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Instrument	Specific Targeted Research Project
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Publishable Final Activity Report

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Dissemination Level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

EXECUTIVE SUMMARY

NETADDED

NEw Technologies to Avoid Digital Division in E-Divided areas

Hybrid satellite-wireless networks for advanced communication services to isolated areas in Africa and Asia

WHY NETADDED?

Today, broadband connectivity is as important for economic prosperity and quality of life as decent road and public transport networks. Through their immediate and far reaching connectivity, satellite communications allow to extend broadband networks to rural and isolated areas.

R&D projects like TWISTER have led to commercial deployments of hybrid satellite-wireless solutions in Europe where ADSL and cable modem solutions are not available, demonstrating the capability to design, deploy, operate and maintain high quality satellite broadband Internet access services for the benefit of public services, SMEs and households. Countries outside Europe are dealing with the same e-Inclusion issues and in addition, they have specificities that necessitate the adaptation to the local constraints.

NETADDED aims at developing and validating technical features improving the deployment and operation of such hybrid satellite-wireless technologies, in coherence with the growing demand of broadband communications in the International Cooperation (INCO) countries, linked in particular to education & health applications, which are key for developing countries.

WHAT IS NETADDED?

NETADDED (New Technologies to Avoid Digital Division in e-Divided areas) is a project led by EADS Astrium SAS which has been selected for co-funding by the European Commission in the 3rd Call for proposals of the Aeronautics and Space priority of the Sixth Framework Programme (FP6). The project has been running between the 1 April 2007 and the 31 October 2009 and has consolidated the team as active player in bridging the Digital Divide in INCO countries.

NETADDED OBJECTIVES

The project objectives are two-fold:

1. Development objective: to support education & health development in Africa & Asia
2. Technical objective: to provide a sustainable technical solution adapted to the specific environment. This goal assumes the following features:
   - The specification, implementation and validation of self-installation process usable by customers
   - The implementation of compact and robust transportable terminals, easy to deploy and adapted to the field conditions of INCO countries
   - The reduction of operating costs through the development and validation under real conditions of remote satellite control capabilities
   - The development and validation of mechanisms of service differentiation
   - The integration and validation of standardized satellite solutions with innovative wireless technologies providing better efficiency, coverage and robustness
   - The implementation of a low cost distant learning system adapted to satellite-wireless broadband infrastructure

NETADDED THEMES AND VALIDATION SITES

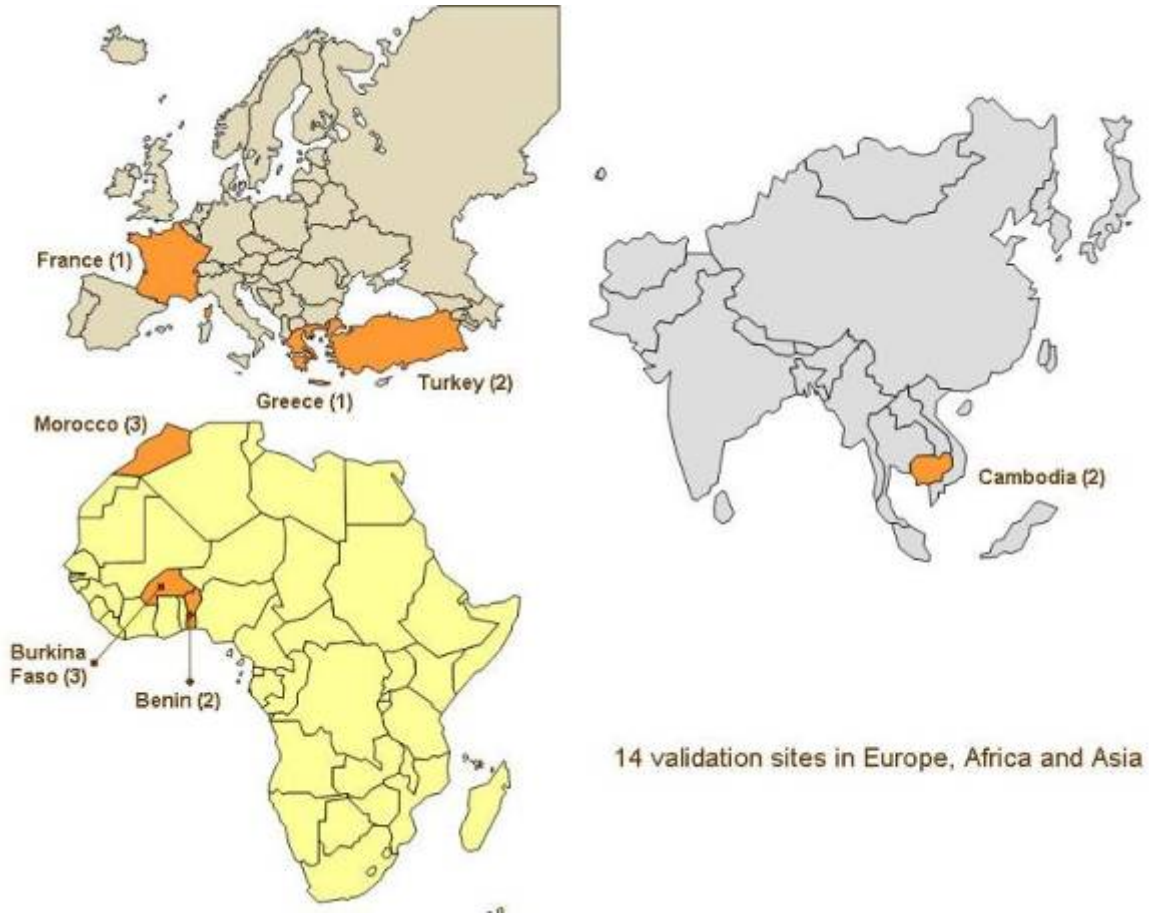
The suitability of the proposed network solutions is evaluated in terms of performance, quality of the proposed applications & contents and level of user satisfaction through validation sites selected with the support of national and regional public authorities. NETADDED has selected innovative applications meeting the specific needs of rural user communities in the participating countries:

- Broadband Internet access for rural schools in **Morocco**, in support to the remote continuing education programme of the Ministry of Education.
- Access to educational contents for NGOs in Africa working on two main e-learning actions: basic education for illiterate population in the most isolated areas of **Burkina Faso** and specific medical training in **Benin**.
- Use of satellite as part of National Telemedicine Network for continuous medical education on laparoscopic surgery between Medical Universities in **Turkey**.
- Access to e-Government and e-Commerce services for rural tourism user communities in **Greece** and **Turkey**.
- Wireless Sensor Networks (WSNs) dedicated to precision agriculture for farming user communities in **France**.
- Remote connection of Teacher Training Centers and High School in **Cambodia** to leading schools and universities in the capital to enable distant learning at affordable prices.

MAJOR PROJECT ACHIEVEMENTS

The NETADDED Consortium has fully achieved the objective of deploying and validating cost effective and efficient solutions, based on hybrid satellite-wireless networks and adapted to the particular context of INCO countries.

The NETADDED project has deployed and operated 14 validation sites, corresponding to a total of 14 satellite terminals installed in 7 different countries (Burkina Faso, Benin, Morocco, Greece, France, Turkey and Cambodia). These sites have allowed to assess the added value of satellite (combined or not to wireless) with respect to terrestrial solutions alone.



NETADDED validation sites

The deployed validation sites have allowed to test and validate under real conditions the following applications, prototypes and innovative issues:

- A self explanatory satellite terminal installation system,
- A transportable broadband satellite-based solution,
- A remote control mechanism for hybrid satellite-wireless networks,
- A soil moisture platform based on Wireless Sensor Networks
- A mathematical tool for available bandwidth estimation for wireless mesh networks
- The end-to-end integration of hybrid satellite-WiMAX networks,
- An efficient satellite network monitoring tool.

The NETADDED Consortium has defined and implemented remote monitoring and supervision of the validation sites that has enabled efficient detection of anomalies, technical diagnosis and optimized interventions on site.

The Evaluation phase of the project has allowed to evaluate the various sites in terms of performance, suitability wrt needs, satisfaction of the users and sustainability.

VSAT deployment in Africa

COORDINATOR CONTACT POINT

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NETADDED CONSORTIUM

EADS astrium	A world leader in the design and manufacture of satellite systems. Earth observation, Telecommunications and data relay satellite system designer and manufacturer.
cnes	The French Space Agency, established since more than 40 years, has developed a wide range of competencies and tools dedicated to the engineering, design and validation of next generation satellite telecommunication systems.
Cemagref	French scientific and technological institute for agricultural and environmental research, with extensive experience in remote sensing, GIS, quality and food safety as well as traceability.
Sabancı Üniversitesi	Private, independent young university in Turkey which aims to perform state-of-the-art research activities.
telemedicine technologies	Software engineering company specialized in the health sector. Distributor of Skylogic-Eutelsat broadband satellite services.
DEPARTEMENT POSTE - TELECOMMUNICATIONS NOUVELLES TECHNOLOGIES	Moroccan Ministry of Industry, Trade and New Technologies
GREF	International solidarity association founded in 1990 which collaborates with projects in the educative, cultural and social fields to support the durable development.
UMVF	French Cyber University for health and medicine aiming at opening up the opportunity of high quality professional education to everybody through Internet.
T.C. İSTANBUL ÜNİVERSİTESİ	Continuing Medical Education and Research Center of Istanbul University. IMF is the oldest educational institution in Turkey and a major actor for the development of telemedicine throughout Turkey.
FMPC	Faculty of Medicine and Pharmacy of Casablanca.
forthnet	Leading provider of data network services in Greece, present both in the telecommunications and in the content business.
Université Blaise Pascal	Government College of Engineering in computer science, part of University of Blaise Pascal Clermont-Ferrand II.
CONNECTED SCHOOLS	International solidarity association working on professional insertion of underprivileged youngsters and students in emerging countries.

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ACRONYMS

ADSL	Asynchronous Digital Signal Line
AP	Access Point
AUF	Agence Universitaire de la Francophonie
BUC	Block Up Converter
CEMA	Cemagref
CMF	Casablanca Medical Faculty
CNES	Centre National d'Etudes Spatiales
COTS	Commercial Off The Shelf
CPE	Customer Premise Equipment
CPI	Cross Polarization Interference
CPU	Central Processing Unit
CS	Connected School
DoD	Department of Defense
DVB-RCS	Digital Video Broadcasting – Return Channel Satellite
DVB-S	Digital Video Broadcasting – Satellite
DVB-S2	DVB-S version 2
EIRP	Equivalent Isotropic Radiated Power
ELU	Easy Line Up
FNET	Forthnet
GPS	Global Positioning System
HW	HardWare
IDU	In Door Unit
IEEE	Institute of Electrical and Electronics Engineers
IP	Internet Protocol
IRSP	Institut Regional de Santé Publique
IWB	Interactive White Board
KO	Kick Off
LAN	Local Area Network
LCD	Liquid Chrystal Display
LED	Light Emitting Diode
LNB	Low Noise Block
LOS	Line Of Sight
MAC	Medium Access Control
MAN	Metropolitan Area Network
MANET	Mobile Ad-hoc NETwork
MEM	Micro Electro Mechanical
MF-TDMA	Multi Frequency – Time Division Multiple Access
MIMO	Multiple In Multiple Out
MRTG	Multi Router Traffic Grapher
NAT	Network Address Translation

NE	Network Element
NGO	Non Governmental Organisation
NLOS	Non Line Of Sight
NMS	Network Monitoring System
NS2	Network Simulator – version 2
NTOP	Network TOP
ODU	Out Door Unit
PBX	Private Branch eXchange
PoE	Power over Ethernet
PoP	Point of Presence
QoS	Quality of Service
RP1	Reporting Period 1
RP2	Reporting Period 2
RTC	Real Time Clock
RTD	Research and Technological Development
SABU	Sabanci University
SLOPS	Self Loading Periodic Stream
SLOT	Combination of SLOPS and TOPP
SNMP	Supervision Network Monitoring Protocol
SNR	Signal Noise Ratio
SW	SoftWare
TDMA	Time Division Multiple Access
TOPP	Train Of Packet Pair
TTSA	Telemedecine Technology SA
UBP	Université Blaise Pascal
UMVF	Université Médicale Virtuelle Francophone
UPS	Uninterruptible Power Supply
VLSI	Very Large Scale Integration
VNC	Virtual Network Computing
VoIP	Voice over IP
VSAT	Very Small Aperture Terminal
WiFi	Wireless Fidelity
WiMAX	Worldwide Interoperability for Microwave Acces
WLAN	Wireless LAN
WLL	Wireless Local Loop
WMAN	Wireless MAN
WP	Work Package
WSN	Wireless Sensor Network

1 MAJOR PROJECT ACHIEVEMENTS

1.1 OVERVIEW OF KEY PROJECT OBJECTIVES

The aim of the NETADDED project has been to develop and validate technical features that will enable to improve performance of deployment and of operation of hybrid satellite-wireless technologies, in coherence with the growing demand of broadband communications in the INCO countries, as well as with their evolution in Europe. This necessitates telecom infrastructure solutions that are easy to deploy and operate, robust to failures, easy to upgrade and with good capillarity capability. They also have to be flexible enough to be shared between several communities of users, in case of limited ability to pay for the infrastructure deployment and service operation.

1. The African countries targeted by Non-Governmental Organizations working in the areas of education or health care are often suffering from a lack of a reliable communications infrastructure. As such the NGOs need to install themselves temporary communication means for the duration of their mission. The use of a transportable broadband satellite-based solution would enable the use of services such as Internet access, interactive access to data bases, VoIP, videoconferences or collaborative work, significantly improving their work conditions.

   NETADDED objective 1: Implementation of a compact and robust transportable broadband satellite-based solution.

2. Currently the installation of a bi-directional satellite terminal requires a certified installer. These certified installers are mostly based in the European countries with an established market. Organizing the installation of a satellite terminal in a country in Africa can be quite a complex and expensive operation. The development of an easy installation method could enable the end user to install his terminal by himself.

   NETADDED objective 2: Definition and field testing of procedures for simplified installation by customers.

3. Satellite terminals are very often used in remote locations with limited accessibility and limited alternative communications means. Hence, it is important to set up a robust and flexible remote control and maintenance methodology for the Customer Premises Equipments.

   NETADDED objective 3: Improved autonomy in terms of maintenance and operation of both satellite and local loop segments.

4. To share a broadband satellite access point between different users, the most mature technology today is WiFi. The constraint of 100 mW as maximum EIRP allowed by the radio regulations for WiFi transmissions in the 2,4 GHz band restricts the performances of WiFi in terms of coverage and associated data rates. NETADDED project will work on ways to improve performances in the local loop segment by integrating new wireless technologies with satellite.

   NETADDED objective 4: Integration of satellite with new wireless technologies having improved performances.

5. In the recent period, the quick development of Information Technologies has created a demand for broadband IP services in specialized domains such as the Health sector. The objective is to provide end-to-end QoS over heterogeneous systems for critical applications like surgery support, on-line monitoring or shared diagnosis.

   NETADDED objective 5: Provide services differentiation on the satellite segment.

6. The education situation in developing countries is particularly critical in the provinces as kids from rural areas cannot afford studies in the capital and teachers are reluctant to go to the provinces because of low salaries. Distant learning fundamental added value is to compensate for the absence of local skilled teachers in remote sites. The objective in NETADDED is to demonstrate that distant learning can be successfully implemented in isolated areas to the satisfaction of students and teachers.

   NETADDED objective 6: Implementation of a low cost distant learning system adapted to satellite-wireless broadband infrastructure.

1.2 KEY RESULTS AND ACHIEVEMENT OF OBJECTIVES

The NETADDED consortium has consolidated the choice of **14 validation sites in 7 different countries**: Burkina Faso, Benin, Morocco, Greece, France, Turkey and Cambodia.

User communities have been clearly identified, combining different profiles (citizens, public bodies, teachers, medical staff, …) as well as local contact points. Concrete applications have been identified, developed or improved in order to address the specific needs of each identified end-user.

To propose the **appropriate broadband solutions** for the different validation sites contexts, a number of network architectures adapted to the requirements and characteristics of each validation site has been defined and validated.

At the end of the project, fourteen (14) validation sites had been deployed:

- 3 validation sites in Burkina Faso, 3 in Morocco, 2 in Cambodia and 1 in Turkey on education application domain;
- 2 validation sites in Benin on health care application domain;
- 1 validation site in Greece and 1 in Turkey on e-business and rural tourism; and
- 1 validation site in France on precision agriculture domain.

These validation sites have allowed to **test and validate under real conditions** the RTD and Innovation activities, aiming at improving the conditions of deployment and exploitation of hybrid satellite-wireless solutions, which are at the centre of the NETADDED project:

- A market survey for available equipment for the definition of a **self explanatory satellite terminal installation** to be applied by customers has been carried out allowing the selection of an adapted COTS product, the ELU system from Siemens, that has been studied and improved during the project. This system only requires a laptop computer to assist the customer in dish pointing and cross-polarization adjustments. User guides and videos have been realised in order to assist a non expert user in performing the required alignment operations for the terminal installation.
- A **transportable satellite terminal** adapted to the field conditions in African INCO countries has been designed, manufactured and tested in real fields conditions. This terminal has been used by a local NGO in Burkina Faso during a basic education campaign.
- A **remote control mechanism** has been defined and prototyped. This prototype allows the operator to remotely monitor in real time the satellite and wireless installation. A dedicated web interface has been developed to facilitate the usage of this mechanism, even for non experts.
- Different **services differentiation methods** on the satellite segment have been investigated and implemented. The MEDSKY platform has been upgraded with new QoS management mechanisms and rules, and with a new efficient satellite network monitoring tool, available on-line

and in near real-time. Those new features are currently in beta testing and shall be soon implemented in the operational platform.

- End-to-end integration of **hybrid satellite – WiMAX networks** has been validated on test-bed prior to the deployment in real conditions in Morocco.
- A **Wireless Sensor Network** dedicated to precision agriculture has been specified, developed and tested in laboratory. Fast and accurate mathematical techniques to estimate the available bandwidth in wireless mesh networks have been defined, tested and validated by simulation.
- The characterisation of various **distant learning hardware and software tools** has been completed allowing the implementation of a low cost distant learning system.

Major efforts in the last period of the project have been concentrated on the usage and evaluation of sites using the tools and procedures put in place in the deployment phase and optimised during the operation. The evaluation has been performed at two levels:

- **Assessment of network usage and reliability** through the monitoring and supervision tools put in place at the NOC and on each of the sites. The generic monitoring and evaluation procedure defined in NETADDED proposes a list of key parameters to be analysed for network usage and reliability evaluation.
- **Evaluation of the quality of the proposed services** as well as the level of user satisfaction using an evaluation questionnaire defined by the Site Coordinators and approved by the Steering Committee.

Concerning **dissemination**, NETADDED partners have widely communicated on the project scope, objectives and results with presentations at **more than 70 events**. Besides, a number of papers and articles have been published and Sabanci University has applied for a patent on their work on the estimation of residual bandwidth in 802.11 wireless networks. Furthermore, ISI (Integral Satcom Initiative) endorsement has been granted to the project in October 2007.

The knowledge gained by NETADDED partners will continue to be disseminated beyond the end of the project through online information (publication of main project results on NETADDED website, contributions to EU web sites) and the effort initiated to raise awareness of local and regional authorities on satellite-based solutions will be pursued through participation to dedicated events or related projects.

Validation site (number)	Satellite service provider	Satellite	Frequency band (UL/DL)	VSAT terminals (ODU / IDU)	Service provided (data rate DL/UL)	Contention rate	Level of satisfaction (1 to 5)
Benin (2)	Eutelsat	W3A (7° East)	Ku-band	D-Star	Max 512/256 kbps Guaranteed 256/128 kbps	1/2	4
Burkina Faso (2)	Satlynx	NSS-10 (37.5° West)	C-band	ODU: Prodelin IDU: iDirect	Max 512 / 256 kbps Guaranteed 51.2 / 25.6 kbps	1/10	5
Morocco (4)	Eutelsat	W6 (21.5° East)	Ku-band	ODU: NJRC IDU: Viasat Linkstar	1024 / 512 kbps	1/50	2
Casablanca (1) & Istanbul (1)	Eutelsat / TTSA	AB1 (12.5° West)	Ku-band	ODU: Andrew IDU: Viasat Linkstar	Coliseum: 1024 / 512 kbps Premium: 2048 / 1024 kbps	Not applicable	5
Embaros (1)	Hellasat	F2 (39° East)	Ku-band	ODU: Andrew IDU: Advantech	1024 / 512 kbps	Not available	3
Cambodia (1)	Camshin	Thaicom (120° East)	Ku-band	IPSTAR	512 / 256 kbps	1/30	2

Table 1: Synthesis of broadband satellite solutions implemented in NETADDED validation sites

	Wireless technology	Frequency band	Equipment provider	Service provided (data rate)	Max transmission distance deployed
Validation site in Benin					
	WiFi 802.11	2.4 GHz	APX Synstar	54 Mbps (*)	1.2 km
Validation site in Burkina Faso					
	Hiperlan2-like	5.7 – 5.8 GHz	Alvarion	54 Mbps (*)	1.4 km
Validation site in Morocco					
	WiFi 802.11g/b	2.4 GHz	Airspan	54 Mbps (*)	20 m(indoor)
	WiMAX 802.16d	3.4 – 3.6 GHz	Airspan		2.8 km
Validation site in Embaros (Greece)					
	WiFi 802.11g	2.4 GHz	Linksys	54 Mbps (*)	840 m
Validation site in Cambodia					
	Long range WiFi	5.7 – 5.8 GHz	Canopy	7 Mbps	14 km
Validation site in France					
	WiFi 802.11b WiFi 802.11g	2.4 GHz	Linksys (WRT54GL router)	11 Mbps (*) 54 Mbps (*)	640 m
	ZigBee 802.15.4	2.4 GHz	Proprietary LIMOS development	250 kbps (*)	30 to 300 m
Validation site in Turkey					
	WiFi 802.11g	2.4 GHz	Airties	54 Mbps (*)	1.5 km

(*) Theoretical data rate.

Table 2: Synthesis of wireless solutions implemented in NETADDED validation sites

Figure 1: NETADDED Poster

NETADDED objective 1: Implementation of a compact and robust transportable broadband satellite based solution.

One of the main goals of NETADDED is to define the best satellite-based solution adapted to the real field conditions of Africa. The satellite terminal must be compact and robust, easy to deploy, transportable and suited to weather and temperature conditions.

Through WP 4.2.2 Transportability, the NETADDED project has analyzed the user requirements for a transportable terminal adapted to the field conditions in African countries. A trade-off between a number of solutions has been carried out resulting in the selection of ABC S@t solution developed by CNES based on Inmarsat technology.

The transportable satellite terminal is based on the integration of COTS elements, put together in a compact and robust packaging. Shock and vibration have been taken into account for the study of transportation conditions of the terminal. Special attention has been paid to the resistance of the selected equipments to temperature cycles, humidity and dust.

For the equipment selection, CNES has identified the most suitable standards to be respected for the choice of the equipments. The selected equipments satisfy the standard criteria of MIL-STD 810 E, thus guarantying their resistance to High Temperature, Humidity and vibrations.

Following the user needs, the transportable terminal has been completed by the definition and development of a software application for the optimization of bandwidth use in the domain of e-learning applications.

This first prototype has been used by a local NGO in Burkina Faso during a basic education campaign (October 2008 – March 2009). A set of tests have been defined and carried out in the field, allowing to:

- Validate the proper operation of the terminal in terms of performance, reliability, robustness and autonomy;
- Identify limits and necessary improvements (software or hardware);
- Test its operability by typical non-technical users; and
- Analyse the usage.

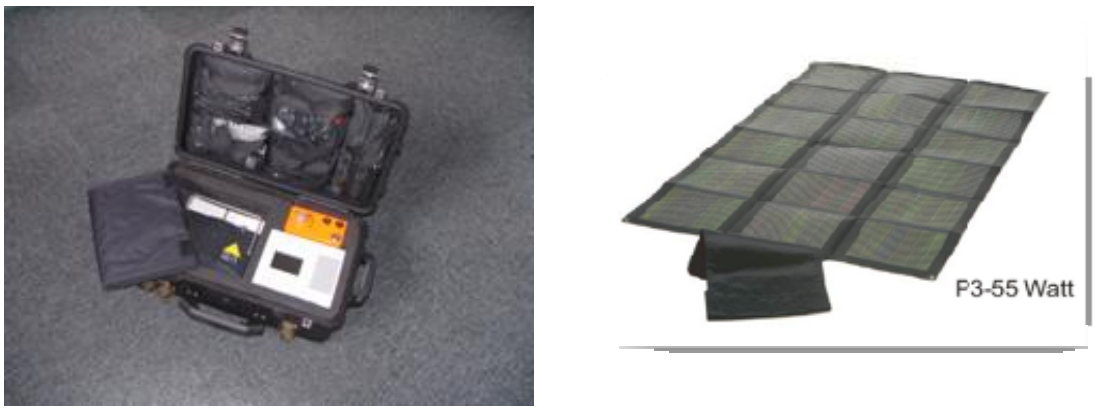


Figure 2 : Transportable terminal and its foldable solar charger

Internet access, videoconferencing and sharing of medical content were the main applications used during the test campaign. The main outcomes following user's feedback on the usage of the transportable solution are summarized in Table 3.

The last period of the project has been devoted to develop a number of improvements to the transportable terminal, through a dedicated study carried out by the CNES:

- The performance of the batteries has been enhanced guaranteeing a longer autonomy and lifetime
- The load management system has been optimized;
- A more powerful charger has been integrated, improving the rapidity of equipments charge and allowing simultaneous connection of a larger number of devices;
- A rugged laptop has been integrated inside the suitcase, and a lighter suitcase has been selected to reduce the weight of the solution;
- The thermal dissipation has been optimized;
- The router's user interface has been modified by replacing the LCD command screen by buttons and leds, and led indicators for battery status have been integrated.

The new version of the transportable solution was finalized in June 2009.

Transportability	The light weight of the terminal (12 kg) allowed to transport it easily by car or motorbike
Resistance to shock and vibration	The terrible state of roads raised some minor problems of stability of the suitcase's external connectors. Equipments placed inside the suitcase were well protected.
Resistance to high temperature, humidity, dust	Neither high temperature (36°C on average) and humidity nor the very dusty environment revealed any visible failure.
Rapidity of deployment	On average 6 minutes by non technical skilled NGO educators.
Autonomy	The batteries had an average autonomy of 2 hours. They had to be charged every night after the learning session. During the sessions, solar panels were largely used to complement the batteries, along with a generating group when necessary.
User interface	User friendly terminal, except for the LCD touch screen not well adapted to the sunny environment of Burkina Faso, and complexity on cabling and adapters for external power supply sources.
Usage	Duration average 28 minutes per session to be added to the 6 minutes of terminal set-up. Both connected and off-line modes were used. Both cabled and wireless connection modes were used.
Operational costs	105 Mbytes of total amount of exchanged data using Inmarsat system during the test campaign, for 670 €.

Table 3: Main outcomes on transportable terminal usage in Burkina Faso

Table 4: Validation of the transportable solution in real operational conditions

NETADDED objective 2: Definition and field testing of procedures for simplified installation by customers.

The installation of a bi-directional satellite terminal, especially the pointing of the dish, is quite cumbersome while it needs to be done accurately. It requires the pointing of the dish (azimuth, elevation and cross polarization) and the parameterization of the Customer Premises Equipment.

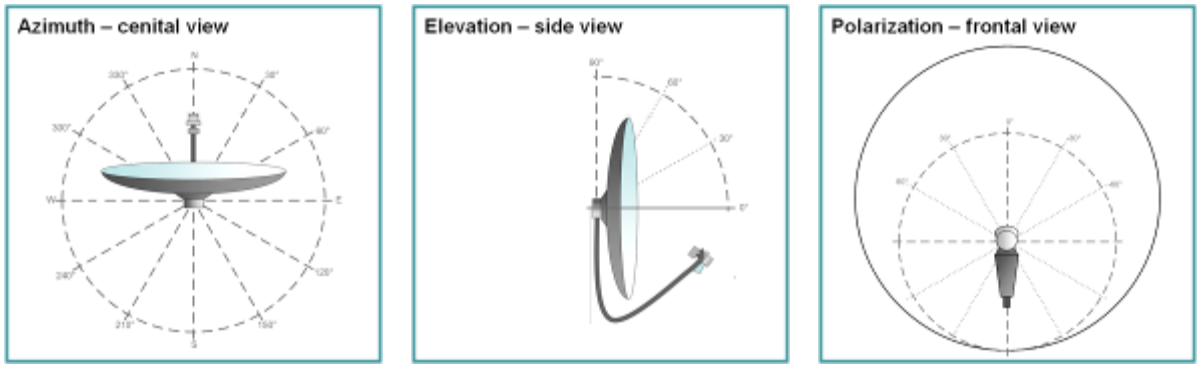


Figure 3: Antenna pointing parameters

This type of installation requires a certified installer, having followed a training to be able to do the installation correctly. A faulty installation would result in a degradation of the customer's service and could cause disturbance of signals of other customers.

These certified installers are mostly based in the European countries with an established market. Organizing the installation of a satellite terminal in a country in Africa can be quite a complex and expensive operation.

The development of an easy installation method could enable the end user to install his terminal by himself. The method consists of a set of logical steps defined in a manual or an interactive multimedia presentation and a set of simple, easy to use tools such as a GPS or a compass. The ultimate objective would be a stand-alone solution where neither an expert installer nor a service operator has to intervene.

A market survey for available equipment for the definition of a self explanatory satellite terminal installation to be applied by customers was carried out allowing the selection of an adapted COTS product that would be studied and improved during the second phase of the project and validated in Greece.

The ELU system (Siemens Easy Line-Up for Satellite Networks) has been employed as the solution to address the terminal installation process. It requires only a laptop computer to assist the customer in dish pointing and cross-polarization adjustments.

Since the original ELU software targets technicians, work has focused on providing the necessary material, in terms of user guides, videos, etc., to assist a non-expert user in performing the required alignment operations for the terminal installation.

A two-phase evaluation process has followed. The first phase has allowed to improve the user guide (without actually testing the software application) following some feedback from typical non-expert users. The second phase has allowed to test the ELU software by performing several line-up runs by typical non-expert users in a simulated environment.

Three aspects of the system were tested: functionality, performance, and usability. Essentially, the tests were carried out to provide proof of the system's alignment accuracy and ease of use, and to verify that its behavior and capabilities conformed to the specified functional requirements. In particular, the main functional aspects of the system that were tested are:

- Antenna alignment: the ELU application should support all relevant configuration issues and provide the necessary feedback during the initial antenna alignment phase.
- Antenna polarization alignment: an antenna must both be pointed correctly at the source of reception/transmission and, in the case of linear polarization, it must also be oriented about its axis in order to minimize cross polarization interference (CPI).
- Terminal registration: after the configuration has been finished the application should initiate a line-up request transmitting authentication information in order to get registered on the central site.

Performance was measured by checking the quality of the signal after the satellite terminal installation.

In general, the tests showed that the usability of the system is quite good. Obviously, we cannot expect from users with no technical expertise to do as well as an expert technician, and this was evident from the tests. However, the system did allow all users to perform an acceptable line-up and establish the necessary communication link.

Figure 4: ELU user guide interface

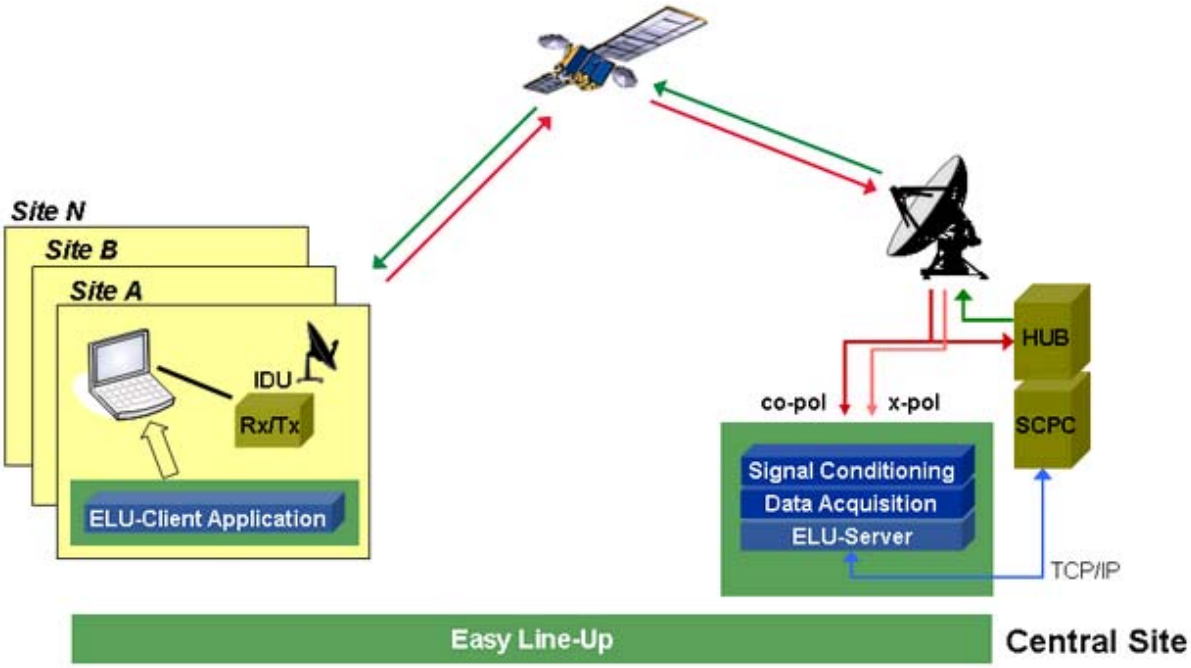


Figure 5: ELU test topology

NETADDED objective 3: Improved autonomy in terms of maintenance and operation of both satellite and local loop segments.

Satellite terminals are very often used in remote locations with limited accessibility and limited alternative communications means. Hence, it is important to set up a robust and flexible remote control and maintenance methodology for the Customer Premises Equipments.

Through WP 4.3.1 Remote Control activity, the NETADDED project has defined and prototyped a remote control mechanism that enables the local loop operator to remotely monitor in real time the whole satellite (and wireless) installation. This mechanism allows to:

- Monitor both satellite and local loop segments, from both provider and user sides
- Issue alerts about network failures
- Perform remote interventions (such as a hardware reboot) for problem solving or QoS improvements

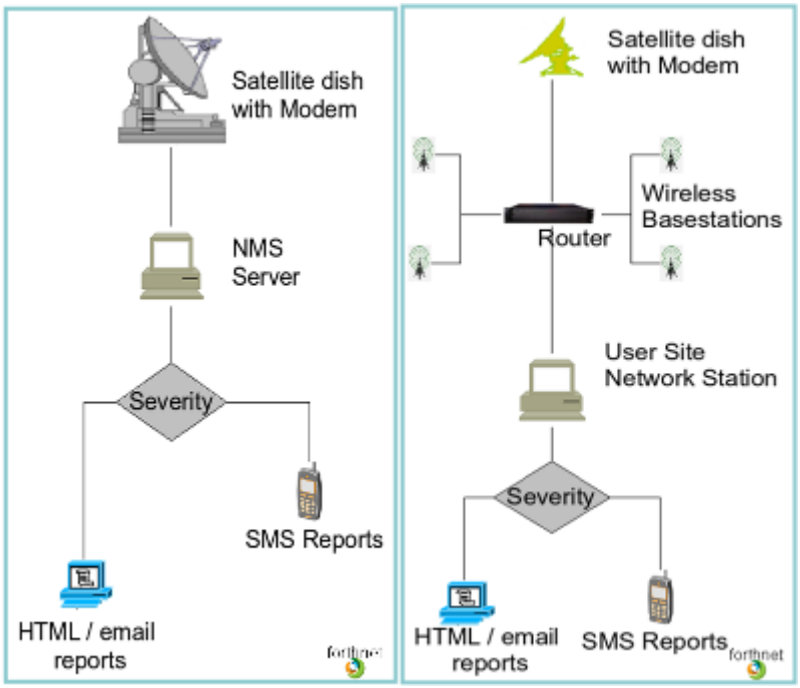


Figure 6: Remote control system: at provider site (left), at user site (right)

Figure 7: Remote control hardware solution

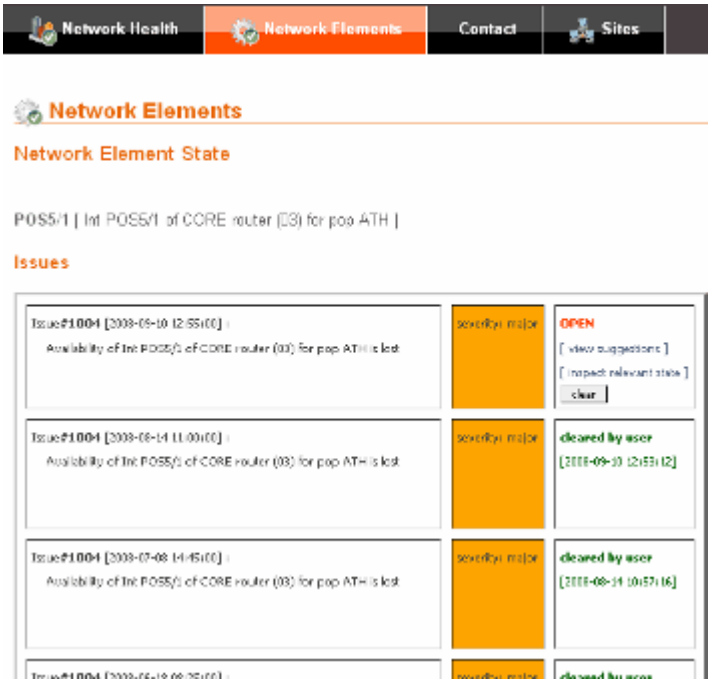


Figure 8: Remote control user interface

The remote control platform has been tested, following the test procedure described below.

Feature to be tested	Description
Functionality	Behavior and capabilities
Dependability	Reliability/availability
Usability / Maintainability	Ease of use/ease of maintenance
Performance	Desirable operational characteristics
Capacity	Behavior under stress, scalability

The main **functional** aspects of the remote control system that were tested are:

- Remote control: the network provider is able to aggregate network information and resolve potential issues at the validation sites.
- Bandwidth utilization efficiency: information pertaining to critical network issues from the validation sites is propagated to the network provider and the appointed operators (at both sites) are notified through email or SMS.
- Autonomy: operators at the validation sites are able to resolve non-critical network issues with no requirement for network administration expertise.

Performance tests that were used for the remote control system included the following measurements in their evaluation:

- CPU and memory utilization at the NMS.
- Average operational and environmental temperature at the NMS.
- Efficiency of automatic detection of error resolution and of NE network information.
- Amount of traffic that the introduction of the NMS brings to a validation site.

In general, the tests showed that the **usability** of the system is quite good. Only a few seconds were necessary for the system operator to access all system's functionality. This was certainly expected as the system functionality is rather simple. **Capacity** tests for the remote control system mainly focused on stressing the NMS at the validation sites by introducing a large number of NEs for monitoring.

The tests were run in a simulated environment allowing to test the remote control in three different network environments. As a result we had the opportunity of testing the framework in a very demanding scenario which involved more than 1500 network elements. The tests run in the simulated environment have then been complemented by further testing in real conditions, which has taken place at the end of the second reporting period, after the installation of the Embaros site was carried out. These tests confirmed the results obtained in the simulated environment, as expected, and justify the potential of the remote control framework.

NETADDED objective 4: Integration of satellite with new wireless technologies having improved performances.

Investigation of evolution of 802.11 technologies to intelligent wireless networking

A novel node-based available bandwidth estimation algorithm for WiFi mesh networks has been developed and tested successfully. Sabanci University applied for the patent of this algorithm to the Turkish patent office on 11th November 2008.

Through WP 4.3.2 Intelligent Wireless Networking activity, the following research items have been investigated:

Residual Bandwidth Estimation - As part of this activity SABU investigated the accurate estimation of the residual channel capacity of wireless networks. The residual bandwidth is defined as the difference between the network link/path capacity and the current throughput of the system. Note that the residual bandwidth identifies the additional user demand that can still be satisfied under current conditions. The proposed SABU algorithm is a passive estimation algorithm, which listens to the channel and uses analytical techniques to calculate the residual channel bandwidth. The proposed algorithm was tested with extensive numerical simulation experiments and they are shown to perform much better than those previously proposed in the literature.

During the second period of NETADDED, the proposed algorithm has been enhanced in the following aspects:

- Error probabilities of neighbouring nodes and hidden node effects have been included to the model for improved accuracy
- A more complex and realistic probabilistic model have been utilized
- The accuracy and performance of residual BW estimation have been improved so that average estimation error dropped from %5-10 to %1-2 range
- The algorithm has also been applied to mesh network routing protocols and a considerable increase in end-to-end throughput has been observed
- Complexity level of enhanced algorithm has been investigated. The new algorithm has been found to be less complex and more feasible compared to other methods in the literature.

Intelligent User Association - Another important issue in WiFi networks in general was identified as the over-simplicity of the user association method given in the IEEE 802.11 standard. In the current standard, users associate with the access point (AP) with the highest received signal strength with the anticipation that this AP is the closest one, and thus, it can provide the highest throughput. However, throughput not only depends on the instantaneous received signal strength but also on the number of wireless stations already associated with the AP. A more enhanced association protocol was proposed by SABU in earlier studies. In this project, SABU investigated the performance bounds of this more enhanced association protocol. In order to obtain provable worst-case performance bounds, SABU used game theoretical

techniques. The results indicated that the worst-case bounds are significantly worse than the average performance obtained in the numerical simulations. Thus, as a conclusion we suggested the use of mechanism design tools such as pricing of the consumed wireless bandwidth to guarantee better user performance under all operating conditions.

Resource management and scheduling for multimedia traffic in MIMO based ad hoc or mesh networks - In MIMO systems, the structure of the physical layer has greater importance since spatial dimension is also exploited. With MIMO technology in the physical layer, the remaining network layers should be designed with in a cross-layer fashion, so that the available resources can be most efficiently managed. Multimedia communications in MIMO enabled ad hoc/mesh networks is expected to achieve the most benefit from the capacity and reliability provided with MIMO technology. Based on these observations we concentrated our research efforts on MIMO technology on designing effective and jointly optimal scheduling, routing and resource management schemes to be used in MIMO enabled ad hoc wireless networks for multimedia communication purposes. A cross-layer integrated management platform that considers fairness constraints and channel matrix estimation errors is planned for development.

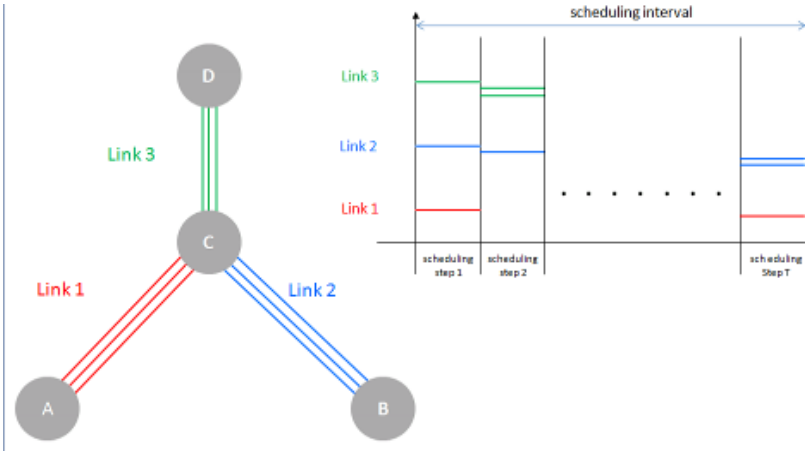


Figure 9: Stream based scheduling in MIMO enabled wireless network

During the second period of NETADDED project:

- A simple multi-access type MIMO enabled networking model has been setup for preliminary analysis.
- Basic fairness and QoS criteria has been integrated to the model to evaluate resource management performance.
- Initial results on this simple scheme gave promising results with a throughput increase of 40 to 60% while satisfying QoS and fairness criteria.
- Opportunistic scheduling of wireless resources based on stochastic approximation methods is being developed.
- Further research involves appropriate/compatible routing algorithms and multimedia specific QoS constraints

Wireless Sensor Networks

A soil moisture platform based on Wireless Sensor Networks dedicated to precision agriculture has been specified, developed and tested in laboratory. Besides, a fast and accurate mathematical technique to estimate available bandwidth in wireless mesh networks called SLOT has been formulated and validated by simulation.

The LiveNode platform has the following hardware and software components:

- LIMOS 'LIght weighted Multi-threading Operating System' based on LINDA concept,
- CIVIC 'Communication Inter Véhicule Intelligente et Coopérative': Embedded wireless communication protocol,
- LiveNode 'LIMOS VErsatile Node': component-based concept adoption enabling to implement wireless sensor node such as wireless soil moisture sensor node, WiFi-ZigBee gateway etc. by using the same hardware.

The soil moisture WSN platform has been evaluated under real outdoor conditions in Allier (France) validation site and the SLOT tool has been used to estimate the available bandwidth of the Allier validation site experimental platform.

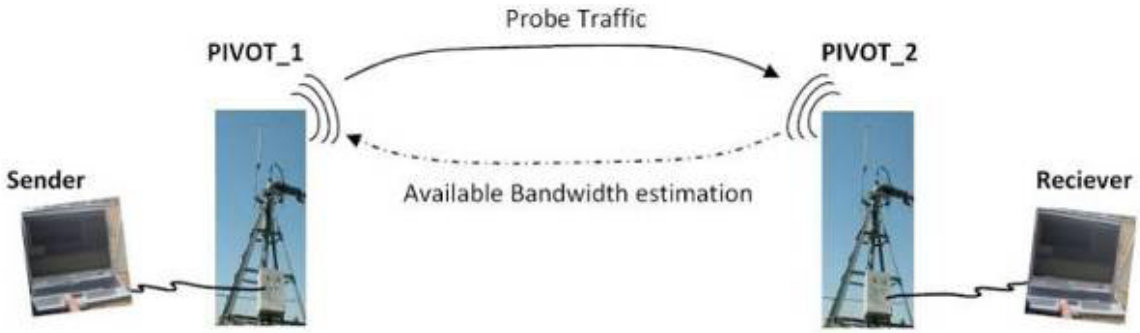


Figure 10: SLOT test topology in Allier (France)

Figure 11: Wireless sensor prototype

Investigation of advanced broadband wireless technologies having increased throughput and coverage

Through WP 4.3.2 Intelligent Wireless Networking activity, the NETADDED project has investigated the IEEE 802.11s amendment for mesh networking.

Through WP 4.3.4 Integration of new wireless technologies with satellite, the NETADDED project has investigated WiMAX IEEE 802.16 and ETSI BRAN HiperLAN/2 technologies. The following activities have been carried out during the first phase of the project:

To validate the integration of new broadband wireless technologies with satellite solutions, a test-bed has been set-up at Astrium premises.

- State of the art of new wireless technologies having increased throughput and coverage and selection of products adapted to the needs in Moroccan validation sites: Following the analysis of the BWA solution portfolio presented by Alvarion , Motorola and Airspan Networks, Astrium decided to select Airspan Networks MicroMAXd product that operates in both 3.5GHz and 5.4GHz bands and is designed to support rural broadband access at an affordable price.
- Set up of test bench for integration of new wireless technologies with satellite
- Integration and validation of the selected wireless product (Airspan MicroMAX) with satellite, in preparation of deployment at two validation sites in Morocco:
    - Performance calibration of hybrid satellite-wireless network
    - Set-up and validation of advanced QoS policies
    - Set-up and validation of advanced security features
    - Performance evaluation of VoIP and videoconferencing applications over the hybrid satellite-wireless network

The test bed has been used during the second phase of the project for the calibration of the performance of the hybrid WiMAX-satellite network that has been deployed in two Moroccan validation sites. All along the deployment and service exploitation phase, the test bed has supported installation teams and has helped to solve any problems encountered on-site.

Figure 12: NETADDED test bed at Astrium premises

NETADDED objective 5: Provide services differentiation on the satellite segment.

Through WP 4.3.3 different services differentiation methods on the satellite segment have been investigated:

- Methods to improve quality of service dynamic control, directly by the end-user, with a QoS device installed at hub level
- Methods to control QoS through a low cost device to be installed on site
- Differentiation of services for several IP based videoconference applications
- QoS policies to improve the quality of image in videotransmission in different application contexts

Besides, QoS management specially adapted to the user requirements so to enable sharing of the satellite resource by user having different usage profiles (typically videoconference with guaranteed bit rate and Internet like services) and per use tariffs to reduce costs for the end user has been implemented.

The issue of service differentiation cannot be addressed efficiently without a powerful traffic monitoring system so as to monitor and control how the network and the users behave once the appropriate QoS policies are implemented. It has been a major task in NETADDED to design and develop a service differentiation system with fully embedded traffic monitoring system.

The development and integration to the MEDSKY platform of an efficient satellite network monitoring tool, available on-line and in near real-time, with appropriate time resolution and adapted graphs for quick action, has been achieved. In addition, the QoS management and rules have been completed and adjusted several times to take into account experience feedback. Also a new software development on the videoconferencing application has been launched with the purpose to enable a better multicast management as well as a better integration with satellite networks and TCP acceleration features, along with the management of powerpoint slides. These new features are currently in beta testing and shall be soon implemented in the operational platform.

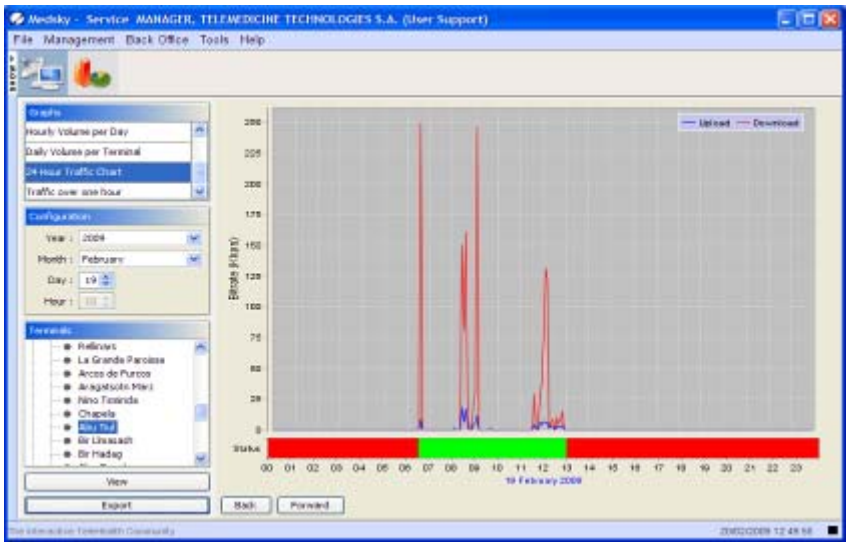


Figure 13: Satellite network monitoring tool

NETADDED objective 6: Implementation of a low cost distant learning system adapted to satellite-wireless broadband infrastructure

When it comes to "e-learning" and "distant learning", the number of products and services offering can be overwhelming. Some are high-end, full featured and expensive, others are cheap or even free but unreliable. Connected Schools NGO aims at providing professional education to disadvantaged children in emerging countries by means of distant learning to compensate for the lack of skilled teachers there.

The objective of the activity carried out through WP 4.3.5 in NETADDED was therefore to evaluate and integrate various hardware and software to implement a low cost distant learning system (ie server and client) with many functionalities as possible in the following list: audio conferencing, whiteboard sharing, desktop sharing, video call, video broadcast, video conferencing, chat, Internet access, fast access to stored training content, email, forum.

The characterisation of various distant learning hardware and software tools has been completed, allowing the implementation of a low cost distant learning system (ie server and client).

- First a set of software was selected on the basis of three criteria: cost, feature set and fame. The performance of each tool has been detailed and quantified for each criteria and finally the goal was achieved to provide a reasonably reliable, user friendly, well performing "collaborative work" toolset at no cost.
- For the hardware evaluation the primary factor considered was cost and the second was power consumption. The combination of low power notebooks with the use of LED projectors has made possible the concept of a "single solar panel" powered distant learning classroom

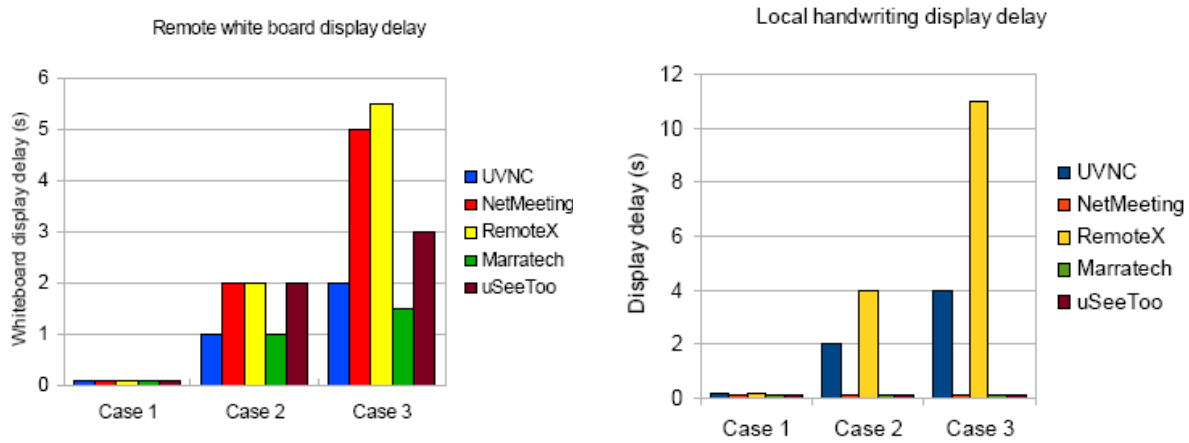


Figure 14: Performance comparison of videoconferencing tools

Whiteboard sharing performance comparison

2 COMMUNICATION NEEDS OF NETADDED RURAL COMMUNITIES

The objectives related to user need identification are:

- To identify clearly the validation site and user communities,
- To describe the current status regarding Internet access and application usages (education, health, business …),
- To identify user expectations,
- To define scenarios of broadband usages, further related to solution assessment.

The work has been organized in five tasks with respect to the five Regions covered by the project

- The Africa Region, with CNES as task leader
- The Mediterranean Region, with DEPT&NT as task leader
- The European Region, with CEMAGREF as task leader
- The ACC Region, with SABU as task leader
- The South East Asia Region with Connected Schools as task leader

Communication needs of rural user communities

The African mobile market is experiencing the fastest growth in the world: the number of subscribers increased from 16 million in 2000 to 198 million in 2006 and this growth is expected to continue and to reach 278 million subscribers by 2007. However, it is estimated that only 7% of rural households in Africa currently have a mobile service subscription. Low incomes inhibit people to pay for the service and there is a total absence of retail channels to support the service (e.g., sale of handsets and prepaid cards) as well as electricity to recharge mobile phones. The broadband services are especially demanded by non-governmental organizations and health organizations operating in the region.

In South Mediterranean region, the digital divide begins from the access of population to PCs. For example in Morocco, the percentage of the households owning a PC is merely 11%. Also only 3% of the population living in (powered) rural areas and 23,7% of the population living in urban environment own a PC. At the national level, among the individuals of more than 12 years living in electrified zone, 63,9% never had access to a computer either in residence or out of the residence, in other words more than 10 million Moroccans are without access to a computer. The divide access to a computer between rural and urban zone is very clear : 56% of the Moroccans of more than 12 years living in urban environment do not have access to a computer out of their residence while in rural zone this percentage goes up to 89%.

In most of Europe, ADSL based wired broadband services penetrated in the rural regions. For example, in France only a small percentage of rural areas do not have broadband ADSL service. Also, recent

statistics indicate that 75% of farmers have ADSL connections at least with rate 512Kbps. Meanwhile, in Greece the penetration of broadband lines is not at the same level as in France. In January 2007, there were 4,4 active broadband lines per 100 citizens which is lower than the European average of 16,9%. Also, considering the coverage of broadband lines, only 19% of Greeks can subscribe to broadband, compared to almost 90% across Europe as a whole. One of the main reasons for this situation is the topography of Greece; the topography consists of many islands and remote mountains.

As a candidate country the broadband penetration in Turkey is not better than Greece; it is only 3%. Only Slovakia, Poland and Greece could be considered close to this percentage (with 4.6, 4.5 and 3.3 percent respectively), and all developed EU countries have broadband penetration rates higher than 15%. However, the fast pace of urbanization in Turkey and the privatization of Turkish Telecommunications company increased the rate of increase of broadband penetration. There are also many government efforts to provide broadband service to all schools and hospitals in Turkey.

Finally, in Cambodia the communications landscape (both Internet and GSM/ 3G) is evolving rapidly in the main cities: Phnom Penh, Siem Reap, Battambang, Sihanoukville. However, it will be a long while before it reaches the rural provinces, where 80% of the population still live. These communities exhibiting a low income do not justify the Telecommunications infrastructure investment (whether wired or wireless) to reach them. In this context the "satellite + wireless terrestrial" connection could prove economically viable, especially given the aggressive pricing that Shin seems to be pushing with their IPSTAR satellite offer.

NETADDED validation sites

The selected pilot sites are compliant with the following **eligibility criteria**:

1) The site should have the potential to show the added value of satellite with respect to available terrestrial solutions, as well as its cost-efficiency with respect to the user needs. For example a rural or isolated area where Internet access and network connectivity are not available or provided with a low quality of services (data rates, pricing …).
2) User communities should be clearly identified, combining different profiles (citizens, public bodies, enterprises…) and potential usages.
3) Applications that could benefit from broadband services deployed at the validation site should be clearly identified and available for implementing experimentations and performing evaluations.
4) Support and involvement of local Authorities is mandatory to ensure the sustainability of the services after the end of the experimentation and facilitate the migration towards an operational and commercial solution.

In **Africa** region, under the administration of CNES, Burkina Faso and Benin have been chosen as countries hosting NETADDED validation sites. There is also a transportable solution that has been trialled in Burkina Faso within the framework of testing and validation activities.

In **South Mediterranean region**, Morocco has been chosen as the country for validation activities under the administration of MAEG. Two validation sites have been selected in Morocco (namely Moukresset and Oulad Mkoudou) that are characterized by geographic isolation and low population density.

In **Europe**, France and Greece have hosted validation sites. In Greece, Forthnet has selected two validation sites in Crete Island demonstrating the satellite based broadband solution in rural areas, whereas in France, Cemagref has validated a wireless sensor nodes based solution in a typical farming environment.

In an **associated candidate country**, Turkey, two validation sites have been deployed: One site to demonstrate satellite based broadband solution in tele-medicine applications and the other site to demonstrate hybrid satellite-terrestrial wireless communications solution in the tourism sector. This second site has also demonstrated the effectiveness of investigating new intelligent wireless technologies such as wireless mesh networks.

Finally, Connected Schools has coordinated two validation sites in **Cambodia** where the people remain isolated from mainstream internet related sources due to cultural barriers and lack of internet web-sites in local Khmer language.

Results indicate interesting differences in user needs and expectations according to the users' locations. For example, in Africa and Cambodia, **a satellite solution that is durable** to the difficult local conditions such as extreme heat/humidity and frequent power outages is needed. Meanwhile, in Turkey, France and Greece a solution that is **cost-effective** is required in order to be commercially viable.

In all cases considered, an overarching conclusion is that satellite broadband solutions are usually interim solutions leading the way to cheaper and better quality broadband solutions in the future. Nevertheless, satellite solutions are essential in the meantime, since otherwise a large portion of the population is left isolated from knowledge and global community.

14	Validation sites	User community	Application domain	Technology
3	Bogandé, Ouahigouya, transportable (Burkina Faso)	NGOs, rural population, institutional, hospital staff	Education	**Satellite + WLL (Hiperlan/2)**
2	Ouidah, Parakou (Benin)	Medical staff, students NGOs	Health care	**Satellite + WLL (WiFi)**
2	Mokrisset, Oulad Mkoudou (Morocco)	Schools, health care centers	Education	**Satellite + WLL (WiMAX)**
2	Casablanca, Istanbul	Oncology, Laparoscopic surgery user communities	Health care	**Satellite**
1	Allier (France)	Farmers	Agriculture	**WLL (WiFi mesh)**
1	Embaros (Greece)	Public bodies, tourism industry	Education, Business, Tourism	**Satellite + WLL**
1	Bordubet (Turkey)	Tourism user communities	Tourism, Business	**Satellite + WLL (WiFi mesh)**
2	Phnom Penh, Angtasaom	Teachers, students, administrative staff	Education	**Satellite + WLL (Hiperlan/2)**

Table 5: NETADDED rural user communities

3 ASSESSMENT OF DEPLOYED NETWORK TECHNOLOGY

The network engineering and development activity in the project covers the RTD and Innovation work carried out for the improvement of the space component and local loop of hybrid end-to-end solutions. It includes in particular the activities of technical specifications, engineering and design, development, integration and in lab validations. It also gathers preparatory activities necessary for the proper deployment of equipment at the validation sites.

End-to-end system design

This activity makes the link between user needs identified previously and the technical developments conducted for Deployement and Exploitation improvements. The objective is to customize these developments regarding the previously identified field constraints. Moreover, it draws up a list of all authorizations and regulation issues that must be considered before going to on site deployments

Deployment improvement

Improvement for the deployment of satellite-based solutions are necessary for the identified regions to better fit with local conditions that are sine qua non conditions for wider scale adoption of broadband infrastructures in most of the targeted countries. Two main topics are processed in this workpackage:

- A simplified installation process avoids the necessity for the intervention of a trained and certified technician,
- A transportable terminal, easy to use and able to provide quickly a broadband connection which can fit with end-users requirements in remote areas.

Exploitation improvement

Improvement for the exploitation of satellite-based solutions are performed at different levels:

- Remote monitoring,
- Quick and easy extension of local area network into wide area network,
- QoS enhancement on the same access point,
- Assessment of new wireless local loop (WLL) technologies,
- Development of new e-content adapted to this hybrid Satellite-WLL solution.

3.1 END-TO-END SYSTEM DESIGN

3.1.1 Objectives & starting point

The objectives of the end-to-end system design activities are mainly related to the preparation of the validation site deployment and are listed hereafter:

- The translation of the user and service requirements into technical specifications,
- The selection of the most appropriate technical solution (satellite broadband Internet access offers and the available wireless local loop solutions),
- The analysis of the regulatory issues for the target country,
- The definition of the validation site network design,
- The preparation of the installation acceptance procedures,
- The preparation of the monitoring system,
- The definition of the evaluation methodology.

A complementary objective has been added to this activity to address the major issue of power supply for communication devices in remote areas.

3.1.2 Main results

The definition of the validation site network design has been completed for all validation sites, as well as the selection of the appropriate technologies depending on the site specificities, the analysis of the prerequisites and the administrative and regulatory authorizations for the deployment and exploitation of the validation site.

Some validation site architectures have been modified during the project life, due to some unexpected issues encountered on the validation site, like performances, technical or administrative issues. The new architectures defined allowed to better fit with the end-users needs and the specificities of each site.

The major issue of power supply has been addressed in the relevant validation sites, in order to provide the adequate power supply solution. UPS have been added to increase the reliability of the power supply, autonomous power supply solutions have been designed specifically, like in Burkina Faso, France or Cambodia and low consumption devices have been designed and developed, following an "energy driven" conception. Furthermore, a global state of the art and a comparative analysis between renewable and fossil energies have been carried out.

3.1.3 Validation site design for educational applications in Burkina Faso

OUAHIGOUYA Validation Site

In Ouahigouya the satellite broadband access is shared between the following users:

- DSF headquarter (Développement Sans Frontières)
- GREF headquarter City Office
- Town hall
- Hospital
- DPEBA (Direction Provinciale de l'Education de Base et de l'Alphabétisation)

The satellite PoP is installed at DSF headquarter. Two point to multipoint Alvarion's BreezeACCESS VL stations operating at 5.8 GHz frequency are fixed on a 12 metres mast., with 120° range flat antennas. The end users are equipped with a BreezeACCESS VL reception station to access Internet and to communicate with the other host sites.

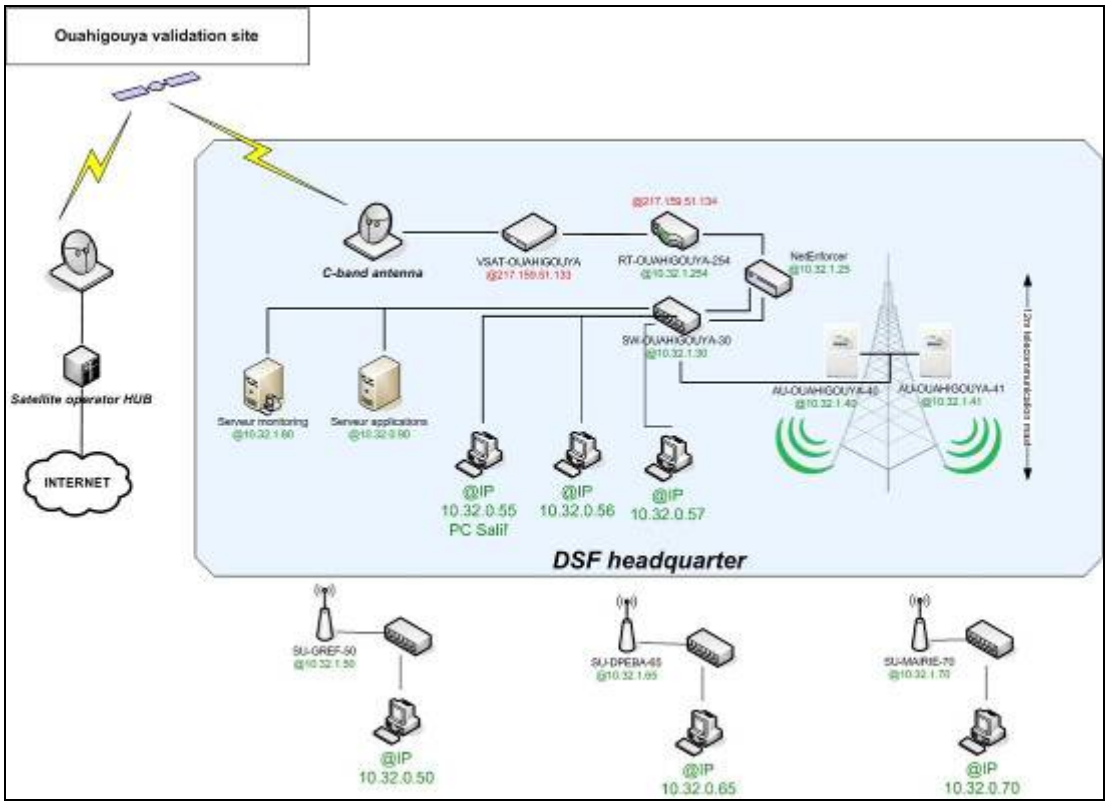


Figure 15: Validation site design – Ouahigouya (Burkina Faso)

BOGANDE Validation Site

In Bogandé the satellite broadband access is shared between the following users:

- FIMBA headquarter
- GREF headquarter
- Town Hall
- Hospital
- High Commission
- DPEBA
- Training centre: Diepergou (located approximately 2 Km far from Bogandé)

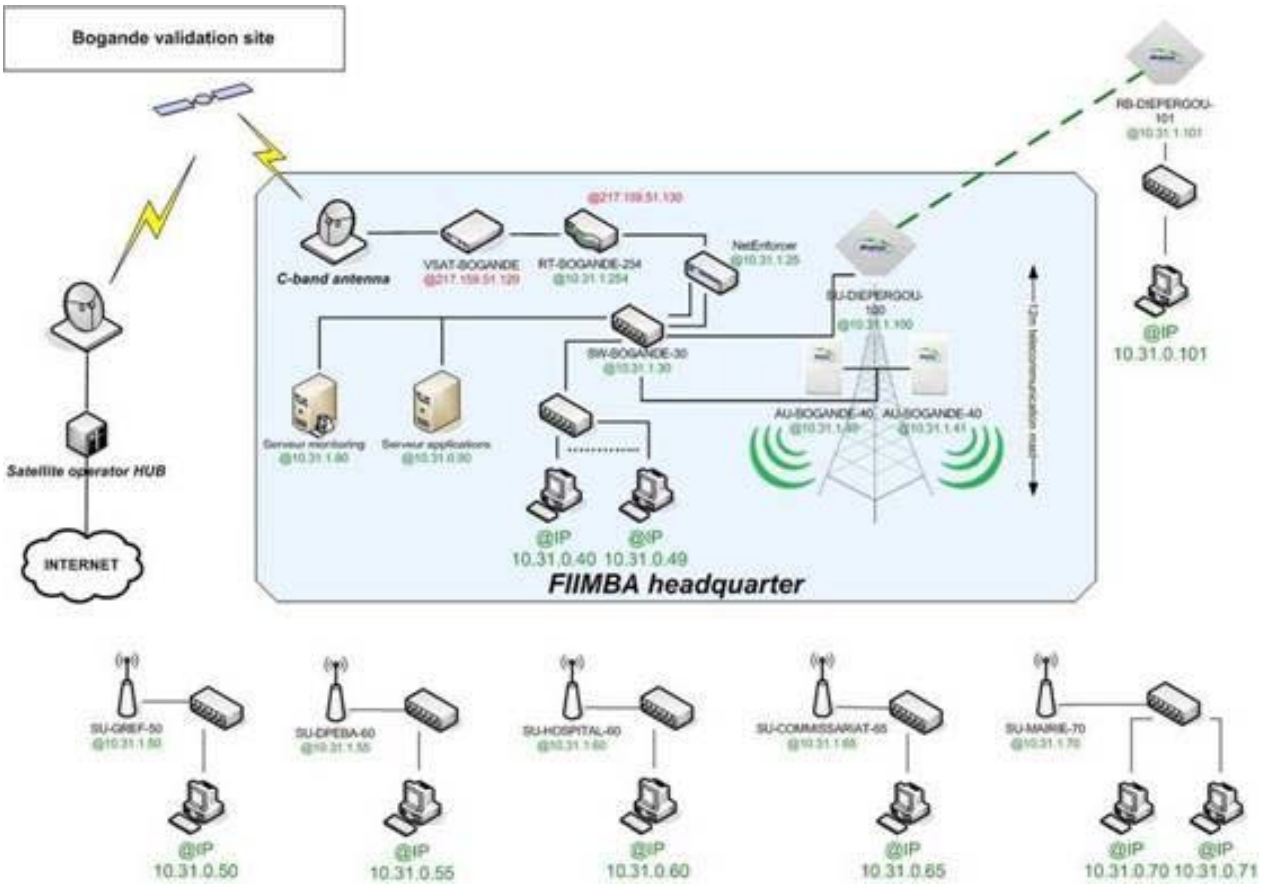


Figure 16: Validation site design – Bogandé (Burkina Faso)

3.1.4 Validation site design for remote medical training in Benin

OUIDAH (IRSP) Validation Site

A Ku-band VSAT station in correspondence to the servers room (room 125) of the administrative and pedagogical bloc of IRSP provides a satellite Internet access service of about 512/256 kbps (downlink/uplink).

Instead of connecting the residential building, the end users considered as a priority the connection of the study rooms through the deployment of a cabled network and of four wireless AP.

The following rooms have been equipped with a wireless access point:

Room	Dimension (LxL)	Height	Distance from the PoP (m)
125	2.85 x 4.85 m	3 m	PoP – Server Room
111	10.90 x 5.85 m	3 m	10 m
123	10.9 x 5.85 m	3 m	15 m
147	4.65 x 8.80 m	3 m	25 m
Amphitheatre	outdoor	9 m	40 m

Figure 17: Relative distances between the PoP and end-users at IRSP in Ouidah (Benin)

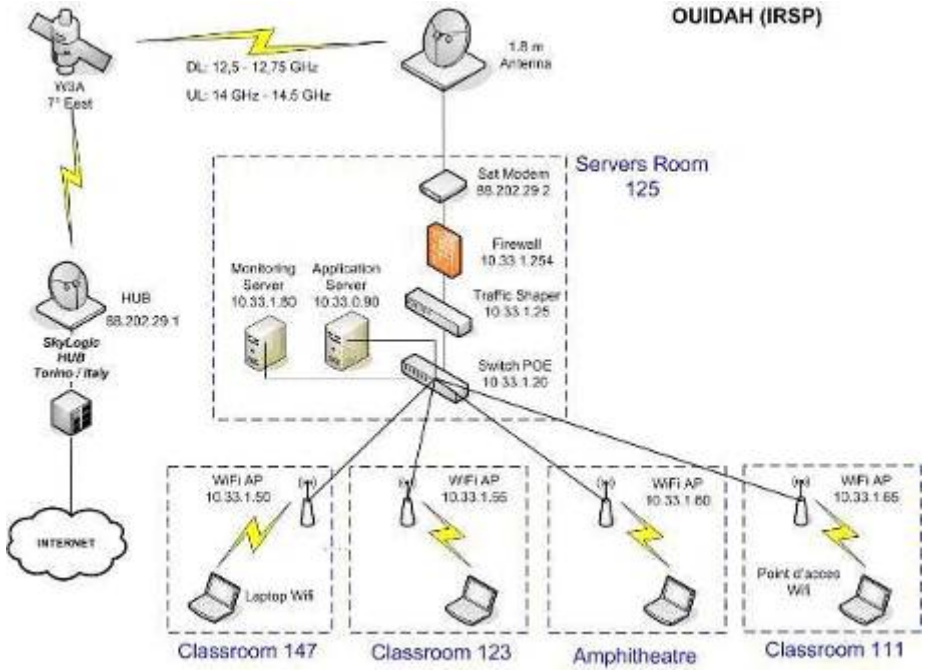


Figure 18: Validation site design – Ouidah (Benin)

PARAKOU Validation Site

Initially, it was foreseen to install the Point of Presence for the satellite access inside the Campus at the AUF headquarter (room 13) as the AUF staff had to be in charge of the local management of the network.

The initial site configuration has been modified before the deployment because AUF could not install the Digital Campus at the University of Parakou before the end of 2009.

Then, a back-up configuration has been considered here, with the PoP installed at the teachers room and a cabled LAN connecting the Library (10 m), the IUT (25 m) and the Cyber Room (35 m).

Room	Distance from the PoP (m)
Teacher Room	PoP
Library	10 m
IUT	25 m
Cyber Room	35 m

Figure 19: Relative distances between the PoP and end-users at Parakou University (Benin)

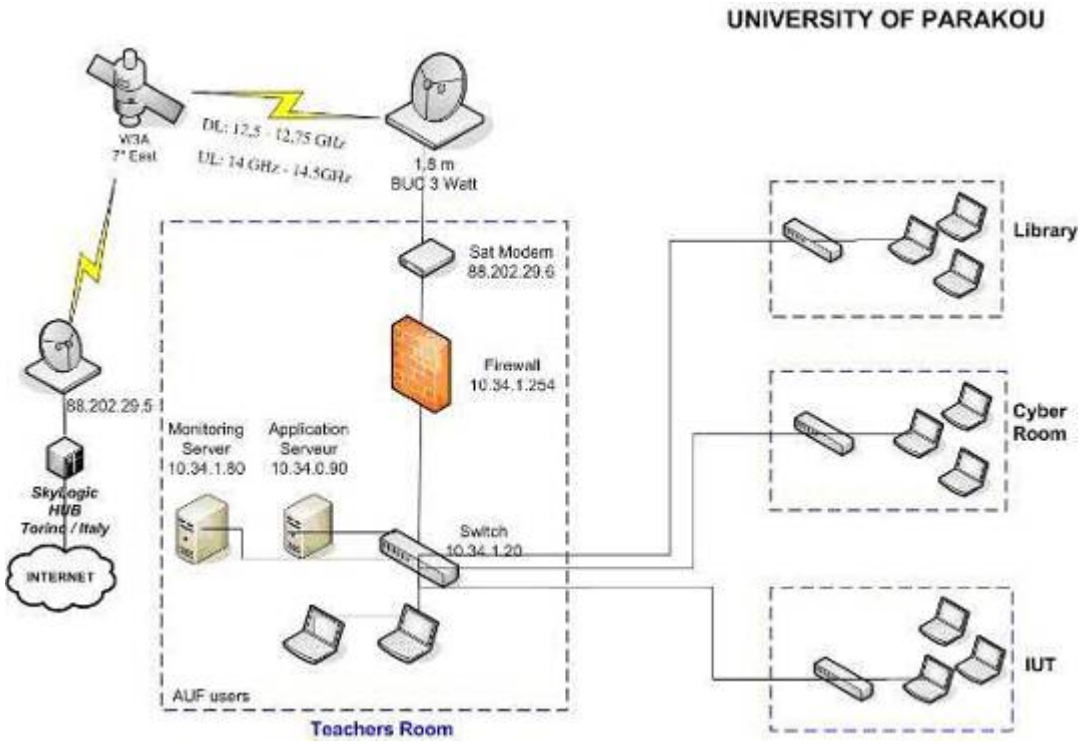


Figure 20: Validation site design – Parakou (Benin)

3.1.5 Validation site design for agricultural applications in France

The validation site is used for the validation on real conditions of all research issues on wireless communications for agricultural and environmental applications carried out by Cemagref and LIMOS research laboratory. On each farm the deployed wireless network architecture allows to evaluate the features of the mesh heterogeneous networks and their possibilities for agricultural and environmental data exchange applications.

The main wireless network components used are the wireless access point and the gateway Wi-Fi/ZigBee. The wireless access point are developed by means of the Wi-Fi router Linksys WRT54G selected for its software configuration possibility, its strength and its low cost. The gateway Wi-Fi/ZigBee developed by LIMOS Laboratory is adapted at this using context. Also the gateway Wi-Fi/ZigBee can be inserted in a wireless sensor or to complete a wireless access point.

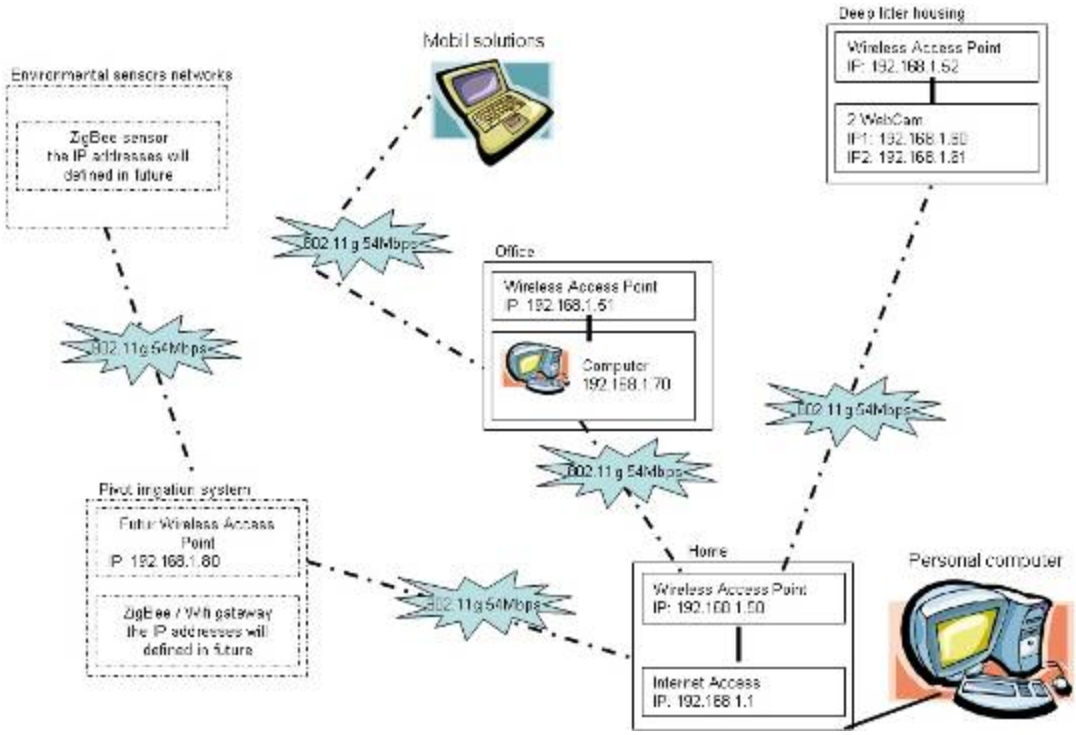


Figure 21: Validation site design – Allier, farm 1 (France)

3.1.6 Validation site design for tourism applications in Turkey

The local wireless broadband network consists of three nodes in secondary zone (1 WOB-200, 2 AP-400) and seven nodes in primary zone (2 WOB-200 , 5 AP-400). The WOB-200 node (WOB-200 #1) in the primary zone is situated in the main lobby building and this node acts as the mesh gateway node #1. This Mesh gateway node is connected to TTnet xDSL PoP via a CPE router owned by hotel administration. TTNET xDSL PoP, CPE router and WOB-200 #1 are all located in the same building so that connecting them through a basic LAN interface would be possible.

The wireless connection between primary and secondary zone WOB-200s is done through outdoor line-of-sight (LoS) wireless 802.11 link and an WOB-200 node located closed to main lobby building has been installed at the top of an erected pole. This outdoor unit (WOB-200 #2) also acts as a second wireless mesh gateway as it is connected to the CPE router via a wired Ethernet interface. Due to hills blocking direct LoS connection between these two zones, WOB-200#3 has been installed at the top of another erected pole situated at the highest point in the secondary private beach area. Long distance LoS directed wireless link had to be used for this connection between WOB-200 #2 and WOB-200 #3 as the physical distance between two disjoint zones is approximately 1.5 km.

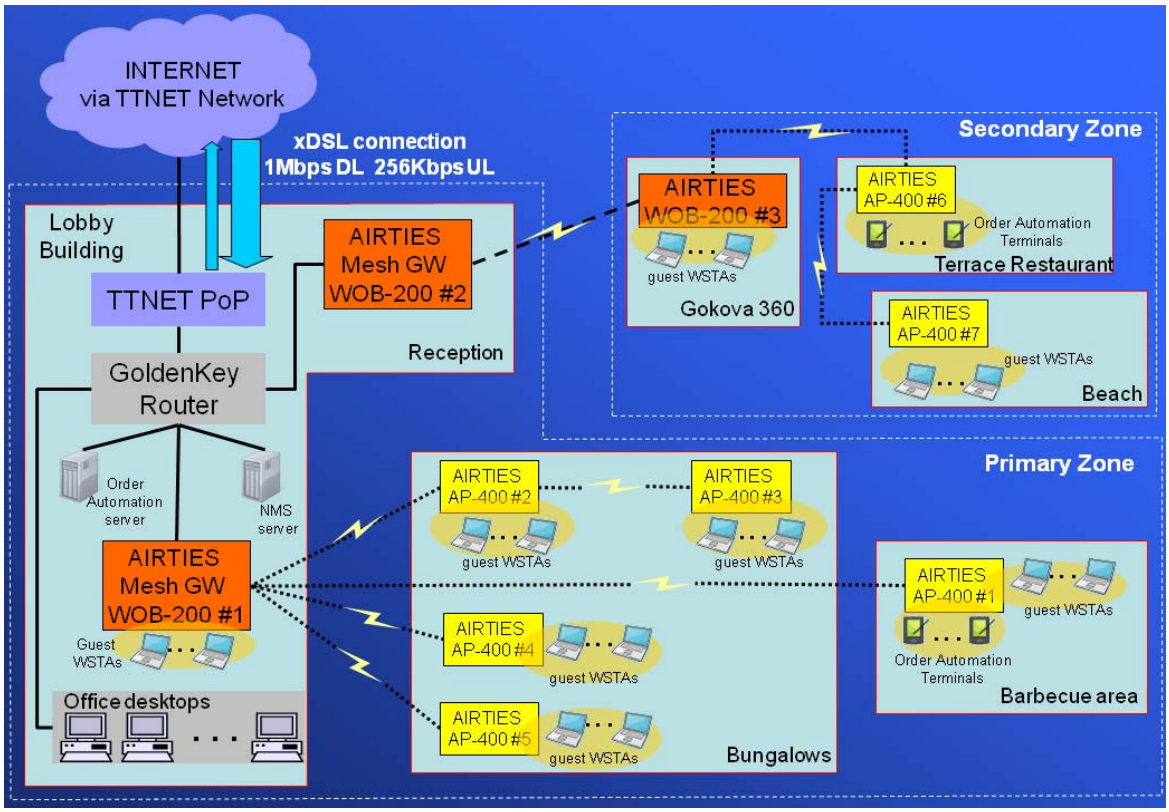


Figure 22 : Validation site design – Bordubet (Turkey)

5 AP-400's in the primary zone are distributed over the main hot-spots such as bungalow, restaurant and barbeque facilities that are the locations where the demand for Internet access is estimated to be the highest. Previous research on wireless mesh networks showed that multi-hop behaviour causes performance degradation due to increased levels of interference and contention. Hence, we aimed to minimize number of hops between AP-400's (that also act as end-user access devices) and the mesh gateway node WOB-200 #1 without compromising good wireless coverage. Consequently, the number of hops between AP-400s and mesh GW WOB-200 nodes do not exceed three in the worst possible case.

Two 1 Mbps ADSL links are used in the broadband side of the hybrid mesh network. The general network diagram and geographical deployment plans for Goldenkey Bordubet validation site are provided in the figures below:

Key Future evolutions

- Adoption of auto-mesh feature in Airties wireless mesh nodes which will bring automatic neighbour selection process that will adapt to variable wireless channel conditions
- Improving the coverage on different parts of the Hotel area based on development and establishment of more facilities
- Hotel customer's oriented specialized IP services such as Video On Demand could be provided with or without an extra charge. Capacity improvements on the broadband connection side and/or higher number of AP nodes might be required.
- Similar hybrid wireless mesh+xDSL or wireless mesh + satellite solutions could be deployed in other Hotel resorts belonging to Goldenkey hotel chain.

3.1.7 Validation site design for community services in Greece

Hellasat was selected as the satellite operator, having managed to negotiate better service than what was initially provided. The offer made by Hellasat was selected based on the following requirements:

- Consistency of performance;
- Low price;
- SNMP support;
- Compatibility with the software used for the installation of the satellite terminal (Siemens ELU).

Information regarding the selected satellite offer and the characteristics of the link are shown in the following table.

Satellite	HellasSat F2
Operated band	Ku
Geostationary position	39° East
Polarisation	Linear orthogonal
Forward link air interface	MPEG2/DBB-S
Return link air interface	DVB-RCS
Downstream/Upstream bandwidth (kbps)	1024/512
Monthly subscription price (€)	355
Installation fee (€)	721
Equipment cost (€)	2975

Table 6. Satellite link characteristics for the validation site of Embaros (Greece)

With regards to the wireless technology, the unlicensed frequency band of 2.4GHz was selected in order to minimize costs in deployment, involving both the use of the band and the acquisition of the radio equipment. The main criteria for the selection of the most suitable technology were:

- Coverage;
- Transmission rate;
- LOS / NLOS;
- Receiver sensitivity;
- Power consumption;
- Cost.

There were mainly three WiFi solutions that were considered for the deployment of the validation sites, namely 802.11b, 802.11a and 802.11g. We evaluated these technologies in order to determine which best meets our needs for the validation sites.

The 802.11g is the newest standard of the three, attempting to overcome the shortcomings of the other two standards. It supports a bandwidth of 54Mbps, like 802.11a, but uses the unlicensed 2.4GHz band so the signal range is good and not easily obstructed. On the other hand, its implementation is more costly than that of 802.11b and, as opposed to 802.11a, other devices may interfere on the unlicensed signal frequency used by the technology. For the reasons described 802.11g is more widely deployed and was also selected for the validation sites. Furthermore, to deal with NLOS transmissions, directional antennas will be used in the validation sites to improve signal reception.

The general architecture of the validation site of Embaros is shown in the following figure.

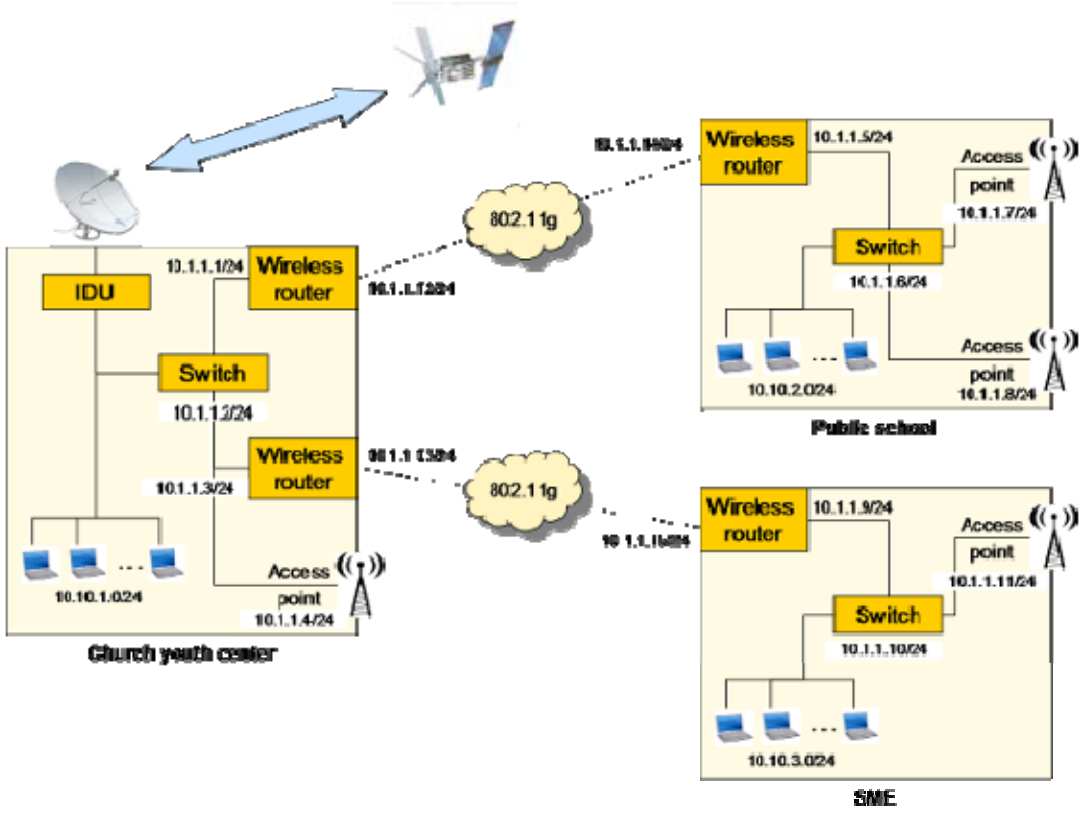


Figure 23: Validation site design – Embaros (Greece)

3.1.8 Validation site design for remote medical training in Casablanca & Istanbul

These sites do not need Internet access via satellite, but high quality multipoint videoconferencing for national and international cooperation in the medical area (oncology and laparoscopic surgery).

None of the sites need wireless systems behind the satellite terminal. From the networking perspective, the main requirement was to interconnect one workstation (PC) equipped with audio and video peripherals to the satellite link on a multicast enabled environment to save bandwidth when multipoint sessions are performed. This link has also to present on-demand guaranteed bandwidth to achieve the required level of quality of the video at a sustainable cost.

Istanbul Medical Faculty validation site: The deployment of the validation site in Istanbul has been completed in May 2007 and since its activation has shown to be continuously operational and stable, confirming the design concept. Network design in Istanbul is comparable to the one in Casablanca described in the next paragraph, in so far as it only involves a satellite terminal and no additional wireless network.

Casablanca Medical Faculty validation site: Three (3) different sites needed to be equipped with a satellite dish: the Casablanca Medical Faculty as initially anticipated, but also the Ibn Rochd Hospital and the Moulay Youssef hospital. The CMF site asked to connect to the satellite terminal three (3) locations in the building, the telemedicine room, the amphitheatre Ibnou Naffisse and a 2nd amphitheatre. Considering the distances, a fibber optics Ethernet link had to be deployed,

The network infrastructure at the level of each site is quite simple as illustrated in the diagram below.

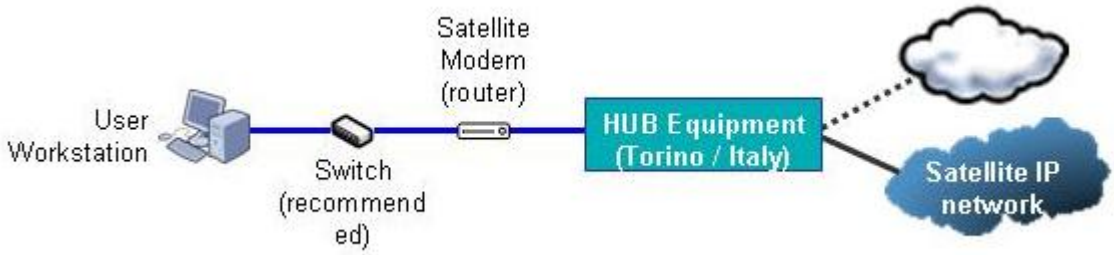


Figure 24: Network infrastructure for both validation sites of Casablanca and Istanbul

The satellite IP terminal is connected directly to a workstation. A public IP Address is allocated to the workstation and the satellite modem is acting as the gateway towards Internet. Resolution of domain names is performed at the level of the HUB. The system enables end-to-end multicast enabled satellite connectivity.

3.1.8.1 Validation site design for educational applications in Morocco

Each validation site is composed of two areas. And inside each of the four areas, the architecture is composed of:

- 1 VSAT terminal. The satellite segment is based on bidirectional broadband services from Eutelsat. The capacity of each VSAT terminal is 1 Mbps downlink and 512 kbps uplink . The contention rate is 1/50 and the type of the service proposed is Best Effort.
- 1 WiMAX Base Station (Airspan products), collocated with the VSAT terminal.
- Several WiMAX Access Points (Airspan products); one per centre to be connected to Internet. The local area network (LAN) behind the Access Point can be configured by a WiFi hot spot or by a traditional Ethernet LAN. WiFi (IEEE 802.11g/b) is an option of the Airspan ProST products. Therefore, this architecture does not require any additional equipment. It is also possible to have a WiFi hot spot and an Ethernet LAN on a single site.

The figures below illustrate the end-to-end architecture solution defined for the sites of Mokrisset and Oulad Mkoudou.

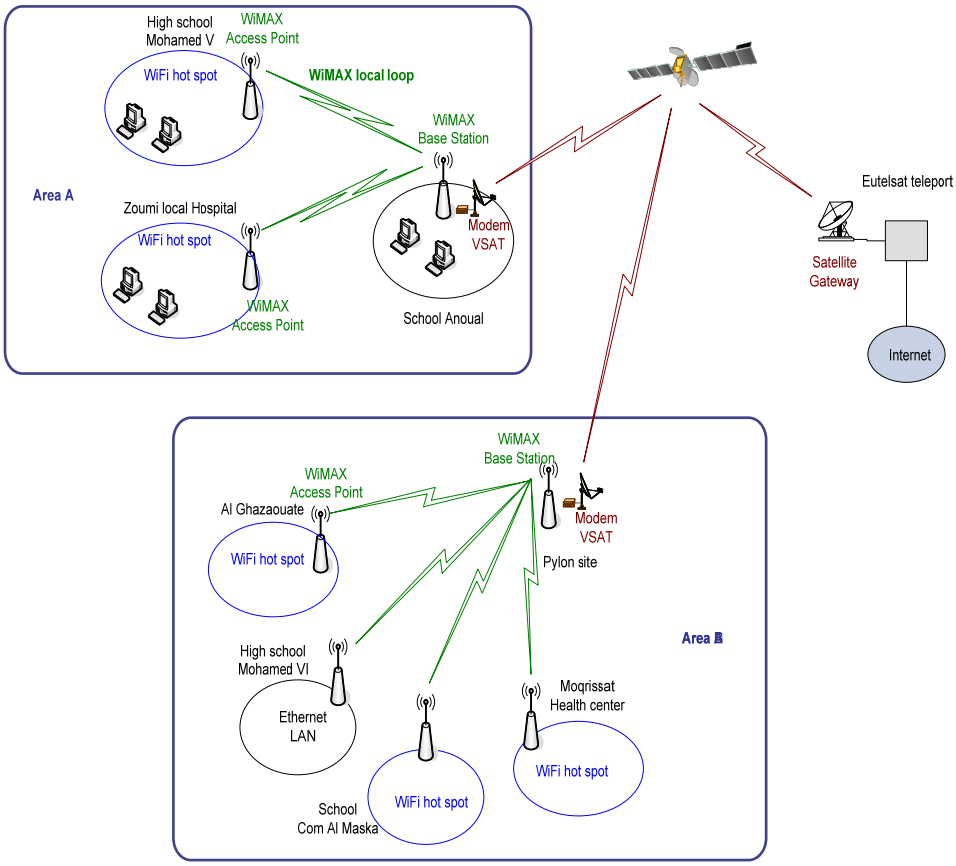


Figure 25: Validation site design – Mokrisset (Morocco)

The areas covered by the WiMAX networks are represented in the figures below, for each area (A, B, C and D) of deployment.

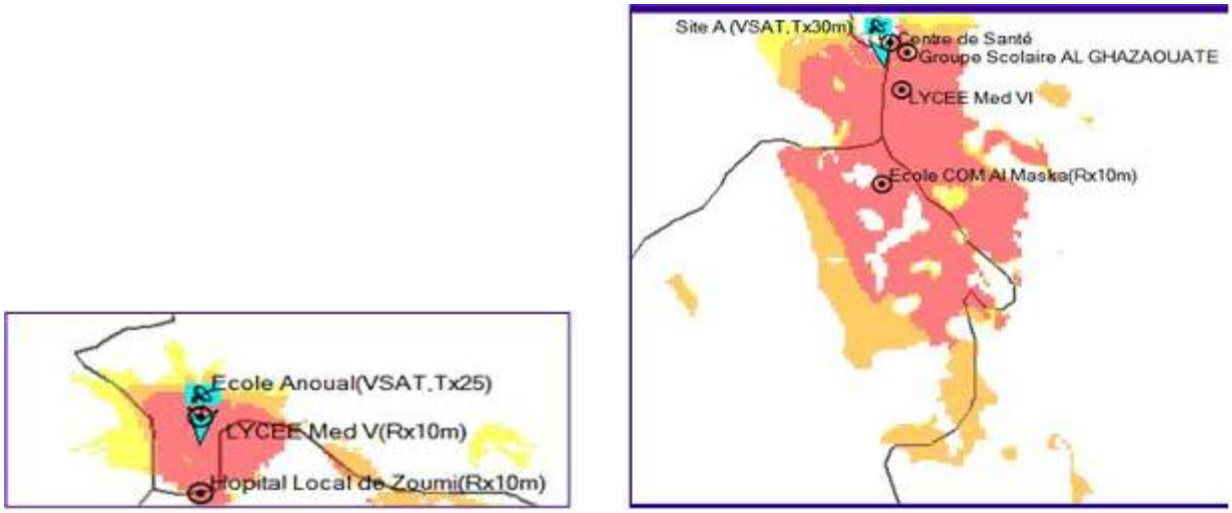


Figure 26: WiMAX coverage plot in areas A and B (respectively) - Mokrisset

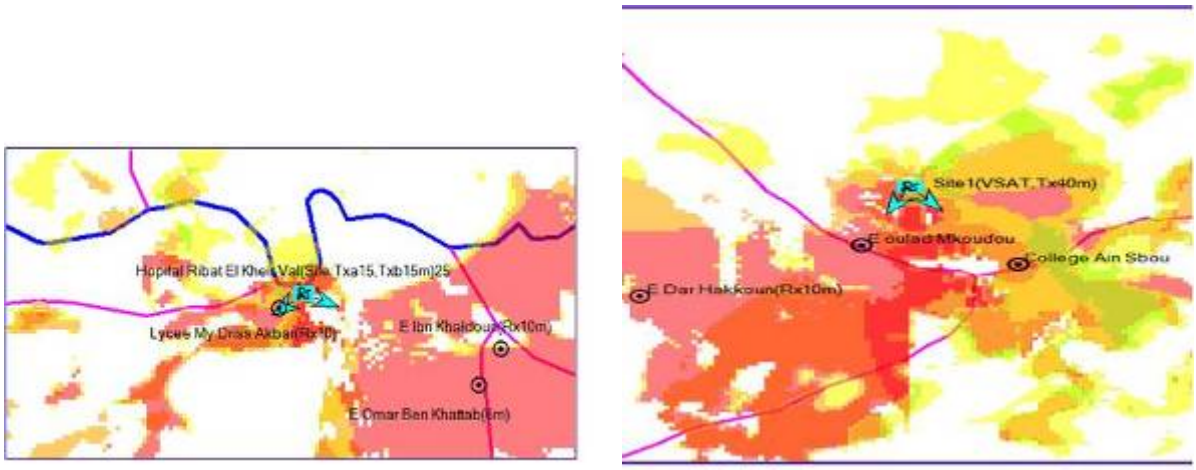
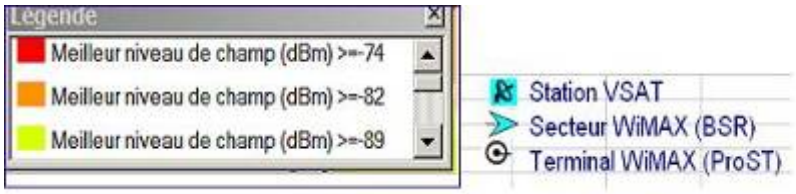


Figure 27: WiMAX coverage plot in areas C and D (respectively) – Oulad Mkoudou



Coverage plots obtained by simulation

3.1.8.2 Validation site design for distant learning in Cambodia

We have successfully deployed both validation sites, one in Phnom Penh and one in Angtasom as originally committed. It should be noted however that the list of schools, universities or partner NGO's actually connected inside the Wireless Network has changed significantly in Phnom Penh. The main change has been the withdrawal of the Ministry of Education, Youth and Sport and associated institutions in Phnom Penh (NIE and DRP), the reason being a relative lack of project drive by the MoEYS in the NETADDED imposed timescales.

To compensate for this attrition, we have added an interesting site in Boeng Salang, a slum north of Phnom Penh. The organization is called Taramana. It is a small NGO helping disadvantaged children with food, health care and education. We have also expanded the list of schools in the Angtasom area, by adding the Takeo Vocational Training Centre and the 1st May High School. All in all we still have 10 buildings wireless connected on our 2 validation sites. Network details are given in the following paragraphs.

Network characteristics

The diagram below shows the status of both validation sites as of December 2008. During several months tests have been run regularly to evaluate the quality of the communication at various levels:

- Internet access speed and reliability for each site
- Communication speed and quality between schools inside the same wireless network
- Communication speed and quality between our two validation sites Phnom Penh and Angtasom, at the application level, i.e. in particular for audio/video conferencing and desktop sharing.

Key deviation and action plan

After several meetings with Camshin technical management over a 4 months period, where we have shared network performance data with them, the conclusion was clearly that the overall system performance with 2 satellite hops was inadequate for real time distant learning applications between PP and Angtasom. More precisely excessive transmission delay and high packet loss result in very poor audio quality, not even mentioning video.

Phase 1

We initially agreed with Camshin to change the network architecture as follows:

- Change the satellite access in PP to a "Long Range Wi-Fi" connection**.** This solution main advantage is to halve the round trip delay between our two sites since we only get one satellite hop.

- Provide us with a static channel access for the Angtasom remaining satellite link. In the normal "dynamic channel allocation", every VoIP packet contends for the satellite resource with many other potential simultaneous users. Every time the resource is overbooked, packet loss increases. This static channel access is a means to grant us a fixed access time and thereby reduces packet loss.

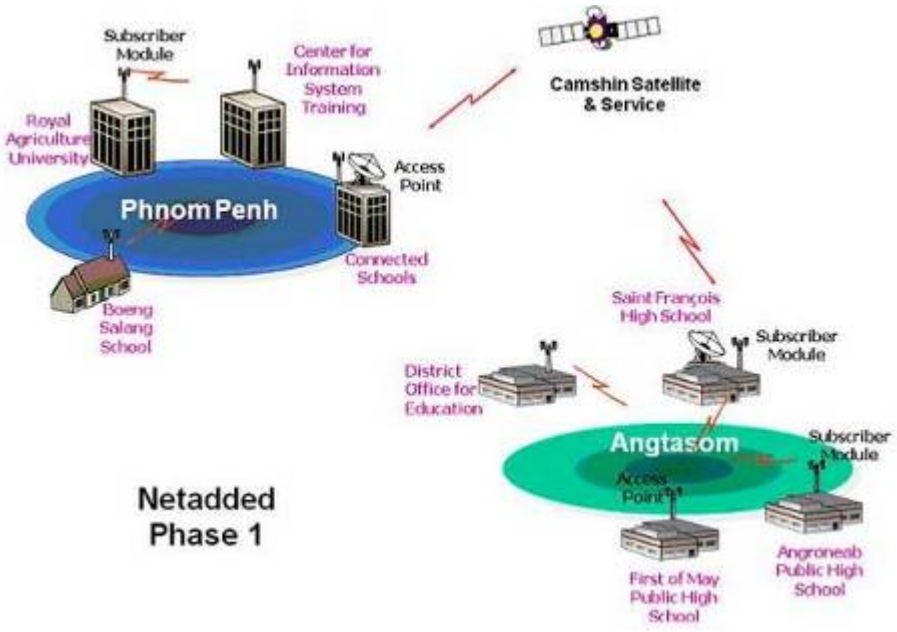


Figure 28: Cambodia validation sites initial architecture - Phase 1

These various actions impacted our communication between Phnom Penh and Angtasaom very positively:

- Packet loss has been virtually eliminated
- Round trip delay has been brought down to 600ms (with no jitter)
- Satellite Internet connection in Angtasaom (speed and rate) improved significantly.
- Overall audio quality score has improved from below 5 to 8 in average

Camshin had initially mentioned that the price impact of this solution would be marginal. Unfortunately after one month of satisfying tests, they sent us the final quote was as follows:

- 750$ per month for the long range Wifi access in PP
- 1500$ per month for the dedicated satellite access in ATS

This was to be compared with a 350$ per month fee (each site) for the shared satellite access. Although it was tempting to pay the bill for the duration of the NETADDED project, it was clear that this price would jeopardize long term project viability and that we had to find another compromise.

Phase 2:

After balancing the various options, we reluctantly went back once more to Camshin asking to try the following option: keep the Long Range Wifi access and the traffic shaper bypass in PP, but go back to the regular shared satellite access in ATS at 350$ per month. Once this was configured we ran another 10 days of testing with the following results.

Network parameters	**Long Range Wifi in PP** **Shared satellite link in ATS**
Average Round Trip Delay (ping)	1300ms
Average Packet loss (Rx+Tx)/2	3%
Average Skype audio quality	5,7

Table 7: Long-range WiFi in Phnom Penh and shared satellite link in Angtasom (Cambodia)

The results matched our expectations. Although not ideal, this is likely the best compromise we could find. This has been documented at high level in our D4 report (Rev2) and in detail in our D30 report.

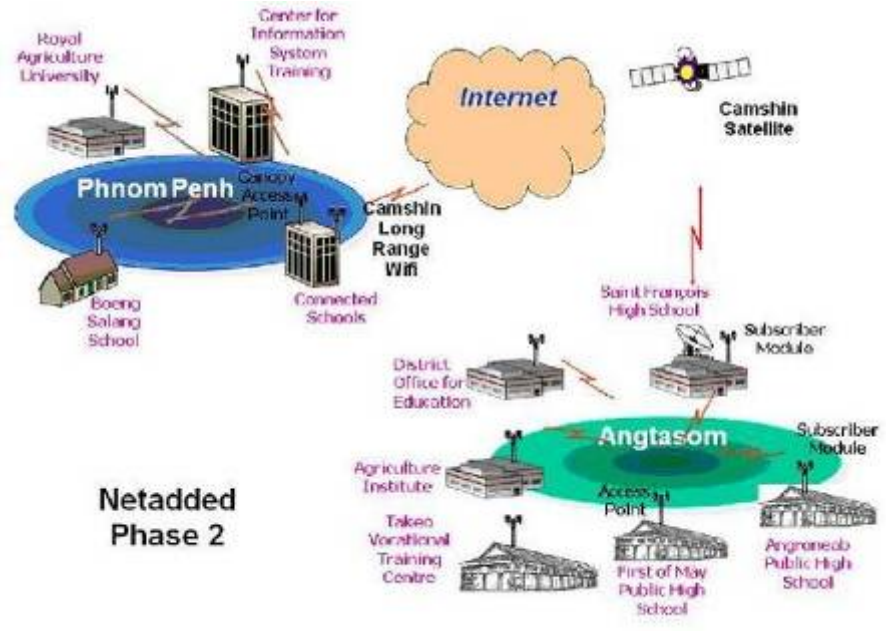


Figure 29: Cambodia validation sites final architecture - Phase 2

The final network architecture diagram is presented on the following figure.

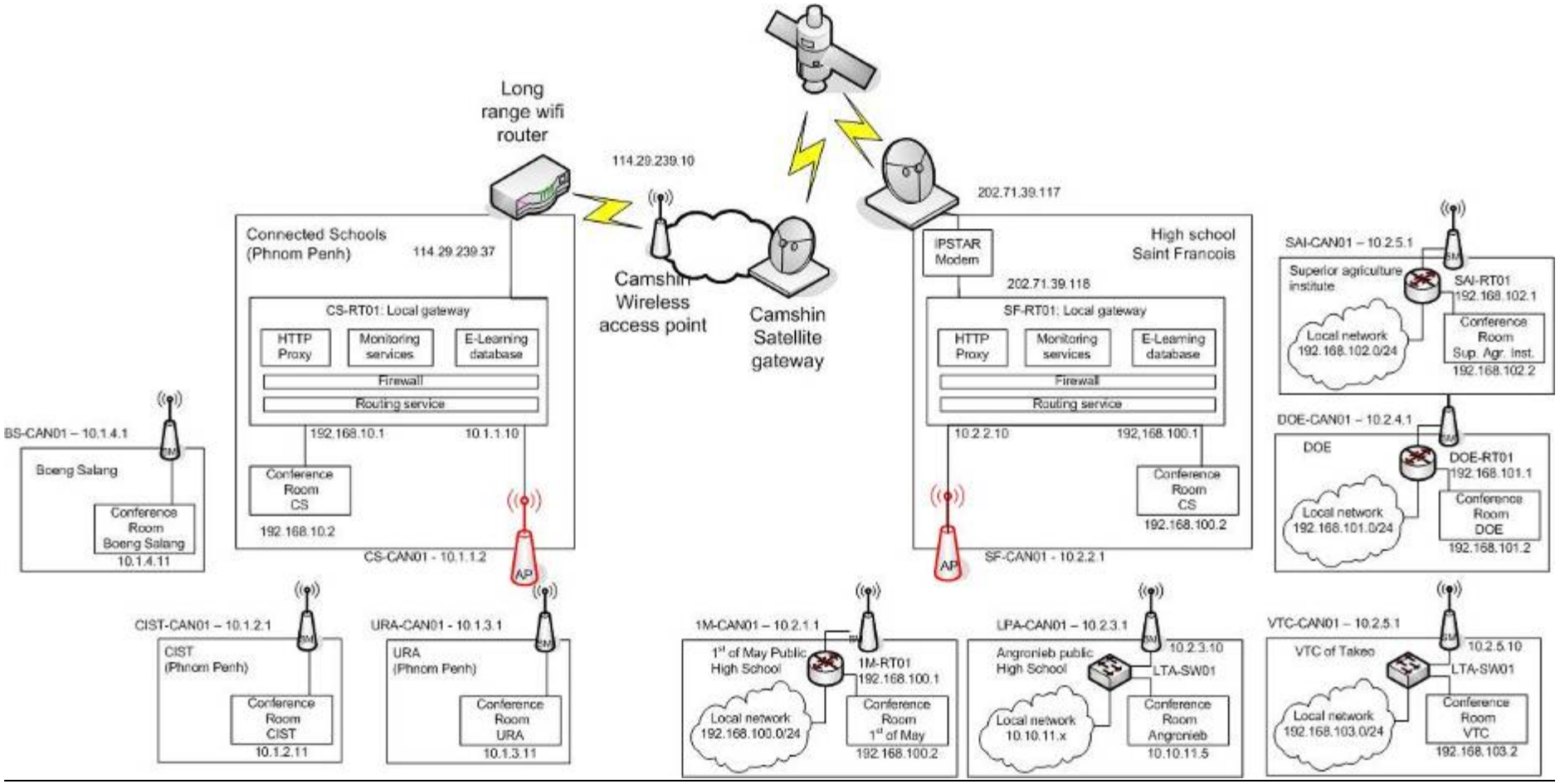


Figure 30: Cambodia validation sites network final architecture - Phase 2

3.1.9 Electrical power solutions in NETADDED

Solar energy, wind energy and fossil energy (group generator) are the major candidates to provide power supply solutions for remote areas without access to the electrical network.

Depending on the geographical conditions of a specific area, one or another solution is more adequate. The sizing of power supply solutions relies on those geographical characteristics and should comprise not only the size of the solar panel or of the windmill, but also the storage capacity of the battery.

Combination of several sources of energy is often considered in order to ensure the reliability and availability of the electrical power. Some typical combinations are: solar panel & windmill, solar panel & generator or windmill and generator.

Solar energy are more predictable than wind energy due to the regularity of the amount of sun on a dedicated area whereas wind is more periodic and long periods without any wind can be encountered. From a general point of view, strong winds are often located closed to the sea coast (as presented on the figure below).

The following figure presents the quantity of solar energy received in the world. As we can see on this map, the African continent is one of the most appropriate areas for solar energy.

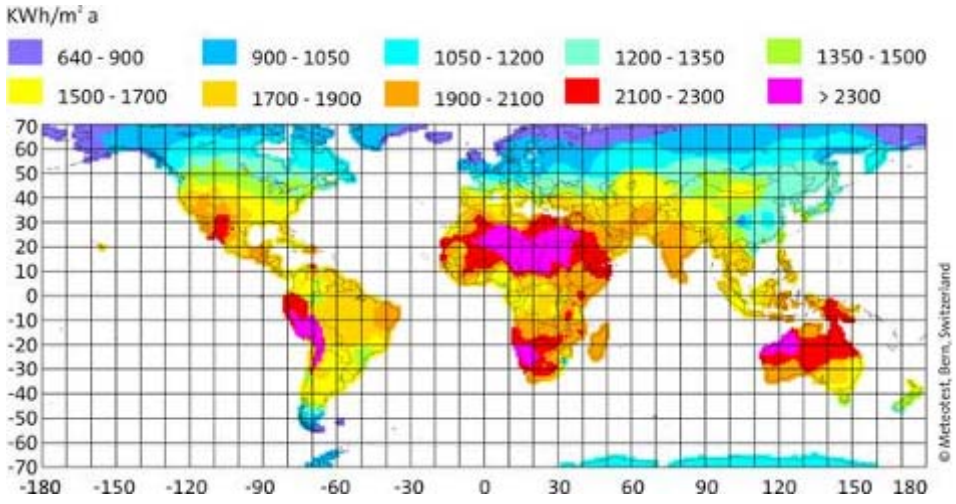


Figure 31 : Level of solar energy in the world (source Météo France)

In the case of solar or wind energy solutions, the economical model are comparable, in the sense that the initial investment is quite important, but the maintenance and recurrent cost are minimised or unexistent. On the contrary the initial cost of a group generator is less important, and the major cost are related to the necessary fuel.

In the context of deployments such as those carried out in NETADDED, the initial cost is often paid by NGO or government institutions, whereas the recurrent cost can be paid by local end-users. Therefore, it may be more suitable in those cases to choose solar or wind energy, in order to ensure the sustainability of the installation. Furthermore, in the case of mobile station, embedded on a vehicle, fill-up of the generator

can be done at the same time as the full of the vehicle, whereas in the case of a fixed station, filling-up the group generator can be problematic if there is no fuel station close to the satellite station.

The life duration of a group generator seams to be shorter than the one of solar panels or windmill.

And finally, the group generator can create a disturbing noise, if it is located close to a classroom or an hospital for example.

Recommendations

The analysis of the existing solutions shows that renewable energies can be less expensive than fossil energy is we consider a large period of usage. Furthermore, even if it can seam more convenient to use a group generator at first glance, the constraints in terms of maintenance, life duration and fuel make it less suitable for the types of deployment considered in NETADDED. The dependency toward the fuel cost and the fact that it represents a recurrent cost are also two major drawbacks.

The choice between solar energy and wind energy depends on the geographical constraints and characteristics. The sizing of the system and in particular the sizing of the battery is a key issue to ensure the complete autonomy of the system. No generic solution can be really described, and each solution must be tuned depending on the specificities of each site, as it has already be done during the NETADDED project in the validation sites of Cambodia, France and Burkina Faso.

3.1.9.1 Power supply solutions in Cambodia

Most schools in Cambodia provinces do not have electricity. It was therefore a natural part of NETADDED project to create a power supply system to power the distant learning centres of the validation site. Since Cambodia climate lends itself well to using solar energy whereas it is not a good place for windmill, the goal was to develop a generic solar power supply system for classrooms in Cambodia.

The usage scenario considered to define and size the photovoltaic system is the following one:

- Five hours per day of distant learning using the Canopy antenna, one computer, an LCD projector, a microphone and loudspeakers,
- Three hours per day of Internet navigation after school hours for four people each using a computer.

The average daily load is therefore estimated at about 2000 Wh/day.

	Model	Quantity	Power (Watt)	Total power (Watt)	Hours/day (Hour)	Consumption (Wh/day)
Laptop computer (main)	Dell	1	43	43	8	344
Video projector	Toshiba DLP TDP P8	1	195	195	5	975
Microphone		1	0,05	0,05	5	0,25
Loudspeaker (additional)		1	8	8	5	40
Antenna and modem	Motorola Canopy	1	10	10	12	120
Router		1	10	10	8	80
laptop computer	Dell	4	35	140	3	420
Light bulb		1	8	8	3	24
Total			309,05	414,05	49	2003,25

Table 8: Power requirements - Cambodia validation sites

The design criterias comprise the cost, the effective supply, the simplicity and the reliability of the solution. The sizing of the solutions focus on the batteries and the solar panels, based on the quantity of solar energy of the area considered. The following graph gives a good estimate of the solar energy by month for our solar panel (data with 26°) associated with the number of black days.

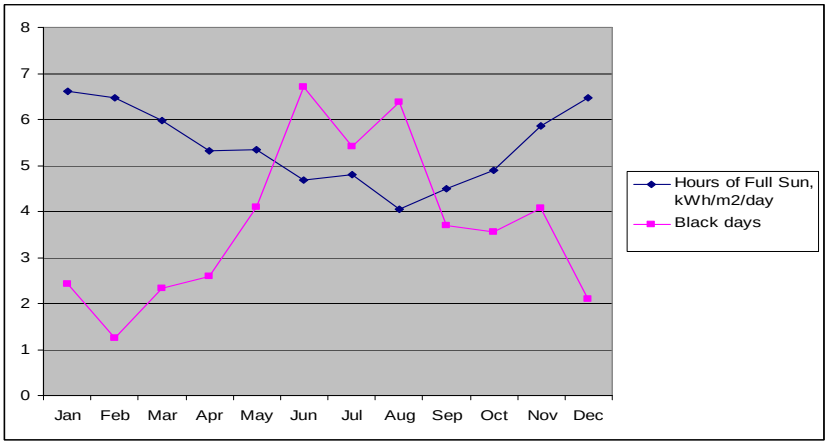


Figure 32: Solar energy and black days by month in Cambodia

The solar array chosen and available in Cambodia from Sharp supplier delivers a peak of 175 Watts. Assuming an array temperature rising to about 70°C and a suboptimal irradiance of 800W/m2 instead of 1000W/m2 due to dust and mist, we estimated based on the supplier data that one array would deliver about 120Watts average. Considering that we have an average of 5.41 KWh/m2 per day or 5.41 hours of full sun per day and we need 2000Wh per day + 12% loss in the inverter, the number of arrays needed equals: (2000 + 12%) Wh / (120 * 5.41) = 3.45 arrays. By taking four arrays, we compensate an estimated 6% loss in the wiring and the charge controller and also provide enough energy to charge our four batteries.

The complete autonomous power supply system for a classroom in Cambodia is therefore described as follows :

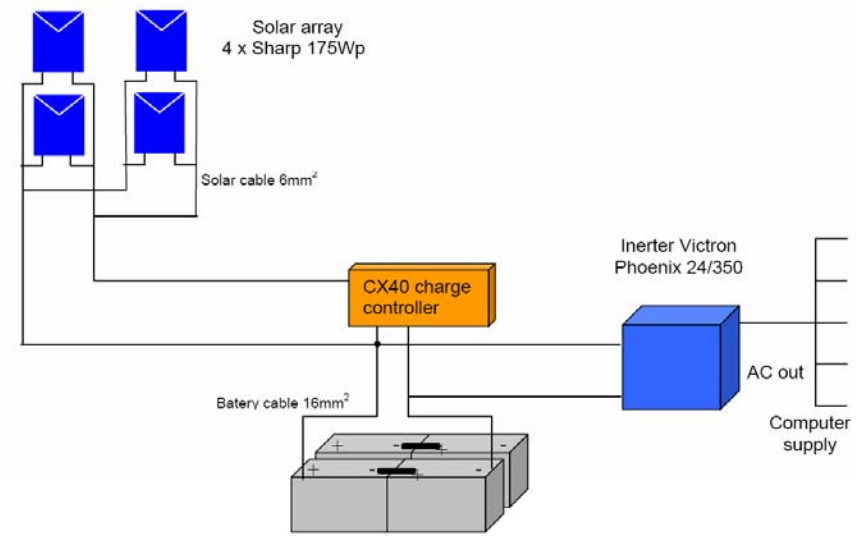


Figure 33: Power supply system block diagram for distant learning centres in Cambodia

Likewise we oversized the battery capacity a little in order to reduce the daily depth of discharge and thereby increase batteries life. Targeting a 50% maximum daily discharge, a 2000 watt.hours power requirement results in 4000 watt.hours capacity. Hence our choice of four batteries of 100Ah capacity at 12 Volts.

Finally as most of the items require a 220V power supply (computers, projector), we also installed a 12V DC-> 220V AC inverter.

Equipment Description	Quantity	Unit Price (in $)	Total Price (in $)
Sharp 24V 175W Solar Panel	4	956	3824
Phocos CX40 12/24 V Battery Charger/ Regulator	1	119	119
Victron Phoenix 350/24V DC-AC Inverter	1	195	195
Haze 12V 100Ah Battery	4	206	824
Others: cabling, connectors, panel mounting materials, sockets, fuse, screws, clips...			330
Labor, Transportation, Lodging	1	250	250
Total (incl. 10% VAT)			**6075**

Table 9: Devices and cost of the power supply solution in Cambodia

In the end, installing a low power (48Watt) LED projector and low power (18Watt) notebook computers enabled us to increase the number of computers to 9. We tested and verified that the classroom was working for nine hours per day with ALL items turned on, i.e. nine computers, one projector and one antenna.

3.1.9.2 Power supply solution for Transportable Terminal in Burkina Faso

In order to ensure the complete autonomy of the transportable terminal used by NGO in Burkina Faso, a power supply solution has been integrated to the terminal. This solution comprises a high capacity battery that can be charged by a solar cover or the external sector.

The PowerFilm foldable solar charger is extremely lightweight and compact.

It is designed for users who need lightweight portable and remote power for laptops, cell phones, satellite phones, GPS units, and other devices and systems. The charger can be folded to a small size that can easily be stowed in a backpack or laptop bag.

The foldable Solar Chargers can be used for:

- Charging 12V electronic devises (with 12V Female Cigarette Lighter Adapter accessory)
- Charging many Lithium, NiCad, or NiMH Batteries (with Battery Charger Pack accessory)

Foldable Solar Charger	
Manufacturer	Global Solar
Model	P3-55W
Public Price	~€1500
Dimensions	Folded: 280x230x33 mm Unfolded: 140x815x1.5
Weight	1.7 Kg
Temperature resistance	-40°C to +80°C
Power	55 Watt
Operational tension	16Volt
Operational current	3.7 A

Table 10: Solar charger characteristics in Burkina Faso

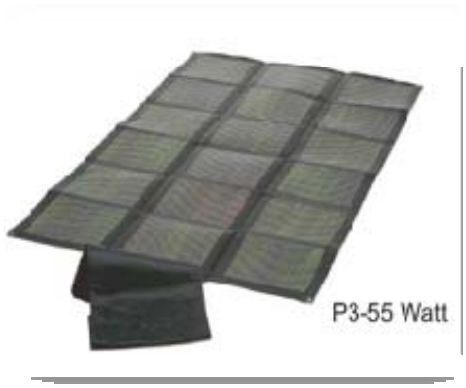


Figure 34: Foldable solar charger

3.1.9.3 Low consumption node for Wireless Sensor Network in France

A Wireless Sensor Network has been deployed in France, for high precision agriculture applications. Regarding electrical consumption, the major objective is to determine low consumption devices for all types of equipment: WiFi router and ZigBee nodes.

In this specific deployment, all WiFi nodes are connected to the electrical network, nevertheless, we decided to design an autonomous and generic solution, based on solar panels, which could be used for future deployments.

Regarding the sensors, energy is a key issue in so far as they are working on batteries. In this case, it is essential that the LiveNodes take into account this major issue, from the conception. This type of conception is also called "energy driven".

Two steps have been considered to address the energy problematic in the validation site of Allier:

- Design and realisation of an autonomous power supply solution dedicated to the routers,
- Optimisation (minimisation) of the consumption of the LiveNodes, from the conception phase of those sensors.

Autonomous Power Supply solution for the routers

The combination of a battery (YUASA 12V 24Ah) and a solar panel (Shell S25 25W) allows a complete autonomy to the WiFi router in terms of energy. In order to ensure an efficient work between the battery and the solar panel, a "solar regulator shunt" controls the output voltage of the solar panel in order to charge or not the battery. This kind of regulator allows not to charge the battery when it is already full and or when the voltage of the panel is lower than the one of the battery.

The sizing of the solar panel and the associated battery allows a complete autonomy to the relay node during three days ("black days"). This sizing has been realised taking into account the router consumption (250 mA), the storage capacity of the battery (24 Ah) and the fact that the battery should not be discharged completely in order to optimise their life period.

The following figures show the relay node and its associated solar panel.

Figure 35: Autonomous relay node with solar panel

Low consumption LiveNodes

LiveNode conception is considered as « energy driven », which means that the choice of devices and components are realised in order to minimise the energy consumption, both for hardware and software.

Therefore, the design of the LiveNode comprises ZigBee modules and a pull-up and pull-down alimentation regulator in order to enhance the life duration of the batteries.

The electronic card of the LiveNode comprises an innovative mechanism to manage energy consumption. It is based on the combination of a voltage regulator and a real-time clock (or RTC). The RTC is derived from new developments and can switch off or switch on the voltage regulator. When no action is required the major components of the card are switched off, except the RTC, which consume about 50µA. Therefore the global autonomy of the system relies on the frequency of the actions to be realised like measure acquisition or measure transmission. The following figure presents the electronic card of the LiveNode.

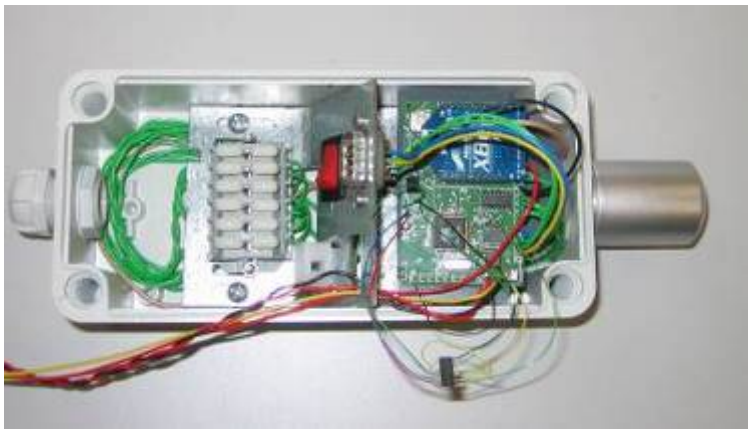


Figure 36 : Electronic card of the LiveNode

This sizing allows a complete autonomy to the sensor during 9 months. The usage hypothesis is one measure each day (typically for humidity measurement).

In order to improve the autonomy of the LiveNode, a complementary solar panel could also be envisaged.

3.1.9.4 Low consumption device for Remote Control in Greece

One of the fundamental requirements for the remote control framework to be used at the NETADDED validation sites is to be able to operate in areas with limited electrical power. To address this requirement an appropriate hardware solution for the NMS installed at the validation sites has been selected.

For the installation at the validation site of Embaros (Greece) a mini-ITX technology board has been chosen, in view of its low electrical power consumption and small size. An appropriate enclosure has also been selected as well.

The chosen solution combines the following elements:

- Low power CPU.
- High efficiency PSU (over 96% efficiency).
- Wide input PSU, operating at 6-26V wide input, delivering 60 Watts/80 Watt peak of power.
- Flash disks.

As a result, the power consumption is only 13.5 watts at the socket, on average. More detailed hardware specifications are presented in the following table.

Motherboard & CPU	mini-ITX motherboard and appropriate processor with low-power requirements. VIA EPIA EN12000EG [RD01].
Hard disk	20 GB Automotive grade, Hitachi 's Endurastar J4K30 [RD02]; A 4GB SSD.
Enclosure	Serener GS-L10 [RD03].
Power supply	6-26 Volts DC input, 13-15 Watts consumption [RD04].

Table 11: Hardware low power specifications of NMS for remote control

The photos of the NMS solution and the picoPSU-60WI power supply solution are shown on the following figures.

Figure 37: NMS solution for remote control

Figure 38: Pico PSU-60WI power supply solution

3.2 DEPLOYMENT IMPROVEMENT – INSTALLATION PROCESS

3.2.1 Introduction

The deployment improvement activities, which are the focus of task 4.2, contribute to the project's objectives by addressing the need to simplify the installation and deployment of satellite-based solutions, to better fit with local conditions for wider scale adoption of broadband infrastructures in the target countries.

In order to establish and maintain reliable and high quality two-way communication services via satellite and in order to avoid interference to an existing service caused by unauthorized and/or out-of-tolerance transmission, operators are requested to perform a pre-transmission line-up when accessing a satellite for the first time. For this purpose, one of the challenges of installing low cost small earth station terminals is that for the initial antenna alignment and terminal configuration a service technician is required which needs to be trained to install bi-directional satellite communication systems. Consequently, the deployment of a satellite-based telecommunication system consumes a lot of time and money (traveling costs, expenses, etc.). Addressing this critical point is the main focus of the activities in task 4.2.1 of the project.

The work that has been carried out has focused on two main directions:

- Implementation, or adoption, of a software application to aid the local operator in the initial alignment and configuration process.
- Development of an installation manual, familiarizing the installer in the use of the software and greatly simplifying the entire process.

3.2.2 Synthesis of user and service requirements

The constraints and assumptions which need to be satisfied for the realization of the line-up functionality are the following:

Requirement	Feature to be implemented
Low cost solution	• Adopt a cheap solution or implement one.
Terminal identification and configuration	• Authenticate and register the terminal with the central site.
Antenna alignment	• Guide the operator through the initial line-up. • Provide continuous monitoring of the antenna alignment. • Configuration of GPS coordinates. • Minimize cross polarization interference.
Centralized management of Line-Up data	• A web based management interface should be provided.

Procedure followed should be independent of terminal and HUB vendor.	• Take into account different vendor offerings.
Usability	• Provide an instruction manual to assist the installer, through videos, screenshots and diagrams, in effectively using the system.

Table 12: Line-up user requirements

3.2.3 Selection of adapted line-up solution

An evaluation of three potential solutions that address the satellite terminal installation and the line-up process was carried out. As a result of that evaluation the Siemens ELU software was employed as the solution to address the terminal installation process.

The ELU system is targeted towards assisting technicians to perform the line-up procedure more efficiently. To address the need to enable a non-technician (i.e. the customer) to perform the installation procedure, we designed and developed a user guide to assist the client in using the ELU software to perform the installation of a satellite terminal without requiring the presence of an expert technician.

3.2.4 Development of the instruction manual

Work focused on providing the necessary material, in terms of user guides, videos, etc., to assist a non-expert user in performing the required alignment operations. After the development of the material which took place in the reporting period an evaluation process followed which consisted of two distinct steps. The first step involved a first round of improving the material without actually testing the software application. In this first phase it was necessary to get some feedback from typical non-expert users as the material was prepared by technicians. This was very helpful in order to identify concepts and parts of the procedure whose detailed explanation was overlooked or taken for granted.

The second evaluation phase involved testing the actual software and performing several line-up tests on the actual validation sites where the software was to be installed.

Specific actions that took place during the working period include:

- Modified the ELU software installation procedure to meet our requirements.
- Created an online user guide to ease the use of the software while performing the terminal installation and help the user get familiarized with the concepts and procedures involved.
- Created videos of the installation procedure to further assist the user in understanding the steps involved.
- Finalized the design document for the terminal installation. More details can be found in deliverable D6.

- Finalized the report regarding the presentation of the line-up user guide. More details can be found in deliverable D7-8.
- Carried out the laboratory tests for the line-up system. The tests involved performing several line-up runs by typical non-expert users in a simulated environment. More details can be found in deliverable D9.

In the following figure the main page of the ELU guide is shown.

Figure 39: ELU user guide interface

The manual consists of a navigation area on the left and the content area on the right. In the navigation tree, each entry represents a link which enables direct access to a certain page. The navigation tree is divided in main sections and sub-sections. On the top right of each page there are navigation buttons that direct to the previous page or to the next topic of the guide.

A large part of the instruction manual involves a step-by-step walkthrough of the installation process. This ensures that even if the user does not fully understand how the line-up process is performed, s/he can still carry out the terminal installation, following screen-by-screen instructions, and verify the success of the procedure.

Besides the main topics that explain the installation process in a step-by-step manner, the guide also includes topics for troubleshooting installation issues, a glossary describing some common terms and concepts of the installation process and some links where additional information can be found.

In addition to the step by step explanation of the installation process the guide also includes several descriptive diagrams that help the interested user to better understand how each aspect of the line-up process is performed. Furthermore, there are several informational videos throughout the user guide that direct the installer in performing specific actions. Videos have been recorded for each crucial aspect of the installation process including mounting of an antenna, starting the ELU Client software, starting the ELU line-up procedure, performing the antenna and polarization alignment, etc.

3.2.5 Laboratory tests and validation

The largest part of the activities in WP4.2.1 during the reporting period focused on planning and carrying out the tests for the line-up system. The line-up system is comprised of two distinct parts: the ELU software, and the associated instruction manual. These two elements were not tested separately as the instruction manual essentially constitutes accompanying resource material and the effectiveness of the provided installation procedure as a whole needs to be evaluated.

So the work was logically structured in two parts: the integration test plan and the test case results. The test plan describes the integration approach and provides input which is essential in order to understand where the test efforts are focused on and how they need to be carried out. The second part details the test cases which have been identified in the test plan and presents the outcome of the execution of the tests in appropriate format, i.e. tables, charts, etc.

The requirements specified in deliverable D6 constitute general acceptance criteria for the line-up system as a whole and thus serve as the basis for defining the scope and the pass/fail criteria of the tests. Even though testing, in general, involves several phases in a product's lifecycle, due to the fact that the line-up software is an off-the-shelf application that has been selected for our purposes, the test scenarios mainly involve integration testing. Furthermore, due to the nature of the software, and its intended use in the project, our tests are mostly concerned with usability aspects, in order to verify that the installer is able to carry out the initial alignment and configuration of the satellite terminal.

In the test plan we focused mainly on the instruction manual for the line-up software, which is the part that has been developed in the project and is available for modifications and improvements. On the other hand, the evaluation of the ELU software, which is used to perform the line-up, was part of the process which was used to select the most appropriate software to satisfy our needs for the deployment improvement. Therefore, the ELU software was not tested explicitly, even though to perform the tests the ELU was obviously utilized.

Three aspects of the system were tested: functionality, performance, and usability. Essentially, the tests were carried out to provide proof of the system's alignment accuracy and ease of use, and to verify that its behavior and capabilities conformed to the specified functional requirements. In particular, the main functional aspects of the system that were tested are:

- Antenna alignment: the ELU application should support all relevant configuration issues and provide the necessary feedback during the initial antenna alignment phase.
- Antenna polarization alignment: an antenna must both be pointed correctly at the source of reception/transmission and, in the case of linear polarization, it must also be oriented about its axis in order to minimize cross polarization interference (CPI).
- Terminal registration: after the configuration has been finished the application should initiate a line-up request transmitting authentication information in order to get registered on the central site.

Performance is used slightly differently here as opposed to its typical use in software engineering. In essence, the performance measured in the tests represented the accuracy with which the antenna was aligned. In other words, performance was measured by checking the quality of the signal after the satellite terminal installation. Performance was measured following the process described below:

- A technician used a spectrum analyzer to optimally align the antenna.
- The antenna was aligned using the line-up software.
- The system's performance was computed after a significant number of alignments had been carried out.
- The system's performance is compared to that obtained by optimally aligning the antenna by the expert technician.

To test the accuracy of the alignment we measured the signal's strength (EIRP), and the signal to noise ratio (SNR) value. We also recorded the deviation of these measurements from the corresponding measurements obtained by an optimal alignment. A test was considered complete when acceptable SNR and EIRP values have been achieved, or at most 4 adjustments of the antenna have taken place in order to improve each measurement. An acceptable value for SNR is 10db, while an acceptable value for EIRP is 43 dbW. The average deviation from the nominal accuracy values in the five performance test that were executed is approximately 15% for the SNR measurement, and 10% for the EIRP measurement.

In the usability tests the goal is to measure the ease with which users accomplished the specified task. Unlike test case descriptions in other test categories (e.g. functional test cases), in usability test cases no explicit description is specified as to how to perform the test. Clearly, the goal is for the user to be able to easily identify the required steps to perform the task and perform the necessary actions efficiently.

Furthermore, the test cases are not considered separately; the user is expected to perform the tasks described in the various test cases as a sequence of actions, simulating a complete line-up session. Before carrying out the tests the environment was appropriately setup so as to ensure that each test was valid.

The tests have been carried out by three different user groups, each having an increasing level of familiarity with the system's interface and satellite terminal installation in general. The first user group is

only familiar with the basic concepts and functionality of the system but has no familiarity with the interface or satellite installation at all. The second group has a minor familiarity with the system's interface but no experience with satellite installations. The third group involves an expert technician who is assumed to have excellent familiarity in all areas mentioned. The performance of the user belonging in the third group is considered optimal and is only used as a reference point to compare the performance of typical users of the line-up software with that of an expert technician in the field.

Test case description	Average time to complete test
Assemble the antenna and the ODU.	151.5 mins
Install the IDU.	7.5 mins
Connect the cables between the IDU and the ODU.	16.5 mins
Install the ELU client application.	5 mins
Start the line-up procedure.	2.5 mins
Perform the initial alignment maximazing the SNR value.	26 mins
Perform polarization alignement.	29.5 mins

Table 13: Line-Up usability test measurements

It took approximately 143 minutes to the expert technician (user group 3) to perform the line-up, using standard equipment (not the ELU software). It took, on average, 242 minutes for users belonging to the first group to complete the line-up, while it took 235 minutes for users belonging to the second group.

In general, the tests showed that the usability of the system is quite good. Obviously, we cannot expect from users with no technical expertise to do as well as an expert technician; and this was evident from the tests. However, the system did allow all users to perform an acceptable line-up and establish the necessary communication link.

3.2.6 Integration and validation under real conditions

The satellite terminal installation has been carried out in Embaros validation site in Greece, by the local representative of the selected satellite provider (HellasSat). The deployment to this validation site has been without problems and the expected functionality has been verified by carrying out simple functional tests.

The usability and effectiveness of the line-up framework has been verified by the local administrator at the validation site. The local administrator was able to use the associated instruction manual as a reference manual and troubleshooting guide to assist in the installation and resolve a few minor issues that were presented. The installation manual has received very positive feedback, especially with regards to the

included videos which were very informative and helpful in explaining the general deployment procedure and the ELU system in particular.

The installation time was found to be more or less the same as that recorded in the tests. This was expected because the environment in both cases does not affect the time needed to perform the installation; the installation is affected only by the expertise of the installer and the tools used to perform the installation – which in both cases are more or less the same.

Space Hellas S.A. (www.space.gr) assisted in the use of the ELU system, providing the Siemens ELU server to perform the tests, as HellasSat is not equipped with the necessary infrastructure to support the ELU system. Space Hellas was chosen due to the fact that they are the official representative of Siemens Space in Greece.

In Figure 40, the deployment of the satellite network and the general operation of the ELU line-up system is illustrated.

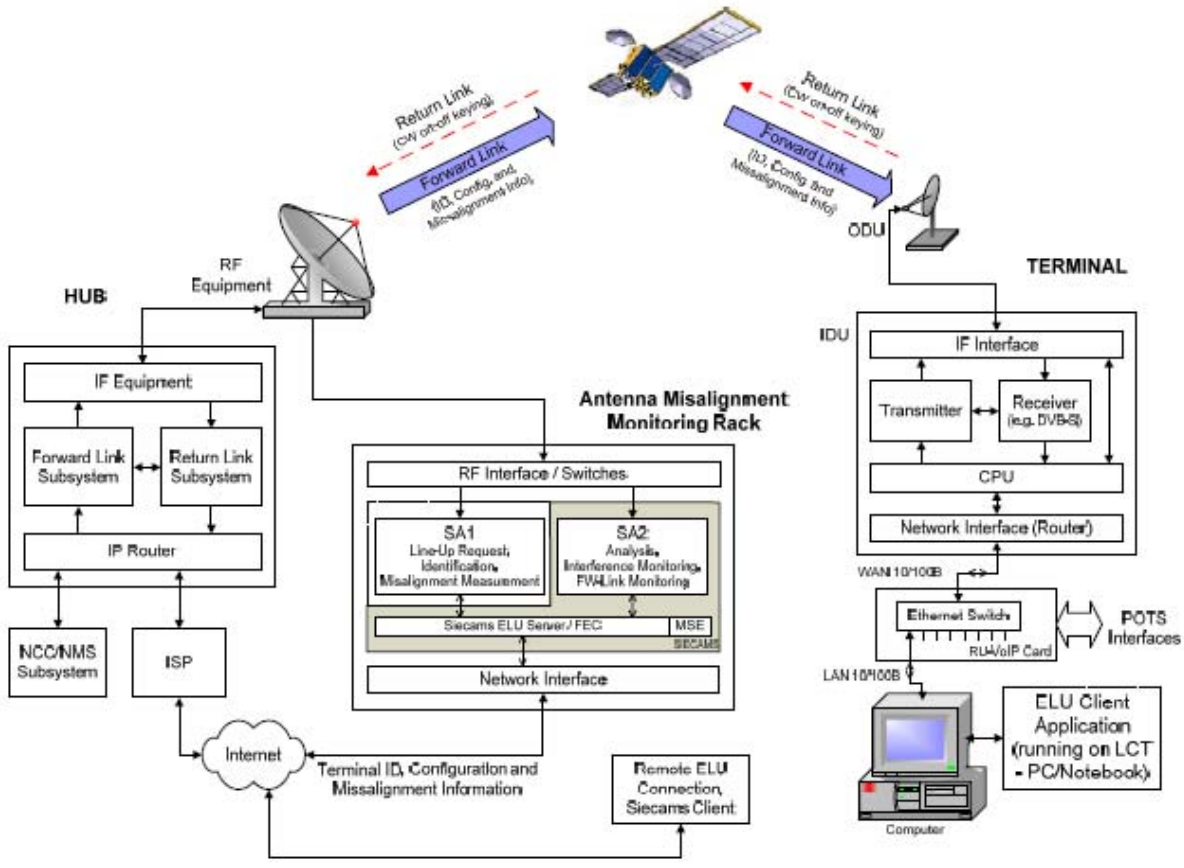


Figure 40: Satellite Network showing ELU-Server system and ELU-Client application (courtesy of Siemens Space – www.siemens.at/space)

3.3 DEPLOYMENT IMPROVEMENT – TRANSPORTABILITY

3.3.1 Introduction

Currently, NGOs working on educational and alphabetisation programmes in Burkina Faso - in direct contact with the most isolated rural populations - do not have access to any affordable telecom infrastructures.

This factor makes exchanges with NGO headquarters very difficult and results in a real loss of efficiency for the educational programmes.

Moreover, most of the local populations - the target of NGO humanitarian actions - are largely illiterate and do not have any kind of access to information or any means of communication with other communities.

In this context CNES designed and developed a transportable satellite-based solution adapted to the real field conditions of Africa, that could be used by the educators during the teaching courses to introduce new pedagogical methods: multimedia contents, documentaries, on-line exercises, videoconferences and so on.

Different candidate solutions were analysed in order to answer to the different user requirements in terms of application scenarios and to the technical constraints in terms of performances.

The trade-off was based on different criteria, taking into account:

- Robustness and compactness of the solutions
- Capability to suit African temperature and humidity conditions
- Ability to be easily deployed by non-qualified personnel
- Equipment and service costs
- Geographical coverage

A prototype of the transportable terminal was implemented and tested in real field conditions by local NGOs. The validation period lasted 6 months, from October 2008 until March 2009. The NGO staff carried the transportable solution to the different learning centres and each training centre benefited from the solution for about one month. Corrective actions were taken by CNES from the NGOs feedback. A new solution was implemented and finalised in June 2009.

3.3.2 Synthesis of user and service requirements

The following user and service requirements have been taken into account for the implementation of the transportable solution:

Compact	All the equipment fit in a compact suitcase, including the satellite antenna, whose dimensions respect the hand luggage requirements for transport by plane.
Performing:	The data rate should be adapted for real-time applications (at least 200 kbps)
Suited to high temperatures and humidity rate	The suitcase should be waterproof and dustproof
Resistant to shocks and vibrations that may be endured during transportation	All components should be characterized at least by a Protection Index IP54.
Completely autonomous in terms of electrical energy supply.	Use of a high capacity battery and a light foldable solar charger
Universal	The system should be compatible with all operating systems (PC, Mac, Windows, Linux...) Worldwide coverage should be available
Cheap	As the need to access Internet through the transportable solution is not continuous for the target communities, fees on traffic data is preferable than a fixed subscription.

Table 14: Transportable terminal requirements & specification

3.3.3 Transportable solution design

CNES designed a transportable terminal, called ABCS@T (Always Be Connected by satellite), composed of four main functional blocks:

- Internet Connection: the solution includes a satellite terminal providing Internet access up to 464 kbps. An Inmarsat BGAN Explorer 500 is used.
- WiFi Connection: the solution includes a WiFi router allowing different simultaneous users to access Internet. The router communicates with the modem via Bluetooth or a cabled link.
- End-user terminal: the solution includes a Bluetooth telephone, directly connected to the BGAN system and a tablet PC, connected to the router via WiFi.
- Power supply system: the solution includes integrated high capacity batteries that can be charged by a solar cover or the external sector.

ABCS@T terminal was designed in order to provide a transportable solution to be used in a rugged environment and to be deployed by non technical profile personnel.

A prototype of the solution was implemented, using robust and well suited equipments, answering to the IP54 certification requirements. The devices were integrated and fixed inside a robust suitcase in order to be protected against vibrations caused by the transportation. A simplified user interface was designed and set up to simplify as much as possible the configuration process necessary to use the terminal.

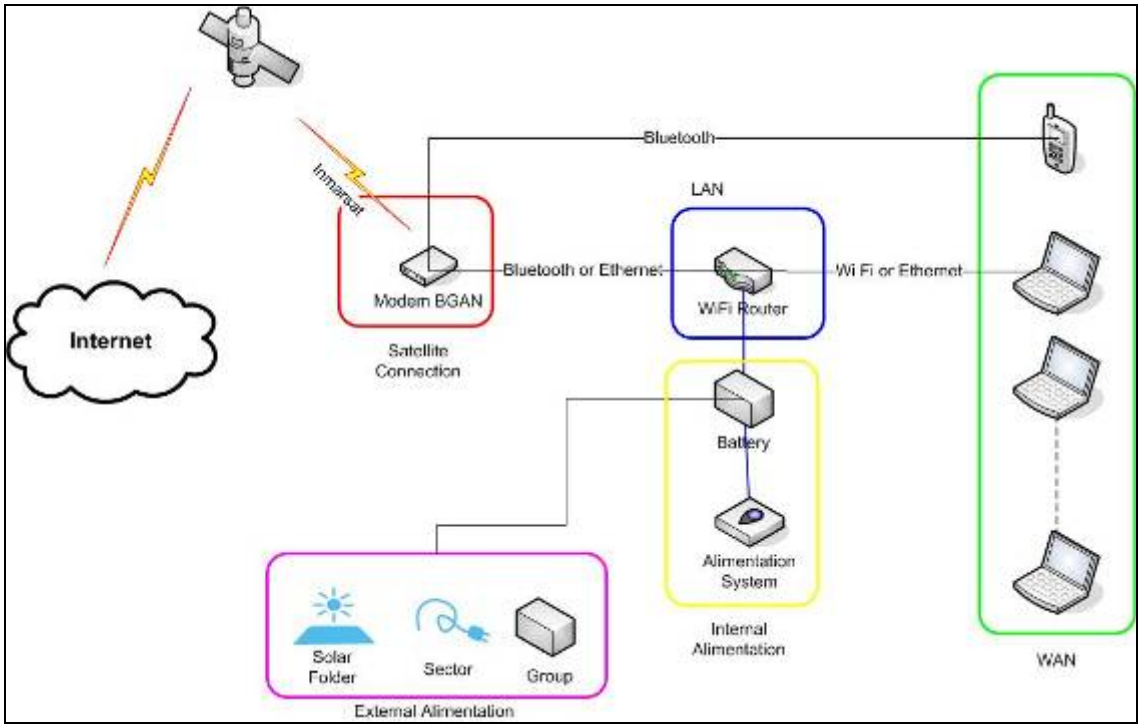


Figure 41: ABCS@t network architecture

The constraints identified from the NGOs needs have been satisfied as follows:

- Compactness:
  - All the equipment fit in a compact suitcase, including the satellite antenna
  - Dimensions: 559x351x229 mm
  - The suitcase dimensions respect the hand luggage requirements for transport by plane.
- Transportability:
  - The suitcase is autonomous in terms of energy supply: use of a high capacity battery and a light foldable solar charger
  - The overall solution is light: the weight is 9 Kg
  - The suitcase is provided with wheels and with a retractable handle, which makes hand baggage very practical.

- Rapid to deploy:
  - The deployment time is less than 10 minutes
  - The solar foldable solar charger can be deployed in 1 minute
  - The satellite modem can be pointed in less than 5 minutes
  - The WiFi connection is available 1 minute after the router is switched on
- Resistance:
  - The suitcase is waterproof and dustproof
  - Protection Index IP54.
- Easy to deploy:
  - Simplified use: no need for network connexion
  - Just one input to power all the equipment
- Universal:
  - the system is compatible with all operating systems (PC, Mac, Windows, Linux...)
  - Worldwide coverage

3.3.4 Training of NGOs and preparation of tests

GREF teams were trained to the usage of the transportable solution.

The training sessions took place at CNES premises on September 2008 and were based on a theory course and on practical demonstrations. A simplified procedure was also delivered as a support for the test in real field conditions.

3.3.5 Laboratory Tests

A set of typical use case scenarios was defined in order to estimate the amount of generated traffic and then to be able to estimate the cost of each application. The following cases were defined as typical use for an Internet activity:

- Streaming (5 minute, data rate)
- E-mail sent with an attachment (image JPEG 40 KBytes)
- E-mail sent with an attachment (doc WORD 300 Bytes)
- Videoconference (5 min: Windows Live Messenger)
- FTP serveur
- Chat (5 min: Windows Live Messenger)
- VoIP (5 min: SKype)

- Bluetooth Phone

The following tests were performed in laboratory at CNES premises:

1. Measure of average UL and DL bit rate for FTP "get" and "put"
2. Measure of the average throughput (kbps) for different e-mail protocols
3. Measure of max UL and DL bit rate for a web application
4. Measure of the transmission delay
5. MOS tests for Video/Audio applications
6. Throughput for Video conference, VoIP, streaming and phone calls
7. Maximum range for Bluetooth connection in LoS and NLoS conditions
8. Maximum range for Wifi connection in LoS and NLoS conditions
9. System autonomy in term of Power supply

3.3.6 Test on real field conditions (Burkina Faso)

In view of the conditions of use that the transportable solution would experience, four main critical factors were identified:

- High temperature
- Humidity
- Shocks and vibrations
- Dust

In order to test equipment resistance to high temperatures, humidity and to shocks and vibration, CNES defined a list of test procedures to be applied on-the-field.

These tests were defined to evaluate materiel resistance to the environmental conditions typical of the target countries (Burkina Faso and Benin). The tests assessed the effects of such conditions on materiel safety, integrity, and performance:

- Validation of the terminal functioning: performances, reliability, autonomy..
- Identification of limits and necessary improvements: software or hardware
- Testing of its operability by non-technical staff
- Analysis of the usage

ABCS@T was shipped to Burkina Faso by plane in October 2008, as hand baggage. It was brought by car from the capital Ouagadougou to the town of Bogande, where GREF teams trained the local NGOs during about a week.

The area is characterized by a tropical climate, with temperatures varying from 15 to 45 degrees and relative humidity which may vary between 40% and 80%.

The solution was tested in the rural Learning Centres (CDAF), created by the NGOs in order to help the development of the local population, located in the most isolated areas around Bogande.

The experimentation on-field lasted about 6 months, until the end of March 2009.

Figure 42: Usage of ABCS@T on a training centre – Diepergou (Burkina Faso)

The configuration deployment of the terminal avoided direct exposure to the sun during operation: the transportable terminal will be deployed near the training centre in the shade.

The transportable solution was used in the rural educational and healthcare centres with the following applications:

1. Internet access, in order to enrich the pedagogical contents during the learning sessions. Researches were performed on-site concerning the major topics of the education course.
2. Video-conference with other communities located in Burkina Faso
3. In the rural health centres ABCS@T was used in order to transmit the medical dossiers to the hospital of Bogande, connected to Internet by the fixed infrastructures of NETADDED Project (VSAT + HiperLan/2 network).

For each session, the connection time to Internet varied between 5 and 40 minutes, according to the specific scenarios.

ABCS@T was also used "off-line": contents were charged at the NGO FIIMBA headquarter and where used to work with the local communities on specific topics.

3.3.7 Synthesis of Results

In-field experimentation results have been analyzed in order to better identify the usage profiles and the hardware and software suitability of the implemented solution.

- **Transportability -** The transportation of the suitcase didn't cause any troubles for the end-users. ABCS@T was sent to Burkina Faso by plane as a hand luggage. A declaration has been made to the custom at departure and arrival airport.

  The NGOs carried the solution in the countryside by car and by moto. The weight of the terminal was considered as satisfactory by the end-users (12 kg).

- **Resistance to shock & vibration** - The vibration and shocks caused by the terrible state of the roads raised some minor problem of stability only for the external connectors of the suitcase that would be reinforced in the updated version of the prototype.

  On the contrary, the equipments placed inside the suitcase were well protected by the foam and any relevant issues were detected.

- **Resistance to high temperature & humidity rate** - The transportable solution was operated at an average temperature of 35/36° Celsius.

  Any visible failure due by high temperatures was revealed. Anyway, particular precautions were taken by the operators as the suitcase was always protected by the direct sun radiation.

  During the experimentation period the humidity rate was of about 20-30% (dry season) , so any particular limits could be experienced.

- **Resistance to dust** - The transportable solution was tested in a very dusty environment. Any relevant failure due to dust was detected, as sensible equipments were sufficiently protected and conditioned.

- **Rapidity of deployment** - The deployment of the terminal was easily performed by the local NGO educators, after the training made by the GREF. The average time for deployment was of about 8 minutes.

- **Autonomy** - The terminal autonomy in terms of power supply was also tested. The batteries were charged every night after the training. During the learning sessions, solar panels were largely used to complement the batteries. The average measured time of autonomy of the batteries alone was of about 2 hours.

  In same cases a generating group was used in complement to the internal batteries, in order to allow multiple equipments to be simultaneously power-supplied (in particular laptops and video-projector).

- **Ergonomic tests** - Even though the simplified user interface was easily accessible by the end users, the LCD touch screen of the router was not well adapted to the sunny environment of Burkina Faso.

  In the updated version of the prototype this LCD screen has been replaced by buttons.

  The number of cables and adaptations provided with the suitcase was too high according to the NGO teams and in some cases it was complicated to select and manage them.

  Therefore the ergonomics of the alimentation options have been optimized in the next generation prototype with a single input/single output system.

  All external power supply sources (220 v sector, solar panels, generating group...) will directly feed the ABCS@T batteries, from which any devices could be alimented in order to simplify the functioning.

- **Usage & fees** - The user manual was regularly consulted by the end-users in order to follow the appropriate procedure and for error solving.

  The usage cost is determined by the price of the INMARSAT communication, i.e. 6,3€ per MBytes

  During the experimentation period the total amount of exchanged data was of about 105 Mbytes, what corresponded to a cost of 670 €.

3.3.8 Enhanced version of the transportable terminal prototype

Through the experimentation lead in real frame conditions, the limits and the straights of the design and implementation of the transportable solution could be clearly identified. In consequence, CNES decided to start a new research and development study in order to provide a new pre-commercial version of ABCS@T solution.

The following improvements were implemented:

- Enhance the performances of the batteries in order to guarantee a longer autonomy and lifetime. The batteries implemented in the tested prototype are NiMh-type batteries, designed to work at a maximum temperature of 40°C. The idea is to integrate in the solution batteries based on Li-Ion and Ni-Cd technology, capable to operate at temperatures up to 70°C. These batteries present a slightly inferior capacity (about 25%)
- Optimize the load management system, in order to guarantee an optimal functioning of the charge. This implies a specific study for the developments of electric circuits and their integration into specific components, compliant with the specific quality requirement in terms of temperature resistance. The implementation of the circuit must be validated by a complete set of tests to ensure the correct functioning of the system.
- Integrate a more powerful charger in order to improve the rapidity of the charge of the equipments and to allow the simultaneous alimentation of a larger number of devices.
- Integrate a rugged laptop inside the suitcase, as an option device.
- Further reduce the weight of the solution, by selecting a lighter suitcase.
- Optimize the thermal dissipation, by using more suitable protection foam.
- Modify the user interface of the router, by substituting the LCD command screen with buttons and led. In order to perform this task, a software development has been necessary, followed by laboratory tests to validate the inter-compatibility of the different components and the stability of the system.
- Introduce led indicators for the batteries status.

The new version of the transportable solution was finalized in June 2009.

3.4 EXPLOITATION IMPROVEMENT – REMOTE CONTROL

3.4.1 Introduction

The Remote Control framework, which is the focus of task 4.3.1, contributes to the project's objectives by addressing the need for remote satellite control capabilities to reduce operational costs. Therefore, its primary goal is to establish the platform that is necessary to ensure the efficient and reliable operation, as well as improve the operational autonomy, of the validation sites.

The objectives of the work within the task is to provide both the local-loop operator and the local networked community (WiFi, WiMAX, meshed WiFi) access to a network monitoring system including the possibility to monitor remotely the operation of the satellite installation. This has been accomplished through the development and customisation of a network management application that enables to:

- View network performance of terrestrial (WiFi) and satellite links
- Issue alerts about network failures
- Perform remote interventions (such as a hardware reboot) for problem solving or QoS improvements.

The remote control platform is comprised of a hardware and a software part. Both have been taken into account while implementing our custom solution. To acquire the appropriate hardware installation we have considered the unique and extreme conditions that the equipment in our validation sites will potentially be exposed to. The locations of the validation sites range from agricultural areas of France to small villages in Africa. These locations are usually situated in areas with high temperature conditions, limited electrical power, and other operational or environmental idiosyncrasies.

Besides the environmental aspect, the operational and economical aspects are also important and dictate a special focus on improving the autonomy in terms of maintenance and operation of both the satellite and local loop segments. This consideration lead us to choose a two-level network topology, one installation residing at the network provider site and the other at the remote validation sites, to minimize maintenance costs by avoiding as much as possible on-site interventions.

The validation site installation monitors the health of each remote site and presents detailed information through a web interface, in a way that is easy to understand by non expert network operators. The network provider installation receives only the most important information from each installation site, but can display a more detailed account of this information, if required. The communication between the two software installations is mainly done with the use of SNMP alarming to minimize the required satellite bandwidth usage.

3.4.2 Synthesis of user and service requirements

The following user and service requirements have been taken into account for the implementation of the remote control solution:

Requirement	Feature to be implemented
Operation in high temperature conditions.	• Enclosure provides efficient insulation.
Operation in difficult – outdoor conditions.	• Enclosure specifically designed to cope with harsh environmental conditions.
Operation in areas with limited electrical power.	• Hardware installation with low-power requirements. • Passive, fanless, cooling solution.
Minimal usage of satellite bandwidth for the remote control and monitoring of the satellite installations.	• Two level monitoring scheme. • Only critical issues are propagated to the provider installation. • Use of SNMP alarming.
Provide autonomy in terms of system maintenance of both satellite and local-loop segments.	• Two level monitoring scheme. • Local administrators deal with non-critical issues.
Low cost implementation.	• Custom software implementation. • Use of open source OS and applications. • Minimal maintenance costs avoiding on-site interventions.
Need for monitoring of the status and the quality of the satellite link.	• Use of SNMP alarming/polling.
Need for monitoring of the status of the wireless network.	• Use of SNMP alarming/polling.
Limited or absence-of knowledge in computer networking from the personnel on the satellite installation.	• Simplified maintenance actions. • Highly usable user interface. • User guide and howtos.

Table 15: User requirements for remote control mechanism

3.4.3 Design and development of adapted solution

3.4.3.1 Hardware specification

The hardware specification for the remote control station is given in the following table.

Motherboard & CPU	**mini-ITX motherboard and appropriate processor with low-power requirements.** • **VIA EPIA EN12000EG [RD01].**
System memory	1 GB RAM DDR2.
Hard disk	**At least 4GB capacity with endurance in harsh conditions including high temperatures (over 70 °C) and vibrations.** • **20 GB Automotive grade, like Hitachi 's Endurastar J4K30 or N4K30 [RD02];** • **A 4GB SSD.**
Enclosure	**Fanless, tightly sealed mini-ITX chassis.** • **Serener GS-L10 [RD03].**
Power input	**12-24 Volts DC.**
Power consumption	**13-15 Watts.**

Table 16: Hardware specification

Figure 43: Remote control enclosure

The above figure shows a photo of the remote control station hardware implementation. From the photo it is evident that a minimal installation procedure is required, making it straightforward to setup the hardware configuration in a matter of minutes. Furthermore, a fanless cooling solution has been chosen (for the enclosure and for specific components, i.e. the hard disk, as well) for heat dissipation in order to conserve power.

3.4.3.2 Network topology

By breaking the monitoring in 2 levles, a minimization of the required satellite bandwidth, for monitoring reasons, can be obtained. On the ISP side, major system variables are needed to be monitored for all the installation sites. Such variables are the satellite path status and the health of the major network elements, on each installation site. On the user side, a more in detail representation of the status of the site is required. The information will be obtained mainly with the usage of periodic SNMP polling.

The two-level topology of the network is shown in the following figure:

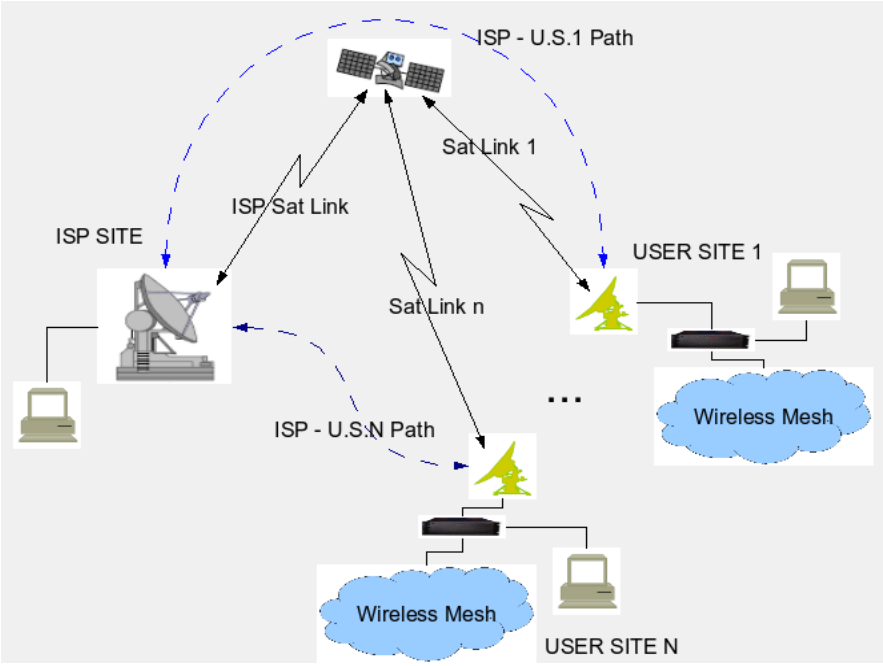


Figure 44: General network topology of the Remote Control platform

3.4.3.3 Software design

For the creation of the whole network monitoring model, two distinct application platforms were developed. One running on the network station of each user site installation, and one running on the satellite ISP provider. A flow diagram illustration of each one is shown in the following figures.

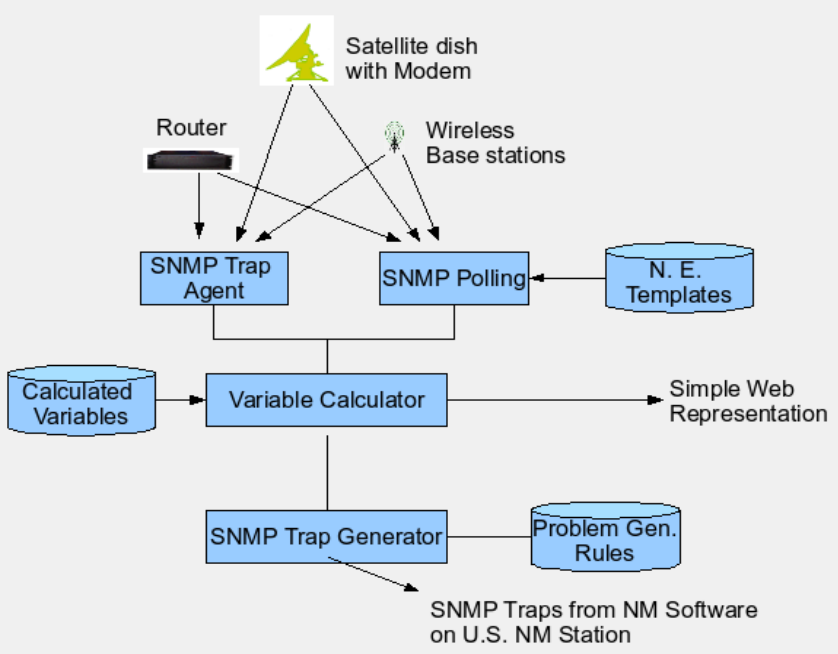


Figure 45: Flowgram of software on User Site

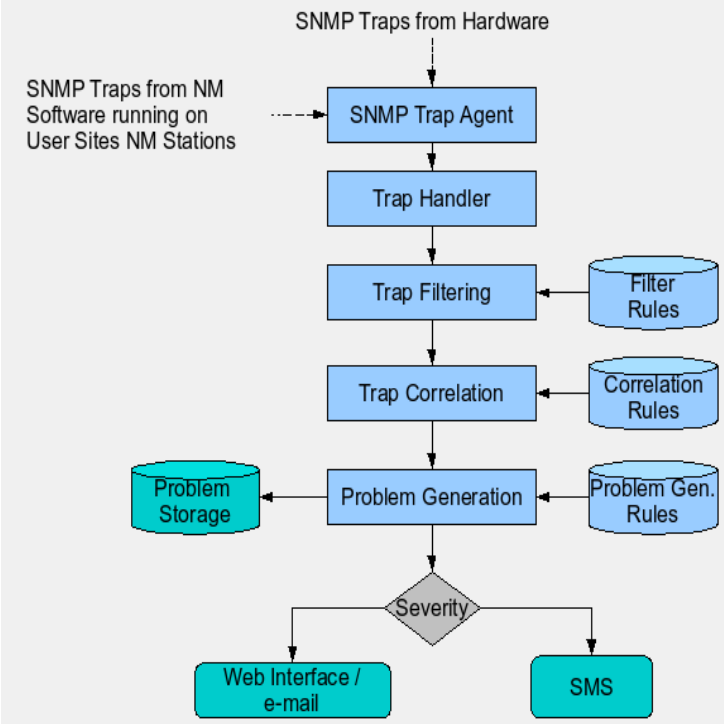


Figure 46: Flowgram of software on Satellite ISP

3.4.3.4 Network Statistics Collector

Network statistics collector should be an application with minimal operational requirements from the network management station, that will support the collection of various information from the network elements, in small time, without complex customizations and without creating big traffic overhead in the network. For this, an asynchronous SNMP collection engine was developed in C++. This engine has the ability of collecting simultaneously whatever required information (and can be obtained through SNMP) from a large number of network elements. The requests to the network elements are done asynchronously so timeouts in some network elements will not slow down the SNMP operation. The implementation in C++ gave also a module with minimal operational (CPU/Memory) requirements.

For the minimization of the complexity of the application customization, a template based polymorphic module in C++ was created. This engine has the ability of self learning the way to collect information from each network element required, without any user input from the User Sites. The only input required is a small XML file for each type/provider of the network element that exists in the network (modem/routers/interfaces/access points etc), and the IPs of the elements FNET require to collect information. The templates can be created from the ISP, which provides the User Sites with the network elements. For the creation of these XML templates a minimal network knowledge is required. The list of IPs of the network elements can be given also from the ISP. The (re) identification procedure for each network element is done only when is required and not each time the collector runs. This is done for minimizing the execution time and the bandwidth overhead of the collector. For the small time storage of the statistics the selection of RRD was made. Therefore, a module that can store any kind of collected information into RRD files was created. Finally, the selection of MySQL as the database for supporting the network platform, created the need for a communication module between the database and the network management applications.

The application was tested in the following 4 scenarios.

1. Collection of status and bandwidth information from interfaces of Cisco and Juniper Routers. For the identification and collection of 100 interfaces, it required only 15 seconds.
2. Collection of status, bandwidth information and quality if interfaces from 4 Colubris Hotspots.
3. Collection of CPU and Memory Usage information from 210 Siemens DSLams.
4. Temperature from 100 Forthnet's PoPs, through the switch temperature sensor, that are located there.

For all the above collection scenarios only the creation of 4 XML files was required and a list of the IPs of the Network elements from the DB. Total application execution time for collection only was less than 10 seconds. Total application execution time for self learning (for all elements - required only once in the first execution of the application) was less than a minute.

3.4.4 Integration and test results

For the development of the remote control system both software and hardware components need to interact and cooperate, so integration efforts need to cover both these aspects. Nevertheless, integration of the hardware components is considered straight-forward and no particular strategy is deemed necessary. Therefore, even though we considered several hardware configurations in our test process, so as to evaluate the system's flexibility, we mainly focused on the integration of the software components that comprise the remote control framework.

We dealt with two distinct topics: the integration test plan and the test case results. The test plan describes the integration approach and provides input which is essential in order to understand where the test efforts should be focused on and how they need to be carried out. The second topic involved running the test cases which were identified in the test plan and present the outcome of the execution of the tests in appropriate format, i.e. tables, charts, etc.

The objective of integration testing is to validate that all software module dependencies are functionally correct and that data integrity is maintained between separate modules for the entire solution. Whereas functional testing is focused on testing all business rules and transformations, integration testing is principally focused on testing all automated aspects of the solution and integration touch points.

In the following table, the high-level elements that are included in the test process are shown.

Feature to be tested	Description
Functionality	Behavior and capabilities
Dependability	Reliability/availability
Usability/maintainability	Ease of use/ease of maintenance
Performance	Desirable operational characteristics
Capacity	Behavior under stress, scalability

Table 17: Test elements for the remote control system

The main functional aspects of the remote control system that were tested are:

- Remote control: the network provider is able to aggregate network information and resolve potential issues at the validation sites.
- Bandwidth utilization efficiency: information pertaining to critical network issues from the validation sites is propagated to the network provider and the appointed operators (at both sites) are notified through email or SMS.
- Autonomy: operators at the validation sites are able to resolve non-critical network issues with no requirement for network administration expertise.

Availability is essentially concerned with the system uptime while reliability, over and above, provides guarantees regarding system service. From this description, we can deduce that reliability places stronger requirements on the system's performance. Both properties are typically measured using statistical testing methods. A statistical test provides a mechanism for making quantitative decisions about a process or processes.

The general process followed to statistically assess the reliability of the system is the following:

- Establish the operational profile for the system;
- Construct test data reflecting the operational profile;
- Test the system and observe the number of events that signify a reliability failure, as well as the timing of these failures;
- Compute the system reliability after a statistically significant number of failures have been observed.

Performance tests that were used for the remote control system included the following measurements in their evaluation:

- CPU and memory utilization at the NMS.
- Average operational and environmental temperature at the NMS.
- Efficiency of automatic detection of error resolution.
- Efficiency of automatic detection of NE network information.
- Amount of traffic that the introduction of the NMS brings to a validation site.

Capacity tests for the remote control system mainly focused on stressing the NMS at the validation sites by introducing a large number of NEs for monitoring. The main issue was to ensure that the necessary time for the NMS to gather and consolidate network information from the NEs was not larger than the interval at which this information was collected. The parameters that were taken into account are:

- The underlying network's bandwidth.
- The number of NEs.
- The type of NEs.
- The number of network variables collected for each NE type.

We focused at the validation sites NMS and not the network provider NMS, because the former has a much higher probability to encounter more network traffic, thereby placing more demand on the capacity of the software system. Even so, the test results allowed us to draw some conclusions for the capacity of the provider NMS as well; only the scale was naturally different.

In the following figure the topology of the test environment that was used is depicted. As can be seen from the diagram, the environment is comprised of one provider monitoring station and three validation sites with increasing level of complexity. Site 1 is a small wireless network composed of five wireless access

points and the monitoring NMS. The second validation site is composed of about 50 network elements (not counting their sub-elements). Finally, the third site consists of about 1650 network elements (again, not counting their sub-elements).

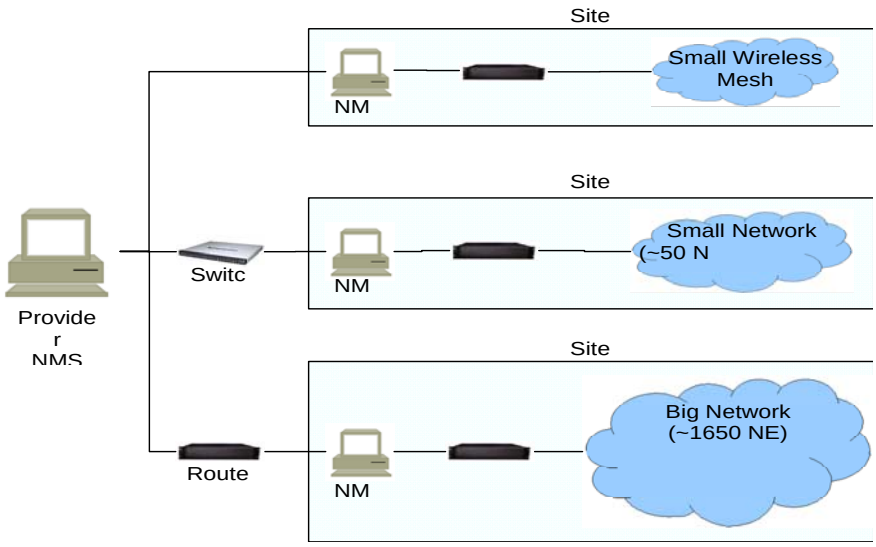


Figure 47: Test environment topology for the remote control system

The network elements in the second and third validation sites were carefully selected to provide a diverse configuration, consisting of routers, switches, server stations and DSLAMs. Taking also the wireless network elements in the first site into account, we are confident that the test environment successfully simulates most cases of network usage that can arise in potential deployment scenarios.

In the usability test cases the users of the NMS web interface executed a number of simple tasks. The tasks collectively represent the main functional areas of the web interface and the ease of performing them constituted the main usability criteria for the remote control system.

The measurements recorded in the test cases involved the time required to accomplish a specific task. This was a general indication of the user's familiarity with the actions required to carry out the task at hand. The longer the time it took the user to resolve the error, the greater is assumed to be the significance of the error as its impact on the user's ability to carry out the task clearly increased. Obviously, a user's inability to carry out a task signified that the relevant documentation and functionality needed to be closely reconsidered or revised.

Moreover, the number and kind of errors users made while interacting with the interface constituted a more specific indication of which parts of the interface should be improved to provide better usability. This also provided a measure of the efficiency of the available documentation which is relevant to the error.

The tests have been carried out by three different user groups, each having an increasing level of familiarity with the system's web interface. The first user group is only familiar with the basic concepts and functionality of the system but has no familiarity with the interface at all. The second group has a minimal familiarity with the system's interface. The third group is quite familiar with the interface and is considered

representative of a regular system user. None of the users in the three user groups has substantial network administration expertise.

In general, the tests showed that the usability of the system is quite good. Only a few seconds were necessary for the system operator to access all system's functionality. This was certainly expected as the system functionality is rather simple. Nonetheless, we can observe from the measurements that there is also a layering of relevant functionality, bringing critical operations closer to the user, as is definitely desired.

3.4.5 Future platform improvements

Future work on the remote control platform will be focused on two key areas. The first work area involves a comprehensive authorization framework allowing users with different roles to access specific parts of the system. Currently, only two roles are allowed: the network provider administrator and the validation site operator.

The second area in which the system can be improved is by enhancing the hardware implementation in order to take advantage of future developments in enclosure components, motherboards and CPUs. Such enhancements can provide hardware solutions with lower power consumption and better performance, both of which are crucial in the usage scenarios of the NMS.

3.5 EXPLOITATION IMPROVEMENT – INTELLIGENT WIRELESS NETWORKING

3.5.1 Introduction

NETADDED objectives comprise the end-to-end optimisation of hybrid satellite & wireless network. In this context, improvements on the wireless terrestrial segment can be as crucial as satellite optimisations. The objective of the work within this task is to define smart mechanisms and techniques for wireless networking optimisations. Special focus is realised on mesh networks, as one of the most promising future type of wireless networks. This is realised through:

- Definition and evaluation of optimised mechanisms for wireless network, focusing on:
  - Bandwidth estimation,
  - User association,
  - MIMO mechanisms.
- Development and implementation of WSN (Wireless Sensor Network) for precision agriculture purpose:
  - Bandwidth estimation,
  - Development of Wireless Sensor Node, called LiveNode,
  - Development of specific applications for precision agriculture.

Those analysis and development have been realised respectively by Sabanci University and by Cemagref and UBP.

3.5.2 Main results for Sabanci University on intelligent wireless networking

The objectives of SABU activities were to produce specifications and design of new protocols, schedulers, load balancing, routing algorithms to optimize performances in terms of capacity, range, end to end delay, QoS and to provide auto-configuration and failure resilience. In particular, multi-radio, multi-spectral systems will be considered with specific associated software and hardware developments. Generic system architectures design and evaluation through definition of metrics and simulations have been planned. Simulation with comparative experimentations to characterize each solution proposed.

The SABU efforts towards achieving more intelligent and efficient wireless networking capabilities for wireless mesh networks concentrated on three open research problems. Proper handling and effective resolution of this problems would greatly contribute to the success and wide-spread deployment of mesh networks in the wireless local loop segment.. The following chapter starts with a brief summary of these research problems and how they are handled within the framework of NETADDED research activity. The generic methodological approach that has been followed is explained afterwards. Then each problem and proposed algorithm/technical solutions have been presented separately.

Summary of Research Problems

- **Residual Bandwidth Estimation** - As part of this activity SABU investigated the accurate estimation of the residual channel capacity of wireless networks. The *residual bandwidth* is defined as the difference between the network link/path capacity and the current throughput of the system. Note that the residual bandwidth identifies the additional user demand that can still be satisfied under current conditions. The proposed SABU algorithm is a *passive* estimation algorithm, which listens to the channel and uses analytical techniques to calculate the residual channel bandwidth. The proposed algorithm was tested with extensive numerical simulation experiments and they are shown to perform much better than those previously proposed in the literature.
- **Intelligent User Association** - Another important issue in WiFi networks in general was identified as the over-simplicity of the user association method given in the IEEE 802.11 standard. In the current standard, users associate with the access point (AP) with the highest received signal strength with the anticipation that this AP is the closest one, and thus, it can provide the highest throughput. However, throughput not only depends on the instantaneous received signal strength but also on the number of wireless stations already associated with the AP. A more enhanced association protocol was proposed by SABU in earlier studies. In this project, SABU investigated the performance bounds of this more enhanced association protocol. In order to obtain provable worst-case performance bounds, SABU used game theoretical techniques. The results indicated that the worst-case bounds are significantly worse than the average performance obtained in the numerical simulations. Thus, as a conclusion we suggested the use of mechanism design tools such as pricing of the consumed wireless bandwidth to guarantee better user performance under all operating conditions.
- **Resource management and scheduling for multimedia traffic in MIMO based ad hoc or mesh networks** - Further research activities have been started by SABU on next generation Wi-Fi networks that employ Multiple Input Multiple Output (MIMO) based wireless physical layer specified by 802.11n standard. MIMO technology uses the spatial dimension in addition to frequency and time resources and has the promise to revolutionize the design of wireless networks, which will make MIMO based WMNs a viable possibility for the near future. The first 802.11n based MIMO products are expected to be available in 2009. However classical MAC layer solutions (802.11x) are not designed to handle special physical layer features and complexities coming from the utilization of MIMO systems. New cross-layer MIMO schemes are required for optimal management of radio resources and spatial diversity and multiplexing gains, while satisfying user level fairness and QoS criteria. At SABU, new research activities have started for a novel scheduling, routing and resource management platform for MIMO based wireless mesh/ad hoc networks. Our preliminary results for cross-layer MIMO research resulted in promising results. For a simple one-hop multi-access network comprised of multiple MIMO enabled WSTAs sending data packets to a single AP, we have implemented a novel MIMO stream based

scheduling algorithm that can manage diversity/multiplexing trade off by meeting QoS and fairness requirements of the end users. This capacity optimal opportunistic scheduling scheme achieved 30 to 40% throughput increase as compared to a simple round-robin type MIMO user scheduling. The research activity in SABU is continuing with cross layer solutions for tighter coupling between L1 and L2-4 implementations, such as MIMO adapted routing and resource management.

Generic Methodology

The methodology of all these research activities listed in the previous section is developed around a system model based on the user requirements. Based on the developed system model, a heuristic solution is proposed. The heuristic solution is analyzed either by extensive numerical simulation experiments, by tests in real conditions or by analytical methods.

Given this common methodology, the performance of residual bandwidth estimation algorithms are measured in realistic simulation environments developed on commercial state-of-the-art software such as OPNET. The hardware implementation of the residual bandwidth estimation methods were pursued by finding collaborations with the industry who would be interested to offer this feature in their products. Unfortunately, SABU was unsuccessful in materializing such collaboration in the current financial climate. Nevertheless, SABU is still hopeful such collaboration opportunities to be possible in the near future when multimedia traffic becomes much more prominent in wireless networks.

For the research efforts in developing intelligent user association protocols, SABU investigated the derivation of mathematically provable performance bounds, since the performance analysis based on numerical simulation experiments was performed in an earlier study. To this end, SABU utilized *non-cooperative game theory* to model the user associations in wireless networks as an atomic congestion game. Game Theory is an important economical theory first developed by John Nash that allows the analysis of the behaviour of selfish agents. In a user association game, the users are agents who aim to maximize their throughput based on the responses of other users by associating with the AP that provides the maximum throughput. In this study, first it was shown that there is equilibrium where no user unilaterally changes its association. Second, the quality of this equilibrium was obtained under different system objectives such as maximizing the overall network throughput, maximizing the throughput of the user in the worst condition, etc.

3.5.2.1 Residual bandwidth estimation

Accurate Non-Intrusive Residual Bandwidth Estimation in WMNs

With the proliferation of 802.11 based wireless networks, people begin to expect the same service quality from wireless networks that they experience over broadband wired networks. A key step in the provision of better service quality is to estimate the traffic handling capacities of the wireless network links/paths.

The difference between the network link/path capacity and the current throughput of the system identifies the additional user demand that can still be satisfied under current conditions. This difference is known as residual bandwidth within the framework of ad hoc wireless networks.

The problem of accurate estimation of residual bandwidth without causing significant overhead in 802.11 based wireless multi-hop networks is still an open problem. The main difficulty encountered in the estimation process is the dynamically varying wireless medium characteristics changing according to the user traffic patterns and the channel conditions. In order to obtain a good estimate of the residual bandwidth, the transmission activity in the channel should be modelled accurately by causing as little disruption to the network operation as possible.

In this workpackage, SABU analyzed the wireless link capacity under various network conditions considering the effects of different link rates and packet sizes, channel impairments. and hidden nodes. This work differed from those available in the literature, since it combines real measurements with analytical calculations. In fact, this is why this residual bandwidth estimation method is so powerful; i.e., percent estimation error remains between 2.5-7.5%. Since measurements are made by overhearing DATA-ACK messages and by inserting very small time-stamps on retransmitted packets, the algorithm is non-intrusive for network operations. The computational complexity is low, and thus, the algorithm can be implemented easily on each wireless node. SABU also demonstrates how flow admission control is successfully carried out by estimating the path residual bandwidth through the proposed method.

Enhanced residual bandwidth estimation

Enhancements on the initial Residual BW estimation algorithm have been made with a more complex and realistic probabilistic model and future work will be carried out to ameliorate this method and to apply it to different domains of intelligent networking research. Improvements focused on the following aspects:

- Error probabilities of neighboring nodes and hidden node effects have been included to the model for improved accuracy,
- A more complex and realistic probabilistic model have been utilized,
- The accuracy and performance of residual BW estimation have been improved so that average estimation error dropped from %5-10 to %1-2 range,
- The algorithm has also been applied to mesh network routing protocols and a considerable increase in end-to-end throughput has been observed,
- Complexity level of enhanced algorithm has been investigated. The new algorithm has been found to be less complex and more feasible compared to other methods in the literature.

Overlapping behaviour for competing links

In original model overlapping transmission behaviour between competing links were not modelled. The basic simplifying assumption was that competing links were only interfering with the primary link. In more

realistic networking scenarios, competing links transmission would collide out overlap with each other as depicted in below figures.

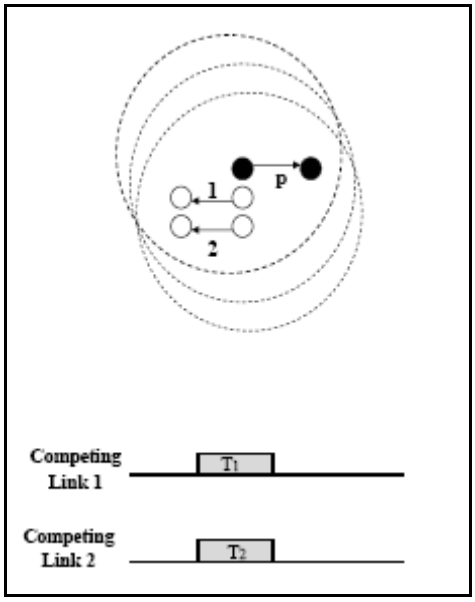


Figure 48: Competing links sensing each other's transmission

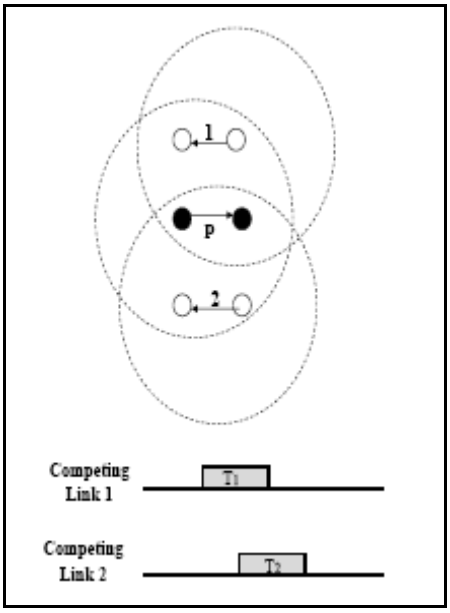


Figure 49: Competing links not sensing each other's transmission

In the new enhanced network model competing link transmission overlaps and collision are included in the calculation of total transmit time in competing links. Consequently, time-sharing model based on the knowledge of amount and type of transmission events in a unit-time interval in a hypothetical primary link saturation condition becomes more accurate.

Collisions due to hidden nodes

In the original residual bandwidth estimation algorithm developed by SABU, the hidden node effects were considered only within the realm of DATA packet based collisions. However, in real networks, hidden node effects would also include collisions caused by concurrent transmission of ACK packets in addition to DATA packets. In this respect, two distinct cases of hidden node we consider the hidden node problem in two cases with respect to the location of the hidden node and the primary link, as shown in the previous figure. Each of these cases yields a different failure probability

Application of enhanced algorithm to mesh routing protocols

The enhanced residual BW estimation algorithm has been applied to mesh routing function. Observations on how residual bandwidth estimation can contribute to the average end-to-end network throughput (when residual bandwidth is used as a routing metric) have been made.

The residual bandwidth based metric has been compared with the popular existing routing metrics, namely, hop count and airtime metric from 802.11s draft standard. As for the residual bandwidth estimation, we consider our proposed method and the other two analytical models [R2] and [R1]. We consider the well-known max-min routing where the path which has the maximum residual bandwidth is selected. The residual bandwidth of a path is determined as the minimum of the residual bandwidth of the links on the path.

Here are the results for end-to-end network throughputs when above stated methods are used in wireless mesh networking.

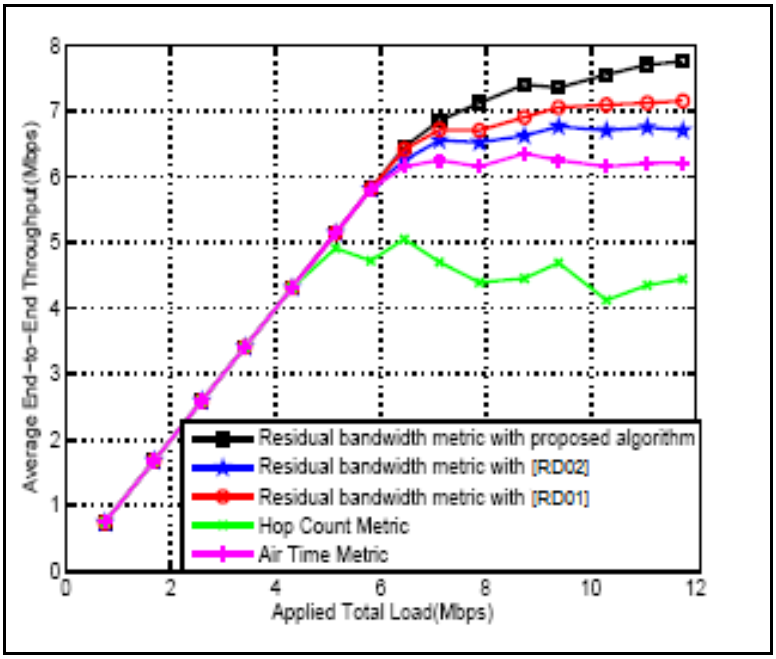


Figure 50: End-to-end network throughput with different network metrics

As it may be observed from above figure, the enhanced residual BW estimation algorithm has the best accuracy, as the path, which has highest positive residual capacity is consistently selected, resulting in the highest end-to-end throughput. Residual bandwidth based routing metrics via algorithms [R1] and [R2] outperforms the hop count and airtime metrics, but their end-to-end throughput remains below our enhanced residual BW estimation scheme.

Software and hardware specifications

The simulation for the enhanced residual BW estimation algorithm was also performed in OPNET and NS2 as it was the case for the basic algorithm developed throughout RP1 period. None of these algorithms were implemented on hardware. Below table shows the simulation parameters.

TABLE 1: Simulation Parameters

Transmission range	200m
Carrier-Sensing range	400m
Propagation model	Free Space
RTS\CTS	Disabled
Packet arrival distribution	Poisson
Packet Size	2048,4096,8192 bits
Channel rate	11,24,36,48,54 Mbps
Slot time	20 μs
SIFS	10 μs
DIFS	50 μs
CW_{min}	16
CW_{max}	1024
Routing protocol	AODV
Network area	1500mx1500m

Table 18: Simulation parameters

Performance Evaluation

The performance evaluation of the enhanced Residual BW estimation method proposed by SABU compared with the other relevant techniques in the literature is presented in this section. In the following figure, the accuracy of passive estimation method is depicted. We consider a network where 10 nodes are randomly placed in a 500 m x 500 m area. In this setting, 5 source/destination node pairs are randomly selected, and the simulations are repeated for ten realizations of the described scenario. The results presented are the averages of these realizations. One link is randomly chosen to be the primary link. The data rates of the links and the size of the packets are randomly selected. The actual residual bandwidth is obtained in the simulations as the value in saturation. The results are normalized to this residual bandwidth value. As reflected from the results in this figure, our approach closely approximates the actual residual bandwidth value. The average estimation error with our basic Residual BW estimation algorithm presented in RP1 activity report was around %5-10. In the enhanced version, this performance figure is in%1-2 range corresponding to a significant improvement in .the accuracy and performance of residual BW estimation.

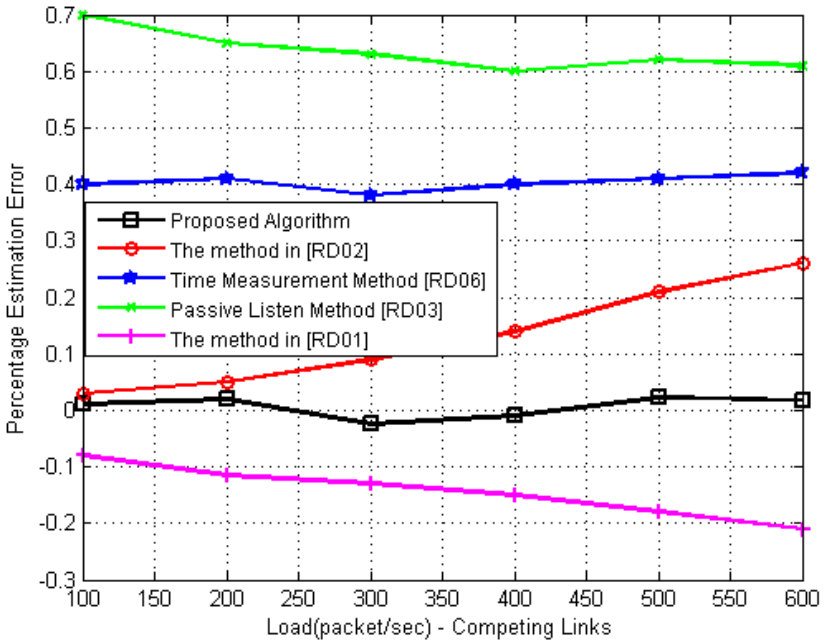


Figure 51: Performance of different passive residual bandwidth estimation methods

Complexity level of enhanced estimation algorithm

In this section, evaluation of the convergence and complexity of our scheme against the previously compared methods will be presented. The limitation of the passive residual bandwidth estimation methods such as [R3], [R6] is their low convergence rate, since they require measurement of the network activity for some operational time. Our proposed residual bandwidth estimation method may also have a similar limitation as it utilizes a network monitoring scheme that measures the activity of the competing links for an update period. In order to observe how quickly each estimation scheme responds to changes in the available network capacity, we have performed simulations to observe the estimation error as the update period is varied from 0.01 seconds to 1 second.

In below figure, the convergence performance of our estimation method, and two passive methods [R3](passive listen method) and [R6] (time-measurement method) are depicted in terms of the percentage estimation error. We consider the network model used in performance evaluation section, with 10 nodes, and with 5 source/destination pairs. One link is randomly chosen as the primary link. The load on the competing links is randomly assigned, and the packet sizes and data rates are randomly chosen from the previous table. As shown in the previous figure, our proposed enhanced residual bandwidth estimation method exhibits a steady-level of decreasing with the update period. Thus, our proposed method does not exhibit the similar limitation as the other passive methods.

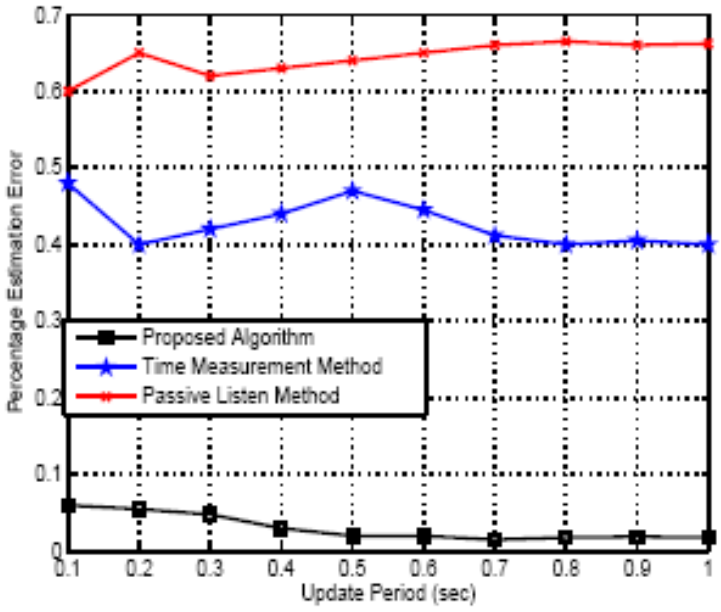


Figure 52: Convergence performance comparison

3.5.2.2 Intelligent user association protocol

In 802.11 wireless networks, users associate with access points that can provide the best service quality. In this work, the convergence and steady state performance of a practically well performing load-based user association scheme has been analyzed. The analysis was based on a novel game theoretical model, which extends the results on atomic congestion games. The existence of and convergence to a Nash equilibrium for this game is proven. The bounds on the efficiency of equilibrium compared to centralized optimum solutions were established under different system costs.

In current implementations of WLANs, each station (STA) scans the wireless channel to detect the access points (APs) nearby, and associate itself with the AP that has the strongest received signal strength indicator (RSSI). Thus, it is expected that a STA associates itself with the closest/strongest AP. It is known that this association policy can lead to inefficient use of the network resources. The most important disadvantage of RSSI-based user association is that RSSI does not provide any information about the current load of the AP in terms of number of users associated with it. It has been well established that when there are multiple STAs connected to the same AP with different physical transmission rates, then the saturation throughput of all users is bounded by the slowest transmission rate. Therefore, even though there are other less loaded APs in the region, most STAs may associate with the same AP, and experience congestion.

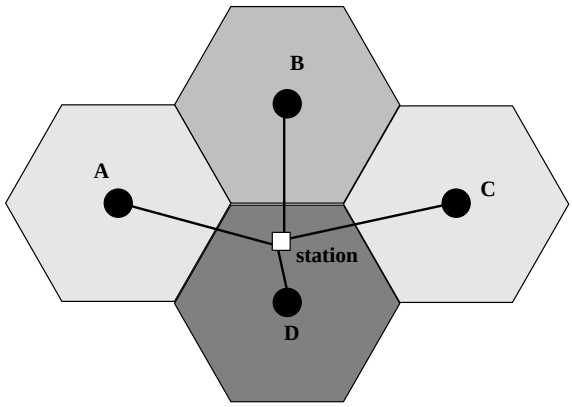


Figure 53: Division of a geographical area into non-interfering cells using three independent non-overlapping channels. STAs can be in a position to associate with any of several access points

The authors Athanasiou et al., proposed a new association scheme to resolve this problem. In this scheme, each STA collects usage statistics from the APs, calculates airtime cost for each AP, and associates with the AP that has the minimum cost. The airtime cost is first proposed as a default metric for routing in wireless mesh networks according to the draft 802.11s standard, and it reflects the average latency a packet experiences during a transmission. If all APs operate at separate orthogonal channels, the airtime cost metric depends only on the individual physical transmission rates and the number of users associated with the AP. In the work by Athanasiou et al., it has been shown by extensive simulations that the airtime cost based user association scheme can significantly improve the average user throughput and end-to-end delay compared to RSSI based user association.

The airtime cost based association scheme proposed by Athanasiou et al., is a greedy scheme, where each STA chooses to associate with the AP from which it expects to receive the best performance. In this setting, the users are non-cooperative and behave selfishly to optimize their own performance. The non-cooperative and selfish behavior may have negative consequences for the whole system. Foremost, when a new STA associates with an arbitrary AP *S*, those users already connected to the same AP may experience performance degradation. Thus, this new association may trigger re-associations in the network, since those STAs associated with AP *S* may now find some other AP with lower airtime cost than AP *S*. It is important to understand whether such a system ever achieves an equilibrium within a finite time, and if such an equilibrium is achieved, then the efficiency of the equilibrium should be compared to the centralized optimum solution.

SABU has two main contributions in this work. First, in order to understand the interactions between the users, we provide a novel game theoretical model for the user association problem in 802.11 WLANs. In so called "user association game," the user's utility obtained from an AP depends on the number and transmission rates of other associated users. They prove that this game has a Nash equilibrium solution, where no user attempts to change its association given the decisions of other users, and the equilibrium is reached within finite number of steps. Second, in order to understand the efficiency of the Nash equilibrium solution, different system (social) costs are considered, and determine prices of anarchy for

these costs. SABU also shows that the lexicographical optimum solution of the airtime costs of the users is a Nash equilibrium solution.

3.5.2.3 Resource management and scheduling for multimedia traffic in MIMO based ad-hoc or mesh networks

The objective of this intelligent wireless networking research activity is to design an effective and jointly optimal scheduling, routing and resource management platform that is required when MIMO technology is utilized in wireless ad hoc/mesh networks for multi-media communication purposes. A cross-layer integrated management platform that considers fairness constraints is being designed. Within the realm of this objective, competing and interacting MIMO network features such as transmission power levels of network nodes, capacity requirements of network flows, spatial degrees of freedom utilization and multiplexing/diversity trade-off are going to be mathematically modelled. Based on this mathematical model and by taking into account dynamically varying physical channel estimations and fairness/QoS criteria, specific algorithms for optimal scheduling, routing and resource management for end-to-end multimedia communications will be designed.

System model

The basic problem we try to solve is to optimize total end-to-end throughput of network flows while satisfying fairness/QoS criteria in a multi-hop MIMO based network. The network model on which our proposed algorithm is based consists of a $\mathcal{G} = (\mathcal{N},\mathcal{L})$ directed graph. N represents the set of MIMO enables nodes and L represents MIMO links setup between these nodes. Each node has M transceivers that could be used for reception and transmission. Following Rayleigh fading based channel assumption, this will give us M spatial DoF per node and per link.

In our model we will have M spatial DoF scheduled for every t time-step in order to avoid interference related problems. Therefore no interference suppression and/or spatial re-use capabilities have been included in our frame-work. We have a subset of N as the set of E number of end-user nodes. These end-user nodes establish end-to-end multimedia based network flows between themselves and aggregator/mesh GW node. There are F number of multi-media flows that are generated by end-user terminal applications. For every multi-media flow a fairness/QoS criteria pair of (λ_f, PE_f) have been defined. $\lambda_f < 1$ represents usage ratio of flow f out of total capacity offered by the given network. On the other hand, $PE_f < 1$ stands for BER tolerance level of flow f. PE_f is a QoS requirement in the sense that BER in every wireless link utilized to carry flow f should at most be as high as PE_f.

For every flow f, a data arrival rate of x_f has also been defined. The depiction of this network model could be seen in below figure.

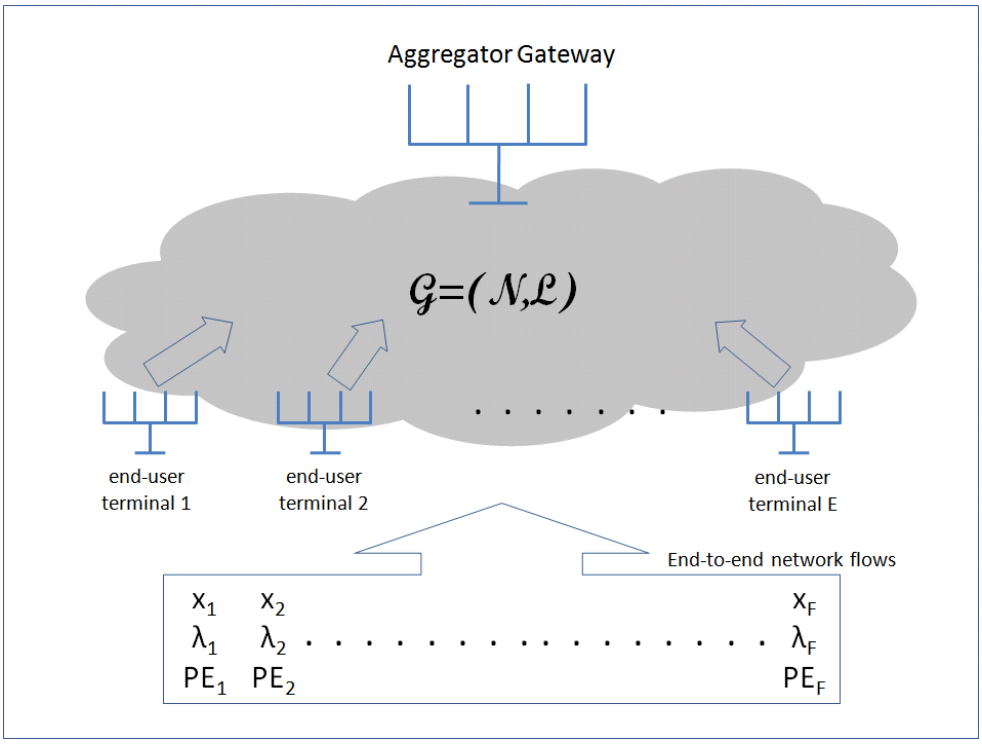


Figure 54: MIMO network model

Stream-based Scheduling in MIMO enabled wireless network

Within the framework explained in network model, a TDMA based scheduling method has been proposed of a scheduling interval of T scheduling step. In MIMO literature a spatial DoF usable in a MIMO enabled wireless link is called as a MIMO stream. Therefore the scheduling task for every scheduling instant t consists of deciding how M available DoF will be distributed of L links on the network. Below figure shows an example network where M=3 and L=3.

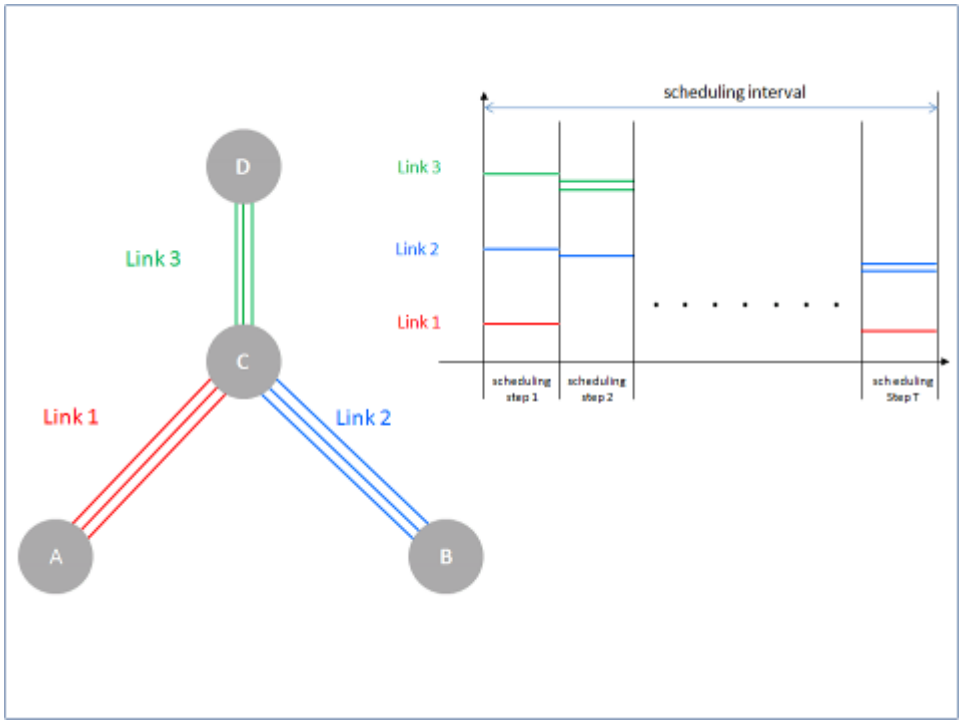


Figure 55: Stream-based scheduling example

Routing scheme

The routing function in our proposed algorithm has been defined by matrix A that represents how network flows are carried from end-user terminals to the aggregator GW on links belonging to multi-hop wireless network G = (N;L).

$$A = \begin{bmatrix} a_{1,1} & a_{1,2} & \dots & a_{1,F} \\ a_{2,1} & a_{2,2} & \dots & a_{2,F} \\ \dots & \dots & \dots & \dots \\ a_{L,1} & a_{L,2} & \dots & a_{L,F} \end{bmatrix}$$

Optimization problem

According to provided contextual frame-work, mathematical expression of the optimization problem we aim to solve is as follow. Objective function :

$$Max \sum_{f=1}^{F} x_f$$

Subject to constraints:

1. Flow based fairness constraints depending on how MIMO stream based scheduling and routing decisions
2. Link capacity constraints depending on BER tolerance levels of flows, wireless channel matrices, scheduling and routing policies.
3. Spatial DoF constraints

Approaches towards finding an optimal solution to optimization problem

The optimization problem mentioned in previous section has a non-convex, non-smooth objective function and could be modeled as an integer programming problem with linear constraints. There is an extra complication coming from varying wireless channel characteristics that changes link/stream capacities in every scheduling instant. Therefore global optimization methods that aim to satisfy fairness criteria would have a huge number of decision variables. Considering all these factors, a standard optimization approach to the given problem becomes unfeasible in terms of computational expenses.

Therefore the global integer programming problem explained above has been reduced to an MDP (Markov Decision Process) problem subject to fairness constraints. A stochastic approximation based approach has been adopted with iterational and opportunistic convergence to objective function goal while satisfying fairness criteria. Spatial multiplexing/diversity trade-off has also been shaped in order to satisfy BER requirements that constitute a critical QoS criteria for multi-media based network flows.

Preliminary results

The MIMO scheduling algorithm developed by SABU has been applied in a basic multi-access network with L end user terminals producing network flows (one multimedia flow per end-user terminal) targeted towards a single access point. For comparison and performance benchmarking purposes, a simple temporal fairness based scheduling scheme has also been implemented. The experimental multi-access network has been setup according to parameters in below table via Matlab tools simulation capabilities.

Spatial channels per node	4
Signal to Noise Ratioı (transmitting side)	20 dB
Bandwidth	20 Mhz
Maximum end-user terminal to access point ratio	300 m
Carrier Frequency	2.45 Ghz
Path Loss Exponent	3
Scheduling interval	1 second
Scheduling step	1 ms

Table 19: Simulation parameters

Simulation results are presented in below figure.

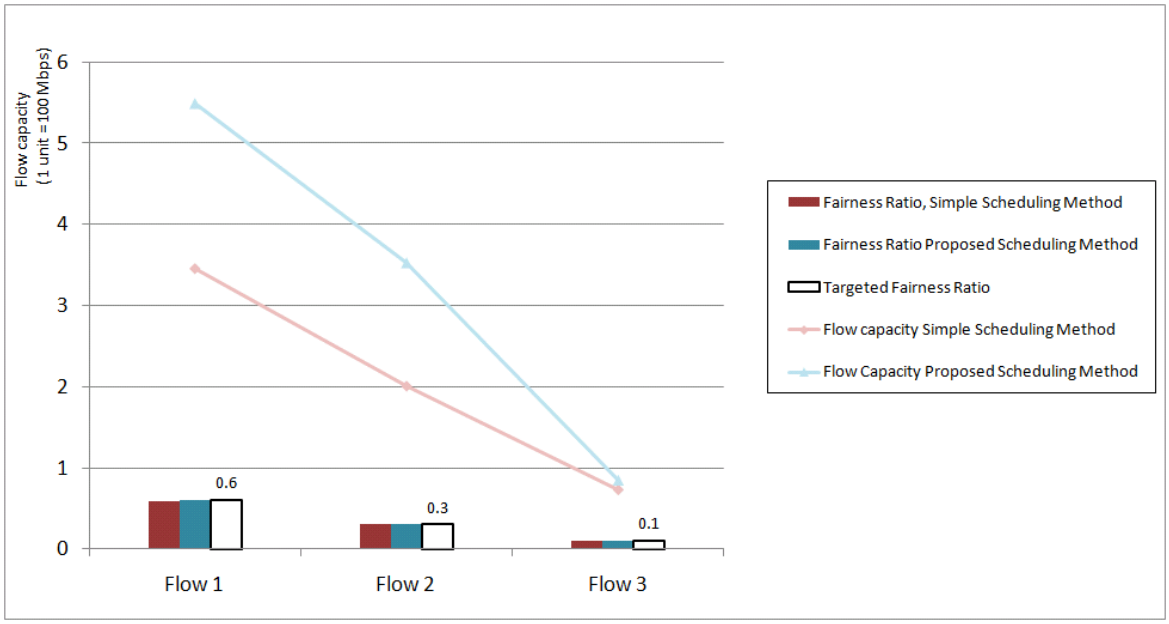


Figure 56 : Preliminary Results for L=3

As displayed in above figure an increase of 60% in total flow capacity have been obtained for a multi-access network with 3 end-user terminals.

3.5.2.4 Results & recommendations

Residual Bandwidth Estimation

- The developed methods are lightweight protocols that can be implemented on wireless equipment to enable them the estimation of the current capacity of the wireless network. The usable capacity of the wireless channel depends on the number of users, their transmission rates, rates of the flows, channel quality and the presence of hidden nodes. The algorithms estimate the remaining usable capacity of the channel for an incoming flow based on measurements and analytical calculations.
- The result can be implemented by a wireless equipment manufacturer as an add-on functionality.
    - Collaboration with a wireless equipment manufacturer is required for commercial success.
    - The result is most important in wireless mesh networks, where the flows are routed between wireless APs. Therefore, this functionality may also enter the IEEE 802.11s wireless mesh standard.
- The algorithms were tested on OPNET and NS2. Further efforts are required for embedded implementation on a Linux based AP
- Throughout the second year of NETADDED project, the proposed algorithm has been enhanced in following aspects
    - Error probabilities of neighboring nodes and hidden node effects have been included to the model for improved accuracy
    - A more complex and realistic probabilistic model have been utilized
    - The accuracy and performance of residual BW estimation have been improved so that average estimation error dropped from %5-10 to %1-2 range
    - The algorithm has also been applied to mesh network routing protocols and a considerable increase in end-to-end throughput has been observed
    - Complexity level of enhanced algorithm has been investigated. The new algorithm has been found to be less complex and more feasible compared to other methods in the literature.
- A patent application is pending. Following dissemination activities were performed
    - I. C. Atalay, Y. Sarikaya, O. Gurbuz, O. Ercetin, "Accurate Non-Intrusive Residual Bandwidth Estimation in 802.11 WMNs," presented at IEEE WIMESH workshop which is held in conjuction with IEEE SECON 2008, San Francisco, USA, June 2008.
    - Y. Sarikaya, I. C. Atalay, O. Gurbuz, O. Ercetin, "On-line Residual Capacity Estimation for Resource Allocation in Wireless Mesh Networks," submitted to Mobile Networks and Applications Journal (under review).

- The proposed residual bandwidth estimation technique could be adapted to new wireless technologies such as WIMAX and 802.11n.

Intelligent User Association Protocol

Efficient association of users with the available access points is required to balance the loads of the access points in the network, and thus, to prevent congestion. A new promising greedy user association scheme has been proposed for this purpose, where each user is associated with the AP that can provide the lowest per packet latency. The algorithm is analyzed theoretically by modeling it as a form of an atomic congestion game. Our results indicate that the price of anarchy of load-based user association is high, and in many cases depend on the number of users or the number of resources in the network. However, an encouraging result is that a fair solution for all users (lexicographic optimum) is also an equilibrium solution. Further studies are needed both to improve the given bounds, and to design mechanisms that can drive the system to more favorable equilibriums.

Following dissemination activity was performed as part of this research work.

- O. Ercetin, "User Association Game in 802.11 Wireless Local Area Networks," *IEEE Transactions on Wireless Communications*. Vol.7, No.12, 5136-5143, December 2008.

Resource management and scheduling for multimedia traffic in MIMO based ad hoc or mesh networks

In MIMO systems, the structure of the physical layer has greater importance since spatial dimension is also exploited. With MIMO technology in the physical layer, the remaining network layers should be designed with in a cross-layer fashion, so that the available resources can be most efficiently managed. Multimedia communications in MIMO enabled ad hoc/mesh networks is expected to achieve the most benefit from the capacity and reliability provided with MIMO technology. Based on these observations we concentrated our research efforts on MIMO technology on designing effective and jointly optimal scheduling, routing and resource management schemes to be used in MIMO enabled ad hoc wireless networks for multi-media communication purposes. A cross-layer integrated management platform that considers fairness constraints and channel matrix estimation errors is planned for development.

During second Reporting Period of NETADDED project:

- A simple multi-access type MIMO enabled networking model has been setup for preliminary analysis.
- Basic fairness and QoS criteria has been integrated to the model to evaluate resource management performance.
- Initial results on this simple scheme gave promising results with a throughput increase of 40 to 60% while satisfying QoS and fairness criteria.

- Opportunistic scheduling of wireless resources based on stochastic approximation methods is being developed.
- Further research involves appropriate/compatible routing algoritms and multimedia specific QoS constraints.

3.5.3 Main results for Cemagref & UBP on intelligent wireless networking

The development of the wireless networks to extend the distribution of broadband access in rural area and the example of the three farms of this NETADDED Allier site is an interesting opportunity for Cemagref and UBP (ISIMA). The needs of data acquisition solutions for precision agriculture and environment management are more and more important. The wireless networks have been deployed by Cemagref for the agriculture and the environment management and UBP implemented the basic components of this wireless sensor platform. The WiFi and ZigBee technologies have been used at the same time for the development of the wireless sensor nodes.

For the development of these wireless sensors nodes, a LivePlatform has been adapted with the component-based concept scheme. LivePlatform is a set of components (LiveNode) and each component has conceptually 3 layers. This concept is interesting to make advance in wireless communication, VLSI and MEM technologies (Very Large Scale Integration and Micro Electro Mechanical technologies). The key features of Wireless sensor node are low cost, reliability and small footprint. Therefore WSNs meet the requirements of the precision agriculture and economically viable. The news devices have been developed on this base of LiveNode platform, this platform is a hardware and software one to implement the different types of devices like the wireless sensor node, the gateway, the routers. In laboratory, after the design of each elements, the equipments have been realized and tested. An experimental deployment of the Wi-fi/Zigbee livenodes have been realised on a wireless access point of farm 2 to realise the measure and the tests in the field. Different software have been developed and adapted to realised the bandwidth and the broadband estimations with two portables computers connected on this wireless network . This experimental site is a real wireless experimental platform for the research and the teaching.

Three mains results were obtained in this project:

- The development and the validation of a new wireless platform: the LivePlatform,
- The development and the validation of a new Bandwidth estimation technique,
- The deployment of a hybrid wireless architecture for agricultural application.

3.5.3.1 The LiveNode platform development

LiveNode Platform

In recent years, many wireless sensor nodes have been implemented such as BTnodes, ESB/2 nodes, SmartTags, EYES node, TinyNode, Mote, Mica2, TmoteSky, Atlas, Imote, etc.

In principle, all these hardware platforms are very similar. The core processors are based on low power 8 or 16 bit RISC microcontroller (Atmel ATMEGA128 or Texas Instruments MSP430 family]). The unique wireless access medium is based on Bluetooth or IEEE802.15.4, which has a radio range less than 200m outdoors. Moreover most of the wireless sensors are not fully compliance with the IEEE802.15.4 standard. Note that, all these nodes enable to implement a simple wireless sensor node: temperature sensor, light sensor etc. The new trend in wireless sensor node design is to use ZigBee wireless medium access standard IEEE802.15.4 (TmoteSky) and a more powerful CPU such as 32 bit RISC microcontroller (Imote is based on ARM). In this section we present the LiveNode platform, which is composed of hardware module LiveNode and basic software module: LIMOS operating system. The LivePlatform enables to implement rapidly a prototype to meet the requirements of an application.

LiveNode hardware module

The LiveNode is a small board (70*55mm) and is powered by a 9V standard battery (PPP). LiveNode has the following components:

- One AT91SAM7S256 running at 48MHz,
- One standard wireless access medium IEEE802.11b (WiFi) or IEEE802.15.4 (ZigBee) connected via UART1,
- One standard GSM access medium connected via UART3,
- One GPS receiver connected via UART0,
- One versatile signal conditioner enable to adapt to different type of sensors such as soil humidity sensor, temperature sensor, light sensor etc.
- Three 8 bit extension connectors: one for SPI bus (8 bit) permit to connect to 3 LiveNodes to form a fault tolerant multi wireless access medium to meet the requirements of an application; the second one is for I²C interface and for analog inputs; and the third one is a general purpose I/O connector.

Figure 57:LiveZigBeeNode and LiveWiFiNode

The LiveNode hardware module is represented on the figure below.

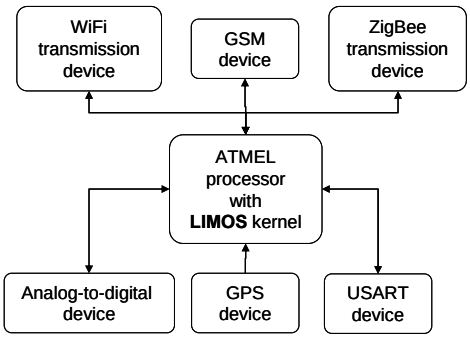


Figure 58: LiveNode components

Wireless access mediums

The LiveNode may be equipped with three types of wireless access medium to meet the requirements of an application: IEEE802.11b, IEEE802.15.4 or GSM (GPRS). In LivePlatform with the same board, we can embed on the board a ZigBee (LiveZigBeeNode) or a WiFi (LiveWiFiNode) or a GSM (LiveGSMNode) module. Moreover, thank to the modularity, a multisupport LiveNode may be implemented easily by connecting two, three or 4 LiveNodes together through SPI connector. For example a LiveWiFi&ZigBeeNode is formed by a LiveWiFiNode and a LiveZigBeeNode.

- WiFi module IEEE802.11b: LiveWiFi - Internet is very popular and it is indispensable for many applications: smart care, smart home… Thus, in a wireless sensor network the LiveWiFi&ZigBeeNode will be used as Internet router relay or access point for other LiveZigBeeNodes. The WiFi module is based on Wi-EM from Digi International Inc. It has 200m range outdoor and consumes 400mA. The theoretical bandwidth of Wi-EM is limited by the bandwidth of the connection port: 230 Kbps in case of high speed UART and 9 Mbps in case of SPI.

- ZigBee module IEEE802.15.4 - The LiveZigBeeNode is based on IEEE802.15.4 standard; XBee OEM RF modules of MaxStream Inc. LiveZibBeeNode may be equipped with low energy consumption and short range XBee module (50mA and 30/100m (indoor/outdoor), or a high energy consumption and long range XBee-Pro module (270mA and 300/16 00m). Thus, according to the requirement of the applications, the adapted LiveZigBeeNode will be used.
- GPRS module - In some applications such as low data rate environmental data collection (soil humidity data collection in urban park situated far away from sink node) and robust alarm message, a GPRS wireless MODEM is useful and adapted. In LivePlatform each LiveWiFiNode or LiveZigBeeNode may be equipped with a GSM access medium: GM862-QUAD from TELIT Inc. The LiveGsmNode consumes 380mA.
- GPS receiver: Low cost DGPS receiver - Each LiveNode has GPS receiver. The LiveWiFiNode or LiveZigBeeNode with a GPS receiver is used to track a mobile object such as vehicle etc. Currently, we develop a low cost differential GPS receiver based on a set of wireless GPS receiver nodes. Thus a set of LiveZigBeeNode equipped with GPS receiver will be used to localize urban buses. The GPS receiver consumes 70mA in case of continuous mode and 35mA in case of trickle power mode.

LIMOS: LiveNode operating system

It is obvious that general-purpose real-time operating systems do not meet the requirements of WSN applications due to the resource constraints (memory, power, CPU, etc.) and their wireless capability as well. Most of the existing wireless sensor nodes run three types of real-time operating systems: one is based on event driven (TinyOS, Contiki), the second one is based on classical multi-threading (NutOS), and the last one is based on data centric multi-tasking (AmbientOS). For example BTnodes run NutOS and TinyOS; ESB/2 nodes run Contiki and TinyOS; µnodes run AmbientRT and TinyOS; EYES node run TinyOS, and TmoteSky run Contiki and TinyOS.

However, these OSs are not integrated with the fault tolerant concept and the unified high level abstraction driver. Moreover, on one hand, for more complex real-time applications the event driven is not adapted; and on the other hand, the resource-aware and parallel programming issues are not taken into account. LIMOS combines the advantages of TinyOS and SDREAM, and thus can be applied to a variety of WSN applications ranging from simple single-task to multi-task hard real-time applications.

3.5.3.2 SLOT bandwidth estimation technique

We developed two different available (residual) bandwidth estimation methods. The first method is an active one estimating the available bandwidth by probing (investigated by UBP). The second method estimates the residual bandwidth by passive listening of the channel and by analytical modelling of 802.11 MAC (investigated by SABU). We developed a theoretical model of a new technique name SLOT and verify its results by simulation on NS-2 (Network Simulator version 2).

The deployment and the associated research work deal with obtaining wireless network measurements efficiently in agricultural wireless sensor networks and/or MANETS. This necessitates quick and accurate methods for estimating network resources as the typical agricultural wireless sensor network is prone to failures and topology changes. To reach this purpose, algorithms (SLOT technique) based on active probing methods are proposed in following research activity. SLOT is the result of the combination two active algorithms SLoPS and TOPP . These later use respectively binary and linear research on the available bandwidth. SLOT is specifically designed to operate on MANETs or WSNs. The performances of SLOT technique are given in three evaluation phases. The first one is a simulation using NS2 (Network Simulator-2) to validate the behaviour of available bandwidth estimation process of SLOT. In the second phase, SLOT is implemented using Visual C++ and tested in LIMOS laboratory. These tests are done in many times and with four nodes, and participate to improve the SLOT program. This phase is used as transition from the simulation model to an estimation tool. The third phase is to evaluate the performances of SLOT program in real conditions with the wireless network on the farm.2

To confirm completely the theoretical and simulation results of SLOT technique, the SLOT technique is implemented by using C++ language to enable to evaluate real-world wireless network. Firstly the SLOT tool has been used to evaluate the wireless network in LIMOS laboratory and secondly it has been used to evaluate the wireless traffic of farm2's site in cooperation with CEMAGREF. In the following part, we present the performance results obtained with the SLOT tool using.

SLOT Experimentation in Laboratory

The following figure represents the experimentation topology.

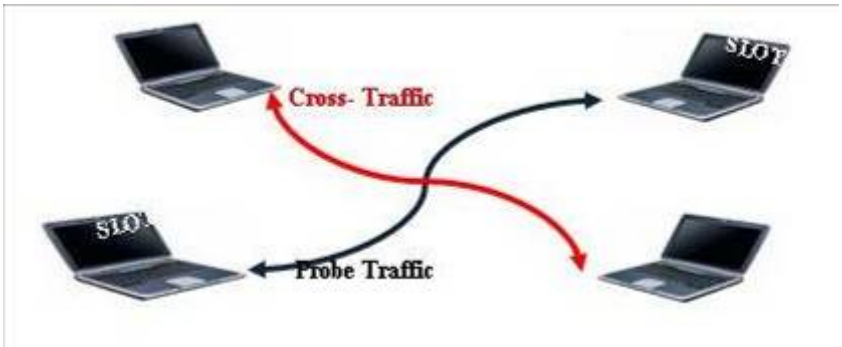


Figure 59: SLOT laboratory experimentation topology

The figure below shows the screen capture of the laboratory experimentation of SLOT technique. Each stage of graph is an estimation step of the available bandwidth. In this case the cross traffic rate is 0 Mbps (no cross traffic). The measured available bandwidth is around 4,302 Mbps as maximum available bandwidth. It represents the real exchange capacity of the network.

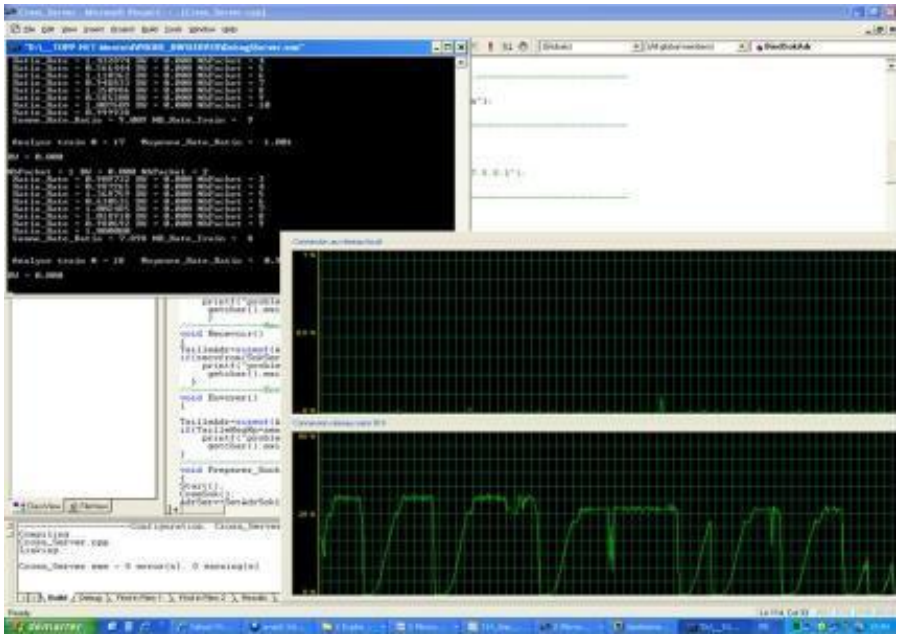


Figure 60: Periodic available bandwidth estimation - cross traffic rate 0 Mbps

In other hand, the figure below shows the evolution of the cross traffic rate generate by PC_3 in the Laboratory experimentation. We can show the transition of the cross traffic rate from 1Mbps to 3Mbps and to 5 Mbps. We remind that the cross traffic rate is constant, but we can see the perturbations due to the interference with the probe traffic..

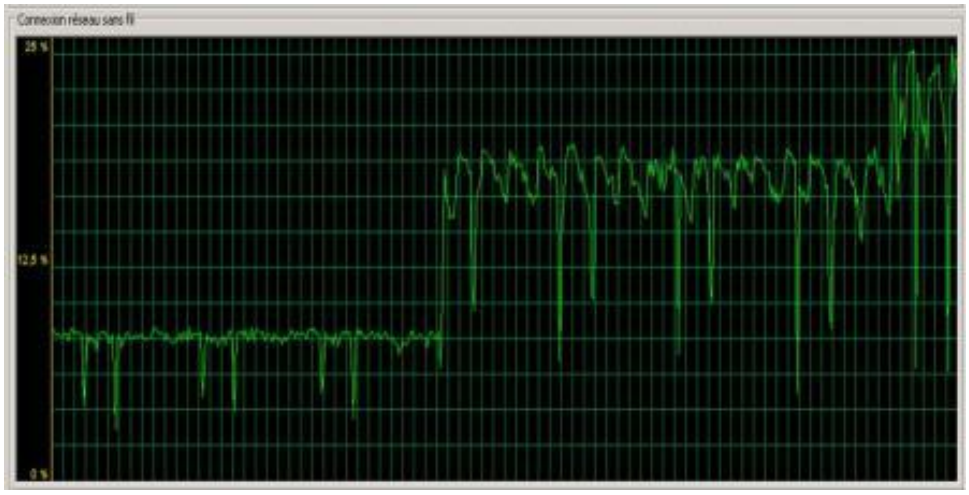


Figure 61: Cross traffic generation process

Finally, the figure below shows the estimation process with a cross traffic rate equal to 3 Mbps. Then the link load does not decrease to 0 Mbps but is stabilized to 26% of 11 Mbps then to ~3 Mbps. The maximum of each increasing part is the available bandwidth value. In the left of the display screen we can see that the estimation is equal to 2.399 Mbps.

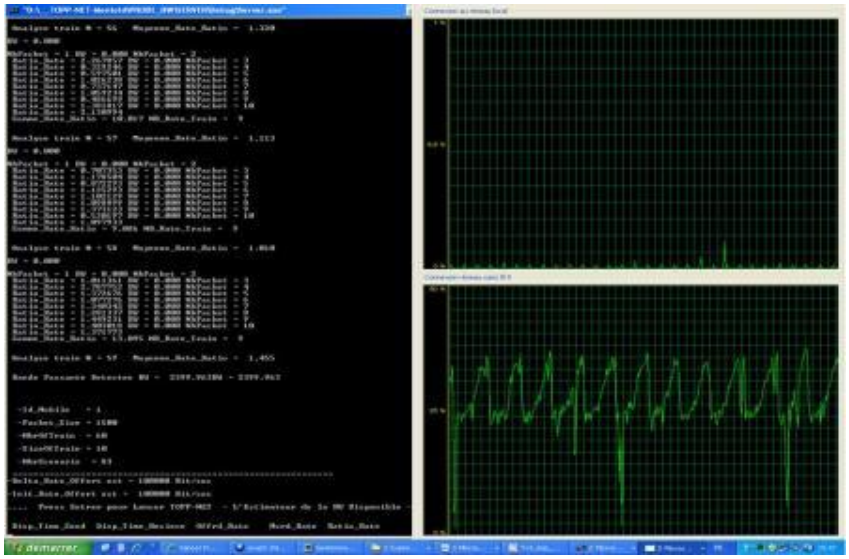


Figure 62: Bandwidth estimation process - cross traffic rate 3 Mbps

SLOT Experimentation in real conditions in Farm 2

1. *Topology*

The topology of our network is illustrated in the following figure. It is composed of two agricultural pivots irrigation systems (PIVOT_1 and PIVOT_2), each pivot is equipped with WiFi IEEE 802.11g (54 Mbps of theoretical bandwidth). The pivots are ad-hoc configured and the distance between the two pivots is 200 meters. To estimate the available bandwidth we must probe the link between pivots, thus two laptops are used: one as sender and another one as receiver. Each laptop is connected to pivot through an Ethernet link.

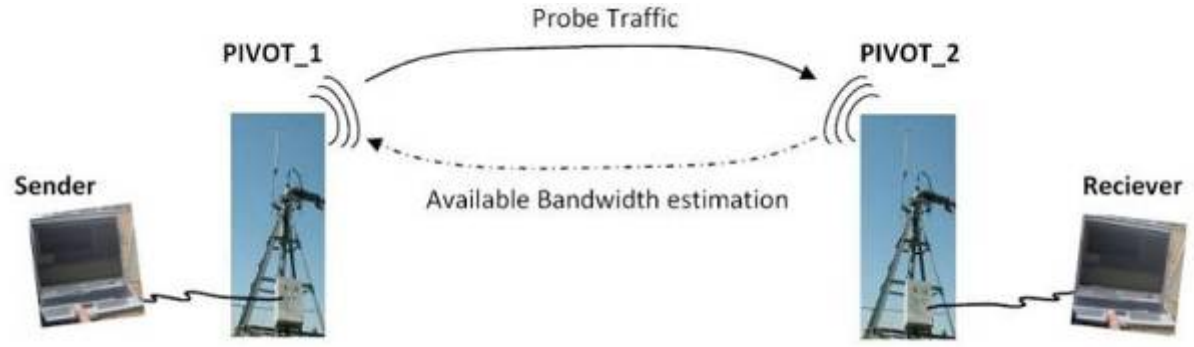


Figure 63: SLOT experimentation network topology in Farm 2

	Sender	Pivot_1	Pivot_2	Receiver
IP Address	10.0.10.1	10.0.10.10	10.0.10.20	10.0.10.111
UDP Port	21001	21010	21010	21011
Distance	Connected to Pivot_1	200m		Connected to Pivot_2

Table 20: Network configuration - Phase 1

2. *Maximum Bandwidth estimation*

The obtained results of the laboratory test correspond to the theoretical model and NS2 simulation ones. Thus, we tested the tools in Farm 2 to evaluate the available bandwidth of the deployed network to estimate the bandwidth need. The same scenarios as simulation are played.

In the graph of the Figure 64, dots represent the values of the maximum bandwidth estimated. Due to different factors (brittleness of the wireless link, climatic conditions) these values are noisy. To eliminate these noises we used EWMA (Exponentially Weighted Moving-Average) filter. The solid line is the represent the filtered initial values of estimation.

We can observe that the most estimated values of the available bandwidth of the link Pivot_1←→Pivot_2 are between [6 Mb/s – 8 Mb/s]. While the mean value is equal to 6.627 Mbps. This bandwidth represents the real and the practical exchange capacity between the Pivot_1 and the Pivot_2 (link capacity). However, this latter are equipped with WiFi cards IEEE 802.11g having a theoretical capacity of 54 Mbps, also this bandwidth usable stay low.

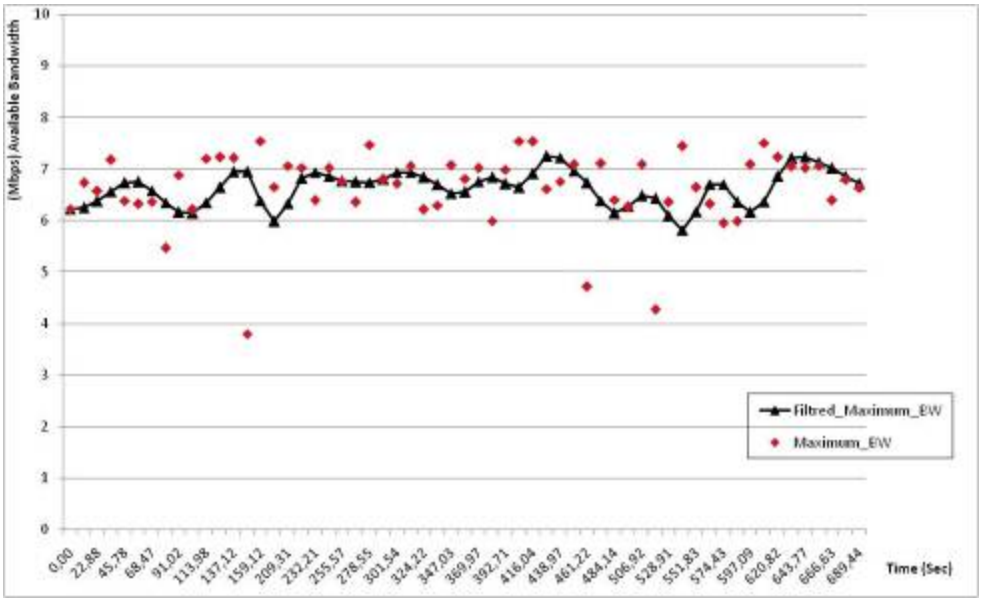


Figure 64: The maximum values of Available Bandwidth and its filtered curve

3. Bandwidth estimation with different cross traffic rate

The diagram in figure below, illustrates available bandwidth estimation values when cross traffic varied from 0Mbps, 1Mbps, 3Mbps and 5Mbps. The y-axis shows the measurement in Mbps and the x-axis shown the time in seconds. Every 240sec we change the cross traffic rate and this rate remains constant all this period until the cross traffic rate reach 5Mbps. The dots represent the estimation values of the available bandwidth without filtering. The filtered values of the available bandwidth by using EWMA filter are plotted in solid line.

We observe that the estimated values decrease from [7Mbps - 8Mbps] to [3Mbps -4Mbps] when the cross traffic rate increase from 0Mbps to 5Mbps. This shows that the available bandwidth measurements are depended on the cross traffic rate. Also we can observe that when the cross traffic rate increases the available bandwidth values becomes more instable. Thus the stability of the available bandwidth values depends on the cross traffic rate. To confirm this conclusion we measured the minimum, the maximum and the mean values of the available bandwidth and their standard deviation. All these statistical parameters are presented in the next figure.

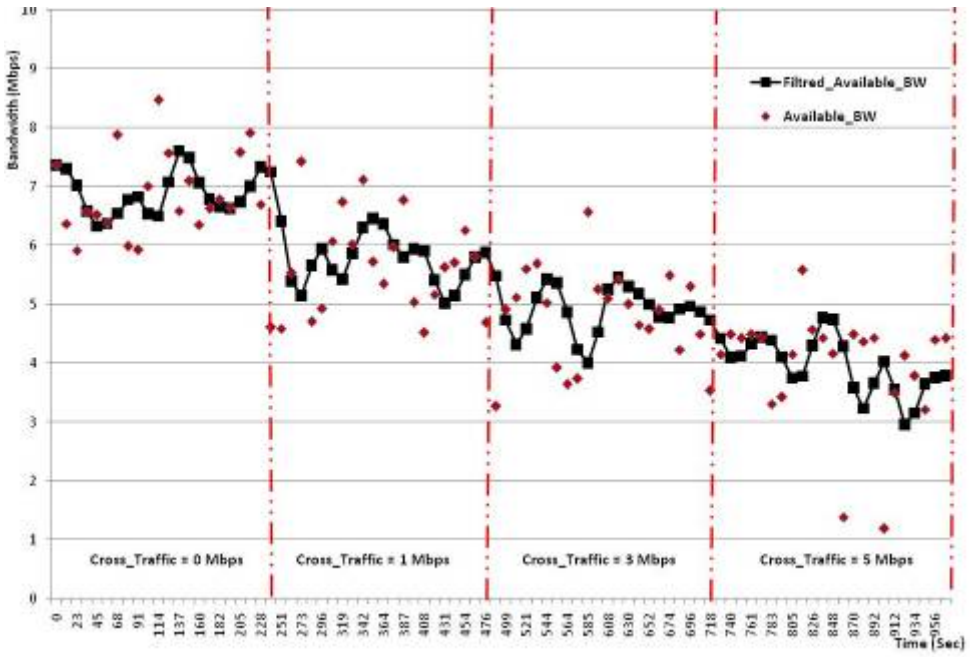


Figure 65: The available bandwidth estimations values with different cross rates

Cross-traffic (Mbps)	Available bandwidth (Mbps)			
	Max	Average	Min	Standard deviation
0	8.469	6.869	5.915	2.553
1	7.429	5.695	4.519	2.91
3	6.57	4.906	3.273	3.297
5	5.582	3.958	1.187	4.394

Table 21: Different statistic parameters of the estimated values

Conclusion

The experiment results (indoor and outdoor) show that the SLOT tool provides the same available bandwidth as the theoretical and simulation ones.

3.5.3.3 Hybrid wireless architecture for agricultural application

The development of the irrigation and water management application has been realised by means of several types of wireless sensors like the logic programmable computer and the applications of the LiveNode for example with the wireless soil moisture sensors. Also in this framework of development, different types of wireless modules have been realised, installed and tested in laboratory and on the pilot site. A main part of this development has been the realisation and the assembling of the wireless sensors with LIMOS laboratory at UBP. Several Wi-Fi and ZigBee electronic cards have been made and tested in collaboration with LIMOS laboratory. These cards will equip the future wireless nodes for the different sensors networks deployed on each pilot farm. Also in the same logic, four wireless GPS cards were realised.

The recording of the traffic realised on each site allows to analyse the traffic according to the wireless networks utilisation and the wireless sensors developed, tested and used for the agricultural and environmental applications. All the developments of the different devices have been realised in the framework of NETADDED project, (Wi-Fi-ZigBee gateway, moisture wireless sensors and remote irrigation monitoring system) will continue to be improved on this experimental platform after the end of NETADDED project.

3.6 EXPLOITATION IMPROVEMENT – SERVICES DIFFERENTIATION

3.6.1 Introduction

The objectives of this activity were the following ones:

1. Interconnection of satellite beams (AB1 EU and W3A Africa),
2. Implementation of Quality of Service processes to ensure guaranteed bandwidth on demand and per use tariffs.
3. Integration with the MEDSKY™ IP based Applications including appropriate user interface.
4. Specify & integrate the necessary automated audit trail mechanisms to perform post processing and evaluate performances and operations.

In NETADDED, the applications to which service differentiation mechanisms have been applied are exclusively the following:

- Via satellite Internet access,
- IP based videoconferences with guaranteed bit rate.

These services present different usage profiles requiring studying, designing and implementing quality of service policies specific to each type of application. Everyone can obviously understand that performing a high quality videoconference will require a permanent bit rate throughout the session; while on the contrary, web browsing is not dramatically affected by fluctuations on the effective bit rate. In addition, these two types of traffic implement different IP protocols (UDP versus TCP) with significant implications in terms of network architecture and quality of service.

Also, in this work package we focus on bandwidth sharing amongst all satellite terminals. We do not consider the problem of bandwidth sharing amongst users connected to a same satellite terminal through a local area network.

Finally, we want to stress that the issue of service differentiation as specified above cannot be addressed efficiently without a powerful traffic monitoring system so as to monitor and control how the network and the users behave once the appropriate QoS policies are implemented. It has been a major task in NETADDED to design and develop a service differentiation system with fully embedded traffic monitoring system. The traffic monitoring systems proved to be also particularly useful for trouble-shooting.

3.6.2 Overview of the implemented service differentiation infrastructure

The following network infrastructure was deployed.

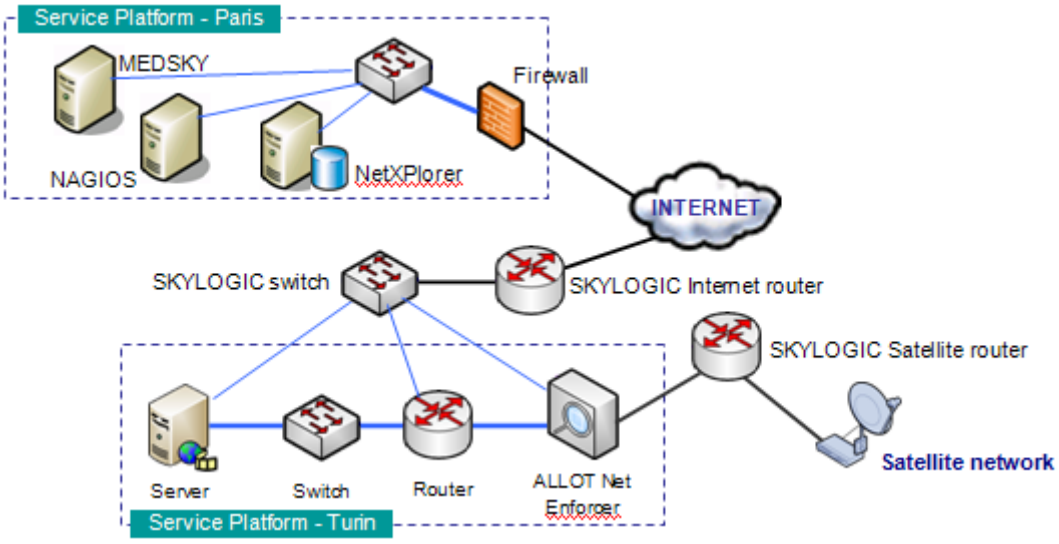


Figure 66: Network infrastructure for Service differentiation

The ALLOT Net Enforcer captures and controls all the traffic between the satellite network and the Internet. Depending on the recorded requests by the users (through the MEDSKY Client software), the MEDSKY server controls automatically the ALLOT NET ENFORCER to apply dynamically adapted QoS rules for videoconferencing.

The ALLOT Net Enforcer has a very limited storage capacity and therefore, on an hourly basis, all traffic data captured by the NET ENFORCER is automatically repatriated by the MEDSKY server and inserted into the long term archiving facility (SQL database) connected to the ALLOT NETXPLORER. The time resolution is 30 seconds. The NETXPORER user interface is used to configure the NET ENFORCER monitoring reports as well as all the QoS rules.

All equipments are maintained and configured remotely (thin blue lines in the Turin Service Platform).

The MEDSKY server also retrieves data collected by the NAGIOS server. NAGIOS continuously controls whether the satellite terminals registered into the MEDSKY database are switched on or off. This information is then exploited by the MEDSKY software to display ON/OFF events in the corresponding monitoring graphs and / or to generate alerts (SMS, Emails) towards maintenance personnel.

The following figure shows the implemented logical (software) architecture.

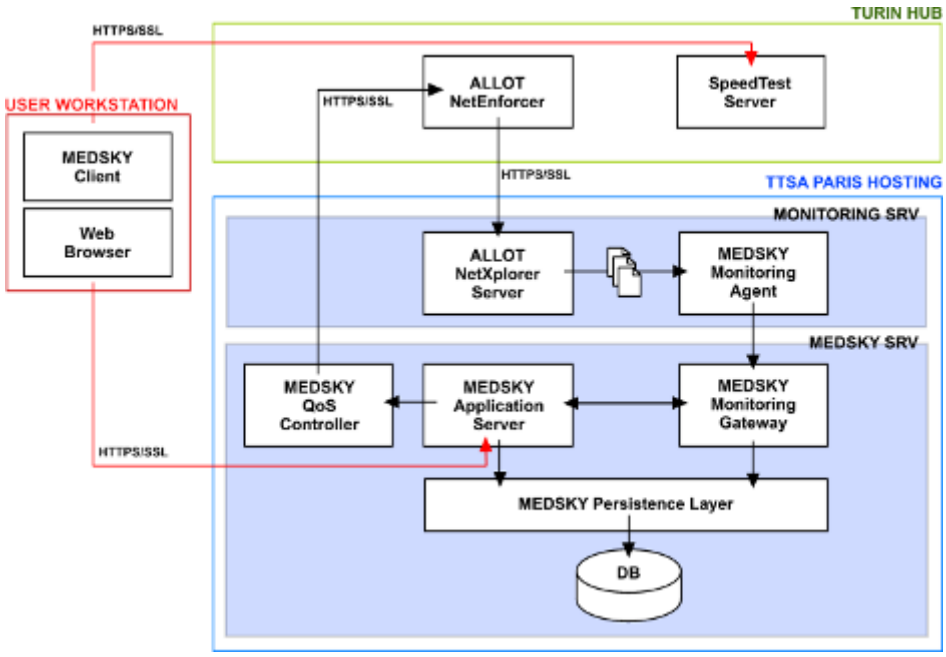


Figure 67: Logical software architecture at MEDSKY platform

3.6.3 Improvements realised

Improving the traffic monitoring system

Experience feedback throughout the first months of operation has conducted the TTSA team to re-design the user interface of the network monitoring system to improve usability and efficiency. Also performances in terms of processing delay had to be consistently improved.

As the amount of collected data was increasing over time, the display time for a specific graph tended to be in the order of minutes, making the system not usable. Also the initial graphs showed to be of interest for long term assessment of the usages, but of no use for short term decision making and network usage control.

To reduce display time, we have implemented a number of pre-processing so to prepare the graphs' data in advance. The display time dropped down to a second. Also a new series of graphs was designed and implemented as detailed hereinafter.

Monthly volume per year

This graph enables to evidence mid term evolutions. It shows the total data volume transferred (download, upload) per month over a year. The user interface enables to sort the corresponding data for one single terminal or for any group of terminals. It is possible to export corresponding data in an excel document. The graph below shows the total volume for year 2008.

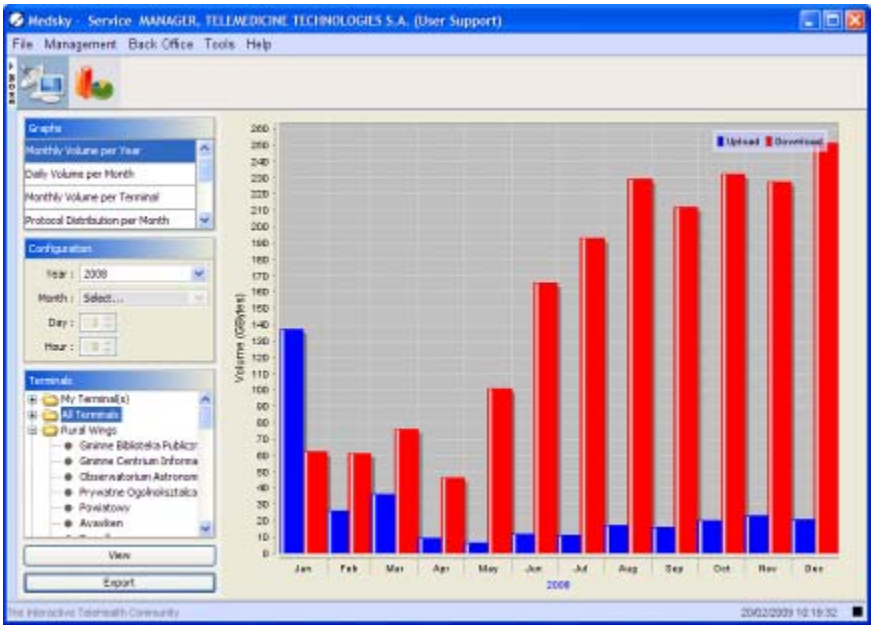


Figure 68: TTSA satellite network - Total data volume transferred per month over a year

Daily volume per month

This graph is similar to graph 1, but details the total daily volume traffic throughout one month, either for a group of terminals or for a single terminal. It is useful to monitor the effect of particular events on the total demand or for short term action.

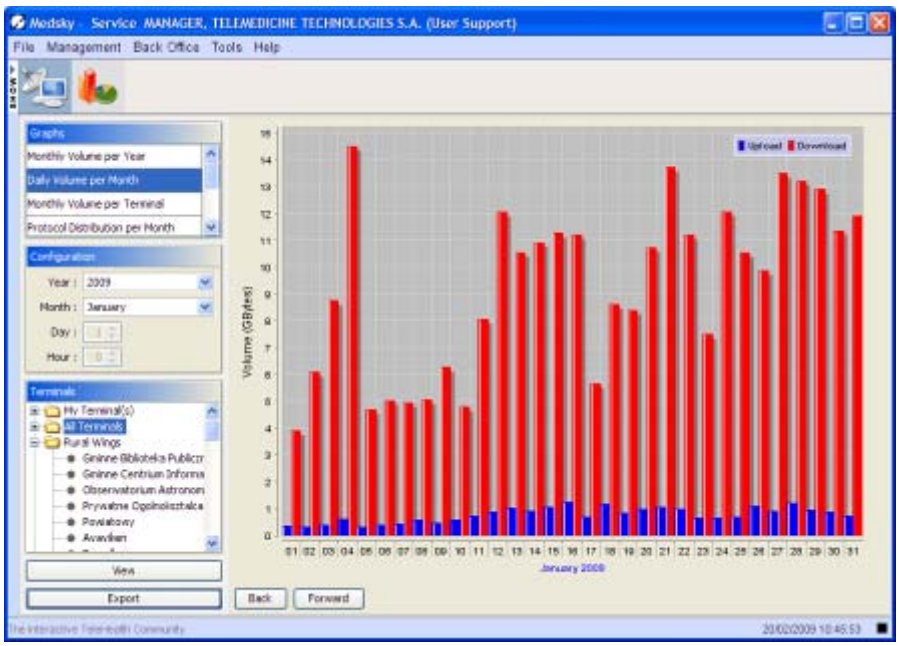


Figure 69: TTSA satellite network - Total daily volume traffic throughout one month

Monthly volume per terminal

Enables to monitor which terminals are really active in the network during one month. This graph was already available in the first version of the monitoring tool, but it has been improved. Instead of IP addresses, each terminal is now identified by its name that makes it much more user friendly.

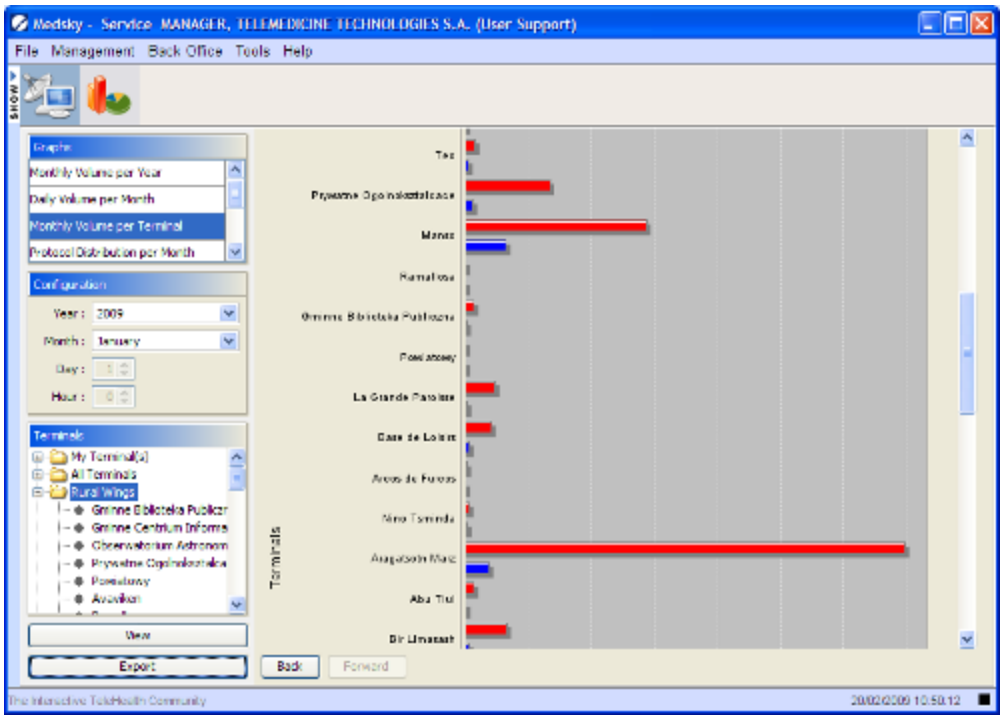


Figure 70: TTSA satellite network - Terminals' activity over one month

This graph proves to be very useful to monitor which terminals are really active in a month and which ones are mainly contributing to the demand.

Protocol distribution per month

Was already existing in previous version but its presentation has been improved. This graph details the total monthly volume, either for a group of terminals or for a single terminal.

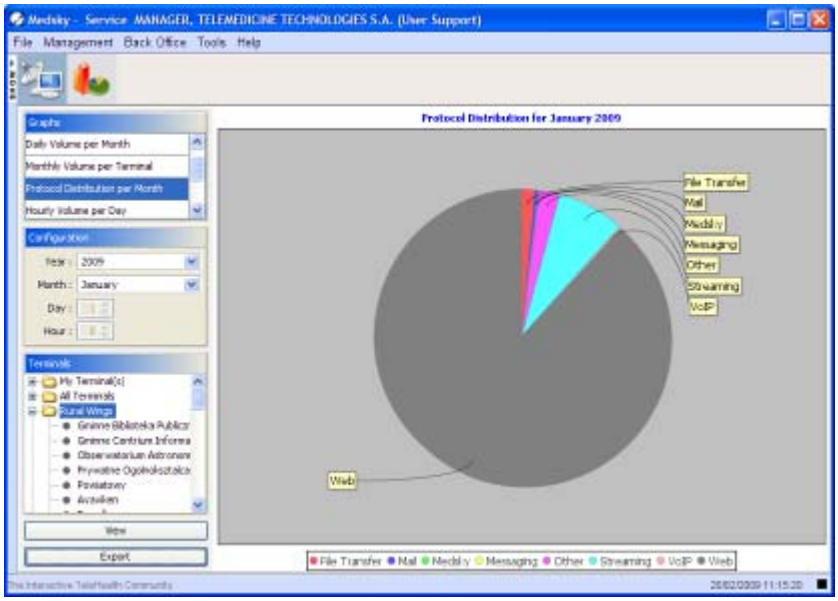


Figure 71: TTSA satellite network - Protocol distribution per month

Hourly volume per day

This graph details the total hourly volume across one day, either for a group of terminals or for a single terminal. Data can be exported in an excel document. The major interest is to monitor daily usage profiles. It also enables to identify saturation effects at peak hours.

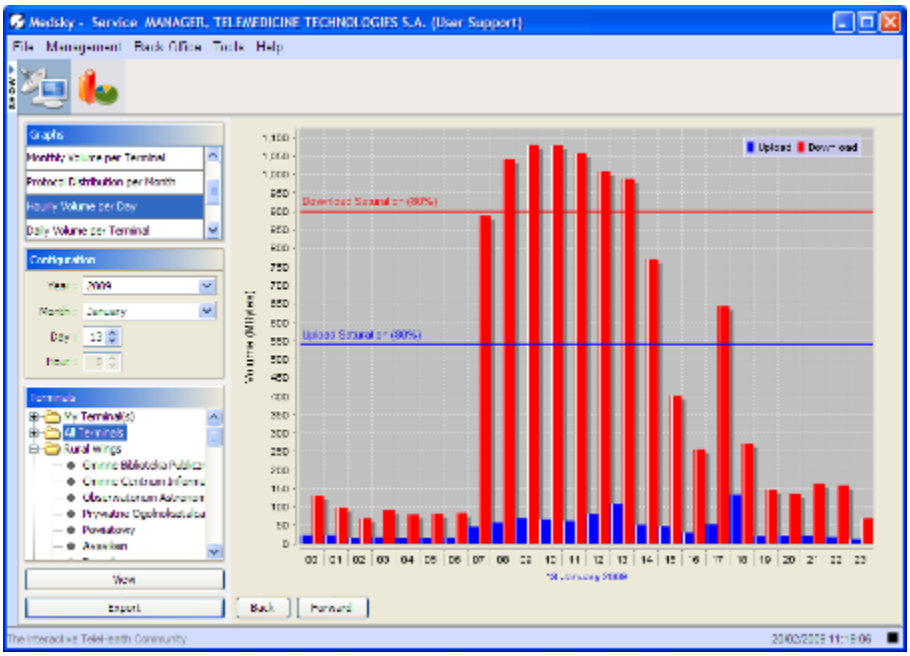


Figure 72: TTSA satellite network - Total hourly volume per day (per terminal or per a group of terminals)

Whatever the traffic and the selected day, both ordinates (Y axis) and coordinates (X axis) are fixed. A saturation level is indicated at 80% of the total available bandwidth. This level differs for upload and for download as the corresponding total available bandwidth are 1.5Mbps and 2.5Mbps respectively.

Daily volume per terminal

This graph is the replication of graph 3 but for a monitoring period restricted to one day. It is very useful to compare with the results of graph 5 and see which terminals have been mostly contributing to the traffic of one particular day.

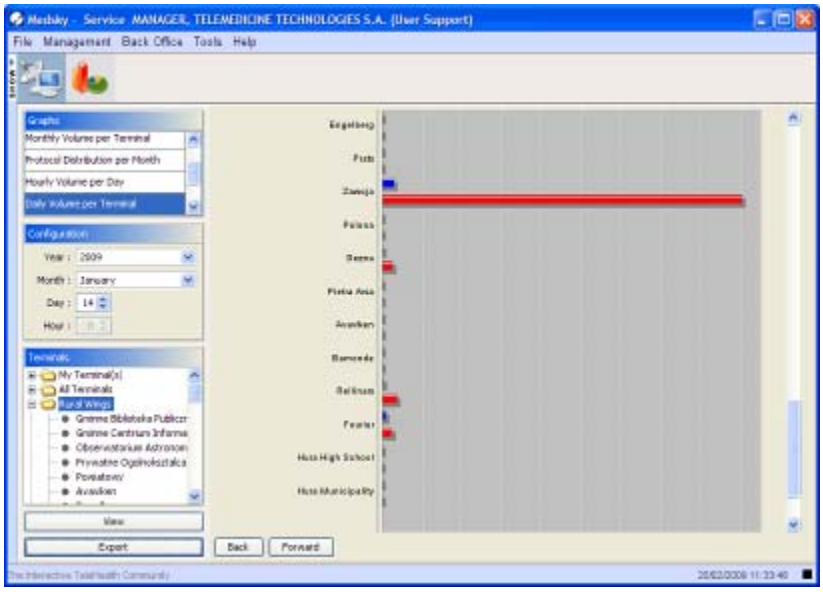


Figure 73: TTSA satellite network - Terminals' activity over a day

24 hour traffic chart

This graph is a complement to the previous 2 graphs. It shows the bit rate profile across one day. Values are averaged over periods of 5 minutes to obtain a readable display and short response time. The chart can be plotted either for a group of terminals or for a single terminal. Data can be exported in an excel document.

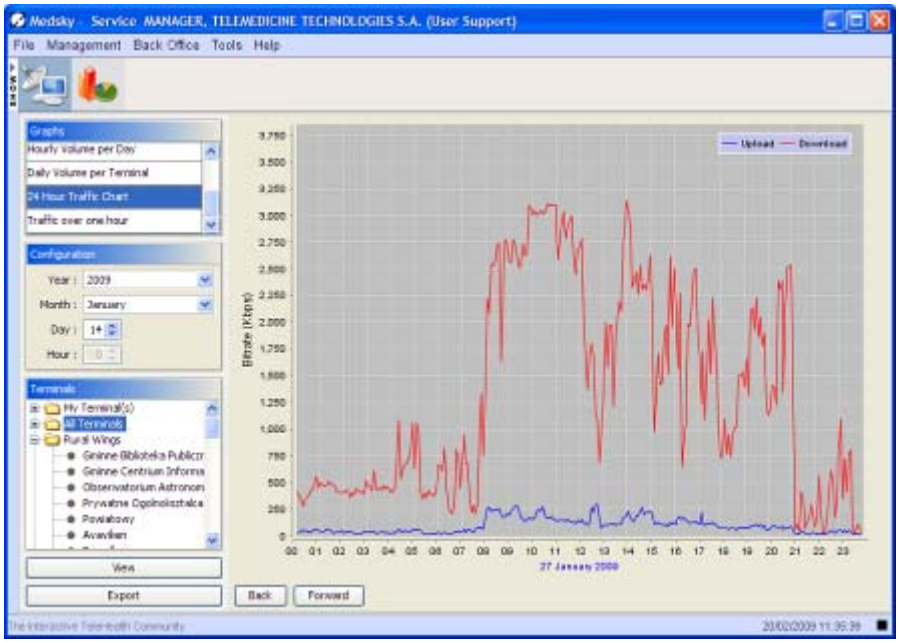


Figure 74: TTSA satellite network - Bit rate profile over one day

Traffic over one hour

This graph is a zoom on one single hour of the previous chart. In this case values are averaged over periods of 30 seconds (the best of the monitoring device). This chart is very useful to analyze a specific event and see in details how terminals are behaving.

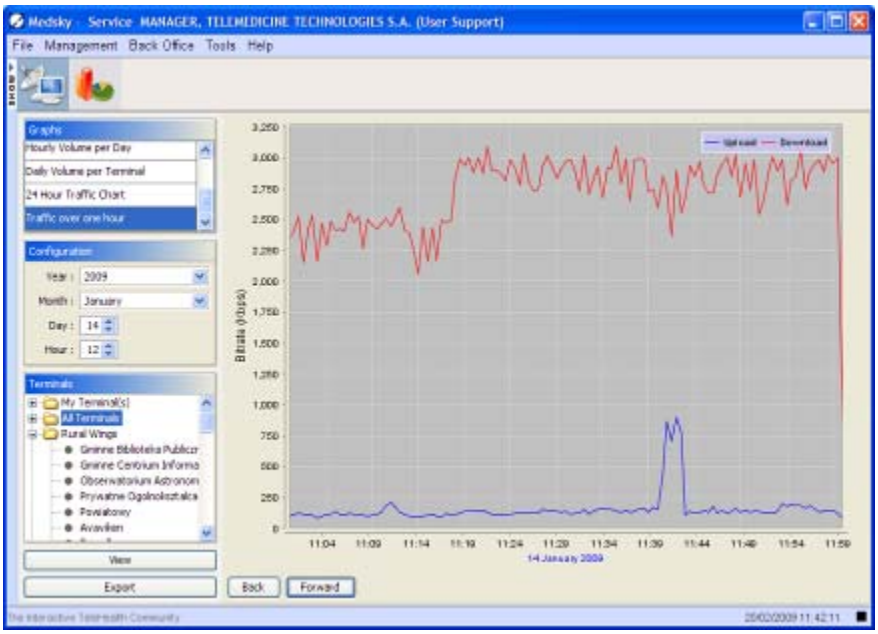


Figure 75: TTSA satellite network - Bit rate profile over one hour

Buttons "Back" and "Forward" enable to easily browse data from one hour period to the next or previous one.

When the graph is applied to one only terminal, we have added information about whether the terminal is on or off, as monitored through our NAGIOS platform.

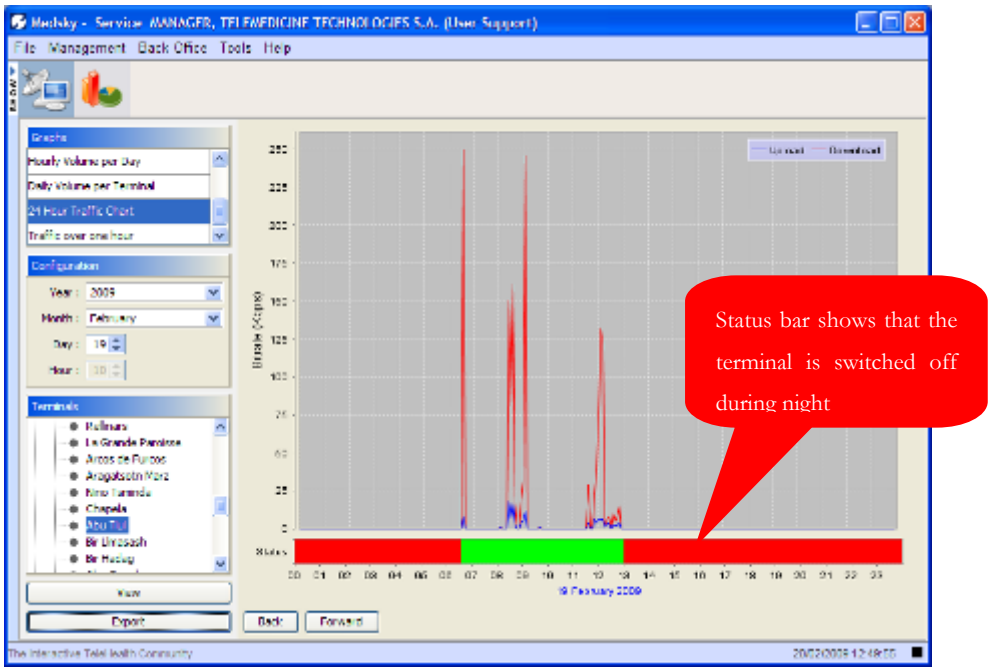


Figure 76: TTSA satellite network - Terminals' status

Improving QoS rules for speed tests

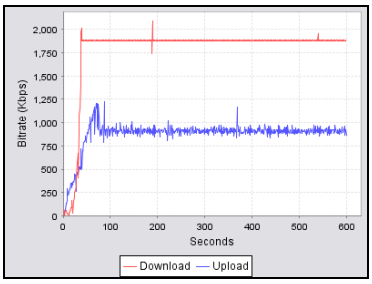
Speed tests are a complement to the control of the radiofrequency parameters of a terminal which can also be monitored remotely in case a problem is reported. One advantage of the speed test is that it can be performed by the end user autonomously. The application of a QoS policy to ensure guaranteed bit rate is a requirement to effectively control whether the maximum achievable throughput corresponds to the requirements.

To get rid of eventual artefacts due to the Internet branch of connectivity (between the satellite HUB and the speed test server located in the Internet) and to seamlessly apply appropriate QoS rules, TTSA has developed its own fully integrated speed test system. The increasing traffic has resulted in higher stress on the bandwidth resource and the QoS rules initially designed had to be adapted.

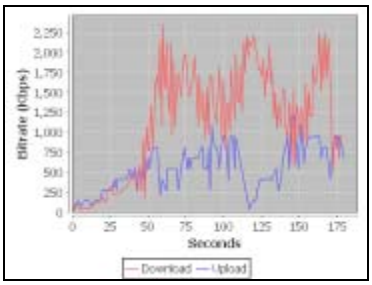
The increased demand for bandwidth requires applying stronger QoS policies than initially implemented to achieve the expected result. The adaptations which have been implemented enable obtaining acceptable results. One can see though that on the forward link (from the HUB to the terminal) a steady bit rate is not always achieved on a permanent way if traffic is really congested. One possible explanation is that the speed test server is located on the network branch located between the router to Internet and the QoS

device. In all cases, this evidences that when the traffic is really congested, the overall QoS system cannot perform optimally and there may be some fluctuations around the targeted objective.

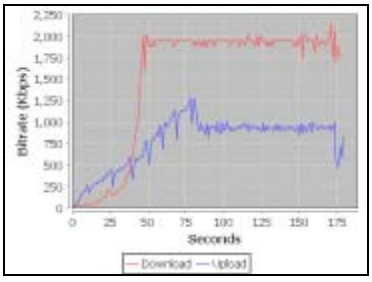
The graphs below summarize the obtained results.



Reference speed test recorded at the time of initial deployment



As the demand for bandwidth has been increasing, speed tests become less stable.



Upon adaptation of the QoS rules, a profile close to the initial one has been restored.

The newly developed graphs enabled to confirm the efficiency achieved as follows.

Signature of the speed test on the hourly traffic chart of the concerned terminal is clear.

The overall demand for bandwidth was high at the time when the speed test was performed

Improving the integration of the selected videoconference solution

The implemented videoconference solution was presenting two major drawbacks:

- TCP acceleration implemented on the DSTAR platform by SKYLOGIC proved to be originating unexpected disconnections due to the TCP/IP control signalling between the Easymeeting client and the server. A temporary solution had been implemented consisting in disabling the TCP acceleration for the terminal which main usage is videoconference. We have implemented a UDP based signalling for the control signals. This solution is much more satisfying as it enables better overall performances and reaction time at the level of the user interface.
- Also, easymeeting delivers a self view enabling the connected user to control the video he sends to the other participants. This self view was consistently degraded when static multicast routing disabling the reception of the terminal's own flux was not applied. The software has been modified to enable disable static multicast routing, a feature inducing significant workload for network operation and maintenance.

Miscellaneous

Daily routine operation of the platform deployed evidenced the need for a number of improvements and / or upgrades that are shortly summarized as follows:

- At installation time, the ALLOT NETXPLORER (version NX7.3.1 build 22) showed to require a 32 bit version of windows server 2003. The hosting server provisioned at installation time was running in 64 bits. As a result, the ALLOT NETWPLORER has been deployed on a compliant XP version on top of a virtual machine VMWARE. This configuration showed to work to implement the monitoring infrastructure as it was designed at that time. However, this system showed a number of limitations in terms of maintenance, also inducing a heavy maintenance workload. It was then decided (May 2009) to upgrade the NETXPLORER to the latest available version (version NX9.2.1 build 07). The deployment of this new version was performed in July 2009. However a number of issues were addressed for resolution to the ALLOT support (as we have a gold support subscription). It resulted that, to obtain a full support with all required warranties, the hosting machine shall be (a) dedicated, and (b) fully compliant with the reference configuration recommended by ALLOT.
- The upgrade to the last version of NETXPLORER will allow to implement a more efficient and reliable traffic monitoring software platform: no further need to maintain manually a large number of "reports". It becomes possible to fully automate the administration of the platform as new terminals and new graphs are implemented. A source code re-factoring has been engaged in this direction.
- Finally, it has been decided to engage the re-factoring of the source code for the implementation of the videoconference session booking system. The work has enabled to generate a much clearer source code, easier to maintain, enabling to adapt efficiently new QoS rules depending on the type of application. The system has also been improved to implement error management for instance in case some resources, such as the videoconference server, are no more available.

3.7 EXPLOITATION IMPROVEMENT: INTEGRATION OF NEW WIRELESS TECHNOLOGIES WITH SATELLITE

3.7.1 Introduction

To provide immediate broadband Internet connectivity to rural and isolated areas, satellite communications combined with wireless local networks are cost-effective, reliable and sustainable broadband access solutions. Over the past years, hybrid Satellite-WiFi networks have been deployed in several European countries. WiFi systems have been successfully used to aggregate the demand of sharing satellite Internet access between several users over a short 600-meters diameter area around the access point. Further enhancements are thus considered in this workpackage to extend the wireless local loop coverage and to improve security features and QoS mechanisms.

The comparison among different technical specifications and performance has been the starting point to select the most suitable broadband wireless technologies relevant to the project.

To validate the integration of these new broadband wireless technologies with satellite solutions, a test-bed has been set-up at Astrium's premises. An assessment of available COTS equipment has been performed in order to select those that better meet the identified system requirements and constraints. After thorough discussions with the selected broadband wireless solution suppliers, loan contract has been agreed for in-lab testing and validation during a trial period.

Test activities consisted of a series of steps:

- Definition of the test methodological approach,
- Elaboration of a testing strategy,
- Search for tools that can properly address the requirements and goals of the tests,
- Set-up of monitoring software for the test results analysis,
- Test runs
- And evaluation of the test results.

3.7.2 Synthesis of user and service requirements

The following table summarizes the main users' requirements identified.

Requirement	Feature to be implemented
Broadband access to Internet	Global coverage thanks to satellite terminals Large coverage of the wireless network to extend the satellite coverage
Large number of services & applications	Higher data rate to fulfil with the requirements of all kinds of traffic

	QoS mechanisms in order to prioritize some traffic or to ensure limited latency and jitter to real time traffic
Good quality	Higher data rate & QoS mechanisms
Seamless	End-to-end performances, simplicity of usage
Cost effective	Wireless network to share the satellite terminal & subscription cost Large coverage of the wireless network
Confidence in the network	Security features: confidentiality, integrity & authentication Availability of the network

Table 22: User requirements for broadband connectivity

3.7.3 Technology & Equipment selection

Technology selection

A comparative analysis of the wireless technologies state of the art has been carried out. This analysis' criteria were: theoretical and real performances in terms of data rate and coverage, QoS features, Security features, maturity of the technology and availability of cost effective equipments.

Through this analysis, the IEEE 802.16 standardised technology, also called WiMAX has been selected. In fact, WiMAX allows to:

- Increase the coverage area (several kilometres instead of hundreds of meters),
- Increase the global throughput,
- Provide QoS and Security functionalities more efficient that the one proposed in WiFi,
- Provide more robustness in urban areas thanks to the air-interface definition based on the OFDMA scheme, which allow to deals with multipaths (only in the IEEE 802.16e release).

Two versions of this standard are standardised : 802.16d, also called "fixe WiMAX" and 802.16e, also called "mobile WiMAX". As far as there was no interconnection with mobile users in the NETADDED context, and for economical reason, the "fixe" version has been selected for the test-bed experiments and the installation in real conditions.

WiMAX can operate in under licensed or unlicensed frequency bands. Therefore, it was possible to envisage validation test at ASTRIUM premises using the 5.4 GHZ unlicensed frequency bands and real deployment with wireless operator in licensed frequency bands (like 3.5 GHz).

Nowadays, WiMAX products, event if they are not as inexpensive as WiFi equipments, have become more affordable, and it can be considered like a real mature technology, already deployed in lots of countries.

Equipment selection

A market analysis has been realised between existing IEEE 802.16d equipments. Different products from the most famous providers: Airspan Networks, Motorola and Alvarion have been compared.

Airspan MicroMAXd base station equipment has been selected. The main reason of this choice are that:

- Airspan products are fully compatible with the standards (both fixe and mobile WiMAX) whereas Motorola Canopy is comparable to WiMAX but is a proprietary solution,
- Airspan products can operate in both licensed and unlicensed frequency bands, whereas BreezeMAX series from Alvarion only operate in under license frequency bands,
- MicroMAXd is the lowest cost solution which answer to the requirements (IEEE 802.16d).

Two Airspan CPE ranges of products exist: EasyST (all indoor CPE) and ProST. The last version, ProST2 is compatible with both fixe and mobile Base Station. And the ProST WiFi version integrate a WiFi access point in the equipment. Therefore, ProST and ProST Wifi have been selected for the project.

Airspan also proposed the Netspan client/server supervision tool, used to configure and supervise the equipment.

Figure 77: Airspan MicroMAXd

Figure 78: Airspan SDA

Figure 79: Airspan ProST with an SDA

Figure 80: Airspan ProST WiFi

3.7.4 Integration and test bed validation

3.7.4.1 Test-bed platform description

Test-bed architecture

The test-bed platform was located at ASTRIUM premises and was composed of:

- Bidirectional Satellite access provided by TTSA (2560 kbps on the forward link and 1536 kbps on the return link),
- Airspan WiMAX equipments (1 MicroMAXd base station & 2 ProST & ProST WiFi access points),
- WiFi equipments,
- Network equipments (switchs), workstations and VoIP equipments in order to create real or emulated traffic to perform the tests.

The Netspan supervision tool was used to manage and configure the WiMAX equipments.

The following figure presents the test-bed architecture.

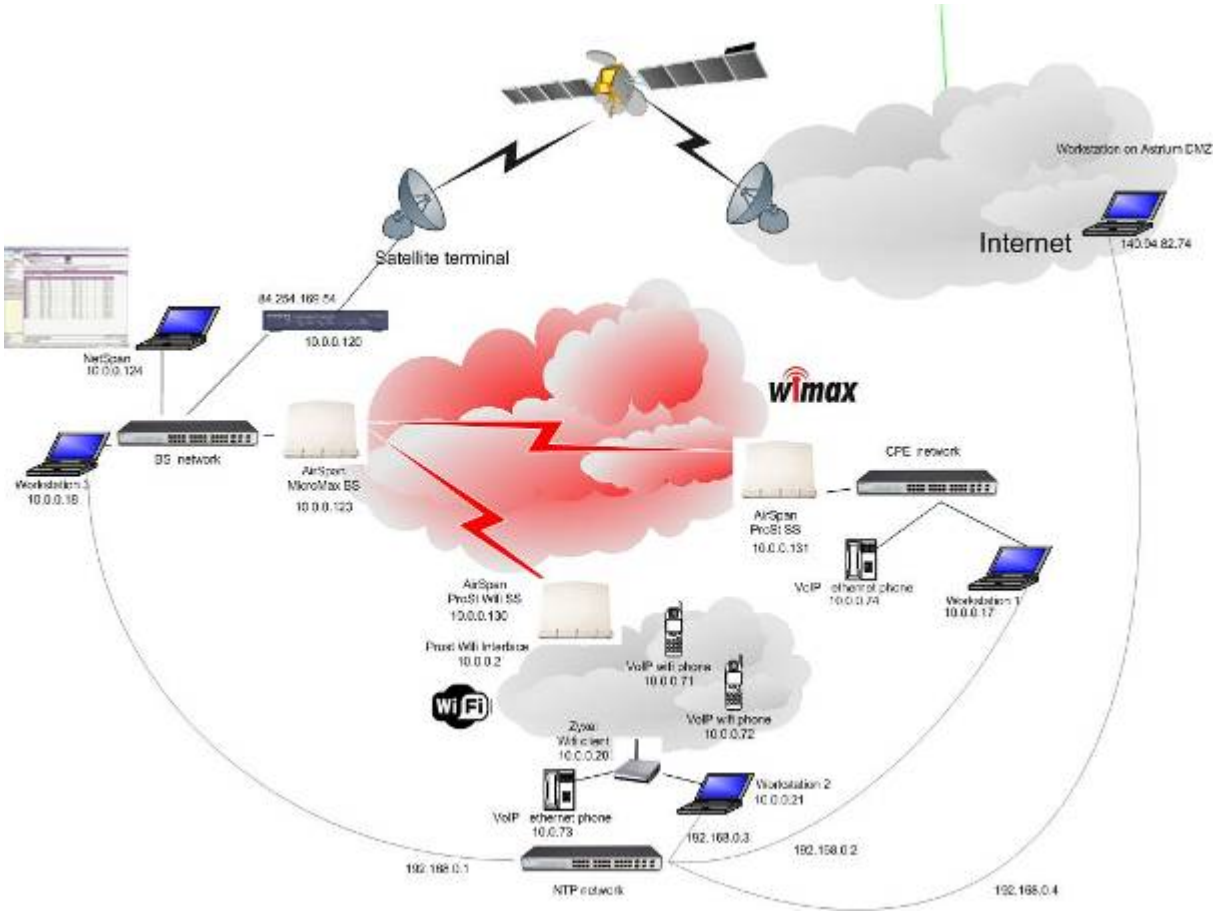


Figure 81: Test-bed platform architecture

Measurement tools

Four types of measurement tools were used:

- Traffic generator
  - IPerf – client & server tool which can generate UDP and TCP data streams and measure the throughput of the network, the packet loss rate and the delay and jitter (for UDP traffic),
  - MGEN – Multi GENerator is an open source generator which can perform IP performances analysis based on UDP traffic only. It is used for long test period,
- Graphical representation, used for MGEN results post-processing (Trpr & Gnuplot)
- Network traffic analysis
  - Wireshark – open packet sniffer,
  - RIO (Real time IP Observer), ASTRIUM proprietary tool.
- Network time synchronisation with NTP time synchronisation service.

Traffic generators allow to stress the network in order to determine the highest performances and their limits whereas traffic analysis tools allow to observe the usage of the network and the performances achieved for the traffic which is transmitted, from a non-intrusive way.

Network synchronisation tool was used to perform latency measurement with MGEN.

The figure below presents some screenshots of the results obtained with those tools.

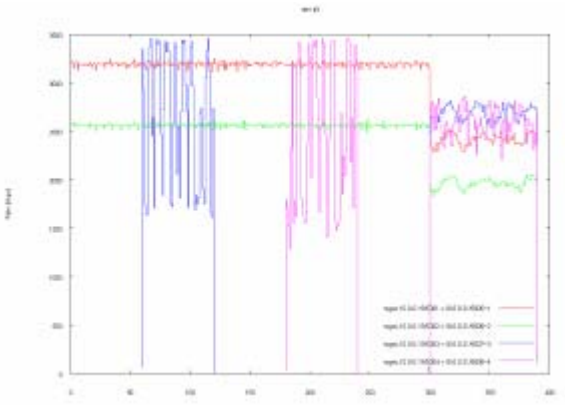


Figure 82: MGEN file trace analyzed using trpr/gnuplot result example server side

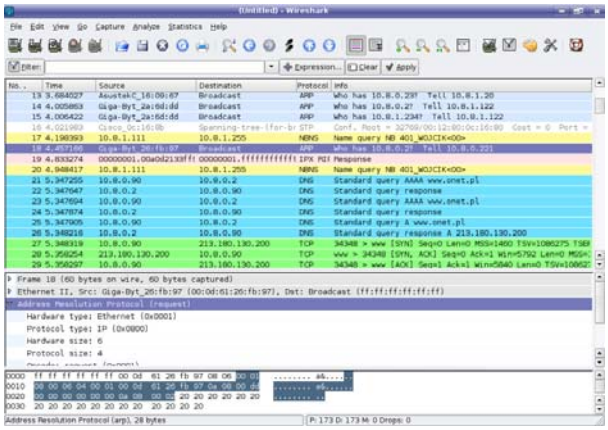


Figure 83: Wireshark interface

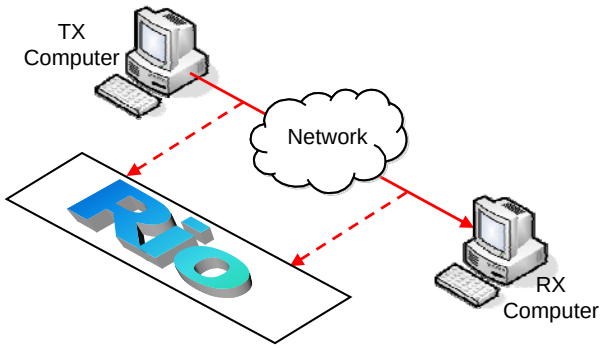


Figure 84: RIO network topology

Figure 85: RIO interface

Applications

Real applications were transmitted through the network in order to evaluate the possible usage of the network and the performances which can be achieved from the user point of view (quality, availability).

File Transfer (using FileZilla client and server open software), VoIP and videoconference (using Marratech software) applications were installed and used during the validation tests.

3.7.4.2 Tests & Results

Test plan

Five types of tests have been performed:

- Performances measurement (throughput, latency, jitter and packet loss),
- Quality of Service – in order to verify the implementation of the QoS and the prioritisation of the traffic,
- Security – in order to evaluate the impact of the encryption & authentication mechanisms on the performances,
- DFS – in order to evaluate the impact of the DFS mechanisms on the performances,
- Applications – in order to verify the applications quality from the user point of view.

Four target test scenarios have been defined in order to evaluate the WiMAX system performances and the hybrid network end-to-end system performances:

- Scenario A : a simple WiMAX point-to-point (PTP) network (CPE + BS),

- Scenario B: a combined WiFi/WiMAX network combining two PTP links using WiMAX as backhaul solution for WiFi hotspot (CPE WiFi + BS),
- Scenario C: a complete WiFi/WiMAX solution including a point-to-multipoint WiMAX network (CPE WiFi + BS + CPE),
- Scenario D: a hybrid end-to-end solution coupling satellite and WiMAX system.

Those scenarios have been set up in order to assess the performances and impact of each segment of the network (WiFi, WiMAX and satellite). Tests have been realised with both large packet size and small packet size.

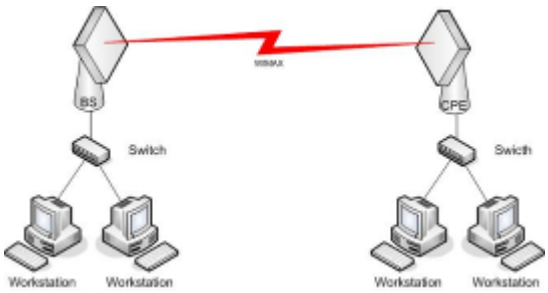


Figure 86: Scenario A

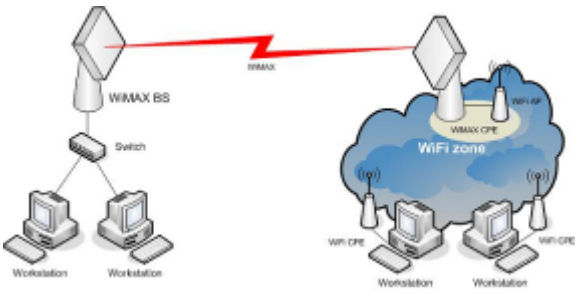


Figure 87: Scenario B

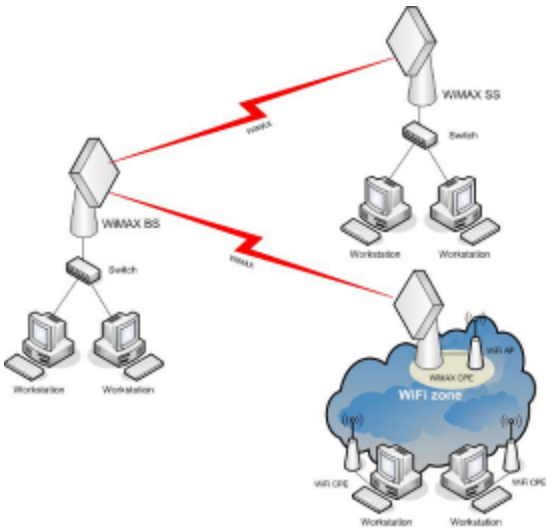


Figure 88: Scenario C

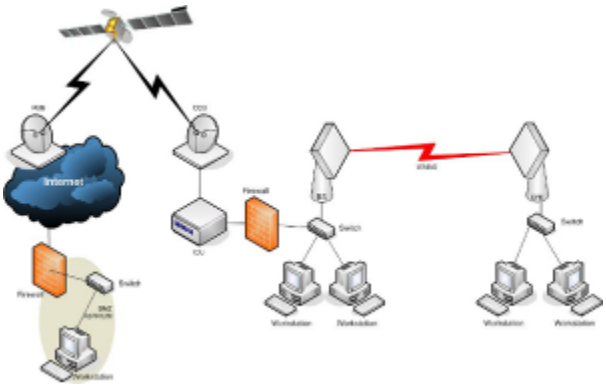


Figure 89: Scenario D

Test results

Main conclusions and lessons learned are summarized hereafter:

- To make a good usage of the available bandwidth, it is advisable to configure the applications (if this feature is available), the network protocol stack such as TCP/IP or by inserting a PEP in

order to have a traffic profile which is mainly composed of large size network packets (close to the maximum of TCP/UDP payload which is 1470 bytes). Otherwise, network packets of little size will give a little bandwidth. There is no need to configure MTU size, since BS WIMAX acts as an Ethernet switch.

- The satellite link increases (obviously) the latency (about 500-600 ms).
- Ciphering feature has no significant impact on network performances, it is advisable to configure by default this feature on all wireless equipment. Nevertheless, there is a small case of utilization where ciphering affects the network where it is applied on the WIFI link. In this particular case, when a subscriber station does not transmit any traffic, network gets unreachable from the base station point of view. To unlock the situation, subscriber station must transmit data.
- Since CPE WiFi offers very bad performance, it is advisable to associate a ProST Ethernet CPE and a WiFi access point which will give better results.
- DFS feature is not operational with wireless equipment loaded with AIRSPAN SR6.5 firmware and the defect has been declared by ASTRIUM in Airspan tracker system. AIRSPAN has to supply an updated firmware beta version which corrects the defect. Although this should look as a blocking issue when deploying wireless outdoor equipment in license free frequency bands (DFS activation is mandatory in this context (refer to ERC recommendations)) ,in case of NETADDED wireless network deployment in Morocco, this is not an issue since this network will be deployed with a WIMAX operator licensed context.
- When using the Airspan MicroMAX system, the service profile should be configured in downlink with a maximum MIR corresponding to the capacity of the radio channel in order to obtain the best performance.
- Given that the WiMAX system does not allow to manage in terms of QoS the interface between two network segments (WiMAX, satellite) having different data rates, in order to setup a reliable end-to-end QoS the WiMAX network shall be limited in bandwidth to the satellite capacity in the uplink direction.
- The obtained results put the light on the benefits of such a solution, essentially in terms of network deployment, available throughput and quality of services on end-to-end applications and validate the fact that hybrid satellite-WiMAX or Satellite-WiMAX-WiFi networks can easily be deployed in an outdoor environment.

Astrium test bed was kept operational after the test performances in order to help to solve any major issue that would have been encountered in the validation sites in Morocco. The Moroccan operator selected to perform the validation site installation, WANA, has a strong experience in wireless networks deployment, therefore, no major issues raised up and no specific activity has been carried out involving WiMAX devices in Astrium laboratory.

A remote supervision system was set up, based on NTOP and VNC softwares, allowing to perform distant supervision and to collect usage statistiques from Astrium premises.

3.8 EXPLOITATION IMPROVEMENT: E-LEARNING APPLICATIONS DEVELOPMENT

3.8.1 Introduction

The major mission of Connected Schools is to provide professional education to unfavoured children in emerging countries by means of distant learning to compensate for the lack of skilled teachers there. For this purpose, HW and SW collaborative work tools are analyzed based on the high level requirements defined during the first phase of the project. The main objective of the work carried out in the WP4.3.5 has been to select the most promising distant learning tools taking into account the following two main constraints:

- Cost as province schools and communities in emerging countries have a very low purchasing power,
- Power consumption as the electricity grid is often not available in those areas.

The activity started with a "requirements gathering" phase, followed by the review of the various technical, financial and human constraints. The list of fundamental features for distant learning application has then been prioritized based on the specifics of the pilot site user requirements but also adapted to a generic solution that could be deployed nationwide.

To match the economical model of such emerging countries, cost issues have been addressed through low cost hardware selection.

The most important part of the work activity consists in the selection and the tests of the SW and HW tools. To evaluate the tolerance of the software to individual network disturbances a network simulator is used. Finally real life tests on satellite Cambodian network have been run.

Most schools in Cambodia provinces do not have electricity. It was therefore a natural part of CS's endeavour to create a power supply system to power distant learning centres. Since Cambodia climate lends itself well to using solar energy whereas it is not a good place for windmill, the goal was to develop a generic solar power supply system for classrooms in Cambodia.

3.8.2 Synthesis of user and service requirements

To enable high quality collaborative work, the necessary features that a good distant learning tool should offer are summarized in the table below. This list is exhaustive compared to the real need of the targeted users in Cambodia and only sophisticated and expensive proprietary tools offer such a panel of functionalities. Therefore, an attempt to specify the minimum requirements of the distant learning application has been made.

Furthermore, the prioritization of those features has also been reviewed taking into account the constraint of satellite delay that would damage the (audio and video) quality.

One of the difficulties was to balance this feature set between the pilot project and a generic solution that could be deployed nationwide. In the context of the pilot project the vast majority of the conferences will be point to point. However in the case of a nationwide (or at least regional) deployment, there would likely be cases for multipoint conferences.

User required functionalities	Priority
Audio call (one to one)	1
Desktop sharing (includes whiteboard sharing)	2
Video call (one to one)	2
Fast access to stored training content in local language	2
Internet access	2
Audio conferencing (multipoint)	3
Chat (instant messaging)	3
Email	4
Video broadcast	5
Video conferencing	5
Forum	5

Table 23: Prioritized list of collaborative work functionalities

The delivery of good quality e-learning courses is also improved by the choice of hardware devices. The list of hardware requirements is given hereafter and distinguishes the specific needs on teacher side and on distant class side. The results of the market survey performed on several most important hardware for distant learning can be found in the AD17.

On teacher side	On distant class side
o One standard computer o One microphone o One projector o One Interactive Whiteboard o One set of Loudspeakers o One antenna and modem	o One notebook computer o One wired microphone o One LED projector o One graphics tablet o One set of Loudspeakers o One light bulb o One antenna and modem o One solar panel o One battery charger/ regulator o One 12V/100Ah battery o DC-DC converters

Table 24: Hardware requirement for distant learning

3.8.3 Methodology

Selection of the collaborative work tools to be evaluated

The list of existing distant learning tools that would match those high level requirements is endless.

However, a few were eliminated on the basis of two important criteria:

- Web based conferencing tools that would entirely rely on some central server based in a western country (Windows Live Meetingsn Elluminate, Global Commmunications Network, etc…),
- Professional tools with prohibitive costs (Adobe Connect, Centra, Wimba, etc….).

Unfortunately, freeware or low cost tools did not comply with the full list of requirements. A combination of multiple freeware was thus needed to satisfy the audio/video conferencing performance while sharing facilities such as whiteboard.

At last, the selection of the tools to be evaluated was done based on the three following criteria : cost, feature set and maturity.

The first evaluation of the selected tools have been realised using the prioritized list of functionalities. The table below shows how each tool match the user required functionalities. If the feature is available this is indicated in the table in green colour, otherwise either this feature does not work and is reflected in red colour or this is simply not applicable. The yellow colour is used to rate the application with average results.

User required functionnalities	Priority	Asterisk + Softphone	Windows Live Messenger	Skype	Marratech	Vsee	UltraVNC	RemoteX (Skype Extra)	USeeToo (Skype Extra)	Netmeeting	Talk&Write (Skype Extra)
Audio call (one to one)	1										
Desktop sharing	2										
Video call (one to one)	2										
Fast access to stored training content in local language	2	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable
Internet access	2	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable
Audio conferencing (up to 1+3)	3										
Chat	3										
Email	4	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable
Video broadcast	5										
Video conferencing (1+3 max)	5										
Forum	5	Not Applicable	Not Applicable	Not Applicable	Not Applicable		Not Applicable	Not Applicable	Not Applicable		Not Applicable

Table 25: First evaluation of collaborative work software

Drawing-up of criteria list to evaluate and weigh the selected tools

An exhaustive list of criteria has been defined to evaluate and rank them by weight.

Prioritized Criteria list for Audio/ Video Conferencing Tools	Weight
Cost (per user)	5
Stability: bugfree operation, dropped calls, resistance to network jitter, delay, packet loss and low bandwidth	5
Performance: Audio quality for a given set of network conditions (round trip delay, jitter, packet loss, bandwidth)	5
www Internet independency (can be fo voice traffic or for call supervision)	5
User friendliness: good man machine interface, full name directory	4
Audio conferencing capability (max number of users) and efficiency (data rate value on the satellite link in case of multiple users on both ends of the link)	3
Ability to traverse NAT, proxys and firewalls	3
Video call quality	2
Ease of installation and maintenance investment (client + server)	2
Support for multiple operating systems	2
Long term company sustainability, large customer base	2
Open source	1
Others: call waiting, call forwarding, call hold, voice mailbox, shortdialing	1
Video conferencing capability	1

Prioritized Criteria List for Desktop/ Whiteboard sharing tools	Weight
Cost (per user)	5
Stability: bugfree operation, dropped calls, screen refresh, resistance to network jitter, delay, packet loss and low bandwidth	5
www Internet independency (ideally NOT Web server based)	5
Desktop sharing functionnalities : Full applications sharing, bidirectional sharing, remote user control capability, powerpoint annotation support.	5
Integrated Whiteboard sharing	5
Performance: PPT display delay for desktop sharing and data integrity for the whiteboard sharing for a given set of network conditions (round trip delay, jitter, packet loss, bandwidth)	5
User friendliness: good man machine interface, full name directory	4
"One to Many" support	3
Ability to traverse NAT, proxys and firewalls	3
Ease of installation and maintenance investment (client + server)	2
Support for multiple operating systems	2
Open source	1

Table 26: List of criteria to evaluate and rank the distant learning software

Evaluation tests

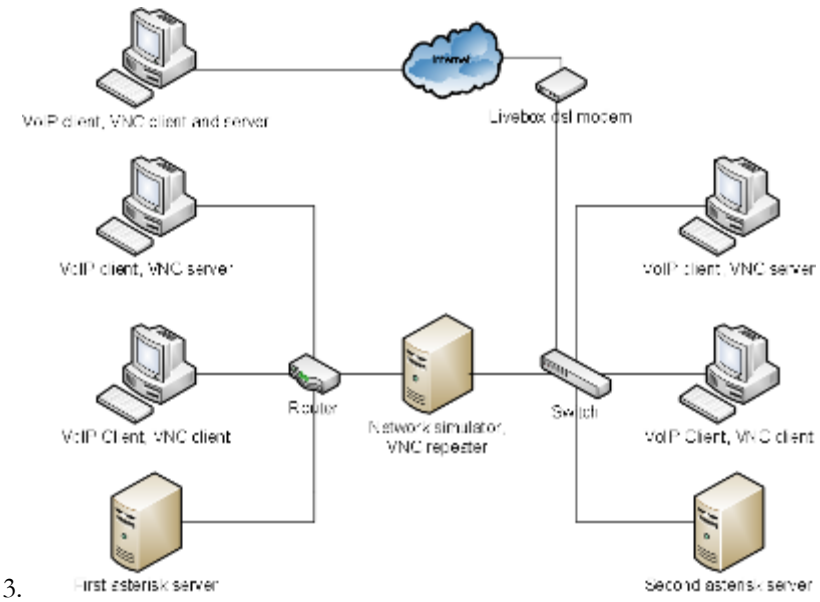
To fill-in the Table 26, the stability and network performance parameters of the selected audio / video conferencing tools are evaluated based on a test campaign. Those tests have been run in Toulouse whereas the final tests have been made in Cambodia on the Camshin (IPStar) satellite link.

Otherwise, most criteria of the Table 26 are given in a binary manner, either the functionality is implemented on the software or not. Furthermore, subjective evaluation (Means Opinion Score) is made on the video and audio quality.

3.8.4 Test environment description

In order to characterize the various tools versus network performance in a controlled environment, a network simulator has been used to evaluate the tolerance of the tested software to individual network disturbances: delay, jitter and packet loss, and subsequently to combinations of all.

To simulate the satellite link in Cambodia, measurement tools have been developed to collect the network metrics between Phnom-Penh and Ang-Ta-Saom (each site having a satellite-based Internet access). A combination of open source software described in AD17 has allowed to provide the satellite link characteristics such as packet loss, jitter, round-trip delay, bandwidth.



3.

Figure 90: Test set up diagram in TLS (WAN)

3.8.5 Validation under real conditions

To measure the performance of the selected software in real conditions, several tests have been performed from Phnom-Penh to the satellite connection in Angtasaom using either the satellite or the long range WiFi technologies.

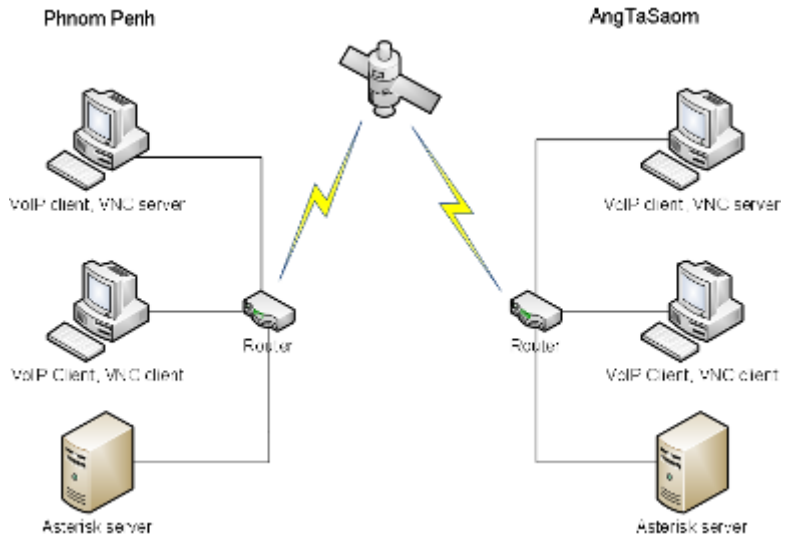


Figure 91: Test set up diagram in PP & ATS - Two satellite links

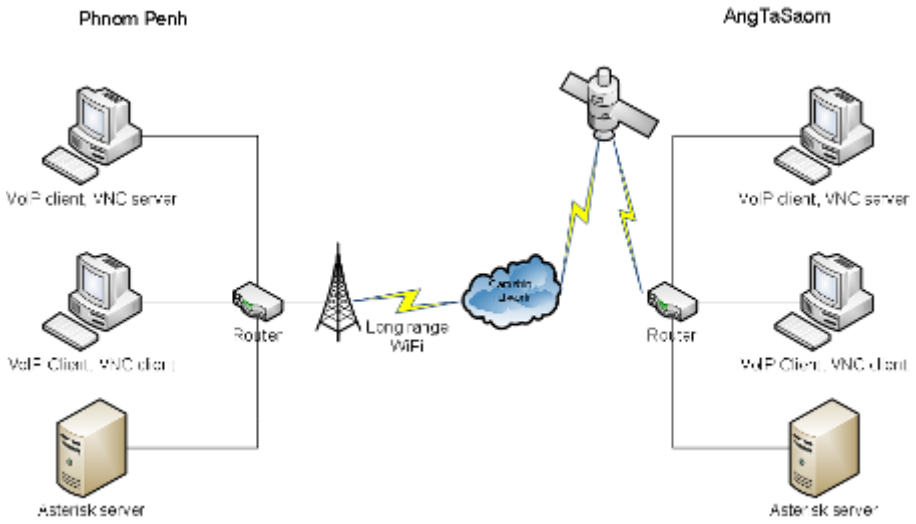


Figure 92: Test set up diagram in PP & ATS - One satellite link & long range WiFi

3.8.6 Results and recommendations

Screen sharing comparison summary

UltraVNC, RemoteX and VSee do not have integrated whiteboard and Marratech does not have desktop sharing. A combination of multiple SW packages that fit within the same user interface framework such as USeeToo and RemoteX which are Skype Extras has been tested. As Marratech integrates a whiteboard but has not desktop sharing, UltraVNC is used to improve the solution. Unfortunately, VSee could not be complement with a standalone "Whiteboard sharing".

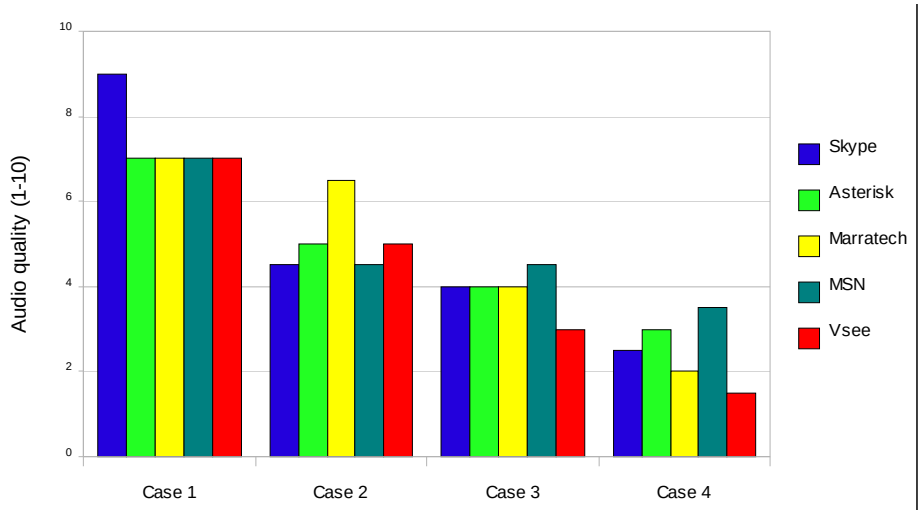
The following table summarizes the result and Skype has been selected to go forward until further notice.

Functionnality	Live Messenger + Netmeeting	Skype + Remote X + USeeToo	Marratech + UltraVNC
Audio/ Video Conferencing	137,5	158,5	132
Screen Sharing	178,5	187,5	173
Final score	***316***	***346***	***305***

Audio quality versus delay, jitter, packet loss

After testing each SW versus each network disturbance parameter, a combination of these parameters (see chart below) has been tested as the only means to synthesize performance.

	Delay	Jitter	Packet Loss
Case 1	0	0	0
Case 2	1000	50	5,00%
Case 3	2000	100	10,00%
Case 4	3000	150	15,00%



From the results given in the Table 27, Skype came out as the relatively clear winner. In particular it really is the only one that is capable of placing call reliably over the Camshin satellite network. The only caveat is that audio performance is still not adequate for "live lectures" via satellite.

Audio/video conferencing tools comparison summary

CRITERIA	Weight	ASTERISK + X-Lite		Windows Live Messenger		SKYPE		Marratech		Vsee	
		Grade	Score	Grade	Score	Grade	Score	Grade	Score	Grade	Score
Cost (per user)	5	5	25	5	25	5	25	5	25	5	25
Performance: Audio quality for a given set of network conditions (round trip delay, jitter, packet loss, bandwidth)	5	3,5	17,5	3,5	17,5	3,5	17,5	4	20	3,5	17,5
Stability: bugfree operation, dropped calls, resistance to network jitter, delay, packet loss and low bandwidth	5	2	10	2	10	4	20	3	15	4	20
www Internet independency (can be fo voice traffic or for call supervision)	5	4	20	3	15	3	15	4	20	3	15
User friendliness: good man machine interface, full name directory	4	4	16	5	20	5	20	4	16	4	16
Audio conferencing capability (max number of users) and efficiency (data rate value on the satellite link in case of multiple users on both ends of the link)	3	5	15	0	0	3	9	2	6	2	6
Ease of installation and maintenance investment (client + server)	2	1	2	5	10	5	10	4	8	5	10
Ability to traverse NAT, proxys and firewalls	3	1	3	5	15	5	15	2	6	5	15
Video call quality	2	3	6	3	6	3	6	3	6	3	6
Long term company sustainability, large customer base	2	3	6	5	10	4	8	1	2	3	6
Video conferencing capability	1	0	0	0	0	0	0	0	0	0	0
Support for multiple operating systems	2	3	6	3	6	5	10	4	8	1	2
Others: call waiting, call forwarding, call hold, voice mailbox, shortdialing	1	5	5	3	3	3	3	0	0	0	0
Grand Total			**131,5**		**137,5**		**158,5**		**132**		**138,5**

Table 27: Audio and video conferencing tools evaluation results

Power supply system

Most schools in Cambodia provinces do not have electricity. It was therefore natural to create a power supply system to power the distant learning centres. Since Cambodia climate lends itself well to using solar energy whereas it is not a good place for windmill, the goal was to develop a generic solar power supply system for classrooms in Cambodia.

The autonomous power supply system for a classroom with 8 computers and an video projector in Cambodia is therefore described as follows :

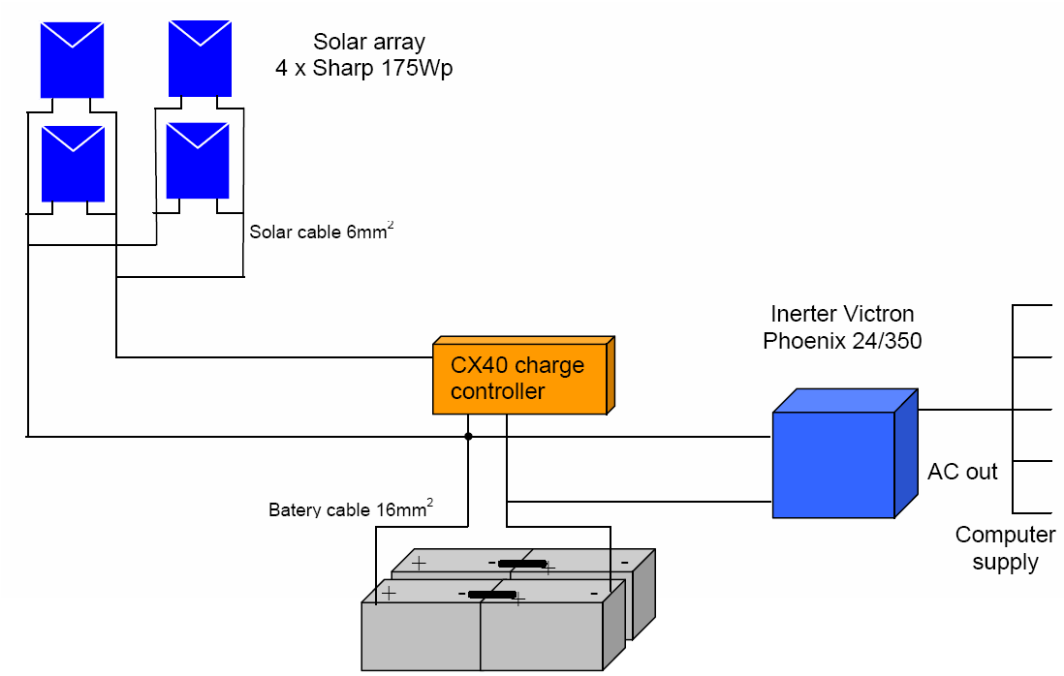


Figure 93: Power supply system block diagram

Working on new technology is always rewarding as things only get better if you wait. In particular 2008 has been the year of low power notebooks and we have also seen the first commercial low power LED projectors. These two have a rather dramatic impact on system power consumption. The chart below is an attempt to size a "minimal configuration" distant learning classroom, with just one laptop and to compare (roughly) power consumption evolution between the beginning and the end of our NETADDED project:

Equipment	Qty	Usage Hrs/ Day	2007 Average Power Consumption (Watt)	2007 Total Daily Power Consumption (Watt*hour)	2009 Average Power Consumption (Watt)	2009 Total Daily Power Consumption (Watt*hour)
One antenna	1	8	10	80	10	80
One notebook computer	1	8	35	280	12	96
One wired microphone	1	6	0,5	3	0,5	3
One set of loudspeakers	1	6	1	6	1	6
One LED projector	1	6	200	1200	48	288
One Interactive Whiteboard (Wii)	1	6	3	18	0,5	3
One light bulb	1	2	8	16	8	16
Conversion Loss/ Cabling Loss			26	160	8	49
Total			**283**	**1763**	**88**	**541**

The chart below is not meant to be perfectly accurate but rather to show realistic orders of magnitude based on 2008 market information. Therefore we have no doubt that before 2009 is over we will be able to demonstrate a less than 100 Watts, less than 2000€ distant learning classroom in action.

Distant classroom equipment	2007 Price (Euros)	2007 Qty	2007 Total Price (Euros)	2009 Price (Euros)	2009 Qty	2009 Total Price (Euros)
Antenna	400	1	400	250	1	250
Computer	500	1	500	300	1	300
Microphone	5	1	5	5	1	5
Webcam	50	1	50	50	0	0
Projector	800	1	800	400	1	400
Loudspeakers	35	1	35	35	1	35
Interactive Whiteboard	1800	1	1800	50	1	50
Light bulb	6	1	6	6	1	6
Solar panel	700	3	2100	600	1	600
Battery charger/ regulator	100	1	100	100	1	100
DC-DC converters (or Inverter)	150	1	150	60	1	60
Batteries	150	3	450	150	1	150
Miscellaneous (cabling, connectors, etc.)	100	1	100	100	1	100
Total			**6496**			**2056**

4 SITE DEPLOYMENT AND OPERATION

This activity has covered all the work related to deployment and installation at user premises, as well as exploitation and maintenance during the period of validation and user feedback.

Validation site procurement, deployment and acceptance

This activity includes all activities required to deploy at the validation sites the infrastructure and applications to offer end-users a ready to use service and validate under real conditions the improvements provided by development of Deployment and Exploitation improvementts.

Network operation and maintenance

This activity includes all activities required to provide operation support and technical maintenance to the validation sites all along the validation period. In addition, during network operation end-user usage and network performances will be gathered so as to be able to evaluate them.

This activity has been organised per site coordinator:

Site Coordinator	Validation sites	
CNES	Burkina Faso, Benin	*5 validation sites*
DEPT&NT	Morocco	*2 validation sites*
TTSA	Casablanca, Istanbul	*2 validation sites*
FNET	Greece	*1 validation site (*)*
CEMA	France	*1 validation site*
SABU	Turkey	*1 validation site*
CS	Cambodia	*2 validation sites*
		Total: 14 validation sites (*)

(*) The deployment of Fragokastello validation site has been cancelled in the frame of NETADDED. The network might be deployed outside NETADDED.

4.1 VALIDATION SITE PROCUREMENT, DEPLOYMENT & ACCEPTANCE

4.1.1 Objectives

Procure, deploy, accept each validation site (infrastructure and applications) to offer end-users a ready to use service and validate under real conditions improvements provided by development performed.

- Preparation of global validation site deployment plan to:
  - Define in an unambiguous manner the role of each entity involved in validation site procurement, deployment and acceptance,
  - Monitor, at the level of the project coordinator, the process and schedule of all validation sites.
- Procurement activities: COTS and adapted equipment procurement (software and hardware) including preparation of RFPs and selection process for COTS,
- Deployment activities: integration of COTS and adapted equipment (developed through WP 4) at end-user premises,
- Acceptance activities: test the correct operation of the validation sites before operation and performances evaluation through the execution of validation site acceptance procedures.

4.1.2 Validation site deployment process

The deployment of a validation site starts with the selection of services and equipments providers and ends with the site inauguration. The deployment time period between these two events can be estimated at more than 3 months, which is a non negligible delay to be taken into account for the preparation of the deployment plan.

The ideal deployment process for a validation site, presented in Figure 94, has 4 phases.

The process is activated once the service and equipments providers are selected by the Site Coordinator. In a first phase, the Site Designer (usually the Site Coordinator) consolidates the validation site network design according to the site profile, the application requirements and the end-users expectations and locations. The Site Coordinator checks that there are no regulatory issues and that all required administrative authorisations will be obtained before the installation date.

In a second phase, while the equipment procurement and configuration activities are on-going, the Site Coordinator has to ensure that the installation prerequisites, identified during the site survey, are completed. Examples of typical installation prerequisites are building of a shelter, Ethernet or electricity cabling.

In a third phase, the validation site installation is carried out by the corresponding site installer. Ideally, the satellite terminal is installed first and the broadband services activated. The wireless and networking equipment are installed next. When required (several site installers) a site installation coordinator is appointed for the overall coordination of the validation site installation.

Following finalisation of the installation activities, the Site Coordinator, the Site Installation coordinator and the Site installers jointly organise and carry out the Network Acceptance Test Review to verify correct operation of the network and formally start the Evaluation Period. This acceptance test review can be followed by a formal site inauguration in the presence of the users, the local administrator (interface coordinator – users) and where applicable the local authorities.

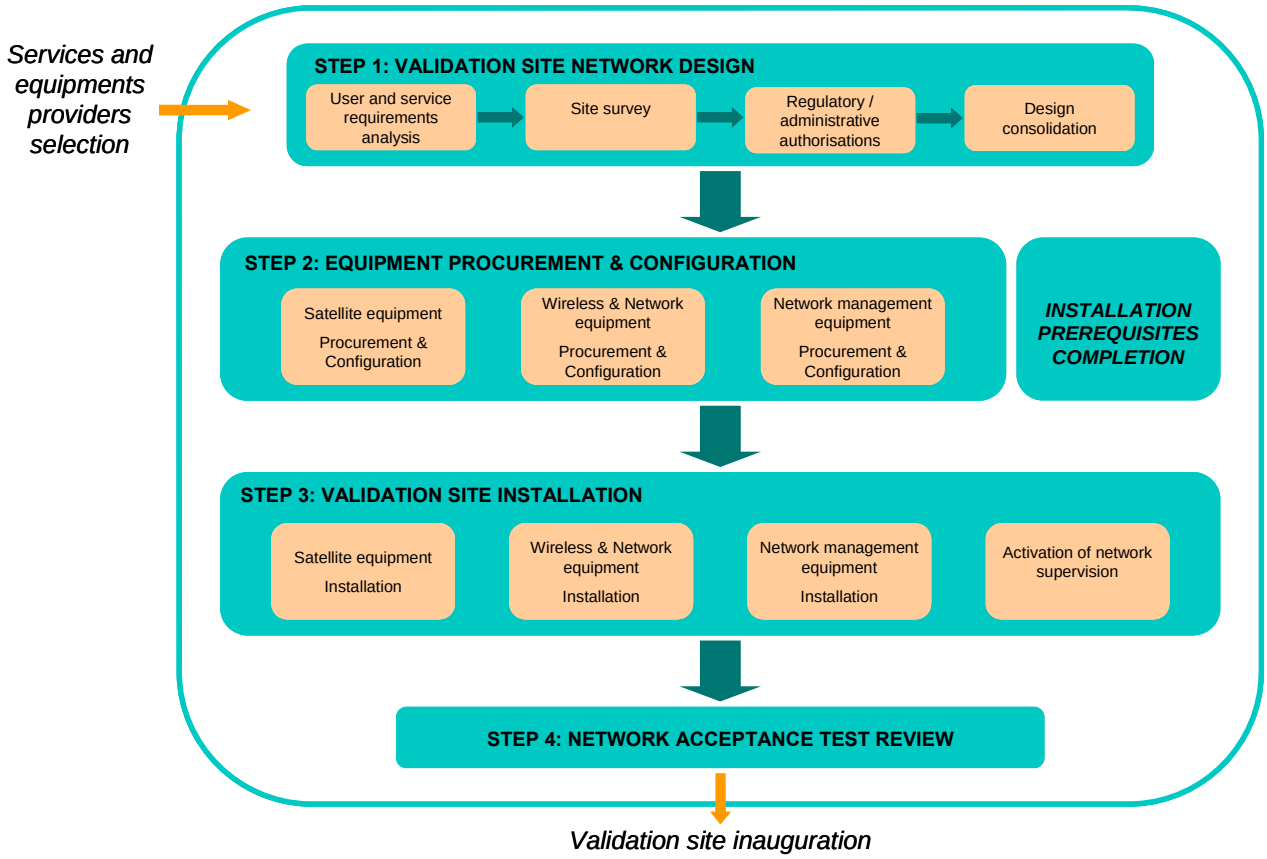


Figure 94: Generic validation site deployment process

4.1.3 Validation site acceptance procedures

Following the finalisation of the installation activities, the Site Coordinator, the Site Installation coordinator and the Site installers jointly organise and carry out the End-to-end Acceptance Review to verify correct operation of the network deployed at the validation site and formally start the Operation & Evaluation Period. In general, this acceptance test review is followed by a formal site inauguration in the presence of the users, the local site administrator (interface coordinator – users) and where applicable the local authorities.

Table 28 summarises the roles and responsibilities of the different actors involved in the validation site deployment and if their participation is required for the acceptance review.

Validation site acceptance test procedure

A generic test procedure, described in the following paragraphs, has been proposed by Astrium within the framework of End-to-end system design activities (WP 4.1), following their past experience on deployment of hybrid satellite-wireless networks. This procedure is then adapted by the Site Coordinators to the particularities and context of their validation site deployment activities.

The generic Validation Site Acceptance Review should be carried out on two levels:

1. **Equipment** level **acceptance test review**, testing the correct operation of each equipment or services after on-site installation, configuration and integration.
2. **Network** level **acceptance test review**, testing the end-to-end operation of the deployed network.

The *Installation Coordinator* is responsible for the organisation and execution of the Validation Site Acceptance Review. He should collect and synthesize the Acceptance Test Review results at Equipment level into a Validation Site Acceptance Review Report (D30) before the Network Acceptance Test Review takes place. At the Network Acceptance Test Review, a sub-set of the tests at Equipment level as well as the end-to-end tests can be carried out, the results of which will be added to the Validation Site Acceptance Review Report.

The *Site Coordinator* has to be present during the Network Acceptance Test Review and will co-sign the minutes of the review[1]. It is highly recommended that the Site Coordinator be present at the installation of the different Equipments and Services so as to be able to check and co-sign the Equipment Level Acceptance Test Reports.

[1] Applicable for those sites where the Site Coordinator is different from the Installation Coordinator.

Entity	Role	Participation to
Site coordinator[2]	Responsible for the site selection and exploitation	Required
Site designer[1]	Responsible for the site design according to the	Required
Site administrator[1]	Responsible for site supervision and maintenance during exploitation	Required
Local administrator	Member of the user community and first point of contact for the subscribers regarding questions and problems with services & equipment	Optional
Installation coordinator[1]	Responsible for the overall coordination of the validation	Required
Service provider 1	…	Not required
Service provider 2 …		
Equipment provider 1	…	Not required
Equipment provider 2 …		
Satellite installer	Usually a contractor of the Satellite Service provider	Required
Equipment installer 1	…	Required
Equipment installer 2 …	…	Required
Local authority 1	…	Not required
Local authority 2 …	…	Not required
Subscriber 1	User of the network	Optional
Subscriber 2 …	User of the network	Optional

Table 28: The site actors

The following tables summarize the set of Acceptance Tests to be performed at both Equipment (Table 29) and End-to-end Network (Table 30) levels. Table 30 shows the different test categories for which at least one test should be defined and executed. Each category can be split into the different tests to be executed (Example: there are 3 wireless links in the validation site, so there will be 3 "wireless network performance" tests, thus in the following table you should write one row per test, and create 3 different test forms)

[2] As defined in Annex I of Contract, Figure 4

Test #	Equipment Test Description	Related equipments	Network segment[3]	Test definition[4]	Test execution[5]
1	Satellite terminal installation – acceptance certificate	Satellite terminal	Satellite segment	Satellite provider	Satellite installer
2	Equipment 1 installation – acceptance certificate	Equipment 1	Wireless segment	Equipment provider / Site designer	Equipment installer 1
3	Equipment 2 installation – acceptance certificate	Equipment 2	Wireless segment	Equipment provider / Site designer	Equipment installer 2
4	Equipment 3 installation – acceptance certificate	Equipment 3	End-user premises	Equipment provider / Site designer	Equipment installer 3
5	Equipment N installation – acceptance certificate	Equipment N	…	Equipment provider / Site designer	…

Table 29: Equipment acceptance tests

Test #	End-to-end Test Description	Related equipments	Network segment	Test definition	Test execution
1	Broadband Internet access service: Test the performance of the service at satellite terminal level in terms of: - Upload/Download data rate - Web browsing	Satellite terminal	Satellite segment	Site designer	Satellite installer/provider

[3] Satellite segment / wireless segment / user segment.

[4] Responsible for acceptance test form definition.

[5] Responsible for the on-site execution of test and filling-in of the form.

Test #	End-to-end Test Description	Related equipments	Network segment	Test definition	Test execution
2	Wireless network performance: Test the performance of each wireless link in terms of: - Time delay - Signal quality (Received Signal Strength Indication) - Data transmission rate	Wireless equipment 1, wireless equipment 2, …	Wireless segment	Site designer	Installation coordinator
3	End-to-end system performance: Test the performance of the broadband access to Internet at each node of the network, checking the following indicators: - Upload/Download data rate - Bandwidth sharing - Web browsing	Network equipment 1, wireless equipment 2, …	Wireless segment, end-user segment	Site designer	Installation coordinator
4	Network management system performance – Supervision and monitoring system	Equipment 3, …	Network management segment, Site administrator premises	Site designer	Installation coordinator, site administrator
5	Network management system performance – Quality of Service	Traffic Manager (if deployed)	Network management segment	Site designer	Installation coordinator, site administrator
6	Network management system performance – Security features (if activated)	Equipment N, …	Wireless segment, end-user segment	Site designer	Installation coordinator
7	Test of Applications	Equipment N, …	End-user premises	Site coordinator	Site coordinator

Table 30: End-to-end Network acceptance tests

4.1.4 Deployment achievements

4.1.4.1 Deployment activities in NETADDED

The NETADDED project has deployed and operated 14 validation sites, corresponding to a total of 14 satellite terminals installed in 7 different countries:

- 3 validation sites in Burkina Faso, 3 in Morocco, 2 in Cambodia and 1 in Turkey on education application domain;
- 2 validation sites in Benin on health care application domain;
- 1 validation site in Greece and 1 in Turkey on rural tourism and e-business; and
- 1 validation site in France on agriculture application domain.

These sites have allowed to assess the added value of satellite (combined or not to wireless) with respect to terrestrial solutions alone.

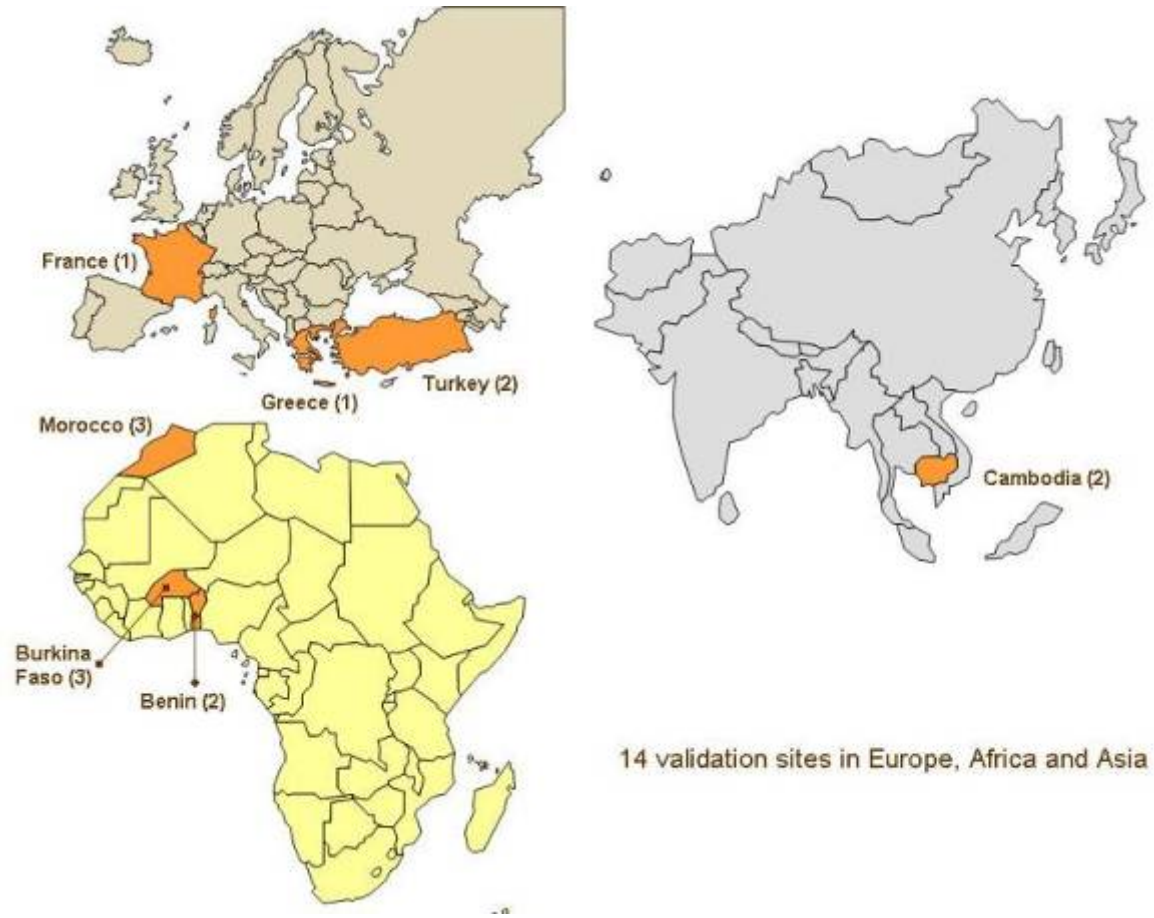


Figure 95: Geographical distribution of NETADDED validation sites

The table below presents a synthesis of the key milestones achieved for the deployment of NETADDED validation sites.

Validation Site	Country	Site Coordinator	Installation of satellite terminal	Installation of local loop and end-users equipment	Site Acceptance Review
Bogandé	Burkina-Faso	CNES	Jan. – Feb. 2008	Jan. – Feb. 2008	Feb. 2008
Ouahigouya	Burkina-Faso	CNES	Jan. – Feb. 2008	Jan. – Feb. 2008	Feb. 2008
Transportable Terminal	Burkina-Faso	CNES	October 2008	n/a	October 2008
Ouidah	Benin	CNES	Oct. – Nov. 2008	Oct. – Nov. 2008	Jan. 2009
Parakou	Benin	CNES	Oct. – Nov. 2008	Oct. – Nov. 2008	Jan. 2009
Mokrisset	Morocco	DEPTTI/ASTR	April – May 2009	May – June 2009	July-Aug 2009
Oulad	Morocco	DEPTTI/ASTR	April – May 2009	May – June 2009	
Casablanca	Morocco	TTSA	Sep – Oct 2009	n/a	October 2009
Embaros	Greece	FNET	May-June 2009	March 2008	June 2009
Allier	France	CEMA	n/a	April to Sept 2008	October 2008
Marmaris	Turkey	SABU	n/a	Sept. 2008	Sept. 2008
Istanbul	Turkey	TTSA	April 2007	n/a	April 2007
Phnom Penh	Cambodia	CS	February 2008	July 2008	September 2008
Ang Ta Saom	Cambodia	CS	February 2008	July 2008	September 2008

Table 31: NETADDED validation sites

Figure 96: Hybrid networks deployment

4.1.4.2 Continuity of service after NETADDED

A total of 14 validation sites have been deployed with satellite, satellite+wireless and xDSL+wireless architectures. Out of the 14 validation sites, 13 validation sites will remain operational, representing 93% of all deployments:

- 7 sites connected through hybrid satellite-wireless networks
- 2 sites satellite only
- On 3 sites, the wireless local loop is now linked to terrestrial backhauling: satellite has allowed to initiate the market
- 1 site, ADSL+wireless, deployed for test purposes, will be maintained
- 1 site (the transportable solution) was not planned to stay on site

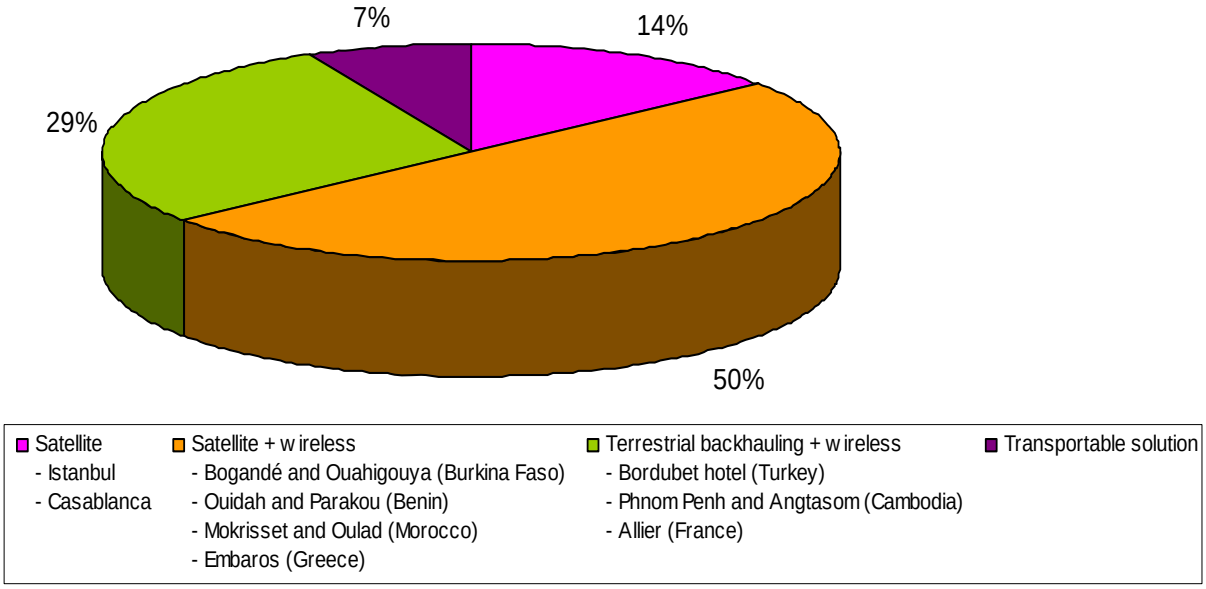


Figure 97: After NETADDED end-to-end solutions

4.2 NETWORK OPERATION AND MAINTENANCE

4.2.1 Objectives

Provide all the conditions that will enable end-users to use in real conditions network architectures that have been made available at their premises to meet their needs.

Following this objective, the site coordinators have carried out the following activities during the operation of the validation sites:

- Provided support to end-user communities during the period
- As much as possible, established a one-stop contact point/interface for the end-users
- Where and when required contacted other relevant partners within NETADDED consortium for support in case of problem
- Prepared, broadcasted, had completed and collected user-satisfaction questionnaires
- Logged network performances

4.2.2 Network monitoring tools

In order to evaluate the usage of the system, different monitoring tools can be used. Such tools may be dedicated equipments, terminal added functionalities or software tools installed on network equipments or servers. In any case, network monitoring can be applied at two different levels:

- at satellite service provider hub level: this kind of monitoring enables the Internet Service Provider to carry out the evaluation of the activity of the different deployed satellite terminals. By studying the distribution of the satellite bandwidth between the sites it is possible to realize the comparison between them detecting the most active sites and the less active ones.
- at local level: this type of monitoring enables the network operator to follow the end-users activity for a given site. It is possible to study the distribution of the site's available bandwidth among the end-users and thus identify the most active users and characterize their traffic

The tools that can be used for monitoring purposes are very diverse, often network devices offer a monitoring possibility by using local log records or MRTG statistics; for example: network routers, satellite Point of Presence terminal, traffic shaper equipment (Netenforcer, Packeteer, Planet, …), etc. Another possibility is to perform the monitoring through specifically installed software on servers devoted to network supervision usually based on remote network supervision protocol (SNMP) and equipment management information databases (MIB); that is the case of the Nagios platform, Pandora system, NINO network management solution etc.

To define generic statistics collection process and suggest a common method of gathering usage information that can be easily implemented on the validation sites, NTOP software has been selelcted by the NETADDED consortium as the baseline network monitoring tool.

NTOP SOFTWARE

NTOP allows to collect traffic statistics on the overall network (satellite, WiMAX and WiFi). NTOP is implemented on the majority of the NETADDED validation sites.

NTOP software need tos be installed on a PC, which capture IP packets over the network and process those packets to categorise the type of flows, protocols, receivers, etc… A web interface allows to configure and consult all statistics remotely. HTTP/HTTPS authentication is available on the server.

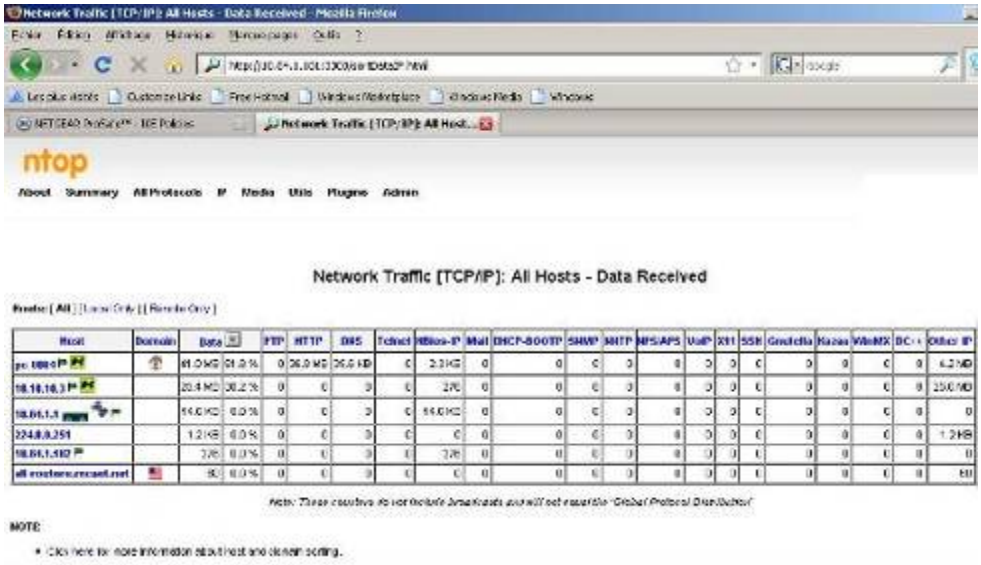


Figure 98: NTOP network traffic

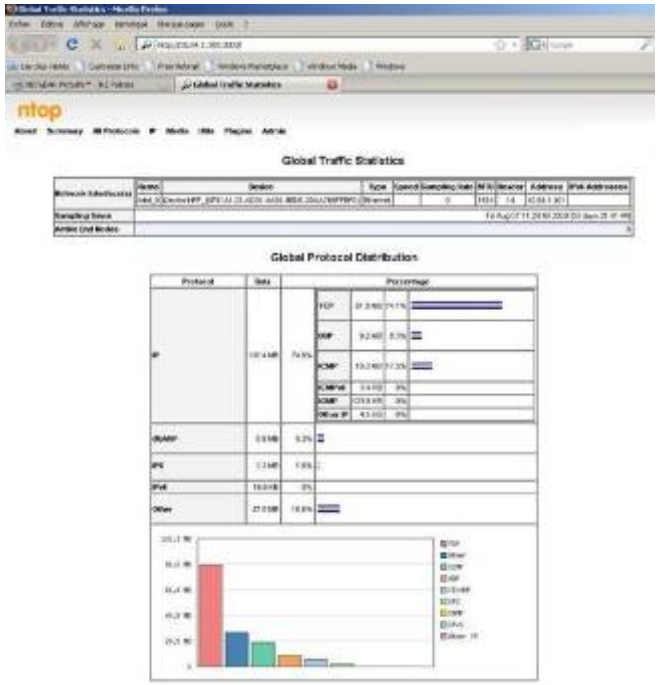


Figure 99: NTOP global traffic statistics

NTOP is a network traffic probe that shows the network usage. NTOP is based on libpcap and it has been written in a portable way in order to virtually run on every Unix platform and on Win32 as well.

NTOP users can use a web browser to navigate through NTOP (that acts as a web server) traffic information and get a dump of the network status. In the latter case, NTOP can be seen as a simple RMON-like agent with an embedded web interface.

NTOP retrieves all relevant information regarding the traffic on the satellite link. This gives a view of the network usage at the application level: web browsing, email, chat etc. it also provides information on traffic input and output.

NTOP is a portable open source framework which is easily deployed and has minimal requirements to leverage its use.

In the following figure the operation of NTOP in a network is depicted.

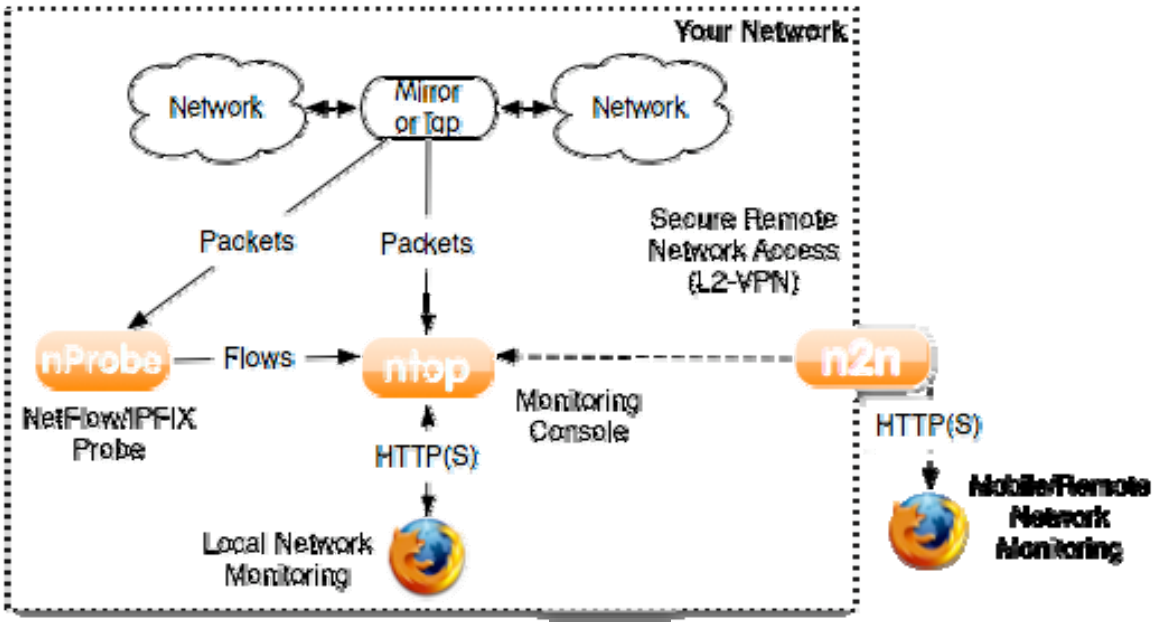


Figure 100: NTOP operation

NTOP is shown to be a valuable tool for quick access to network monitoring, with a simple to use integrated web interface and minimal requirements. It is available for network administrator with minimal effort and cost, as opposed to expensive and complex management platforms.

4.2.3 Network maintenance and customer support: generic process

To ensure user satisfaction and correct operation of the NETADDED validation sites, a generic network maintenance and support process, describing the roles and responsibilities of all parties involved has been defined. The generic process has been adapted by each Site Coordinator to the context of operation of their validation sites. For each validation site, the following entities / actors are involved in network operations:

- Site Coordinator
- Local Administrator
- Hotline
- Customer Support Level 1, Level 2 and Level 3
- Support and Maintenance entity

Site Coordinator:

The NETADDED Partner that is responsible for the selection of the Validation Site and interface with the Validation Site Subscribers.

Site (local) Administrator:

A member of the User Community that is the first point of contact for the Subscribers regarding questions and problems with the Equipment and Services.

Subscribers:

The NETADDED users.

Hotline or Call Centre:

Entity that provides technical support between 09.00 to 17.00 hours (GMT + one (1) hour) in order to support technical faults of the Network that are reported by the Site Coordinator.

Customer Support Level 1:

The resources and procedures put in place by the Site Coordinator allowing to receive and handle the notification of a problem by the Site Administrators or the Subscribers.

When a user calls for technical assistance, the customer support level 1 helps the user with simple problems or general "how-to" questions.

If the Subscriber detects any problems or malfunctioning of the Network, the Subscriber will contact the Site Administrator. The Site Administrator will provide support to the Subscriber to analyze the situation. If the first analysis indicates a potential problem with the Equipments or Services which can not be solved locally or if the cause of the problem is undefined then the Site Administrator must call the Site

Coordinator for support. If the Site Coordinator is not able to solve the problem the Site Coordinator may call the Hotline.

Customer Support Level 2:

The resources and procedures put in place allowing to receive and handle the notification of a problem by the Site Coordinator to the Hotline, to perform a first analysis of the problem and to propose an action plan involving where required the Level 2 Support of the Support and Maintenance Entity. All the actions will be traced in an Anomaly Report.

Level 2 questions may, for example, deal with advanced features and possible product bugs or failures.

The Support and Maintenance Entity can ask to the Site Coordinator, Site Administrator or Subscriber to execute some procedure to solve the problem.

Customer Support Level 3:

The resources and procedures put in place by the Support and Maintenance Entity to answer any request to solve a problem concerning the Equipment or Services under their responsibility.

If the level 2 technician cannot help the caller, a level 3 technician may be consulted either by the Subscriber or by the level 2 technician. Some research and investigation at this level might be required.

Support and Maintenance Entity:

Provides User Support to the Site Coordinator to ensure the correct operation of the Network at the Validation Site.

Maintenance:

All activities necessary to repair or replace broken and malfunctioning Equipments, and to perform the routine actions which keep the device in working order or prevent trouble from arising.

Network Control Centre:

Any server, equipment, hardware and/or software put in place by the Support and Maintenance Entity for the remote Supervision of the Network.

Anomaly Report:

The report created when a problem on the Network is detected through the Network Control Centre or when a problem is signalled at the Hotline and which outlines the action plan to resolve the problem, which traces all actions taken and the results achieved and which is closed once the problem has been resolved

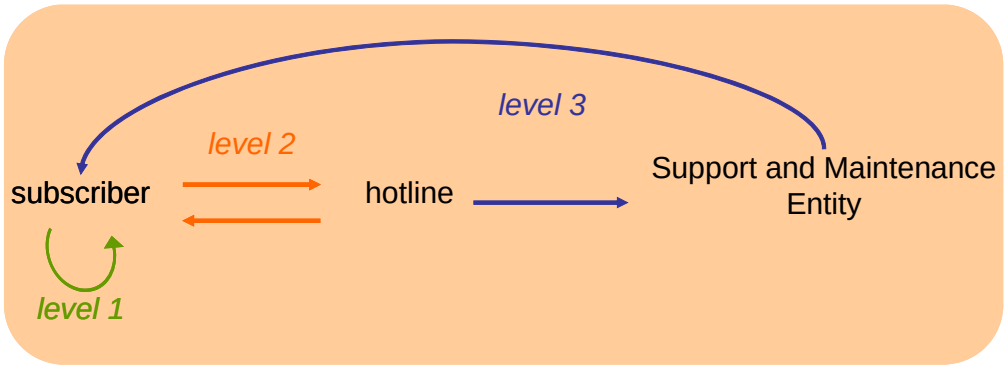


Figure 101: Customer Support and Maintenance process

4.2.4 Network monitoring and maintenance in NETADDED validation sites

4.2.4.1 Network monitoring and maintenance in Western Africa

MONITORING TOOLS DESCRIPTION

For the validation sites in Benin and in Burkina Faso, a traffic shaper and different monitoring software tools have been installed in order to monitor the network performances and usage.

In particular, two types of supervision systems have been set up:

- Real time supervision, to detect anomalies and send alerts during the operation phase;
- Performance measurement, to provides statistics about:
    - The amount of traffic transmitted (uplink and downlink),
    - The type of traffic transmitted (uplink and downlink).

Real time supervision allows to detect if the network devices are working properly. This can be done by sending two types of requests:

- Ping requests to the specific machines;
- SNMP (Simple Network Management Protocol) requests in order to poll the targeted nodes for MIB values.

The real time supervision of the validation site is done using the two following monitoring tools :

- What'sUpGold (WUG);
- OP Manager.

These tools poll constantly at regular time intervals equipment and an alarm is returned if a failure occurs.

In order to monitor the network performances, specific MIB values of the supervised hosts are polled with three monitoring tools:

- MRTG: Mainly used in order to extract data from the Traffic Shaper;
- SNMPview: Mainly used to extract traffic data and SNR levels (for Alvarion's broadband wireless products);
- IPscan: Used to discover the active private IP addresses at a given time.

The monitoring of the system has been remotely performed by CNES, while maintenance interventions have been operated by the local administrators.

MAINTENANCE PROCEDURE

- Periodic network maintenance
    - A local network technician common to both sites in Burkina Faso was trained by Cnes for rapid & efficient interventions and problem solving
    - In Benin, the network maintenance was performed by the network administrators working at IRSP and Parakou
    - A three-months network maintenance visit was performed by the local administrator for network assistance and system control documented with an "intervention form"
- Network Operation and maintenance were also remotely performed using the monitoring tools by sending automatically e-mail:
    - Each time an alarm has been activated
    - At the beginning of each month with the MRTG, IPscan and SNMPview reports
- Direct end-user calls or e-mail in case of equipment dysfunction
- Satellite operator notification in case of:
    - QoS restrictions or modification on a VSAT
    - Reconfiguration on the i-Direct system or maintenance operation

4.2.4.2 Network monitoring and maintenance in Allier (France)

MONITORING TOOLS DESCRIPTION

For the monitoring of the wireless networks, the firmware DD-WRT v23 SP2 standard have been chosen on each Wi-Fi Access point. This firmware contains a SNMP package and a MRTG module installed on a specific computer to register and to consult all the monitoring data of the routers. This package permits to trace in real time the traffic for all the networks and for each router, network interface by network interface. The figure hereafter displays a graph for wireless access point 1 (router 1), hour by hour for each interface of this router 1. More details of each network interface can be obtained by clicking on each graphics.

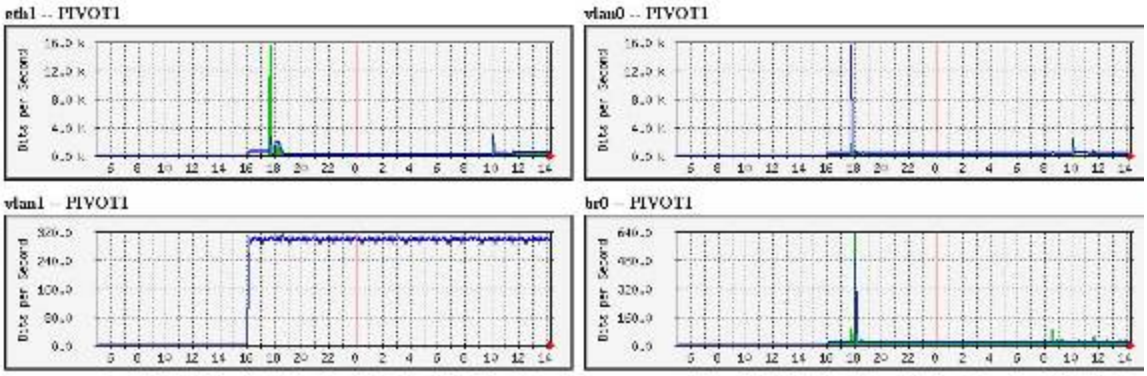


Figure 102: Example of index page of MRTG bandwidth monitoring

The next figures show an example of the graphical representation of the Wi-Fi traffic written by MRTG. Actually we don't have a real graph about the real traffic because the networks aren't in service on the different experimental sites. For each network interface (LAN, WIFI, or Internet), the traffic network is displayed hour by hour , day by day, or month by month for both the upload and download flows.

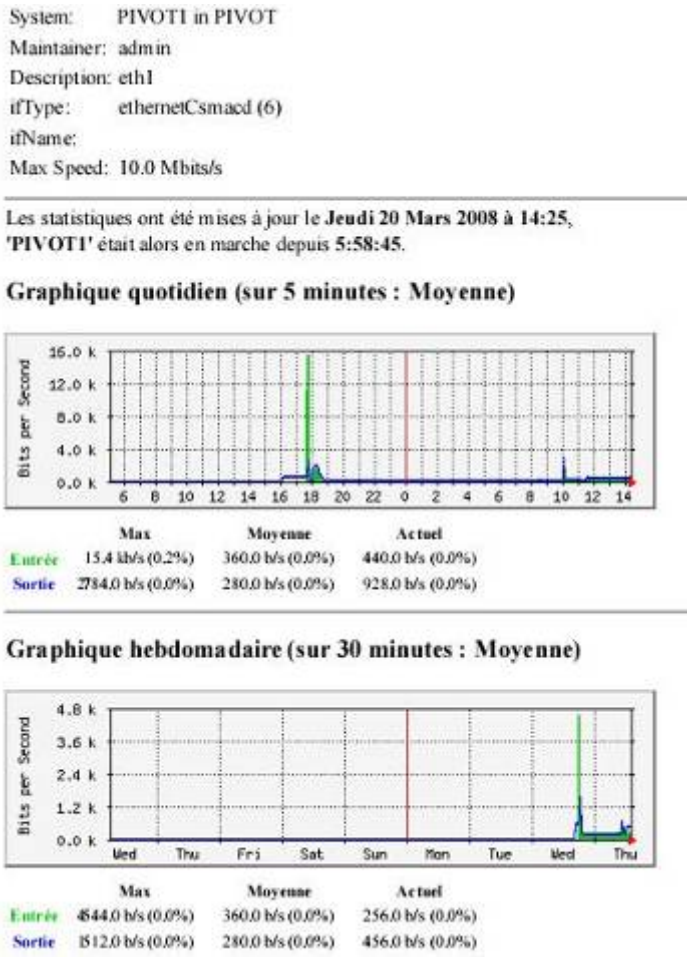


Figure 103: Example of bandwidth graphs and statistics

In each farm, a computer under Ubuntu 8.04 OS has also been installed, with NTOP software to collect statistics port by port and protocol by protocol from the network equipment as illustrated in the next figure. All statistics have been saved manually at the end of each month.

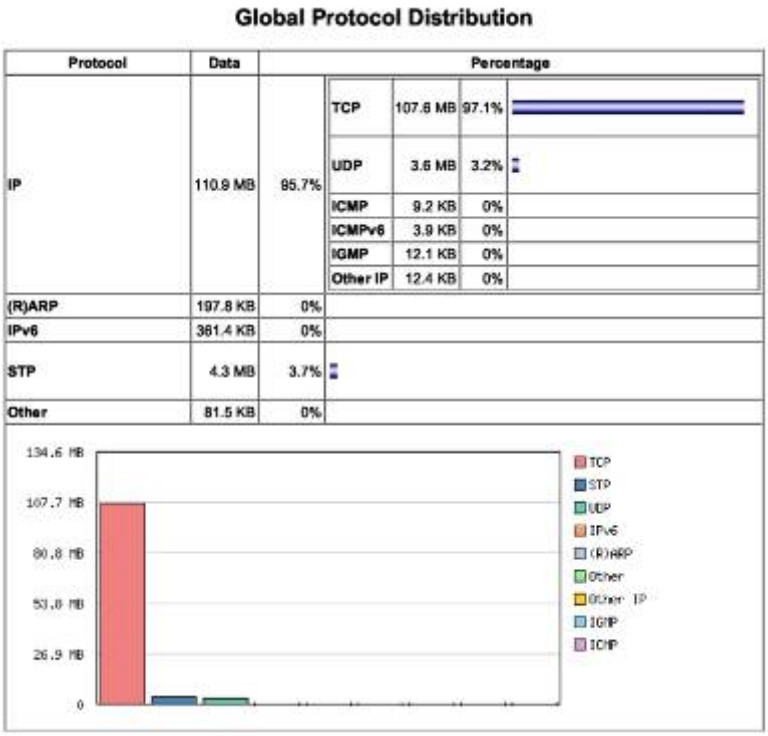


Figure 104: Example of global protocol distribution produce by NTOP

MAINTENANCE PROCEDURE

All maintenance operations are realised on the experimental Wi-Fi and ZigBee technologies used respectively to distribute the broadband in the fields and in the building and to integrate the sensors on the wireless networks with the Wi-Fi/ZigBee gateway. All anomalies are detected by the distance control system installed at Cemagref premises.

4.2.4.3 Network monitoring and maintenance in Bordubet (Turkey)

MONITORING TOOLS DESCRIPTION

The monitoring and supervision system which has been set up in Bordubet validation site have two complementary systems for monitoring and performance evaluation purposes. As monitoring and supervision system, NTOP open source network management software has been deployed. NTOP is also being used for performance evaluation purposes. The existing platform DUDE from Mikrotik is also operational for network supervision. The network monitoring provides statistics about the amount of

traffic transmitted (uplink and downlink), the type of traffic transmitted (uplink and downlink), the anomalies (number, type of anomaly, status, etc…) during operation.
The traffic statistics are forwarded to a PC in SABU premises for monitoring and performance evaluation purposes.

NTOP SW runs on a LINUX Virtual Machine running on a host station connected to CPE router in Bordubet premises. This machine and the router is configured in such a way that all incoming and outgoing traffic passing through the CPE router could be accessed by NTOP SW. The access to the virtual machine is strictly controlled via authentication so neither hotel customer nor hotel staff has access to NTOP statistics about network usage and performance.

MAINTENANCE PROCEDURE

For Bordubet validation site, the following actors are involved in the network operations:

- The site coordinator is Mr. Ismail Cem Atalay from SABU
- The local administrator is Mr.Kudret Erduvan, the operations manager of Goldenkey Bordubet Hotel
- The Customer Support Level 1 service for wireless mesh network equipments is provided by Mr.Bilal Sarioz, who is the local technical representative of network equipment manufacturing company Airties. If the problem seems to be related with broadband network connection (satellite or xDSL), the site coordinator directly call customer support of DEXAR or TTNet which are the ISP companies.
- Customer Support Level 2 for wireless access equipments is carried out by Airties customer support engineer in Istanbul NCC. For broadband internet access problems concerning satellite or xDSL connection customer support centres of DEXAR or TTNet will be notified by the local administrator if necessary.
- Customer Support Level 3 is only relevant for wireless mesh products manufactured by Airties. If the network problem involves software bugs and functionality improvements/changes, next level of customer support and maintenance is consulted within Airties organization so that these fixes could be prepared and added to the updated system design.

4.2.4.4 Network monitoring and maintenance in Istanbul and Casablanca

The Network monitoring and maintenance in the two validation sites in Istanbul and Casablanca were provided through the MEDSKY platform.

4.2.4.5 Network monitoring and maintenance in Morocco

MONITORING TOOLS DESCRIPTION

Satellite network monitoring and maintenance tool is deployed at satellite service provider hub level (Teleport / HUB premises). It is an Extranet web-based application. The VSAT indoor unit acts as an IP router. So, its registration on the supervision tool is very simple since it is SNMP based. Indeed, once the VSAT terminal (Satellite Modem) is installed and up, it is registered on the supervision tool (via its IP address).

The monitoring tools used at local level are **NTOP** and **UltraVNC**. This tools enable the network operator to follow the end-users activity for a given site. They also allow to study the distribution of the site's available bandwidth among the end-users and thus identify the most active users and characterize their traffic. Those monitoring tools are installed together on the host PC connected to the router.

The main supervision parameters are the following ones:

- Anomalies supervision
  - Status of the major devices of the distant validation site. The satellite modem, the first ingress router and the NTOP computer of each area are polled periodically to check there operational status. Anomalies and interruption of service are observed and reported.
  - Anomalies of services observed by the end-users can be reported to WANA through the hotline, or directly to the DEPT&NT thanks to anomaly forms provided to the contact point of each area.
- Performances and usage statistics
  - The volume of traffic transferred through each satellite terminal is supervised and reported by WANA thanks to the VSAT tool,
  - The volume of traffic is also observed thanks to NTOP software, at ASTRIUM premises. NTOP allow to monitor the usage in much more details, giving information of the IP addresses (and therefore the end-users) and the type of traffic (mainly based on the protocol distribution).

As represented in Figure 105, this NTOP PC is connected to the CISCO router through a switch. NAT option is activated on the CISCO router in order to ensure the relation between the IP public address provided by NORTIS and the private IP address of the LAN. In order to allow remote access to the NTOP server, a VPN tunnel is created between Astrium premises and the CISCO router and UltraVNC software is installed on the server.

Furthermore, the network supervision is ensured by the SNMPc Network Management System, based on the administration of public and proprietary equipment MIB, which is integrated in the supervision system at EADS Astrium premises. SNMPc is the Network Management System used for the network monitoring and supervision, based on SNMP protocol. This tool delivers proactive real-time monitoring:

- By using polling and server components that run on the computers and network devices located on the different LAN, the NMS can manage the whole system.
- Regarding the workstations management, SNMPc polls periodically the workstations interfaces to be sure the Ethernet interfaces are ok, but also to check that the TCP/IP protocol stack is well running on the CPU of the machines.

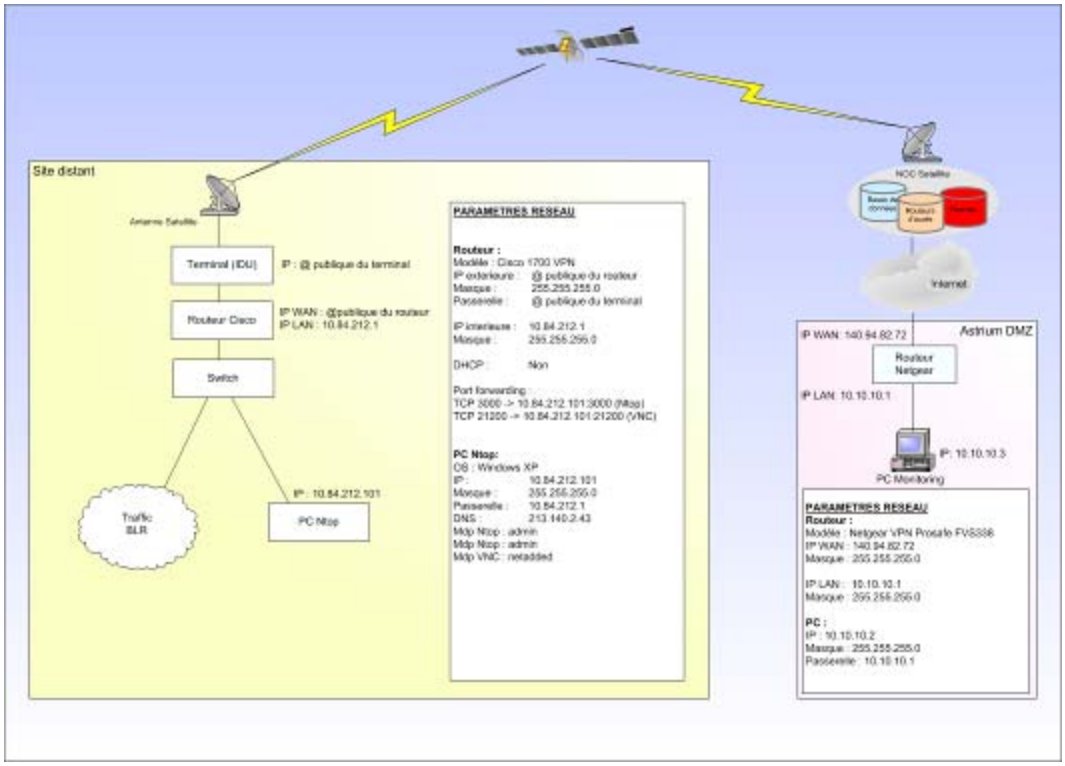


Figure 105: NTOP architecture for remote and local supervision (Morocco)

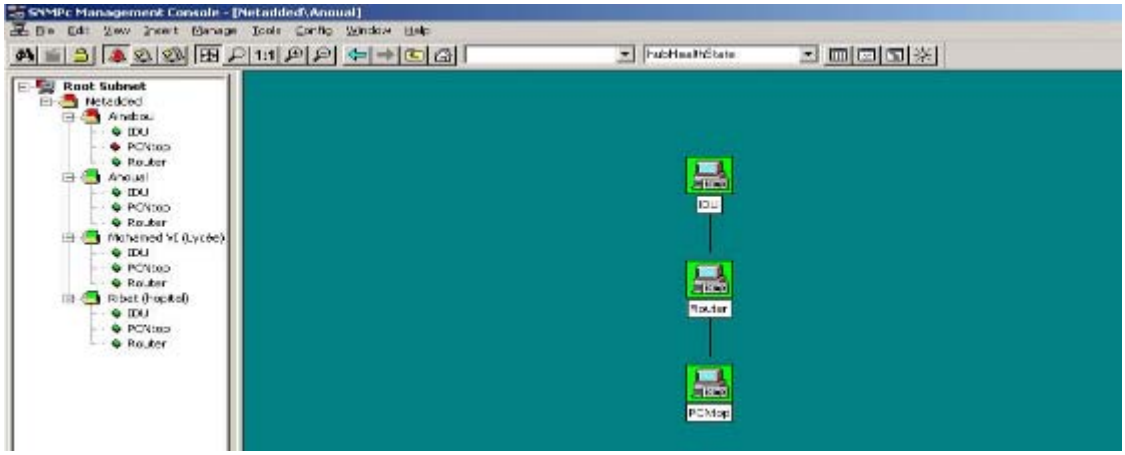


Figure 106: Remote site administration through SNMPc at Astrium premises (Moroccan sites)

The supervision and monitoring process of the validation sites of Mokrisset and Oulad Mkoudou (Morocco) is realised in close cooperation between the actors involved, in order to provide full assistance to the end-users and comprehensive supervision:

- DEPT&NT, as the validation site coordinator, is responsible for the overall supervision procedure and synthesizes all the anomalies collected and reported. DEPT&NT provides direct assistance for issues raising on the local area networks in so far as those networks have been deployed in the frame of the GENIE program,
- WANA is responsible for the wireless and satellite networks. Anomalies raised on those two segments are observed directly by WANA or reported to WANA by the end-users (through the hotline) and then reported to the DEPT&NT for consolidation of the overall statistics. WANA also provides high level traffic usage statistics, observed on each satellite terminal,
- ASTRIUM provides assistance to DEPT&NT by ensuring a remote survey of the network devices status and the supervision of the traffic usage. Distant monitoring is realised from the BlueLAB at ASTRIUM premises in Toulouse.

To ensure user satisfaction and correct operation of the NETADDED validation sites, the following network maintenance and support process has been defined:

Entity responsible		Role	Contact
Local Administrator / Site Coordinator		Level 1: First investigation level to avoid applications, PC or connectivity issue (cable to be plug…). If not the case, he will ask solution through hotline.	DEPT&NT Tel: +212 537 268 752
Hotline		Level 2: Hotline team is in charge of reception of customer calls, request treatment on line or offline. It is the client point of contact for all production problems. It performs follow up of all production operation with support and maintenance entity. It is open from Monday to Friday from 8h00 to 18h30. If not solved, problem is sent to Customer support team	WANA Tel: +212 529 292 929 Client number : 2525
Support and Maintenance entity	Customer support	More detailed investigation will be done to solve the problem (customer maintenance team could be requested to go on site). In case of no solution, a ticket is create in network ticketing tool.	Via hot-line
	Network support	Hand over to network support (Level 3) to investigate and solve the problem (Customer equipment and network equipment, with involvement of constructors if needed).	Via hot-line

Table 32: Maintenance actors and roles – Morocco

4.2.4.6 Network monitoring and maintenance in Cambodia

MONITORING TOOLS DESCRIPTION

The supervision tools have been deployed in both sites (Phnom Penh and Angtasom), in the servers corresponding to the two main network nodes and where the bandwidth is most limited.

The two solutions chosen are:

- **Cacti** to monitor the network via SNMP but also to display graphs concerning the satellite link quality.
- **NTOP** to provide statistics regarding the usage of the satellite link (traffic type at applications level and amounts of data transmitted).

These monitoring tools are centralized on the two main servers of the Phnom Penh and Angtasom networks. Cacti server is located on the server in Phnom Penh and collects data from the whole network. NTOP is installed on both servers to collect data for both nodes. Both tools are focused on the satellite link. There is no tool yet to monitor and differentiate the use of the network by the different schools inside a site.

Cacti is able to produce graphs from saved data for various durations.

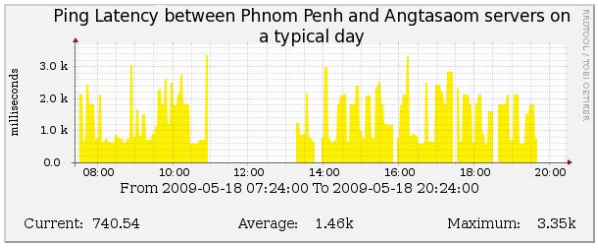


Figure 107: Ping latency graph

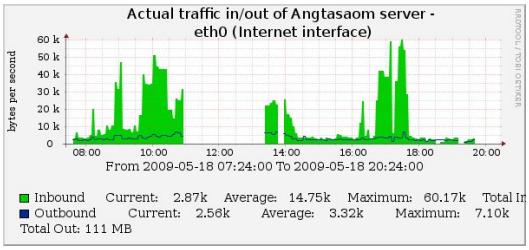


Figure 108: Data rate

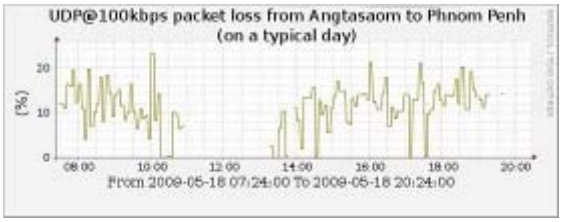


Figure 109: Packet Loss

Figure 110: UDP max data rates

Since the beginning we have deployed other functionalities/services on the server. Most of them are tools useful to help local users, administrator or technicians working on the network. The main goal is to have a healthy network meaning without virus and computer overloaded with useless software.

- **Squid** and **Squiguard** make it possible to screen web accesses accurately. Time has been spent to configure it well according to the needs of the users. Accesses have been restricted to improve the security of the whole network without impacting users browsing activity too severely. **HAVP** and **ClamAV** scan all the file downloaded from the Internet in order to prevent virus propagation in the local network. It acts in concert with Squid.

- **Samba sharing** has been deployed in all sites to easily share documents or useful software. When a technician needs to urgently install a software he can find it easily in a shared folder on the server (accessible from anywhere in the network).
- **Windows domain** has been deployed in Connected Schools to help authentication and management of account for administrators as well as for students.
- **FOG** (a Linux-based, free and open source computer imaging solution for Windows XP) has been deployed on the Phnom Penh server (and soon in Angtasaom) and allows easy re-installation on corrupted computer for instance via the network. A basic common fresh install of Windows XP (and additionnal required softwares) is done quickly (few minutes).
- **DeepFreeze** has been installed on some computers whose configuration is not likely to change a lot. Thanks to this tool the configuration of the computer is exactly the same at each reboot. If a virus destroyed some files, nothing will have changed at the next reboot. This tool is very powerful but also very restrictive (additional software cannot be installed easily for instance).

A **local website** has been developed to simplify the access to some local resources:

- Anomalies reports
- Local resources that give access to most of the monitoring tools (password protected) such as cacti, NTOP, squid statistics, NTOP, FOG management …
- Files accessible from Internet (distant learning video to share with France …)

Save mechanism has been implemented to protect data on the server from a crash. Data are periodically copy on a separate hard disk.

MAINTENANCE PROCEDURE

A dedicated team in Cambodia has been formed to handle this task and processes adapted to the specificities of the Cambodian sites have been defined. The network administrator (Robin Thebault) is usually based in Phnom Penh. A young graduate technician from the CIST and based him in Angtasom to handle all local maintenance, Chansoriya Im, has been hired to provide quick support to the local users and train the teachers on computer tools.

Most of the problems in ATS can be resolved by the local technician. These problems can be discovered by the users or by the technician himself. Initially the technician tries to solve the problem on his own. If he cannot or if the resolution requires a global action (Internet access problem for example) the action is handed over to the administrator who will take the relevant action, like calling the ISP Camshin if Internet Access is down.

Some problems can be detected through the supervision tools. In this case, the network administrator tries to solve it and then asks the technician to act locally if required.

Problems can be detected by all the actors (users, technician, administrator) or by the supervision tools.

4.2.4.7 Network monitoring and maintenance in Crete (Greece)

MONITORING TOOLS DESCRIPTION

With regards to network maintenance, in the validation site of Embaros, the NTOP framework was installed as a traffic monitoring solution. At the end of the second reporting period, the remote control platform developed through WP 4.3.1 was also implemented at Embaros and was thus tested in real conditions while used for monitoring and solving network issues at the validation site.

MAINTENANCE PROCEDURE

To ensure user satisfaction and correct operation of the validation site of Embaros, a network maintenance and support process, describing the roles and responsibilities of all parties involved has been defined. This is described in the following diagram.

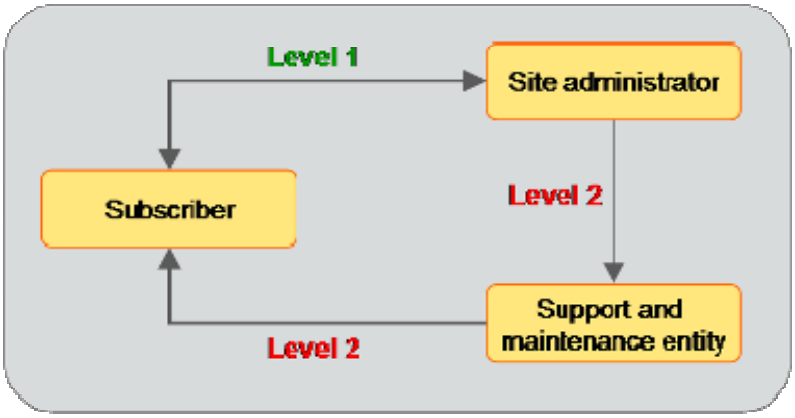


Figure 111: Customer support and maintenance process for the Embaros site (Greece)

When a user calls for technical assistance, the Level 1 Customer Support helps the user with simple problems or general "how-to" questions. This is performed through the Site Administrator who has access to the necessary infrastructure to resolve such issues.

If the first analysis indicates a potential problem with the Equipment or Services which can not be solved locally or if the cause of the problem is undefined, then the Site Administrator must call the Level 2 Customer Support. A level 2 technician is therefore consulted by the Site Administrator. After some necessary investigation at this level to resolve the issue the technician will inform the user of its solution.

5 EXPLOITATION, EVALUATION & RECOMMENDATIONS

This activity has been divided into three major tasks.

Usage and performance analysis

For each validation site, the usage and performance has been evaluated during the operation at three levels: network usage, network reliability and users satisfaction.

This activity has been organised per site coordinator:

Site Coordinator	Validation sites	
CNES	Burkina Faso, Benin	*5 validation sites*
DEPT&NT	Morocco	*2 validation sites*
TTSA	Casablanca, Istanbul	*2 validation sites*
FNET	Greece	*1 validation sites*
CEMA	France	*1 validation site*
SABU	Turkey	*1 validation site*
CS	Cambodia	*2 validation sites*
		Total: 14 validation sites

Recommendations

Based on the analyses conducted in the precedent task, major recommendations have been extracted and presented to the public community. This work package also includes all the activities which have been conducted in preparation for the "after-NETADDED".

Dissemination

In order to capitalize on the experience gained during NETADDED, for the benefits of users having the same kind of needs as the ones addressed within the frame of the project, a range of dissemination activities has been carried out during the project towards different key actors, as well as the creation of a web site, publicly available.

5.1 USAGE AND PERFORMANCE ANALYSIS

5.1.1 Evaluation method

The following figure provides an overall description of the evaluation method that has been followed in NETADDED validation sites.

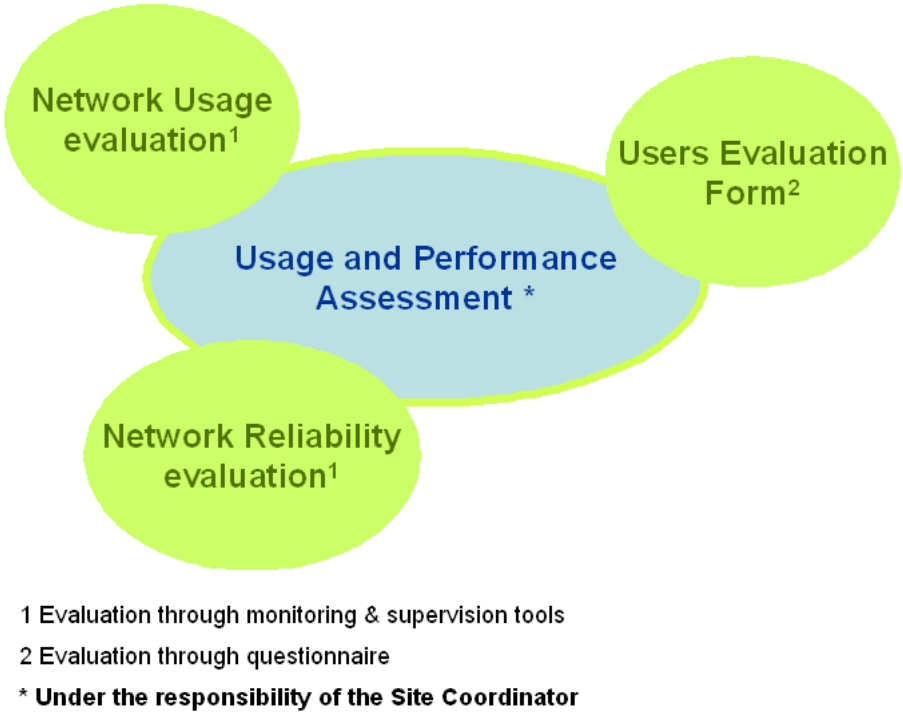


Figure 112: NETADDED usage and performance evaluation method

As illustrated above, the evaluation is performed at two levels:

- **Assessment of network usage and reliability** through the monitoring and supervision tools put in place at the NOC and on each of the sites. The generic monitoring and evaluation procedure defined in NETADDED proposes a list of key parameters to be analysed for network usage and reliability evaluation. The monthly traffic & reliability data are collected in "Monthly traffic report" and "Monthly reliability report" excel files.
- Evaluation of the **quality of the proposed services** as well as the **level of user satisfaction** using an evaluation questionnaire defined by the Site Coordinators and approved by the Steering Committee.

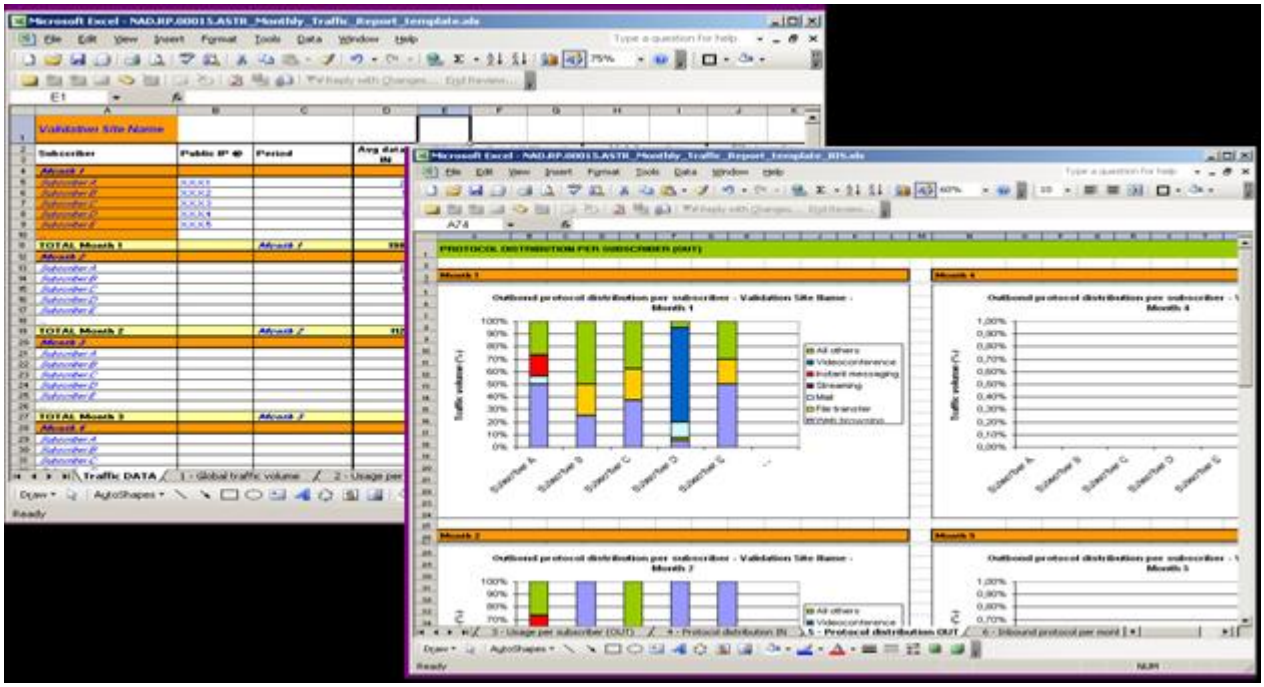


Figure 113: Monthly traffic/realiability report excel files

الجنس والعمر (جمال الموز)

معلومات شخصية	السن		
	25<...<40	15<...<25	... <15

معلومات شخصية	الجنس	
	مؤنث	مذكر

معلومات شخصية	من فلك		
	أسئلة الدام أسئلة	أسئلة	تهني

Figure 114: User satisfaction questionnaires in local language

5.1.2 Usage and reliability figures

Usage metrics

With the traffic data retrieved at the validation sites thanks to the monitoring tools, typical usage figures such as those listed below can be provided per site:

- **Global traffic volume per month:** total downloaded and uploaded traffic for the whole validation site.
- **Monthly usage per subscriber (IN/OUT):** downloaded/uploaded traffic volume distribution per subscriber. Allows comparison among the relative weight of the subscribers activity over the total traffic.
- **Protocol distribution per subscriber (IN/OUT):** distribution of downloaded/uploaded traffic per type of application for each subscriber.
- **Inbound/outbound protocol distribution per month:** distribution of downloaded/uploaded traffic per type of application for the whole validation site.
- **Average data rate**

Reliability metrics

From the analysis of anomaly tickets during the site operation, typical figures showing network reliability such as those listed below can be provided per site:

- **Anomalies per month:** total number of tickets opened during the month under evaluation.
- **Anomaly status:** closed tickets (solved anomalies) versus open tickets (on-going anomalies).
- **Anomaly tickets per notification procedure:** classification of anomaly tickets per notification procedure (supervision, hotline, email, …)
- **Anomaly tickets per network segment** (satellite, wireless local loop, user segment) **/ network equipment** (satellite terminal, wireless base station, router…)
- **Anomaly tickets per type of failure**(hardware, software, configuration, …), **per type of intervention** (remote, on-site, …), **per type of solution applied** (reboot, equipment replacement, …)
- **Anomaly tickets per downtime periods** (period between the ticket opening and closing)
- **Intervention carried out by:** classification of anomaly tickets according to the actor involved in the anomaly resolution (site coordinator, local administrator, service provider, …)

5.1.3 Key results

In total 14 validation sites have been deployed totalling 64 months of cumulated network operations:

- 6-month evaluation period for the validation sites in Benin, Burkina Faso, Cambodia and France
- 5-month evaluation period for Mokrisset & Oulad Mkoudou (Morocco)
- 3-month evaluation period for Bordubet (Turkey) and Embaros (Greece)

5.1.3.1 Network usage evaluation

On these validation sites there have been 55 subscribers and several thousands of end-users.

A subscriber is the person/entity taking the subscription for the satellite service while for each subscriber there can be several end-users. For example, a hospital is a single subscriber and each of its employees is an end-user.

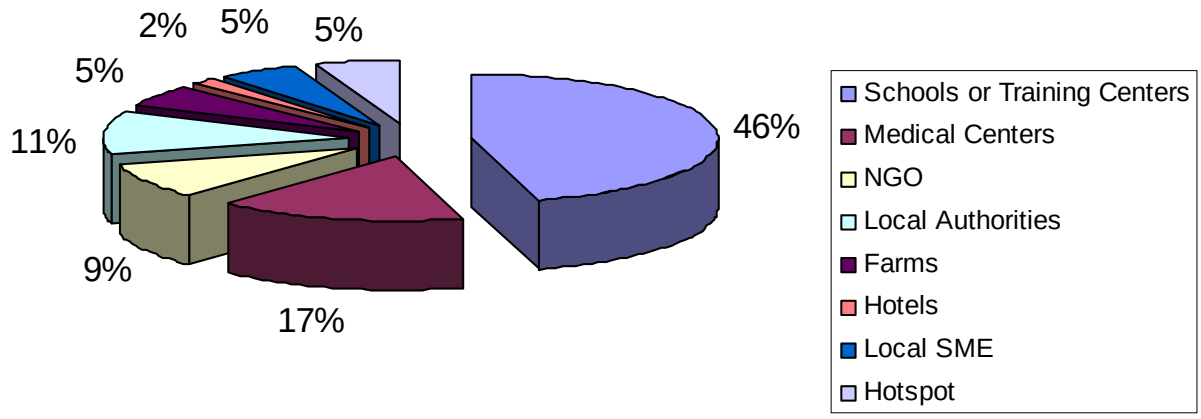


Figure 115: NETADDED subscribers

55 subscribers accross 7 countries

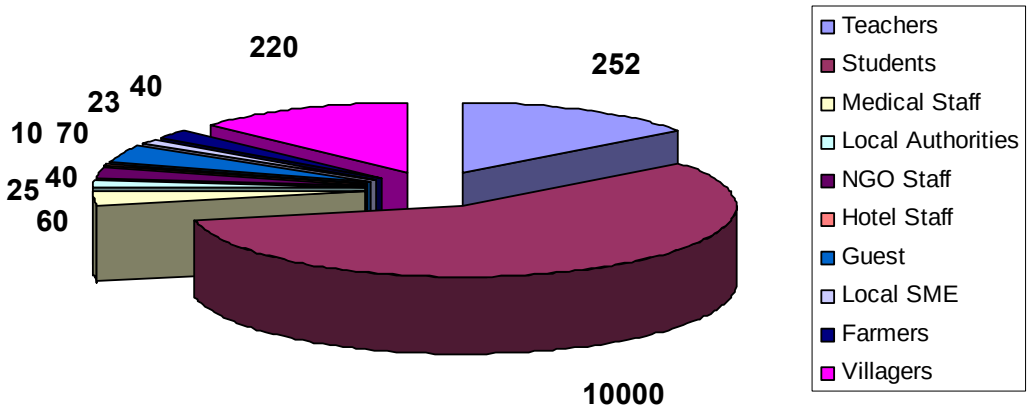


Figure 116: NETADDED users

NETADDED solutions accessible to more than 10 000 users

The usage on NETADDED sites has globally seen a **progressive increase** throughout the project. The following figure represents the increasing monthly traffic registered from November 2008, start of operations in Benin validation sites, until June 2009, end of the evaluation period.

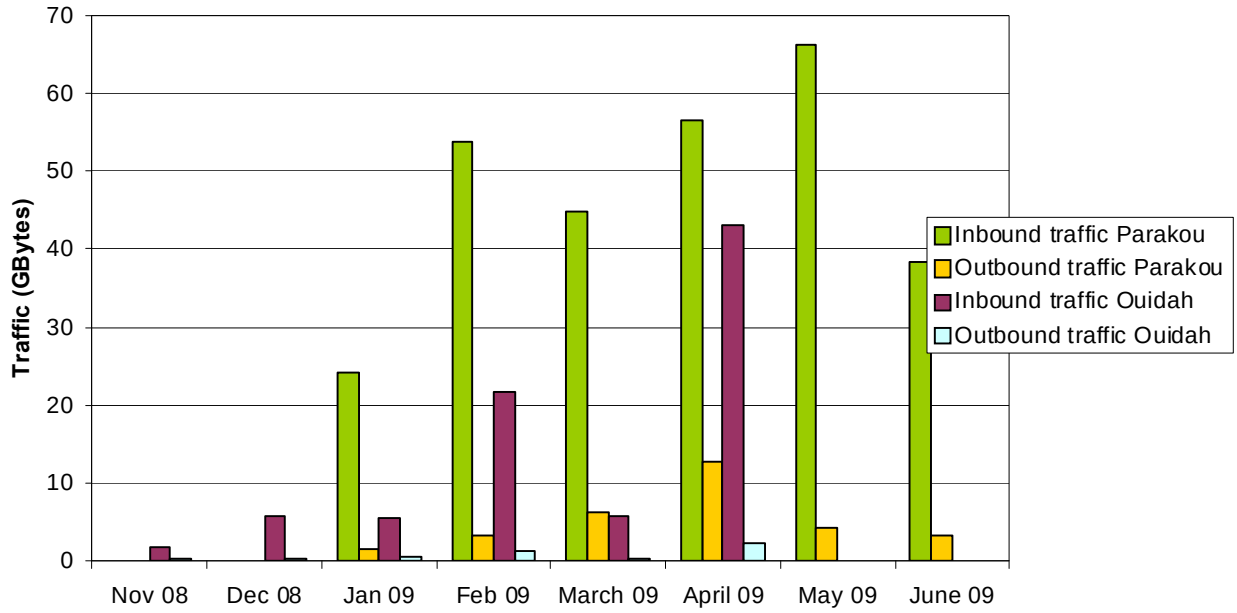


Figure 117: Global traffic volumes per month in Parakou and Ouidah (Benin)

Three main trends have been observed:

1. Validation sites in INCO countries of Africa and Cambodia, Greece: In these cases we can find a **strong usage** with a mixed use of web browsing, email, file transfer and videoconferencing, and **very active users** such as NGOs staff in Burkina Faso, professors&students in Benin and Cambodia as well as SMEs promoting local products in Greece. This is illustrated in Figure 118 and Figure 119.
2. Validation sites in France, Casablanca and Istanbul: In these cases we can find an **occasional usage** for agricultural applications validation & demonstration purposes (France), as well as a **punctual usage** for selected events or scheduled meetings in the context of laparoscopic surgery (Casablanca and Istanbul, TTSA sites) with no internet traffic but videoconference with guaranteed bit rate, as illustrated in Figure 120.
3. Validation sites in Morocco and Turkey: In these cases we can find a **periodic usage** concentrated in high season period for Bordubet hotel in Turkey and academic year for schools in Morocco. Web browsing is the most popular application for these sites, as illustrated in Figure 121.

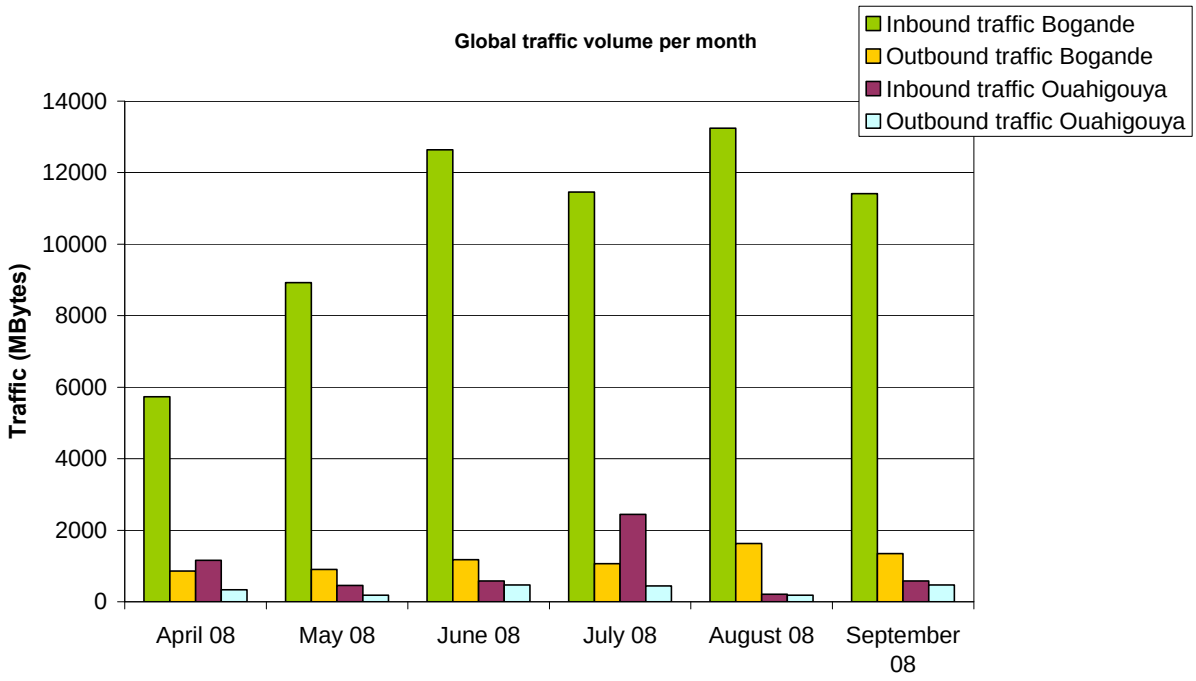


Figure 118: Traffic volume per month – validation sites in Burkina Faso

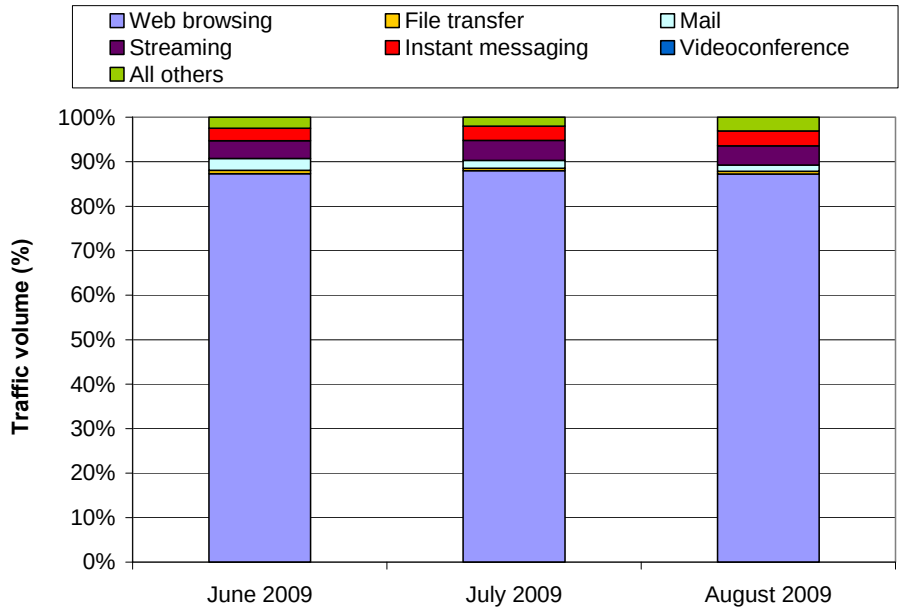


Figure 119: Protocol distribution per month in Embaros (Greece)

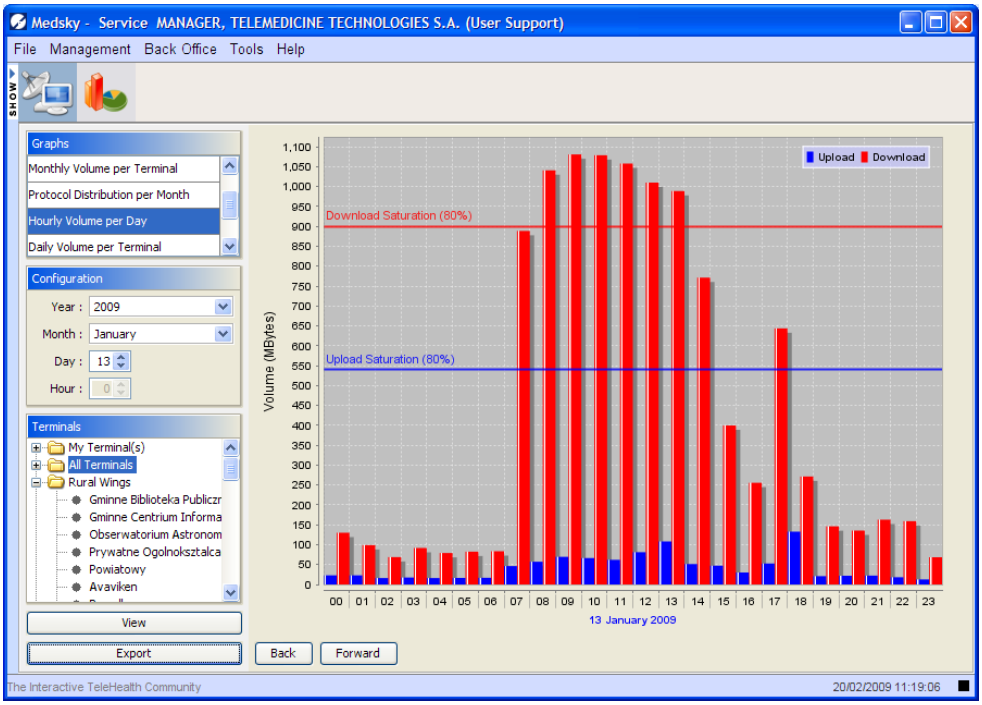


Figure 120: Hourly volume across one day for the Satellite terminal in Istanbul during one videoconference session

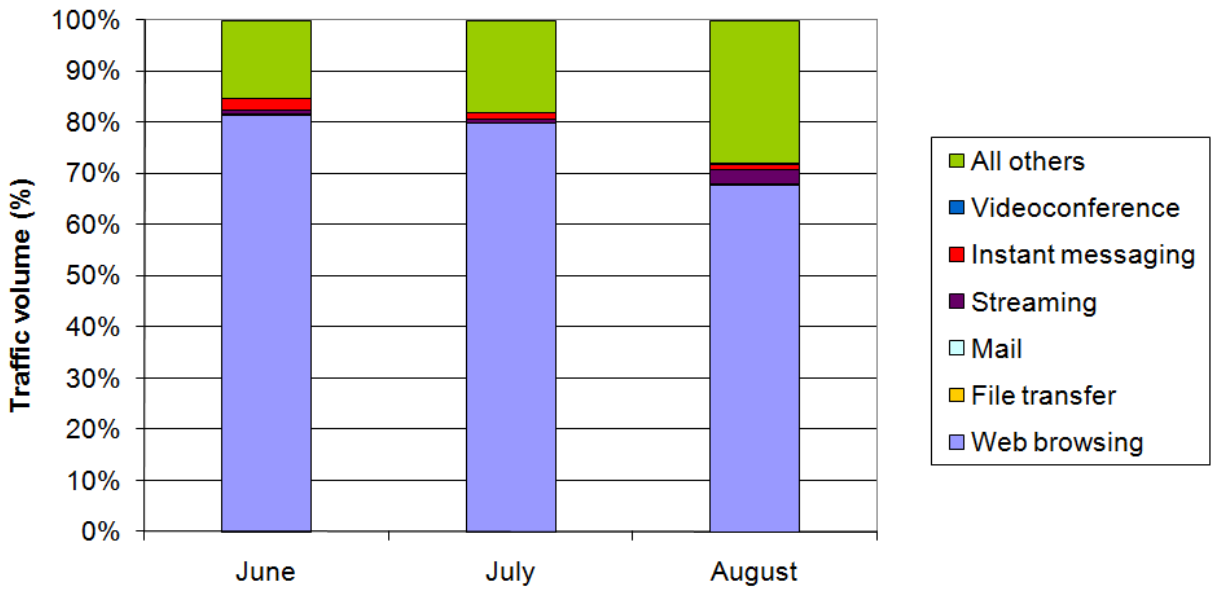


Figure 121: Inbound protocol distribution for the high season period in Bordubet Hotel

5.1.3.2 Network reliability evaluation

The evaluation period has formally started on 1st October 2008 for those validation sites already deployed at this date. The reporting Evaluation Period has lasted on average 6 months per site, with the last sites having ended their usage and evaluation period in September 2009.

In total 320 anomalies have been recorded by the Site Coordinators at level 2 maintenanc, of which 250 occurred due to power supply failures in Burkina Faso, Morocco and Greece. To ensure continued operation in rural and isolated places the use of Uninterruptible Power Supply (UPS) devices is strongly recommended. This kind of devices has been installed in most of NETADDED validation sites.

Globally reliable operations have been achieved thanks to professional design and installation procedures:

- No hardware failure on satellite-terminals, as illustrated in Figure 124 and Figure 125.
- Power outages as the most common anomaly due to instability of electricity networks, as illustrated in Figure 122.
- Most of the problems regarding satellite and wireless networks reliability occur at the initial stages of the operation phase

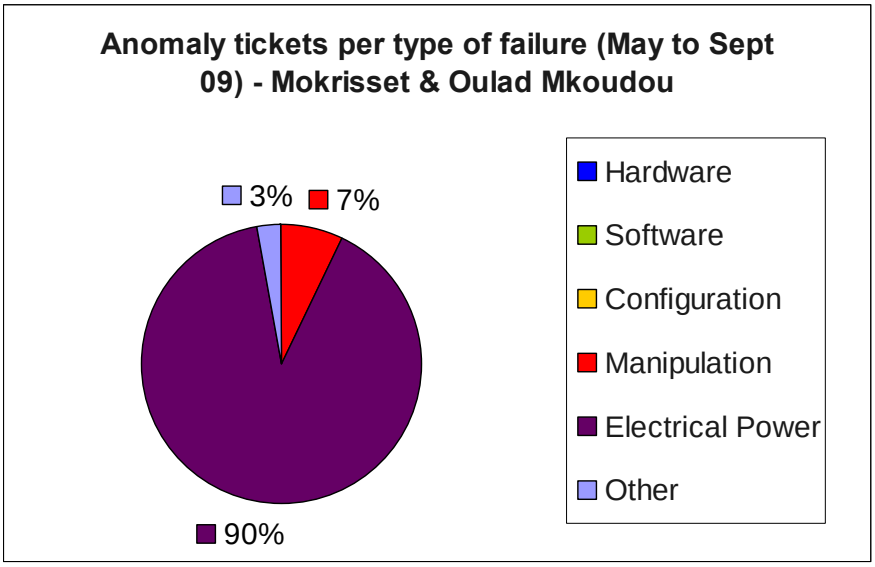


Figure 122: Anomalies distribution per type of failure in Moroccan validation sites

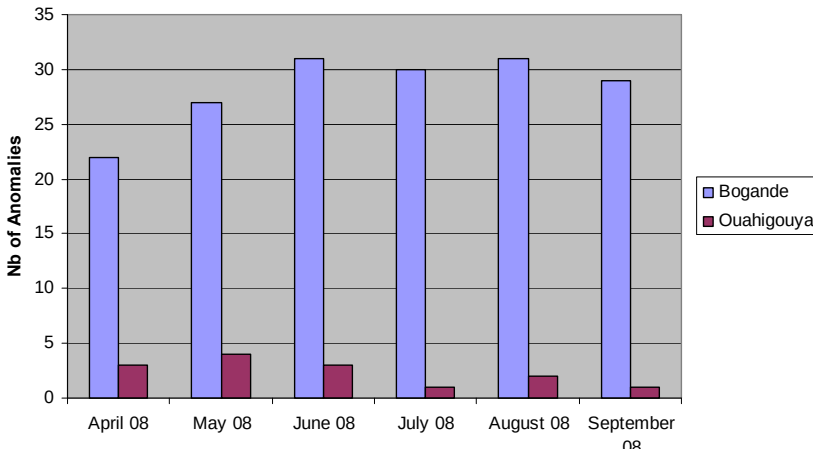


Figure 123: Evolution of anomalies in Burkina Faso sites

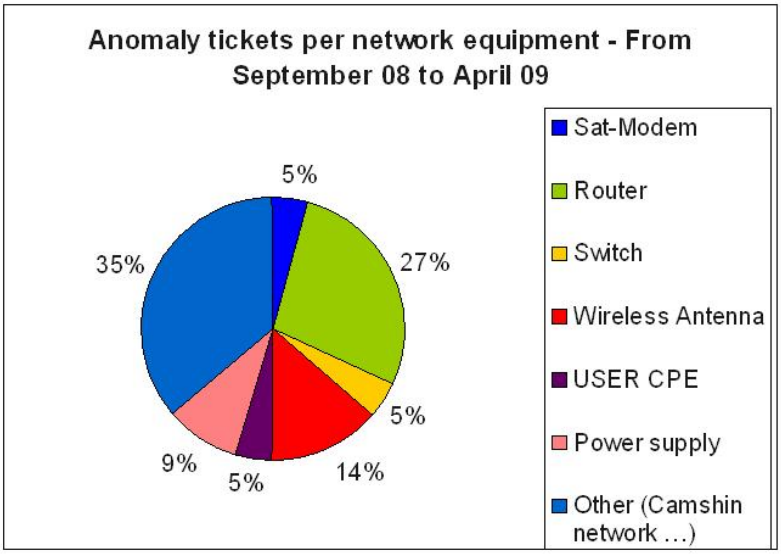


Figure 124: Anomaly tickets in Cambodian validation sites

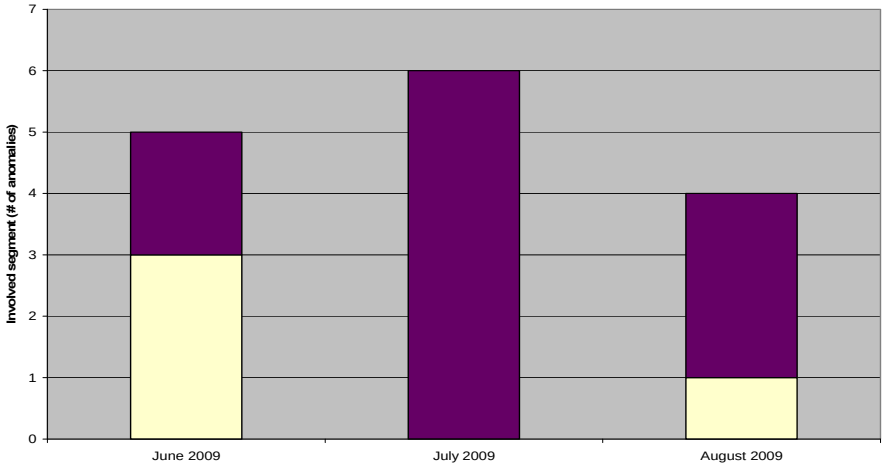


Figure 125: Evolution of anomalies per network segment in Embaros (Greece)

5.1.3.3 Users satisfaction evaluation

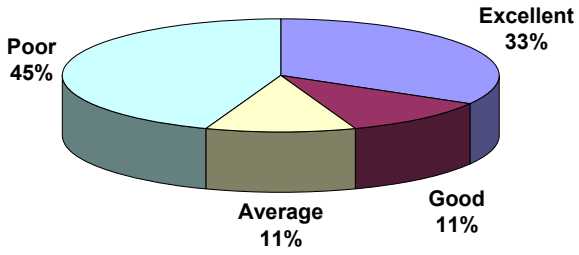
User-satisfaction questionnaires have been distributed and collected by all Site Coordinators for the evaluation of the quality of the proposed services.

The criteria used for the evaluation of user satisfaction are the following:

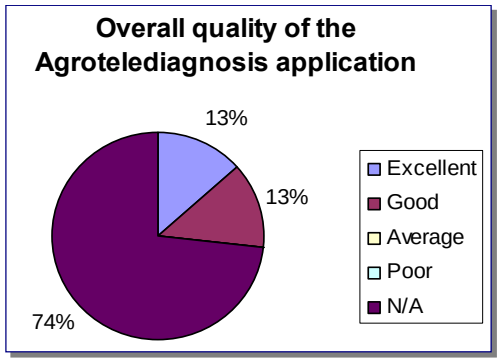
- Equipment reliability, services availability
- Perception of communication speed
- Assessment of user support and hotline

In general, a **very positive feedback from end-users** has been registered, showing two main tendencies:

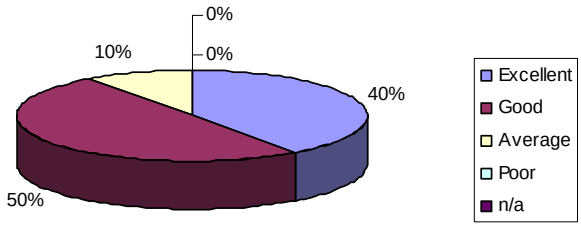
- Low participation of end-users in the survey mostly due to the short evaluation period and the time consuming getting into contact with them
- Interviewed people : essentially main local actors as teachers, doctors, NGO staff with different ICT knowledge and skills.



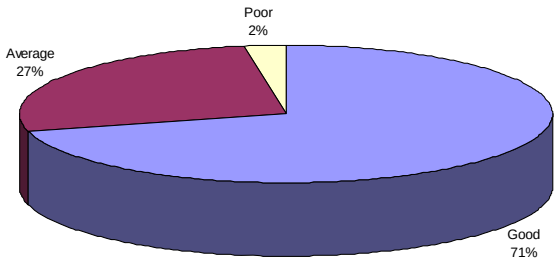
User Internet knowledge
(Oulad Mkoudou)



Evaluation of the Agrotelediagnosis
application in Greece



Service availability evaluation
in Bogandé (Burkina Faso)



Overall distant learning
applications quality in Cambodia

Figure 126: User satisfaction assessment for NETADDED validation sites

5.2 IMPACT OF NETADDED SOLUTION ON APPLICATIONS USAGE

The NETADDED project has deployed and operated 14 validation sites, corresponding to a total of 14 satellite terminals installed in 7 different countries (Benin, Burkina Faso, Cambodia, Greece, France, Morocco and Turkey). These sites have allowed:

- to assess the added value of satellite (combined or not to wireless) with respect to terrestrial solutions alone,
- to bring and create adapted educational and medical contents for INCO communities,
- the development, promotion, take-up and use of innovative IT applications in the domains of education, healthcare, agriculture, e-business and tourism.

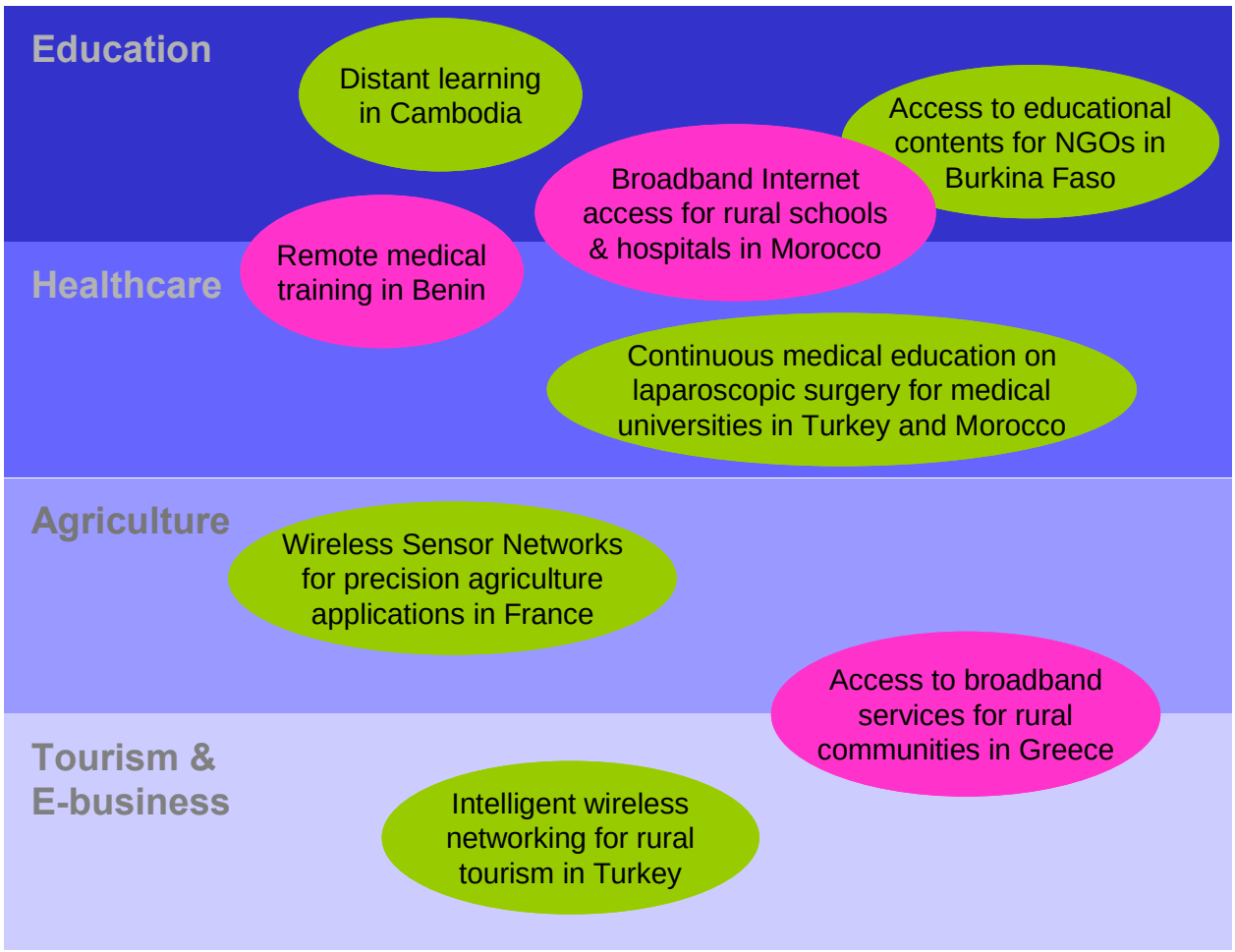


Figure 127: NETADDED application domains

5.2.1 Education

5.2.1.1 Distant learning in Cambodia

In Cambodia, like in most emerging countries, schools have no money, teachers salaries are low and in the countryside farmers are poor and have no access to education. Connected Schools as NETADDED project partner had the goal of assessing whether a satellite + WiMAX connection in a remote area could (a) compensate for the absence of local teachers by enabling new classes and professional trainings to be delivered over distance and (b) increase existing local teachers' competency and lessons quality. Through NETADDED, they have given to the various high schools and training centers in Angtasaom access to the Internet and associated features.

Their assessment of the situation today is that:

- Web browsing is useful for province teachers seeking to improve their lectures but only to a certain degree given that very little is available in local language on the Internet,
- Live conferencing between one teacher and a remote class comes with the following caveats: it works fine inside the high speed low delay local area wireless network, but not so well over the satellite link,
- Synchronizing agendas between the remote teachers and the local classroom is rather complicated,
- Email, chat, forums are "nice to have" features but do not really impact the a.m. objective.

Figure 128: Promoting education for disadvantaged children in Cambodia

In the context of distant learning to compensate for the lack of skilled teachers in remote places, the added value of a "satellite + wireless" local network is much enhanced if it is combined with a large pool of **good quality downloadable education content in local language**.

The best organisation setup for a province school lacking skilled teachers for the topics they would like to teach (ex: Computer Science, Agriculture, Mechanics..) is then one where :

- At least 60% of the classes have a teacher present. These local teachers can make use of good quality recorded content. In particular all hands-on experiments and manual work require a local teacher or a local professional.
- Less than 40% of the classes have no teacher at all. In that case, an adult can still run good quality recorded content to the students, and live interactive conferences can be organized weekly with a distant competent teacher to answer students questions, run exercises and complement the recorded CD's.

5.2.1.2 Access to educational contents for NGOs in Burkina Faso

In Burkina Faso, CNES and GREF have provided satellite broadband Internet access to Bogandé and Ouahigouya, two towns in Burkina Faso particularly affected by poverty and mortality. The access has been shared through a wireless network among local NGOs, the hospital, the town hall and governmental offices.

Besides the fixed installations a transportable broadband satellite-based terminal has been used for a **basic education campaign** by local NGOs in remote rural areas around Bogandé.

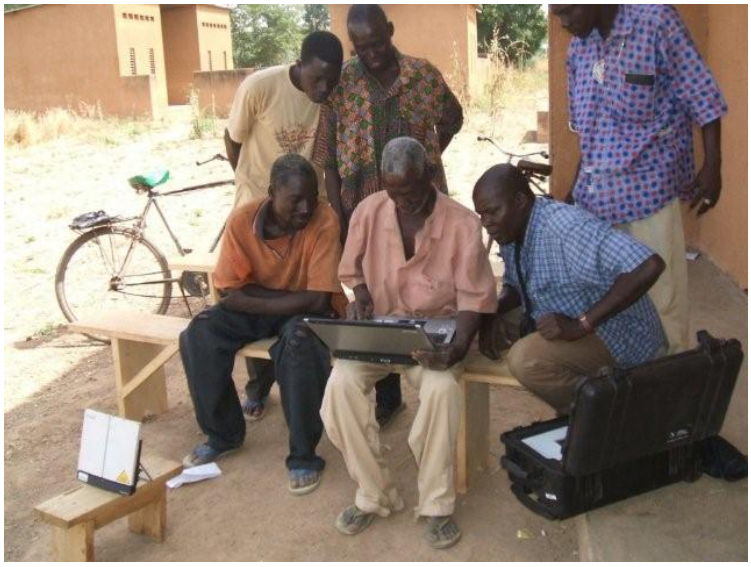


Figure 129: Access to broadband services for NGOs in Burkina Faso

Web browsing, videoconferencing services, access to educational contents by rural communities, e-learning for health care centre's nurses and medical assistants, were some of the applications made available at these sites.

The feedback of the end users has been very positive. Some of them just learned to use Internet for the first time and immediately understood how useful it could be for their personal and professional life.

At the NGO FIIMBA an extension of the network had to be set up in order to answer to the strong demand of citizens to have access to the resources.

At the governmental institutions, the number of necessary displacements considerably reduced, what resulted in an **important money saving**. The access to the world wide web also allowed to rapidly surface the local problems or difficulties to the central authorities.

Thanks to the new ICT infrastructures, the town hall of Bogande could collect from the central authorities an important sum of money to finance and organize for the first year a school manifestation for students and teachers.

At the hospital levels, NETADDED project not only allowed the medical teams to improve their knowledge and competences, but also allowed the doctors to exchange information with their colleagues located in different areas, what allowed in some cases to **save human lives**.

5.2.1.3 Education in Morocco

In Morocco, ten education establishments and two health care centers have been connected to broadband Internet through NETADDED.

The Mokrisset and Oulad Mkoudou regions are geographically isolated and have a low population density. Despite the availability of basic infrastructure, the local populations do not have access to ICT facilities, specially the Internet. In view of the dispersed settlements and geographical isolation of these regions, installing broadband terrestrial solutions would be costly, not profitable, and would not concern the entire population. In this respect, satellite options combined with less costly wireless terrestrial options have proven to be the more adequate choice.

The NETADDED initiative is coherent with the far-reaching national programme called "Génie" driven by the Moroccan Ministry of Education to extend ICT infrastructure to schools for **on-going teacher training programmes** and Internet access to educational content for pupils of all ages.

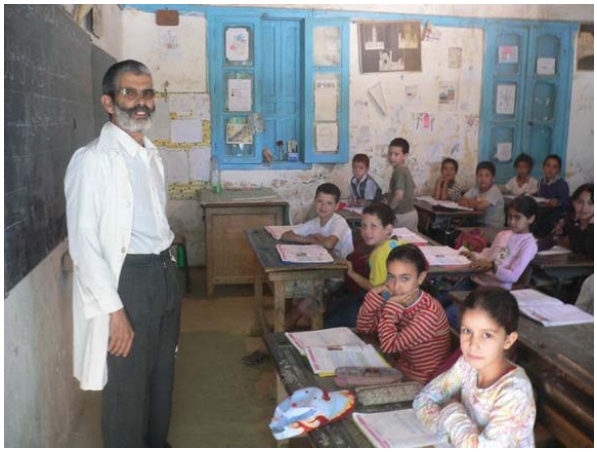


Figure 130: Broadband Internet access for rural schools in Morocco

5.2.2 Healthcare

5.2.2.1 Healthcare in Benin

UMVF and CNES, in accordance with local authorities, have selected two institutional learning centres: the Regional Institute of Public Health in Ouidah and the University of Parakou. Both centres play a key role on the educational and health system of the country.

The deployed network has allowed to establish a broadband Internet Access by satellite in these research and learning centres, thus allowing distant learning programmes, contributing to the training of the medical staff and exchanges with other African learning institutes.

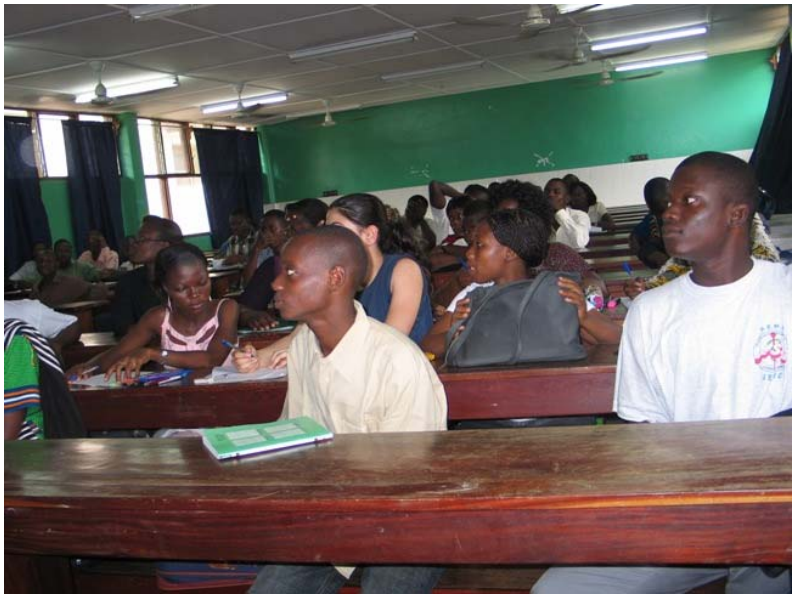


Figure 131: Remote medical training in Benin

The following applications have been made available:

- A Linux-based pedagogical server accessible from the local network and remotely via Internet (http://ouidah.dyndns.org and http://parakou.dyndns.org), including web server, ftp server, Moodle e-learning platform, **mirroring of UMVF web site contents** (www.umvf.prd.fr) and C2i health professional resources,
- A videoconferencing system based on Adobe Connect. UMVF has made available the access to the server http://netconfmedecine.univmed.fr and two virtual rooms have been committed to the Benin sites ("homel" and "crmcfss"),
- Streaming video retransmission of the courses from the FSS (Faculté de Sciences de la Santé) of Cotonou.

The videoconferencing system allowed:

- The organization of synchronous and interactive medical e-learning courses and seminars about public Health and specific trainings
- The participation to telemedicine collaborative works and to multidisciplinary national and international medical staff, set-up by UMVF (ex. the paediatrics group of the University of Nancy).

5.2.2.2 Continuous medical education on laparoscopic surgery

Targeted user community was primarily the one of laparoscopic surgery in Turkey, with perspective of extending to most of the health-care and medical sector in general. The second targeted user community was the one of oncology in the neighbourhood of Casablanca with the perspective of extension to the whole territory of Morocco.

Two classes of applications have been used within the project: Multi Disciplinary Team (MDT) meetings and tele-training. The required services mainly consist in end-to-end satellite communication infrastructure with integrated applications. Laparoscopic surgery generates **high quality video transmissions** requiring advanced broadband services.

Figure 132: Tele-training on laparoscopic surgery for medical universities in Turkey and Morocco

5.2.3 Agriculture

An experimental pilot site was set up in Allier (France) for the validation of **precision agriculture** applications specially developed by CEMAGREF over a Wireless Sensor Ad Hoc network developed by UBP.

An application for monitoring irrigation pivots and one for remote surveillance of cows, both through the use of **intelligent wireless sensor networks**, have been tested and validated.

The experiment results show that multi-support and multiservice intelligent wireless network is a key issue for precision agriculture. Thus it can contribute significantly to preserve environment and then support sustainable development.

Nevertheless, wireless technologies will be adopted and deployed more quickly and widely in industry applications than in agriculture ones due to their cost and complexity. Farmers are not yet able to deploy and maintain a multi-support and multiservice wireless network platform. We need to develop a new generation of wireless node, which acts as an appliance (plug&play black box) and fulfils a service. This means that farmer buys a service from a provider and does not care about what is behind the intelligent wireless platform.

We believe that for agriculture applications to satisfy farmer needs, we have to provide a service to support sustainable development and improve their day-to-day life. Thus, it is important to continue to improve the current wireless sensor network technology to meet the previous requirements and demands.

Figure 133: Wireless sensor networks for remote control of center pivot irrigation systems

Figure 134: Soil moisture wireless sensors

5.2.4 Tourism and E-business

5.2.4.1 Access to broadband services for rural tourism user communities in Greece

The experience from the NETADDED Embaros validation site has shown a positive impact, as recorded by the users opinion, the knowledge gained and the benefits of the services, the realised ones and the foreseen ones in the future.

People at the village of Embaros prior to the site installation had no knowledge about the usage and benefits of broadband access and the services that can be offered on top of the network. Such situation is typical at rural and distant sites where people are not familiar with the technology. People, living at Embaros and at village communities near the site, have now got the necessary knowledge and positive attitude concerning the applicability of broadband networks at rural areas. Electronic services related to the real need of the communities, showed the positive aspect of the network services, and prove that the actual benefit is a matter of having the access and utilising it in a proper way, aligned to social needs.

Users at Embaros site expressed their satisfaction for the results of the site. We can distinguish the main following categories of satisfied users:

- Young people living in Embaros (students) who wanted to have efficient network access, for entertainment and education purposes;
- Community administration staff, teacher and priest welcomed the initiative, which offers a new means to promote the activities of the community, enabled them to frequently update the **community portal**; and
- Farmers and local producers are expressing their enthusiasm related to services that are taking care for their education, consultation and training related to their activities, the **promotion of their products through the network**.

Embaros has now a portal site (www.embaros.com) that promotes the local products, the educating activities that took place within the framework of NETADDED and the community activities in general.

5.2.4.2 Broadband Internet access for isolated hotels in Turkey

The NETADDED solution in Goldenkey Bordubet Hotel was deployed with the objective of providing cheap, reliable and high quality Internet connectivity to the tourist resorts in (especially) rural areas of Turkey.

After the deployment, the hotel customers and staff has high quality wireless Internet access through WSTAs distributed in both Hotel areas.

Since it was possible to cover a large area (in the order of 10.000 m²) with 3 outdoor and 7 indoor wireless APs connected with mesh technology, a cost effective solution has been provided with minimal infrastructure related expenses.

The **wireless connectivity enabled bypassing of physical obstacles** such as dense forest and rivers. It was also possible to connect two remotely located sites with a 1.5 km LoS wireless link.

Figure 135: Wireless mesh network for isolated tourism resorts in Turkey

The demand for Internet based services was met without any major complaints from the hotel customers and staff.

User community at validation site consists of two different types of users. First category is the hotel customers who would like to benefit from broadband Internet during their stay. Users in this category typically use their portable personal laptops and prefer to have wireless connectivity wherever they are in the hotel complex. The typical applications utilized for Hotel customers are web-mail, e-banking, interactive messaging services and streaming video downloads.

Second category of users is the hotel employees using their desktop PCs or handheld POS devices for daily operations. The hotel employees use emails for reservation requests and confirmations as well as for communication with the travel agencies. Another typical business application is Wi-Fi enabled handheld devices that will be used for **order automation** purposes.

Good wireless connectivity in different recreational areas of the hotel complex (including primary and secondary zones) has been beneficial to increase the efficiency and effectiveness of getting orders (food, drinks, magazines etc) from hotel customers.

5.3 ECONOMIC MODELLING

Based on the experience gained through NETADDED pilot experimentations and deployments, the partners have provided cost information on the different satellite-based solutions deployed and operated across the different countries, with the objective of defining possible economical models to be used in INCO countries for the provision of satellite based services.

5.3.1 Cost elements

Hybrid infrastructure CAPEX/OPEX costs

Hybrid satellite-wireless infrastructure has been found to be an efficient means to reduce cost for subscribers in remote areas.

The validation sites deployed in Benin and Burkina Faso consisted in a broadband satellite access to Internet shared among up to 20 subscribers connected through a wireless network. Table 33 shows the typical infrastructure and operational costs for these sites.

Transportable terminal CAPEX/OPEX costs

The costs in Table 34 have been observed for the transportable broadband satellite-based terminal that has been developed by CNES and used by GREF in Burkina Faso for an educational campaign.

5.3.2 Economic models

Economic model for the hybrid satellite-wireless infrastructure deployed in Embaros (Greece)

The costs for the deployed solution at the validation site of Embaros are described below:

- CAPEX: 3696 €
- OPEX: 355 € (satellite link monthly fee), 50 € (power, others)

The overall deployment of the validation site has been financed using EC and Forthnet funding. The future economical model for the sustainability of the site involves the following funding options:

- Local monetary resources,
- Municipal funds,
- Local sponsorships,
- The selection of the appropriate model will be done on a case-by-case basis.

Based on the experience gained through the deployment of the Embaros validation site, for a network operator, the economic potential of broadband satellite-based solutions can be identified in making communities in remote and rural areas knowledgeable about the network. Fibre investments in rural areas are currently not justified because the investment cost outweighs the expected returns in profit. However, familiarization of the local population with the Internet, through a satellite-base solution for example, can

create a critical mass of customers that will justify future investments in network infrastructure by network providers.

CAPEX (infrastructure cost)	
Satellite equipment (outdoor antenna, modem, BUC, LNB, cabling)	3000 €
Wireless equipment (base stations, subscriber units, cabling)	5000 €
Network equipment (firewall, switches, routers, servers, rack, UPS…)	6000 €
Installation costs	4000 €
TOTAL CAPEX	**18000 €**
OPEX (operational costs)	
Satellite service monthly fee	650 € / month
Network maintenance	125 € / month
Electricity	40 € / month
TOTAL OPEX	**815 € / month**

Table 33: CAPEX/OPEX for hybrid satellite-wireless solutions in Benin and Burkina Faso

CAPEX (infrastructure cost)	
Suitcase, batteries, chargers, switch, cables, plugs, electronic components	9200 €
BGAN Explorer 500	3359 €
Bluetooth handset	560 €
Solar Cover 60 W	1183 €
Rugged router	1000 €
Network components	600 €
TOTAL CAPEX	**15902 €**
OPEX (operational costs)	
Inmarsat Fees (6 month evaluation period)	1300 €
IP Data Transfert (Internet)	6.5 € / Mbyte
Fix phone call	0.7 € / minute
Mobile phone call	0.9 € / minute
TOTAL OPEX	

Table 34: CAPEX/OPEX for transportable terminal

Economic model for a distant learning network in Cambodia through a hybrid satellite-wireless infrastructure

The table below is a "high level" view of costs versus revenues of running the service in Angtasom. The assumptions are: (1) a khmer technician handles the network operation and maintenance. He is hosted free of charge by one of the schools; (2) 6 schools and training centres are connected inside the network sharing the 512 kbps Internet connexion; (3) each school pays 20$ per month for the service.

	Price	Qty	Unit	Total Dollars	Total Euros
Salaries and Running Costs					
Salary of a local maintenance technician	180 $	12	month	2160	1662
Internet Connexion	350 $	12	month	4200	3231
Miscellaneaous costs (replacement parts, transportation…)	100 $	12	month	1200	923
Yearly Total				*7560*	*5815*
Revenues					
School connexion charge (6 schools @20$ per month)	120 $	12	month	1440	1108
Yearly Total	*120*			*1440*	*1108*

Table 35: Economic model for distant learning in Cambodia – scenario 1

In the second scenario below, it is assumed that a place is rented in Angtasom and an Internet café opened. Additional assumptions are: (1) another person is then needed to handle the café; (2) 15 man*hours per day of Internet usage 6 days a week, 50 weeks per year. Revenue is 0.4$ per man*hour. The "high level" costsheet now becomes:

	Price	Qty	Unit	Total Dollars	Total Euros
Salaries and Running Costs					
Salary of a local maintenance technician	180 $	12	month	2160	1662
Salary of the Internet café manager	120 $	12	month	1440	1108
Internet Connexion	350 $	12	month	4200	3231
Office rental for the technician and café	120 $	12	month	1440	1108
Miscellaneaous costs (replacement parts, transportation…)	100 $	12	month	1200	923
Yearly Total				*10440*	*8031*
Income					
School connexion charge (6 schools @20$ per month)	120 $	12	month	1440	1108
Internet café income @ 0,4$ per hour	0,4 $	4500	hours	1800	1385
Yearly Total				*3240*	*2492*

Table 36: Economic model for distant learning in Cambodia – scenario 2

In both cases, it is pretty obvious that we do not have a viable business case. The last option could be to try and charge for content. Indeed some teachers are giving private lessons (30 students at a time) after hours and charging the students a small fee (0.15$ per hour per student). Having access to the content could enable them to improve their private lessons to the point that they would be willing to pay for it. However this scenario would be difficult to implement because it is impossible to protect content, and it would require hiring a cashier at each school thereby jeopardizing the potential content revenues.

The fact that we do not see a viable business case does not mean that the service is not worthy and that project should be abandoned. Indeed, how should we quantify the benefits of a local community now having some skilled plumbers, electricians, computer technicians, automotive repair technicians or smarter farmers?

5.4 ROADMAP FOR THE FUTURE

The NETADDED partners having participated to the improvements developments have analysed the lessons learned from the NETADDED project and have defined based there-on a technology roadmap for the different technologies and services developed under the framework of this project.

Most of the NETADDED site coordinators have set up partnerships with solution providers or agreements with relevant organisations and authorities so as to define a viable roadmap for the deployed networks at the NETADDED sites and to ensure continuity of service.

5.4.1 Technology roadmap

Self installation process

Forthnet's participation into NETADDED helped in understanding the user perception about satellite access, the drawbacks of the typical installation process, while it contributed towards reducing the difficulties of the installation process through the self-installation utility.

Finalising the self-installation process, can lead to a packaged offer that reduces the cost of deployment for satellite access users. That will be a critical economical factor within the financial plan of satellite broadband expansion.

Still, Forthnet has not started commercial deployment of satellite access. However, now the types of networking access across the country, seem to position themselves across the country by the competing operators, revealing the gaps at various areas. These areas, remain an interesting market, while tourism and property development at sites, continuously drive the need for wider coverage.

Transportability

The key technological improvements planned for the future concerning the transportable satellite terminal developed by CNES in NETADDED are the following:

- Improve the autonomy of the batteries, using more performing and well-adapted power supply systems
- Simplify the power supply interfaces, by reducing the number of cables and connectors and providing a simple led-based user interface (ex: battery status…)
- Reduce the cost of the communication fees, by implementing more powerful mechanisms like TCP acceleration, compression systems and web caching, in complement with the ones already provided by the Inmarsat system.
- Definition of a dedicated commercial offer with invoicing per use.

A first prototype of the transportable solution was used for in field validation tests, a second version was implemented in order to create an industrialization dossier. A commercial solution will be available by the end of 2009.

Remote control platform

Future work on the remote control platform will be focused on two key areas. The first work area involves a comprehensive authorization framework allowing users with different roles to access specific parts of the system. Currently, only two roles are allowed: the network provider administrator and the validation site operator.

The second work area deals with an extension to the software to automatically activate a backup line (mainly a GMS/SAT mobile phone line) when the main (satellite) link is down, so that in addition to alerting the administrator of the network provider site, it would be possible to connect to the NMS station at the installation site to re-enable the satellite link.

The motivation of Forthnet regarding its participation in this work package is associated with the opportunity to investigate on the development of a network management solution that would enable Forthnet to offer management services to its customers to manage their local network. This expectation has certainly been met since the core of the developed system is currently being used to remotely manage and monitor Forthnet's network infrastructure. The system has been successfully tested in such a demanding environment so further use and investment is definitely warranted.

Intelligent wireless networking

The key technological improvements for the future of hybrid broadband + wireless mesh networks are perceived to be:

- Utilization of MIMO technology and adoption of 802.11n standard for wireless communication between mesh nodes. Exploitation of MIMO physical layer for very high capacity mesh/ad hoc network with increased reliability
- Improved L2-L7 algorithms and protocols to meet high throughput/low delay requirements of demanding application such as real-time audio/video and multimedia

Hybrid broadband + mesh networks such as the one deployed in Bordubet site will be evolving towards more complex, highly resilient mesh networks with better resource management capabilities.

Wireless sensor networks for precision agriculture

Wireless sensor network is key issue to support sustainable development but to make it widespread for smart home and precision agriculture plug&play concept must be developed and it will be deployed base on service and provider business model. Consequently, UBP will develop new wireless sensor network (System On Chip wireless node) and new embedded software meeting the requirements of plug&play wireless node. The new platform will be deployed in cooperation with CEMAGREF at Montoldre's site and in the laboratory for smart home application. UBP is in contact with the city hall of Clermont-Ferrand to experiment the use of wireless sensor network to assist elderly people at home.

Distant learning platform

The following roadmap has been defined by Connected Schools:

- Mutualize content creation: Long term, we believe the only way to really boost content creation in local language is to partner with large international NGO's who operate in the children education domain. They are likely to understand the potential of this project better as well as have more money to put behind it. Our intent is to advertise our project to their local headquarters, bring them together and offer them our computers, our NETADDED communications infrastructure as well as our SW tools, database and processes for creating quality education content and using our distant learning tools in their remote schools. By bringing them all together, the costs of content creation, Internet access and network maintenance will be mutualised. Benefits could be very high. One NGO could bring X hours on content to the party and retrieve 10X. A side benefit will be to reduce exposure to teachers' attrition as those tend to be very volatile. Replacing a good teacher is a lot easier if all his lectures have been recorded,
- Share the costs of the Internet connexions: Satellite Internet access costs will be shared between "Connected Schools" and "Missions Etrangères de Paris" initially. We will also try to request a small fee (10$ to 20$ per month) to the local schools to cover part of the operational costs and to

test their real interest. It is believed that the 5.7GHz spectrum supplied by First Cambodia will remain free,

- Advertise and raise fund,
- Contact other companies foundations in the fourth quarter of 2009 namely: Skype, Google, Dell (notebook computers), Samsung, Sharp (solar panels), Orange and HP.

Deploy the concept nationwide in Cambodia. Of course this may sound unrealistic given our modest size and budget. However we intend to give it a try by partnering with a local Telecom operator, the CIST and one or two international grant providers (ADB, GTZ, USAID).

CNES, with the help of local partners and the support of governmental authorities and organisations like WHO, UMVF and UEMOA, is preparing a future roadmap for the development of applications in the domain of medical e-learning in Benin and of education in Burkina Faso:

- Development of a learning system common to all the universities, institutes, federating the different initiatives and projects which are lead at each end-site,
- Development of e-medical system common to all the health centres, in order to easily access information, support to consulting, spread epidemic alarms,
- Development of a specific e-learning system, allowing the rural population to acquire a specific knowledge on healthcare, agricultural techniques, farming, water extraction…
- New e-commerce in order to develop the economical activity of the area.

Services Differentiation

The overall platform now shows a high level of maturity and can be proposed on a larger scale. The reliability of the satellite network showed to be excellent.

The full and complete integration of applications with the satellite network requires a high investment to achieve reliability and performance as well as efficient trouble shooting as the system's complexity increases. The issue of critical mass of users (and therefore total available bandwidth) remains an open issue, but this is a matter to be dealt with in the context of business modelling.

Operations enabled to collect a number of indications for seamless operations, such as:

- Requirement to have a certified reference list of equipment for the user workstation (video and audio peripherals in particular, use of light equipment (portable PC) with external USB based video analogue/digital converter devices.
- Use DECT wireless microphones to facilitate movements of the remote participant.
- Use microphones with push to talk button

- The achieved quality of videoconferencing (audio and video) is very good and adapted to the requirements of the users.
- The embedded co-working features can still be upgraded to fully match all expectations of the users in terms of functionalities.

All technical choices for service differentiation have been comforted by the results of the operation phase. The developed software will be refactored to reach industrial quality:

- For long term maintenance purpose (as we foresee evolutions in relation with the implementation of new service features using the same or adapted mechanisms, for instance for tele-radiology or tele-echography applications)
- To improve its robustness and ergonomics

This software upgrade will be performed in conjunction with a hardware maintenance operation as the technology's evolution enable to improve performances and reduce maintenance costs.

The later is mainly the result of the observation of that there are many productivity issues from the side of the service operator. The platform has been working fine for the users, but at production costs that can still be considerably decreased (and need to).

5.4.2 NETADDED sites roadmap

After the end of the project, 13 validation sites will remain operational, representing 93% of all deployments.

Connected Schools will maintain its operations in **Cambodia** for at least another year (2010) to allow for more content creation, more local people training, more time for them to change their working habits in an attempt to validate the concept thoroughly. Connected Schools will continue to operate the NETADDED network as it stands today. In its current form however the network does not enable live distant learning (video conferences) between Phnom Penh and Angtasom. One option to overcome this obstacle would be to establish a direct high speed Canopy wireless connection between PP and ATS. This can likely be done with only one relay located half way between the two sites.

The NETADDED site of Embaros (**Greece**) will remain in operation after the end of the project, using the equipment provided and installed within the framework of the project. Forthnet will continue the operation and financing of the site until June 2010, based on the agreement with Hellassat (satellite service provider). The applications will remain available to the community, and no license fees will be required for their use. More distance learning sessions will be organised based on the Agrotelediagnosis platform. Special educating sessions will be organised for the needs of the site. The web site will be further extended to include more content and e-commerce functions. This will need the cooperation and agreement with local cooperatives and enterprises.

In **France**, Allier site, deployed for test purposes, will be maintained by Cemagref and UBP.

In Bordubet Hotel in **Turkey**, the service will be fully sustained after NETADDED. Goldenkey group IT administration has stated that they have concrete plans of deploying hybrid xDSL + wireless mesh technology based access networks in the other 3 hotels operated by the chain.

In **Burkina-Faso**, Bogandé and Ouahigouya sites will continue through the intervention of NGOs and governmental authorities.

In **Benin**, the service will be maintained in Ouidah and Parakou, financed by the WHO (80%) and the FSS "Mother-sons" (20%). The equipment deployed during the project will be left to the end users and to the WHO. In Parakou, the service might be sustained through the UMVF's Mother-Son project (www-sante.ujf-grenoble.fr/SANTE/maee/) and CNES' forthcoming project on Telemedicine.

The teletraining programme on laparoscopic surgery is supported by MMESA (Pr. Avci from IMF has just been elected President of this organism) which will sustain the project in **Istanbul, Casablanca** and in other cities such as Alger or Brussels also participating to this initiative. In addition, an agreement at state level between Benin and France will allow to establish in the near future a national telemedicine network based on extension of the network deployed within NETADDED.

In **Morocco**, there is a contractual commitment from Wana for the sites operation after NETADDED. The current initiative could be extended to other communities in the area of validation sites (connecting new schools, local government, local business entities etc…) Nortis Cimecom, a leading VSAT operator and a longstanding partner of Eutelsat, has been selected by the Ministry for Education and the national telecommunications regulatory authority to deliver satellite-based broadband services to schools beyond range of terrestrial networks. This deployment programme forms part of a far-reaching national programme called 'Génie' driven by the Moroccan Ministry of Education to extend ICT infrastructure to schools for on-going teacher training programmes and Internet access to educational content for pupils of all ages. 25% of schools will be equipped in the first phase of the national programme. The company is consequently now deploying D-STAR in 470 schools in towns and villages across Morocco. The second phase of the 'Génie' programme is currently being assessed by the national telecommunications regulatory authority with the ultimate objective to deliver broadband to a total of 21,000 schools.

5.5 CONCLUSIONS AND RECOMMENDATIONS

The main conclusions and recommendations, issued from the NETADDED experience on **deployment of hybrid satellite-wireless networks for advanced communications services to isolated areas in INCO countries**, are summarized below.

5.5.1 Deployment of broadband satellite-wireless networks

Site identification & sustainability

1. Identifying user needs, promoting services and coordinating **local actors** with the help of a local person will guarantee sustainability of the deployed solution
2. Raise **awareness of local/regional/national authorities** on the advantages of hybrid satellite-wireless solutions for rural and isolated areas

Design

3. **Site survey** is one of the most critical phases of the deployment and has to be implemented in a rigorous and careful fashion
4. **Environmental conditions** have to be considered for the equipment selection and installation planning
5. **Alternative power supply** solutions adapted to INCO context (solar, wind, UPS…) to be exploited

Installation

6. Long **administrative procedures** for the providers selection to be anticipated by the public bodies
7. **Customs and export** procedures can introduce non negligible delays and costs
8. Be ready to respond to **users' reluctance to antenna installations** within residence areas

5.5.2 Operation of broadband satellite-wireless networks

Network maintenance

9. Use of **UPS** has protected equipments from instability of electricity networks
10. Problem resolution time can be reduced by the provision of **on-site spares**
11. Reduction of installation & maintenance costs through use of **local technicians**

Day-to-day usage

12. Promoting the use of the network all along the operation with local support, **events organisation** and **learning support** will guarantee service sustainability

5.5.3 Service quality

13. **Personal usage**: provide a scaled down but complete Internet access solution
14. **Professional usage**: for specific e-health or distant learning applications there is a particular need for advanced broadband services having improved network performance in terms of reliability, availability, QoS and capacity
15. Systematic use of **QoS and remote control** tools allowing
    - Services differentiation on both satellite and local loop segments
    - Overview of overall network status
    - Detection of problems for remote or on-site interventions
    - Reporting of resolved problems

    is necessary for future operators in developing countries.

5.5.4 How to obtain cost effective solutions

16. **Deployment & operation of hybrid satellite-wireless networks in developing countries is expensive** with respect to Europe
17. Reduction of infrastructure costs through reuse of **existing pylons** for wireless equipment deployment
18. Reduction of installation & maintenance costs through use of **local technicians**
19. Reduction of maintenance costs through **improved reliability**
20. Increase the mutualisation factor of the satellite link through **increased wireless coverage** area and **higher bandwidth satellite services** offers
21. Foster **NGOs partnering** with other entities to **mutualise content creation** and **share costs** of Internet
22. Provision of **on-demand broadband services** through the definition of a commercial offer with **invoicing per use** for light-weight compact transportable satellite terminals
23. **Promote investments in hybrid satellite-wireless solutions** as a direct contribution to the development aid