



Aeronautics and space

Integrated Project No 516135 – MOWGLY MOBile Wideband Global Link sYstem

Instrument: Integrated project

Publishable final activity report

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1 Introduction

This document summarises the objectives of the MOWGLY projects. It also entails a summary of the main achievements as well as per work packages.

2 Project objectives

The overall technical objective of the MOWGLY Integrated Project is three-fold:

- Assess the business case
- Define and specify an end-to-end “industrial” telecommunications system for mobility applications taking advantage of existing or planned Broadband Satellite Access Architectures in Ku and / or Ka band (We call “industrial system” the target system that will be installed on revenue service aircraft)
- Develop prototype system for experimentation onboard aircraft, ships and trains

To reach its objectives, the projects needs to address the following aspects:

- Business model
- Mobility
 - handover between spots and gateways
 - synchronisation at physical layer
 - Ku/Ka band coverage & dual band antenna
- Services: Services to passengers versus cockpit services
- Security (authentication/authorisation and Accounting)
- Routing and IP networking
- Regulatory aspects
- Airborne System specification
- Airborne equipment specifications (including functional, operational, mechanical and electrical interface, certification, safety and environmental requirements).

To address these technical issues, the project will implement the work as follow:

- System requirements & architecture
- Telecom System Implementation based on prototypes
- On-board experimentation for the three applications: aircraft, maritime and train.

The project objectives can be demodulated per work package as defined below.

3 Contractors involved

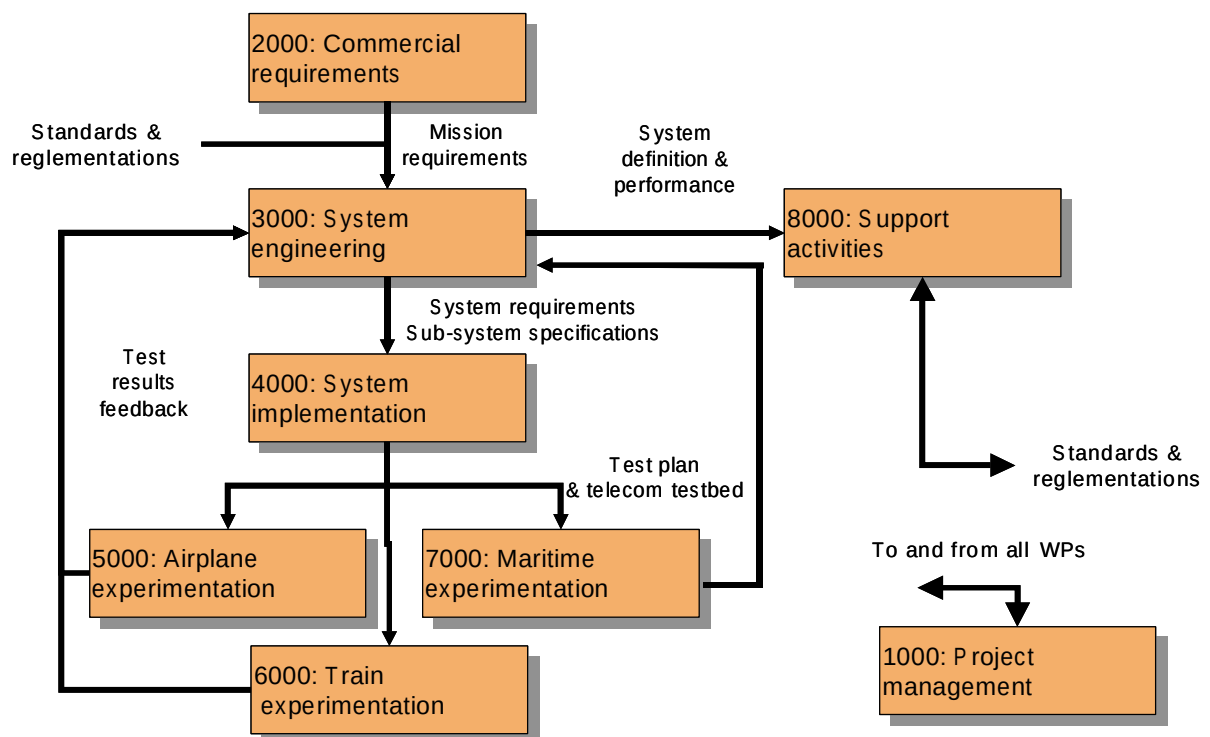
Work Package leaders are indicated in bold characters

CONTRACTORS	Short name	Country
ALCATEL ALENIA SPACE	AAS	France
AIRBUS	AIRBUS	Germany

ROCKWELL COLLINS FRANCE	RCF	France
ORBIT	ORBIT	Israel
EUTELSAT	EUTELSAT	France
ALSTOM Transport	ALSTOM	Spain
ALCATEL CIT	ACIT	France
MBI	MBI	Italy
TRIAGNOSYS	TGS	Germany
Teleinformatica e Sistemi s.r.l.	TeS	Italy
VIDEO&SUONO	V&S	Greece
University of Surrey	UNIS	UK
INECO	INECO	Spain
ADVANTECH	ADV	UK

4 Activity report per Work Package

The overall study logic is depicted in the figure below:



• Figure 1: MOWGLY project study logic

4.1 WP2000: Commercial Requirements

4.1.1 Work Package objectives summary.

Commercial requirements are key inputs to MOWGLY project. Combined with the regulatory inputs, they allow defining the mission requirement. Commercial requirements are defined at the beginning of the project and iteratively refined during the entire project to take into account market moves.

WP2000 will lead the service definition. It will be validated with service assessment implementing - a service model tested against representative users. It will detail the Mobile satellite broadcast system business modelling ensuring fair revenue sharing between the actors of the media and telecommunication industry. This will be used to define the collective mobile satellite connection mission requirements.

In order to capitalise on experience of other projects, a clustering WP is foreseen, where outcome from other European Union projects (FP5/FP6 and related) in the area of IP broadband services for mobile applications will be analysed. Also an internal clustering activity will be carried out, to ensure the harmonization of solutions adopted across the different mobile environments.

For the business modelling (WP2300), a detailed traffic estimate is required. Traffic models will depend not only on the application, but also on the capacity and throughput of the transport network since the medium access and the packet scheduler will impact the traffic flow and thus modify the traffic peak rates. Thus, it is key to model an aggregate traffic model with a service mix from all kind of interactive and streaming applications in the mobile distribution network (regardless of train, vessel and aircraft environment). Reasonable assumptions on the QoS support of the transport segment resource management must then be taken to derive the statistics of the transport network. From this, cumulative usage and traffic forecast can then be derived as input to the business model. Of course, the satellite segment can alter depending on the customer. Different capacity and pricing solution may a fed-back input to the traffic generation parameters itself.

4.1.2 Contractors involved

AAS, AIRBUS, RCF, EUT, ALSTOM, ACIT, MBI, TRIAGNOSYS, UNIS, INECO

4.1.3 Work performed and end results

The objectives of WP2000 have been mainly achieved through

- Creation of Mission requirements for Mobile Broadband System
- Definition of business model integrating all the stakeholders and their related interactions
- Validation of a business plan showing that the respective actors may have in a mid-term a positive Return On Investment.

4.2 WP3000: System Engineering

4.2.1 Work Package objectives summary.

The objective of the WP3000 is to specify the industrial system based on the commercial requirements produced in the WP2000 and the performance feedback provided by the WP5000, 6000 and 7000.

A full technical definition will be available at system level for the requirements and architecture. At sub-system level the requirements definition will be available. After this phase, detailed design could be started in the frame of industrial product development (see roadmap and development plan).

The conclusions of the WP3000 will be the following one:

- All the technical features to be developed will be defined and evaluated.
- Non-recurrent and recurrent cost of the sub-systems will be known.
- Detailed development plan will be written.
- Deployment cost including regulation and licensing will be known.
- System performances will be evaluated.

For mobility aspects, two major points deserve research among many other mobility aspects that have been investigated elsewhere:

- Large scale mobility depending on service coverage
- Mobility support for moving platforms

Moving platforms suffer fading and multi-path effects. Whereas the maritime channel and the aeronautical channel tend to be “friendly channels” where fading due to attenuation changes along the propagation paths and two path fading varies slowly, furthermore shadowing effects can be neglected. However the train channel suffers severe repetitive fading. In recent publications the railway channel at higher frequencies shows deep fade events and fast oscillating behaviour which can not be handled due to the dynamic behaviour by DVB-RCS2 channel estimation and mode adaptation. This study will use cutting-edge concepts for space-time coding for transmit diversity and antenna diversity for receivers to countermeasure the railway channel. Interfaces to DVB-RCS 2 signalling need to be defined to exploit the receiver knowledge of the channel for estimation and synchronisation. Such a concept will outperform current coding and interleaving concepts since no additional bandwidth is required and decoding delay is minimised.

For the trials, only prototypes will be developed. They should be based on the first versions of the specifications produced in WP3000. In the WP4000, 5000, 6000 and 7000, a compliance matrix to WP3000 specifications will be produced to assess the relevance of the experimentation.

- Engineering Models

The MOWGLY activity is based on the use of the existing Network Emulation Platform (NEP) which is as a support tool for engineering activities that replicates the “ADSL-in-the-Sky” system architecture protocol stack.

The NEP will serve as an emulation tool supporting the MOWGLY engineering activities. New platform operation scenario will be defined representative on the MOWGLY targeted environment, in particular concerning propagation condition and hand-over. For instance, particular hand-over condition can be modelled through DVB-RCS session logoff (on the old spot) followed by an immediate new session logon (on the new spot).

The NEP is the result of Alcatel Space expertise on emulation tool and combines :

- a real time environment allowing to seamlessly interconnect hardware equipment and software application
- an evolutionary and modular emulation design, enabling to test the addition of new functions to a system.

The NEP integrates all system features of the A9780 R2. product. Figure 14 presents the NEP architecture with one satellite terminal. The NEP also supports multiple satellite terminals and satellite terminal population emulators.

The NEP offers four type of interfaces :

- Traffic User interfaces (one per satellite terminal) allowing to interconnect any type of network, typically used in Ethernet mode to connect user LANs.
- Traffic Server interface (one for the NEP) allowing to connect the platform to an ISP infrastructure and application servers.
- Platform User interface (one for the NEP) allowing to operate the platform through a man-machine interface.
- Management Interface (one for the NEP) allowing to send or receive OAM flows from the platform.

4.2.2 Contractors involved

AAS, AIRBUS, RCF, ORBIT, EUTELSAT, ALSTOM, ACIT, MBI, TRIAGNOSYS, TES, UNIS, ADV

4.2.3 Work performed and end results

There are two major parts of WP3000's contribution: one is system specification and architecture to provide a final solution for commercial purpose, and one is system definition for all the prototypes and trials that have been developed during the project.

4.3 WP4000: Telecom System Implementation

4.3.1 Work Package objectives summary.

The telecom system (access and service) is seen as the common block between the three systems for aircraft, train and maritime applications. Development, integration and validation of the telecom system on a platform without a real satellite link between the hub and the terminal (only the IDU). The hub-terminal interface is based on an intermediate frequency (like L-band) and may emulate the real satellite link by using a Satellite Link Emulator with static or dynamic profiles.

The resulting developed sub-systems are either prototype or un-optimised commercial equipments. At the end of the validation, the telecom testbed will be ready to be installed and integrated to the aircraft, train and vessel.

The on-board Satellite Terminal (ST) prototype is one of the main development (WP4100) of the MOWGLY project. It will be based on a modulator/demodulator including decoder functions and a protocol engine.

The protocol engine is the part of the on-board satellite terminal (ST) in charge of the following functions of the IETF protocol stack :

- the management of the satellite terminal (L4 – SNMP and Security Management)
- the router or bridge and its satellite interworking function with radio transmit and receive communication chains (L3 – Router/Bridge)
- the access layer of the forward communication chain, supporting MPE over MPEG2 over DVB-S2 protocol de-capsulation (L2 – Receive)
- the access layer of the return communication chain, supporting AAL5 over ATM over DVB-RCS protocol en-capsulation (L2 – Transmit)
- the DVB-RCS control functions in charge of logon and synchronization procedure, DVB-RCS and DVB-S2 table reception and processing (e.g. TBTP reception) (L2 – Control Plane)
- the modem control functions (L1 – Control).

The protocol engine connects with :

- the onboard gateway through an Ethernet interface directly connected to the router/bridge functions
- the modulator and demodulator equipment through an Ethernet LAN.

The two figures below present the functional architecture of the protocol engine and its interface, and a proposed mapping of this functional architecture on one PC.

The Satellite Terminal will then be integrated and validated on a laboratory platform based on a real hub. Out of the required functional tests, a satellite link emulator able to simulate propagation conditions (mainly due to high speed) will be used to verify the performances of the data link between the ST and the hub.

4.3.2 Contractors involved

AAS, RCF, EUTELSAT, ALSTOM, MBI, ADV

4.3.3 Work performed and end results

Very impressive prototypes have been developed during the project: a full satcom solution based on DVB-RCS and S2 standards enabled to support mobility applications for trains, boats and aircrafts and a comprehensive applicative platform (on-ground and on-board) to provide multimedia services to collective users (i.e. travellers in boat, train and aircraft).

4.4 WP5000: Aircraft Experimentation

4.4.1 Work Package objectives summary

The WP5000 – Aircraft experimentation – will deal with the preparation, the execution and the analysis of tests on an airborne end-to-end system prototype on a test bed, on ground and in flight. The main objectives will be then to develop, adapt and validate the system architecture defined in WP3000 with the use of the satellite architecture and modem prototype developed in WP4000. The output of the trial analysis will also provide an assessment of the business model of WP2000 and input for the deployment plan to be proposed by WP8500.

The experimentation will proceed in 5 steps:

- WP5100: Specify the experimental system
- WP5200: Design and develop the airborne antenna system

- WP5300: Integrate the system components on a test bed
- WP5400: Integrate the system on a test aircraft
- WP5500: On-ground and In-flight testing

During WP5100 the adaptation to be done to the global architecture defined in WP3700 will be specified. The needed adaptation to perform on the aircraft network will be notified. The antenna system will be defined according aircraft constraints and the satellite architecture adaptation will also be addressed. The requirements defined here will be used in WP5200 for the antenna design and manufacturing and in WP5300 for the test bed development. WP5200 will provide a verified aeronautical antenna complying with the requirements defined in WP3710 and 5100.

As shown on figure 19, within WP5300 an airborne end-to-end system will be integrated on a test bed. The different components will be then assembled comprising adapted aircraft network, modem and router (developed in WP4x00), antenna system and applications. The tests performed on the end-to-end system will validate the architecture and allow installation on A/C.

The physical installation will then be done on the A/C in WP5400 in parallel with the test cases definition (WP5500).

The final on-board test (Figure 21) will be then performed, comprising ground test which will confirm that the system is operational and to evaluate possible masking by the vertical stabiliser.

The flight test will be used mainly to validate the system performances. Finally, the analysis of the test results will lead to further adaptation of the system, which would enable a commercial deployment. The consortium will take into account the worst operational conditions (On route at high latitude and airport approach including holding pattern) that could impact the system performances.

4.4.2 Contractors involved

AAS, AIRBUS, RCF, ORBIT, EUTELSAT, TES, ADV

4.4.3 Work performed and end results

Results of the flight tests were consistent with ground and lab tests. Moreover, slight reduction in bandwidth on the return link between ground tests and flight tests (144 kbps) has enabled us to demonstrate the need for Quality of Service management function for priority and Traffic Shaping needs.

Finally, end-to-end test of all the services initially evoked (D2400) and tagged as applicable for Field Trials has been successful during flight and has shown not only conceptual feasibility but also technical feasibility since an important part of the platform was already or based upon "qualified avionics material" (e.g. antenna tracking system, BUC/HPA, Avionics Server, Wi-Fi Hot-Spot).

This trial was successful, confirming that DVB-RCS is fully compatible with mobile application with an highest bandwidth efficiency.

- 1- All expected services were demonstrated:
VoIP, Multicast, Web Browsing, VPN access, SMS ...done
- 2- Traffic losses due to aircraft environment :
 - a. Ping : less than 0,1%

b. Synchro burst less than 0,1 %

3- Confirms the antenna pointing capabilities:

No tracking difficulties with the ACU connected to the ARNIC 429

Modem position updated by SNMP

4- HUB capabilities to compensate F and T for terminal fleet

The Antenna System worked perfectly in the Flight Test as designed and expected. The system meets the specifications in terms of:

- o G/T, (according to the Link Budget Calculation)

- o EIRP, (according to the Link Budget Calculation)

- o Tracking, (Excellent Eb/No stability)

- o Environmental conditions (extreme movements of the Aircraft, & -54 Deg C).

The Antenna System allows getting 3Mbps (Forward) & 272Kbps (Return) with good Link Margin, despite the mechanical constraints of the mechanical dimensions of the system in order to use an existing Airbus radome.

From the satellite point of view, no interferences caused by the system were noticed.

Conclusions of the flight tests as far as end-to-end tests are concerned are:

- o QoS function is crucial since return channel needed bandwidth is higher than available one (144 kbps during first flight and 272 kbps during second flight),

- o Final architecture of the onboard system in terms of devices shall be modified to target "as light as possible" system. Indeed, reliability of such a system depends upon the number of LRU!

- o ADSL-like user feeling is not yet achievable through a direct pure connection to the ground networks. Thus, local service platform (in short the CNSU) shall provide local entertainment and services to minimize pure-internet access. Indeed no technology may yet assume current bandwidth consumption when accessing "web 2.0" (e.g. www.youtube.com)

The WP5000 aircraft experimentation field trials on ground in the lab and on the Airbus A340-600 test aircraft were a success but the system needs to be improved in order to become a commercial service.

4.5 WP6000: Train Experimentation

4.5.1 Work Package objectives summary.

The objective of this WP6000 is to prepare, coordinate and perform the train experimentation in MOWGLY. The rail sector is one of the target sectors in this project with some special characteristics that differentiate it from aviation and maritime sectors, like the lack of coverage in tunnels or the possibility of having a terrestrial return link. For this purpose, a team led by INECO will prepare a series of tests and experiments using high-speed rolling stock in a real environment. The experimentation will be performed on high-speed trains from RENFE, the Spanish leading train operator.

Figure 22 – WP6000 work logic

To attain this objective, a series of activities are necessary in advance to properly prepare the experimentation and ensure as much as possible its success. Several sub-workpackages are

defined to tackle these preparation activities as well as the actual experimentation and analysis:

- WP6100: Specify the experimental system
- WP6200: Design and develop the trainborne antenna system
- WP6300: Integrate the system with the onboard train network on a test bench
- WP6400: Integrate the system on a test high-speed train
- WP6500: Field trials

During WP6100 the adaptation to be done to the global architecture defined in WP3700 will be specified. The antenna system will be defined according to train constraints and the satellite architecture adaptation will also be addressed. The requirements defined here will be used in WP6200 for the antenna design and manufacturing and in WP6300 for the test bench development..

WP6200 will provide a verified rail-grade antenna complying with the requirements defined in WP3710 and 6100.

As shown on figure 22, within WP6400 a trainborne end-to-end system will be integrated on a test bench. The different component will be then assembled comprising train network, modem and router (developed in WP4x00), antenna system and applications. The tests performed on the end-to-end system will validate the architecture and allow installation on trains.

The physical installation will then be done on the train in WP6400 in parallel with the test cases definition (WP6500).

The final on-board test (Figure 24) will be then performed, comprising ground test which will confirm that the system is operational and to evaluate possible masking by the neighbouring equipments (catenaries, poles, train's pantograph, etc...).

The consortium will take into account the worst operational conditions (tunnels or under steel roofs of main stations) that could impact the system performances.

4.5.2 Contractors involved

AAS, RCF, ORBIT, EUTELSAT, ALSTOM, TES, INECO

4.5.3 Work performed and end results

Two field trials campaign have been performed.

During the first campaign, from the point of view of the antenna as a tracking system, the performance was not a total failure, but was extremely deficient relative to our expectations. The most likely cause was the lack of the GPS speed input to the IMU stabilization algorithm.

In addition, the collected data suggest a number of other improvements related to speeding up reacquisition and making the IMU algorithm more robust against un-expected inputs.

It was also planned to add a communication channel which will allow to perform uninterrupted data collection of a large number of variables, while still permitting the use of the present communication channel to adjust various parameters during the next trial. Better coordination of data collection should also be achieved for the next trial.

Regarding the catenary and electrical posts, it was clear that they cause some interference. How important that may be depends on the ability of the higher level protocols to manage those repeated dropouts lasting typically 100-400 msec.

A full test of the system on a van, subjecting it to speeds and accelerations which will simulate the train environment (mostly Linear accelerations) was also required before use on a train.

This second trial can be considered as a success, especially if it is taken into account that tests were performed over a prototype in a degraded environment and with late design and configuration changes. Some of the problems met during the trial confirm that it is important to improve the reliability of the MOWGLY system on a real situation but that we are not far from a commercial solution.

Also this kind of product takes relevant hardware, relevant software and relevant funding there.

In a general view, MOWGLY consortium is very satisfied with the antenna and with the tracking system, although there is still room for improvement on the service platform, since some services are not working at all times. In any case, we demonstrated all the expected services and the architecture designed during GA2 was in place.

A summary of main conclusions follows:

- According to the analysis of recorded data, and looking at the Antenna/RF performance of the system (in the Spectrum Analyzer), the Antenna System worked perfectly, with no tracking losses identified.
- Connection service has been provided at stop, low and high speeds. This implies that mobile Internet is possible.
- Core system was stable against loss of connections / timeouts, harsh software shutdown and resume.
- The only loss of signal for the antenna system occurred in obstructions, bridges, tunnels, with an excellent typical recovery of 3-5 seconds after travelling out of the tunnels; on a long tunnel with an immediate 100 de-grees curve, the recovery was about 20-30 seconds.
- There was a 3 or 5 % of traffic losses due to train environment, but did not perturbing users' applications
- The Smart Routing functionality allowed Internet access through terrestrial networks (GPRS/UMTS/HSDPA) when the satellite link was not available.
- For the transport media (Ku-band, Ka-band, Wi-max, Wi-Fi ...) the band-width of the return channel (from train to SOC) is not large enough to support ADSL-like user feeling with several simultaneous users. There is a poor quality of "video streaming".

- SOC has been accessed via both, GPRS and KU satellite links, confirming that ground smart routing function worked properly. Accesses to the SOC have been done also outside the smart router tunnels, which means that for a part of the trials the smart routing function had been disabled.
- The monitoring system demonstrates that services in the SOC have been up and running during all the field trials.

Notes and Recommendations:

- Deeper unitary tests should have been done before trials (e.g. global positioning system).
- Smart Router shutdown function should be tested more extensively by Rockwell-Collins France
- Onboard System Architecture shall be based as much as possible upon railway-proof materials, since the train physical environment is much harder than that of avionics or maritime.
- We should pay attention in defining “the lock” function, since the Modem will give its “lock” indication (Tx command), only after approx. 25 seconds of continuous antenna “lock”, meaning that even though the Antenna System was able to recover immediately after tunnels, the modem will need 25 additional seconds to “lock” if it has lost the “lock” for more than 6 seconds, (DVB-RCS concept). We should investigate how to shorten those 25 seconds,
- Bandwidth management services (QoS), without which few users may “steal” bandwidth from others, should be taken into account. Moreover, Internet “impact” is to be taken into account.
- For an industrial – commercial solution, efforts on the local/remote service platform must be done.

4.6 WP7000: Maritime Experimentation

4.6.1 Work Package objectives summary.

The objective of this WP7000 is to prepare, coordinate and perform the maritime experimentation in MOWGLY. The maritime sector shares some common issues with the aircraft sector. But to be complete, a team led by VIDEO&SUONO will prepare a series of tests and experiments using ships cruising in Mediterranean sea.

To attain this objective, a series of activities are necessary in advance to properly prepare the experimentation and ensure as much as possible its success. Several sub-workpackages are defined to tackle these preparation activities as well as the actual experimentation and analysis:

- WP 7100, Trials specifications: under the leadership of Video&Suono, this WP shall define the end-to-end system for the maritime experimentation, including specially the specification of the on-board architecture and the antenna system.
- WP 7200, On-board vessel network: under the leadership of MBI, this WP shall integrate the on-board network that shall be used to provide access to final users onto the vessel.
- WP 7300, Vessel integration: under the leadership of VIDEO&SUONO, the experimentation system shall be integrated into the test vessel, including both the on-board system and the antenna system.
- WP 7400, Field trials: under the leadership of VIDEO&SUONO, during this WP the actual experimentation shall be carried out, starting first with Ground Acceptance Testing to ensure system functionality, to afterwards proceed to Field Testing where the performances of the system shall be thoroughly checked in a variety of operational situations.

4.6.2 Contractors involved

AAS, EUTELSAT, MBI, V&S

4.6.3 Work performed and end results

The experimentation has been held on a ferry travelling in Cyclades (Greece) area.
The communication chain was composed of :

- Fixed installation located in Rambouillet including:
 - o The service platform (implemented by MBI- an Italian project Partner), connected to the Alcatel HUB satellite on one side and to the external terrestrial networks (Internet, Mobile networks, PSTN...) on the other side ,
 - o the Alcatel 9780 satellite HUB transmitting on Eutelsat Atlantic Bird 2 satellite.
- Ferry on board installation : an auto track antenna (Seatel) connected to a DVB RCS IDU, completed with prototype function, such as customer PEP (Alcatel Alenia Space France) and on board GW (Rockwell Collins France).ODU installed on the vessel for maritime field trial

IP added value services such as authentication, portal, multicast live TV and radio, Vo IP, FTP, HTTP, VPN, SMS, email and MMS have been tested successfully.

The main lessons of these trials were:

- We confirm no differences between fixed and mobile station concerning delays for web browsing (HTTP) and speed for downloads (FTP).
- The communication chain works well : for a first integration in a end to end demonstration, our hub (A 9780) has demonstrated the expected performances .
- The DVB-RCS transmission techniques & A9780 performances have confirmed their capability to fully support broadband transmission in maritime context.

4.7 WP8000: Support Activities

4.7.1 Work Package objectives summary.

The WP8000 includes:

- Satellite communication R&D support
- This activities is closely linked with WP3000 System engineering which define the system specification with the available DVB-S2/RCS standard for the trials. WP8100 supports WP3000 in the definition of the system to be used in the trials. In addition, continue to optimise the DVB-S2 standard for mobility to feed into the DVB standards technical group.
- regulatory activities to allow the deployment of the system
 - standardisation activities to maximise technology re-use, achieve integration of Collective Mobile satellite access
- In addition, it will disseminate the project results and achievements in order to promote the system towards potential investors.

4.7.2 Contractors involved

AAS, AIRBUS, RCF, ORBIT, EUTELSAT, ALSTOM, UNIS, INECO

4.7.3 Work performed and end results

Advanced studies

From the presented material, it is firstly concluded that (although more emphasis has been given to some particular study items) the work performed has covered all main items specified in the work description of WP8100. In particular:

- § The existing standards have been studied and analyzed in detail
- § Available results and theory on modelling the mobility environments, as well as existing mobility solutions (from other projects) were reviewed
- § Three separate simulation platforms: Link-Level, Packet-Level and System level were developed for the purposes of the study.
- § The impact of mobility on the link, system and network performances were analyzed through simulations
- § In the Physical Layer the following main results were produced:
 - o A new model for the multipath fading channel was developed theo-retically and simulated. Moreover the impact of accurate channel modelling on the link performances was simulated.
 - o Solutions (space transmit diversity) for solving the periodic fading ef-fect in the return link in the rail environment, were proposed.
 - o Novel LDPC decoding and carrier acquisition algorithms for DVB-S2 were developed and simulated.
- § In the Network-Level the following main results were produced:
 - o Critical review for IP-level mobility&multicasting, and security indi-cates that the major obstacle for the successful adoption of these mechanisms in a mobile DVB-RCS system is due to the higher-than-terrestrial link errors that may be observed. With proper link budget dimensioning these mechanism can be applied in mobile DVB-RCS.
 - o Simulations conducted on burst synchronisation showed that cumu-lative time correction method with 3 sec guard times can be used to maintain burst synchronisation even without periodic GPS updates. However, with periodic GPS updates, (although absolute

performed better than cumulative) both absolute and cumulative time correction methods resulted in burst timing errors that cannot be compensated for by increased guard times. The interaction between periodic GPS update and SYNC-CMT based closed loop time correction self-induced timing errors. If periodic GPS updates are to be used, SYNC-CMT based correction should be disregarded.

- o Simulations conducted on the proposed position-based spotbeam handover mechanism showed that the handover failure rate can be kept below than 1.4% for 95% of time as long as PER is kept less than 10^{-2} , even with memoryless NCC handover execution design. With $PER = 10^{-3}$, the handover failure rate can be less than 0.28% for 95% of time. Majority of handover failures were due to TIM message loss on the forward link. With a simple improvement on the NCC side of the handover execution phase (NCC with memory), the failure rate can be less than 0.11% for 95% of time even with PER as high as 0.05. Regardless of the NCC-side of the mechanism, at $PER = 0.1$, the observed handover failure rate was as high as 40%.

- o Simulations conducted on handover delay showed that the handover delay on the return link was around 1.21 seconds for more than 90% of the successful attempts. A second peak in the histogram was observed at around 2.4 seconds. The second peak was created due to packet loss on PAT/PMT/SCT/FCT/TCT tables, which forced the RCST wait for the next table on the forward link. Even with PER as high as 0.1, the percentage of successful handover attempts that created more than 2 sec delay on the return link was less than 14%. The handover delay on the forward link for IP packets was upper-bounded by the physical-layer synchronisation delay on the new forward link, which is about 100 msec. For non-IP content, the hand-over delay on the forward link depended on the correct reception of PAT/PMT tables. This exhibited forward link handover delay around 1 second for more than 90% of the successful attempts.

- o Simulations analyses may result in slightly different results for larger uplinks. This is because SCT, FCT, TCT tables tend to be larger for higher number of carriers; and they may suffer from a higher loss ratio for the same PER. Similarly, PAT and PMT tables grow with the number of programs being broadcast in the system. However, we do not expect significant change because the TIM size is not a function of network size, and thus TIM loss probability will not be different within large networks.

- o More sophisticated spotbeam handover mechanisms can be devised. However, the work in this document showed that even with a very simple mechanism acceptable failure rates can be achieved provided that PER is less than 10^{-3} . Further reduction on the hand-over delay is possible if either:

- $\frac{3}{4}$ SCT, FCT, TCT, TBTP PIDs are kept the same across all spot-beams, or/and,

- $\frac{3}{4}$ SCT, FCT, TCT tables are also encapsulated within TIM messages.

We favour the first solution, since the latter significantly increases the TIM size and its loss probability for the same PER.

§ In the System-Level:

- o Feasibility study type of analysis produced for both forward and return links of MOWGLY system.

- o Results for forward link showed that it is dimensioned correctly and can ensure link closure for 99.9% of the time when severe fading effects are neglected.

- o Results for return link showed that the link is power limited and the achieved service availability time is reduced to 99% and 96% of the time, depending on the chosen target PER. This issue can be solved by:

- § Increasing terminal transmit power.

- § Increasing terminal antenna directivity/gain.
- § Increasing transponder gain.
- § Reducing the transmit symbol rate requirement
- o Potential for MOWGLY terminals to exceed allowed interference into adjacent satellite systems evaluated. Results showed that MOWGLY terminals can potentially exceed the allowed interference threshold for a significant portion of time. Solutions to this issue exist (e.g. spreading, more directive antenna) but have not been investigated in this work.
- o Dominant performance degradation sources in maritime satellite and railway satellite environments identified as shadowing and rain at-tenuation respectively.
- o Potential for fading mitigation techniques to counteract the fading ef-fects mentioned above discussed. In particular, in the maritime satel-lite environment closed loop techniques such as power control and ACM have the potential to achieve performance improvement. In the railway satellite environment, the frequency and duration of shadow-ing from power arches makes closed loop techniques inefficient. Should this shadowing be tackled by other means, such as antenna diversity, then closed loop techniques will be able to produce per-formance improvements similar to the maritime satellite environment.
- § ACM/SNR Estimation
- o SNR estimation technique proposed for use in the DVB-S2 standard (SNORE) modelled and performance simulated.
- o New SNR estimation technique developed and performance simu-lated. Performance also compared to that of the SNORE algorithm. The analysis showed that the new technique performs on a par and in several occasions slightly better, than SNORE. The new technique is also significantly simpler than SNORE and poses reduced compu-tational complexity.
- o ACM algorithm modelled in MATLAB and performance evaluated in channel conditions relevant to the MOWGLY environments. Simula-tions showed that ACM clearly has the potential to improve system throughput and availability times significantly.
- o The effects of the large round trip delay on ACM performance were also investigated. Simulations showed that under the assumption of a 500ms delay and a relatively fast varying rain attenuation perform-ance is significantly degraded. The amount of performance degrada-tion is proportional to the fading slope. It was concluded that at the system design fade the maximum slope that is likely to be encoun-tered, or that the system needs to be able to handle needs to be identified and the ACM algorithm parameter values should be refined accordingly.
 - Other solutions for mitigating the effects of the round trip delay, such as predictive SNR estimation and utilization of the estimated local fading slope, were outlined and briefly discussed. Additional investi-gation of these techniques is required for better understanding of the performance effects they can yield.

Standardisation

Interaction with Standardization bodies and dissemination of results is essential for the MOWGLY project.

The use of existing standards contributes to strengthen the competitiveness of the European telecommunication companies in comparison with American competi-tors. Not only: a standardized mobility solution is a key factor for pushing forward the commercial objectives of a future MOWGLY system. By raising its profile within the European SATCOM community, the project succeeds in achieving its objective with respect to opening the DVB standards in order to support mobile-vehicular applications.

Regulation

Deregulation and the emergence of private satellite operators in the past decades have made that accessing appropriate orbit/spectrum resources and establishing safe spectrum regulations have become a critical issue when developing new telecom services such as MOWGLY.

In that respect, mobile applications face particular difficulties in sharing spectrum with other applications due to their mobile and wide reach nature. On the other hand, the regulatory path to the International Telecommunications Union (the "ITU") has been opened in the past years for systems such as Connexion by Boeing and regulatory mechanisms are already in place at international, regional and national levels.

More precisely, one remembers that in June 2003 the ITU has granted status and recognition to these applications at Ku-band, including designation a portion of Ku-band for satellite communications with ships and aircrafts, definition of the associated technical limitations to share spectrum with other applications and recommendations to administrations for their national licensing processes. Satellite communications with trains, on their side, involve reduced international regulations and should be handled under existing national VSAT regulations with possibly some adjustments.

Since then, European and US national regulators in particular have been transposing, harmonizing and complementing these international regulations for application in their national airspaces, waters and territories. It offers MOWGLY the rare opportunity to have almost stabilized regulations at Ku-band in these two important regions at an early stage of the project, with surprisingly some differences between both sides of the Atlantic.

From an industrial viewpoint, the MOWGLY consortium has dedicated an important workforce to the analysis of these spectrum regulations so as to ensure full compliance of the system design and operations with applicable spectrum regulations and provide maximum confidence and safe and stable revenues to future operators and services providers.

The consortium has also identified the regulatory promise of Ka-band for the provision of satellite based mobile communications even if the international regulations of the ITU require some further developments. These regulatory developments at Ka-band should follow similar paths as Ku-band in the recent years with thus limited concern on a favourable outcome.

For the next stage, efforts will also be pursued to refine understanding of local restrictions that apply in addition to international, US and European regulations. In this activity, MOWGLY strength relies on the implantation of its members in various countries and to their world-wide recognized expertise in that field. MOWGLY strength also lies in the integration of the regulatory problematic in the earliest stage of design of the system providing the highest level confidence to future operators and service providers that regulatory risk on revenues is minimal.