

Specific Targeted REsearch Project

FLAVIA ***FLexible Architecture for Virtualizable wireless future*** ***Internet Access***

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D 7.2 Stack customization and multi-channel trials

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1.0 (FINAL DRAFT)	17/06/2013	MC Brugnoli, G. Bianchi	CNIT	Final review and editing

NOTE: The document will be updated with some screenshots and pictures regarding the on-site results extracted from the prototypes.

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Executive summary

This reports aims to present the plan to evaluate the different prototypes developed within FLAVIA. The purpose of these scenarios is to replace the technology within arealistic context we have defined in D7.1 - a backhaul deployment, followed by a distribution of the bandwidth in a home context.

We designed and developed the following prototypes across this context.

Regarding backhaul deployment:

- Cell selection by MS, for management purpose;
- Measurement framework for LTE, for monitoring and quality guarantee purpose;
- RAN Sharing / Virtual Operators, for improving efficiency;
- Dynamic Scheduling Strategy, for flexibility;
- Video prioritization, for service delivery;

Regarding bandwidth distribution in the home context:

- Bandwidth aggregation and rate adaptation techniques, as well as topology control for illustrating how legacy 802.11 paved the way to programmability;
- Direct Link Setup and programmability to understand the benefits of FLAVIA architecture on fully reprogrammable hardware;
- Controlling this programmability by introducing monitoring.

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Introduction

In the previous deliverable, we have introduced the context we have placed the prototyping activities of the FLAVIA project. Mainly, the purpose was to see how carriers, virtual operators, carriers, users could enable new usages and new business models to be enabled in the wireless connectivity space, in the same fashion as MVNO have modified the cellular networks.

Therefore, we have designed these prototypes to be the illustration of the path taken, and this will also be reflected during the actual presentation of these prototypes.

In order to illustrate this path, we will start by the home environment use cases; here, we have explored with two prototypes the capabilities of the contention-based technologies to deliver more. One of these prototypes is actually the base of an ongoing tech-transfer that we have reported in WP8 activities. With this positive *technological feedback*, we have pushed forward the prototyping of FLAVIA concepts to a full re-programmability level, by introducing several examples around the wireless MAC processor hardware. We complete then this re-programmability aspect by underlying the potential danger of such approach, and solving it introducing another prototype focused on security against misbehaving.

We proceed with a similar approach on scheduled-based systems. We evaluate consecutively Cell selection, RAN sharing for offering operator virtualization, dynamic scheduling for service differentiation, as well as video prioritization for delivery of content, and completed by monitoring via measurement framework.

For the contextualization, we reuse throughout this document the same "home" deployment, with the 3 flats equipped with FLAVIA prototypes, and provided by bandwidth via the backhaul technologies powered by FLAVIA prototypes.

A global coverage map of the prototype is provided in Figure 1.

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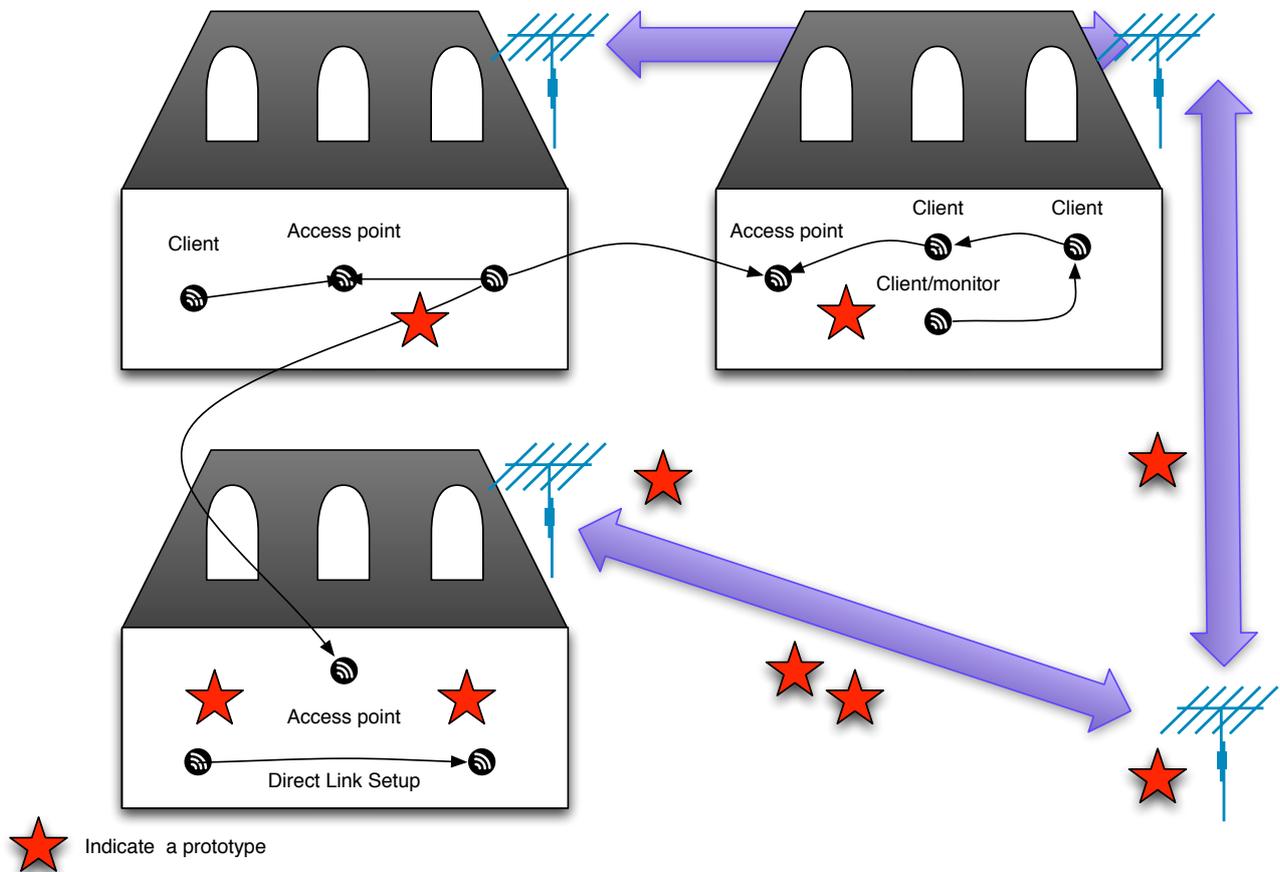


Figure 1: the coverage of the different prototypes, shared between contention and scheduled based technologies.

For each prototype, we replace quickly the context and the situation, as well as the proceedings of the demonstration.



1 Contention technology at home: from Wi-Fi to full network re-programmability

For these trials, we place ourselves within the home, with adjacent flats exposing contention-based wireless networks, and equipped with wireless devices. We explore the dynamic in three steps: one, review of the Wi-Fi/802.11 improvements brought by FLAVIA technologies. Then, we introduce a generalization through the use of the wireless MAC processor. Finally, we exhibit a case where re-programmability is used to misbehave, and where FLAVIA brought solutions.

1.1 From bandwidth increase to dynamic topology: pushing 802.11 to the limit

These two trials have the following goal: evaluate the capability of augmentation of 802.11 protocols, in order to bring 1) more bandwidth 2) more flexibility regarding critical topologies at home.

1.1.1 TRIAL1: Bandwidth aggregation and better rate management

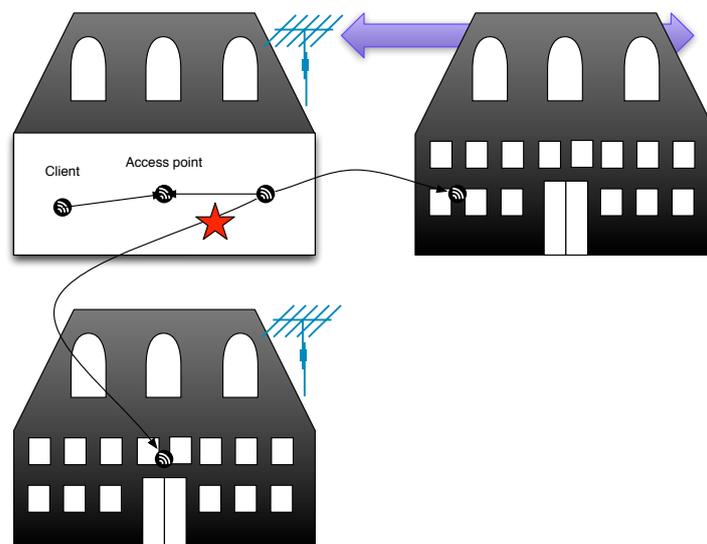


Figure 2: Trial 1 situation.

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Situation: a mobile user on his laptop is using the full capacity of its Internet access and he is experiencing issue with different flow. FLAVIA technologies are then enabled in order to deliver superior bandwidth capacity, by virtualization and by rate management.

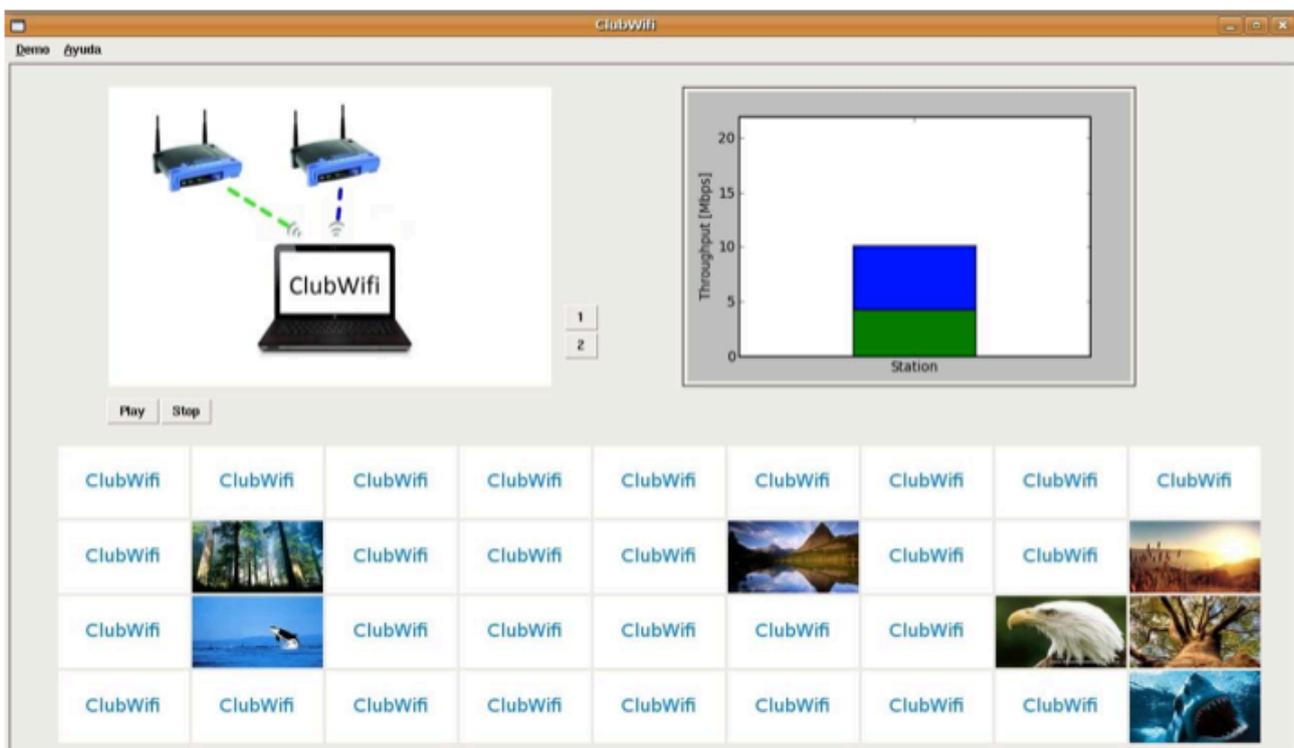


Figure 3: automated tools for repetitive bandwidth aggregation trial.

Methodology: a python program is designed to automatically configure the wireless interface to support virtualization, connect to two access points, and then perform random images downloads to demonstrate bandwidth augmentation. Rate adaptation is demonstrated by transferring different content on the Internet.

Evaluation: Bandwidth measurements are conducted in order to quantify the bandwidth improvement. Debugging tools are also used to illustrate and assess the multichannel capabilities.



1.1.2 TRIAL2: Dynamic topology and power efficiency

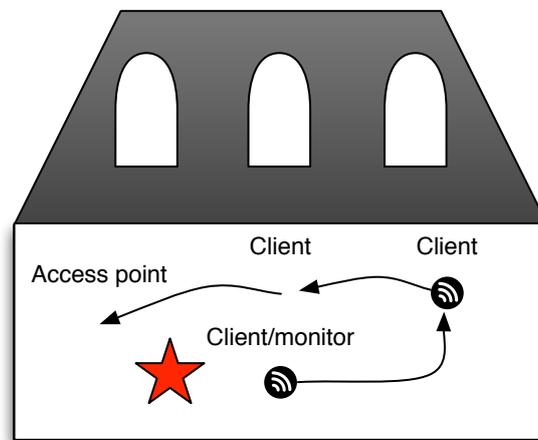


Figure 4: Trial 2, situation.

1.1.2.1 SOLOR

Introduction

Current IEEE 802.11 WLANs suffer from the well-known rate anomaly problem, which can drastically reduce the network performance. Opportunistic relaying can address this problem.

SOLOR optimizes the topology of the network, i.e., which are the nodes associated to each relay-capable node; and the relay schedules, i.e., how the relays split time between the downstream nodes they relay for and the upstream flow to an access point.

Prototype

SOLOR requires the FLAVIA Power Saving (PS) Service to support three main functionalities:

- 1) Interface SOLOR optimizer – SuperSense. To analyse the WLAN deployment and compute the optimal configuration of the network, i.e. topology and schedules.
- 2) Scheduler and synchronization: To implement the resulting relay schedules, time share timers between the AP link and the relayed user; and keep the multiple relays coordinated and synchronized.
- 3) NoA: To implement Notice of Absence protocol and the algorithm so that



relays advertise its clients when they are going to be absent (e.g. because they are transmitting to the AP or sleeping) and, thus, they can go to sleep.

- 4) Association handler: To force legacy nodes to connect to the proper relay-capable node.

In the left part of Figure 5 it is shown the PS Service implementation within the FLAVIA architecture as explained in D4.2 **Errore. L'origine riferimento non è stata trovata.**, and in the right part of Figure 5 it is presented a closer view to the SOLOR prototype.

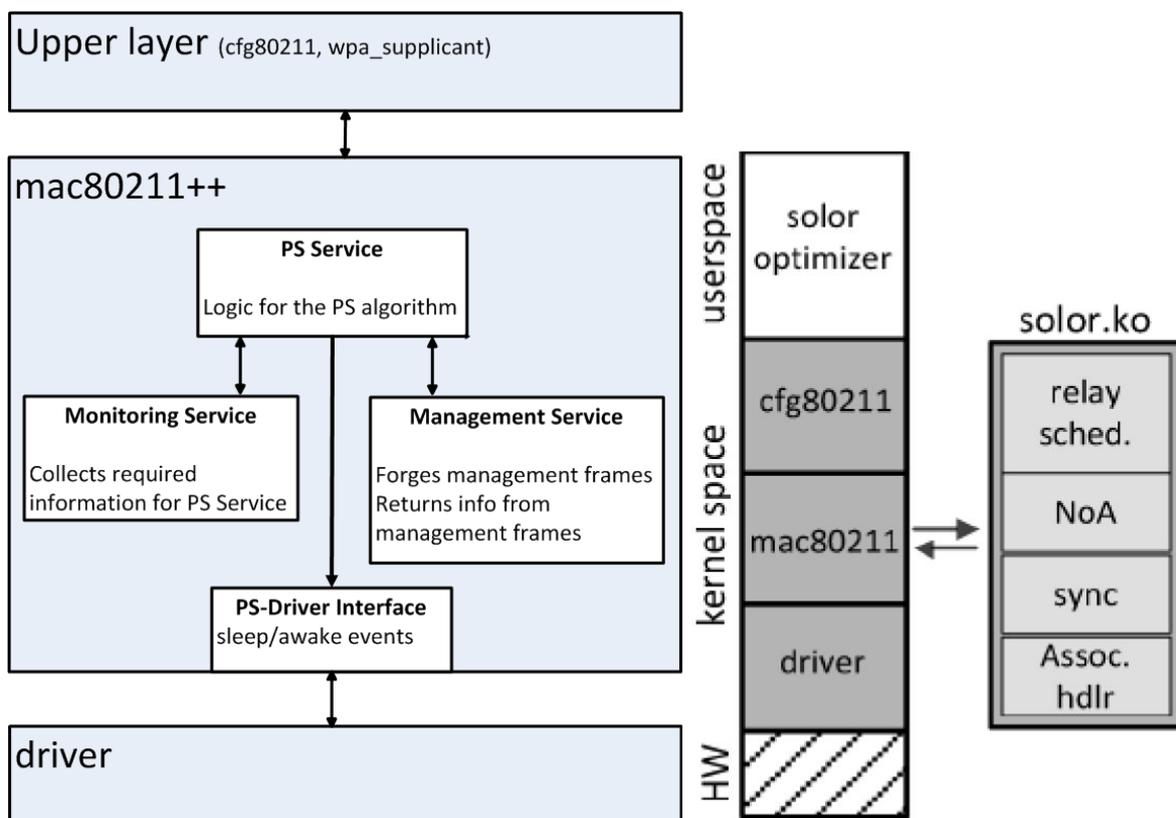


Figure 5: SOLOR implementation within the FLAVIA architecture

Considerations for the demo

SOLOR operates in nodes (relays) with a single physical interface, i.e. the interface has to split its time between serving its client (relayed) and transmitting to the AP. The time share values are computed after solving an



optimization problem. However, due to implementation issues, it is currently not supported that two virtual interfaces over the same physical operate over two different channels. Due to this, the prototype for the demo will have two virtual interfaces operating over two different physical interfaces to allow for this. Note that the two physical interfaces will never be activated at the same time, mimicking in this way the behavior of a single physical interface.

1.1.2.2 SUPERSENSE

Introduction

The estimation of the quality and the reliability of wireless links represents a challenging task in wireless multi-hop networks. Indeed, the cross traffic may affect the estimation procedure, that in turns may cause route flapping (i.e., the instability of the routing protocol).

The SuPerSense (SPS) service mitigates the instability of the link quality estimation in heavy load traffic conditions, implementing a time coordinated probing mechanism (i.e., a TDMA-like probing scheme) that mitigates the effect caused by the self-interference within a wireless multi-hop network.

Prototype

SuPerSense (SPS) service requires the following functionalities and services:

- 1) Service Scheduler and Synchronization: to schedule the periodic transmission of the probes used for the link quality estimation according to a contention free access mechanism (TDMA-like).
- 2) Signaling Protocol: to broadcast the information directly estimated and collected from the neighbors

Considerations for the demo

SPS can operate on devices with single or multiple physical interfaces tuned on different wireless channels. The synchronization is obtained exploiting the Time Synchronization Function implemented by the underlying driver.

All nodes switch their operating mode according to the following rule:



$$T_{SPS} = s \cdot 2^e$$

$$T_{MON} = s \cdot m$$

$$T_{TX} = T_{SPS} - T_{MON}$$

$$T_{TSF} \bmod T_{SPS} = 0 \rightarrow \text{monitoring}$$

Equation 1

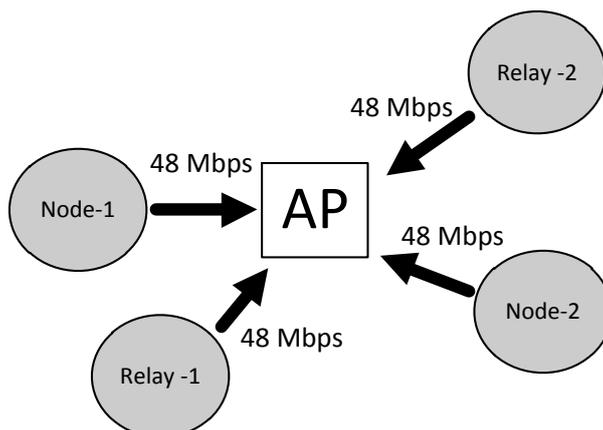
In this equation, s is the slot time representing the minimum time granularity with which the SPS service operates, e and m are the exponent and the number of slots used to compute the duration of the entire Super-frame and the time length of the active monitoring period, respectively. The Super-frame duration can be computed simply left shifting the slot duration of a number of bits equal to e , while the time spent in active monitoring mode can be easily computed through a multiplication. Both these operations can be easily implemented in hardware, and thus they can be supported by the wireless processor.

2 Script

1) Initial scenario:

- 2 relay-capable nodes (desktop pcs)
- 2 legacy WiFi nodes (laptops)
- All connected to the same AP (laptop), with good quality link.

- Topology



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- Per-node performance

Node	Throughput	Interface Power consumption (estimation)
Node-1	6.3 Mbps	0.69 Watts
Node-2	6.3 Mbps	0.69 Watts
Relay-1	6.3 Mbps	0.69 Watts
Relay-2	6.3 Mbps	0.69 Watts
Total	25.2 Mbps	2.76 Watts
Efficiency (bits/joule)		9.13 Mbpj

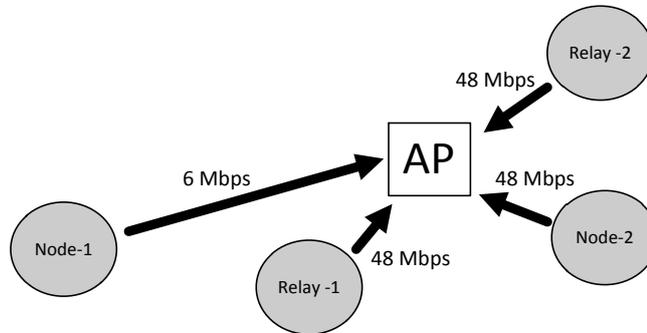
- Quality of all links of the network

Each node displays the weighted directed graph that represents the network topology. For each wireless link, the node will use as link cost the expected number of transmissions necessary to successfully deliver a data frame, which depends on the frame error probability. We will further show that the estimation of the link quality is not affected by the data traffic transmitted by all nodes, and thus by the high contention high of the channel.



2) Node-1 moves (or its link becomes a bad quality link)

- Topology



- Per-node performance

Node	Throughput	Interface Power consumption (estimation)
Node-1	3.1 Mbps	1.28 Watts
Node-2	3.1 Mbps	0.6 Watts
Relay-1	3.1 Mbps	0.6 Watts
Relay-2	3.1 Mbps	0.6 Watts
Total	12.4 Mbps	3.08
Efficiency		4.02 Mbpj

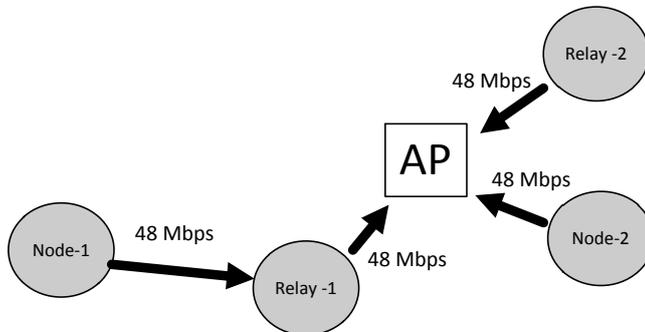
- Increasing frame error rate (increasing cost) of the link connecting Node-1 to AP

Each node displays the weighted directed graph that represents the network topology. In particular, Node-1 will experience a high frame error rate that, in turn, will result in a higher cost of the link established with the AP.



3) Relay-1 capabilities are activated

- Topology



- Per-node performance

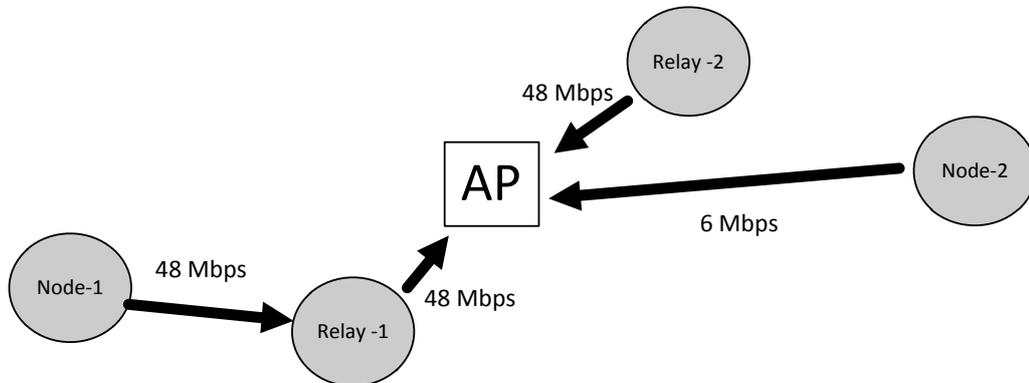
Node	Throughput	Interface Power consumption (estimation)
Node-1	3.52 Mbps	0.17 Watts
Node-2	8.8 Mbps	1.55 Watts
Relay-1	3.76 Mbps	0.76 Watts
Relay-2	8.8 Mbps	1.55 Watts
Total	24.9 Mbps	4.03 Watts
Efficiency		6.17 Mbpj

- Detection of the cheapest path
 Node-1 will detect and select the cheapest path passing through Relay-1 to reach the AP.



4) Node-2 moves (or its link becomes a bad quality link)

- Topology



- Per-node performance

Node	Throughput	Interface Power consumption (estimation)
Node-1	1.63 Mbps	0.08 Watts
Node-2	3.64 Mbps	1.76 Watts
Relay-1	1.76 Mbps	0.62 Watts
Relay-2	3.64 Mbps	0.60 Watts
Total	10.67 Mbps	3.06 Watts
Efficiency		2.65 Mbpj

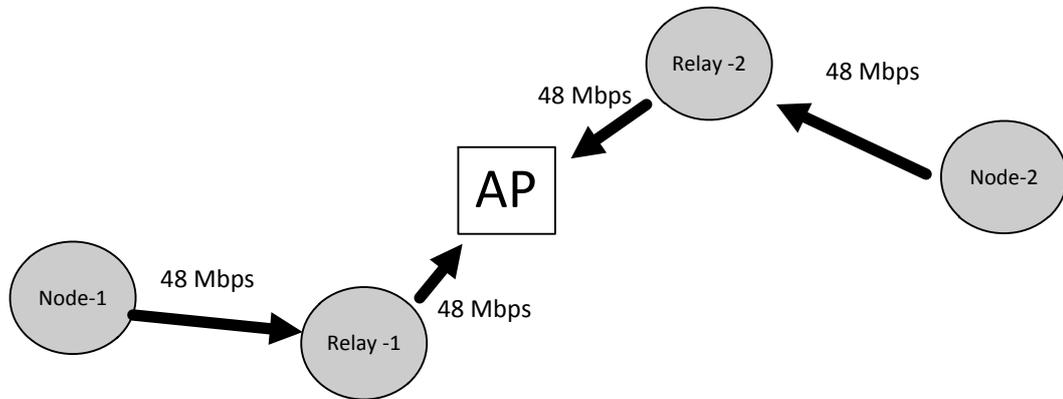
- Increasing frame error rate (increasing cost) of the link connecting Node-2 to AP

Each node displays the weighted directed graph that represents the network topology. In particular, Node-2 will experience a high frame error rate that, in turn, will result in a higher cost of the link established with the AP.



5) Relay-2 capabilities are activated

- Topology



- Per-node performance

Node	Throughput	Interface Power consumption (estimation)
Node-1	7.31 Mbps	0.35 Watts
Node-2	7.31 Mbps	0.35 Watts
Relay-1	7.31 Mbps	0.91 Watts
Relay-2	7.31 Mbps	0.91 Watts
Total	29.2 Mbps	2.52 Watts
Efficiency		11.59 Mbpj

- Detection of the cheapest path
 Node-2 will detect and select the cheapest path passing through Relay-2 to reach the AP.

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In the Direct link demo two stations exchange packets directly as in ad-hoc mode (without using the AP as a relay) while keeping the association to the AP. The channel and the access mode used for the direct link can be managed in a completely independent manner, i.e. the channel can be different from the AP one and the backoff rule can be changed.

In the virtualization demo the Access point reserves a timeframe for different groups of stations using customized medium access schemes. In this test bed are there two access schemes: **TDM** access scheme and **DCF** access scheme.

Methodology:

For both the demos, there is a *demo-manager* script, called **demo-flavia-wmap.sh**, able to apply the desired configurations and interaction commands. A README file provides a full description of `./demo-flavia-wmp.sh` script functionalities and parameters.

Two other scripts are available for debug purposes: **test**, that run a periodic ping of all the stations for verifying the association state, and **view-logs** that visualizes the log (locally stored in the `/log` directory) of the iperf sessions running in each node.

Evaluation:

Direct Link demo:

The scenario configuration involves:

1. the selection of the DL channel (the AP one or a different one)
2. the selection of the DL backoff rules
3. the selection of two over three stations involved in the DL (by means of the **hostname**)



Direct Link

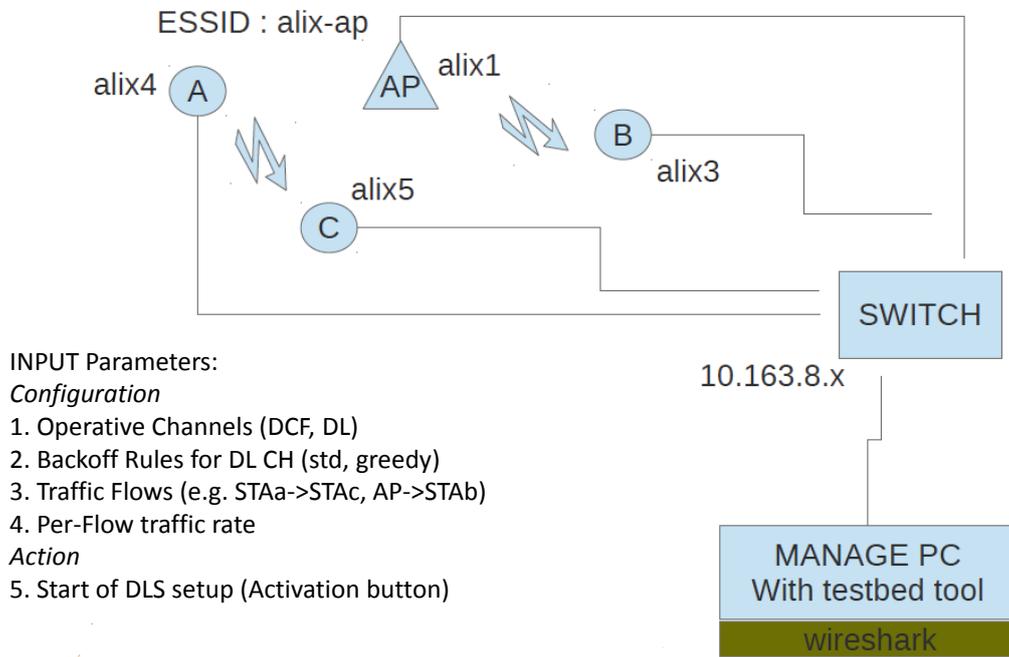
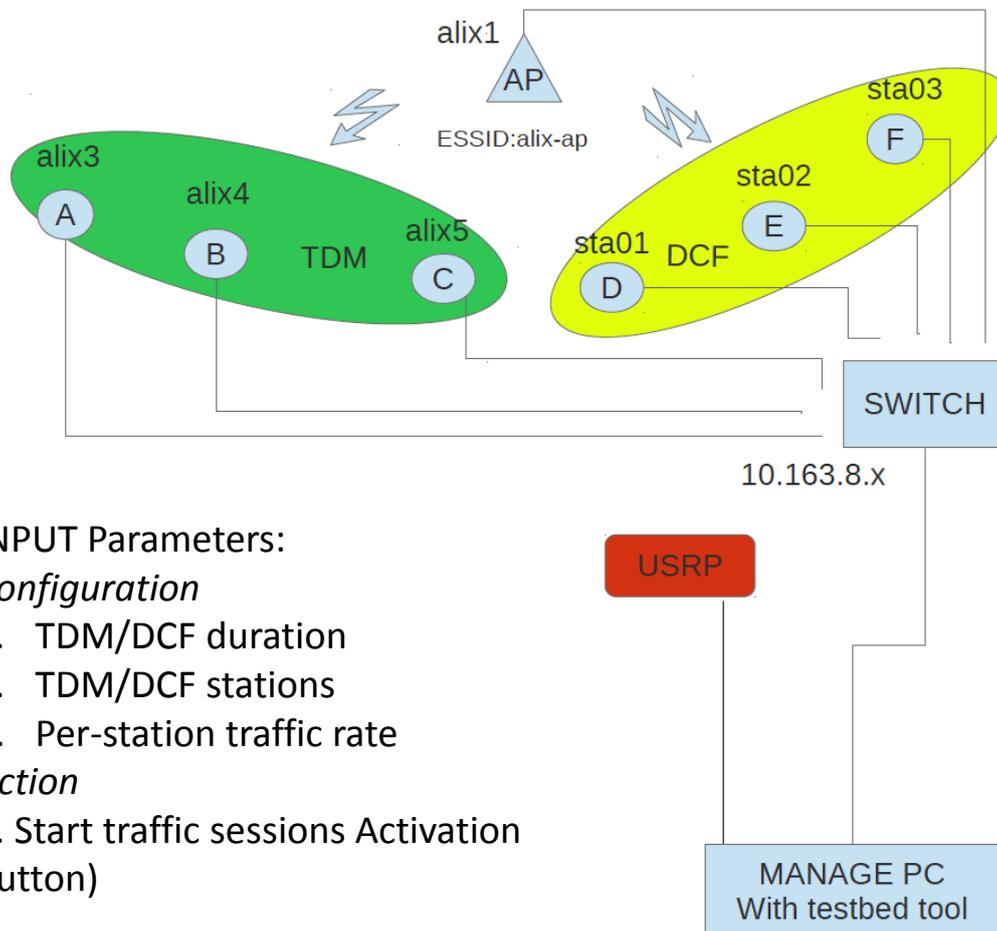


Figure 7: Direct Link prototype.



Virtualization



INPUT Parameters:

Configuration

1. TDM/DCF duration
2. TDM/DCF stations
3. Per-station traffic rate

Action

5. Start traffic sessions Activation button)

Figure 8: Virtualization prototype using wireless MAC processor.

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Virtualization demo:

The scenario configuration involves:

1. The time interval for each group of stations within the beacon interval
2. The list of stations belonging to each group
3. The traffic rate of each group of stations

The most important common parameters for the script `./demo-flavia-wmp.sh` are, **start-iperf** and **stop-iperf**. These parameters switch on and off the iperf sessions according to a configuration file that specifies which nodes are involved in the traffic flows and at which rate.

For Iperf setup the script must be executed in this way:

```
./demo-flavia-wmap.sh start-iperf<iperf_conf_file>
```

NOTE: if we need to stop all iperf session of a previous experiment use the command:

```
./demo-flavia-wmap.sh stop-iperf
```

The iperf configuration file has the following structure:

```
client server duration(s) update-interval(s) bandwidth(kbit) port packet-length(byte)
```

Here there is an example of configuration file for iperf:

```
sta01      alix1 5000      2      3000      44450      1470
sta02 alix1 5000      2      3000      44451      1470
sta03 alix1 5000      2      3000      44452      1470
alix3 alix1 5000      2      3000      44453      1470
alix4 alix1 5000      2      3000      44454      1470
alix5 alix1 5000      2      3000      44455      1470
```

In this example the first row create a iperf session with sta01 like client, alix1 as server, 50000 seconds of duration, 2 seconds of logging interval, 3000Kbits of source rate, 44450 is the port for the UDP protocol, and at the end 1470 is the dimension in byte for the UDP packet.

The same procedure will be used for both demos to replicate real traffic characteristics.

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2.2 Monitoring: bringing security to re-programmability

Following the last trial that demonstrated the power of re-programmability, this trial is designed to assess the capability of controlling the behavior of reprogrammed entities.

2.2.1 TRIAL4: Monitoring to defeat misbehaving

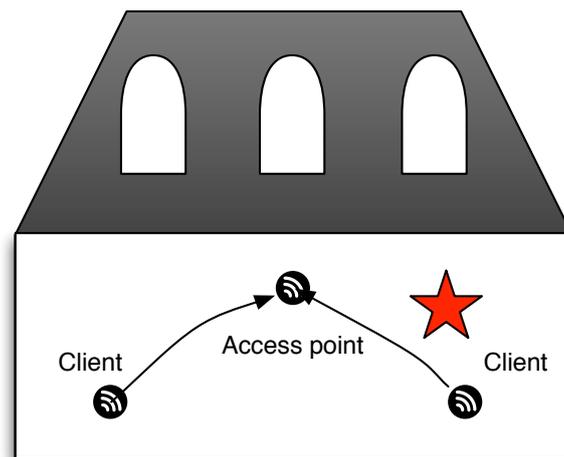


Figure 9: Trial4 : Monitoring.

Situation: « an operator is providing basic Internet access, a misbehaving node tries to obtain more bandwidth by modifying standard MAC or PHY parameters or disrupt the network operation by flooding management frames »

Methodology:

The nodes involved into the demo are:
ACCESS POINT: AP1 (Soekris net5501)
STATIONS(2):sta01 , sta02 (Soekris net 5501)

At the startup all the stations are automatically connected with the access point (Figure 10) stations have a wpa_supplicant daemon that permits to run and keep the associations in the considered scenario. On the AP, the hostapd daemon and the monitoring and misbehavior detection modules are activated.

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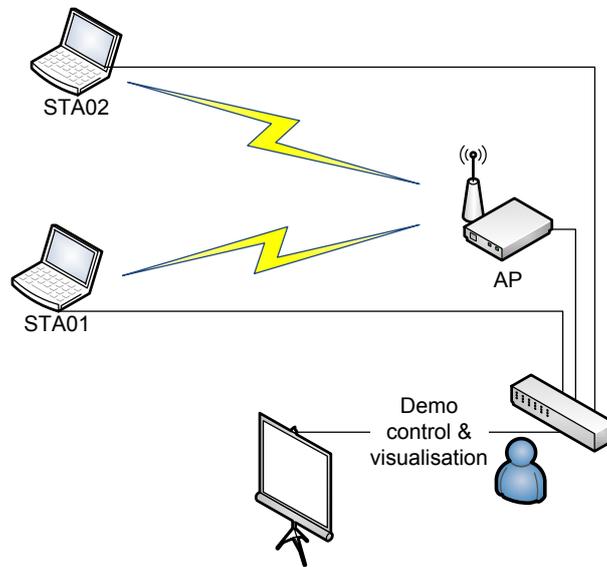


Figure 10: Setup for monitoring purposes.

Evaluation: For traffic generation iperf is used. The iperf output is one of the metrics of the testbed scenario, which should show fairness of network resources sharing in IEEE 802.11.



3 Delivery and enabling: new paradigms in scheduled-based systems.

In this section, we bring the attention to the advance provided to FLAVIA to scheduled-based systems.

3.1 TRIAL5: Cell selection by MS

Situation: The purpose of this algorithm is to allow the operator to decide which terminal will be connected to which base station.

Methodology:

Cell selection Algorithm essentials:

- Uses measurements provided by Sequans framework
- The MS is configured to select the best BS or the best from a preferred list.
 - In case of best BS selection the MS will scan the frequency list configured and will select the best SNR BS.
 - In case of Best from a preferred list the MS will scan the frequency list configured and will select the best complying with the preferred list configured. It should not be the best BS found.

Evaluation: Based on the output of the equipment, the criteria will be based on the frequency, SNR, RSSI and bandwidth as showed on Figure 11.

BS ID	Rx Frequency (KHz)	SNR(dB)	RSSI (dBm)	Bandwidth	Status
0.0.2.0.33.1	5500000	32.29	-63.09	10MHz	operational
0.0.2.0.34.2	5480000	22.02	-83.02	10MHz	-

Figure 11: Selection criteria for BS



Frequency Scanning Parameters

Start Rx Frequency(KHz)	<input type="text" value="5470000"/>
End Rx Frequency(KHz)	<input type="text" value="5520000"/>
Scanning Main Step(MHz)	<input type="text" value="5"/>
Scanning Intermediate Steps (KHz)	<input checked="" type="checkbox"/> B0 Start freq scan <input type="checkbox"/> B1 125KHz <input type="checkbox"/> B2 250KHz <input type="checkbox"/> B3 375KHz <input type="checkbox"/> B4 500KHz <input type="checkbox"/> B5 625KHz <input type="checkbox"/> B6 750KHz <input type="checkbox"/> B7 1250KHz
Bandwidth(MHz)	<input type="text" value="10MHz"/>
	<input type="button" value="Apply"/>

Figure 12: Parameters for selection of base station.



3.2 TRIAL6: Measurement framework for LTE

Situation: In this trial, a flexible architecture that supports easy access of measurement from a 4G USB dongle is presented.



Figure 13: USB Dongle use to perform measurements.

Methodology: A companion application has been designed to provide debug and monitoring. It enables running traces, and recovers data for getting measurements and enable RRM (to enable feedback information for improving video transmission, for example).

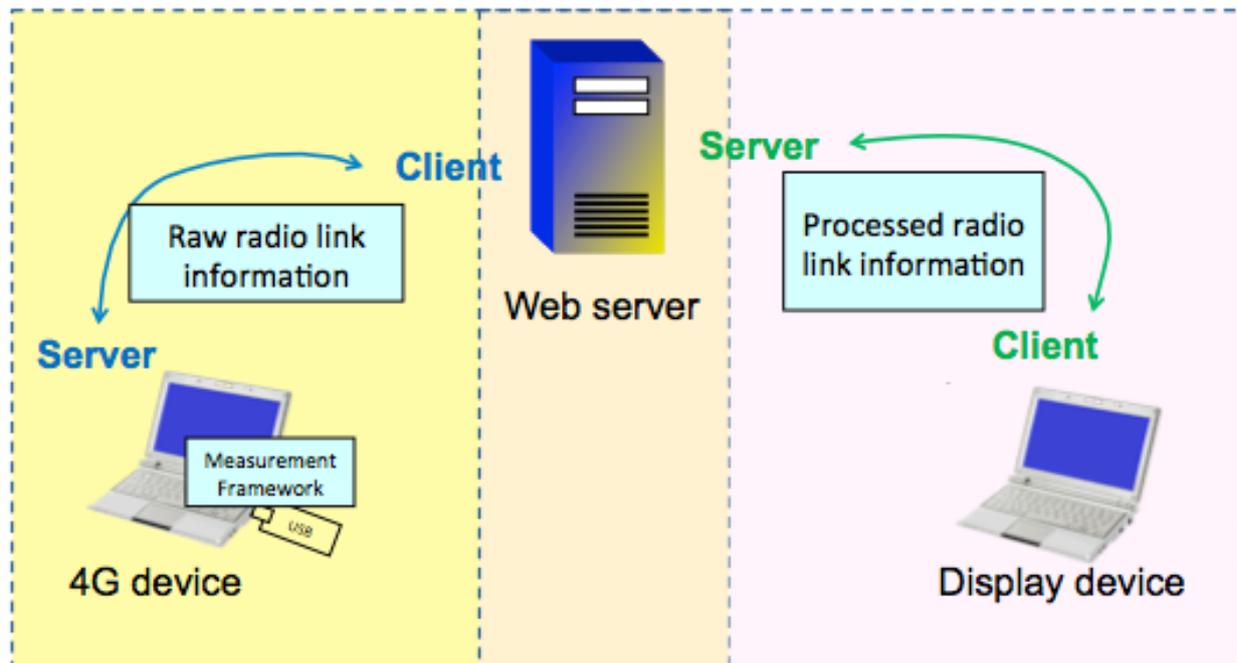


Figure 14 : Client/server communication for measurement collection.

Evaluation: Based on the output of the equipment, the criteria will be based on the following metrics : RSRP per antenna, C/I per antenna, PER, MCS, CQI, Throughput.



3.3 TRIAL7: RAN Sharing/Virtual Operators

Situation: In this prototype, the support of virtual operator is demonstrated. The target is to show the capability of virtualization of infrastructure for Virtual Operators that share the RAN, Shows the flexibility of the system, which is able to support the traffic of different telecommunication operators with different Service Level Agreement and Key Performance Indicators.

Methodology:

This proof of concept is based on pre-signed agreements:

- the RAN owner signs agreements with Virtual Operators and configures its RAN accordingly via NMS & AAA
- each Virtual Operator will be served with different Service Profiles
- One Virtual Operator per Fully-Qualified Domain Name
- A Virtual Operator would be able to support: pre-paid, post-paid, flat rates data services (accounting based on time or data volume)

Therefore, a virtual operator Mobile Station that desires to connect will have the following modus operandi:

- Requests to make Network Entry -> the RAN Owner AAA admits it based on its Fully Qualified Domain Name + user + password
- AAA Server notifies it to the ASN GW and this to the BS
- BS services:
 - o MOSU receives the NE request and consults ADMCON
 - o ADMCON estimates available resources based on QOSS and SCHED statistics
 - o MOSU performs the NE in collaboration with Cell Selection
- Connections are created for the MS based on the QoS and Service Profiles agreed between the operators

Evaluation: The evaluation of the good behavior is based on the logging from the CPE side. An example log is provided here after:

```
>>>> 0822.710 s - Scan/Evt - <<<<>>> Connection attempt #2
>>>> 0822.710 s - SPY/Ss - DL SYNCHRONIZATION
>>>> 0822.710 s - Scan/Evt - Connect_BS: waiting bs_connect_status
>>>> 0824.180 s - SPY/Ss - UL ACQUISITION
>>>> 0825.140 s - SPY/Ss - RANGING
```

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```
>>>> 0825.280 s - LIC/Itf - licNotifySfCreation: cid 296, cs 0, mir 0, bidirectional, basic, ,accepted 1
>>>> 0825.280 s - SPY/Sf - bidirectional basic SF add: sfid= 0 cid= 296 bcid=296 said=65535
state=active
>>>> 0825.290 s - LIC/Itf - licNotifySfCreation: cid 1320, cs 0, mir 0, bidirectional, primary,, accepted 1
>>>> 0825.290 s - SPY/Sf - bidirectional primary SF add: sfid= 0 cid=1320 bcid=296 said=65535
state=active
>>>> 0825.300 s - SPY/Ss - CAPABILITIES NEGOTIATION
>>>> 0825.360 s - SPY/Ss - AUTHORIZATION
>>>> 0825.360 s - SPY/Ss - REGISTRATION
@@@ START DHCP @@@ - appsDhcpTaskStart
>>>> 0825.450 s - SPY/Sf - CID update : old cid=296 -> new cid=296
>>>> 0825.450 s - SPY/Sf - CID update : old cid=1320 -> new cid=1320
>>>> 0825.450 s - SPY/Ss - OPERATIONAL
>>>> 0825.450 s - SPY/Sf - Link is UP, state: OPERATIONAL [ CINR: 3105, RSSI: -6375 ]
>>>> 0825.450 s - SPY/Ss - Serving BS is 00:00:02:00:21:01
>>>> 0825.450 s - Scan/Evt - Connect_BS: resume, status :12
>>>> 0825.470 s - LIC/Itf - licNotifySfCreation: cid 2664, cs 1, mir 64000, uplink, data, management,
accepted 1
>>>> 0825.480 s - SPY/Sf - uplink data SF add: sfid= 7 cid=2664 bcid=296 said=65535 state=active
>>>> 0825.480 s - LIC/Itf - licNotifySfCreation: cid 2668, cs 1, mir 64000, downlink, data,
management, accepted 1
>>>> 0825.480 s - SPY/Sf - downlink data SF add: sfid= 8 cid=2668 bcid=296 said=65535 state=active
>>>> 0825.490 s - LIC/Itf - licNotifySfCreation: cid 2672, cs 4, mir 4096000, uplink, data, data,
accepted 1
>>>> 0825.490 s - SPY/Sf - uplink data SF add: sfid= 9 cid=2672 bcid=296 said=65535 state=active
```



3.4 TRIAL8: Dynamic Scheduling Strategy

Situation: In this prototype, the dynamic scheduler is demonstrated. The goal is to enable reactivity to situations, such the following. A mobile station is experiencing 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. The dynamic scheduler enables strategy of time fairness to be implemented.

Methodology:

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.

Evaluation:

The graphical tool output is providing status on the current operation mode as well as giving generic statistics about the operation in progress.

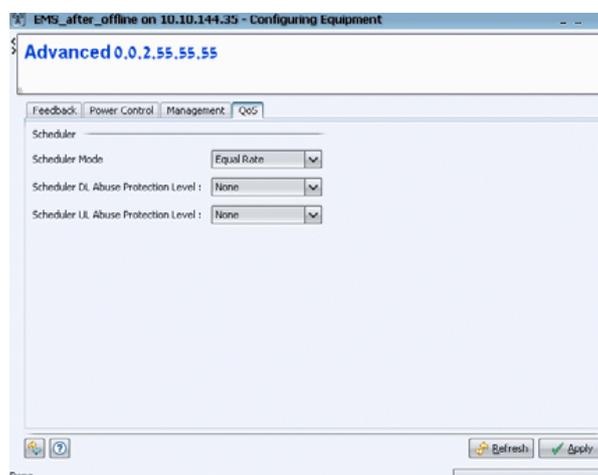


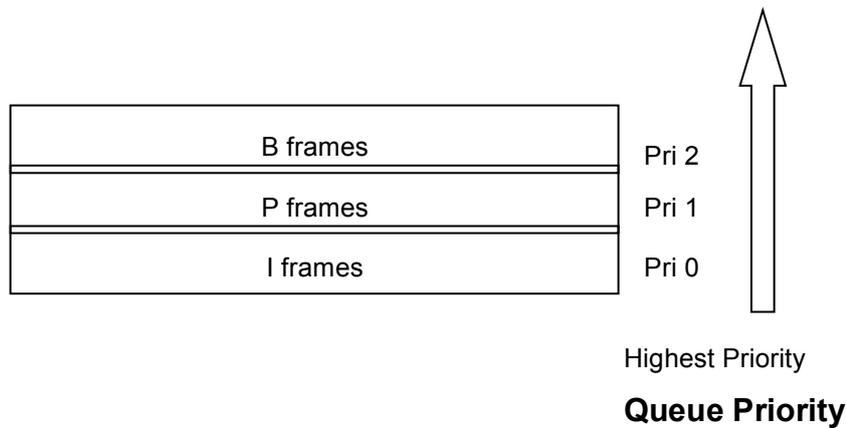
Figure 15: Dynamic scheduler graphical tool.



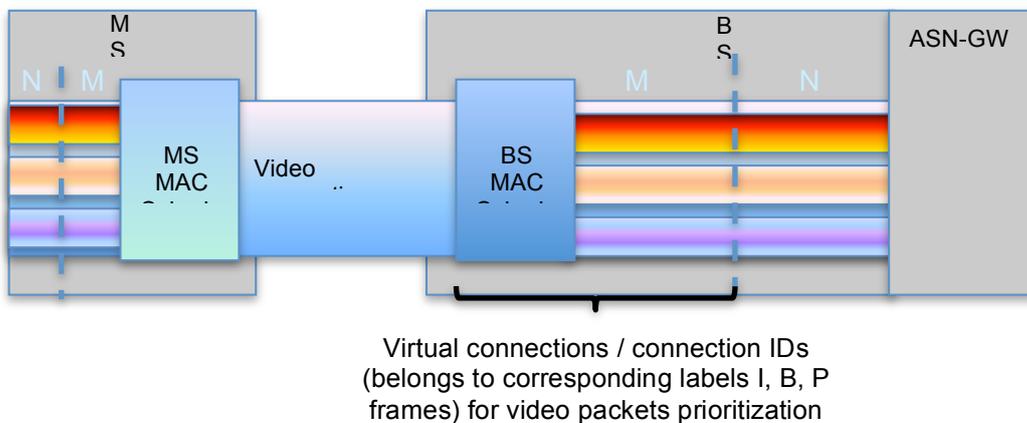
3.5 TRIAL9: Video prioritization

Situation: This prototype is designed to address the problem of premium content in backhaul network. With the growth of Over The Top players, it is necessary for service providers to offer traffic optimization schemes in order to deliver premium quality to paid customers. In this one, we exploit directly the nature of the content – video – and provide MAC flexibility to insure premium delivery.

The prioritization used is the following:



Which translate into:



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Methodology:

MAC will manage three virtual connections representing one real (video) connection. Basically when not all video packets can be transmitted (air resources shortage), we will prioritize I/S packets and drop P/B packets.

This enhancement can be implemented in BS for DL video transmission and in MS for UL direction, which represents 1) the case where user are watching something ; 2) the case where user are broadcasting (more and more frequent, such as YouTube usage).

Evaluation:

The evaluation is based on video quality.



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4 Conclusions

In this deliverable we introduce the different prototypes developed during the activities of this work package. We started with the contention-based technology prototypes, and illustrate the path taken: evaluating the potential of the technology, and then implement it in a broader way with the wireless MAC processor. As well, we have explored the evolution of scheduled-based systems, enabling new business models and new efficient use of the deployed wireless hardware based on the re-programmability. We hope these prototypes will contribute to the path leading to an extension of Software Defined Networks into the wireless space.