Validation of the SDMB architecture - Key features and trials

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***Abstract*—The Satellite Digital Multimedia Broadcasting (SDMB) system intends to implement a multicast layer over unicast terrestrial 3G UMTS mobile networks. The system concept is based on a combined satellite and terrestrial repeaters architecture for delivery of interactive broadcast/multicast multimedia services (MBMS) to mobile end-users. The system will aim at permitting indoor penetration by means of dedicated large power GEO satellites providing several beams over Europe. To this end, the European IST integrated project MAESTRO has one of its major objectives to validate a number of key SDMB performances and functions by conducting laboratory and field trials with a representative SDMB experimental platform. This paper reports on the followed validation approach and outlines the trials that are performed in the course of the project.**

***Index Terms*—SDMB, performance, validation, trials**

I. Introduction

The Satellite Digital Multimedia Broadcasting (SDMB) system intends to implement a multicast layer to complement 3G UMTS mobile networks for broadcasting. The system concept is based on a combined satellite and terrestrial repeaters architecture for delivery of interactive broadcasting/multicasting digital multimedia services to mobile end-users. The system will aim at permitting indoor penetration by means of dedicated large power GEO satellites providing several beams over Europe.

The MAESTRO project approach is to take advantage of the natural assets of satellite systems and ensure that the SDMB system achieves the highest possible degree of interoperability with terrestrial 2G and 3G mobile infrastructures in order to encourage multimedia usage adoption in Europe and contribute to the successful deployment of 3G [1].

MAESTRO aims at specifying and validating the most critical services, features, and functions of satellite system architectures, achieving the highest possible degree of integration with terrestrial infrastructures. It aims not only at assessing the satellite systems' technical and economical feasibility, but also at highlighting their competitive assets on the way they complement terrestrial solutions.

In the remainder of the paper, section II provides an overview of the S-DMB concept and section III describes the validation approach followed by MAESTRO. Section IV outlines the main features and the various functionalities of the test bed. Section V describes the methodology followed in the trials and summarises the scenarios that are conducted, and the paper concludes with section VI.

II. S-DMB Concept

S-DMB enhances a 3rd generation mobile environment by integrating a reliable, flexible, scalable, efficient and cost-effective content delivery medium. S-DMB delivers content directly to the mobile terminals in the form of download and streaming services [2].

The S-DMB architecture (see Fig. 1) combines high-power bent-pipe geo-stationary satellites and terrestrial repeaters (i.e. Intermediate Module Repeaters - IMR) to provide a large point-to-multipoint content delivery network (CDN). The satellite component operates in the IMT2000 Mobile Satellite Systems (MSS) frequency band, i.e., adjacent to the band for the terrestrial mobile. S-DMB provides a unidirectional link towards the mobile terminal and adopts the 3GPP standardised terrestrial W-CDMA air interface enabling maximum re-use of T-UMTS technology. This allows low cost user terminal as well as smooth integration in the 3G cellular network architecture.

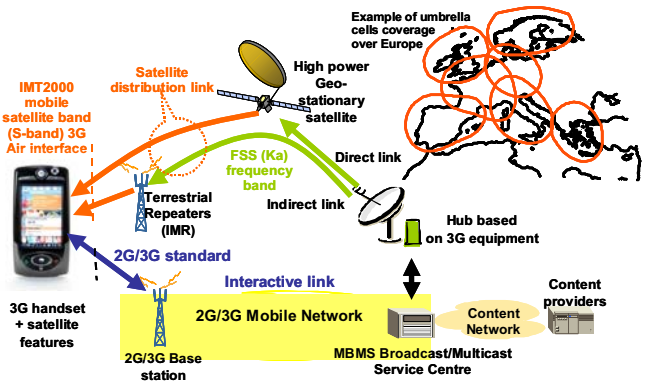

Fig. 1. The S-DMB system architecture

The satellite component enables immediate full coverage service, low transmission cost for point to multi-point applications with a large number of terminals involved as well as high QoS for streaming applications. On the other

hand, the terrestrial cellular component is best suited for point-to-point applications and also point-to-multipoint applications with high geographical selectivity.

S-DMB fully exploits the inherent broadcast properties of the satellite to render a reliable, flexible, and scalable content delivery service in view of 2.5G and 3G mobile environments.

III. Validation Approach

A MAESTRO experimental platform has been developed based on the sub-system and trial specifications defined by the project. It enables to carry out laboratory and field trials to validate the SDMB system key functions and performances. In order to be able to develop the test bed and carry out validation tests within the duration of the project, MAESTRO:

- Reuses major parts from the FP5 IST MoDiS project experimental platform and the ESA ATB project (i.e., the real-time propagation channel emulator - SIMSTAR).
- Defines successive functional releases corresponding to a set of features for implementation in the MAESTRO test bed sub-system. This way it is possible to carry out trials for a particular release of the test bed while developing additional features for a subsequent test bed release in parallel.
- Drives the architecture definition activity so as to define the required functions for each test bed release.

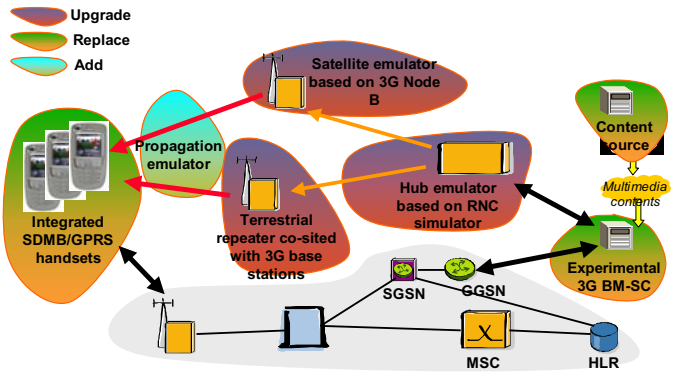

Fig. 2. The MAESTRO experimental platform architecture

Fig. 2 illustrates which parts of the MAESTRO platform are new, and are being replaced or upgraded compared to the MoDiS platform.

IV. Test Bed Features and Functionalities

Three test bed releases are defined in MAESTRO. The first two are developed, tested and validated in the course of the project, whereas the third one which will be very close to the commercial system will be developed at a subsequent stage.

A. MAESTRO Release 1

In the scope of Release 1, MAESTRO is setting up one laboratory and one field test bed representative of the broadcast component of the SDMB system, i.e. no interactive link with the 2G/3G network is considered. Release 1 aims at validating transmission layer features only.

1) Lab Test bed

The main goal of the laboratory test bed is to confirm the trades-off deduced from simulation results, therefore allowing non-regression testing, as well as to perform a thorough comparison between different scenarios with clear variance of selected parameters. The test bed is therefore used to evaluate the impact of various parameters on the transmission performances. Performance is estimated at the terminal by measuring the Block Error Rate (BLER).

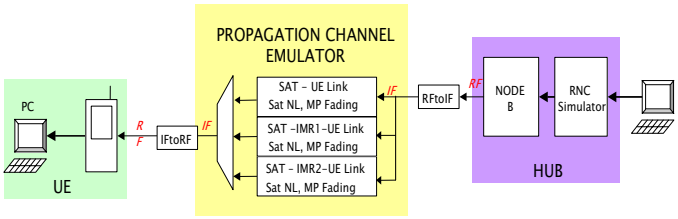

Fig. 3. Release 1 lab test bed architecture

The laboratory platform differs from the real SDMB system described in Fig. 1 in the following ways:

- The satellite is replaced by the real-time propagation channel emulator (SIMSTAR), which features satellite transponder non-linearity, Doppler/frequency offset, intra-system interference, satellite multi-path and terrestrial multi-path channels. Each multi-path channel (both terrestrial and satellite) can emulate up to 6 paths providing a total of 18 paths. The SIMSTAR emulator operates in the base-band domain, and hence frequency conversion modules translating the base band (BB) signal to IF and from IF to RF and vice versa are required at each end of the emulator.
- The Hub functions are fulfilled by a Node B associated to a RNC simulator featuring broadcast support and adapted to the MAESTRO application.
- The MAESTRO terminal is a UMTS integrated handset, which is connected to a PC for further analysis of the data. It features a higher integration level and a complete UMTS/GPRS protocol stack compared to the one used in MoDiS.
- The content provider is replaced by a simple data generator/video server.
- The MAESTRO Release 1 platform does not feature any interactive link in the sense that it does not interact with a 2G/3G network.

2) Field Test bed

The goal of the field test bed is to demonstrate the feasibility of the SDMB system and to correlate the overall measured QoS with both simulations results and laboratory measurements.

The main differences of the field test bed compared to the lab one, are the absence of the propagation channel emulator and the addition of terrestrial repeaters. The field platform

differs from the real SDMB system described in Fig. 1 in the following ways:

- The satellite and transmission parts of the Hub are replaced by an equivalent transmitter located at a high altitude place (e.g. mountain, etc.), set in such a way that the received radio level at the terminal is about equivalent to what would be received from a satellite. For the trials, transmission is performed in the terrestrial IMT2000 frequency band.

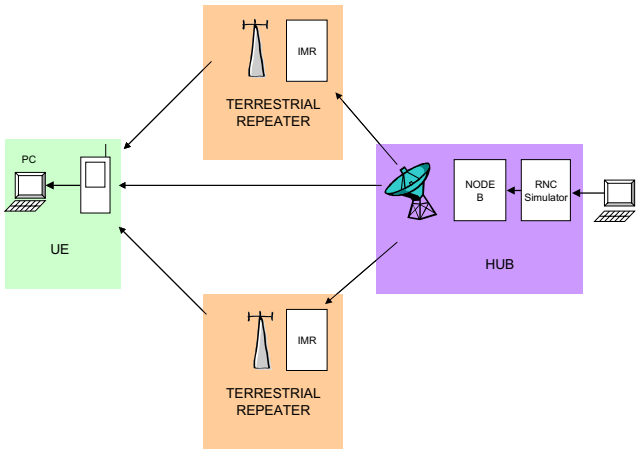

Fig. 4. Release 1 field test bed architecture

- The Hub used in the test bed is composed of a Node B and an RNC simulator featuring broadcast support and adapted to the MAESTRO application.
- The Hub feeds the terrestrial repeaters directly. A maximum of 2 on-channel repeaters are used in the MAESTRO field test bed.
- The MAESTRO terminal is a UMTS integrated handset, which is connected to a PC for further data processing.
- The content provider is replaced by a simple data generator/video server, which may at first be integrated in the RNC simulator.
- The MAESTRO Release 1 platform does not feature any interactive link in a sense that it does not interact with either a 3G or a 2.5G network.

B. *MAESTRO Release 2*

The Release 2 test beds are based on the Release 1 ones. The main upgrades consist in integrating both the BM-SC and a 2G terrestrial network to the existing platforms. In Release 2, in addition to the lower layer features already implemented and validated in Release 1, application, transport and network layer features are tested and validated.

1) *Lab Test bed*

Further to Release 1, the Release 2 laboratory platform (see Fig. 5) differs from the real SDMB system described in the following aspects:

- The MAESTRO terminal is composed of a modified 3GPP mobile terminal connected to a PC. The mobile implements physical and access layers functionality while the PC implements network, transport and application functions.
- The service centre functions are simplified and adapted to the MAESTRO application.
- There is no external content provider. Only local streaming and download servers are used.
- The test bed does not involve any terrestrial network operator. The SDMB terminal equipment (TE) which is essentially a laptop, is directly connected to the service centre to emulate the interactive GPRS link.
- On top of that, there is neither MBMS, nor billing implemented, and only a few (maximum three) UE are used at a time.

In the scope of release 2 test bed, the following network layer functions are being addressed:

- User authentication, at two levels in the system: a) during terminal attachment to the GPRS network, and b) when a user requests access to one or more SDMB services.
- User authorisation, where users are checked to see whether they indeed have permission to access the particular network service being requested.
- Ciphering and deciphering (i.e. encryption and decryption), where ciphering is supported between the BM-SC and the user terminal using an IP-based encryption method. The key management protocol employed within the test bed is able to support large groups of users in an efficient manner that minimise management overheads on the network.

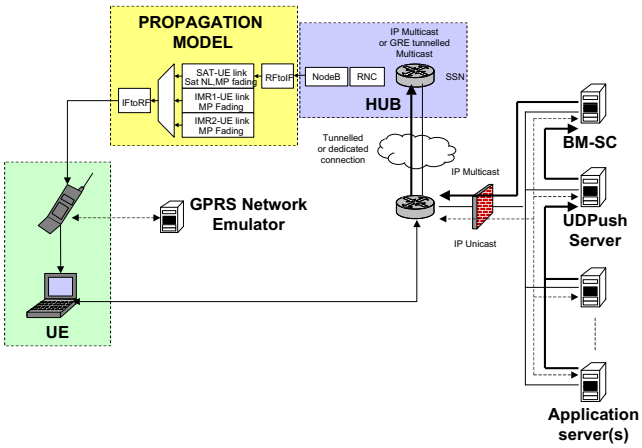

Fig. 5. Release 2 lab test bed architecture

- QoS Control. This comprises the establishment of broadcast bearers, whether in the propagation channel emulator in the laboratory test bed or the transmission equivalent in the field test bed, which are controlled using the signalling control plane interface between the BM-SC and the Hub.

As concerns the transport layer the following functions are implemented:

- Packet level Forward Error Correction (FEC)
- Interleaving
- Carousel
- Selective retransmission

As the test bed does not make use of external Content

Providers, but of local content servers instead, authentication and authorisation of Content Providers is not considered to be within the scope of the Release 2 test bed. In addition, billing functions, either for the user or the Content Provider, are not implemented at this stage.

2) Field Test bed

Here again, the goal of the field test bed is to demonstrate the feasibility of the SDMB system using a terminal built on a commercial UE. As with the Release 1, the Release 2 field test bed apart from the replacement of the channel propagation emulator by an equivalent transmitter located at a high altitude location and the addition of two on-channel repeaters, the GPRS emulator is substituted by an operational 2G mobile network (see Fig. 6).

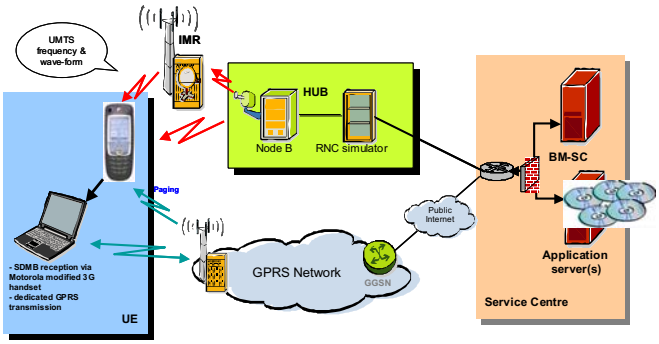

Fig. 6. Release 2 field test bed architecture

V. TRIALS

The lab and field trials for Release 1 are scheduled for the first semester and for Release 2 in the second. At the time of writing this paper the trials are ongoing.

A. Release 1 Trials

One of the main goals of Release 1 is to evaluate the end-to-end reception performances under different operational environments and parameters settings. For the lab trials, evaluation is performed by conducting BLER measurements on the receiver's side. Parameters to be evaluated are the following:

- User environment (e.g. indoor/outdoor)
- Area (e.g. urban/suburban/rural)
- UE mobility (3km/h, 50 km/h, 130km/h)
- Number of transmitting sources (e.g. Satellite only, Sat + IMR, Various numbers of IMR inside or outside the rake windows etc)
- Information rate
- TTI
- Slot format (and hence spreading factor)
- CRC size
- Number of blocks per TTI
- Inter-system interference

Another main goal of the MAESTRO project is to prove that the UE can recombine signals issued on the direct path (satellite emulator) with signals issued on the terrestrial path (on-channel repeaters).

The recombination process involves a rake receiver which can be characterised by the following parameters:

- Algorithms used to do the channel acquisition and the tracking
- Size of the window
- Number of rake fingers

It is not expected for the SDMB system to require different channel acquisition and tracking mechanisms other than the ones used for T-UMTS.

The field trials objectives are to assess the overall quality of the SDMB reception on the handset terminal and the drive test tool for both indoor and outdoor environments.

The reception quality on the handset terminal is determined by the BLER. On the other hand the MAESTRO drive test tool is used to measure the inner modem BER and Eb/Nt as well to obtain the macro-diversity situation (RAKE status) and overall RF coverage of the area under investigation. These complementary measurements help to draw firm conclusions on the reception quality.

The measurements on the handset terminal and the drive test tool are synchronised with GPS timestamps so that they can be correlated with each other in the post-processing phase.

The outdoor measurements are carried out on an itinerary defined so as to ensure reception of data from:

- Satellite only
- Satellite plus one or two repeaters
- One repeater only

B. Release 2 Trials

In Release 2 trials the performance of the system is evaluated under the presence of a reliable transport layer, including FEC/interleaving, carrousel and retransmission. Streaming and file download services are validated and demonstrated.

The following are the key aspects of the SDMB system that are validated as part of the Release 2 test bed lab trials activities:

- Validation of application layer functionality:
  - Demonstration of correct delivery of service announcements to TE for both streaming and file download services (i.e. successful reception and processing of multicast announcements detailing the services available to the user).
  - Demonstration of correct operation end-to-end of streaming service (i.e. successful reception and display of a streaming video service on the TE).
  - Demonstration of correct operation end-to-end of file download ser-vice(s) (i.e. successful reception and storage of a file downloaded from the server).
- Validation of transport layer performance:
  - Evaluation of FEC performance
    - for both streaming and download services
    - under various propagation conditions (radio impairments)
    - under various terrestrial network / terminal situation
    - for different FEC levels

- Evaluation of interleaving performance
  - for both streaming and download services
  - under various service conditions (streaming only, P&S only, streaming & P&S)
  - under various propagation conditions (radio impairments)
  - under various terrestrial network / terminal situation
- Evaluation of carousel performance
  - for download service only
  - under different network/terminal conditions (reception of terrestrial, satellite)
  - under various service conditions (P&S only with 1 file, P&S with several files)
- Evaluation of terrestrial retransmission performance
  - for download service only
  - under different network/terminal conditions
  - under various service conditions (P&S only with 1 file, P&S with several files)

VI. Conclusion

The SDMB proof-of-concept was successfully demonstrated by the IST project MoDiS with field trials conducted in the Monaco area throughout year 2004 [4].

MAESTRO goes a step forward by incrementally validating by both lab and field trials a number of key functions and performances that are even closer to the commercial version of the SDMB system.

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