

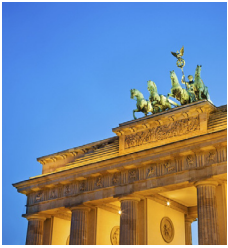
# **EANTC Independent Test Report**

Huawei's Cloud-based Broadband Network Gateway Solution  
Performance, Resiliency and Functionality

March 2018



## About EANTC



EANTC (European Advanced Networking Test Center) is internationally recognized as one of the world's leading independent test centers for telecommunication technologies.

Based in Berlin, the company offers vendor-neutral consultancy and realistic, reproducible high-quality testing services since 1991. Customers include leading network equipment manufacturers, tier 1 service providers, large enterprises and governments worldwide. EANTC's Proof of Concept, acceptance tests and network audits cover established and next-generation fixed and mobile network technologies.

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## Introduction

EANTC verified a set of functionality, performance, resiliency and security features of Huawei's Broadband Network Gateway (BNG) solution back in February of 2017<sup>1</sup>. Following the solution's continued development and success of previous tests, the vendor recommissioned EANTC for a second round of testing. The new testing phase took into account the solution's additional performance and high-availability options as well as recently added functionalities. The test cases design emphasized on the broadband subscriber's quality of experience as well as the reliability, manageability and architectural benefits for service providers.

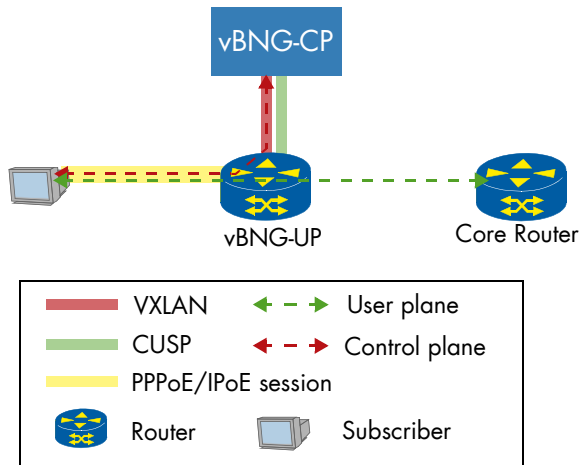
### Test Highlights

- ➔ Cloud-based BNG solution supported dual stack IPoE and PPPoE plus dual-stack PPPoE session with Prefix Delegation
- ➔ Demonstrated VXLAN and CUSP configuration using NETCONF and tested secured CUSP communication
- ➔ Up to 20.992 million single stack IPv4 or IPv6 subscriber sessions per vBNG-CP (tested without RADIUS authentication and accounting)
- ➔ Established 2.56 million IPoE or PPPoE single stack sessions at the average rate of 10,400 sessions/s without RADIUS authentication
- ➔ Scaled up to 200 vBNG-UP devices per vBNG-CP deployment
- ➔ Cloud-based BNG supported redundancy concepts
- ➔ Cloud-based BNG solution supported multicast, CGN and HQoS functionality

Figure 1 below illustrates Huawei's Cloud-based BNG deployment with a separation of the control and user plane. The central part of the Cloud-based BNG solution is the virtualized BNG Control Plan (vBNG-CP) component, which is the implementation of the control plane for the broadband access. The virtualized BNG User Plane (vBNG-UP) is responsible for user traffic forwarding based on flow definition retrieved from vBNG-CP.

1. <http://www.eantc.de/fileadmin/eantc/downloads/News/2017/EANTC-Huawei-CloudMetro-MarketingReport-v1.0.pdf>

Our tests substantiated Cloud-based BNG solution's control plane performance and scalability, functionality, security and resiliency mainly using two different test beds as described in the section „Cloud-based BNG Test Setup“.



**Figure 1: Control and User Plane Separation**

## Executive Summary

Our team of engineers successfully executed and verified a series of tests at Huawei's lab in Nanjing, China. Huawei's Cloud-based BNG proved to perform exceptionally well, establishing new PPPoE or IPoE single stack sessions at an average rate of 10,400 sessions per second. EANTC witnessed that a single vBNG-CP deployment provided up to 20.992 million of single stack user session capacity. These performance numbers were achieved without a backend performing RADIUS authentication and accounting and also without transmitting of QoS policies for the subscribers.

The segregated control and user plane architecture of Cloud-based BNG solution proved to manage up to 200 vBNG-UP devices using single vBNG-CP deployment.

The Cloud-based BNG solution was subject to BNG-UP access link and vBNG-CP failure scenarios wherein it successfully recovered broadband access services.

Our tests also verified a set of Cloud-based BNG's functionalities such as dual-stack subscriber access support, on-demand subscriber bandwidth reservation, Hierarchical Quality of Service (HQoS), Carrier-Grade Network Address Translation (CGNAT) and multicast.

In the manageability test area, EANTC verified the successful usage of the NETCONF protocol by vBNG-CP's management module to provision secured CUSP (Control plane and User plane Separated BNG protocol) and VXLAN tunnels on vBNG-UP devices.

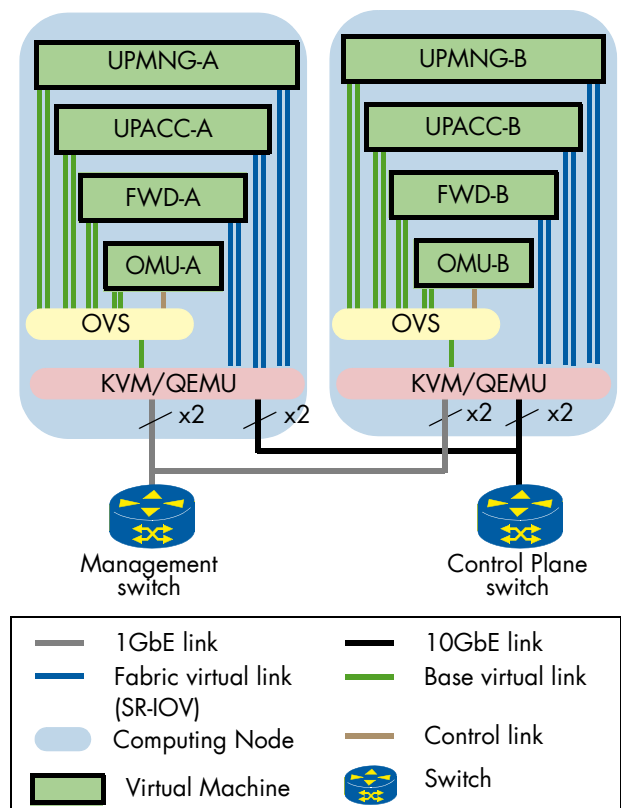
Finally EANTC witnessed centralized Cloud-based BNG resource visualization capability of Huawei's Network Cloud Engine (NCE) management tool.

## Cloud-Based BNG Architecture

The key element of Cloud-based BNG is the separation of the control and user plane in a software defined networking (SDN) and network function virtualization (NFV) architecture. The intention is to handle the subscriber session signaling and additional services in a Cloud-based, virtualized controller, while the forwarding of user data is handled by the vBNG-UP devices.

The central part of the Cloud-based BNG solution is the vBNG Control Plan (vBNG-CP).

On the southbound interface, the vBNG-CP manages vBNG-UP devices. The vBNG-UPs can be controlled via CUSP protocol to forward and handle specific traffic flows. They use VXLAN encapsulation to transport necessary data from the subscriber's sessions to the vBNG-CP during the session establishment process. The vBNG-CP itself is a set of virtual network functions (VNFs) using the standard MANO (NFV Management and Orchestration) architectural framework.



**Figure 2: Cloud-Based BNG-CP Architecture**

As shown in the Figure 2, vBNG-CP contains 5 different components.

- The UPMNG (User Plane Management) VM processes BRAS services (such as user management, AAA, and RADIUS), manages OpenFlow and NETCONF channels between a group of UPs and CPs, and manages UP device states. A group of UPs corresponds to a process of the UPMNG VM. Multiple process instances are deployed on the VM. UPMNG instances run in an active/standby configuration on different compute nodes to provide resilience against faults. EANTC verified the scale-in and scale-out and resiliency functionality of UPMNG modules during the initial testing phase in February of 2017. The tested software version of the vBNG-CP was HUAWEI VNE 9000 Patch Version: V100R003SPH001.
- UPACC (User Plane Access Control) components processes user access protocol packets, such as PPPoE/IPoE packets, sent by the vBNG-UP devices to grant user access. UPACC stores the information of PPPoE and IPoE subscribers and it can scale based on the number of line cards installed and configured on the vBNG-UP devices. UPACC instances run in an active/standby configuration on different compute nodes to provide resilience against faults. This is one of the key deployment changes on this vBNG-CP version compared to the previous version that we tested in February of 2017.
- OMU (Operational and Management Unit) manages UP resources (such as IFNET, VPN, and route) and is responsible for system state monitoring.
- FWD (Forwarding) components manage the IP channel between the vBNG-CP and vBNG-UP elements. Load balancing is used to implement multiple instances. In our tests, we created a pool of 2 FWD instances on the vBNG-CP to provide sufficient capacity for 20 million subscribers.

The compute nodes use KVM/QEMU as the virtualization platform, and OpenStack for the orchestration of the components.

## Cloud-based BNG Test Setup

As shown in Figure 3 and Figure 4, Huawei deployed two test beds for this testing phase; one for the functionality, resiliency and security testing and another for performance and scalability testing. In both test beds Huawei used the same software version of vBNG-CP and vBNG-UP devices. Three different types of vBNG-UP devices were used in the functionality test bed while for the performance tests Huawei deployed a fourth vBNG-UP type. According to Huawei all the four vBNG-UP devices deployed in the test beds can support the tested functionality. Also Huawei claims that any device from their NE40E Universal Service Router<sup>1</sup> and ME60 Multiservice Control Gateway<sup>2</sup> lineups can be used as vBNG-UP.

To verify the function and traffic forwarding of the Cloud-based BNG components, we used an external traffic generator, the TestCenter N11U from Spirent connected to the vBNG-UP devices on the subscriber side and to the core router on the network side.

### Functionality Test Bed

For our functional and security tests we deployed a vBNG-CP component on a set of compute modules. Huawei used one control node and two compute nodes for the vBNG-CP deployment.

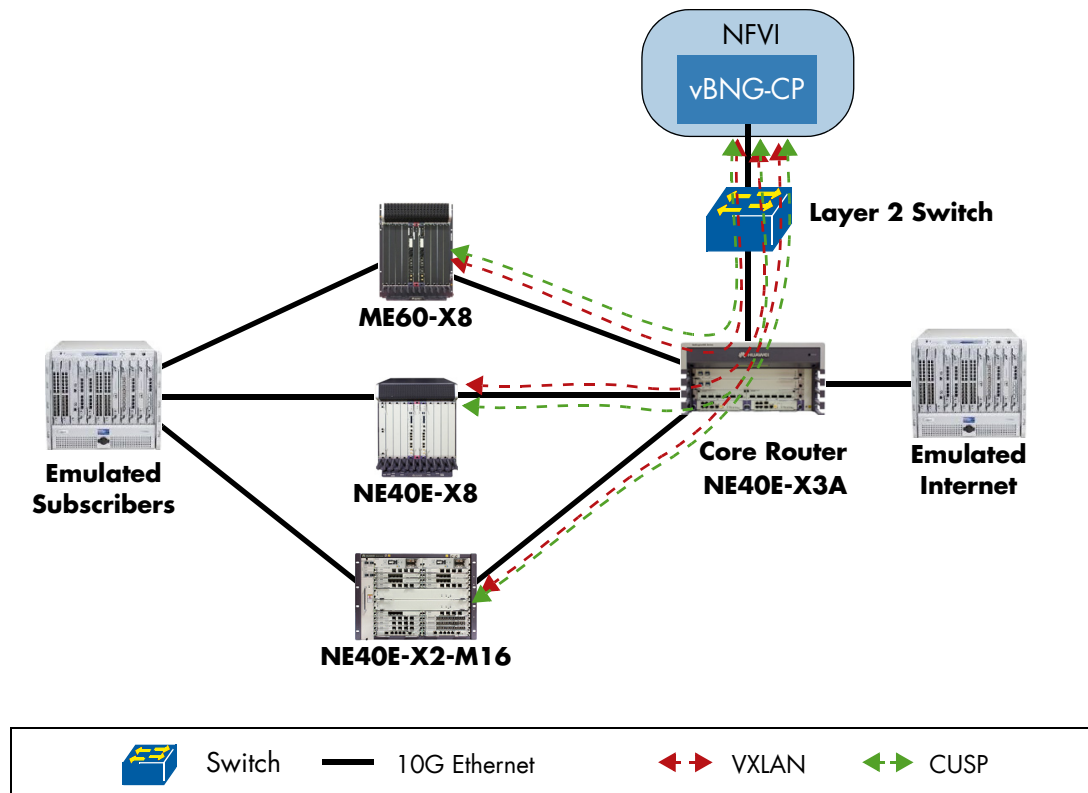
The deployment shown schematically in Figure 1 included the minimal requirements of the vBNG-CP components in a redundant active/standby configuration for the functionality tests.

An external RADIUS server was used for authentication and accounting of the user sessions. In addition, EANTC tested the following features and functionality in Huawei's Cloud-based BNG solution:

- Single stack, dual-stack including dual-stack with Prefix Delegation (PD) user access
- Multicast
- Network address Translation (NAT)
- Quality of service (QoS)
- Resiliency feature

Huawei used ME60-X8, NE40E-X8 and NE40E-X2-M16 devices utilized as vBNG-UPs in the functionality test bed.

1. X16A, X8A, X3A, X16, X8, X3, X2-M16A, X2-M8A, X2-M16, X2-M8, M2F, M2H, M2K and X1-M4
2. X16A, X8A, X16, X8, X3, X2-M8A and X2-M16A



**Figure 3: Test Setup – Functionality Tests**

### Performance and Scalability Test Bed

For the performance and scalability tests, we used five Huawei NE40E-X8 vBNG-UP devices. Each device was populated with 4 Line Processing Unit (LPU) modules (2 Physical Interface Cards (PIC) per LPU). Huawei claims that a NE40E-X8 can support up to 512,000 subscribers with the minimum requirement of 4 LPUs. We used 8 10GbE ports on the subscriber side that were directly connected with test equipment.

Since throughput performance was not scope of the test, we used one 10GbE port per vBNG-UP in the network side.

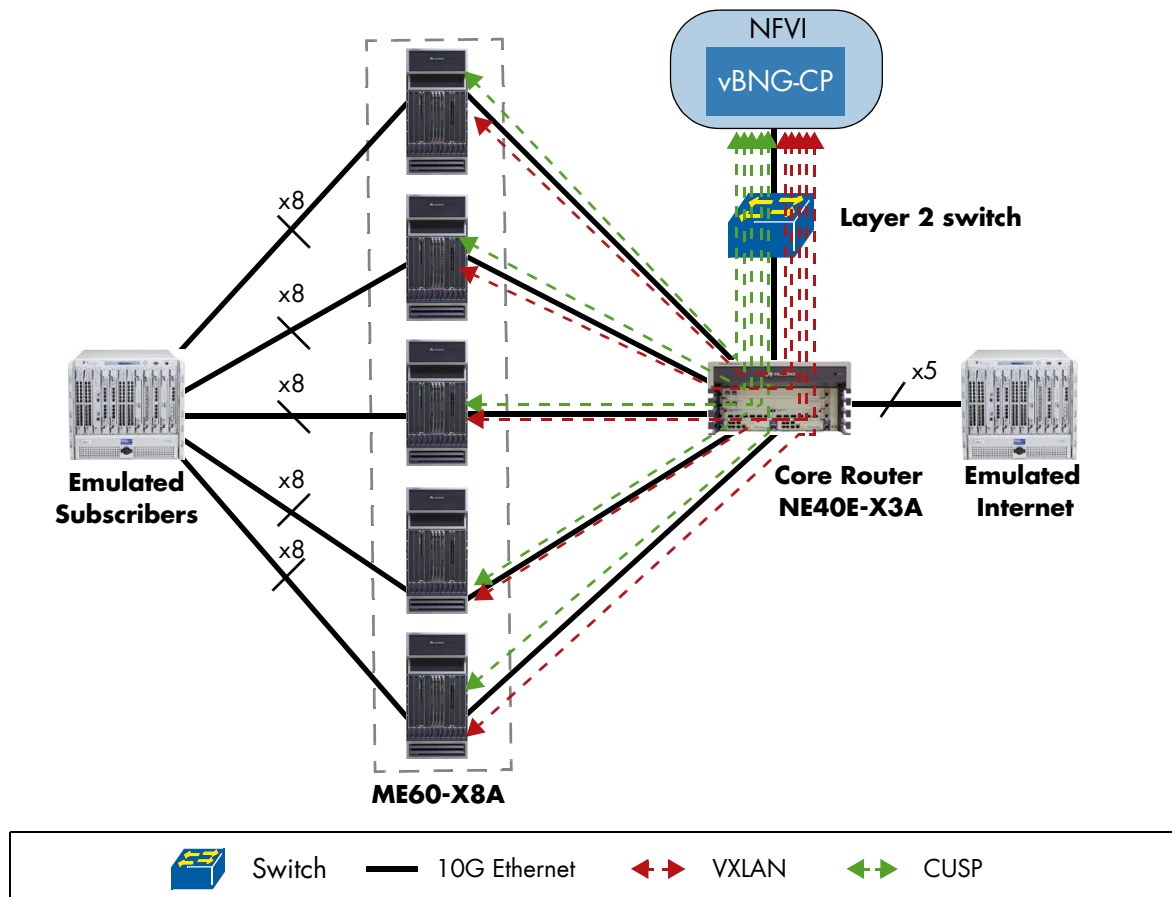
Huawei deployed one vBNG-CP component on a set of 10 compute nodes and one control node. The deployment included the required number of vBNG-CP components in a redundant active/standby configuration.

In this test setup RADIUS server was not deployed. All of the performance and scalability tests were performed without RADIUS authentication and accounting enabling for the user sessions.

The Cloud-based BNG was configured to accept single stack IPv4 or IPv6 IPoE/PPPoE user request. As requested by Huawei, all performance and scalability test cases were performed with this configuration.

## Solution Under Test

vBNG-CP				
Performance Test Bed				
Node Type	vCPU per VM	Memory per VM	HugePage	Software
2x OMU	4	16GiB	1GiB	8.180 (VNE 9000 (vBRAS-CP) V100R005C10SPC002T )
2x FWD	10	16GiB	1GiB	
12x UPMNG	12	64GiB	1GiB	
12x UPACC	10	80GiB	1GiB	
1x Control Node and 10x Compute Nodes	<b>Hardware:</b> HUAWEI RH2288Hv3 <b>CPU:</b> 2x Intel(R) Xeon(R) CPU E5-2690 v3-12Core @ 2.60GHz <b>RAM:</b> 24x 16GiB <b>NIC:</b> 4x Broadcom Corporation NetXtreme BCM5719 Gigabit Ethernet PCIe 4x Intel 82599EB 10-Gigabit SFI/SFP+ Network Connection			OS: Linux kernel version 3.0.93-0.8 hypervisor: QEMU v2.3.0, Open vSwitch v2.3.2 SR-IOV with DPDK libvirtd (libvirt) 1.2.17
Functionality and Resiliency Test Bed				
Node Type	vCPU per VM	Memory per VM	HugePage	Software
2x OMU	4	16GiB	1GiB	8.180 (VNE 9000 (vBRAS-CP) V100R005C10SPC002T )
2x FWD	10	16GiB	1GiB	
2x UPMNG	12	32GiB	1GiB	
2x UPACC	10	48GiB	1GiB	
Compute Node 1	<b>Hardware:</b> HUAWEI RH5885H v3 <b>CPU:</b> 4x Intel(R) Xeon(R) CPU E7-4820 v2-8Core @ 2.00GHz <b>RAM:</b> 32x 8G <b>NIC:</b> 4x Intel Corporation 82580 Gigabit Network Connection 4x Broadcom Corporation NetXtreme BCM5719 Gigabit Ethernet PCIe 4x Intel 82599EB 10-Gigabit SFI/SFP+ Network Connection			OS: Linux kernel version 3.0.93-0.8 hypervisor: QEMU v2.3.0, Open vSwitch v2.3.2 SR-IOV with DPDK libvirtd (libvirt) 1.2.17
Compute Node 2	<b>Hardware:</b> HUAWEI RH5885H v3 <b>CPU:</b> 4x Intel(R) Xeon(R) CPU E7-8890 v2-15Core @ 2.80GHz <b>RAM:</b> 32x 16G <b>NIC:</b> 4x Intel Corporation 82580 Gigabit Network Connection 4x Broadcom Corporation NetXtreme BCM5719 Gigabit Ethernet PCIe 4x Intel 82599EB 10-Gigabit SFI/SFP+ Network Connection			
Control Node	<b>Hardware:</b> HUAWEI RH1288H v3 <b>CPU:</b> 4x Intel(R) Xeon(R) CPU E5-2660-10Core @ 2.60GHz <b>RAM:</b> 8x 32G <b>NIC:</b> 4x Intel I350 Gigabit Network Connection			
vBNG-UP Device				
Test Bed	Device Type		Software Version	
Performance	HUAWEI ME60-X8A		Version 8.180 (V800R010C10SPC001T)	
Functionality and Resiliency	HUAWEI NE40E-X8		Version 8.180 (V800R010C10SPC001T)	
	HUAWEI ME60-X8		Version 8.180 (V800R010C10SPC001T)	
	HUAWEI NE40E-X2-M16		Version 8.180 (V800R010C10SPC001T)	



**Figure 4: Test Setup – Performance Tests**

## Cloud-based BNG Functionality

Once Huawei successfully deployed the functional test bed topology, we performed a set of functionality tests.

### vBNG-UP Provisioning Using NETCONF

By relying on NETCONF, the management module provides a mechanism to scale-out and scale-in based on the operator requirements. It allows to install and modify network configuration on the vBNG-UP nodes in a predictable manner.

EANTC verified the successful use of the NETCONF protocol by vBNG-CP's management module to provision CUSP and VXLAN tunnels on vBNG-UP devices.

As a prerequisite of this test, we configured IP connectivity between vBNG-UP and vBNG-CP. This included VLAN, IP and routing protocol configuration in the network.

We started this demonstration by configuring CUSP and VXLAN on vBNG-CP. Once we applied the configuration on the vBNG-CP, CUSP and VXLAN tunnel were automatically provisioned on vBNG-UP devices.

EANTC verified that CUSP and VXLAN related commands were newly added in the vBNG-UP configuration file and CUSP and VXLAN channels were successfully established between vBNG-CP and vBNG-UP.

We verified the functionality by establishing subscriber sessions and generating bidirectional traffic.

We demonstrated the identical process for three different Huawei products fulfilling the vBNG-UP role. Those were the ME60-X8, NE40E-X8 and NE40E-X2-M16.

In a separate test case, we also verified secured CUSP communication between vBNG-CP and vBNG-UP. We reviewed and analyzed the CUSP communication and observed that Huawei used TLS1.2 as secured transport layer protocol for the CUSP communication. During the TLS handshake process, the cipher suite TLS-DHE-DSS-WITH-AES-256-CBC-SHA was negotiated between vBNG-CP and vBNG-UP. EANTC suggested Huawei to avoid SHA1 hashing algorithms and prefer stronger cypher suites in futures tests.

In this security feature test, Huawei's ME60-X8 device was utilized as vBNG-UP.

## Subscriber Access Functionality

During the initial testing phase carried out in 2017, Huawei's Cloud-based BNG solution was able to support only IPv4 subscriber sessions. In second phase, we were able to verify that the solution can also support dual stack subscriber session which reflects today's direction towards the inclusion of IPv6 in the Customer Premises Equipment (CPE) devices. Typically dual stack subscriber session is more resource consuming on the BNG nodes while simplifying IPv6 transition from the subscriber point of view.

We performed three series of test runs and verified the following subscriber access functionality on Huawei's Cloud-based BNG solution:

- Dual stack IPoE sessions
- Dual stack PPPoE sessions
- Dual stack PPPoE sessions with Prefix Delegation (PD)

In all test runs, RADIUS authentication and accounting was enabled. We also reviewed and analyzed RADIUS accounting statistics for each type of session, corroborating the results obtained with our traffic analyzer.

## Centralized IP Address Pool Management

In conventional deployments of broadband services, a provider would manually allocate IP address resources on each BNG node placed in different geographical locations. This approach is based on an estimated number of subscribers per region. However, even with careful planning, resource distribution faces the fundamental problem of uneven utilization and resource wasting. Furthermore, such rigid deployment of resources increase management efforts and prevents the operator from rapidly deploying new services or modifying the existing ones.

Huawei claims that their Cloud-based BNG solution is capable of perform a centralized management of the IP address pool allocation.

For this test, Huawei configured a single shared IPv4 address pool for two different domains in vBNG-CP. Each domain was associated with different vBNG-UP. Once the configuration was deployed, both vBNG-UPs received a unique range of IP addresses from the same address pool. We established PPPoE sessions from the traffic generator connected to both vBNG-UP devices and verified that the established sessions received IP addresses within the expected IP ranges.

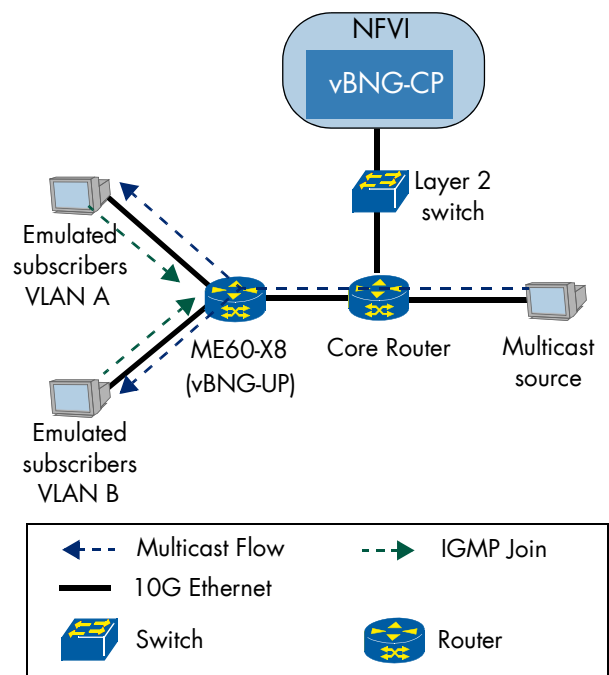
## Multicast Functionality

In the multicast services deployment over broadband network, the modern Digital Subscriber Line Access Multiplexer (DSLAM) or Optical Line Termination (OLT) devices performs the IGMP snooping function in order to prevent unnecessary replication of multicast traffic in the network. In this scenario, the BNG would send a single multicast stream for each multicast group to the DSLAM or OLT devices, where it will be then replicated and sent to the interested receivers.

When IGMP snooping is not supported on DSLAM or OLT devices, the BNG will listen for all IGMP messages and perform replication when required, in order to provide multicast services.

Huawei claimed that the Cloud-based BNG solution is capable to support both deployment models.

To verify Huawei's claim, we deployed the test setup as show in Figure 5. We configured two set of IPoE subscriber groups, each set with a unique VLAN Id. In each set, we emulated 1,000 subscribers and each subscriber joined 3 multicast groups.



**Figure 5: Test Setup – Multicast Functionality**



We used the same test setup to verify the following two scenarios:

- Multicast forwarding per VLAN ID

This scenario reflects the case where the DSLAM or OLT devices support IGMP snooping.

In this test scenario, we observed that the vBNG-UP sent only one copy of traffic for each multicast group. Finally we sent IGMP leave messages from the emulated subscribers and as expected vBNG-UP stopped to forward the traffic.

- Multicast forwarding per subscriber

This scenario reflects the case where the DSLAM or OLT devices don't support IGMP snooping.

In this test scenario, Huawei configured vBNG-UP device to forward multicast traffic based on IGMP join messages received from individual users.

We verified that the vBNG-UP replicated multicast traffic for each user individually.

With this two test scenarios, we verified the multicast support for Huawei's ME60-X8 device, acting as vBNG-UP.

### **Carrier-Grade Network Address Translation**

Due to the shortage of IPv4 addresses, service providers may want to implement Carrier-Grade Network Address Translation (CGN) feature in the BNG in order to provide services where a public IPv4 address could be shared by many subscribers.

EANTC witnessed CGNAT functionality supported on Huawei's Cloud-based BNG solution. In addition, we verified that the vBNG-CP performed centralized management of public and private IPv4 address pools.

For this test, Huawei configured public and private IPv4 address pools in the vBNG-CP. Once we established PPPoE IPv4 sessions, the vBNG-UP received a range of public IP address pool from the vBNG-CP.

To verify the correct functionality of NAT, we generated bidirectional traffic over the established PPPoE subscribers and analyzed the packet captures on the core network and access network sides. As expected, for traffic flowing from subscribers to the core we observed private and public source IP addresses on the access and core sides respectively.

In a separate test run, we verified port range limiting feature on vBNG-UP. This feature limits the number of unique flows (5 tuple flow) that a user is allowed to use.

### **On-Demand Bandwidth Reservation**

EANTC witnessed that Huawei Cloud-based BNG solution supported on-demand subscriber bandwidth policy changes for specific services. The services in this case were identified based on the IP address of the subscriber.

For this test, we established two PPPoE subscriber sessions in the same domain. The vBNG-UP programmed the bandwidth policy for both subscribers based on the information retrieved from the vBNG-CP using CUSP.

We generated bidirectional traffic for both subscribers and the traffic was forwarded at the maximum rate specified in the bandwidth policy.

While forwarding the traffic, we modified the bandwidth policy for a subscriber by increasing the bandwidth for his specific IP address. This modification was applied by sending out RADIUS CoA-Requests (Change of Authorization) for the specific subscriber to the vBNG-UP.

We verified that the bandwidth increased on-demand for the specific user. In addition, we verified that the policy change on a subscriber did not affect other user traffic.

We performed this test using Huawei's ME60-X8 device as vBNG-UP.

### **Hierarchical Quality of Service (HQoS)**

In broadband access networks, where multiple PPPoE/IPoE sessions from different subscribers are terminated on the same interface, there is the need to implement a hierarchical traffic classification, queueing and policing. HQoS allows to pre-classify subscriber traffic to make sure each service gets the network resources required. It eliminates the need to reserve resources for unused services. In Huawei's HQoS implementation, the shaper and queue at the ingress or egress interface is split into multiple hierarchical levels such as port level, customer group level, individual customer level and individual customer service level.

Huawei claims that their Cloud-based BNG solution is capable of performing HQoS functionality.

To verify this, Huawei configured shaping in three different queue levels, namely port queue, group queue and user queue. For this test, we emulated 2,000 subscriber generated three different Class of Service (CoS) traffic and validated that the vBNG-CP forwarded traffic correctly into the respective shapers and queues configuration.

## Performance and Scalability

In our next series of tests we asserted the performance of the Cloud-based BNG solution with one vBNG-CP and five ME60-X8A vBNG-UPs as shown in Figure 4.

We measured the maximum session establishment rate and the total session capacity of the vBNG-CP.

As Huawei requested, all tests were performed without RADIUS authentication and accounting. Instead of RADIUS authentication, Huawei used local authentication using CHAP method for PPPoE subscribers.

The modifications Huawei requested to improve the performance of the solution is beyond what can be expected in real service provider scenarios. Huawei asked EANTC to run the test cases with this configuration to show maximum performance values achievable in theory.

### Subscriber Session Setup Rate

We measured the maximum IPoE and PPPoE single stack session establishment rate supported by a single vBNG-CP solution in combination with five Huawei ME60-X8A vBNG-UP devices.

We performed this separately with four different user access scenarios:

- IPoE single stack IPv4 session setup rate
- IPoE single stack IPv6 session setup rate
- PPPoE single stack IPv4 sessions setup rate
- PPPoE single stack IPv6 session setup rate

In all of the four test runs, we achieved successful establishment of subscriber sessions at the average rate of 10,400 sessions/s without observing session failures or sessions retries.

Session Type	Auth. method	Total sessions	Setup Rate [session/s]
PPPoE IPv4	none	2,560,000	10,400
PPPoE IPv6	none	2,560,000	10,400
IPoE IPv4	none	2,560,000	10,400
IPoE IPv6	none	2,560,000	10,400

After the sessions were established, we sent bidirectional test traffic for all sessions to verify the forwarding between the core network and the emulated subscribers.

### Subscriber Session Capacity

Huawei set the bar high with it's Cloud-based BNG solution, by delivering 20.992 million of subscriber session capacity with a single vBNG-CP.

To achieve this performance number, the test bed required 41x vBNG-UP devices. However, Huawei was unable to provide those many vBNG-UP devices for this test. Huawei decided to perform this test with a specific test method.

Huawei asked EANTC to witness this test case with the following configuration changes and test procedures.

Configuration changes on vBNG-CP:

- Configured UP detection timeout to zero on vBNG-CP. Enabling this command, vBNG-CP will not send UP keep alive messages to vBNG-UP. This will allow vBNG-CP to maintain the UP sessions, even in the case of vBNG-UP is disconnected.
- Disabled RADIUS accounting for the users. Configuring this, vBNG-CP will not request any user accounting information from vBNG-UP.

Test procedure:

- Step 1: Established 2.56 million (5120,000 per vBNG-UP) subscribers using 5x vBNG-UP devices and sent bidirectional traffic to verify the functionality of the user session.
- Step 2: Disconnected CUSP and VXLAN sessions on 4x vBNG-UP devices out of 5. Since the user keep-alives were disabled, all sessions remained established on the vBNG-CP. To ensure that the existing sessions are not impacted during the whole test procedure, we kept one vBNG-UP remaining untouched and we continuously generated bidirectional traffic until the end of the test.
- Step 3: Using the traffic generator, terminated all the sessions established through the disconnected 4 vBNG-UPs. Since CUSP and VXLAN was disconnected already, vBNG-CP was unaware about this.
- Step 4: Reconfigured CUSP and VXLAN sessions on 4x vBNG-UP devices and established another set of 2.048 million (4\*512,000) sessions from the traffic generator. To verify the functionality, we generated bidirectional traffic for the newly established sessions.
- Step 5: Repeated the steps 2-4 until the total number of subscriber sessions are achieved to 20.992 million.

We performed this test four times with different types sessions:

- IPoE single stack IPv4 sessions
- IPoE single stack IPv6 sessions

- PPPoE single stack IPv4 sessions
- PPPoE single stack IPv6 sessions

In all four test runs, vBNG-CP achieved 20.992 sessions.

Using this method, EANTC verified that the vBNG-CP was able to provide 20.992 million concurrent subscriber access.

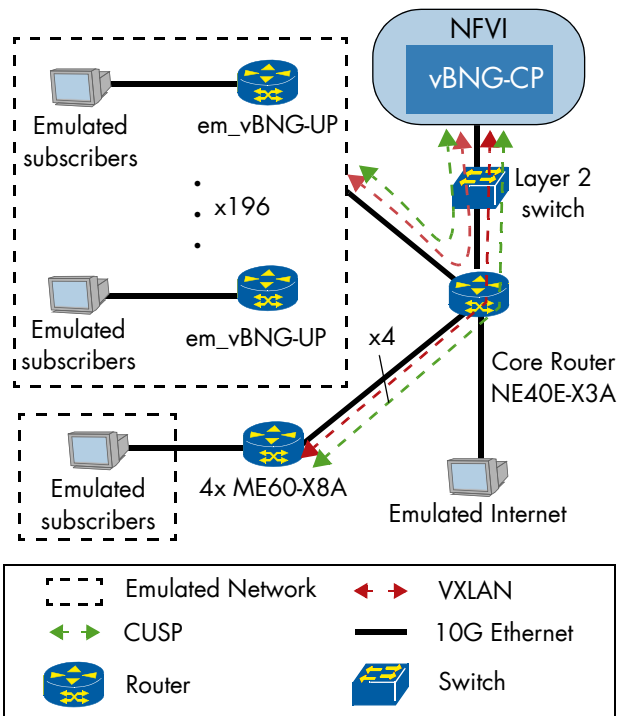
### vBNG-UP Devices Management Scalability

In the conventional deployment of the broadband services, the provider would assign a number of hardware Broadband Network Gateways (BNG) to serve a specific geographic location and each BNG device needs to be managed individually.

With the Cloud-based BNG solution, Huawei seeks the possibility to deploy a centralized management capability of a large number of vBNG-UPs relying on IP connectivity only, without geographical limitations.

The goal of this test was to verify vBNG-UP device management scalability of a single vBNG-CP platform. Huawei claims that a single vBNG-CP is capable of managing up to 200 vBNG-UP devices.

To verify this scale number, Huawei needed to optimize the vBNG-CP configuration that we used for the performance tests.



**Figure 6: Test Setup – vBNG-UP Management Scalability**

The changes were:

- Added 2 more UPMNGs and UPACCs components (including active/standby)
- Changed the number of manageable vBNG-UPs per UPMNG from 8 to 32.

Since Huawei had a limited number of vBNG-UP devices available for the test, we used Huawei’s proprietary test tool to emulate vBNG-UP devices. As shown in Figure 6, we configured the test setup using 4x Huawei ME60-X8A vBNG-UP devices and 196 emulated vBNG-UP devices.

For the verification, initially we established PPPoE sessions from the traffic generator connected with all Huawei ME60-X8A devices. Meanwhile we started vBNG-UP emulations from the tester tool and established few PPPoE sessions to verify the functionality of vBNG-UP emulation.

In addition, we also verified that 200 CUSP and VXLAN channels were established on vBNG-CP as expected. Finally we generated bidirectional test traffic for each PPPoE subscriber sessions established from vBNG-UPs including emulated vBNG-UPs. This confirms that all 200 vBNG-UPs were successfully managed by vBNG-CP.

During the test, we asked Huawei to add one more (in total 201) vBNG-UP device. The vBNG-CP showed a warning message “The UP num has been reached the upper limit” while deploying one more vBNG-UP device.

### Resiliency

In case of vBNG-UP access link failure, Huawei claims that the impact of the failure can be mitigated using two different failover implementation, namely 1:1 hot standby redundancy and N:1 warm backup redundancy.

- 1:1 hot standby redundancy

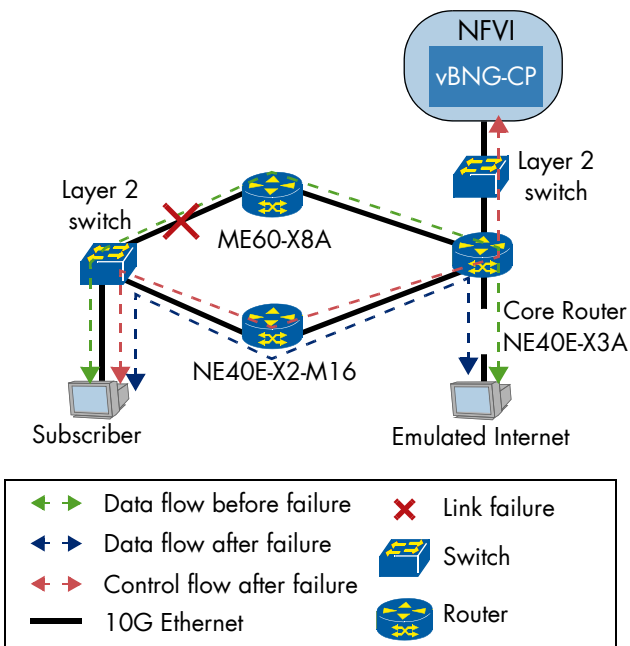
In this redundancy concept, vBNG-CP manages the vBNG-UPs and assigns master and slave roles to them. Interfaces on vBNG-UPs share a virtual MAC between redundant nodes. When a subscriber’ comes online, vBNG-CP performs live time synchronization of user tables between both the vBNG-UPs. The vBNG-CP monitors the status of access links and if a link failure occurs, it changes the role of the slave interface to master. Since both the vBNG-UP interfaces share a Virtual MAC, in case of link failure, the user traffic can be forwarded through the new master vBNG-UP interface.

As shown in Figure 7, we configured the test setup and simulated a link failure while generating bidirectional traffic over 5,000 PPPoE and 5,000 IPoE

IPv4 subscribers. We simulated the link failure by removing a physical link.

We measured the failover time by evaluating the number of lost packets. During the failover, we observed that all active sessions were unaffected and the measured maximum failover time was 160ms.

After reconnecting the link, the traffic was automatically switched back to the initial path. The solution does not support manual switchover. We measured 30ms as maximum failover time.



**Figure 7: 1:1 Hot Standby Redundancy**

- N:1 warm backup redundancy

In this redundancy concept, vBNG-CP maintains a single backup vBNG-UP for a set of active vBNG-UPs. In case of an access link failure on an active node, the vBNG-CP copies the user and route table from the failed node to the backup node. In contrast to 1:1 hot standby concept, the user table is not synchronized in real time.

In our test, Huawei deployed one backup node for two active vBNG-UPs. As requested by Huawei, in this test we validated the functionality of N:1 warm backup redundancy concept using a low number of emulated subscribers. Since this redundancy mechanism does not synchronize the user table and routing information, the service down time is directly proportional to the number of sessions established on the failed vBNG-UP.

In our test, we established 500 PPPoE and 500 IPoE IPv4 sessions and we measured a maximum service down time of 1.23s. In the real scenarios, we expect the vBNG-UP to handle tens of thousand subscribers, where the failover time will be higher than the value we measured.

### Test Highlights

- ➔ Measured 160ms as max. failover time with 1:1 hot standby vBNG-UP redundancy concept
- ➔ vBNG-UP supported N:1 warm backup redundancy concept
- ➔ No impact on the existing subscriber sessions during and after vBNG-CP failover
- ➔ Huawei demonstrated subscriber database separation feature

### Data Center Disaster Recovery

In a physical network environment, EANTC typically tests link and node failures. In a virtual network environment, there are additional test scenarios such as VNF component failure, compute node failure and data center disaster.

In this testing phase, Huawei demonstrated data center disaster recovery scenario using two vBNG-CPs deployed in separate set of compute nodes. One vBNG-CP was configured with the master role and second one was with the backup role.

For this demonstration, we established 10,000 PPPoE and 10,000 IPoE IPv4 sessions and generated bi-directional traffic. We noticed that the sessions were synchronized between vBNG-CPs in real time.

While generating the traffic, we performed a reboot on the master vBNG-CP and as expected we observed no impact on the established user traffic. However, new sessions could not be established during and after the reboot. In order to accept new subscriber sessions, we needed to manually change the role from backup to master on vBNG-CP. Once the rebooted vBNG-CP was in operational mode, we performed manual switch back command again.

### Subscriber Database Separation

Huawei claims that subscribers information can be outsourced from the vBNG-CP to an independent database running on Virtual Machine (VM). This independent database VM can be deployed to store dynamic user information and it can provide better scalability and reliability. For instance, during a vBNG-CP failure, user information is recoverable from database VM without service interruption.

During our test we indentified some performance constraints in the current implementation of the independent database VM. Huawei confirmed that such limitations will be addressed in a subsequent software release in Q2 2018. Therefore, Huawei requested EANTC to witness the functionality of

database separation by emulating 10 subscribers only.

For this verification, we asked Huawei to disconnect subscriber database VM from the vBNG-CP. Then we rebooted the vBNG-CP while generating traffic over 10 PPPoE IPv4 subscribers. After reboot is completed, we noticed that all sessions were dropped and no traffic was forwarded.

Additionally, we performed a variation of the previous test, where the time subscriber database VM was connected to the vBNG-CP. As expected, the user traffic was unaffected during and after the reboot. We also verified that vBNG-CP retrieved all 10 subscriber information from the database VM.

### Centralized Resource Management

In our final series of tests, we witnessed centralized Cloud-based BNG resource visualization capability of Huawei's Network Cloud Engine (NCE) management tool.

Following statistics were demonstrated:

- vBNG-UP Statistics including current and peak user statistic including trend chart
- IPv4 and IPv6 address pool statistics
- Domain Overview
- vBNG-UP access Interface statistics including status of the link

The demonstrated NCE management tool version V100R018C00 automatically updates statistics every 15 minutes. The user can perform a manual synchronization on the tool to retrieve the latest statistics from the Cloud-based BNG components at more granular intervals. The synchronization time is dependent on the number of available vBNG-UPs and it's interfaces. NCE uses NETCONF protocol to retrieve information.

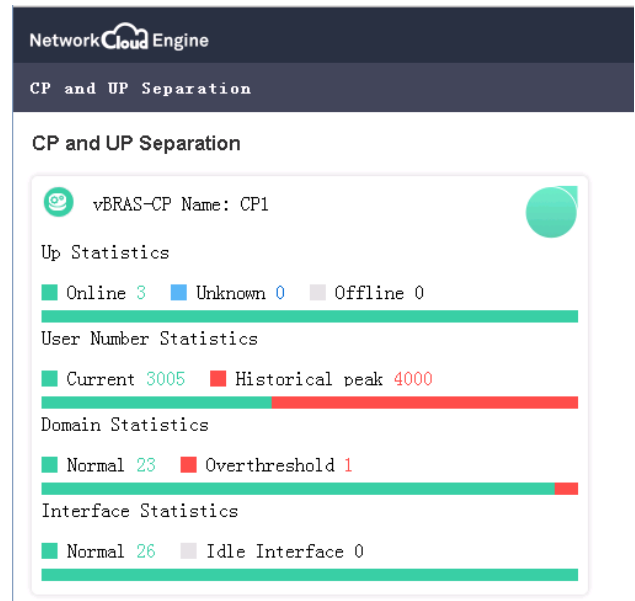


Figure 8: NCE - vBNG-UP Statistics

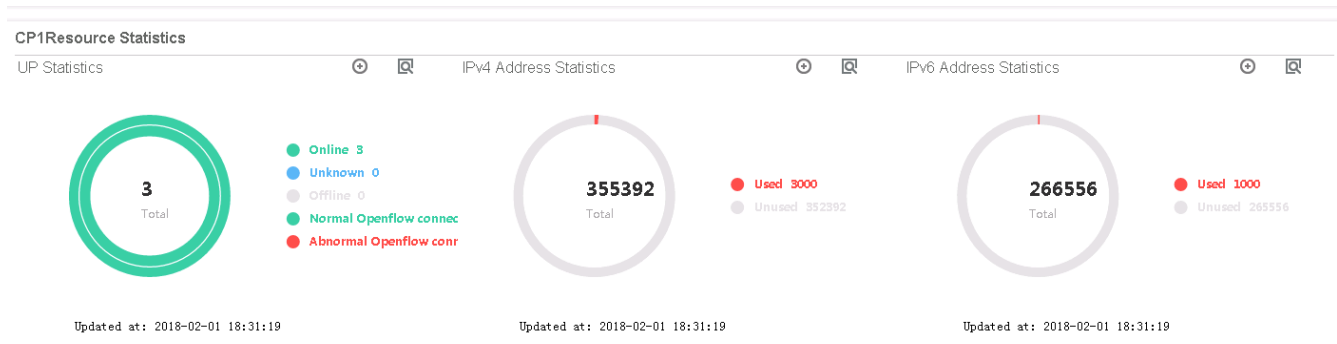


Figure 9: NCE – IP Resource Statistics

## Conclusion

During the two weeks of the test campaign, EANTC verified functionality, performance, scalability, redundancy and manageability of Huawei's Cloud-based BNG solution. The Cloud-based BNG solution performed very well across all of the test scenarios we evaluated.


Initially we verified a set of Cloud-based BNG's features such as dual-stack subscriber, multicast, CGN, HQoS and on-demand bandwidth reservation. All tested features functioned as expected.

Then we focused on the performance and scalability test scenarios. We measured maximum session capacity and session setup rate of a single vBNG-CP component and we were impressed by the large scale results. Also, we verified the maximum number of vBNG-UP devices that a single vBNG-CP can handle.

During the tests, Huawei's BNG demonstrated excellent coordination between the CP and UP devices.

Once we concluded the performance and scalability, we turned our attention to the high availability concept of the Cloud-based BNG solution.

Finally, we witnessed BNG resource visualization capability of Huawei's Network Cloud Engine (NCE) management tool.



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