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Virtualized Residential Gateway

Driving the delivery of enhanced residential services

Strategic White Paper

Fixed broadband access networks are undergoing significant change. Access speed requirements are continuing to trend upwards and service providers are continuing to invest in the enhancement of their fixed access infrastructures. Meanwhile, new application delivery models are competing with existing service provider residential services, often resulting in downward ARPU pricing pressure. In addition, there has been an increase in the number of smart devices and appliances within the home, with consumers continuously looking for innovative solutions, which enhance their life style and experiences.

Facing these evolving dynamics, service providers are looking at how to increase revenues with innovative services while continuing to lower capital and operational expenses. In today's networks, residential services are implemented using operator-provided, in-home equipment, including the residential gateway (RGW). This approach often impedes service innovation and velocity due to the complexity imposed by the need to support many RGW device variants.

What's needed is an evolution from existing to new service delivery architectures that drive revenue while being cost-effective and efficient. That's why service providers are increasingly exploring the virtualization of RGW functions and the possibility of delivering these functions from within the network cloud. But what should a service provider consider before adopting a virtualized Residential Gateway (vRGW) solution? This paper reviews the market drivers, evolved architecture model, benefits and capabilities (for each building block) of the vRGW solution.

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Market drivers

Service offerings delivered over broadband access networks continue to evolve rapidly. Under these new market conditions, over-the-top (OTT) players are well-positioned to capture service revenues over access infrastructure installed and maintained by the fixed access provider. As a result, OTT providers pose a serious challenge to the service provider's business. In fact, this challenge could lead to the commoditization of residential services, such as telephony, Internet and Pay TV. No wonder, then, that service providers are being challenged to maintain and increase profitability.

The new connected user is continuously updating their home network environment. This has led to a significant proliferation of smart devices and appliances within the home. Each individual or family member may have their own set of devices with the consumer looking for ease of use and flexibility in managing their home environment. Yet consumers today often face an inconsistent and unsatisfactory experience related to devices and services within the home. This provides service providers with opportunities to enhance the consumer experience by quickly adding new and innovative services.

In doing so, the service provider can re-engage and enhance the experience of existing consumers while adding new consumers.

Evolution to a virtualized residential gateway architecture

Figure 1. Residential gateway – current deployment model

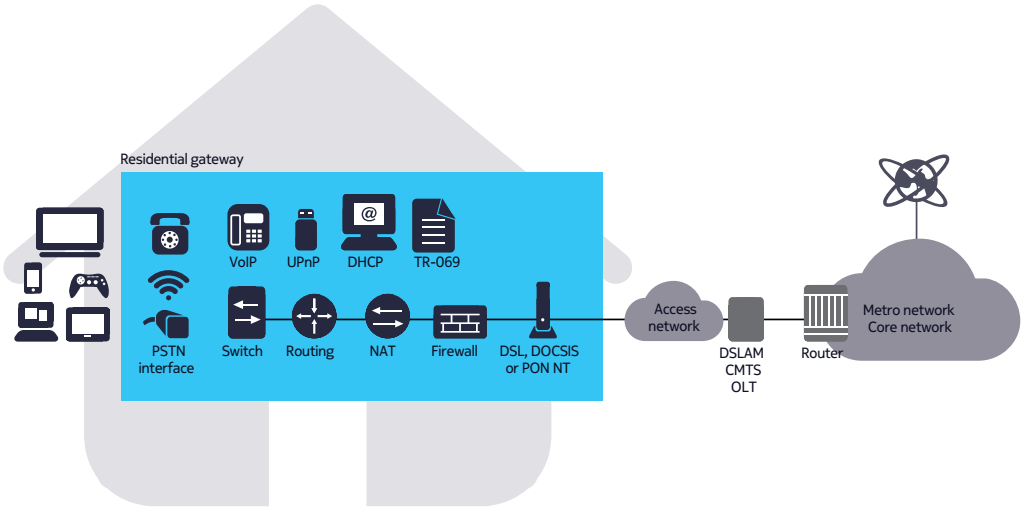


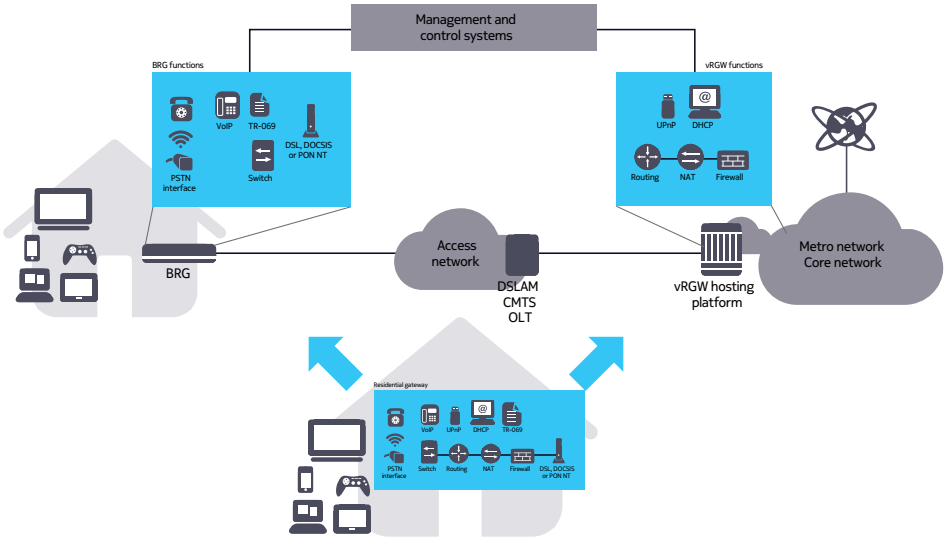
Figure 1 illustrates the existing residential services deployment model This model includes a residential gateway, which is deployed in the home and supports a wide range of functions required for delivery of residential services. The gateway functions can include network termination (cable modem, DSL modem, optical network terminal (ONT), Ethernet/Plain Old Telephone Service (POTS) interfaces, Ethernet switching, IP routing, network address translation (NAT), firewall, VoIP, Universal Plug and Play (UPnP), Dynamic Host Configuration Protocol (DHCP), as well as Broadband Forum TR-069, which enables remote device management.

This model typically requires support for RGW equipment variants with multiple hardware revisions and firmware versions, which often require significant lab validation cycles. This architecture with intelligence distributed within the RGW is often more complex to provision, troubleshoot and quickly resolve customer problems. This leads to frequent and costly truck rolls for deployment or maintenance.

The residential service delivery architecture has undergone minimal change over the years and can often be an impediment to rapid and innovative service delivery. This calls for a new approach, which is prompting the reconsideration of existing service delivery architectures with the goal of implementing a new architecture that accelerates time to market while also delivering operational efficiencies.

By virtualizing the functions historically implemented in the RGW device, service providers can enable service innovation and improve operational efficiencies. This is achieved by distributing specific networking and service functions currently implemented in customer premises equipment (CPE) and moving them into the network cloud.

Figure 2. Virtualized residential gateway end-to-end architecture



When these functions are moved into the network cloud, the evolved architecture is referred to as the "virtualized residential gateway (vRGW) architecture." The architecture is illustrated in Figure 2 and comprises the following building blocks:

- Bridged residential gateway (BRG) – The vRGW architecture model simplifies the operations and functions within the home so that the BRG can run a subset of the functions formerly required within the home residential gateway. An existing RGW may be used to perform the BRG role within the vRGW architecture.
- Virtualized residential gateway (vRGW) – Specific networking and service functions, formerly available in the home residential gateway are now moved to and hosted in the network cloud. These vRGW functions can be implemented as physical network functions (PNFs) on an existing networking platform and/or as virtualized network functions (VNFs) on a server-based infrastructure.
- Management and control systems - These systems are responsible for rapid customer activation, device management, service management, orchestration, fault isolation and customer care. With these systems, service providers can host a self-serve portal that provides a web interface to end users in the home. This enables users to control and manage their home configuration on the vRGW. The portal provides the same look and feel – in addition to the same level of control as that provided by an embedded web portal on existing RGWs in the home.

The end-to-end architecture is compliant with the Broadband Forum (BBF) WT-317-Network Enhanced Residential Gateway (NERG) document.

Benefits of a virtualized residential gateway architecture

The vRGW architecture offers several significant benefits around service innovation and velocity, operational efficiencies, and reduction in life cycle total cost of ownership (TCO).

Service innovation and velocity

A key benefit of the vRGW architecture is the flexible service creation platform. The vRGW architecture provides several unique or new attributes, which enable service providers to provide innovative, value-added services with greater flexibility and faster time to market.

Home visibility: The vRGW architecture enables visibility for devices on the home LAN. Being able to view active users/devices within the home provides a vastly improved approach to troubleshooting, diagnosing, and resolving faults. As a result, service providers can proactively monitor and take prompt action to resolve issues, significantly improving the overall customer experience. Additionally, the ability to notify other systems when a home device becomes active or inactive allows for definition of device-specific policies, which can help enable presence-based services.

Granular subscriber and device context: The vRGW model offers a significantly enhanced and more granular approach, providing a per-device and user-level context in addition to the per-home context. This allows the application of per-user, per-device and per-application policies and management enabling services, such as per-user parental control, bandwidth boost and differentiated QoS per device, quota management per user and/or device to manage resource consumption, in-browser notification, URL-based white list, and stateful firewalls. For example, specific policies related to parental control or Internet usage restrictions (e.g., full Internet access for parents versus restricted access for kids) may be applied on a per-device or group-of-devices basis.

Home LAN extension: The vRGW architecture is unique in its ability to extend the home LAN towards the service provider's network to include services in the data center for enabling value-added services, such as cloud-based home media or content storage in the service provider's network. The Digital Living Network Alliance (DLNA) framework provides media interoperability for consumer devices within the home. By moving DLNA storage to the cloud, customers can continue to access their content even when they move away from their home network. With the focus on 'smart home' initiatives, home automation gateways can also be hosted in the network cloud to help maximize flexibility and operational efficiencies.

Traffic steering: A key benefit of the vRGW architecture is its ability to steer specific traffic flows to the network cloud, which can host some value-added network functions. This steering capability, in conjunction with the option to efficiently combine (service chain) a set of network functions in a particular order (e.g., content cache or anti-virus filtering), enables new enhanced opt-in service options on a per-host basis.

Evolution to IPv6: For those cases where an existing RGW deployed in the home does not support IPv6, the vRGW model provides an efficient migration path by supporting IPv6 on the vRGW. The existing RGW may continue to be used (in bridged mode), minimizing or negating the need for upgrading the home gateway or incurring the added cost and complexity associated with new device testing and validation.

In addition to these attributes, the vRGW solution complements other evolving technology trends within the home network. For example, the virtual set-top box (vSTB) is an evolving area of focus for service providers offering pay TV services. A vSTB solution can be easily integrated in the vRGW architecture, as required.

Viewed as a whole, service providers should consider the benefits of the vRGW architecture, including operational efficiencies that will lower TCO.

Operational efficiencies

- Less complex and faster upgrade procedure: The vRGW model significantly reduces home device complexity, enabling more agile service deployment models.
- Reduced truck rolls: The vRGW architecture offers a single and simplified device deployment option for different services. This minimizes truck rolls and enables plug-and-play deployment.
- Simplified service provisioning and troubleshooting: Network or cloud-hosted RGW functions are easier to manage compared to a decentralized deployment model. The centralized management model gives service providers better visibility of the subscriber's network, simplifies service provisioning with support for monitoring QoE – in addition to providing metering and remote management.
- Reduced lab validation cycles: The vRGW model reduces the complexity of home-deployed devices, as well as equipment variants, which need to be certified and validated in the lab. This improves time to market and deployment.
- Reduced help desk service calls and problem resolution times: The vRGW model supports a centralized and efficient configuration/management model, resulting in fewer calls to the help desk and faster call resolution.

Reduction in life cycle TCO

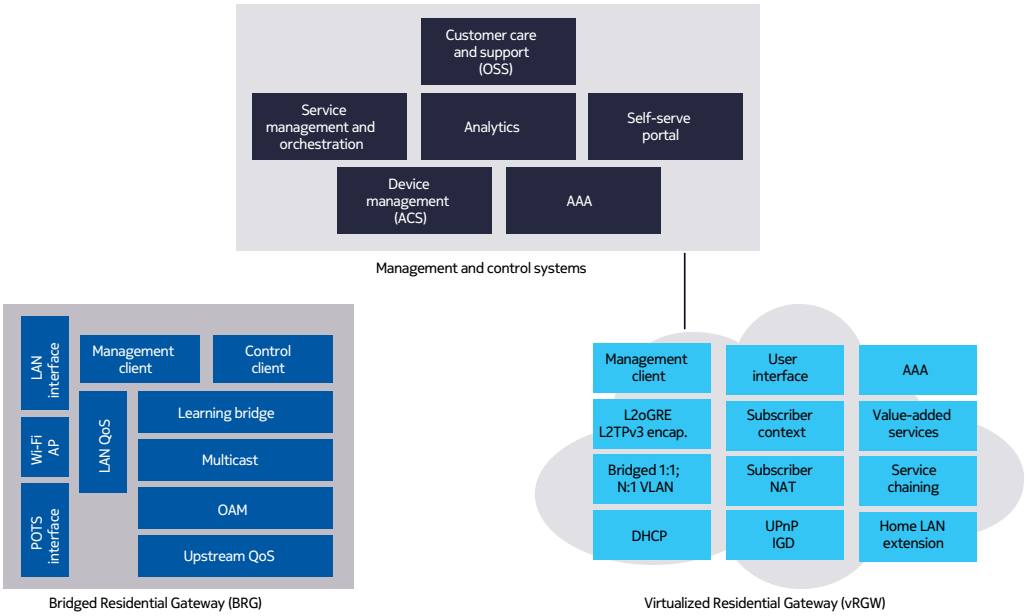
With the vRGW, many functions and services that formerly required replacement of the home-based RGW – due, for example, to CPU or memory constraints – can now be rolled out from the network or the cloud. This translates into an extended life cycle for the RGW that, over time, translates into a reduction of average CAPEX per home.

Indeed, several service deployment lifecycle studies done by Bell Labs[1], Nokia's research arm, have demonstrated a substantial reduction in overall TCO when moving to a vRGW deployment model. These modeling studies include a broad range of variables, such as installation/commissioning, help desk, truck rolls and hardware replacement (i.e., CAPEX-related) costs.

Virtualized residential gateway architecture building blocks

Having discussed the benefits of the vRGW architecture, we now examine the building blocks in more detail. Figure 3 illustrates the functional distribution and capabilities within these blocks. The required capabilities within each block – the BRG, the vRGW, and the management/control systems functions – are examined in turn.

Figure 3. Function distribution of the vRGW solution



1 TCO studies conducted by Nokia's research arm, Bell Labs

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Bridged residential gateway

The BRG supports network functions, which enable connectivity and data transfer between home-based devices and centralized functions in the vRGW. When assessing the BRG, service providers need to consider whether it supports the following capabilities:

- Local Area Network (LAN) interfaces
- Learning bridge
- Plain Old Telephone System (POTS) interfaces
- Voice over IP (VoIP) client
- Upstream QoS (packet prioritization)
- Network tunnel protocols
- Wi-Fi access point (AP)
- Operations and Maintenance (OAM) management client (TR-069 or NETCONF)
- Multicast replication towards the customer premises network
- Control client (OpenFlow)

The BRG is configured as a learning bridge. Local traffic does not leave the customer premises – the BRG bridges traffic between locally attached devices. Traffic destined to external destinations is bridged to the vRGW over a VLAN (1:1 or 1: N model) or, more typically, an IP tunnel (Layer 2 traffic encapsulated over IP).

In the event that connectivity has to be provided over an IP tunnel, the BRG initiates the tunnel establishment, which is based on information received through DHCP options or configured using TR-069. This includes the tunnel end-point IP address, as well as the tunnel protocol. Soft GRE is currently emerging as the industry's choice for this protocol. Once the tunnel is established, LAN devices connected to the BRG are assigned IP addresses and configured through this tunnel from the DCHP server in the vRGW. BRG-originated services, such as VoIP, are also provided IP addresses from the vRGW DHCP server.

In cases when the vRGW becomes unreachable due, for example, to loss of uplink connectivity, the BRG activates a local DHCP server function. The server allocates IP addresses from a dedicated address range within the home subnet to all devices that come online. This assures that local LAN connectivity is maintained during uplink failures. Once the reachability to the vRGW is restored, the address management is relinquished by the BRG and handled by the vRGW.

Software-defined network (SDN)-enhanced control of the BRG

When considering the vRGW model, it may also be advantageous for the service provider to augment and control the BRG's forwarding behavior. For example, it may be preferable to filter out unwanted traffic at the BRG instead of at the vRGW. In other cases, though, it might make more sense to assign DSCP traffic priority at the BRG before the traffic enters the network. If so, the BRG flow switch forwarding behavior is determined by flow tables that are programmed using OpenFlow through the control interface. In BBF TR-317, it is recommended that BRGs support OpenFlow and operate as either a learning bridge or flow switch.

Virtualized residential gateway

The vRGW function is hosted in the network cloud. When assessing the vRGW, service providers need to consider whether it supports the following capabilities:

Connectivity between the BRG and vRGW

The connectivity from the BRG to the vRGW includes bridged 1:1, N:1 VLANs or Layer 2 over IP tunnels (L2oGRE and L2TPv3 tunnel encapsulations). The tunnel transport can be IPv4 or IPv6. The wide area network (WAN) address on the BRG can be obtained via DHCP or Point-to-Point Protocol over Ethernet (PPPoE) from either the vRGW hosting platform or the service provider's existing broadband infrastructure and can be used for tunnel transport. The tunneled traffic can contain a dot1q tag, which corresponds to a service set identifier on the BRG. This capability enables wholesale/retail models.

Address management for the home LAN

The vRGW provides address management per home. DHCP messages from LAN devices in the home are received on the vRGW. The vRGW assigns a unique address to devices in the home via DHCP from an address range, which is configurable per home. The address range across homes can overlap. Each address range can be associated with a configurable lease time. DNS and other options, (including custom options), can be returned in DHCP messages to devices in the home. The vRGW should support managing and assigning an IPv6 prefix per home via Stateless Address Auto-Configuration (SLAAC).

Subscriber-aware NAT and UPnP Internet Gateway Device protocol

The vRGW should support a subscriber-aware network address translation (NAT) function. This allows overlapping home LAN IP addresses across homes, while ensuring a unique outside IP address per home. The vRGW should support static port forwarding, as well as the UPnP Internet Gateway Device (IGD) function. This lets web servers, p2p clients and gaming devices in the home to be accessed from the network. Without IGD, the gateway needs manual configuration, which is error prone. The vRGW may also support a DMZ capability, which allows a host, such as a web-server, to be accessible from the Internet, while also being isolated from the secure home domain.

Subscriber (home) and device (host) context

A separate home and host context is maintained on the vRGW. This allows per home and per host level configuration. By default, every host on the home LAN shares the per-home default configuration. Individual devices on the home LAN can be subjected to access control lists (ACLs) which can drop, forward or redirect all or certain types of traffic from the device. This enables use cases, such as blocking Internet access or home user access to certain content during specific times of the day. The ACL also allows a particular device to be redirected to a portal. The ACLs associated with individual devices can be changed at any time during the life of the session.

Authentication, Authorization and Accounting (AAA)

The vRGW should support authentication of a BRG with an AAA server. The BRG can be provided with a RADIUS client used to trigger EAP-based authentication based on the BRG credential. In this case, the vRGW acts as a RADIUS proxy and caches the result of the BRG authentication. The vRGW can subsequently limit access to devices behind an unauthenticated BRG. This is especially important for access via IP tunnels, because the intermediate access node cannot intercept tunneled DHCP messages to insert option-82, which is typically used to authenticate the home residential gateway.

Home visibility

The vRGW should support the capability to show active devices on the home LAN in each home, along with their configuration and operational state. This enables better troubleshooting and home diagnostics. The vRGW can also notify an external system when a new device in the home comes online or an existing device goes offline. This allows device-specific policies, and presence-based services. The vRGW should support the capability to detect loss of reachability to the BRG and report it to an NMS, allowing timely and proactive action from the operator.

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Value-added services

The maintenance of a per-host context enables support for value-added, stateful opt-in services on a per-host basis. Examples include per-application SLAs, URL filtering, parental control, per-application or per-group-of-applications quota management, zero-rating, and in-browser notifications. In addition, service chaining to other VAS functions can be provided. A service chain consists of a set of network functions or enablers, such as web caching, traffic compressors/optimizers, and firewalls that are interconnected in a specific order to provide value-added services to customers. To provide policy-based routing of selected traffic to a chain of service functions in the data center, the vRGW can use per-host ACLs. This aligns with IETF work in the Service Function Chaining (SFC) WG

Home LAN extension

The vRGW should also provide support for home LAN extension to include services in the data center. This will be enabled via a per-home Layer 2 domain that includes access to services in the data center over the WAN. At the same time, they need to appear as if they are residing on the home LAN and are directly available to home devices by means of Layer 2 bridged access. Examples include NAS, which can use shared storage in the cloud, but is also mountable on home devices and dynamically discoverable via DLNA-capable devices.

Management and control systems

The centralized management model simplifies service deployment and improves troubleshooting. When assessing the management and control systems, service providers need to consider whether they support the following capabilities:

Device activation and customer care

Device activation and customer care for the vRGW can be provided by the same customer experience management (CEM) tools used for managing and supporting non-virtual RGWs, subscribers' home networks, and broadband services.

The key elements include:

- TR-069-based device management for remote management of the BRG
- Workflow-based service management and orchestration
- Customer care and support applications, providing unified help desk and subscriber self-care interfaces, operations dashboard, and field-tech console
- Customer experience analytics

In the Broadband Forum's WT-317 Network Enhanced Residential Gateway (NERG) management architecture, these elements reside in the Auto-Configuration Server (ACS), NERG orchestration, and operation support system (OSS) functional blocks.

TR-069 device management

In the vRGW application, the home-based BRG continues to provide basic functionality as a broadband access termination point, a Layer 2 bridge, and a Wi-Fi access point. In the same way that TR-069 has long been used to manage the broadband CPE, it can now be used to provide direct remote management of the BRG. Because the higher-layer features and functionality of the BRG are now in the network or the cloud, the primary use cases for TR-069 management of the BRG are:

- Zero-touch activation
- Wi-Fi access point management
- BRG (Layer 2) diagnostics and troubleshooting
- BRG (Layer 2) device data collection and analytics

Workflow-based service management and orchestration

Workflow-based service management and orchestration allows service providers to simplify the definition, publication, and execution of advanced service troubleshooting and management logic for the vRGW. It does this across a variety of different network elements and BSS/OSS types. Workflow-based service management and orchestration also enable service providers to quickly and easily integrate data sources, such as the TR-069 ACS, into service management and customer care actions.

Additionally, it provides orchestration between the BRG, network elements, and the data center when virtualizing certain RGW functions.

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Customer care and support applications

Workflow-based service management and orchestration is designed to make it easy for external customer care and support applications to access vRGW data and execute service management and business logic through interfaces designed for particular users. Users include those employing subscriber self-care, those seeking agent-assisted care, or those wanting field-tech support.

Cloud-based subscriber self-care allows remote management of the vRGW and home network – simply and easily – by providing direct management access to the BRG using TR-069. Management of advanced vRGW features and home LAN devices is also achieved through integration with AAA and the WLAN gateway or virtualized routing platform.

With this in mind, management features and capabilities should include:

- Real-time alerts and notifications
- Complete in-home device discovery and visibility
- Quality of service prioritizations and parental controls per device
- Usage statistics per device

The subscriber is presented with a unified management dashboard, and it makes no difference if the features are delivered from the BRG or from the network. For the help desk, the support information – whether for virtual or non-virtual RGWs – is presented in the same way, through the same interface.

Self-serve web portal: In addition, subscribers should have access to an operator self-serve web portal to view and modify their default home network and device configuration on the vRGW as needed.

A mediation layer, which interacts with the vRGW, should implement a web interface (e.g., REST API) to the service provider's portal to set, update, view and troubleshoot the home network and connected devices. The web portal can be implemented by the service provider or provided as a pre-integrated solution.

Customer experience analytics

In the vRGW architecture, several sources of information can be collected and analyzed: data from the BRG directly, from the AAA and from the vRGW. Data from the BRG includes broadband access connectivity and performance, as well as Wi-Fi connectivity and performance. From the AAA and vRGW, data can be collected on IP sessions of home LAN devices application usage and performance by home and by device, and device type and operating system version so that service performance can be assessed in more detail and the customer experience optimized.

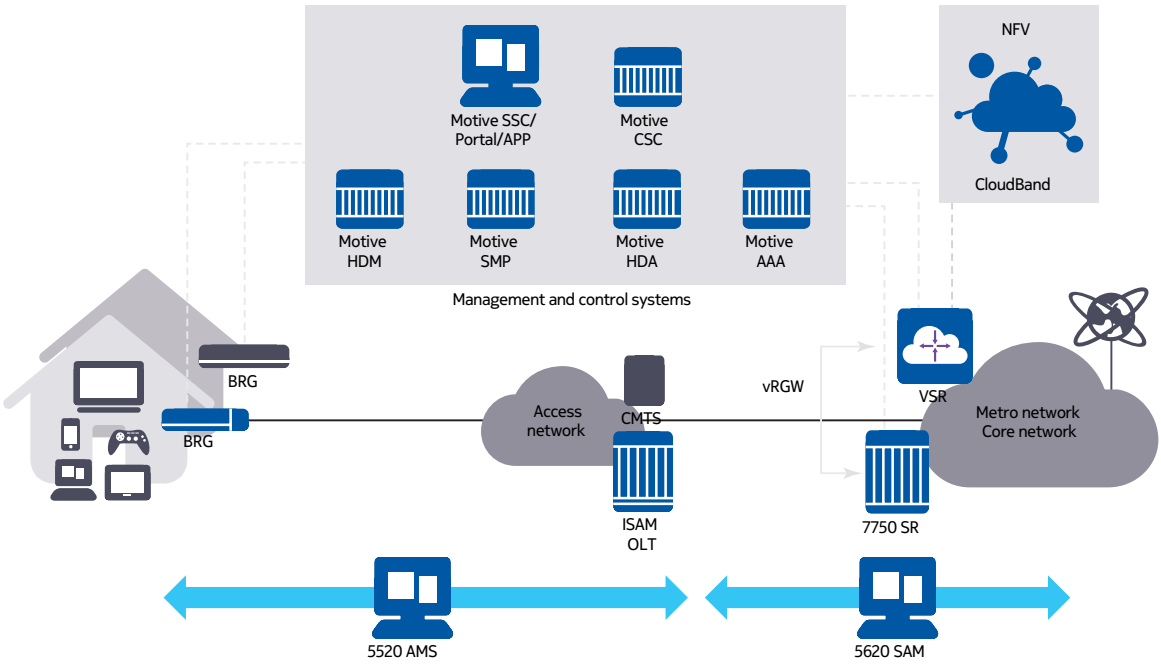
NFV Management and Orchestration

The sub-systems of the vRGW solution (management and control systems and vRGW) can be deployed as VNFs. In that case, they will be on-boarded on a network functions virtualization (NFV) management and orchestration (MANO) platform. This platform automates the dynamic deployment of the functions on a distributed cloud infrastructure as well as the scaling, restoration, and software maintenance.

The Nokia Virtualized Residential Gateway Solution

Now that we have covered key considerations related to vRGW building blocks, we can turn to a closer examination of the Nokia vRGW solution (see Figure 4). Each of its building blocks – the BRG, the vRGW, and the Motive® Management and Control Systems – is discussed in turn.

Figure 4. Nokia Virtualized Residential Gateway solution



The Nokia Bridged Residential Gateway

As part of the Nokia vRGW solution, Nokia will offer a BRG family, which resides in the Nokia 7368 Intelligent Service Access Manager (ISAM) ONT product portfolio. The Nokia BRG will support a comprehensive set of advanced WAN and LAN technologies. WAN technologies includes GPON/EPON/NGPON2/10G EPON/G.Fast. Advanced LAN technologies includes 10GBaseT, USB 3.0, 802.11ac WiFi, POTS line interfaces, soft GRE tunneling protocol, multicast for efficient IPTV traffic distribution, VoIP client, flow-switch control using OpenFlow and local DHCP.

The Nokia Virtualized Residential Gateway functions

The Nokia vRGW functions are supported on the Nokia 7750 Service Router (SR) as a standalone gateway or co-hosted with a BNG or WLAN gateway, and as an application of the Nokia Virtualized Service Router (VSR), the VSR-Residential Gateway (VSR-RGW).

Value-added services requiring service and application visibility for enabling per-home, per-device, per-application service policies can benefit from the Application Assurance (AA) capabilities supported with the vRGW.

The Nokia 7750 Service Router (SR) is a high-performance, edge router designed for the concurrent delivery of advanced residential, business and mobile services. It is powered by Nokia's industry leading FP3 400Gb/s FP3 routing silicon. The 7750 SR leverages its embedded service and application intelligence along with integrated services adapters and/or modules to support advanced application capabilities. These include the Multiservice Integrated Services Adapter (MS-ISA) and the Multiservice Integrated Service Module (MS-ISM), which enable high-touch packet operations for deeper levels of integrated service capabilities.

The Nokia Virtualized Service Router (VSR) is a flexible virtualized service router architected and optimized for x86 server environments. The VSR enables rapid service innovation, extends service reach, opens new markets, and accelerates time to market. It also lowers operating costs with a homogenized physical infrastructure.

The 7750 SR and the VSR are powered by Nokia's robust, feature-rich and industry leading Service Router Operating System (SR OS), which provides a flexible foundation for agile IP services delivery. The vRGW supports duality of deployment (VNF or PNF) with common operations under the 5620 SAM, enabling flexible, rapid vRGW deployment with operations efficiency to meet service providers' service and business requirements.

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Motive management and control systems

Management and control is critical to the success of the vRGW solution. The following products comprise and deliver this essential capability:

- Motive Home Device Manager (HDM) for device management: Motive HDM empowers service provider help desk personnel and subscribers to remotely control and manage TR-069-enabled CPE, including RGWs, IP set-top boxes, VoIP adapters, and cable modem gateways from a variety of different vendors. HDM handles all tasks related to CPE management, including zero-touch provisioning, configuration updates, software upgrades, monitoring, problem diagnosis, and troubleshooting. HDM also provides full support for IPv6-compliant devices, including TR-181.
- Motive Service Management Platform (SMP) and Workflow Builder for service management and orchestration: Motive SMP offers the ability to comprehensively define and normalize key service and device configuration settings, as well as management actions.
  - With Motive SMP, service providers have the ability to maximize existing investments in device management, OSS/BSS, and NMS/EMS systems, as well as extend service management visibility and control across the entire service delivery ecosystem. In addition, call center, self-care and third-party applications can use normalized APIs without having to know about underlying systems or devices.
  - Workflow Builder allows service providers to quickly create, deploy, and test customer care, service troubleshooting, and business process workflows. Workflow designers are equipped with an out-of-the-box palette of flow control, control transfer, display, and device/service operation objects.
- Motive Customer Service Console (CSC) for customer care: Motive CSC gives customer service representatives (CSRs) the visibility, key information and management capabilities they need to quickly set up and manage new services, as well as diagnose and resolve service issues. A robust service management interface includes diagnostic intelligence and other relevant information about a customer's service from multiple sources, such as the customer device, the provider's network, third-party or partner systems, and back-office systems. CSC simplifies diagnostics and service troubleshooting by allowing CSRs to execute service management actions based on pre- built workflows. Using CSC, call center representatives can quickly pinpoint issues and take corrective action.

- Motive Home Device Analytics (HDA): Motive HDA combines predictive analytics with closed-loop processes to help service providers increase customer satisfaction, loyalty, and profitability. This solution offers analytics-based insights that empower help desk agents, boost self-care usage and anticipate emerging issues. With Motive HDA, service providers can adopt a proactive approach to customer experience management and reinvent customer care as a differentiator.
- Motive Authentication, Authorization, and Accounting (AAA) Server: The Motive AAA Server consolidates authentication and helps harmonize QoE across networks and technologies. Service providers benefit from fast time to market, simplified management, and lower TCO. Motive AAA is powered by one of the most advanced and flexible policy management engines in the industry. An intuitive scripting language—known as Policy Flow—is used to define, in a protocol agnostic manner, how the policy management engine processes RADIUS and Diameter requests.

CloudBand NFV platform

The vRGW, as well as the management and control systems of the vRGW solution, may be deployed as VNFs on open NFV platforms, which support OpenStack cloud orchestration, such as Nokia CloudBand. CloudBand provides a high-availability, production-ready lean operations environment with NFV MANO layer (leveraging OpenStack), root cause analysis, and service assurance modules, which reduce operational costs and enhance service availability.

Conclusion

Virtualization of specific RGW functions provides an enhanced service delivery architecture that delivers greater flexibility, helps reduce complexity, and enables the rapid deployment of new and innovative services. This paper has discussed the major factors and building blocks that service providers should consider in the planning and deployment of a virtualized residential gateway solution. Whether it is the BRG, the vRGW, or the management and control system, service providers ought to consider the requirements of each building block and how these blocks relate to each other. The Nokia vRGW solution may be deployed as a complete solution or components may be integrated with third-party solutions.

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Acronyms

AAA	Authentication, Authorization and Accounting
AP	Access Point
ACS	Auto-Configuration Server
ACL	Access Control List
BBF	Broadband Forum
BGP	Border Gateway Protocol
BRG	Bridged Residential Gateway
BSS	Business Support System
CAPEX	Capital expenses
CE	Customer Edge router
CEM	Customer Experience Management
CPE	Customer Premises Equipment
CSC	Customer Service Console
CSR	Customer Service Representatives
DHCP	Dynamic Host Configuration Protocol
DLNA	Digital Living Network Alliance
DNS	Domain Naming System
DSL	Digital Subscriber Line
EAP	Extensible Authentication Protocol
GRE	Generic Routing Encapsulation
HDA	Home Device Analytics
IETF	Internet Engineering Task Force
IGD	Internet Gateway Device
LAN	Local Area Network
M2M	Machine to Machine
MANO	Management and Orchestration
MPLS	Multi-Protocol Label Switching
NAT	Network Address Translation
NERG	Network Enhanced Residential Gateway
NMS	Network Management System

OAM	Operations and Maintenance
ONT	Optical Network Terminal
OPEX	Operational expenses
OS	Operating system
OSS	Operation support system
OTT	Over The Top
PE	Provider Edge router
PNF	Physical Network Function
POTS	Plain Old Telephone Service
PPPoE	Point to Point Protocol over Ethernet
QoS	Quality of Service
REST API	Representational State Transfer Application Programming Interface
SDN	Software Defined Networking
SFC	Service Function Chaining
SLA	Service Level Agreement
SLAAC	Stateless Address Auto-Configuration
SMP	Service Management Platform
SR OS	Service Router Operating System
SSID	Service Set Identifier
TOC	Total Cost of Ownership
UPnP	Universal Plug and Play
VCPE	Virtual CPE
VM	Virtual Machine
VNF	Virtual Network Function
VoIP	Voice over IP
VPN	Virtual Private Network
vRGW	Virtualized Residential Gateway
VSR	Virtualized Service Router
WAN	Wide Area Network

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