TITLE: Business Cases for Virtual Customer Premises Equipment (vCPE) for end users subscribers

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Keywords

FTTH, Customer Premises Equipment (CPE), University/Residential Gateway (U/RGW), Virtual Software Execution Environment (VSEE), IaaS, OpenNaaS, Operational Expenditure, Capital Expenditure.

Abstract

This article summarizes the advantages of the vCPE for residential subscribers use case in terms of OPEX, CAPEX, resource optimization, TTM improvement for new services, troubleshooting and LAN device management.

What is more, the vCPE use case aims to propose a different paradigm for the integration of core-metro and access networks while enhancing the service offering at a lower cost. This new paradigm leverage on: resource efficiency taking advantage of the rise of virtualization solutions that manufacturers provide in their network nodes, value added services (VAS) currently provided by the RGW that can be clearly enhanced thanks to the layer 2 visibility and the set-up of a VSEE in operator premises, and end user environment simplification aiming to remove all dispensable devices from his premises shifting the software execution to the access network without lacking any functionality or service.

In addition, this article describes the role of OpenNaaS as a key part of the operator's network management tool where current and new services can be built upon.

1. Introduction

Nowadays, the subscription of a new service is usually associated to the deployment of new devices within the customer premises. Such is the case of an ordinary xDSL subscription enrolment and its Residential Gateway installation for the Internet access, but it continues increasing with the installation of others triple play services like set top boxes for IPTV. This scenario may even be stressed if the customer decides to contract a FTTH access, where an ONT is additionally installed to terminate the fibre connection.

Service providers are usually responsible for supplying the end to end service – i.e. including the network connectivity devices and also the needed Set-Top-Boxes, recorders, etc. – and, as such, they have not only to deal with initial investment in the devices, but also with the maintenance that such devices might bring up. Home visits for installation or malfunction replacements highly impacts the operation costs of the service. This indicator will probably get worse because newer and more advanced applications are likely to provoke more incidents in the service, as they require more complex devices either prone to failures, to firmware upgrade, lack of memory, etc.

Besides triple play basic infrastructure, embedded video on demand platforms are complementary services offered in the portfolio; these OTT services requires the operator to invest in a separate media box which is added to the user home infrastructure. These services are much less traded than basic broadband subscriptions and it is so, that on top of introducing and additional device in the home, the service and roll out expenses directly faces with the service pricing that the user is able to agree. Again, the CapEx – of the device investment - and OpEx - derivated from the service maintenance – leads to high deployment and operational costs for service provider's current business models, and represent a real barrier to improve the service penetration.

To conclude a broad variety of devices present at home, external hard drives guarantee users to stores its own generated content at the expense of introducing a new black box into the home. Fortunately, UPnP protocol is been adopted by a wide brand of multimedia and smart home devices to make it possible the plug&play discovery and to define a common home LAN protocol communication. However, even if an easy set up of all sort of devices mask the growing complexity of the home LAN, the user instead becomes reluctant to install so many gadgets in a crowded and complex home LAN. A simplification of the home environment is needed to remove some potential dispensable devices.

In short, although there are means to fulfil all multimedia needs raised from the home environment, the costs assumed by the operator and indirectly also by the user, and the inconvenience associated to the service delivery, hinders massive roll outs and shrinks potential incomes. To change this trend, it is necessary to understand the last mile network configuration and the way services are delivered to the end user.

The network model followed during years have being relayed in a reference architecture that keeps the software and hardware complexity on the edges of the service communication. Ever since until nowadays it has being benefited operators by leaving its metro and core networks almost only to transport matters/functions. However, this business model has worked for the moment in which the number of service applications and the number of devices connected to the home LAN were relatively low to jeopardize the quality perceived.

With the introduction of multiservice device generation, new actors come into play with a wide bunch of services in continuous growth. Services of very different nature are now accessed by multiple users at the same time. Some of them require a minimum bandwidth to operate, allows very little delay and jitter, or are able to establish a big number of simultaneous connections towards other users.

In this heterogeneous environment, third party applications are usually treated as background traffic competing as equals for the access resources. This unfair competition penalizes the most sensitive applications inasmuch small variations of the network conditions might impact the quality perceived by the user.

Some of the most demanding services are real time like online video games, VoIP, and high quality video streaming. These applications really challenge the service coexistence where a broad brand of network necessities is impossible to tackle with no access to these applications. As a consequence, the quality of experience perceived is also reduced if the operator is not able to recognize them and apply prioritization mechanisms in the access network.

Network barriers heritage from the current network model forces the operator to only be able to manage its own services, determine its own services requirements, label the traffic and treat it with policies or even allocating specific resources. In fact, when operators currently offer their triple play services, they schedule different networks to each service (different architectures, different bandwidth, different QoS parameters, variety of infrastructure, manufacturers, partners, etc.). This practice of attaching service and device to platform is increasing CapEx and OpEx and shrinking the result of the investment, and will no longer be suitable to efficiently provide converged services to a broad range of devices.

For all the above mentioned, a new paradigm in the access network must be envisioned in order to simplify customer infrastructure: where subscribing to a new service doesn't imply the acquisition of new infrastructure to the user, or by removing dispensable devices to be substituted by a cloud based service delivery. A scenario of home LAN cooperation would be helpful as the operator would be able to take part more actively on the home LAN management. Applications related to: home automation, energy savings, on demand QoS policy schedulers, or e-Health services could be easily provided to the future connected home.

The scenario here depicted of next generation accesses translates all complexity of the home infrastructure to the access network, where the operator can manage it more efficiently relying on its own computational resources. The employment of virtualisation techniques makes it possible to slice part of this IT infrastructure and share it with users just as if it were installed in the home environment.

In this scenario, the operator will shift all multimedia processing distributely offered in separate devices to a centralized data centre. With such configuration the operation and maintenance of the infrastructure devoted to home services is clearly optimized as well as it dramatically speed up the service roll out of new multimedia services.

This new way of creating and delivering value approaching to an IaaS paradigm, supposes turning the IT infrastructure into a high valuable asset that can be directly traded to the user. As a result, the operator will be able to allocate execution capabilities (RAM, CPU) to home subscribers according to their computational needs representing an actual breakthrough for maximizing the revenues in the medium term and facilitating the entry of future home services.

Being part of the home LAN domain is the key target that virtualization makes it possible enabling different services converge in shared networks and infrastructures, avoiding duplications, and shrinking dramatically capital and operational expenditures. This new approach will preserve the capability for

deploying high content media delivery at lower costs, and even open the door to new domotic solutions and business opportunities.

One approach is to analyze the possibility of developing a new access network architecture relying on the virtualization of the layer-3 home routing gateway functionality. Then, the operator could remove in a first instance the Broadband Access Routers at customer premises and get into the home LAN to provide further services with no additional infrastructure installed in the home premises. This solution is the virtual CPE.

This article summarizes the advantages of the vCPE for residential subscribers use case in terms of OPEX, CAPEX, resource optimization, TTM improvement for new services, troubleshooting and LAN device management. It also evaluates the role of OpenNaaS as a key part of the operator's network management tool where current and new services can be built upon.

2. The Virtual CPE

The Virtual CPE current state of the art in home and access network architectures relies on a layer-3 device (the routing gateway) in home premises that performs different functionality depending on the access technology (xDSL modem, GPON modem, etc.) and/or the services provided (Internet access, IPTV, VoIP, etc.). Such functionalities include NAT, local DHCP, IGMP proxy-routing, PPP sessions, routing, etc. This routing gateway is the base equipment for Telco services, enabling Internet access. Advanced services rely on additional devices (e.g. IPTV needs a set-top-box, generic VAS need a Home Gateway). This model, based on the installation of different devices in home premises, implies a high cost for service providers in both initial installation and operational support as they are typically responsible for the end-to-end service.

This problem is even worse in GPON deployments as nowadays its home premises modems, the ONTs, do not include layer-3 functionality themselves and delegate those in a separate routing gateway within the users' homes. As a result, an additional device must be installed in the customer's premises for fibre accesses.

The fact of having a new (layer-2) device in the home, the ONT, is a driver to propose a different paradigm for the home network. Since fibre deployments are in an early deployment stage, this could be the right moment for a radical shift in the way broadband fibre services are delivered.

The architecture proposal for home virtualization is specially focused on GPON accesses, and is based on the following requisites:

- Home and access networks should be layer-2 based networks with layer-2 visibility among them, where the need for routing gateways in the home network is suppressed.
- Installation and maintenance procedures should be simplified and Plug & Play client architecture should be achieved.
- Devices and services should have the capacity of self-provision.
- The vast majority of layer-3 functionality should be moved from the home network to the service provider network, whether distributed across the network or virtualized in a single node.

A CPE virtualization solution is under study aiming to reduce the number of devices in the residential environment by targeting a L2 access network. The key point that makes it possible is the successfully removal of the Broadband Access Router from the customer premises.

Some of the functionalities must remain within the household, such as the L2 switch the SIP client, and the Wi-Fi facility proposing to be held within by the ONT. Instead, some of the functionalities performed by the current HGW can be tackled within the access network. These particular kinds are the networking such as routing, NAT/PAT or DHCP.

The following studies all the necessary networking functionality and the way it can be implemented at some point of the network so the perception of the user is, at least, as good as if the physical router would be at his home.

- For instance, the DHCP server that will allocate IP addresses to user terminals would now be located in the access network and different ways of addressing have been considered. Although differentiating the addressing range among different homes would ease the OLT to identify user traffic origin, for the sake of scalability it would be better to use an Overlapped address system. In turn, it is not desirable applying special addresses to specific devices to define a determined behaviour preferring in contrast a multiservice based addressing system.

- Residential Gateway routing functionalities is the main feature shifted to operator premises in order to meet the layer 2 access network architecture. The role would be taken by the IP edge node (BRAS) by means of virtual routers. Different solutions of router virtualization within the node (Hardware or Software based) have been studied, being finally adopted a software based routing instance for each user and for each service.
- Another key concept is the switch integrated within the home gateway. Without the physical router, this capability must be assumed by the ONT. Regarding this new role of the ONT it is desirable that ONT ports should not be dedicated to specific services or devices, being multiservice ports in order to allow any service/device to be connected at any port.
- As a consequence of previous requirements, it is not feasible to maintain the current delivery system in which one service is delivered through one VLAN as this would mean that each port would be associated to one service. Moreover, the delivery of the different services to the home throughout separated VLANs usually is a complication in the service provisioning, and especially in this architecture in which it was the Broadband Access Router the entity in charge of routing user traffic to the corresponding VLAN. For all the above mentioned it is desirable to deliver triple play service over a single VLAN (on Ethernet ports, Plain Old Telephony Service (POTS) port would send the traffic through another VLAN) .Due to a single VLAN would be used for all services, the OLT would forward the traffic through the MAN (OLT operating in QinQ mode) instead of rerouting the different VLANs to the different services.
- Finally, another functionality shifted to the access network is the Network Address Translation (NAT). There are different possibilities with the NAT performance depending on the addressing system used. It is desirable to perform NAT to all services. The NAT server could be located somewhere in between of the BRAS and the OLT, most likely within the BRAS where the public IP address is allocated to the Virtual Broadband Access Router.

Virtual CPE and layer-2 access network concept suppress the barrier of the RGW aiming at a single device deployment for fibre Internet access, and to decrease capital expenditure. In addition they will allow service providers to enhance the visibility over the customer LAN easing the deployment of remote management platforms, which would translate into fewer troubleshooting visits to the customer home for installation and maintenance purposes, resulting in a significant reduction of operational expenditure.

The possibility of providing current triple play services without investing in user infrastructure supposes an actual breakthrough for maximizing the incomes in the short term and will smooth the way for personalized access and future home services.

Virtual CPE solution relies on router partitioning to cover the service demand for FTTH subscriptions or universities. Shifting U/RGW layer 3 functionalities to the edge node of the access network not only enhance CapEx and OpEx for fibre deployments but enables reaching the residential environment with layer 2 protocols.

This new layer 2 visibility of the access network allows the operator to deploy new services without installing additional hardware at the customer site. The installation of special purpose hardware and software at operator premises brings an opportunity for a redefinition of the access network and the way services are deployed and delivered to the end user.

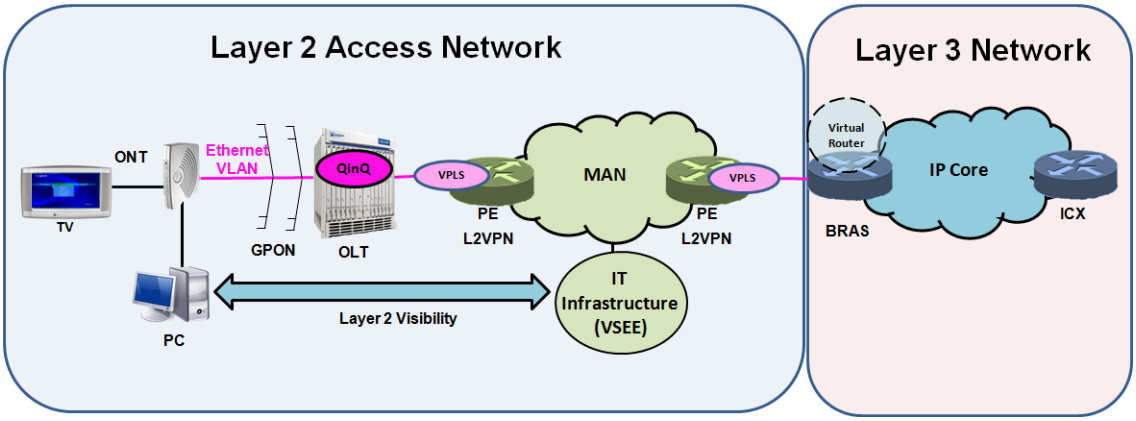

Figure 1: Layer 2 Access Network

Figure 1 shows the Virtual Software Execution Environment (VSEE) within the access network infrastructure. Notice that in the picture it is stressed two regions depicted as Layer 2 and Layer 3 access network. In current deployments where a physical RGW is present, the layer 2 environment is restricted to the home LAN. The physical RGW settles a barrier which delimitates the broadcast dominium where applications may interact without the necessity of an IP layer implication (layer-2 visibility). Shifting the layer-3 functionalities of the RGW to the access network (in the picture until the BRAS) extends in turn the layer 2 visibility until the operator premises where dedicated infrastructure (VSEE) could execute user applications in the same way as it were within the home environment. Among other benefits, this fact opens the door to the deployment of new services that are not anymore constraint by user infrastructure but restricted to IT infrastructure which have far more powerful performance.

3. The Virtual Software Execution Environment (VSEE)

The VSEE is the entity that runs the subscriber execution capabilities currently conducted in a physical RGW. In addition, the VSEE aims to host other service applications that currently don't run within the RGW but in separate devices such as Set Top Boxes for the IPTV service or OTT services.

The VSEE is envisaged to provide service to thousands of users, so in order to optimize the operator infrastructure, the VSEE is composed of a set of physical servers hosting virtual instances sharing the network resources. Each instance is targeted to service a single subscriber so its configuration and resource allocation is personalized according to the needs of a particular subscription and the services subscribed.

Therefore the VSEE represents the pool of resources that the operator puts at disposal to the end users to run service applications. These applications may either belong to operator current services, which its functionality has been virtualized from a physical device, or applications selected by the user from third party services.

The possibility of installing special hardware and software at the operator premises and make it work as if it were inside the household or university is the main driver for the development of a Virtual Software Execution Environment (VSEE); a platform where each subscriber owns a virtual instance capable of executing user's software applications.

With virtualization techniques the operator will be able to partition the VSEE and allocate virtual instances to customer premises with different performance specifications (CPU processing and RAM capabilities), tailoring the network provider resources to the subscriber needs. Thus, the offer of high demanding services are not anymore constrained by the hardware and software capacities of the customer equipment but to network provider's IT and network infrastructure.

This new VSEE at disposal to the user will host all software applications covering not only operator's residential service portfolio but also third party services. This way of combining the enrichment of the overall commercial offer by providing IaaS to third parties opens new business opportunities with the same base infrastructure.

The VSEE solution adoption also facilitates the operator to have a better understanding on the services running within the home LAN leading to a better management: on updating VSEE firmware, smoothing the IPv6 migration, applying QoS for service coexistence. Yet it also represents a challenge when managing thousands of instances.

Although current manufactures behold virtualization solutions within their product portfolio, these solutions have traditionally being concerned with packet forwarding and switching, being the software execution capabilities outside of their roadmap. Little by little manufactures are including new software capabilities in their network products and SDK's, relying in a virtualized pool of resources that enable service providers to customize their nodes running applications such as load balancing and security services.

However, a further step must to be taken because delivering a complete virtual CPE to residential customers is not already addressed by manufactures. Execution capabilities have a very different nature with regard to the routing packet processing capabilities, requiring much more computational resources and management procedures. Hence, the addition of enough computational resources to carrier-grade network products to provide software based services to thousands of users is still a challenge while outsourcing this functionality to external blades or data centres seems to be nowadays a feasible alternative.

Physical location of the VSEE is also a key point in terms of scalability during the solution assessment. Deploying the VSEE in a service centre or a data centre would maximize the IT resource optimization. On the other hand multimedia services with stringent delay requirements could require the deployment of VSEE instances closer to the user, being under study the allocation of an additional service type oriented VSEE on those locations.

Thus, the centralization of user's software execution capabilities into a VSEE business model implies relaying on a comprehensive provision and management system which is aimed to be the balance in matching IT resources with user computational requirements, realize the access network provision, and deploy and manage the virtual instances.

In conclusion, the vCPE model translates all software complexity to the network aiming the simplest devices at the home environment, and getting advantage of the Internet broadband access. Nonetheless, it is not the unique vision of future accesses as other trends bet to empower the physical RGW, turning it into the key point to govern the home network. Therefore, any eventual solution should try to be compliant with standardization groups on this field (e.g. Broadband Forum, ITU-T, IETF).

4. The OpenNaaS

vCPE solution is a disruptive business model that aims to simplify the access to services and facilitate the roll out of new ones. Hence, in order to maximize its potential, it has to be accompanied by a reinterpretation of service delivery, and its provision and activation system.

OpenNaaS plays an important role on the redefinition of current service activation systems as it offers the opportunity to deploy a common provisioning engine for all services merging the operation of all independent provision and configuration systems into a single instance. Its capability to manage different sorts of network devices and a lightweight operational model decoupled from actual vendor details enable a seamless multivendor network infrastructure.

The OpenNaaS approach implies taking control of part of the network infrastructure in order to allow provisioning of virtualized network resources. Since provisioning can even be triggered either by the operator or by third parties applications, it offers a common API to all agents interfacing OpenNaaS, standardizing the resource reservation request and providing the flexibility to interoperate with other applications built above it.

The unified access to network devices of different vendors, the functionality scalability allowing business orientation and the flexibility for the software extension or adaptation is essential for the introduction of new services without jeopardizing the existing ones.

Regarding a potential deployment for vCPE management, although OpenNaaS can be handled by a GUI, it is desirable an adaptation layer that integrates the existing management systems with the API provided by OpenNaaS. Therefore, a unified middleware would translate the tasks that are to be performed and the information stored in the availability system into OpenNaaS commands.

The interaction among OpenNaaS and third parties applications is also a key feature in this model. Due to OpenNaaS network resources support delegation of access rights from user to user, third party applications are able to trigger on real time resources reservations to accommodate the network to its full service performance minimizing the user management regarding updating or changing his subscription. The resource broker establishes the different criteria for accepting third party network provision requests.

As shown in Figure 2, OpenNaaS is suitable to act as a network manages for the redefinition of current service activation systems. It enables the deployment of a common provisioning engine for all services, merging the operation of all independent provision and configuration systems into a single instance. The most immediate responsibilities came up in this document are: the set-up of the VRFs within the edge node and the routing capabilities configuration, the set-up of the virtual execution instances within the VSEE and the computational resources allocation management to different subscriptions, and the layer-2 configuration throughout the MAN ensuring the connectivity among end users and services.

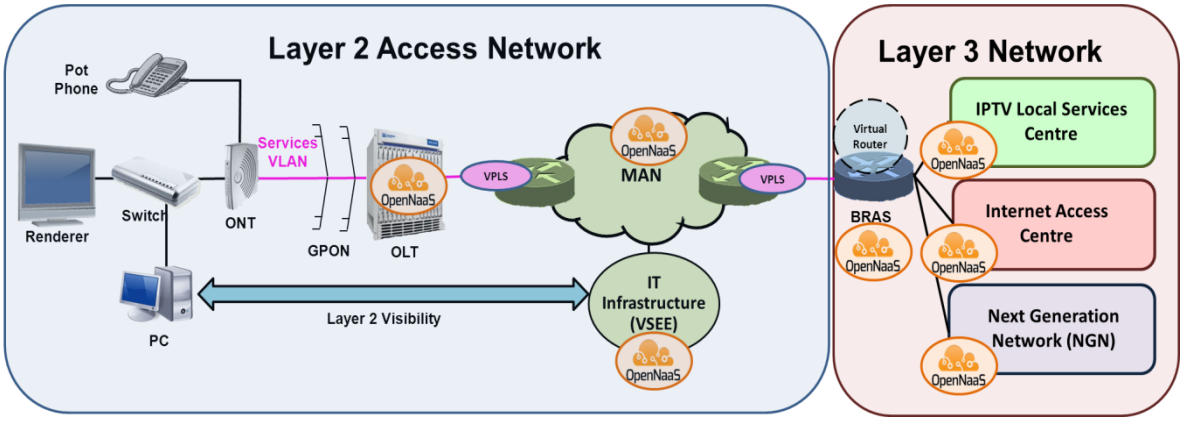

Figure 2: OpenNaaS Applicability in vCPE Architecture

In conclusion, the vCPE use case aims to propose a different paradigm for the integration of core-metro and access networks while enhancing the service offering at a lower cost. This new paradigm aims to leverage on: resource efficiency taking advantage of the rise of virtualization solutions that manufacturers provide in their network nodes, value added services (VAS) currently provided by the RGW that can be clearly enhanced thanks to the layer 2 visibility and the set-up of a VSEE in operator premises, and end user environment simplification aiming to remove all dispensable devices from his premises shifting the software execution to the access network without lacking any functionality or service.

Biographies

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