Specific Targeted REsearch Project

FLAVIA
FLexible Architecture for Virtualizable wireless future Internet Access

Deliverable Report

D 7.1 Specification and planning of stack customization and multi-channel trials

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REVISION HISTORY

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0.5	23/04/12	Y.G.	TID	Overall demo scenario description update based on tasks T7.1/T7.2 progress
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1.0	13/07/12	Y.G	TID	Final release 1.0

STATEMENT OF ORIGINALITY

This deliverable contains original unpublished work except where clearly indicated otherwise. Acknowledgement of previously published material and of the work of others has been made through appropriate citation, quotation or both.

TABLE OF CONTENT

Executive summary

This reports aims to present the plans regarding the validation of the FLAVIA architecture through the integration of the prototyping work carried out within the work packages WP3 and WP4, in order to demonstrate the potential of the solutions identified in WP5 and WP6. The document is organized around the concept of operator-centric scenario, modelled after the use-cases identified in the WP2.

After a short introduction detailing the global organization of the current contribution, we present the plans according to the task organization similar to the decomposition observed in the WP3/WP5 and WP4/WP6, as we have separated the integrations plans following the constraints imposed by the technology. In the first part, we present the plan for a backhaul deployment, where FLAVIA technologies can improve the efficiency of wireless backhauls by fostering the coexistence of different operators sharing network nodes, while providing efficient monitoring; then in the second part, we present how FLAVIA technologies can improve the traditional distribution of the backhaul bandwidth inside homes, by demonstrating 3 deployments, each one of them dedicated to a specific enhancement of the current existing wireless technologies, namely: direct-link, link monitoring, improved rate control, misbehaviour detection and bandwidth aggregation.

Introduction

FLAVIA aims to introduce new paradigms in the provision and the consumption of the Internet connectivity. To this end, the technologies prototyped in WP5 and WP6 work packages give a glimpse of the specific performance and/or functionality improvements developed within the project. We have selected some specific use-cases identified in the WP2 for the purpose of feature demonstration, which are supported by the work carried out in WP3/WP4. More specifically, we focus on the use-cases that cover the distribution and the exploitation of connectivity to a group of users from a provider point of view, as illustrated in Figure 1: FLAVIA Technologies.

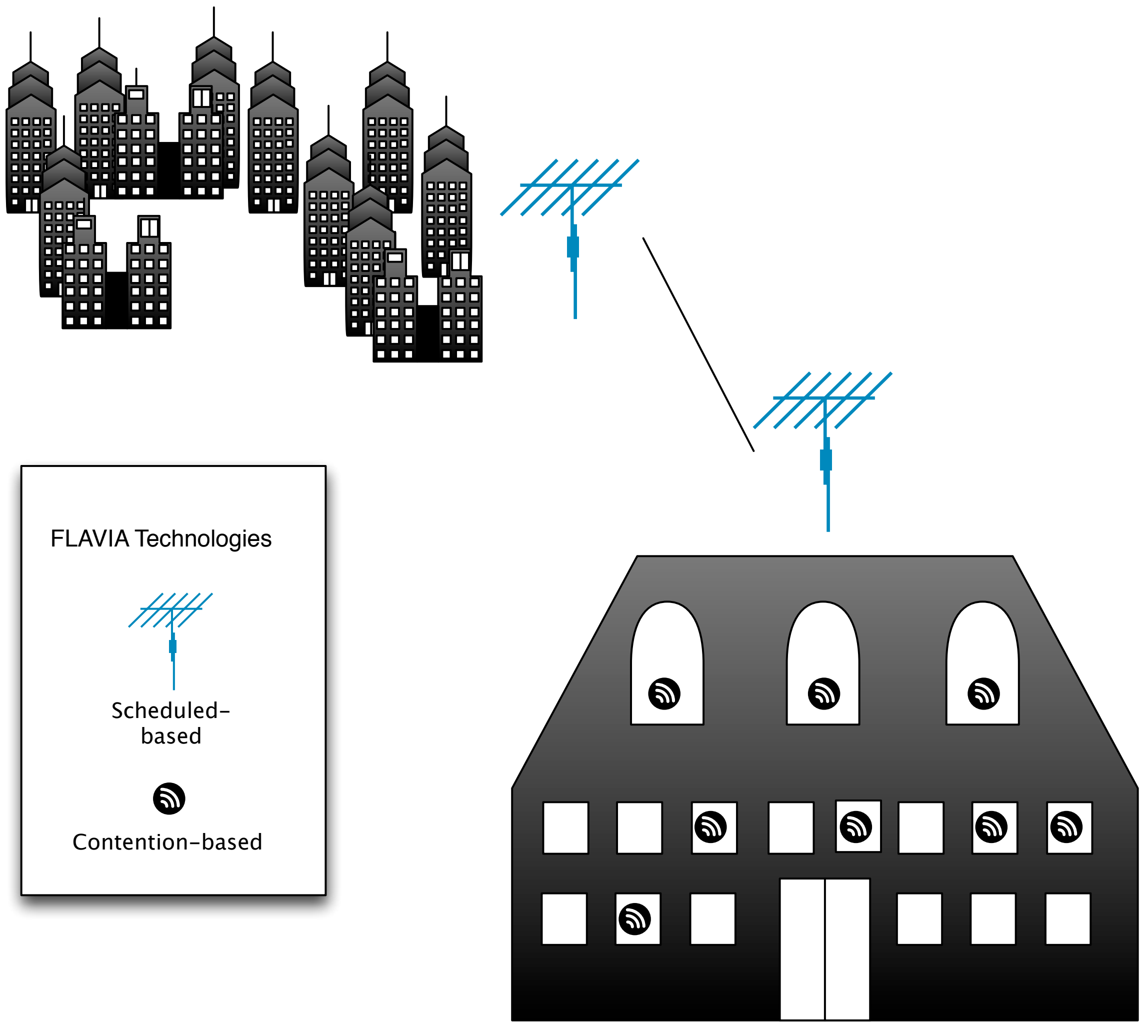


Figure 1: FLAVIA Technologies

In this practical example, a FLAVIA WiMAX backhaul has been deployed to provide connectivity to urban development; this urban development is composed of buildings organized in flats, each of them benefiting from a bandwidth distribution system with a dedicated links and contracted bandwidth. Each of the homes is equipped with an internal Wi-Fi network providing wireless connectivity to end user devices.

Each flat is given a reasonable amount of bandwidth in accordance with the current European-typical deployments in place (1Mbps to 10Mbps), simulating different contracting policy (Flat rate, volume-based accounting). We identified four different aspects to be represented by different demonstrators in that scenario of metropolitan connectivity distribution:

- A first demonstrator targets the capability of the equipment to be reprogrammed to support different scheme;
- A second one targets monitoring and supervision aspect, where the service quality is controlled, a requirement for commercial viability;
- A third one targets virtualization of the physical equipment, enabling virtual operators to share the same infrastructure;
- A last one, application-oriented, demonstrated the capability of the equipment to deliver video as a end-user service on top of the infrastructure.

Then, after the distribution of the connectivity to regular internal cabling, each user is contracting a capacity and uses contention-based technologies to share the resources among household inhabitants, preferably with a satisfactory end-user experience level. As such, the demonstration set is composed of three flats, with different objectives:

- The first one targets re-configurability between devices to provide better video services;
- The second one provides dynamic relaying to improve performance in a monitored environment, featuring misbehaviour detection;
- The last one is focused on bandwidth improvement through aggregation and rate adaptation.

1 Efficient connectivity distribution for Wide Area Networks through FLAVIA scheduled technologies

In this section we present a couple of technologies for enabling efficient use of wireless WAN scheduled-based technologies to enable multi-provider scenario with shared equipment, as described in Figure 2 : Multi-provider scenario.

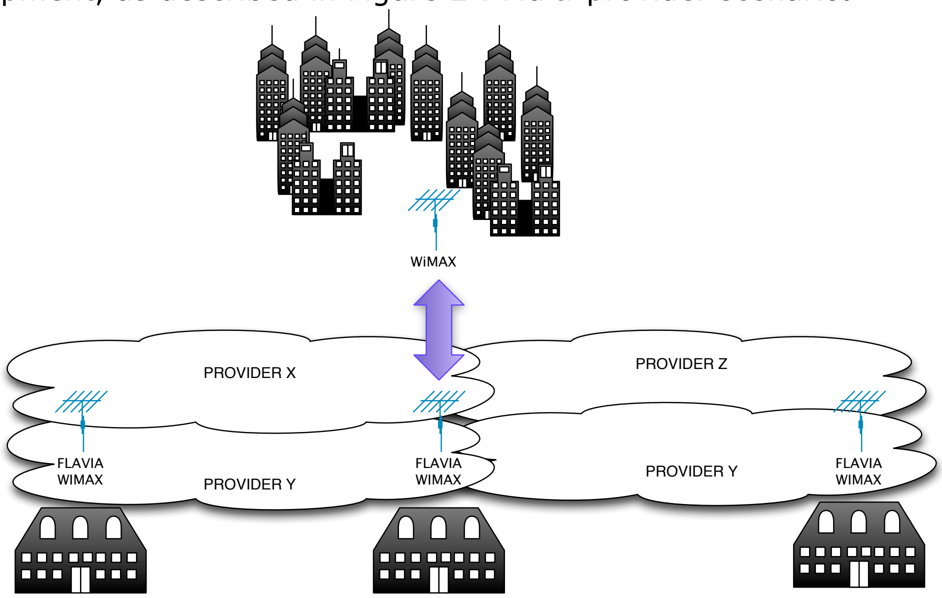


Figure 2 : Multi-provider scenario

In this scenario, a group of operators or communities decides to exploit a shared infrastructure to deploy Internet connectivity to a group of homes. The motivation for sharing infrastructure are numerous, among them, we can identify the following aspects:

- For operators, reduction of the CAPEX (Capital expenditure) and the OPEX (Operational expenditure).
- For communities, this introduces the possibility to reduce the fingerprint of network deployment in the society: backbone deployment, antenna site installation.

Operators might have a large choice in terms of sharing options: from passive forms (sites sharing), partial to full spectrum and radio access sharing. Mobile network operators could also share some elements of the core networks. In any case, such choices need to be enabled through technology; in the framework of FLAVIA we have developed a couple of technologies that can:

- Deploy new communication scheme in a deployed and running equipment to cope with performance issue;

- Monitor and exploit this information at the application level;
- Enable true virtualization in order to leverage the practice of sharing for operators;
- Deploy enhanced services for end users over these networks.

Therefore, we plan to demonstrate these 4 aspects thanks to a combination of four demonstrators.

1.1 Demonstrators

1.1.1 Flexible and Dynamic Scheduling Strategy in WiMAX

We target the scenario 1.1.1 as described in deliverable D2.1.1 [1.1.1]:
"The load balancing, namely the assignment of mobile stations into carriers, can be referred to as a typical Radio Resource Management (RRM) task, which can be achieved using different balancing strategies, including: maximization of aggregate, minimizing sector users outage scenario, etc."

In this demonstrator, a mobile station is working in bad-link conditions; therefore, in a strategy where all stations are benefiting from the same rate (*Equal rate strategy*), the capacity of the whole sector can be impacted. Hence, a better strategy should be deployed, such as the *Equal time Strategy*, as presented in Figure 3: Dynamic Scheduling Strategy.

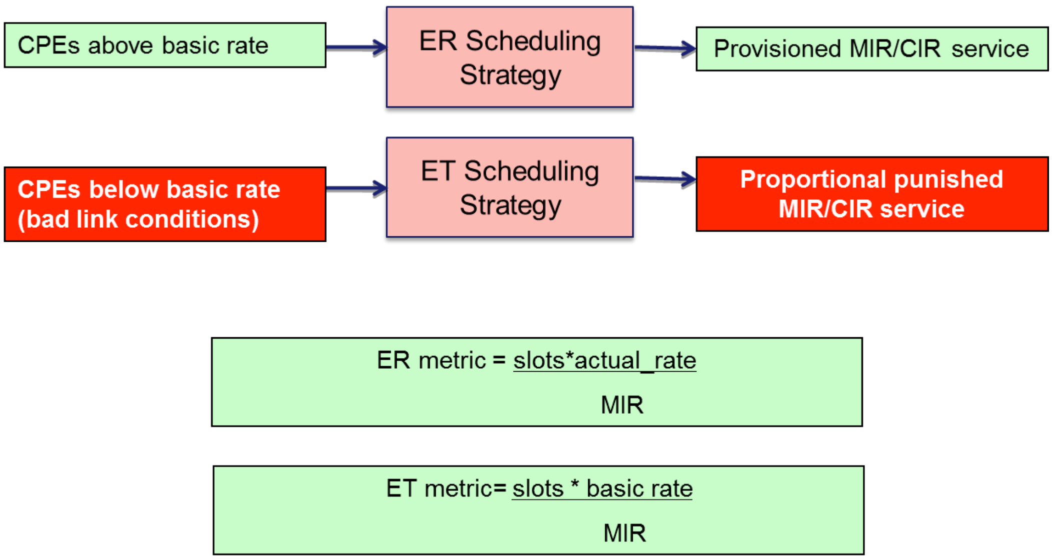


Figure 3: Dynamic Scheduling Strategy

In order to demonstrate this feature, we will build a setup (Figure 4) in which a user using PC1, placed behind a WiMAX CPE, is executing an FTP session against PC2 placed behind the BS.

Using Alvaristar, Alvarion's NMS based on SNMP, we will configure the Scheduling Strategy (see Figure 5 : Scheduling Strategy changed, configuration via NMSFigure 5). First the BS will be configured with Equal Rate scheduling strategy and then we will configure it with Equal Time, checking the behaviour of the system upon a bad-link conditions situation.

Antennas will not be used; all the radio components will be connected via RF cables with attenuation.

We will use variable attenuators to simulate the bad-link conditions. Upon increasing the attenuation, we will show that, when the BS is configured with Equal Time scheduling strategy, the CPE that is working in bad-link conditions is punished with a proportional rate reduction.

The scenario will be demonstrated by the following steps:

1. Configure Equal Rate scheduling strategy via NMS
2. Associate MIR in AAA for CPE-1
3. Test that allocated MIR is received, by using FTP connection between PC1 and PC2
4. Configure in Alvaristar (by SNMP) Equal Time scheduling strategy and Basic Rate
5. Test that the allocated MIR is received, by using FTP between PC1 and PC2
6. Change attenuation until the rate drops below configured Basic Rate and check the proportional reduction of allocated MIR, by using a FTP between PC1 and PC2.

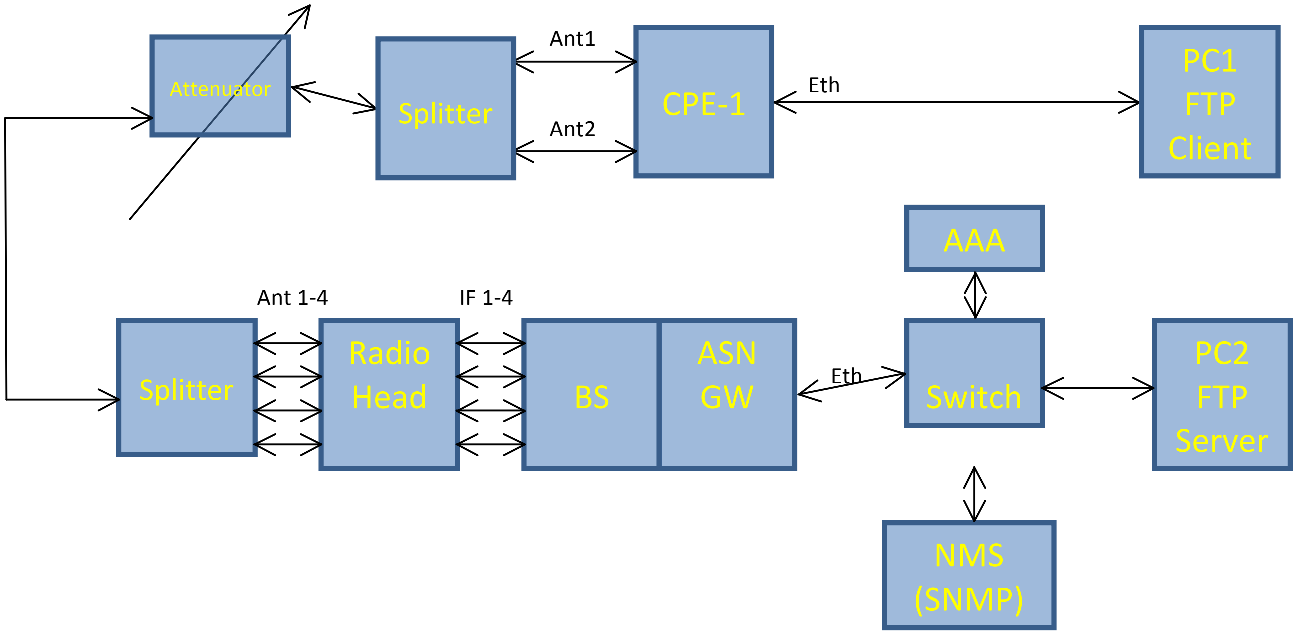


Figure 4 : Dynamic Scheduling Strategy test setup

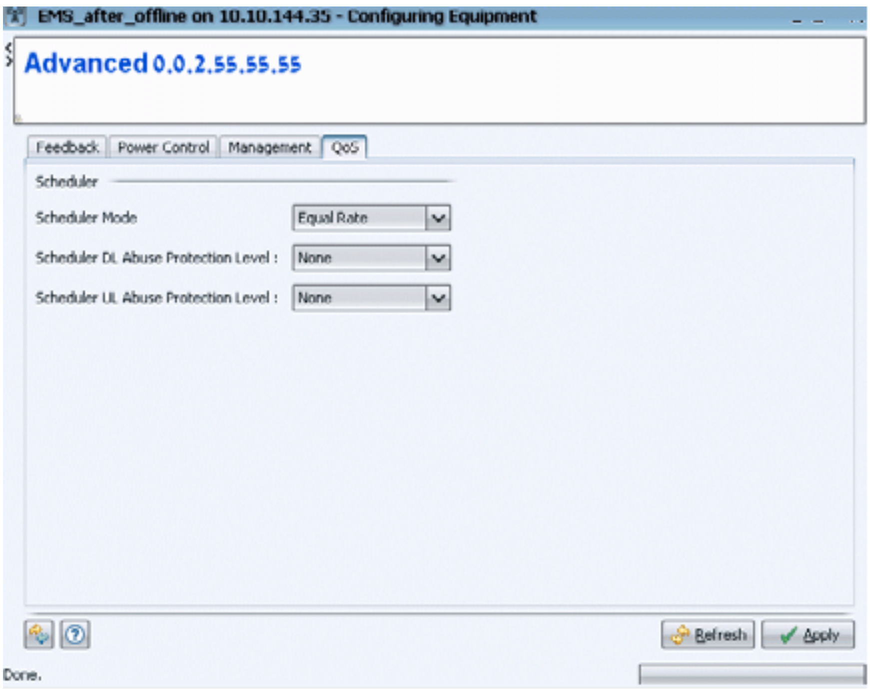


Figure 5 : Scheduling Strategy changed, configuration via NMS

1.1.2 Measurement framework

The deliverable D2.1.1 describes a scenario promoting this measurement framework, namely scenario 1.1.5 [1.1.2]:

"*As an example, a video streaming client on a device could inform the server side of the current radio characteristic (though any feedback link used by the application side).*
Then on the server side, the video could be transcoded to dynamically adapt to the link quality. Such an adaptation requires from the dongle (as well as from the drivers on the host side) an open interface, which could provide enough information, related to the radio link. Moreover, ideally, it could be possible to control the dongle from such an interface."

In this scenario, the radio link information is monitored by the hardware dongle that communicates measurements to the framework. The application could then access these measurements in a real time manner, as sketched in Figure 6 and Figure 7.

The measurement framework introduced in D3.1 is an example of an use case envisioned by the general architecture defined in WP2 that could be demonstrated.
Events generated by the wireless processor are reported and could be used for instance to monitor on the behaviour in the lower layer part of the modem and on the radio interface. Quality related measurements (for instance signal strength, type of modulation and coding scheme used etc.) could be provided to the application processor (the host, in case of hosted architecture, such as a 4G dongle hosted by a laptop). Any applications on the host could then access these measurements to tune their behavior and adapt dynamically to the radio link.

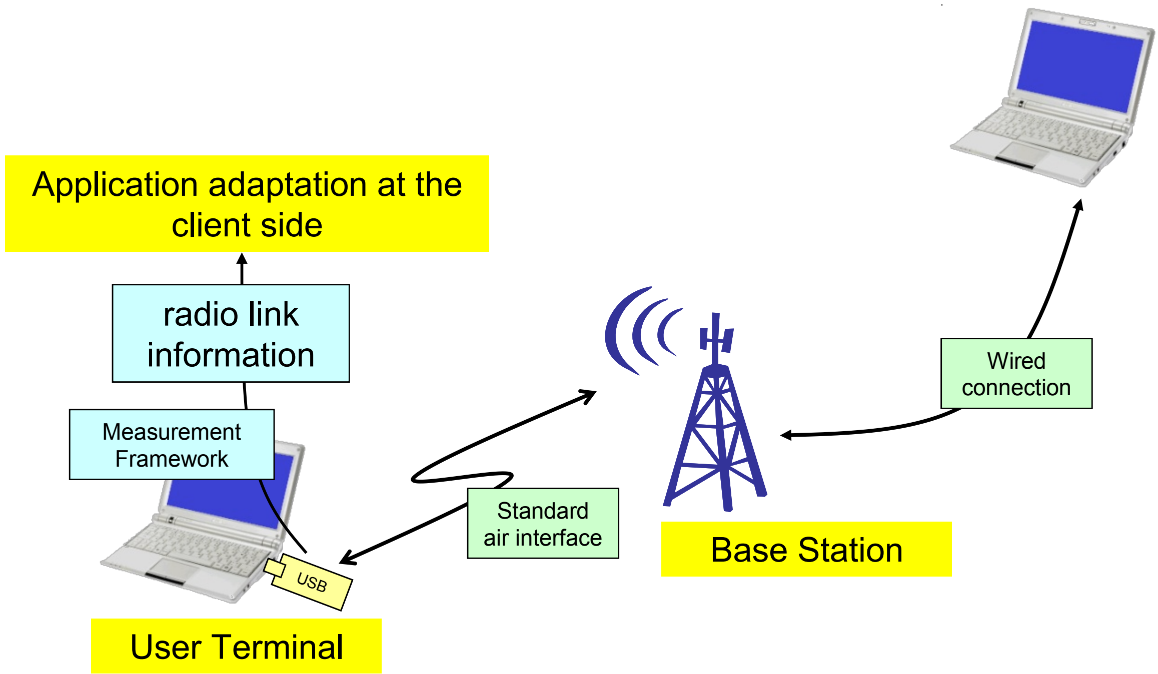


Figure 6: Measurement-based application optimization – client adaptation

In the Figure 6, the measurement framework is running locally on the host connected to the radio modem (the USB dongle). As such, the measurements are available only locally, that would allow only the adaptation of the local application (a client in most of the cases of client-server application, such as streaming video from the internet). In the case depicted in Figure 7, the measurement framework is running remotely, accessing the terminal through a connection (could be wired, wireless). As a result, the server side of the application may have directly access to the terminal information and thus be able to adapt properly the application.

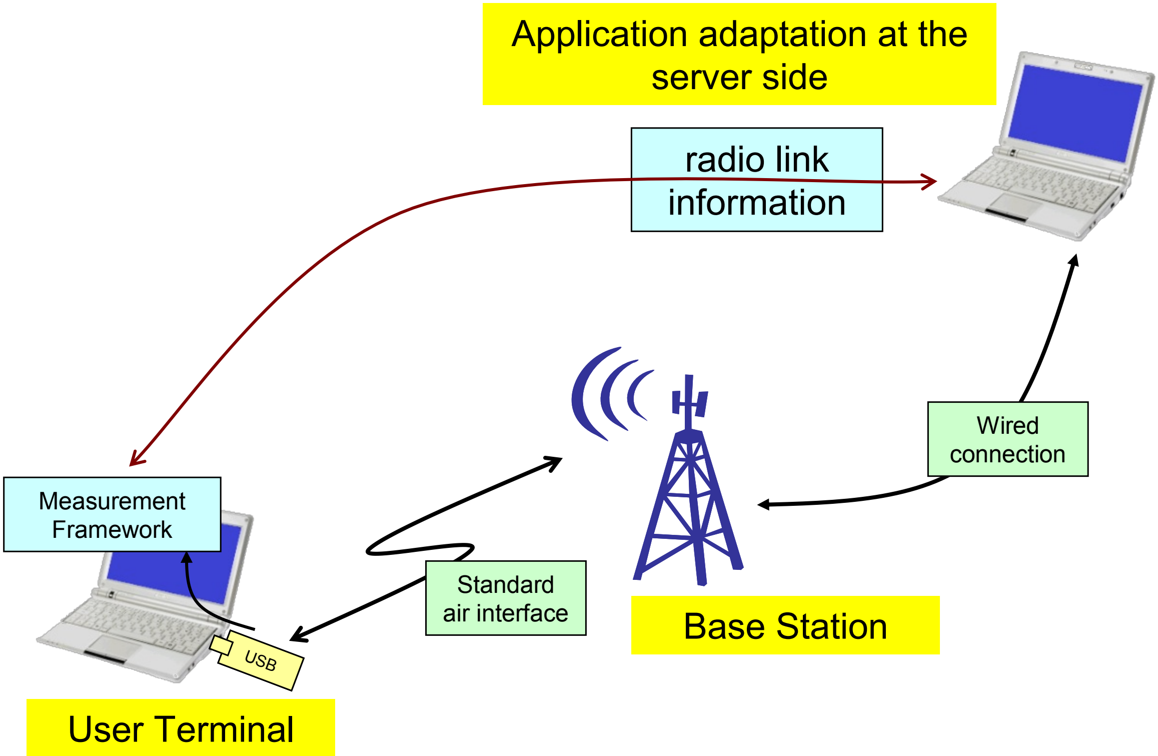


Figure 7: Measurement-based application optimization- server adaptation

Such use cases put the constraint on the measurement framework to be flexible enough to be able to operate both locally and remotely, and still to produce relevant metrics to be exploited by the upper layers.

For the purpose on this demonstration, no direct application adaptation will be show, but the measurement framework will be displayed both locally and remotely showing the flexibility of the implementation. For this purpose, we introduce a graphical interface that will exploit the data generated at the application layer in a similar fashion.

1.1.3 Virtualization for RAN Sharing

We target the scenario 1.2.1 as described in deliverable D2.1.1 [1.1.3]:
"*We consider a scenario where a number of operators share network nodes (i.e. base stations), where the operators do not necessarily deploy the same technology or the same technology release. Another scenario is the roll-out of new technologies on existing base station hardware.*

The scenario that will be demonstrated concerning RAN Sharing proves the capability to give service to different Virtual Operators using the same network infrastructure. It will be based on pre-defined agreement among the operators on the parameters, which define the RAN resources split, and corresponding scheduling policies to be applied.

In the proposed demo, we will demonstrate how each of the Virtual Operators/ISPs can work with a different Scheduling Strategy.
We will have 2 different users with PCs behind their respective CPEs that receive their services from different ISPs. Both users are executing FTP sessions against a FTP server placed behind the BS (see Figure 8). One of them has assigned Equal Rate Strategy and the other one Equal Time Strategy. Then we will use variable attenuators in order to put them below the basic rate. The one with Equal Time strategy is punished due to the bad conditions of the link in order to avoid that the low performance of Link 2 affects the other users.
The sequence of actions is the following:

1. Link-1 is serving Josef@ISP1 with MIR1 at Equal rate strategy.
2. Link-2 is serving Albert@ISP2 with MIR1 at Equal time strategy.
3. Link-2 is above Basic rate.
4. Josef@ISP1 and Albert@ISP2 get the same FTP rate (MIR1).
5. Change both attenuations to drop below Basic Rate.
6. Josef@ISP1 continues to get the same MIR1.
7. Albert@ISP2 MIR is punished proportionally.

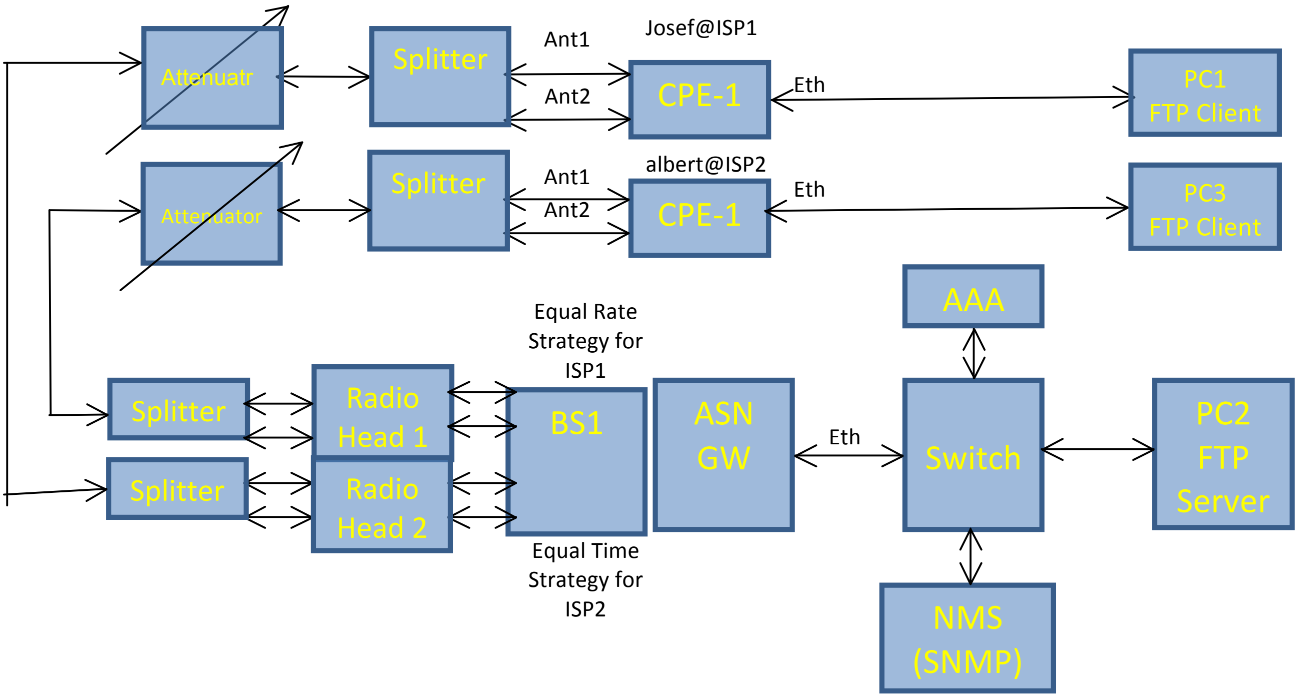


Figure 8: Virtual Operators test setup

1.1.4 Video Improvement Application

This scenario will demonstrate the FLAVIA architecture capability to deliver E2E video, increasing video transfer reliability, lowering resource consumption, and enabling more sessions. Our approach focuses on improving DL and UL MPEG4 video delivery.

Compressed video sequence is composed of Group Of Pictures (GOP) in which frames are coded relatively to other frames. Video compressed frames are divided into three major frame types:

- Key frames (I,S) – frames that are coded independently, frame loss impact entire GOP
- P frames – delta updates of I frames, second in priority
- B frames – bi directional frame, lowest priority

The concept behind optimized video operation is allocating resources to video frames according to their importance. In the proposed scheme, for each MS that is entitled of optimized video service three connections are established:

- Key frames connection – highest priority
- P frames connection – medium priority
- B frames connection – lowest priority

The video sequence PDUs are divided according to their frame type and enqueued to the matching queue. Then queues are treated according to their importance having different QoS characteristics and scheduling when resources run short most efforts goes to key frames queues.

A new Service profile type is defined, named "Enhanced Video Service". Three QoS profiles are defined for this service, one per connection. All connections are HARQ enabled with 4 retransmissions. In Enhanced Video Mode the classification between Primary, Secondary or Third is done via DSCP.

The UL classification uses regular DSCP classifiers. An upper layer classification module divides the packets to key I frames, P frames and B frames, to allow different classifications by different DSCP values. Therefore the upper layer application needs to mark the DSCP values as in the following table per the relevant MPEG-4 frames to allow their classification and appropriate prioritization over the scheduled WiMAX media:

Frame type	DSCP value
Key I frame	9
P frames	8
B frames	1

Once determined packet type the module changes its DSCP value to the value advertised during NWE.

Figure 9 depicts basic UL video optimization scheme.

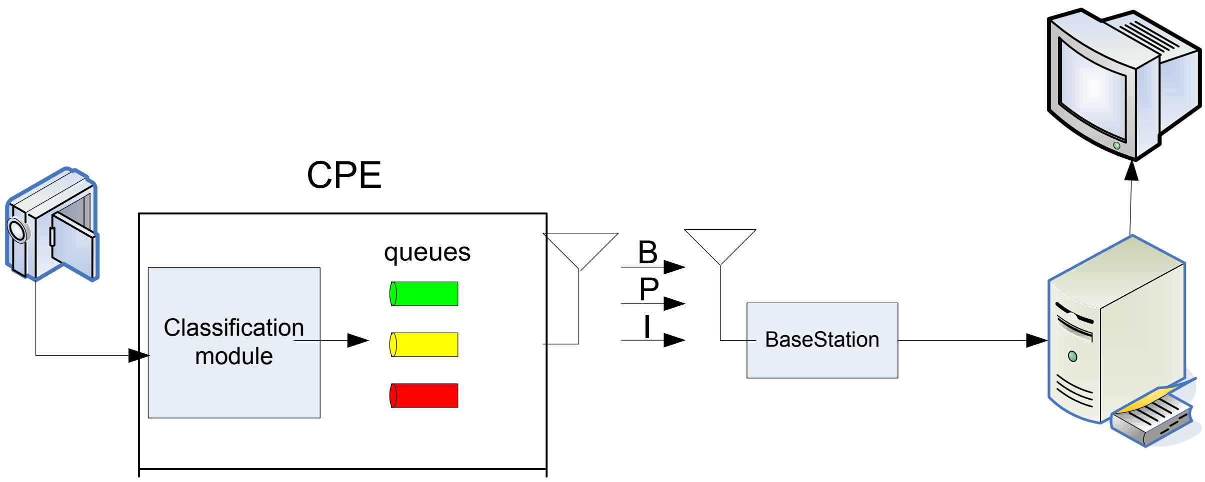


Figure 9 : UL video optimization scheme

The sequence of actions is the following:

1. A new Service is configured via Alvarion's NMS for CPE-1. It will be based on 'Enhanced Video' Service Profile
2. PC-1 behind CPE-1 starts a video streaming session.
3. Verify via the Command Line Interface, the packets transmitted per each of the 3 connections associated to the Enhanced Video Service Profile. Check if there are dropped packets.
4. Reduce via the WiMAX NMS the MIR/CIR of the connections used by B and P Frames.
5. Verify via the CLI if the rate of dropped packets as grown. Verify that the number of dropped packets is low for the connection used for the key frames,

higher for the connection used for the P frames and the highest for the connection used for the B frames.

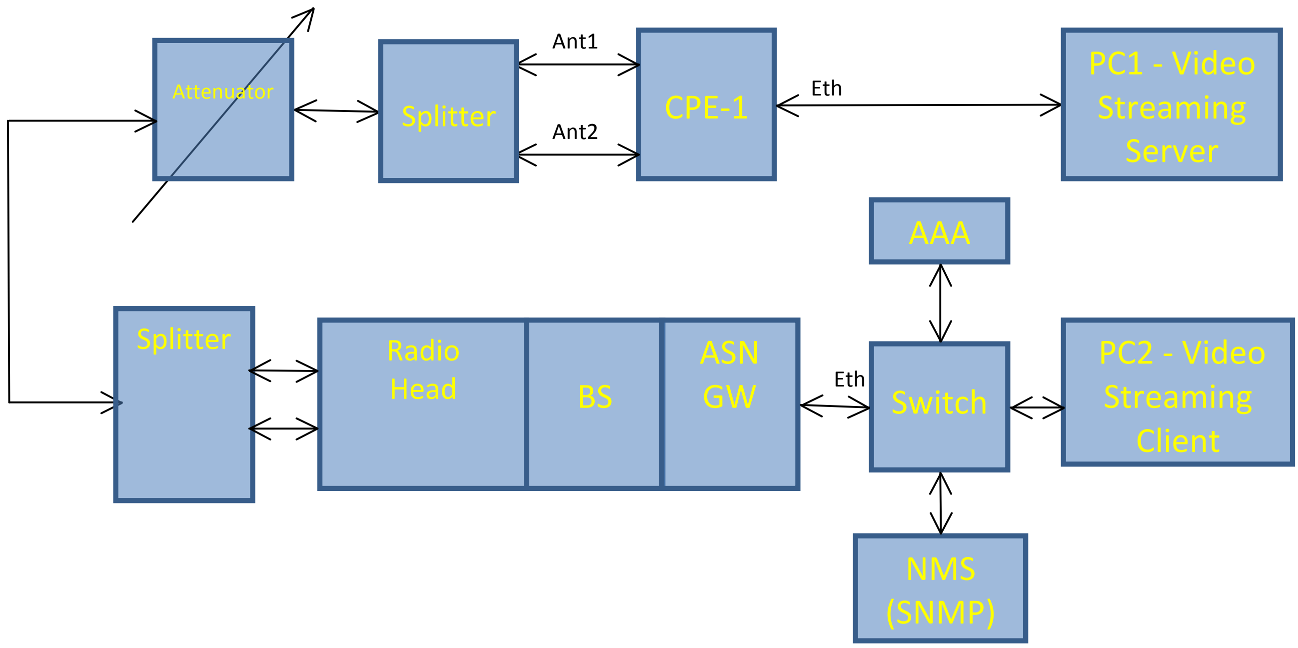


Figure 10: Video optimization in scheduled systems test setup

1.2 Requirements

For the demos envisioned in Section 1.1, we have established the following requirements:

Name	Type	Description	Usage
Alvarion CPE	Hardware	Indoor and outdoor model, should support data, VoIP services	Demos 1.1.1 and 1.1.3, 1.1.4
Traffic simulation tools	Software	Smartbit, TFTP, FTP, Packet Generator, iperf	Demos 1.1.1, 1.1.2 and 1.1.3
USB Dongle Sequans, as displayed in Figure 11	Hardware	Dongle for measurement radio	Demo 1.1.2
Traffic Generator Sequans * as displayed in Figure 12	Hardware	For simulating traffic.	Demo 1.1.2
Laptops	Hardware and Software	Equipment to run the demos in different environments.	Demos 1.1.1, 1.1.2 and 1.1.3, 1.1.4

(*) due to frequency and standard issues, at the writing of this document the equipment of Alvarion and Sequans are not compatible and tested for interoperability. Therefore, we provide two types of equipment for generating traffic.

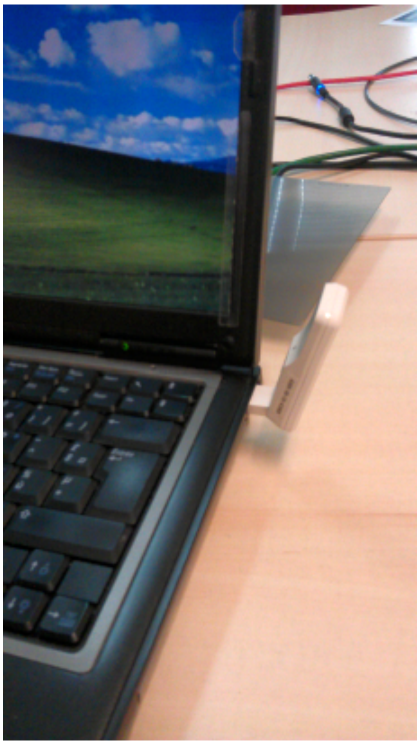


Figure 11: USB Dongle Sequans

Figure 12: Traffic Generator Sequans

1.3 Planning

M17	M21	M23	
Flexible and Dynamic Scheduling Strategy in WiMAX			
Design	Implementation	1st Demo	
Measurement-based application optimization			
Design	Implementation	1st Demo	
Virtualization for RAN Sharing			
	Design	Implementation	
Video Improvement Application			
	Design	Implementation	

	M36
Flexible and Dynamic Scheduling Strategy in WiMAX	
Test/Refinements	final demo
Measurement-based application optimization	
Test/Refinements	Final demo
Virtualization for RAN Sharing	
Implementation/tests	Final demo
Video Improvement Application	
Implementation/tests	Final demo

We plan to propose a first set of demonstrations by M23, where the Flexible and Dynamic Scheduling Strategy in WiMAX and Measurement framework will be demonstrated for the first time with mobile equipment.

These two demos will be completed by the virtualization demo and the video demo that will be developed and tested by the end of the project.

2 Maximization of connectivity for Local Area Network through FLAVIA contention-based technologies

In this section we present a couple of technologies introduced by FLAVIA for enabling efficient use of wireless contention-based technologies in order to provide enhanced capabilities.

In this scenario, a neighborhood composed by different flats in the same building is enjoying wireless connectivity. Each flat is having its own backhaul connectivity; in an ideal full-FLAVIA flavor setup, the backhaul connectivity is provided through a wireless backbone (as presented before) but a typical DSL deployment can be applied here as well.

In each of the flats, the technologies of FLAVIA will be deployed to improve the end user experience. We distinguish three main functionalities brought by FLAVIA, and we split them on three different flats that will exhibit specific capabilities:

- FLAT 1: Dynamic reconfiguration of the hardware according to opportunistic communication: a custom MAC protocol will be deployed and executed by two clients in a synchronous way in order to deliver superior performance compared to the traditional contention scheme;
- FLAT 2: Self-configuration, performance and misbehavior monitoring: WiFi devices connected to an AP will dynamically reconfigure the network topology to adopt a relay approach, thanks to parameters extracted from continuous monitoring and misbehavior detection.
- FLAT 3: Performance enhancement - in this flat, the combination of an advanced rate adaptation technique, as well as bandwidth aggregation through virtualization will enable standard users to benefit from upgraded performance without any hardware changes.

The three flats are illustrated in Figure 13.

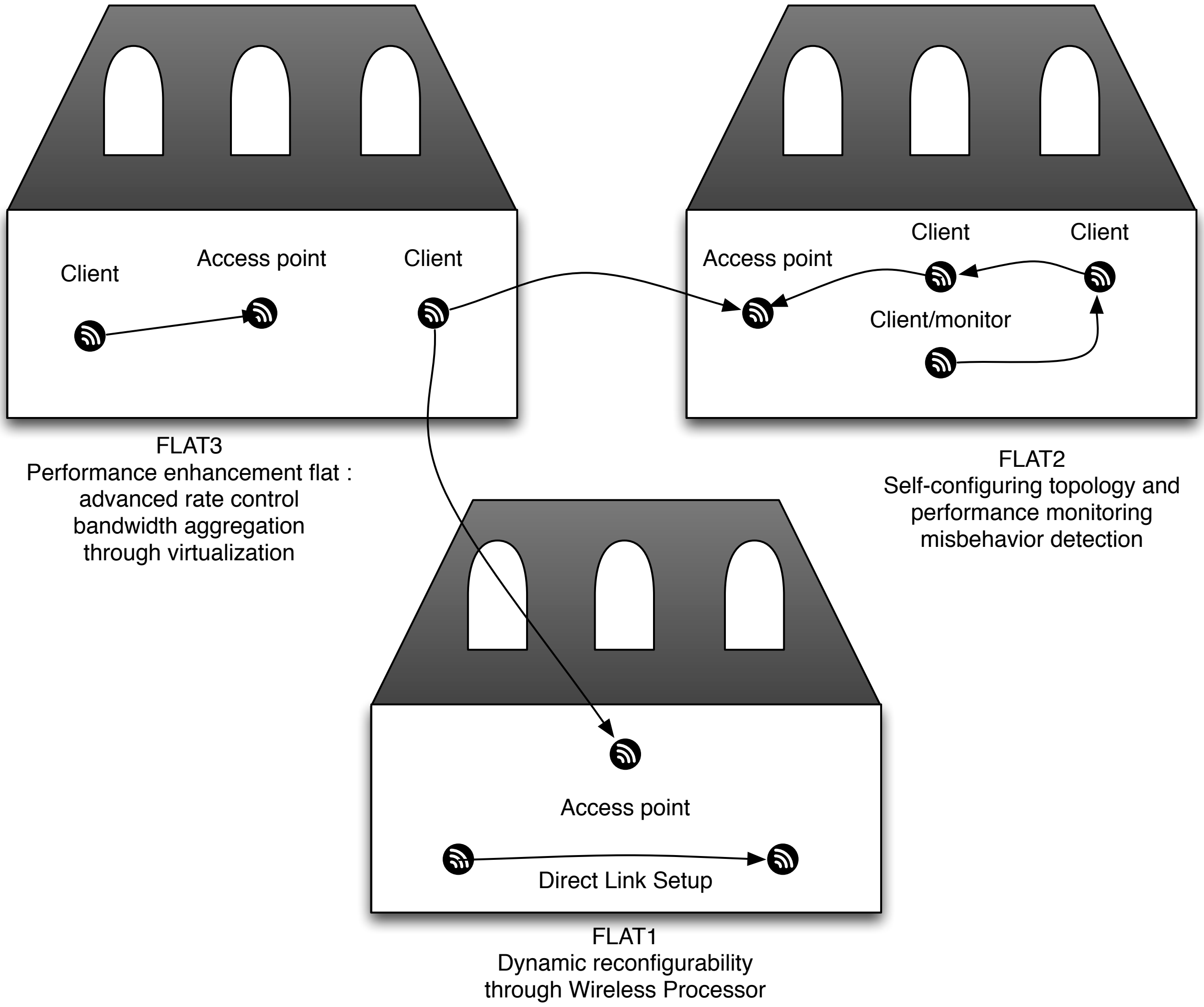


Figure 13: Contention-based technology demonstrators

2.1 Demonstrators

2.1.1 Flat 1: Dynamic reconfiguration

We target the scenario 2.3.2 as described in deliverable D2.1.1 [2.1.1a]:

"We envision Wi-Fi based devices to form self-configuring mesh networks of mobile nodes, customized for audio and video traffic transmission (including reliable groupcast transmission) under strict QoS requirements (in terms of throughput, packet loss and delay, etc.). The mechanisms implemented in such devices will be sustainable to topology changes caused by mobility of nodes, which is of great importance for drastic emergency applications (during or after a disaster or a terrorist act, in case of military field operations).",

,scenario 2.3.3 as described in [2.1.1b]:

"We consider a single-radio, multi-hop scenario with nodes far away from each other. Data and video traffic coexist in the network, with priority being given to the former – although this priority is related to the delivery requirements in terms of quality of experience, and may change depending on network conditions."

as well as scenario 2.3.4 as reported in [2.1.1c]:

"We consider a network scenario in which a single radio channel is used and not all the network nodes are in radio visibility. Each link (i, j) between nodes i and j can support an heterogeneous maximum transmission rate $r_{i,j}$ *(belonging to a set R of available modulation/coding schemes) as a function of the link quality. We also assume that traffic sources activate/deactivate dynamically, originating unidirectional greedy packet flows from node s to node d. A routing path is pre-computed for each source destination couple."*

This demonstration is focused on showcasing the capability of the FLAVIA architecture to negotiate and launch customized medium access functionalities.

We consider the following (typical) domestic scenario: a WiFi ADSL router connects three (or more) stations to the Internet. This usually works well if traffic to the stations comes from the outside. However, when the children are at home and start downloading a high definition video from a streaming server to the Internet-enabled TV set, it is likely that adults trying to work on their laptops will see impaired performance, as the legacy DCF protocol requires traffic to be first from the server to the AP and then again to the TV set, thus duplicating the bandwidth used on the wireless channel.

This problem is obviously not nearly new, and indeed was specifically addressed by the 802.11e task group with the introduction of the Direct Link Setup (DLS), further extended in the 802.11z-2010 amendments. However, a direct link setup is not automatic (i.e. the children should take care of changing the settings of the TV set during the streaming). Moreover, a direct link is set up using the same wireless channel, thus, although to a lower extent, the station connected to the Internet still suffers of a bandwidth reduction.

We will show that by means of FLAVIA the stations in the network are not expected to implement any specific DLS amendment. By default, their Wireless MAC processor card runs a MAC program implementing just the legacy 802.11 DCF operation. As soon as the AP detects that two associated stations are involved in a greedy data session, it delivers a new MAC program (embedded in a common data packet) to just the two involved stations. Stations are configured to accept and install MAC programs coming from the home AP. The AP further signals the (same) time instant at which the two stations will start the installed program. From that time on, the two stations will implement a custom MAC protocol. Such custom MAC protocol may be designed to be strictly tailored to the considered context. For instance, if we assume that at most one direct link connection will be deployed, and that this direct link will always involve the two same radio interfaces (the ones of the server and of the TV set), we can push bandwidth optimization further. For example, we can set the direct link on a separate frequency channel, but of course avoiding that the stations will lose the association to the AP. Finally, since such separate channel will be deployed for just these two stations, further greedy MAC protocol optimizations are possible (such as the use of more aggressive backoff rules).

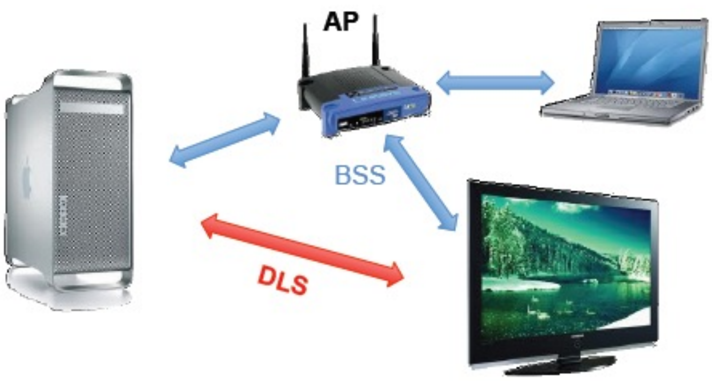


Figure 14- Dynamic reconfiguration use case: a streaming server (left) delivers HD video to an Internet enabled TV; a laptop (right) is connected to the Internet via the AP.

We have debugged and tested this demo using an ad-hoc sniffing platform, as the integration of the monitoring modules is still ongoing.

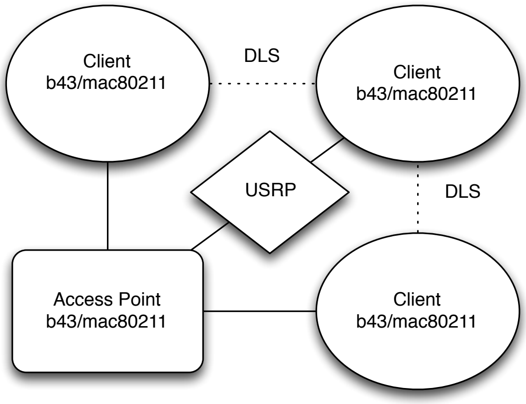


Figure 15: Dynamic reconfigurability demonstrator

2.1.2 Flat 2: Self-configuration, performance and misbehaviour monitoring

We target the scenario 2.1.5 as described in deliverable D2.1.1 [2.1.2a]:

"*We consider what measurements are available to 802.11 stations, that can be inferred without requiring extensions to 802.11, but are not usually made available throughout the 802.11 stack. In essence, we aim to better instrument a node in order to better understand its environment."*

Also, we consider scenario 2.1.2 [2.1.2b]:

"We consider an 802.11 network where the access point aims to enforce particular fairness or access policies. The access point may require particular measurements to assess which nodes are misbehaving and may want to take special actions in the event that stations are found to be misbehaving, such as disassociation, failing to generate ACKs or even jamming transmissions."

In this demonstrator, we integrate 3 FLAVIA-based technologies in order to provide better services to unregulated radio environment. We combine self-configuring WLAN, measurement service and misbehavior detection as presented in Figure 16.

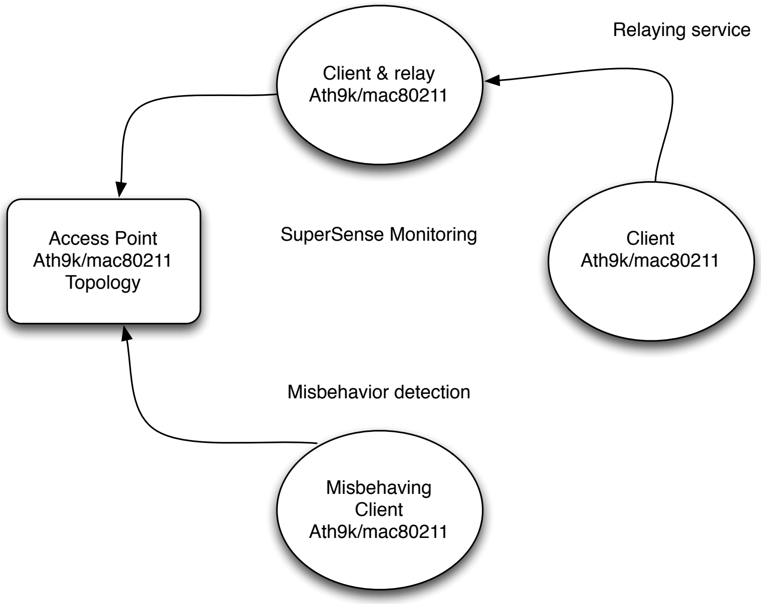


Figure 16: Self-configuration, performance and misbehaviour monitoring demonstrator.

Self-Configuring WLANs using Opportunistic Relays

In this demonstrator, WiFi devices connected to an AP dynamically reconfigure the network topology, building on the presence of opportunistic relays, to improve the overall QoE and energy performance (battery lifetime, reduced consumption). This is illustrated in the simple scenario depicted in Figure 17 (top), in which three nodes are connected to the AP using different modulation and coding schemes (MCS), based on their radio conditions towards the AP. In this scenario, assuming all nodes are constantly backlogged with frames of length L=1500 B, due to the performance anomaly [2.1.2c] effect they would all achieve a throughput of approx. 1.7 Mbps each, for a total throughput of 5.1 Mbps. Note that this is significantly smaller than the maximum achievable gain supported by the highest MCS, namely, 24.6 Mbps.

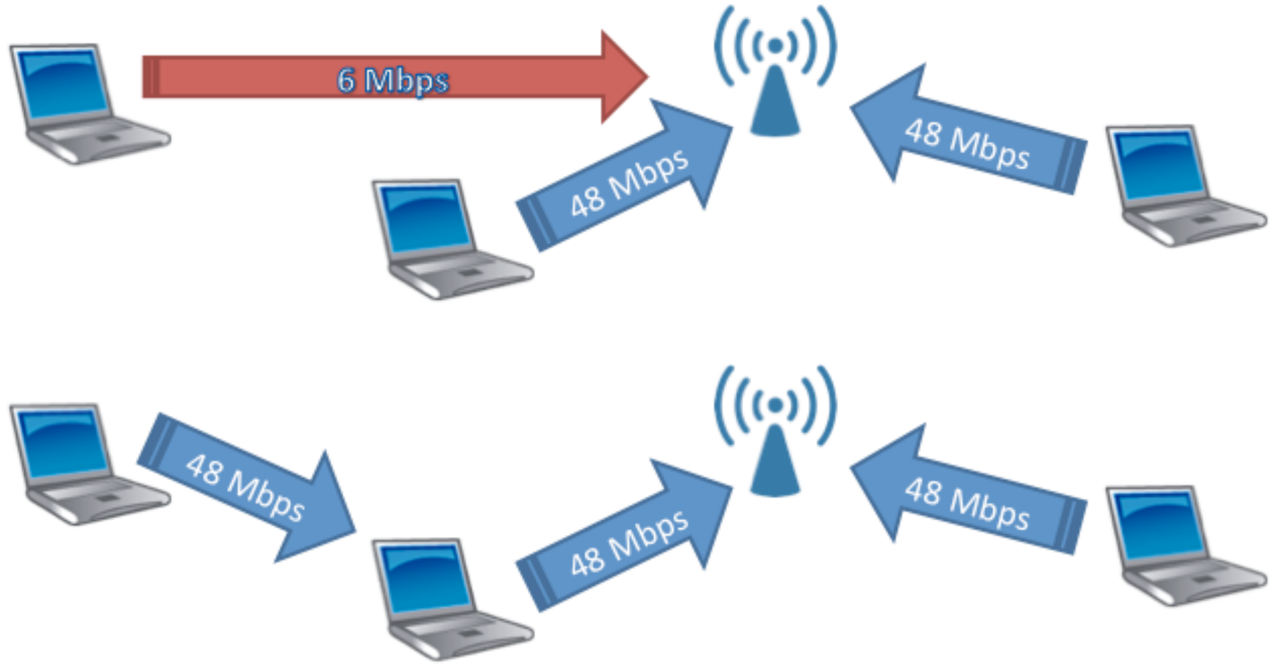


Figure 17 Use of opportunistic relay (bottom) to improve performance in a scenario suffering form the performance anomaly (top).

If one of the nodes is enabled with relaying capabilities, using e.g. Wi-Fi direct [2.1.2d], the situation is that shown at the bottom of the figure. The relay node is a single-radio device, which is able to alternate between serving the node with the poor link towards the AP (and therefore, acting as its AP) and sending all the data (i.e., its own traffic, and the one being relayed) to the actual AP. In these conditions, and assuming that the node acting as relay spends 50% of the time on each configuration, the nodes will experience a throughput of (approx.) 6.1, 6.1 and 12.3 Mbps (from left to right in the figure), thus practically achieving the maximum rate.

In the above scenarios there are two key and related variables that affect the overall performance, and have to be configured according to the users' preferences:

- First, the relative amount of time spent by relays acting as "soft APs" (following Wi-Fi direct terminology) instead of connecting to the AP.
- Second, the objective function to maximize, along with the corresponding constrains in terms of minimum performance (e.g., fairness criterion).

Indeed, in the above example we have considered only the case of saturated nodes, and a 50% ratio in the only relaying node. However, the envisioned framework also supports introducing fairness criteria, as well as maximizing other performance figures; in fact, if nodes are able to estimate the power consumption of the devices (e.g., based on matching MAC addresses to hardware vendors), other performance figures that could be optimized are energy efficiency or network lifetime.

It should be noted that the use of relays to enhance performance has been already experimentally demonstrated for a very simple case, consisting of a two-client network. However, the FLAVIA demonstrator significantly extends this previous work, adding the following contributions:

- The objective is no longer total throughput maximization, but instead the framework supports any convex function to maximize along with the corresponding constraints.
- Furthermore, energy efficiency is also taken into account, with a parameter, tunable by the user, which allows setting the trade-off between performance and energy consumption.
- The solution is not limited to the case of one relay; instead, building on a soft-coordination scheme, relays coordinate their activities when accessing the channel and relaying information.
- By building on the Notice of Absence (NoA) protocol, relays can command stations to go into the doze mode, thus introducing significant energy savings. Furthermore, in case of low traffic, relays themselves can use the sleep state to reduce the energy consumption.

In order to implement the envisioned solution, we will build on the following features that are supported in FLAVIA: first, relays need to access the advanced monitoring services, to gather the required information about the network topology (e.g., links, MCS used between pairs of nodes, expected MCS, traffic generation rate); relays should also be able to discover themselves, in order to perform their soft coordination when accessing the AP (this could be done e.g. using a service announcement protocol, or an explicit inter-node communication based on GAS from 802.11u); finally, when relays are first deployed, they need to force (legacy) nodes to connect through them instead of the original AP. There are some ways to implement this, depending on the envisioned scenario (e.g. if the AP is also a FLAVIA node, if devices already support the 802.11v standard).

Monitoring through measurement services

This demonstration aims at showing the ability of the measurement services implemented through the FLAVA architecture to monitor accurately the radio channel and reconfigure on-the-fly the devices of the wireless network in order to obtain/achieve the best performance.

To illustrate the enhanced monitoring accuracy provided by the SuPerSense service, let us refer to the example network scenario depicted in Figure 18, where three wireless devices form a multi-hop network. The nodes on the two sides of the topology are hidden from each other. Therefore, data transmissions occurring on the wireless link (N3,N2) affect the accuracy of the link quality estimation on the link (N1,N2), since data and probe frames sent over the two links can collide.

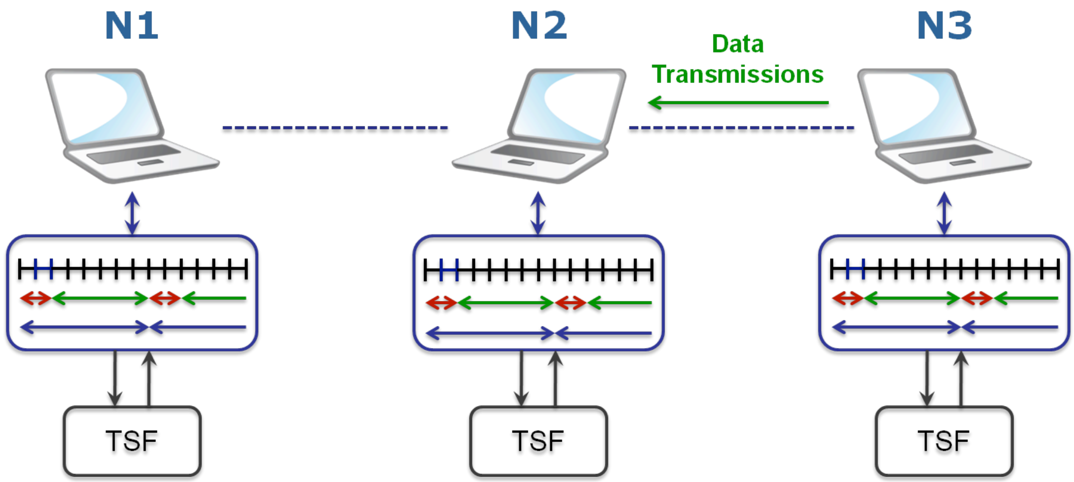


Figure 18 – SuPerSense use case: node N3 transmits data traffic towards node N2 affecting the link quality estimate of link (N1,N2). The coordinated monitoring and transmission activities improve the estimation accuracy.

To overcome the problem of route flapping which may reduce the network performance experienced by end-to-end data connections in mesh topologies, we have implemented a coordinated active probing mechanism that prevents intra-node interference as well as collisions caused by transmission of hidden terminals.
The coordinator of the BSS (e.g. the AP or a cluster head of an ad-hoc network) periodically broadcast in beacon frames the information used to coordinate transmission and monitoring activities. This information is used by all nodes to schedule the transmission of the probes used to estimate the link quality.
During the active monitoring period only one device can transmits its probes, thus preventing the collision caused by hidden nodes, which in turn increases the accuracy of the estimation process.

While this demonstration highlights the accuracy of the link quality, we underline that the proposed solution can be used to improve the precision of the measurements computed through active probes.

Misbehaviour monitoring

The FLAVIA open architecture offers possibilities to misbehave. Therefore, a misbehaviour detection service is introduced to detect the incorrect configuration of stations. This demonstration is focused on the FLAVIA architecture capability to detect misbehaving users and react to them by introducing a punishment mechanism for selfish users. This is illustrated in the scenario depicted in Figure 19, in which an operator provides basic Internet access and a misbehaving user tries to obtain more throughput by modifying standard PHY or MAC parameters.

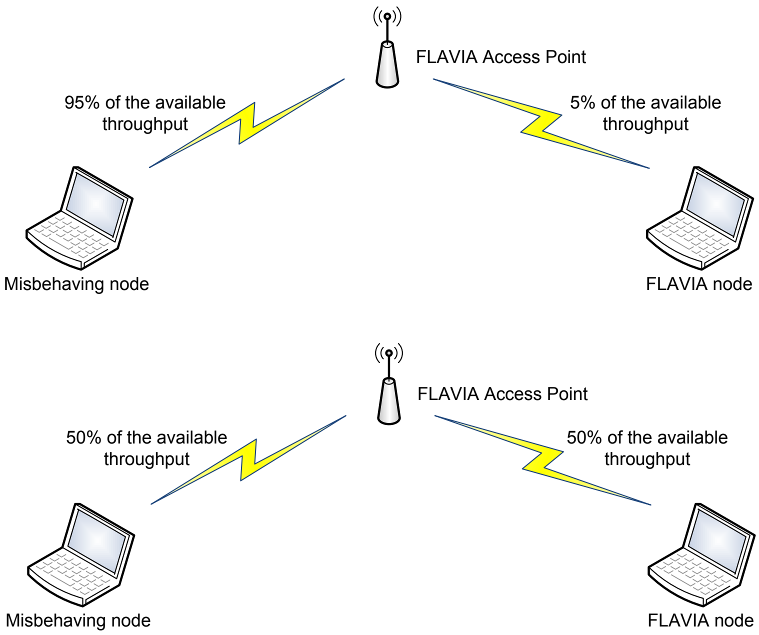


Figure 19: Use of misbehaviour reaction (bottom) to improve performance in a scenario with misbehaviour node (top).

For this purpose, the access points installed by the operators and FLAVIA nodes need to employ extended monitoring functionalities (based on passive monitoring), able to detect anomalous behaviour of the client nodes and to punish such behaviours. There are different approaches that can be followed for enabling the support of this service. For example, the operator may assume that client nodes can in turn observe their punishment or can in general update their strategy on the basis of their utility. Alternatively, the operator may rely only on the observed node reactions (such as contention window doubling as a consequence of collisions) for forcing a fair resource repartition without affecting the node strategy (that is pre-configured by the user and cannot be dynamically updated).

Detection is based on statistical analysis of PHY and MAC parameters, which are calculated using measurements provided by the extended monitoring module. The monitoring module elaborates statistics from PHY and MAC operation and provides them to the MAC parameter calculation module and, finally, after processing, to the information base. All statistics are collected passively without introducing additional traffic in the network.

FLAVIA node PHY and MAC parameter values are analyzed in the Misbehaviour Detection Module (MDM) to detect possible misbehaviour (especially if the network is saturated). Each FLAVIA node should detect misbehaviour based on the PHY and MAC parameter values provided by the extended monitoring module. The MDM module can detect the following types of misbehaviour:

- incorrect setting of EDCA protocol parameters
- incorrect transmission of management frames
- too large TX power settings (above the assumed limit)

Reaction is based on a selected penalty scheme applied by the FLAVIA Access Point. The goal of the penalty schemes is to provide incentives for nodes to behave according to the IEEE 802.11 standard. Among the penalty schemes being considered are selective frame jamming and ACK frame dropping. Both methods reduce the throughput of misbehaving users and be a strong incentive to behave in a standard-compliant way.

In Figure 20 we show an example screenshot from the logging part of the extended monitoring module. The presented log is obtained for a given wireless interface. All PHY and MAC parameters are calculated per each wireless interface operating in a specific radio channel. Every IEEE 802.11 frame (data, management, and control) is captured and analyzed. Moreover, based on a few basic parameters (e.g., supported rates, frame and preamble type, priority of received frame, frame length, Rx power and Rx noise level, timestamp of Rx/Tx fame) several other PHY and MAC layer parameters can be calculated (e.g., number of active nodes in the neighbourhood, Frame Error Rate (FER), per AC and overall uplink delay, L1, L2, and L3 throughput, percentage of channel occupancy, the approximate remaining L1/L2/L3 link capacity). Therefore, the information base and MDM module have a complete view of the stations' activity in the radio channel.

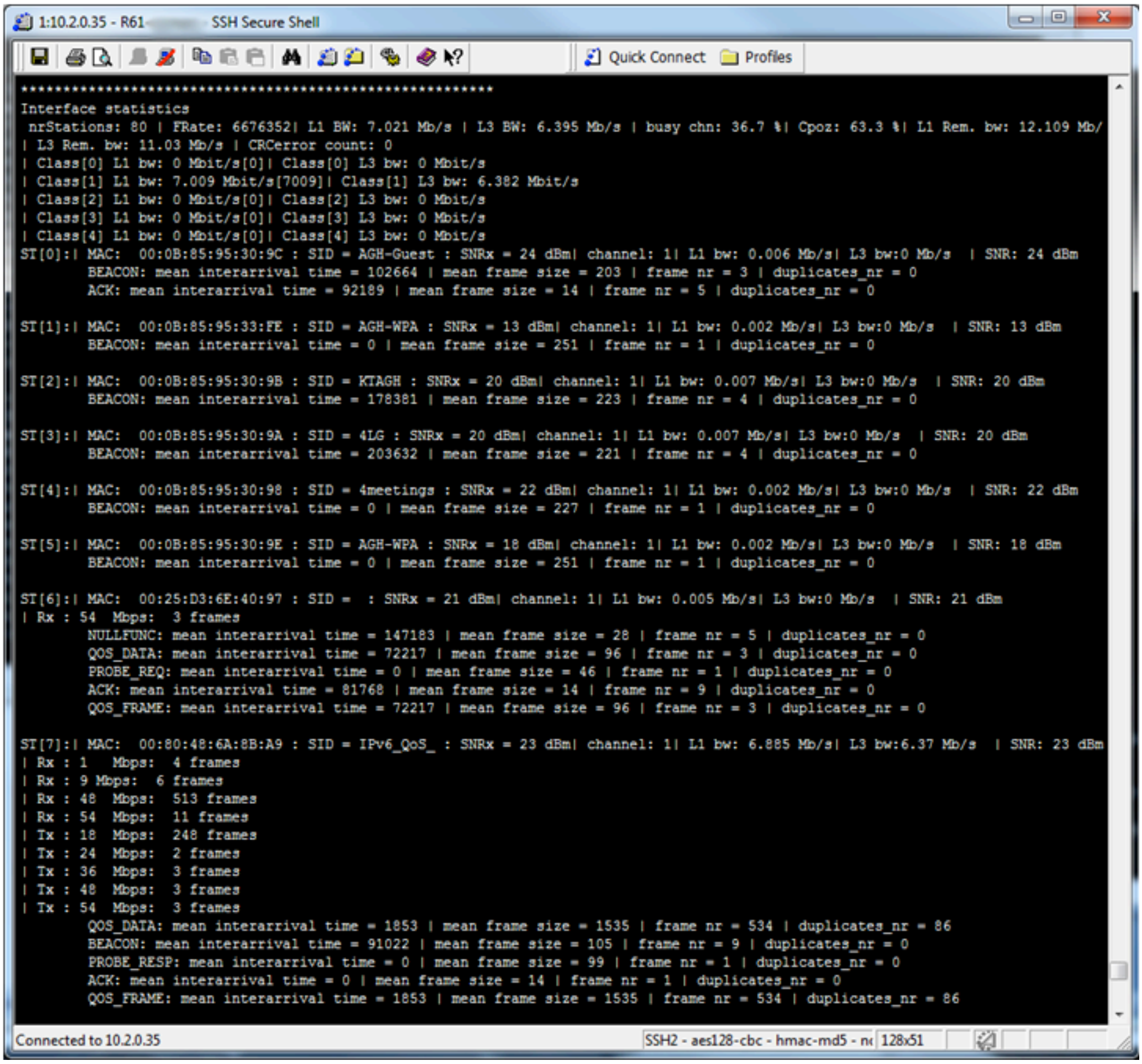


Figure 20: An example screenshot from the logging part of the extended monitoring module.

MDM can be easily configured using a configuration file where we can set the threshold values for maximum number of management and control frames, assumed EDCA parameters, and the maximum Tx power for a specific country. The operation of the MDM module is presented in Figure 21. The screen on the left displays the assumed configuration parameters, while the screens on the right present a real-time analysis of the received data (performed independently for each MAC working in a given radio channel).

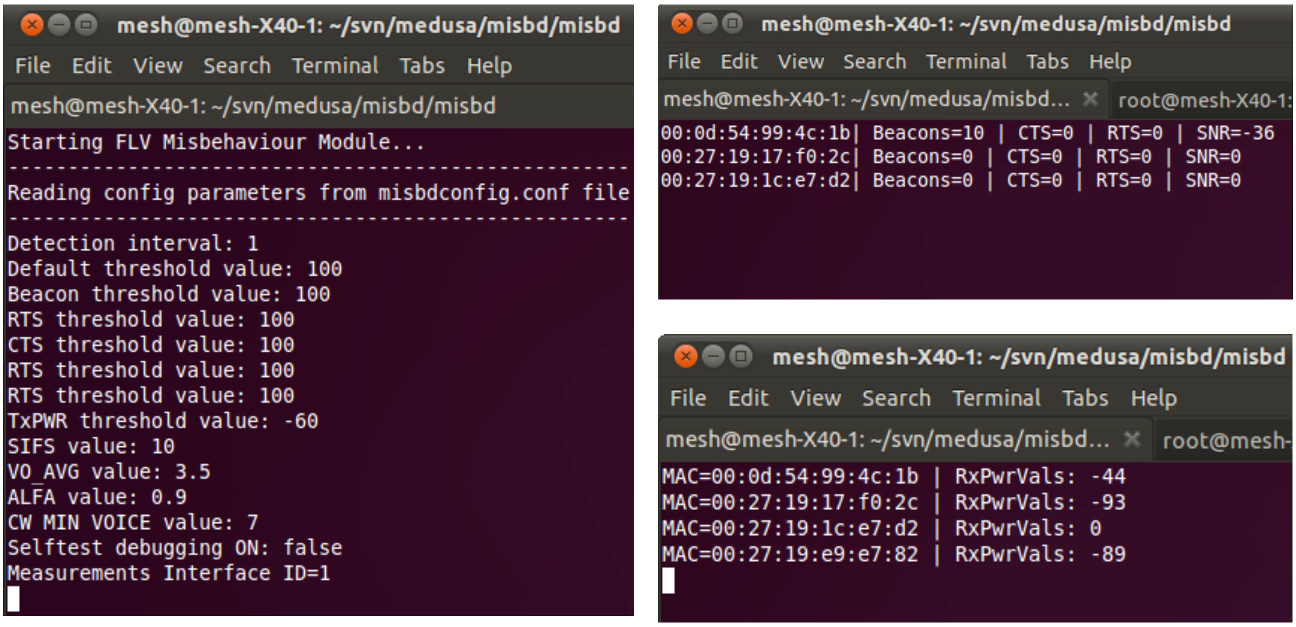


Figure 21: Misbehaviour detection module: configuration part (left) and real-time analysis of data (right)

2.1.3 Flat 3: Virtualization for backhaul bandwidth aggregation

We target the scenario 2.2.3 as described in deliverable D2.1.1 document [2.1.3]:

"*We envision a scenario with a high density of multiple overlapping WLANs connected to broadband backhauls (such as a city neighborhood), in which users are willing to share their spare broadband bandwidths. Users typically see multiple 802.11 gateways in range with high quality. Some access/security mechanisms are in place to prevent unauthorized access*"

In this demonstrator, we propose an improved adaptive rate control algorithm (H-RCA) that will be able to distinguish between collisions and losses due to channel errors, enabling superior performance. As well, an aggregation feature is implemented in the same driver in order to implement bandwidth aggregation for the surrounding AP installed in the neighbouring flats. This is possible thanks to the virtualization of the wireless card and runs on multiple channels, irrespective of the users of the remote access points, in a fair way, as described in Figure 22.

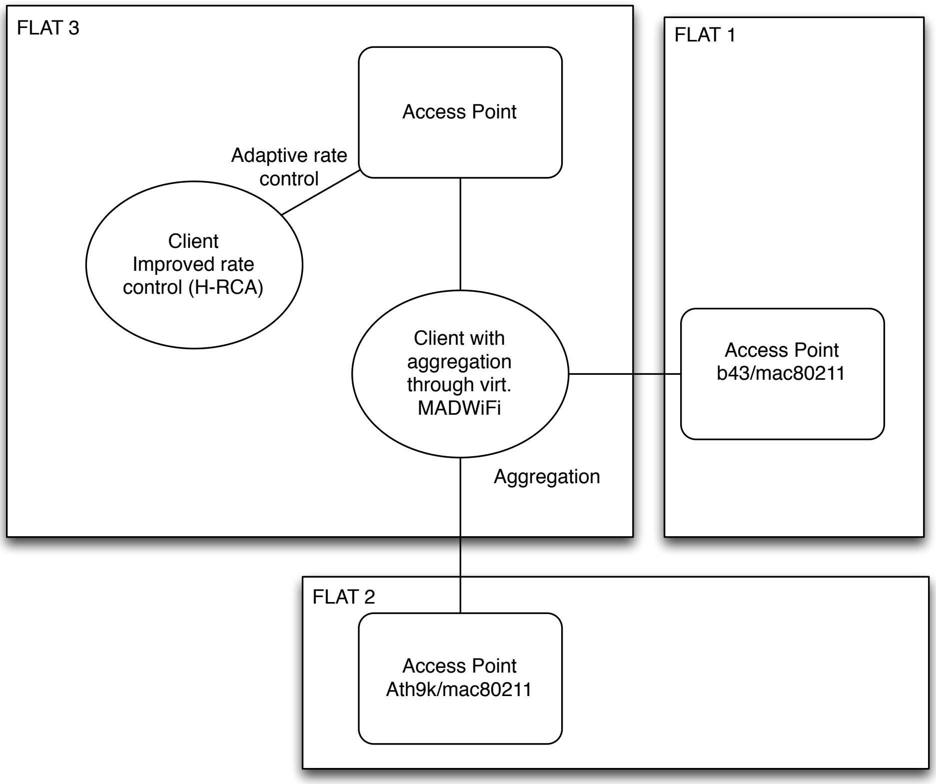


Figure 22: Performance enhancements demonstrator

As a part of this demonstration we will showcase the H-RCA algorithm, which will illustrate FLAVIA's flexibility in incorporating new modules. H-RCA is an adaptive collision-aware wireless rate control methodology that does not require specific hardware support nor any change in IEEE 802.11 standard, thus being implementable on commodity hardware. The key advantage of H-RCA over state-of-the-art rate adaptation scheme is that it does not wrongly interpret frame losses due to collision as poor channel conditions, therefore it will always choose the highest possible modulation rate and achieve important bandwidth gains.

To demonstrate the benefits of H-RCA we will deploy an 802.11 access point and two WiFi clients in close proximity of the AP, thus ensuring good propagation conditions, for which the optimal transmission rate is 54 Mbps with 802.11a/g nodes. To increase the channel competition, we will configure the contention parameters of the clients to small values (e.g. CWmin=CWmax=2), which is possible by propagating the new MAC parameter set through beacon frames from the AP, a feature available in the current standard. In such conditions, we will be able to test H-RCA's robustness to high collision rates and compare its performance to existing rate control schemes, e.g. Minstrel (the default one used with mac80211 drivers).

The demonstration will involve one client uploading a large data file on a server while the second client downloads a file or streams a video. Such an experimental setup is depicted in Figure 23.

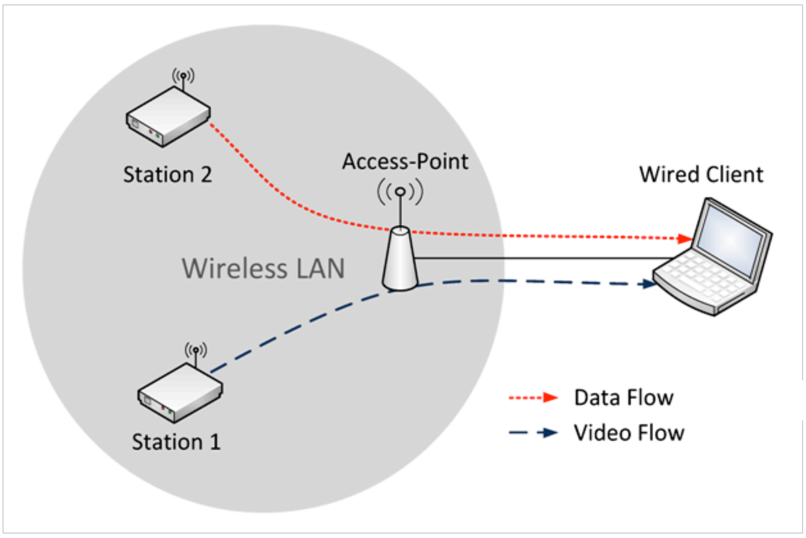
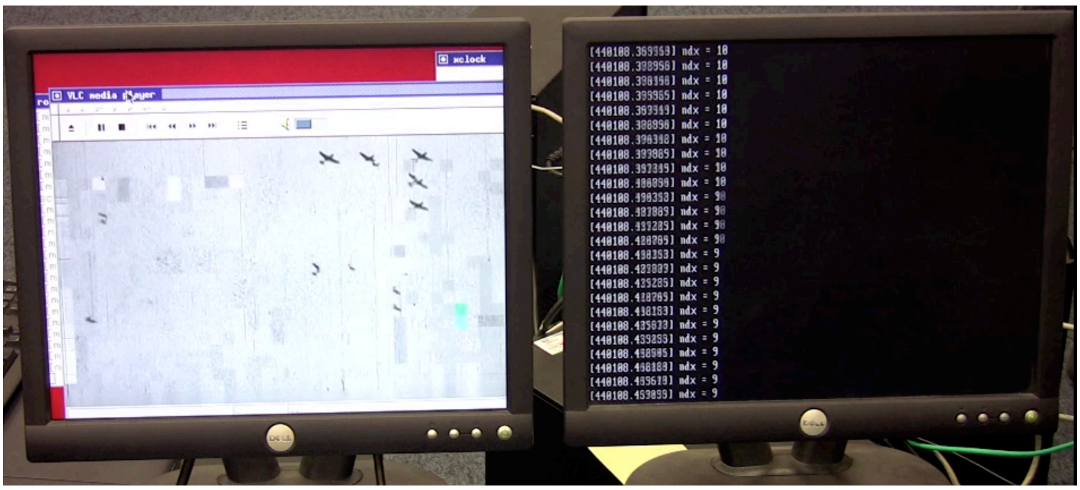


Figure 23: Demo setup for testing rate adaptation

We will assess the H-RCA performance by measuring the file download time, respectively by subjective evaluation of the video playback. Additional, it will be possible to inspect in real time the current rate being employed by a node, and better understand the superior decisions of H-RCA as compared to other mechanism. In Figure 24 we show an example of practical setup used for such visualisation. The screen on the left is used to assess the video quality, while the screen on the right display the log of the rate adaptation decisions, reporting the index of the select modulation scheme. In this exampled we compare the performance of H-RCA with the one attained by the SampleRate algorithm.



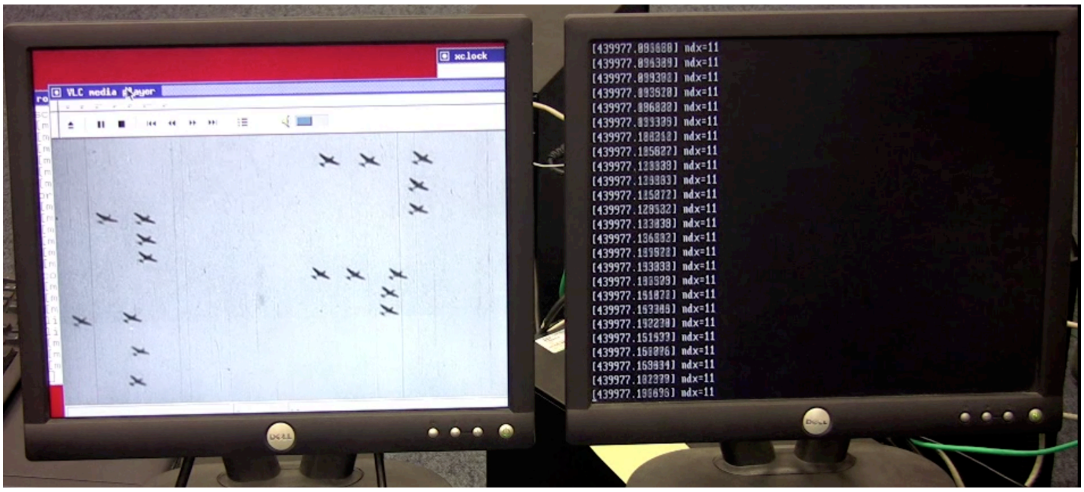


Figure 24: Assessing video quality (left) and rate selection (right) for SampleRate (top) and H-RCA (bottom) rate control algorithms

Apart from the benefit of running an advanced rate adaptation scheme, we complement this with the use of bandwidth-aggregation. In this scheme, a single radio card is virtualized into two logical adapters, which are connecting to different access points, providing bandwidth increase for the final user.

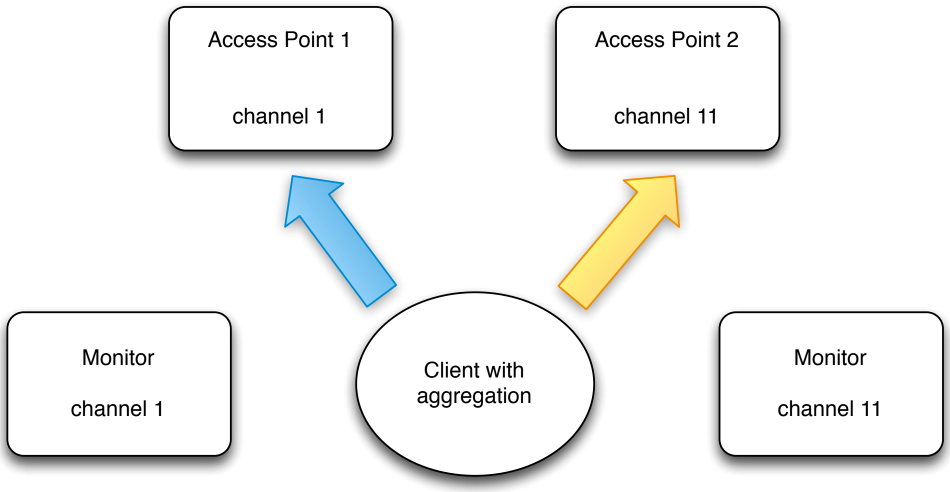


Figure 25: Aggregation component of the demonstrator.

To evaluate and demonstrate this, we will provide a prototype that will connect to the local home access point, as well as to a remote one simultaneously, and using a graphical monitoring tool to demonstrate the dynamic aggregation of the bandwidth. Monitoring software will also be provided to assert the behavior from a channel point of view.

2.2 Requirements

For the demos envisioned at the section 2.1, we have established the following requirements:

Name	Type	Description	Usage
2 Access points featuring broadcom b43 chipset	Hardware	Access point use for offering Internet access to the Flat 1 and flat 3 (through aggregation)	Demos 2.1.1 and 2.1.3
2 Broadcom-based. B43 compatible wireless cards for 2 different computer	Hardware	Hardware that natively support the instance of the wireless processor	Demo 2.1.1
2 laptops running linux with specific patch against b43 support	Hardware and software	Equipment to run the wireless process instance.	Demo 2.1.1
USRP	Hardware	SDR device use for diagnosis purpose	Demo 2.1.1
Ath9k-based wireless cards for 3 different computers	Hardware	Use for client, mesh and detection purpose	Demo 2.1.2, 2.1.3
3 laptops x86 running Ubuntu 11.10	Hardware and software	To run the different daemon and endorse the different role (AP, client,	Demos 2.1.2, 2.1.3
Ath5k-based wireless cards for 2 different computers	Hardware	Equipment to run the rate adaptation and bandwidth aggregation	Demo 2.1.3
2 laptop x86 running Ubuntu 8.04	Hardware and Software	Equipment to run the demos in different environments.	Demo 2.1.3

2.3 Planning

M17	M18	M19	M20	M21	M22	M23	M24	M25	M26
Dynamic reconfiguration									
Design		Implementation				1st Demo			
Self-configuration, performance and misbehaviour monitoring									
Design		Implementation							
Performance enfancements									
Design		Implementation							

M27	M28	M29	M30	M31	M32	M33	M34	M35	M36
Dynamic reconfiguration									
					Integration/Tests				final demo
Self-configuration, performance and misbehaviour monitoring									
					Integration/Tests				Final demo
Performance enfancements									
					Integration/Tests				Final demo

We will present an early demo of the dynamic reconfiguration demonstrator during M23, followed by continuing development on the other demonstrators.

3 Conclusions

In this deliverable we have introduced the different demonstrators that aim to represent the technology developed within FLAVIA. We used the context of delivering Internet services from the backbone to the home, as well as within the home as a example on how FLAVIA technologies might impact current deployments.
We will deliver early demos of the demonstrators (Dynamic scheduler, measurement framework, for scheduled system and recent advances on the wireless MAC processor) in order to demonstrate the advance in the development, as well as give a glimpse of the final full features demonstrators delivered at the end of the projects.

4 References

[1.1.1] FLAVIA, D2.1.1, Scenario 1.1.1: Multicarrier & load balancing strategies, p.14
[1.1.2] FLAVIA, D2.1.1, Scenario 1.1.5: Parameter reconfigurability from application layer, p.19
[1.1.3] FLAVIA, D2.1.1, Scenario 1.2.1: Network Nodes Resources Virtualization, p.21
[2.1.1a] FLAVIA, D2.1.1, Scenario 2.3.2: Infrastructure-less and Infrastructure-independent Mesh for emergency services, p.36
[2.1.1b] FLAVIA D2.1.1, Scenario 2.3.3: Video support in 802.11-based mesh networks, p.37
[2.1.1c] FLAVIA D2.1.1, Scenario 2.3.4: Distributed Allocations in MESH networks, p.38
[2.1.2a] FLAVIA D2.1.1, Scenario 2.1.5: Network Analysis and Monitoring, p.27
[2.1.2b] FLAVIA D2.1.1, Scenario 2.1.2: Punishment mechanisms for misbehaving nodes, p.25
[2.1.2c] Heusse M, Rousseau F, Berger Sabatel G, Duda A. *Performance anomaly of IEEE 802.11b*. in Proceedings of INFOCOM 2003.
[2.1.2d] WiFi Direct – WiFi Alliance - http://www.wi-fi.org/discover-and-learn/wi-fi-direct
[2.1.3] FLAVIA D2.1.1, Scenario 2.2.3: Backhaul bandwidth aggregation, p.31