DC4.2 – Preliminary evaluation report on a point-to-point Ethernet over FTTH access platform for full service end-to-end access

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Abstract (for dissemination)	This deliverable document describes the results of the first and preliminary tests and evaluation on the MUSE SPC test platform. The platform is based on an innovative forced forwarding Ethernet solution developed within MUSE SPC. The tests have been carried out in TNO's integrated lab environment.

DOCUMENT HISTORY

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ABBREVIATIONS

AN	Access node
ADSL	Asynchronous digital subscriber line
APON	Asymmetric passive optical network
ARP	Address resolution protocol
ATCA	Advanced Telecom Computing Architecture
ATM	Asynchronous transfer mode
CPE	Customer premise equipment
DHCP	Dynamic Host Configuration Protocol
DoS	Denial of Service
DSLAM	Digital subscriber line access multiplexer
DRG	Digital residential gateway
DVB-T	Digital video broadcasting – terrestrial
DVB-C	Digital video broadcasting - cable
EN	Edge node
ELN	Ericsson Local Node
FCS	Frame check sequence
FTTH	Fiber-to-the-home
GE	Gigabit Ethernet
HDTV	High definition TV
HGW	Home Gateway
IGMP	Internet Group Management Protocol
IPv4/ IPv6	Internet protocol version4 / version6
IP/MPLS	Internet protocol / Multi-protocol label switching
IPTV	Internet protocol TV
MAC	Media access control
MPEG	Moving Picture Experts Group
P2P	Point-to-point
PESQ	Perceptual Evaluation of Speech Quality
PAMP	Penult Apex Management Protocol

PPPoE	Point-to-point protocol over Ethernet
PON	Passive optical network
PSTN	Packet switched telephony network
PVR	Personal video recorder
QoS	Quality of service
RGW	Residential gateway
RTP	Real-time transport protocol
SA	Service agent
SDH	Synchronous Digital Hierarchy
SDSL	Symmetric digital subscriber line
SIP	Session initiation protocol
TCP	Transmission control protocol
TOS	Type of service
UDP	User datagram protocol
VDSL	Very high-speed digital subscriber line
VLAN	Virtual Local Area Network
VoD	Video on demand
VoIP	Voice over IP
WWP	World Wide Packets
WiFi	Wireless fidelity

REFERENCES

[1] “Test Suite, Part 1: Test Objectives”, MUSE deliverable DTF4.1
[2] “Test Suite, Part 2: Test Methods”, MUSE deliverable DTF4.2
[3] “Prototype for initial test-bed evaluation of Carrier-grade Ethernet platform solution”, MUSE Deliverable DC1.1
[4] “Network Requirements for multi-service access”, MUSE deliverable DA1.2
[5] "Evaluation Report on Initial Full-service Testbed Trials", MUSE Deliverable DC4.3
[6] “SPC Lab and Testbed Trials in the Second Phase of the MUSE”, MUSE deliverable DC4.1
[7] Specification of integrated MUSE trial connecting set-ups of different subprojects, MUSE deliverable DTF4.3

EXECUTIVE SUMMARY

End-2-end tests and evaluations, as a proof of concept, are essential tools in the development of innovative telecommunication concepts and platforms. This document describes the results of the tests and evaluations of an Ethernet based forced forwarding solution for a multi-service and multi-provider access network. The MUSE SPC platform is a solution for point-to-point Ethernet over FTTH networks which support full-service end-to-end access. It describes the integrated lab and test bed environments and results of the end-2-end evaluations and tests.

An extensive number of tests are performed in the lab-trial evaluation focused on end-2-end features such as connectivity, Quality of services, network management and security. Tests were, as much as possible, carried out according to the within Task Force TF4 of MUSE developed test suite describing end-2-end test objectives and test methods. TF4 created an integrated approach towards testing which is innovative and new. This test suite showed to be very useful during these tests and evaluations. Also integrating the platform with an IP/MPLS backbone, home networks and multi-play services generated a lot of interesting information.

The lab-trial evaluations were started before the final solution was ready. This generated a lot of constructive feedback to the development work packages resulting in regular hard- and software updates of the platform. The final result is an Ethernet based forced forwarding access network solution that fulfils the requirements specified by MUSE.

Some of the major results:

- The overall transmission characteristics of the platform proved to be good compared to similar solutions. The throughput of the system is high in combination with low average latency and packet loss.
- Evaluation of the self-provisioning portal demonstrated the ease of changing service subscription by the end-user. Requests are immediately handled by the system and a service binding is instantly created.
- A rate limit applied to an end-user connection (service binding) showed to be very accurate for different traffic types and all packet sizes.
- During the QoS tests, the platform proved to support 4 QoS classes in a scalable fashion under realistic traffic loads.
- The MAC forced forwarding properly segregated the connections of different subscribers and successfully passed all tested security attacks.

The MUSE subproject C platform has also been evaluated in a test bed field trial at Acreo, as reported in MUSE deliverable DC4.3 [5]. DC4.3 also reports on evaluations carried out jointly by Acreo and TNO based on Internet connection between the two test sites. This work includes in particular QoS evaluations for VoIP, and measurement of network performance parameters for the Internet link. Results of such measurements have also formed the basis for one of the proposed ways for interconnecting test sites in the second phase of MUSE, as described in the MUSE deliverable DTF4.3 [7].

During MUSE Phase 2 the subproject C platform will be further developed with additional functionality, and will serve as the basis for research activities addressing issues such as nomadicity, session continuity and end-to-end FMC aligned services. Concerning testing and evaluation during Phase 2, we refer to DC4.1 [6]. The test plan in that document points out specific issues to be studied during the second phase of the project, including nomadism, session continuity, and evaluation for demanding real-time network services.

1 INTRODUCTION

This deliverable document describes the results of the first and preliminary tests and evaluation on the MUSE SPC test platform. The platform is based on an innovative forced forwarding Ethernet solution developed within MUSE SPC. The tests have been carried out in TNO's integrated lab environment. An overview of this integrated lab environment is also given in this document.

For test specifications we will refer as much as possible to the test documents, which are worked out within MUSE TF4. The TF4 deliverable DTF4.1 "Test Objectives" [1] describes what should be tested and DTF4.2 "Test Methods" [2] describes how it should be tested. The latter document contains the necessary test procedures. As TF4 tries to be as generic as possible not all tests are directly applicable to the SPC specific tests. For some tests TF4 procedures are expected to be used; for others modifications will be necessary. Tests methods that will not be available from TF4 have to be defined by SPC. A separate test plan for SPC was described in a project milestone. The test plan is described and used in this deliverable. One such example is procedure to verify that service bindings are set up according to specifications. Other relevant documents are deliverable DC1.1 "Prototype for initial test-bed evaluation of Carrier-grade Ethernet platform solution" [3] and DA1.2" Network Requirements for multi-service access" [4].

Related measurements on the SPC platform in an implementation adapted for testbed evaluation, carried out in the Acreo testbed, are reported in the MUSE deliverable DC4.3 [5]. We refer to that same report also for related tests, performed jointly by Acreo and TNO, including in particular measurements via the Internet connection between the two sites, evaluating network performance parameters and QoS for VoIP.

Responsible partners for the MUSE SPC trials and demos are: Ericsson (EABS), Acreo (ACR), TNO (TNO) and Infineon (IFX).

2 DESCRIPTION INTEGRATED LAB TRIAL ENVIRONMENT

2.1 Lab trial focus areas within MUSE

TNO is the responsible partner within SPC for the lab trial evaluation. This chapter describes the knowledge and skills related to the integrated lab trial environment at TNO Telecom.

2.1.1 Physical layer

Two major types of physical layers can be distinguished; the copper and the fiber physical layer. To drive to capacity of the copper cable to the maximum the last couple of years a lot of research has been done on the copper physical layer, especially on traditional telephony copper cabling to extend the reach of xDSL systems. Spectrum management is an important topic nowadays, because a lot of systems are getting connected to the telephony copper cable. Qualifying the copper loop and calculating the maximum reach and number of xDSL systems is increasing importance.

As a fiber optic cable has more than enough intrinsic bandwidth and the reach of fiber cables is more than sufficient regarding access networks, research on the physical optical layer is not a matter of optimizing the capacity. Research is mainly on the type of fiber used (single- versus multi-mode) and on optimizing the cost of optical components and installation costs.

As TNO Telecom is mainly working in the telecom operator world and not in the optical component business, the knowledge and skills are focused on the copper physical layer and not so much on the optical physical layer.

Copper:

- Test xDSL systems (modem, DSLAM, etc.)
- Spectrum management
- Loop qualification
- VDSL

Fiber:

- ATM PON systems
- Point-to-point (P2P) Ethernet over fiber

2.1.2 Connectivity (datalink and network/IP layer)

Especially regarding the research on fiber optic based access networks the work was focused on integrating platforms and on end-to-end functionality.

- VLAN
- Layer2 (IGMP) and Layer3 Multicast, e.g. for video broadcast
- QoS
- Rate limiting
- IPv4 (and IPv6)
- PPPoE

- Security / Authentication

2.1.3 Services

Within TNO Telecom a lot of groups are working on the development and evaluation of new services. These groups installed many service platforms in the integrated lab environment that can be accessed by other groups who research access, metro, core and IP networks.

- VoD, streaming video to PCs and TV-sets
- Broadcast TV (MPEG over IP), including set-top-boxes
- Telephony: VoIP (protocols: SIP, H323, etc) and PSTN
- Video conferencing
- Fast Internet
- Personal video recorder (PVR)
- Residential gateways with may functionalities: storage, routing, conversion, etc.

2.1.4 Management

The knowledge on management platforms and solutions is rather basic and not very deep. In the lab many element managers are installed that manage all the network elements in the lab environment. The focus has been mainly on configuration management. Other management functionalities like fault, performance and accounting management have not been investigated on a broad scale so far.

2.2 High Level Overview Lab trial environment

The figures below give a brief overview of the integrated lab environment.

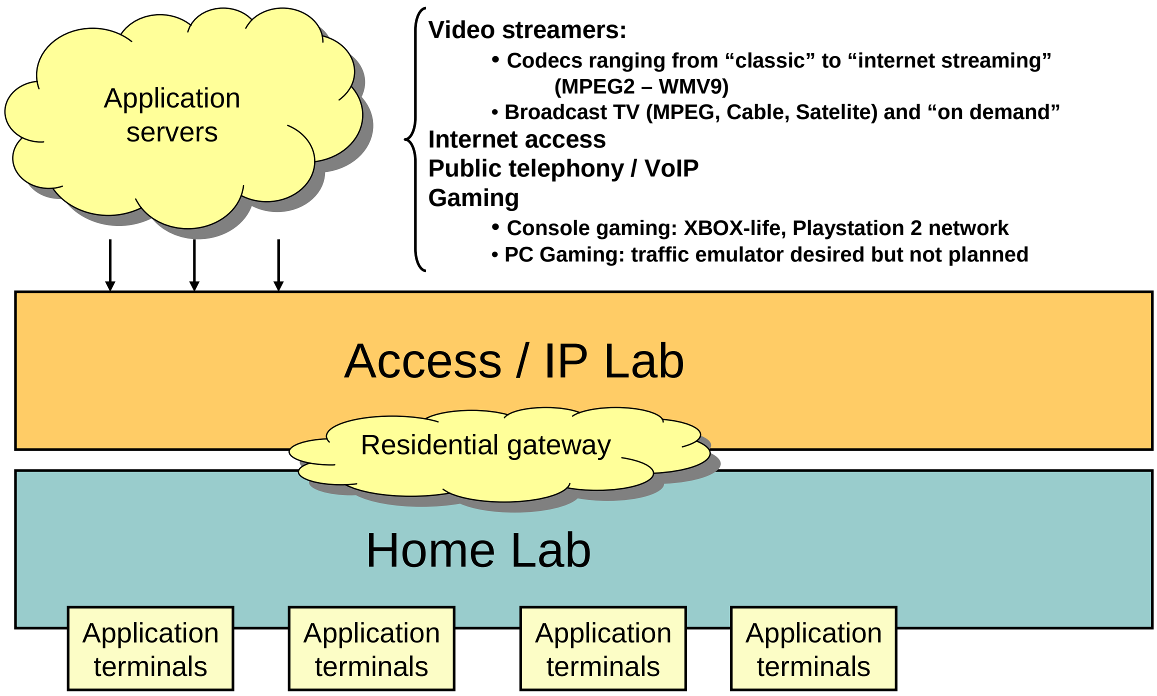

Figure 2-1: *Integrated Lab Environment @ TNO Telecom*

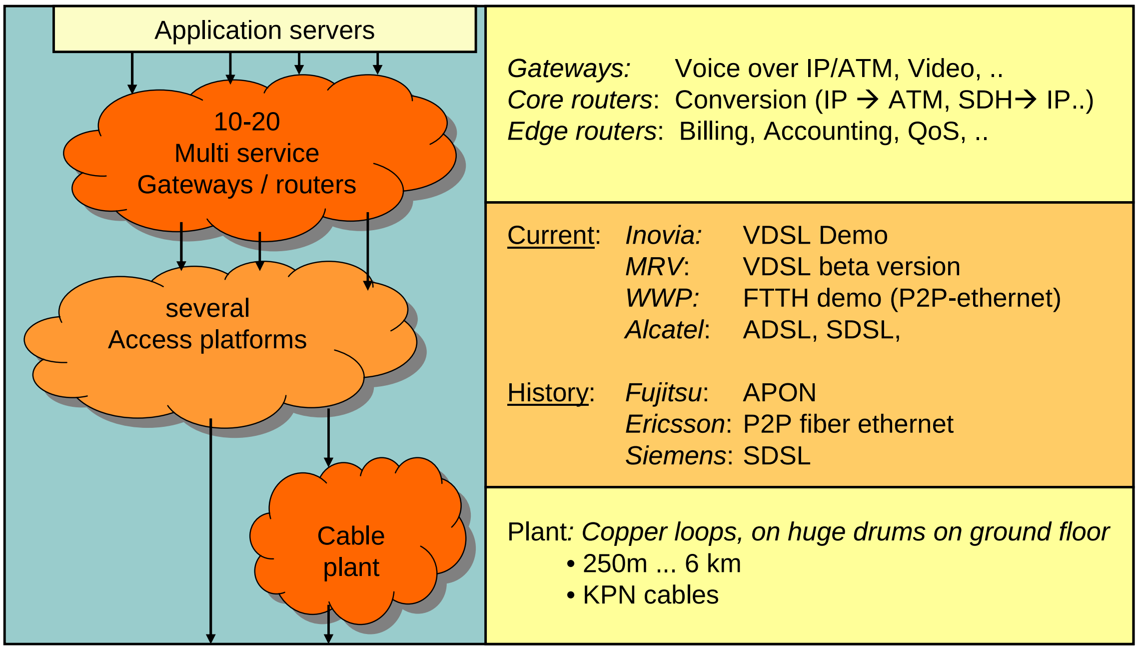

Figure 3-2: *Integrated Lab Environment: Access/IP lab*

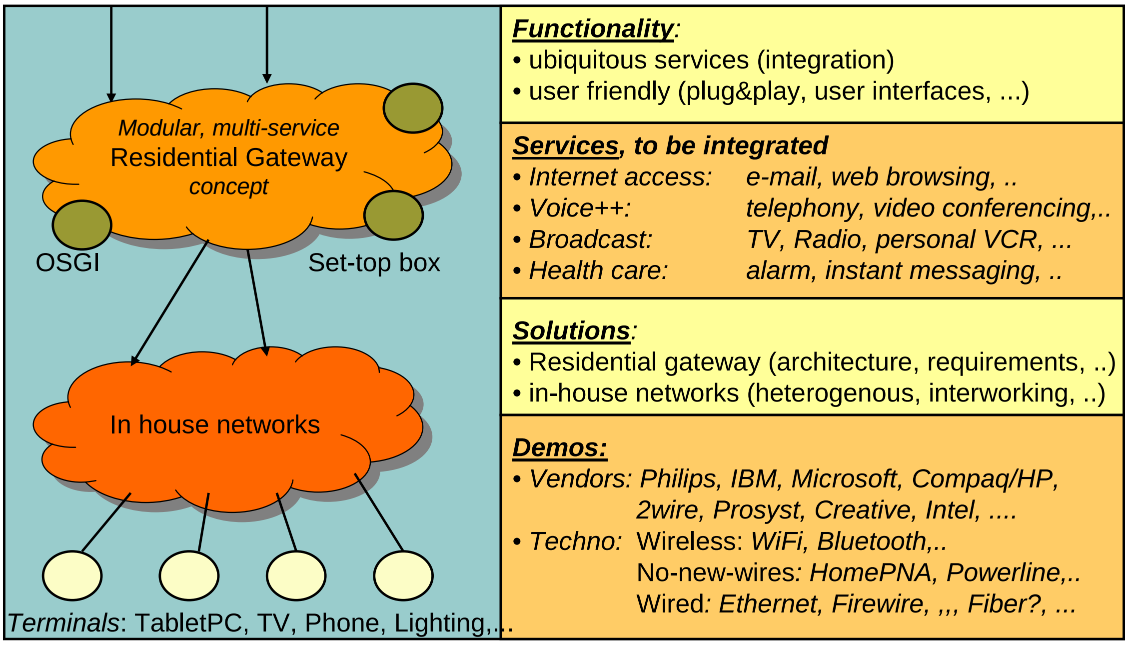

Figure 2-3: *Integrated Lab Environment: Home Lab*

2.3 Medium Level Overview Lab trial environment

In the figure below a more detailed (medium level) overview of the Lab Trial environment at TNO is shown. The different access network solutions are connected to a large scale state-of-the-art IP/MPLS network. This IP/MPLS core and edge network consists of routers of several vendors of IP routers.

The whole network is connected to a management network from which all network elements can be managed.

The services platforms are connected to the provider edge of the IP/MPLS platform. This way all services are available to all the terminals that are connected to this integrated lab environment.

As shown in the figure below the MUSE SPC platforms will become in integrated part of the lab environment. At the moment Ethernet over fiber, ADSL(2+), VDSL platforms are up and running.

According to the MUSE planning the Ericsson MUSE SPC platform was installed in May 2005.

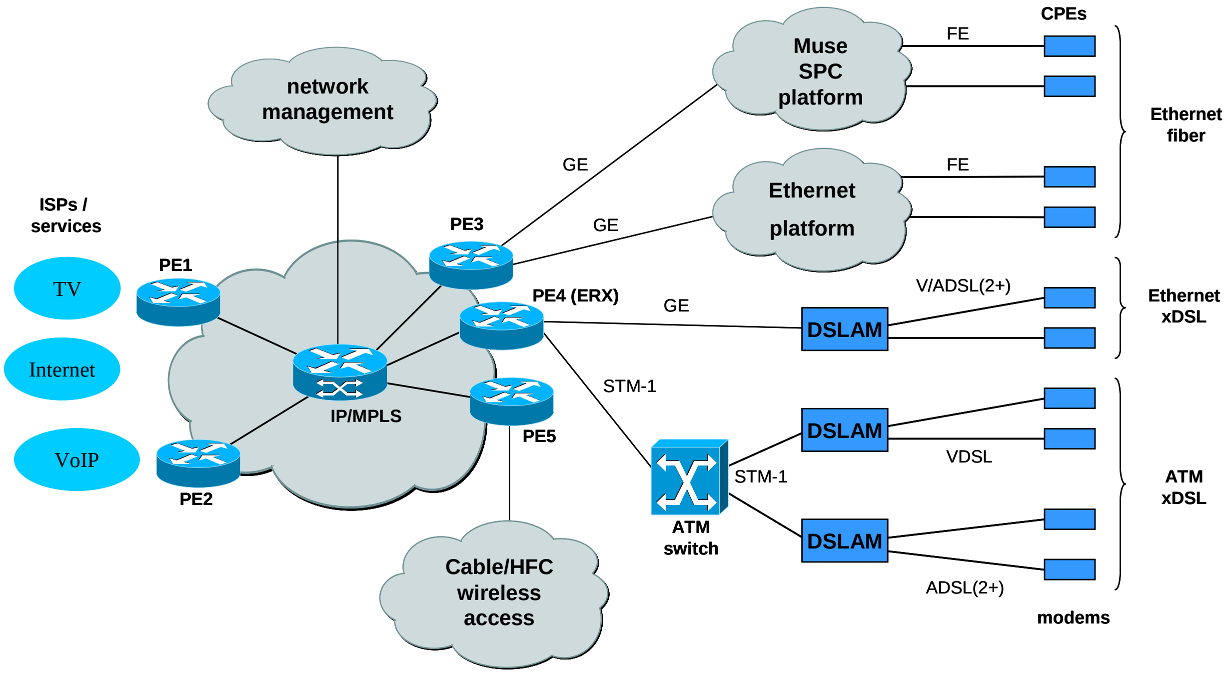

Figure 2-4: *Medium Level Overview of the Integrated Lab Environment*

2.4 Available measurement and test resources

In the integrated lab environment network test and analyze equipment is available for a variety of tests. In addition, service platforms are used for test purposes. Not only the precise network quality can and will be measured, but also the perceived quality of service of voice and video services can and will be measured.
Network test and analyze equipment:

- SmartBits traffic generator and traffic analyzer
- ATM tester
- Network sniffer
- Spectrum analysers
- Function generators
- Oscilloscopes
- Noise generators to simulate cross talk noise in copper systems
- A few kilometers of telephony copper cables

Perceived quality of services:

- Perceived quality of voice test set-up according to the PESQ standard
- Perceived quality of video test set-up (under development)

3 LAB TRIAL TEST AND DEMO SET-UP

3.1 Detailed lab trial test set-up

In chapter 2 a ‘medium level’ overview of the integrated lab trial environment is already shown (Figure 2-4). Figure 3-1 gives a more detailed overview of the lab trial test and demo set-up.

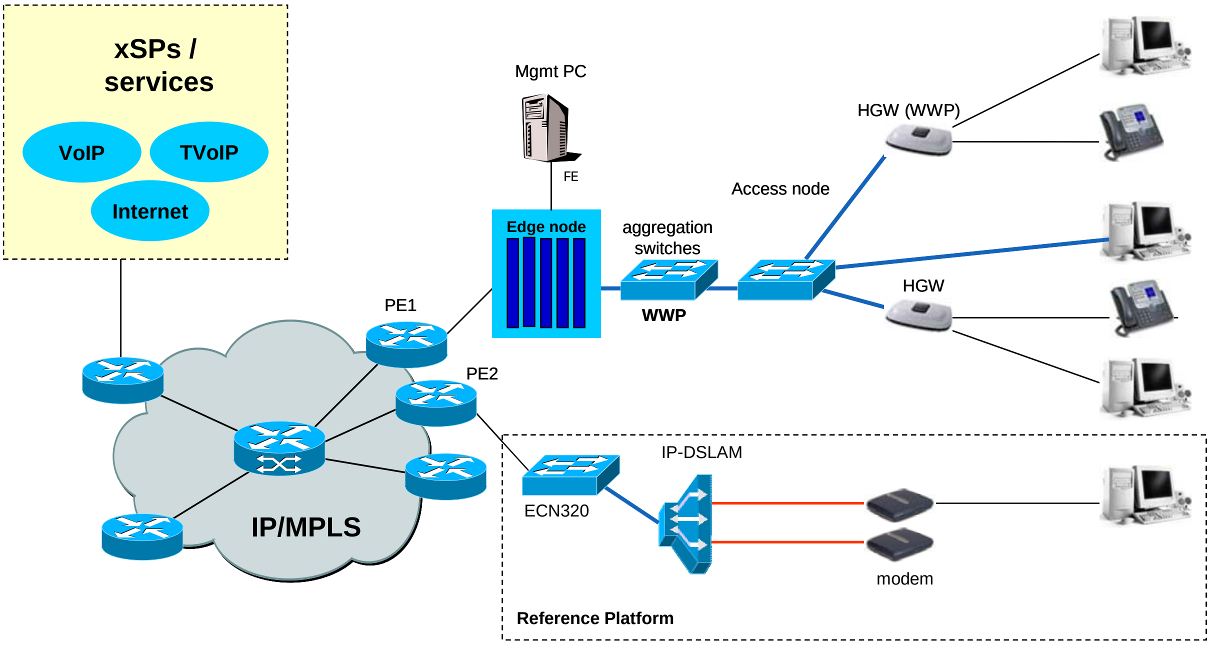

Figure 3-1: *Detailed overview of the lab trial test and demo set-up*

The MUSE SPC platform will be connected to one of the provider edge (PE) routers of the integrated lab environment. Via this PE router every service available in the integrated lab environment can be reached. Depending on what service(s) the customers are subscribed the customer will have access to this specific service(s) by connecting a proper end user terminal (PC, set-top-box, VoIP phone, etc.). The Ethernet over xDSL platform can be used as a reference to the MUSE SPC platform.

3.1.1 Equipment list

In the table below the equipment is listed which is not part of the MUSE SPC Ethernet over fiber platform and which is already available at TNO’s lab trial environment.

Name	Type	number
PE1	Cisco 7206	1
PE2	Juniper ERX	1
ECN320	ECN320	1
IP-DSLAM	EDN312x	2
xDSL-modem	Ericsson, Alcatel, etc.	several

Table 3-1: *Equipment list*

3.1.2 Test equipment

All performance and QoS tests and evaluations are carried out with the traffic generator/ analyzer Smartbits 6000 from Spirent Communications. The Smartbits has several 10/100/1000 BaseT copper ports and 1000BaseSX/LX fiber ports.

To generate traffic flows and set-up measurements the following Smartbits software tools are used:

- SmartWindow
- SmartApplications
- SmartFlow

3.2 Test conditions

To be able to make the lab trial tests and demos as realistic as possible it is important to define under what test conditions the tests and demos will take place. The definition of a realistic traffic mix that represents traffic in a broadband access network is an essential part of these test conditions. Discussions and results on such issues are already available from other work packages within MUSE – for example within DA1.2 and DA3.1. But it is essential to follow up also ongoing discussions in other work packages.

3.2.1 Services and traffic mix

The type of traffic running over a broadband access network will be defined by the type of services the subscribed customers are using. Typical services available today, are listed in Table 3-2 below. The ration between these different services will determine the traffic mix. The table also includes typical values of key parameters needed to generate a realistic traffic mix. The table below shows the values of the typical parameters of the services that are needed to generate a realistic traffic mix. Other typical parameters of these services are given in [1] and [4].

Service	Bandwidth (Mbps)	Protocol	Type	Packet size (byte)	Priority
Internet Access	0,2 - 5	UDP, RTP, TCP/IP	Unicast	64 - 1500	low
TV broadcasting	2 – 5	UDP	Multicast	1500	medium
HDTV	10 - 20	UDP	Multicast	1500	medium
Video on Demand	2 – 5	UDP	Unicast	1500	medium
VoIP	0,05 – 0,2	UDP	Unicast	64	high
Videoconferencing	0,2 - 2	UDP	Unicast	64 (voice) and 1500 (video)	high

Table 3-2: *Services of the traffic mix*

The ratio between these services can be estimated by defining some use cases or by applying real traffic statistics. Use cases are a useful tool for estimating current network behavior and for predicting future network behavior. Real traffic statistics can only estimate current network usage.

As video services are high demanding services regarding traffic load IPTV and VoD are described into more detail in the next two paragraphs.

3.2.1.1 IPTV

A number of TV channels are distributed trough multicast in the network.

The maximum number of TV channels that can be available are limited by the capacity of the forwarding elements in the APEX. The total network capacity in each level sets the maximum number of TV channels that can be distributed simultaneously on that level.

Multicast TV puts high requirements on delay, capacity and packet loss on the network. It must also have priority over the Internet traffic to avoid interrupt during for example large file download.

This use case has three multicast TV providers. All of them have access to the whole network. The table below summarizes the channel content from each provider.

	Provider A	Provider B	Provider C	Total
Number of standard TV channels	20	30	40	90
Number of HDTV channels	2	3	4	9

Table 3-3: *Number of TV channels per provider*

The statistical behavior of the users will put requirements on each level in the network. If for example many users hocked up to the same access switch look at different channels there may be capacity problems in that switch.

3.2.1.2 Video on demand (VOD)

Video on demand gives each user access to a movie during a limited period of time. Since each user running video on demand has its own dedicated connection to the Video server, and the bandwidth requirements are high, the accumulated traffic load in the APEX will be high. Due to this the VOD servers will probably not be connected to the entire network. There will instead be a number of VOD servers connected to routers close to each APEX node.

A VOD server having a 1 Gbps interface can handle up to 200 standard quality video channels (5Mbps) or a mix of for example 100 standard quality channels and 25 HDTV channels (20 Mbps).

To cover a maximum equally distributed usage rate of 5 % (= 5 000 simultaneously video streams), distributed on 1 % HDTV and 4 % standard quality TV, then in a realistic scenario 40 video servers will be needed if each has a capacity of 1 Gbps.

3.2.2 Traffic load

During the tests and demos the platform will be loaded with different traffic loads. The choice has been made to define three different traffic loads to limit the number of tests: light, mild and heavy.

- Light traffic load will not influence the service or functionality under test; packet loss, delay and jitter will be minimal.
- Mid traffic load will influence the service or functionality under test; packet loss, delay and jitter can occur.
- Heavy traffic load will heavily influence the service or functionality under test; packet loss, delay and jitter will occur. Heavy traffic load will fill the link till its maximum capacity.

3.2.3 Users

The users are divided into three different categories.

- Internet user
- Media user
- Advanced user

Each category has different amounts of equipment connected to the net, and also different typical traffic pattern and they can be regarded as three different use cases.

Internet user

The Internet user has two PCs and two IP-telephones connected to the network. TV and video is supplied by other technologies such as DVBT (terrestrial) or DVBC (Cable TV).
Typical traffic is down loading news pages checking bank accounts ordering tickets and other low traffic volume applications. The fraction of high priority QoS traffic will be close to zero.

Media User

The media user has 2 PCs, 3 IPTVs, and 2 IP-telephones. Typical network traffic is dominated by multicast and unicast video. High priority QoS traffic is modeled to 15 Mbit/s

Advanced user

Similar to Media user but more focused on HDTV quality content. Advanced users also generates significant traffic trough gaming and file up/down loading over Internet. 3 PCs, 3 IPTVs, one HDTV and 2 IP-telephones. High priority QoS traffic is modelled to 35 Mbit/s

3.2.4 Test conditions

The combination of traffic mix (use cases/users) and traffic load will define the different test conditions that are used in the lab-trial evaluation. The table below shows the total load of the first mile link (100 Mbit/s) for one user and the next uplink (1 Gbit/s for 40 users) if 50 % all connected RGWs should be as the different use case/traffic load (unrealistic, but high load). The table below shows possible scenarios to define a realistic traffic mix. During the test period it will be decided which of the scenarios will be applied in the tests.

User/ load	Light (10 MB BE*)	Mid (30 MB BE)	High (60 MB BE)
Internet, 0 MB QoS	10%	30%	60%
	20%	60 %	120%
Media, 15 MB QoS	25%	45%	75%
	50%	90%	150%
Advanced, 35 MB QoS	45%	65%	95%
	90%	130%	190%

Table 3-4: *Summary of different test conditions*

* BE = best effort

4 RESULTS LAB TRIAL TESTS AND EVALUATIONS

4.1 Introduction

In this chapter the results of the lab trial test and evaluations will be explained in detail. Besides results of the tests and evaluations also the problems that occurred during the installation and configuration phase will be dealt with. The specification of the tests to be performed was done in a SPC milestone document in April 2005. The description of the different tests, test procedure and what to measure or what to verify are presented below together with the actual test results.

4.2 Problems during installation and configuration

During the installation and configuration of the MUSE SPC platform in TNO's integrated lab environment some problems with the platform occurred. Bugs and failures in the hard- and software always appear when a system like this is connected to other systems and services. In fact the installation and configuration phase is a compatibility and inter-working test. The following paragraphs describe the failures found during set-up.

4.2.1 Time slipage between edge and access node

After first installation and configuration of the MUSE platform at TNO the system seems to work properly. But after a certain hours all connectivity between the end user terminals and the service platforms was lost. Debugging showed that this was caused by loss of synchronization between the edge node and access node. For communication between the two nodes it is essential these are synchronized. A failure in the software was the reason that after a certain period of time the two systems were not synchronized any more, do due this time slippage. A modification in the software has solved this problem.

4.2.2 Miscalculation of the FCS field in the IP packet

Connecting a regular PC to the network and setting up an Internet connection was not a problem. But it was not possible to make connection between a Cisco IP phone and the VoIP server/gateway over the same type of connection. After deep debugging into the system and the devices showed that the Cisco IP phone sends out packets in which the ToS-field (DSCP) is set. The MUSE platform maps the ToS-field according to the settings of the corresponding service binding. In case the value of the ToS-field is changed the FCS value has to be recalculated and changed in the packet. As the system did not recalculate and/or changed the field in the packet, all the packets were marked as corrupt. These corrupt packets are thrown away by the first routers that receive these packets. A modification in the software has solved this problem.

4.3 Transport

4.3.1 Connectivity testing

4.3.1.1 Service binding set-up

In the MUSE SPC platform service bindings are set-up to create customer connectivity to the service the customer is subscribed to. During this test the speed of a service binding set-up will be measured under different traffic loads and traffic mixes.

To measure: The set-up time of a service binding should not drop under increasing traffic load.

Test procedure: The test set-up used to measure the functioning of the service binding set-up is shown in figure 4-1. A PC is used to create service bindings between the PC and the edge node. The set-up time is measured with increasing load, from 0 – 100% on the link.

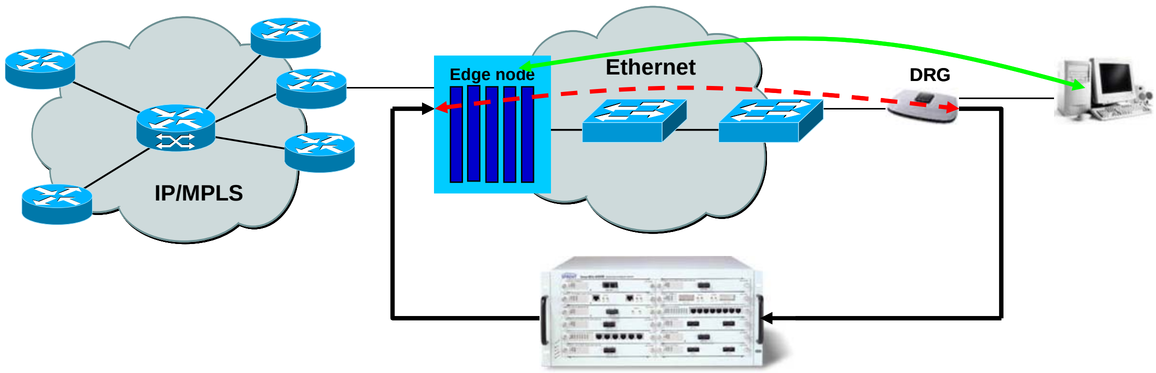

Figure 4-1*: Test set-up service binding set-up*

Test result: No degradation in set-up time occurred, even under very high load (100%) of the link. The set-up time is so short, within several milliseconds, it will not be noticeable by the end-user.

4.3.1.2 Filtering: broadcast handler

The broadcast handler is implemented in the MUSE SPC platform to filter all broadcast messages generated by the end user devices: ARP request, DHCP messages, IGMP joins and other broadcast packets.

During this test it will be verified how the broadcast handler functions when a broadcast storms is generated on a customer port. The test set-up that will be used for the tests is shown in Figure 4-1.

To Measure: The broadcast handler should still work under high traffic load and when a broadcast storm is generated.

Test procedure: The test set-up built to evaluate the functioning of the broadcast filter/handler in the access node is shown in figure 4-2. A Smartbits is used to inject high amount of (broadcast) packets (MAC, ARP, DHCP) into the system. During this broadcast storm of packets it was tried to set-up a service binding between a PC and the edge node.

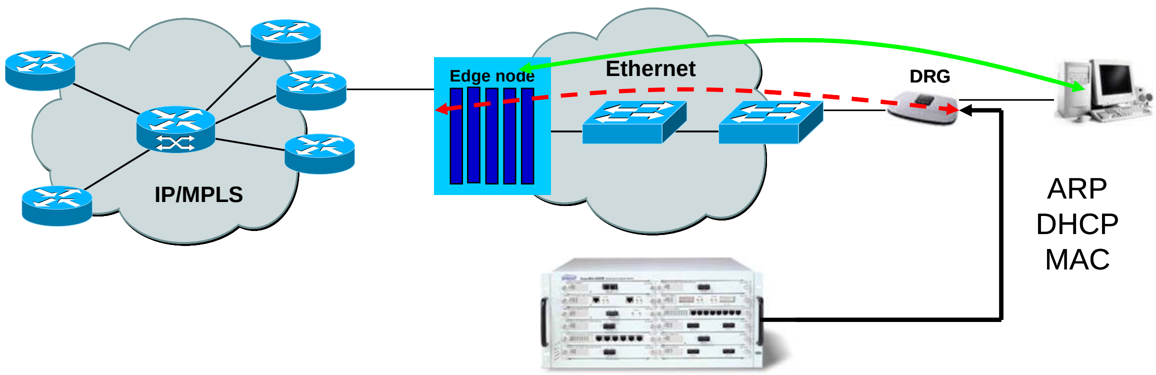

Figure 4-2: *Test set-up to generate broadcast storms and traffic load*

Test results: No degradation in set-up time occurred, even under a very high load of broadcast packets.

4.3.1.3 Multicast

Multicast is implemented in the MUSE SPC platform. This test will verify whether or not multicasting is implemented corrected on the platform. Several multicast channels will set-up over the network and it is to be verified if this channel is multicast to the correct ports and links and not broadcasted somewhere in the system.

To Verify: the correct functioning of the multicast implementation.

Test procedure: Several multicast streams are injected into the edge node and made available to the network via a service agent (SA). A PC is used to set-up a multicast stream from the VoD server to the PC.

Test results: When a PC wants to join a multicast stream by sending an IGMP join message into the network a multicast service binding is created between the PC and the edge node. Tests show that the multicast packets are only streamed to the port on which the stream is requested. It can be concluded that multicast is correctly implemented.

4.3.1.4 VLANs

In the MUSE SPC platform VLANs are used to distinguish between different services and/or service providers. Priorities are also assigned to these VLANs. These priorities are set by the network provider and customers should not be able to change or influence these priorities. During this test it will be tried to send traffic with different priority. If the system functions well the priority should be changed to the priority assigned by the network provider.

To Verify: the priority can not be influenced or changed by the customer.

Test procedure: A service binding with an 802.1p-bit value of 5 will be created in the system. The Smartbits is used the generate Ethernet traffic with the corresponding number, but with the p-bit set to a different value. With a sniffer the p-bit settings of the service binding will be checked.

Test results: Measurement show that the p-bit is set corresponding to the configured value to the service binding. The p-bit value set by the Smartbits is ignored by the system when it is set to a different value.

4.3.1.5 Scalability

The PAMPv2 protocol is used to set-up service bindings. The scalability of the MUSE SPC platform can be simulated by connecting the edge node to a PC which can simultaneously set-up many service bindings using the PAMPv2 protocol. This way many end-users requesting many services can be simulated.

To Measure: how many service bindings can be set-up at a time.

Test result: To be done

4.3.2 QoS testing

4.3.2.1 Transport and network quality (delay, jitter)

The delay a packet flow faces in a network is an important QoS parameter. During these tests the delay and jitter of the network under different conditions (traffic mix and load) will be measured. In Figure 4-3 the test set-up that will be used to measure the end-to-end delay and jitter is shown.

To Measure: the end-to-end delay in the MUSE SPC network under different circumstances.

Test procedure: The test set-up used to measure the network quality is shown in figure 4-3. A service binding is set up between the DRG and the edge. Up- and downstream traffic is injected by the Smartbits and the traffic is analyzed with the same Smartbits. The Smartbits measures delay, jitter, packet loss and throughput. The latency was measured for different packet sizes varying from 64 bytes to 1500 bytes. For each packet size the bit rate was set on the maximum load at which the packet loss is still 0%: on points just below the curve as shown in figure 4-5.

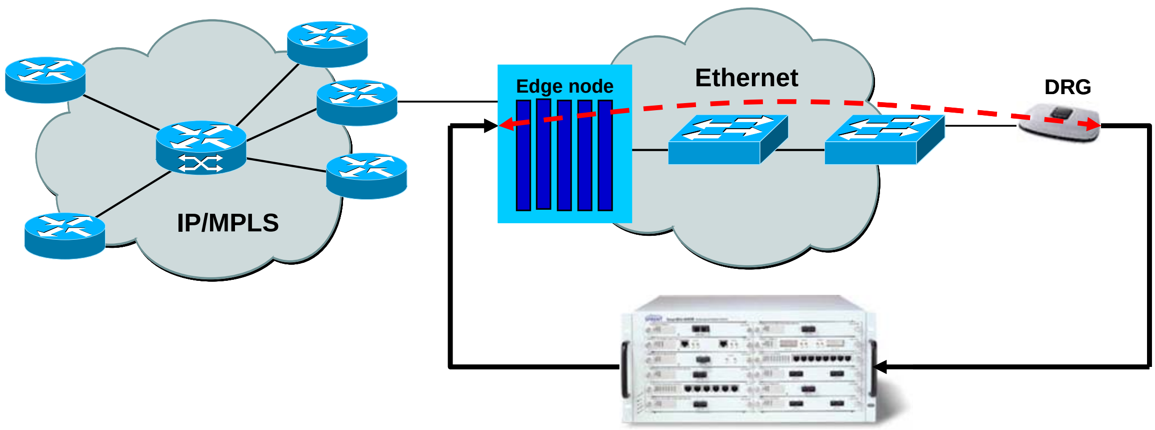

Figure 4-3: *Test set-up to measure QoS, Rate limiting, Throughput, Delay, jitter, etc.*

Test results: Figure 4-4 below shows the results of the latency test. The figure shows a linear growth of the delay as function of the packet size. This is normal behavior, because the delay grows when the packets get larger in size. The intrinsic delay added by the system is 20 microseconds. This is the point where the line crosses the y-axis in the figure below.

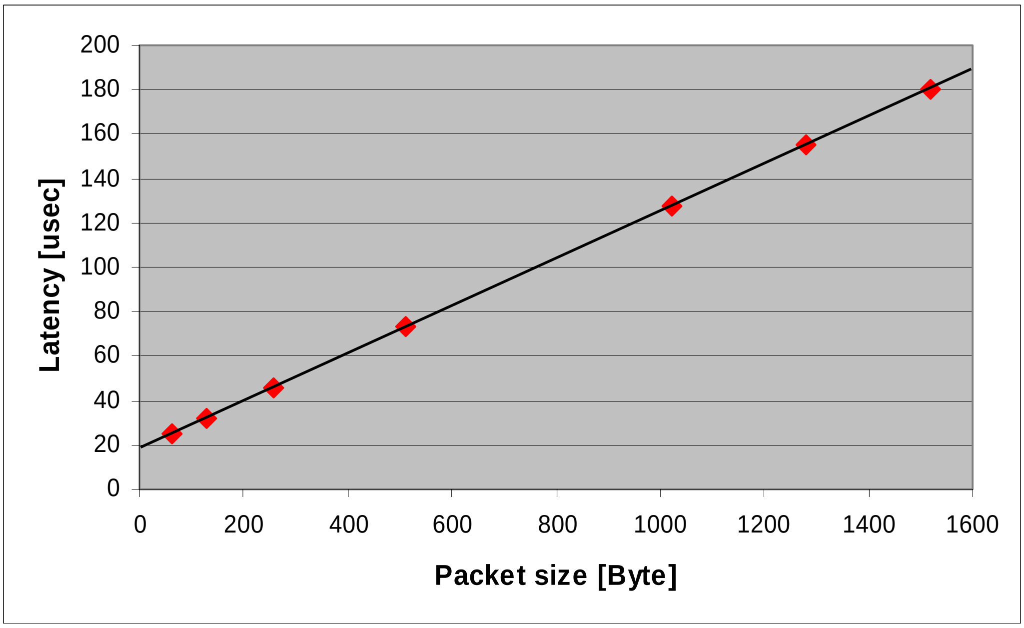

Figure 4-4: *Result of latency test*

The latency is tested under different levels of load. These measurements show that only at 100% load of the system the latency slightly increases.

4.3.2.2 Throughput

The maximum throughput on a network link is an important QoS parameter. During these tests the throughput of a network link under different conditions (traffic mix and load) will be measured. In Figure 4-3 the test set-up that will be used to measure the throughput of a link is shown.

To Measure: the maximum throughput of a link in the MUSE SPC network under different circumstances.

Test procedure: The test set-up used to measure the network quality is shown in figure 4-3. A service binding is set up between the DRG and the edge. Up- and downstream traffic is injected by the Smartbits and the traffic is analyzed with the same Smartbits. The Smartbits measures delay, jitter, packet loss and throughput. Throughput is defined as the maximum load at which no packet loss occurs.

Test results: Figure 4-5 below shows the results of the throughput test. For small packet the throughput is slightly lower than it is for large packets. It is known behavior of Ethernet networks that the throughput for smaller packets can be lower than for larger packets. This behavior depends on the type and dimensioning of the network.

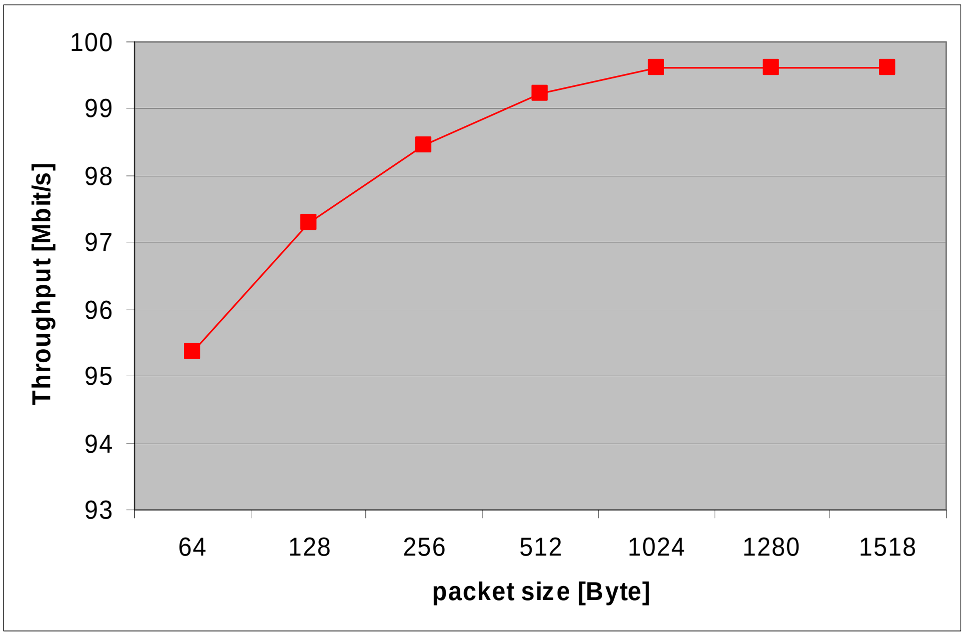

Figure 4-5: *Result of throughput test*

4.3.2.3 Packet Loss

The packet loss in a network is an important QoS parameter. During these tests the packet loss in the network under different conditions (traffic mix and load) will be measured. In Figure 4-3 the test set-up that will be used to measure the packet loss in a network is shown.

To Measure: the packet loss in the MUSE SPC network under different circumstances.

Test procedure: The test set-up used to measure the network quality is shown in figure 4-3. A service binding is set up between the DRG and the edge. Up- and downstream traffic is injected by the Smartbits and the traffic is analyzed with the same Smartbits. The Smartbits measures delay, jitter, packet loss and throughput.

Test results: As explained in 4.3.2.2 the throughput of a network is defined as the maximum load with 0% packet loss. This means that below the curve as shown in figure 4-5 the packet loss is 0%.

4.3.2.4 Rate limiting

A rate limit can be set on every service binding in the MUSE SPC network. During this tests will be measured how accurate the rate limit works under different conditions (traffic mix and load). For example: Is a 10 Mbit/s rate limit on a service binding exactly 10 Mbit/s under all circumstances?

To Measure: the working and accuracy of the rate limit function.

Test procedure: The test set-up used to measure the network quality is shown in figure 4-3. A service binding is set up between the DRG and the edge. Up- and downstream traffic is injected by the Smartbits and the traffic is analyzed with the same Smartbits. The Smartbits measures delay, jitter, packet loss and throughput. A service binding is created with a rate limit of 8 Mbit/s. A Smartbits throughput test is applied to measure the maximum throughput of the service binding.

Test results: Figure 4-6 depicts the results of the rate limiting throughput test. As can be seen the throughput is exactly limited at 8 Mbit/s, as applied to the service binding. Rate limiting is done on IP level and not on Layer2 (Ethernet) level.

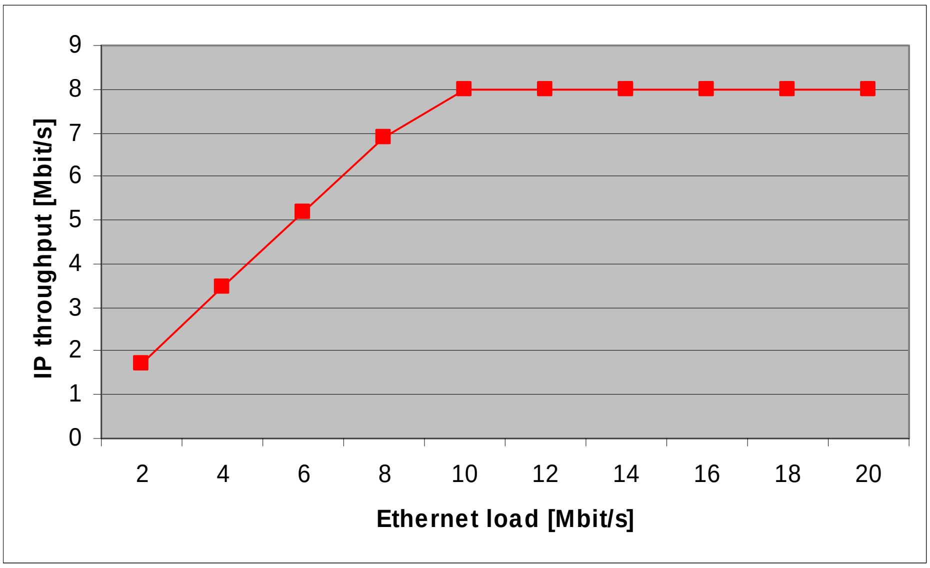

Figure 4-6: *Result of throughput test*

4.3.2.5 CoS

According to the IEEE standards 8 priorities should be supported, but the output queues these priorities are mapped to can differ. To be able to support as many priorities as possible 8 output queues should be available. MUSE has on forehand decided to use 4 classes, because 4 classes are enough to make enough distinction between all services. More QoS classes result in more granularity, but increases complexity also. MUSE will support 8 priorities by mapping them to for queues.

To Verify: how many priorities and output queues are supported by the system.

Test result: The MUSE test and evaluation platform does support 8 queues.

Traffic with a higher priority should always get priority in the network as long as the amount of higher priority traffic does not reach the maximum capacity of a link. For example 40 Mbit/s of high priority traffic should be unaffected by 60 Mbit/s of low priority traffic on a 100 Mbit/s link. This can be verified by injecting 40 Mbit/s of high priority (green line) and 60 Mbit/s of low priority traffic (red line) in the system (see Figure 4-7).

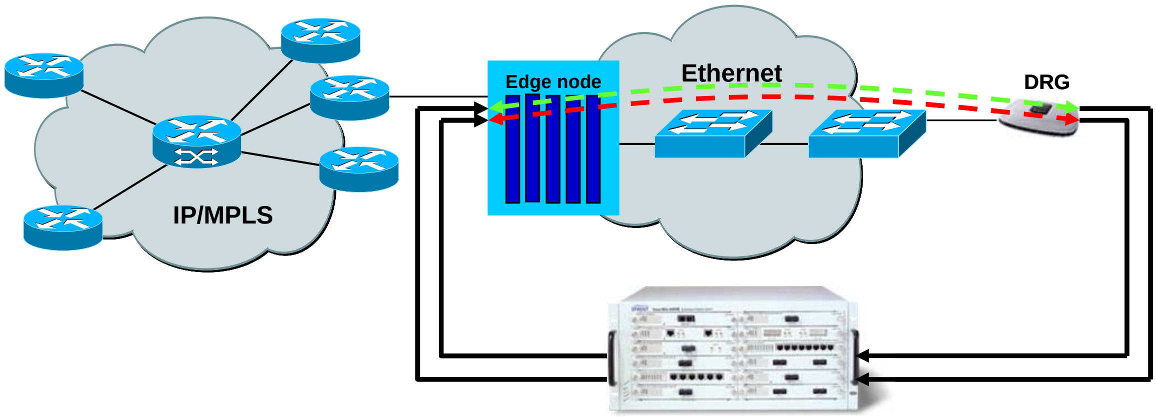

Figure 4-7: *Test set-up to measure CoS.*

To Verify: Keeps high priority traffic unaffected under high load of lower priority traffic.

Test procedure: Two service bindings are configured in the platform: 1) service binding with a rate limit of 60 Mbit/s and high priority, 2) service binding with a rate limit of 40 Mbit/s and low priority. Both links are loaded with traffic over the maximum capacity of the service binding.

Test result: Measurements shows that both streams are limited to respectively 40 Mbit/s and 60 Mbit/s. No difference is seen between low priority and high priority traffic regarding latency in the network. This means the system does not distinguish between higher and lower priority traffic and that priority queuing does not function optimal.

4.4 Network functionalities

4.4.1 Management

Not much management functionalities are implemented in the MUSE SPC platform till now. In future releases management modules will be implemented in the system. When these modules will become available and management functions have to be tested TF4 documents [1] and [2] will be used as source documents to define what and how should be tested.

4.4.1.1 Self-provisining portal

During this test the working of the self-provisioning portal will be verified. This portal helps customers who do not have a subscription to any service to subscribe to new services.

To Verify: the functioning of the self-provisioning portal.

Test result: The self-provisioning portal has shown to function well. An end-user can easily subscribe and unsubscribe to services via this self-provisioning portal. A new service binding is created instantly and the service is activated.

4.4.1.2 Accounting function

In these tests will be investigated what counters are available (total bytes, total packets, number of sessions, etc.) and if these counters are functioning well.

To Verify: the accounting possibilities of the system.

Test result: To be done.

4.4.2 Security

4.4.2.1 Spoofing

If it is possible to spoof the MAC address of another customer subscribed to a certain service, it should not be possible to access the service via another customer CPE or physical link.

To Verify: it is not possible to spoof a MAC address.

Test result: A hard port to VLAN mapping is done in the access node, so it is not possible to communicate over the network using another port VLAN combination. As VLANs are completely separated it is not possible for another user to use the VLAN assigned to for example his neighbour.

If it is possible to spoof the IP address of another customer subscribed to a certain service, it should not be possible to access the service via another customer CPE or physical link.

To Verify: it is not possible to spoof an IP address.

Test result: IP addresses are assigned by the network, so users can not configure their IP addresses. It is not possible to communicate over the network on another link than over which an IP address was assigned.

4.4.2.2 Network security

The management network should by no way be accessible by the end user. It should not be able to access the network elements, and IP addresses of the network elements should not be learned by the end user terminal and/or CPE.

To Verify: it is not possible to learn the IP address of the network elements.

4.4.2.3 Security of management VLANs

It should not be possible by the end user to get into the management VLAN which is used to manage the network elements.

To Verify: it is not possible to get access to the management VLAN.

Test result: To be done

4.5 Perceived QoS testing

4.5.1 Perceived quality of voice

Tests on perceived quality of voice are performed on a VoIP call between TNO (Delft, The Netherlands) and Acreo (Stockholm, Sweden). Results of these tests are given in [5].

- Measuring the end-to-end perceived quality of voice channels under different conditions.
- Well described and useful tests will be available from deliverable TF4.2 “Test Methods” [2].

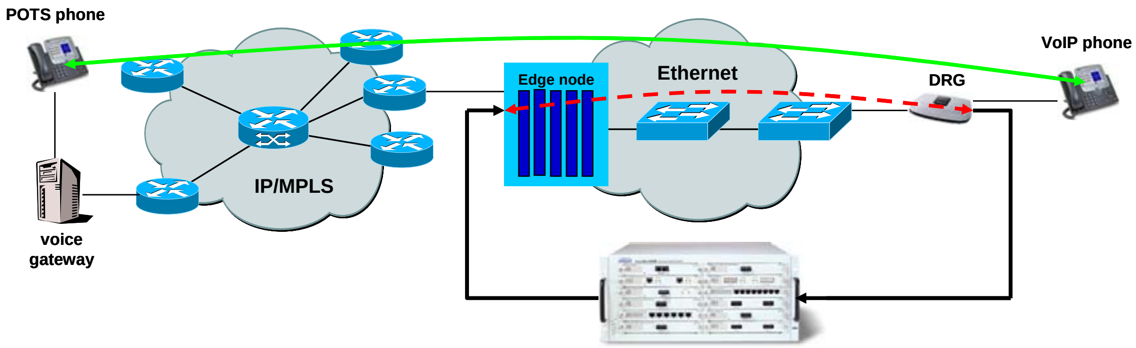

Figure 4-8: *Test set-up to measure CoS.*

4.5.2 Perceived quality of video

Tests on perceived quality of video are not performed during the tests in MUSE I. These tests will be done in MUSE II and described [6].

- Measuring the end-to-end perceived quality of video channels under different conditions.
- Well described and useful tests will be available from deliverable TF4.2 “Test Methods” [2].

Because voice and video are the highest demanding services TF4 focus the most on these two services. Perceived quality of gaming and web browsing are also within in the interest of TF4, but it is not sure proper tests will become available during MUSE phase I. As these tests are seen as a nice add-on, WPC4 itself will not put effort on defining these tests.

5 LAB TRIAL DEMONSTRATION SCENARIOS

An end user wants to install broadband access and new services. In the house the SPC solution is operational. The functional demo shows what has to be done to bring IP telephony, IP television and internet connectivity "alive".

5.1 Configuration

The hardware inventory of that house includes:

- Wiring: Each room has one or more Ethernet wall plugs.
- Home Network: All these wall plugs are interconnected directly or via a "standard" multi-port VLAN Ethernet switch to a central location of the house, and "terminates" at the MUSE Access Node. A home-router can be part of the in-house network to enable for example wireless communication. (see figure below)
- Access Network. The network provider uses the SPC equipment, and has agreements with several service providers (telephony, television, internet access, etc)

The hardware inventory of the demonstration room of ***visible*** equipment includes:

- A "wall" with photos from old-fashioned connectors as well as Ethernet connectors that hides all technical details from the SPC solution. The wall has eight Ethernet connectors (all identical), and the home network is behind that "wall". The audience will only see the "wall" and common user terminals (telephones, TV's and PC's)
- Each device that has no VLAN-aware network interface gets its own converter to make it VLAN aware. These converters are combined with the user's terminal (VoIP phone, set-top-box, etc.)
- Two IP telephones, to demonstrate that a "broken" telephone can simply be replaced by another one without configuration effort. Phone calls can be made to any mobile telephone of the audience.
- Two/three TV sets, to demonstrate multiple TV channels, as well as subscriptions from ***different*** service providers simultaneously for both broadcast TV as well as pay TV (for football or so).
- Two/three user PC's, to demonstrate basic internet access, and to setup / change subscriptions from different providers.
- A management PC, to control the demo, if necessary.

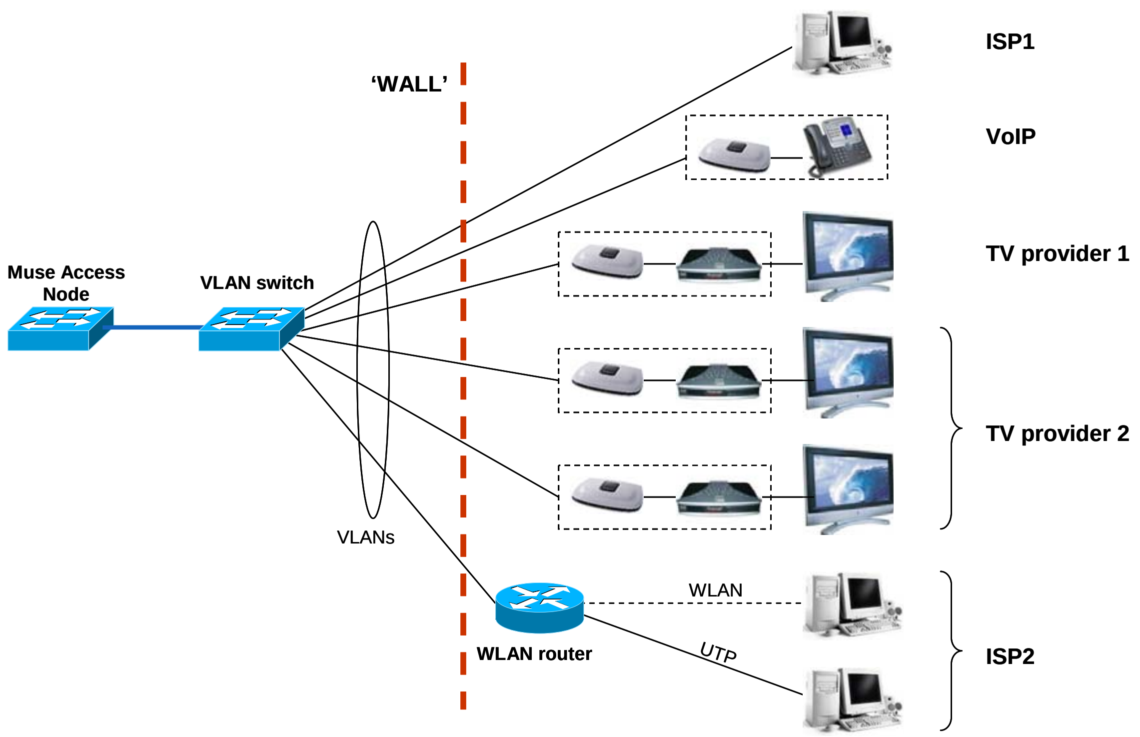

Figure 5-1: *Test set-up as used in demo scenario*

5.2 Preparations done by the end user

The scenario is about an end-user who buys basic broadband access connectivity with a basic Internet access. After he installed this basic service he starts to buy advanced services: VoIP, VoD, broadcast TV, etc. To get all the new services up and running the end user has to walk through the following steps:

- The end user buys his basic broadband connectivity and Internet service directly from a packager. This packager coordinates the installation of the physical network connection (network provider) and the set-up of Internet access services (ISP1).
- The end-user has all the hardware required for IP-telephony, IP-TV, etc. None of them are pre-configured, as if they are bought in a shop. All terminals use DHCP to get necessary IP-routing information from the network provider.

All providers are different companies, so a truly multi-service and multi-provider environment is demonstrated.

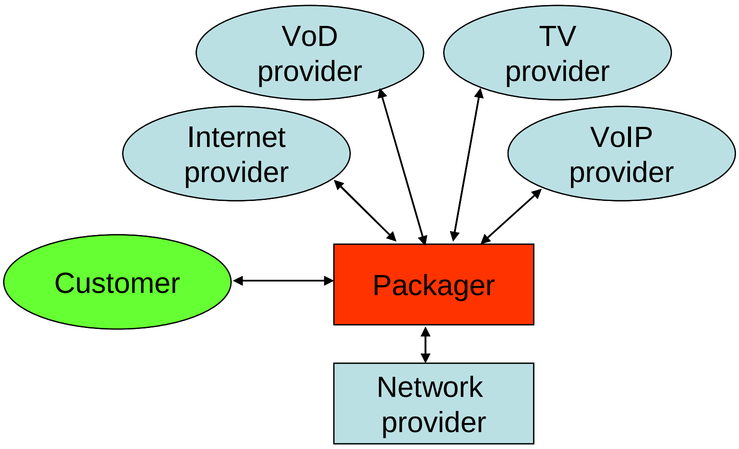

Figure 5-2: *Business role model*

5.3 Demonstating set-up of advanced services

Step 1 – *Basic network access*:

- Connect the user PC, and browse to the "service selection screen" of the network provider. When no service has been selected by the end user he will be automatically get connected to the self-provisioning portal.

Step 2 - *Basic Internet access: ISP 1*

- Select Internet access service from ISP1 to get basic Internet connectivity. Show that web browsing is possible form that moment.

Step 3 – *Telephony*:

- Select "telephony" with your PC on the "service selection screen". First select a wrong provider, and get refused. Secondly select the telephone provider of your subscription and get connected.
- From that moment everything will be auto-configured to provide this user with fixed telephony from that specific access point.
- Plug-in the (unprepared) telephone in any of the Ethernet outlets. Demonstrate that a phonecall can be made!
- Disconnect phone and replace it by another one (as if it was a "broken" device), autoconfiguration starts again immediately, and demonstrates that the second phone works as well.

Step 4 – *Broadcast television*:

- Select a broadcast TV provider with your PC on the "service selection screen", similar as above.
- Connect a first TV, demonstrate by zapping that multiple TV channels are available
- Connect a second TV in another room and demonstrate that multiple TV channels can be seen simultaneously.
- Connect a third TV in a third room, select a second provider from the "service selection screen" (e.g. pay TV for football), and demonstrate the capability of multiple providers.

Step 5 – *Basic Internet access: ISP 2* (with all "standard" features):

- Select "internet access" with your PC on the "service selection screen", similar as above, but now from ISP2. Install a router and show very fast fixed and wireless Internet access.
- Demonstrate that simple browsing works.

- Download a huge file (100Mbyte or more), and show (a) that the quality of the three TV channels is not affected by this and (b) that the download speed is moderate to protect other services.
- Switch-off several TV channels, and do the huge download again. Demonstrate that the speed is significantly higher now.