

A European high speed Access Platform and Residential Gateway

V. Ribeiro¹, V. Pinto¹, J. Wellen², W. Hellenthal², W. Willigenburg², F. Valera³, I. Vidal³, J. García³, M. Ibañez³

¹Portugal Telecom Inovação, S.A. Rua Eng. José Ferreira Pinto Basto, 3810-106 Aveiro, Portugal
{vribeiro, it-v-pinto}@ptinovacao.pt

²Alcatel Lucent, Bell Laboratories Europe, Larenseweg 50, 1221CN Hilversum, The Netherlands
{jswellen, whellenthal, willigenburg}@alcatel-lucent.com

³Universidad Carlos III de Madrid, Avda. De la Universidad 30, 28911 Leganés, Madrid, Spain
{fvalera, ivaldal, jgr, mibanez}@it.uc3m.es

Abstract

This paper presents a complete and integrated demo scenario through which an access platform and residential gateway prototypes, both developed under the scope of MUSE project, will be shown. The paper also intends to clearly expose the innovative aspects of each one of the prototypes.

1 Introduction

Internet access has been, until now, the main driver for the generalization of broadband connections in the residential market. Nowadays the telecommunications market is changing and operators are looking for ways to provide, through a single IP broadband connection, a multitude of residential services. This will, in one hand, increase operator's revenues and on the other hand, provide to the customer a wider range of services until now inaccessible. Although, this multi-service delivery framework imposes network requirements that only a new breed of access platforms can fulfill. At the edge of the access platform a central piece of the overall network infrastructure, usually referred as the residential gateway, is also essential for bridging the access environment with the domestic environment.

There are, therefore, challenges that have to be overcome. MUSE (Multi Service Access Everywhere [1]) is a large integrated European project that intends precisely to address most of these issues. The work presented in this paper can then be seen as some of the results that the project achieved during the past four years.

The remaining paper is structured as follows: section 2 presents the developed high speed access platform and its evaluation, section 3 describes the RGW focusing on its QoS, control and management features as well on its services gateway functionalities. Section 4 describes the complete demonstration scenario to be presented at the conference. Finally, section 5 describes the main conclusions achieved with the paper.

2 The High speed Access Platform

High-speed access technologies face two key challenges. First, obviously the investment costs including operational costs have to be acceptable. Especially housing and powering of networks can impose significant OPEX.

Secondly, access networks more and more need to accommodate demanding services such as IPTV and VoD. Networks need to address this load, preferably at the network edge if possible.

2.1 AsPON Access concentrator

The need for compact Access Multiplexers will remain one of the most important aspects of future access networks. Not only for hybrid nodes, such as the mentioned DSLAM and Radio Access Points, but also for high-speed fiber access networks the footprint, the power consumption and cost should be kept to a minimum. In the MUSE project, an Optical Access Multiplexer has been developed that meets these objectives by making optimal use of available components and transmission techniques. In the downstream direction, a power splitting PON is applied, where in the upstream direction Point-to-Point (P2P) connections are used. This Asymmetric PON (AsPON) solution does not save much fiber, but does not require a complex MAC algorithm: Standard Gigabyte Ethernet can be used both in the Access Node (AN) and the CPE. Power and footprint can be kept to a minimum by using a single transmitter at the AN, and deploying a Parallel Receiver Array (used in optical backbones).

Further improvements involve a Low Complexity Scheduler (LC2WFQ) algorithm that is capable of efficiently multiplexing traffic.

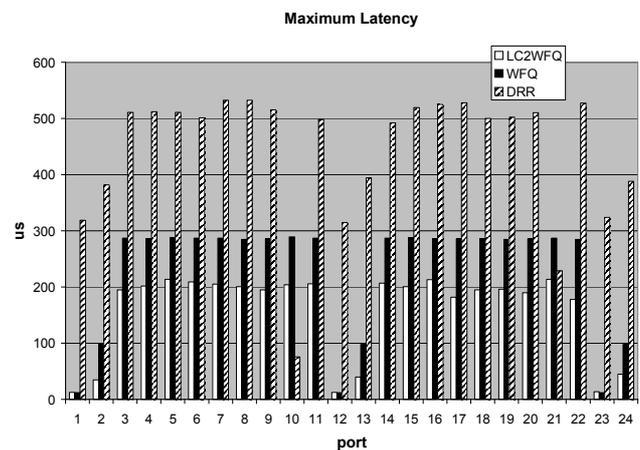


Figure 1: Comparing LC2WFQ to DRR and WFQ

Figure 1 displays the maximum latency of the scheduler for a configuration with different packet sizes. The low latency values clearly illustrate comparable performance to the weighted fair queuing (WFQ) [2] and increased performance compared to the deficit round robin (DRR) [3] scheduler. In this simulated scenario, port 10 and 21 are misbehaving.



Figure 2: AsPON Access Multiplexer blade

The multiplexer was implemented as a single blade serving 48 ports. As shown in Figure 2, the design consists of 6 sections, each containing a Xilinx Virtex 4 FPGA, QDR and MAC chip. Connectivity is provided by 4 12-port Parallel optical receiver arrays for the P2P connections, and a number of SFP transceivers which can be freely configured to provide either uplink connections (up to a total of 6 Gbps) or a PON downlink (up to 6 PONs, ranging from 20 to 125 Mbps per CPE port). Using LX optics, links can range up to 30 km.

Although this research prototype is rather over-dimensioned, with only a fraction of the FPGA gates used, the board is capable of operating at less than 5 Watt/CPE. Compared to standard P2P (Fast Ethernet) optics, a footprint reduction of 77% was achieved, while the dissipation is 86% lower due to the downlink PON. This level is comparable to state-of-the-art VDSL modems.

2.2 Peer-to-peer caching

High-speed access means high network loads. In order to avoid clogging of edge nodes and aggregation networks, caching is a proven method. A peer-to-peer caching system was devised that operates without the need for investments in server farms or external services such as Akamai [4].

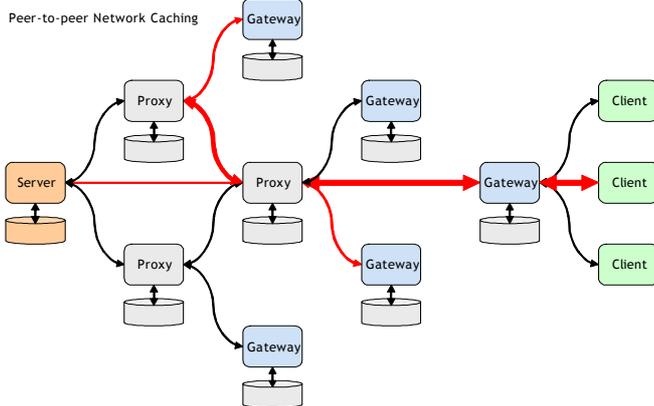


Figure 3: Peer-to-peer caching

In the system, content localization is provided by a hierarchy of Tracking Nodes in the network (Figure 3). By making use of caching resources available in Residential Gateways or Access Points, a multi-Terabyte cache can be constructed that enables fast downloads for the end-user and significant load reductions for the network owner.

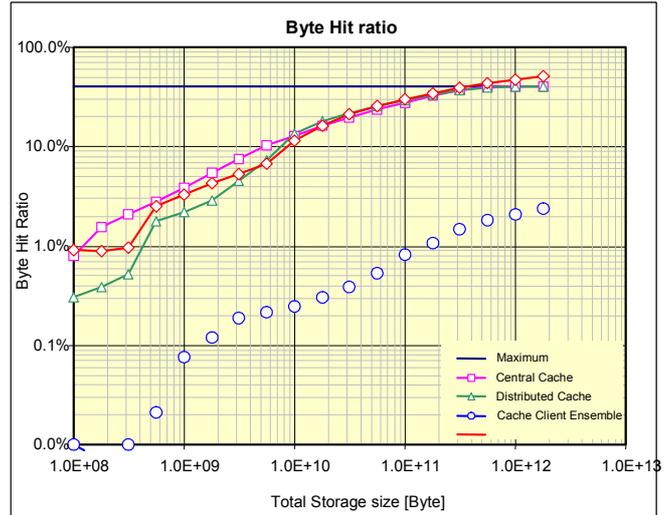


Figure 4: Network load reduction with P2P caching.

As shown in Figure 4, the distributed peer-to-peer cache has the properties of a central cache when the cache per client reaches the size of the content. Other than LAN caching, this system does not use a protocol or signaling. Different from File Sharing networks such as BitTorrent and ED2k, the amount of copies can be controlled to a certain minimum while ensuring an optimal hit ratio.

A prototype of both Tracker and Agent has been developed. Although the system can accommodate several protocols transparently, it currently runs HTTP only.

3 The Residential Gateway

3.1 Quality of service on the RGW

In the MUSE project, the RGW is a key device within its architecture proposal because it is in between the customer network and the access one and must properly adapt all signaling and data protocols. For example, if the transport network provides a Quality of Service (QoS) mechanism, the RGW must forward that QoS in the downstream direction and provide such kind of mechanism in the upstream direction. This is necessary to provide a real end-to-end QoS for whatever kind of service.

In order to design a QoS-capable RGW, its architecture is split in two different levels: the data and the control levels (see Figure 5). The different flows traverse the data level where every packet is processed in order to provide the configured QoS. The control level is used to configure the data one to create, modify or delete different parameters that will be discussed in the following paragraphs.

3.1.1 Data level functionalities

This level, implemented using the Click! Platform [5] is divided in two sub-levels. Each sub-level processes packets in one particular direction (upstream or downstream) and so resources must be different for these two directions. The functional blocks implemented in the RGW are:

- Classification/VLAN tagging. MUSE access and transport networks use the 802.1pq specification to tag Ethernet frames in order to create VLANs and provide

prioritization per flows so the data level will have to mark the different frames.

- Policy/Shaping. Each flow can be configured, either manually or automatically, to reserve a certain amount of bandwidth. When this block detects that the offered bandwidth is higher than the configured one it will decrease or discard packets.
- Dispatcher/Queue System. To accomplish the priority configuration, the RGW has a queue system to store frames that will be extracted by the scheduling block. The dispatcher reads the p-bits from the header putting the frame in the proper queue.
- Scheduling. Depending on the algorithm implemented, this block will extract frames from the proper queue at some configured rate (it depends on several parameters as the interface rate, the flow direction, etc.).

To allow an easy communication between the data and control levels, some points or hooks are defined in the data level to forward frames to a certain application. The application will receive the complete frame (link level) will process (change) it and will send the frame down again to the data layer to the desire hook.

3.1.2 Control level functionalities

The control level is based on flexible Java components, capable of configuring the data level and capable of treating different signaling protocols. Currently, the interface to configure the QoS in the RGW is generic and different mechanisms have been developed, such as SIP based configuration, web access and TR-069 access. The web and the TR-069 access were already present in the first version of the prototype. In respect to the SIP based configuration mechanisms, the RGW architecture shown in Figure 5 has been extended so as to be able to automatically manage the QoS for SIP based multimedia sessions that involve the end user terminals in the home network. The extensions allow to intercept the SIP signaling messages that are used to control the session (establishment, modification and release), and to calculate from them the parameters describing the QoS demands for that session. The following extensions have been developed at the control layer:

- A SIP signaling process. This component receives all the SIP signaling messages that are sent or received by the end user terminals. The SDP offers and answers contained in the SIP messages are used to derive the rules that must be installed in the RGW to guarantee the QoS provisioning. These rules are provided to the Click Configuration Controller Process (CCCP). Concerning SIP/SDP, and due to the problems they show in the presence of NATs, a specific module has been develop in order to detect if the client is using STUN or not (and if not, apply specific SIP-ALG techniques to allow transparent NAT traversal for every message).
- A call admission control module. This component has been implemented as part of the CCCP and performs admission control functionalities, verifying whether the derived rules can be installed or not with the resources that are available in the home network.

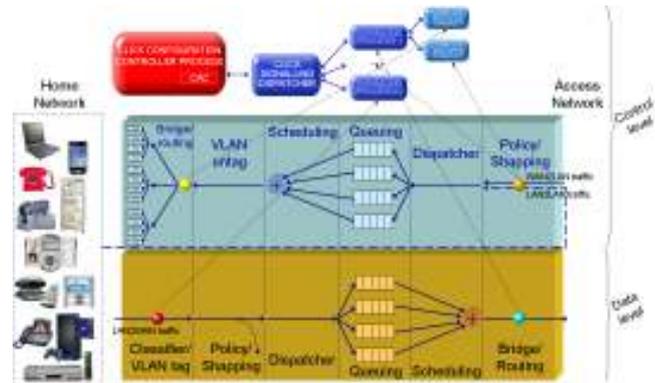


Figure 5: RGW architecture

The proposed architecture for the RGW can also be used to provide QoS within residential environments of next generation networks with SIP based control plane, such as TISPAN NGN [6]. In the current release of TISPAN NGN, the QoS solution is only provided for the access network, and there is no requirement to cover the core networks themselves and the end user networks. Nevertheless, the real QoS perceived by the end user is end-to-end, and whereas in the core network it is assumed that the QoS demands can be satisfied by other means (e.g. over provisioning), that does not happen in the end user network, where there may be resource restraints.

To solve this open issue, the RGW that has been developed within the MUSE project can be used to extend the QoS solution to the end user environment, assuring this way a real end-to-end QoS in TISPAN NGN. This proposal has been presented in a related work [7]. The paper also considers the possibility of implementing a TISPAN specifications compliant interface in the RGW, so as to provide the QoS enablers in the NGN with means to remotely configure the QoS in the home network.

3.2 Management of the RGW

TR069 [8] is the DSL-forum CPE remote management protocol. Remote Management including automatic configuration and remote diagnostics of equipment, will simplify the installation and problem solving processes for the end user, which, in the end, will enable a larger audience to adopt new advanced services.

The TR069 protocol specifies a number of Remote Procedure Calls (RPC) for both the RG and Auto Configuration Server (ACS). Via these RPC the ACS can for example manipulate a set of parameters in a MIB, download files, reboot the device etc. The MIB can be extended by other specifications from the DSL forum, like TR-098 and can be tailored using vendor specific parameters.

The prototype that has been built combines OSGi [9] and TR-069. When designing TR-069 functionality on the RG it proves logical to separate the following:

- encoding the wire SOAP/XML/HTTP
- providing the RPC like getParameterValues
- defining the parameters in the MIB
- applying the changes to the routing/forwarding functionality of the RG

This results in the following architecture:

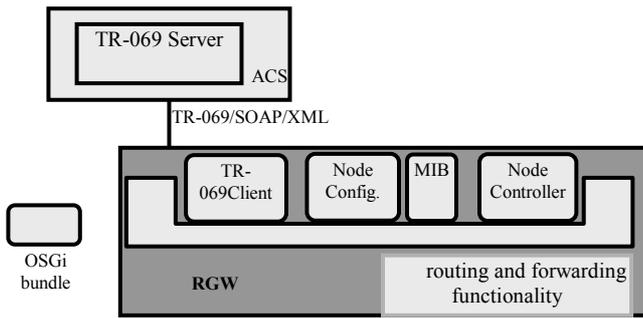


Figure 6: Remote Management using TR-069

The TR069Client bundle (software module in OSGi terminology) contains the TR-069 client protocol engine, which encodes and decodes (Expand abbr.) CWMP messages and handles all the SOAP/XML/HTTP wrapping and unwrapping in communication with the ACS.

A Node Configurator bundle that guards if the underlying hardware/software functionality is ready for communication with the ACS, and implements the remote management and configuration RPC provided by the CWMP, such as a `getParameterValue`, `reboot` or `download`.

The Management Information Base (MIB) bundle, which represents the entire set of Configuration Parameters specified for use with the CWMP management protocol. As in most management protocols, in TR-069 the MIB is built up from hierarchical objects. The objects present in the MIB determine the configuration possibilities. Other OSGi bundles may write or read parameters or subscribe to an intelligent notification mechanism, where changes in values of specific parameters are notified only to interested bundles.

A Node Controller bundle that interfaces with the hardware of the RGW and translates the parameter values in the MIB to configuration of the routing and forwarding functionality.

The RGW communicates with ACS. Through this server configurations and software packages can also be downloaded to the RGW. One example of a software package is the Sesame service described later on. OSGi bundles are also software packages (JAVA jar files) that the ACS can download to the RGW. The next section describes a method to manage the OSGi bundles via a TR-069 extension.

3.2.1 OSGi bundle management using TR-069

The attributes of the bundle as well as its lifecycle state is easily to be included an extension of the TR-069 MIB. This allows the RGW to provide needed information for bundle management to the ACS, and via manipulation of lifecycle parameters to start/stop/refresh/update/install/uninstall bundles.

After a bundle has been installed the information available on the bundle from the OSGi framework is placed in the MIB. A typical bundle installation will follow the following steps:

- The ACS adds a ‘InternetGatewayDevice.OSGi.Bundle’ object
- The ACS writes the BundleLocation parameter URL.
- The ACS writes the BundleCommand parameter “Install”
- The CPE processes the “Install” command and using the BundleLocation URL, downloads the file and updates the BundleCurrentLifeCycleState to “Installed”
- The information from the framework with the new bundle (and its Manifest file) will be updated in the MIB.
- The ACS writes the BundleCommand parameter “Start”
- The CPE starts the bundle and writes the BundleCurrentLifeCycleState to “Active”

Uninstalling follows the following steps:

- The ACS writes the BundleCommand parameter “Uninstall” (after the bundle has been stopped)
- The CPE uninstalls the bundle and writes the BundleCurrentLifeCycleState to “Uninstalled”

3.3 RGW as a service gateway

As described above, the developed access platform allows the distribution of multiple services. At the home network each service is usually terminated in a dedicated service gateway. Although, as the number of services increases, a number of advantages arise if a single device acts as a service gateway common to different services:

- Possibility of interaction between different services, allowing the construction of new services
- Centralization of services configuration and management processes
- A single approach can be used regarding access, control and personalization of services by the user
- The cost of the service gateway hardware can be shared between the different service providers

Considering that the RGW is directly facing the broadband access network, has several interfaces to home network devices and that all services data must pass through the RGW, the RGW is, therefore, an optimum point for the deployment of the common service gateway. In the RGW, an OSGi Service Platform [8] is executed, so the RGW can also act as a multi service gateway.

For demonstration and validation of concepts, a remote medical monitoring service, was implemented as a set of bundles. This service allows a patient to be at home and through simple medical equipment, submit automatically periodical medical measures to a remote medical database. All the setup of the service is performed remotely and automatically by the service provider. Figure 7 presents the entities that intervene in this service.

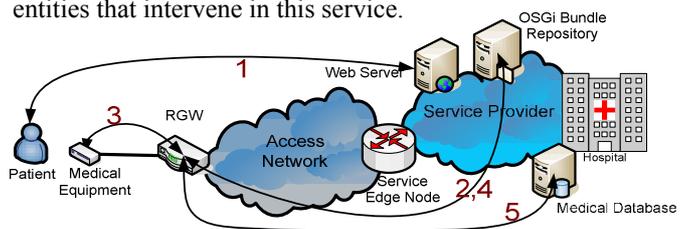


Figure 7: Remote medical monitoring service entities

The first action is the subscription of the service by the user through a web page (Figure 7, step 1). This action triggers the automatic transfer/installation/activation of a bundle (that implements part of the service) from a bundle repository to the RGW (Figure 7, step 2). When the user connects the medical equipment to the RGW (Figure 7, step 3), a process of selection of drivers occurs and ends with the automatic transfer/installation/activation of a set of bundles that allows the communication between the OSGi platform and the medical equipment (Figure 7, step 4). This last set of bundles is used by the first installed bundle and together they implement the remote medical monitoring service. For this moment on, medical measures can be periodically submitted to a remote medical database (Figure 7, step 5). When the service is no longer needed, the customer can access the same web page and unsubscribe the service, which will trigger the removal of the service from the RGW.

Another innovative feature implemented in our RGW is the synchronous update of the RGW network layer configuration with the dynamic install/removal of services. As an example, in order for the medical monitoring service operate correctly, when the service is installed ports on the firewall must be opened and configuration of the treatment (at a QoS level) that the flows generated by the service will get from the RGW must be done. These operations, in our RGW, are performed automatically through a mechanism that uses TR-069 and OSGi features as explained below.

Whenever a service bundle that requires a specific profile (a set of network level parameters that must be configured on the RGW) is installed, an event is broadcasted on the OSGi platform. This event is caught by a special management bundle, which updates a parameter on the MIB. This action triggers a conversation between the TR-069 client on the RGW and the ACS (see Figure 6), which will result in the configuration of the RGW according to the profile. When the service is removed the opposite operations are performed.

4 Demonstration scenario

4.1 Testbed scenario description

The testbed scenario, depicted in Figure 8, is composed by the following entities:

- RGW: has several functional blocks that are related with other devices:
 - P2P VoD. Used with the Video on Demand Server and other RGWs.
 - Remote management. Accessed by the ACS and web access in the home network or in the server side.
 - Firewalling, NAT, QoS, Multicast. These functionalities can be used automatically by in-home devices in order to configure the RGW dynamically.
- Access Multiplexer: is a level 2 optical device used to interconnect the last mile access with the aggregation/core network.
- Edge Multiplexer: it is a dummy device used to simulate a real one.

- Core IMS: some IMS functionalities were implemented in order to create a complete testbed for some IMS tests, like IMS VoD and VoIP using IMS and non IMS terminals.
- ACS: developed in this project and used to configure the RGW remotely using the TR-069 specification.
- Traffic generator: used to stress different tests in order to create a complete scenario.
- End user devices:
 - SIP phone, Laptop, STB
 - Medical equipment. The software is implemented in this project in order to test high priority flows and how this kind of traffic is handled by the RGW.

4.2 Functionalities of the testbed

There are several functionalities developed both in the RGW and the Access Multiplexer devices that could be demonstrated together:

- RGW initial auto configuration. At the startup, the RGW detects the hardware, performs the authentication against its provider and configures its WAN and LAN interfaces.
- RGW operational functionalities. The RGW is capable to filter flows using different parameters (firewalling), translate IP and port addresses (NAPT), handle the QoS necessities and multicast frames as well as the signaling frames.
- RGW configuration. The RGW is programmed to be configured using a web interface (with a servlet) or via the TR-069 specification at the same time.
- Access Multiplexer functionality. It is an optical device performing an asymmetrical optical connection.
- e-Care Service (remote medical monitoring). When the service is subscribed and the RGW detects the medical device, a set of OSGi bundles are downloaded and the device is virtually connected with the e-Care server.

4.3 Trials for the demonstration scenario

There are several trials defined in order to create a complete set of tests that could be used to validate all prototypes implemented.

- Audio call between two different SIP phones. In this first test, an audio call will be established between two software SIP phones located in different home networks. As a result of this test, the CAC will be invoked in each RGW and the audio call will be accepted. In addition, each RGW will be automatically configured to properly process the media related to the phone call.
- RGW configuration. ACS and servlet interoperability. The RGW can be totally configured using both mechanisms at the same time.
 - Test 1. A given profile is uploaded to the RGW from the ACS. The profile just allows a connection from the user STB. The different flows and NAT rules can be browsed using the servlet.
 - Test 2. A new flow rule for the laptop is configured in the RGW using the servlet. All changes will be reflected in the ACS side.

- P2P VoD. An special VoD service will be tested to demonstrate the bandwidth reduction in the video server side.
 - Test 1. A user will request a video to the video server. The video will be served by the own server. Another user will request the same video to the video server. The video will be server also by the previous RGW.
- e-Care service. A medical device is connected to the RGW using a RS-232 connector. When this device is connected to the RGW, OSGi bundles are installed in it in order to handle its flows. The bundles will also request a high priority flow rule in the RGW because it is high risk information.
 - Test 1. The medical device is connected to the RGW. As soon the service is subscribed, the end user sends its information to the medical service side where it can be stored and checked.

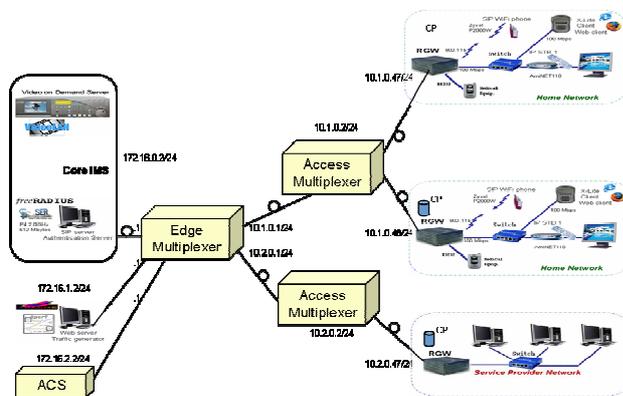


Figure 8: Testbed scenario

5 Conclusions

As presented in this paper, several topics have been studied that enable high speed broadband services in networks and homes.

A high speed FTTH platform has been developed. This platform reduces the size and dissipation in the network and provides a fast and cost efficient Optical Ethernet infrastructure. Over the FTTH platform, a Peer-to-peer caching mechanism has also been implemented. This mechanism improves the user experience without overloading access networks with the video services that are becoming more and more popular.

A prototype of a RGW, which sits on the edge of the access platform, with innovative features has also been described. The implemented RGW is capable of handling different service flows, giving them the correct treatment at a QoS level, therefore allowing the coexistence of multiple services in the home network, each one presenting the expected performance. For QoS related configurations three mechanisms are available on our RGW: automatic SIP based configuration, manual web based configuration or TR-069 auto-configuration. Moreover, our RGW prototype

also implements a service gateway that is remotely manageable and is able to support the automatic install and removal of networked services, without any input of the user regarding configuration or management of those same services.

Finally this paper also presents several test scenarios through which the proposed prototypes can be validated and demonstrated.

Acknowledgments

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