dual stack session to be treated as one session. The support of overlapping IP addresses across the different homes requires extending the BNG model by having virtual Global IP address per home, where the CLIPS sessions are identified by the combination of IP address and home identifier (the S/C-VLAN circuit).

At the same time, the home S/C-VLAN is also mapped to the broadband line session for the purpose of accounting/billing for the entire home, and the BNG handles a mix of VLANs and device sessions – policies can be set up per S/C-VLAN session or per device.

NETWORK AND SERVICE IMPLEMENTATION

For devices that just required direct Internet access, the traffic can be steered directly to the closest exit point. However for the majority of the subscribers, the traffic will be steered towards the appropriate chain of services implemented in the Data Center.

In conjunction with the Service Chaining Control Function (SCCF), the SDN Controller sets up dynamic, per device and application, service chains by programming the Evolved Flow Switch (EFS) component of the SSR using OpenFlow protocol.



The Policy Control (PC) Node is aware of the subscribers and devices and defines the policies. The traffic from the BNG to the Virtual Switch that provides connectivity to the Virtual Machine is tunneled using VXLAN with a unique Virtual Network ID's (VNI) per home that is set up by SDN controller.

CONCLUSION

In the Networked Society, connectivity will be the starting point for new ways of innovating, collaborating and socializing. With the advancement of smart devices, the world today is essentially on the cusp of M2M transformation. Ericsson predicts that by 2020, there will be 50 billion connected devices across many different industries. These include healthcare, transportation, logistics, automotive, education; shipping and mining, just to name a few. However, the most profound changes are in the enterprise, utilities and in our own homes. In the coming years, the telecom industry, especially the broadband operators stand to play a significant role as the middlemen between these devices and the services, by providing the connectivity to the cloud.

In this networked society, Virtual Home Gateway solutions will be playing an increasingly central role and will be a key facilitator in service innovation, service velocity and operational flexibility. The current virtualization and cloud-enablement movements will influence and drive the vHGW solution approaches. To strengthen this solution approach and to build additional flexibility, Ericsson is building SDN and Cloud based virtual Home Gateway solutions. These will facilitate multiple implementation options and offer increasing levels of deployment customizability. Ericsson is actively working at standards development organizations to standardize Virtual Home Gateway solutions and is engaged with operators around the world in vHGW implementation planning, solution design, and Trial activities, progressing rapidly towards deployments in scale.