

# S-DMB System Architecture<sup>1</sup> and the MODIS DEMO

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## ABSTRACT

The Satellite Digital Multimedia System (S-DMB) implements a satellite based broadcast layer in the 3G mobile network to increase its content delivery capacity. It achieves a cost effective nation wide coverage and enable to reduce the cellular traffic fee by about 100 for appealing multimedia content making use of broadcast or multicast mode. The system is designed with the objective to accommodate 3G standardised handsets with negligible cost impact and allow smooth integration in the 3GPP architecture. This paper defines the system architecture and outlines the possible experimental platform for S-DMB system.

## I INTRODUCTION

The concept of overlaying 3G mobile networks (MNW) with broadcast and multicast capabilities is gaining increasing interest in Europe and Japan, because many mobile entertainment services will directly address the challenge of handling heavy asymmetric traffic towards large audience. There is clear evidence that low prices and high quality will be key issues to ensure these services success.

Indeed broadcast distribution mode is the most efficient way in terms of radio and network resources usage and cost to provide large audience with appealing multimedia content. Moreover, with sufficient large storage capacity in the user equipment (UE), unidirectional point-to-multipoint (p-t-m) services are able to provide on-demand and interactive applications because push and store mechanisms make the p-t-m relationship transparent to users.

The S-DMB architecture combines geostationary (GEO) satellites and terrestrial repeaters called Intermediate Module Repeaters (IMR) to provide mobile network operators (MNO) with a cost-effective solution of increased p-t-m transfer capacity over their whole MNW coverage and help to reduce the MNW congestion like a content delivery network (CDN). Relying on local storage capacity in the UE as well as on push and store

mechanisms, it improves the perceived quality of service (QoS) and also optimises the permanent unidirectional link usage.

The expected system will operate in the IMT-2000 Mobile Satellite System (MSS) frequency band which is directly adjacent to the terrestrial MNW frequency band.

The system makes use of the 3GPP UTRA FDD W-CDMA technology to prevent any cost impact on the handset. Implementing S-DMB features in a 3G handset is basically limited to the frequency extension agility to the MSS band and additional application software. This enables the S-DMB system to address the 3G mass market.

Moreover the S-DMB system is designed to achieve full interoperability with the 3G MNW. It relies on the outstanding 3G MNW point-to-point (p-t-p) service capability to manage and control the services delivered via the satellite unidirectional link. The IMR used to cope with the heavy shadowing in urban areas are designed to be smoothly co-sited with the 3G base station.

This paper focuses on the S-DMB system architecture and the experimental platform. Next section outlines the S-DMB business rationale. Section 3 defines the overall S-DMB system architecture and section 4 describes the S-DMB sub-system components (user equipment, satellite, hub (gateway), terrestrial repeater and data server) in detail. Section 5 discusses the possible S-DMB experimental platform within IST MoDiS project [1] and the differences to the proposed operational S-DMB system.

## II S-DMB Business rationale

The success of mobile communication will depend on the availability of attractive services at attractive prices for end users. Part of these services, the capability to deliver messages over video or still-image animations might significantly help mobile network operators to attract people interest. However the main rationale for providing video capability over 3G mobile networks is still access to content. There, increasing knowledge on 3G mobile network performances and related cost has clearly highlighted the need for optimised mechanism to deliver

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<sup>1</sup> The work presented in this paper was carried out within the IST project MoDiS, which is continuation of IST Project SATIN [2][3][4].

video/audio services to a large audience. For a large part of envisaged multimedia services, Broadcast and Multicast mode are seen today as the most cost effective way to answer to this issue.

Based on these findings, the MoDiS project is currently considering the global opportunities for a satellite-based multicast system, known as the Satellite Digital Multimedia Broadcasting (S-DMB) system, which utilizes terrestrial Universal Mobile Telecommunications System (UMTS) standards and IMT-2000 bands allocated to Mobile Satellite Systems (MSS) to provide mobile operators with a cost-effective means of increasing content transfer capacity over their 2.5G or 3G networks. Based on a hybrid architecture combining satellite and terrestrial repeaters, it will include traffic optimisation mechanisms relying on multicast content delivery to the user. By relieving unicast networks of the most cumbersome and less profitable traffic, the S-DMB delivery mechanisms will provide then 3G mobile operators with more efficient and more profitable usage of radio frequency resources, also inducing exciting market opportunities for 3G mobile operators.

### III S-DMB System Architecture

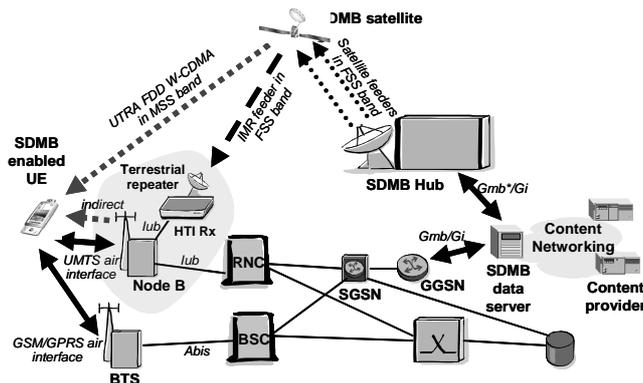


Figure 1: S-DMB and 3GPP MBMS combined architecture

The S-DMB reference architecture [5] is shown in Figure 1. The system is made of the following sub-systems:

- § **S-DMB enabled UE**, it is the user terminal based on a 3GPP standard multi-mode terminal.
- § **S-DMB data server**, it manages the interaction with content providers located inside the UMTS domain or outside and manages the delivery of formatted data towards final users.
- § **S-DMB hub**, it controls the broadcast transmission and provides this capacity to the S-DMB data servers, it is connected to the data server via a standard Gi/Gmb interface as defined in 3GPP TR 23.846 [6].
- § **Terrestrial repeater**, it enhances the signal availability in urban areas specially for indoor environment, it is connected to the hub via Iub interface as defined in 3GPP TS 25.430 [7].

§ **Space segment**, it is based on high power bent-pipe GEO broadcast satellites that provides typical European large nation coverage spotbeams with sufficient transmission power to accommodate 3GPP standardised handset RF reception performance.

### IV S-DMB sub-systems description

#### A. S-DMB enabled user equipment

The functional architecture of the S-DMB UE is shown in the Figure 2. Three type of terminal's architecture are foreseen considering different user requirements:

**Integrated handheld terminal:** S-DMB enabled multi-mode 2G/3G handset with local storage memory and application execution platform (like Java J2ME).

**Pluggable terminal:** A device dedicated to the S-DMB signal reception and cache management functionality interconnected to an external 2G/3G handset terminal via a short range wireless or wire-line interface.

**Standalone S-DMB terminal:** it is a terminal mounted in a vehicle, which can't be separated and used outside the vehicle

With the current technology, three types of storage may be envisaged. The first one is based on *smart card* used in current generation cellular devices, the second one is related to *flash memory card* used in PDAs, digital cameras or MP3 players devices and the third one is related to *micro hard disk drive* product.

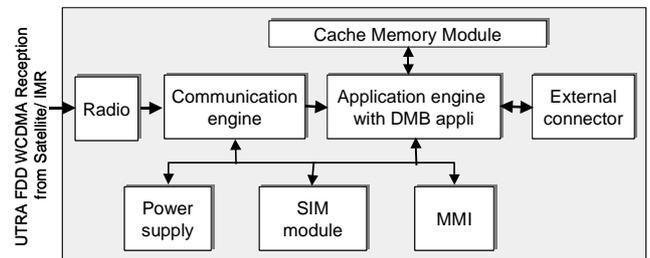


Figure 2: UE Physical Architecture

#### B. S-DMB Satellite

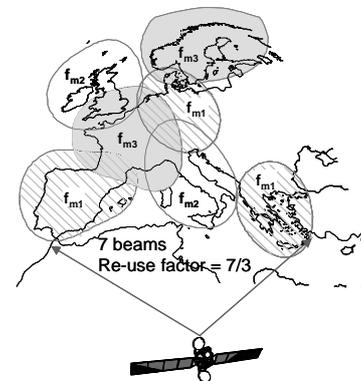


Figure 3: Multibeam GEO satellite Europe coverage

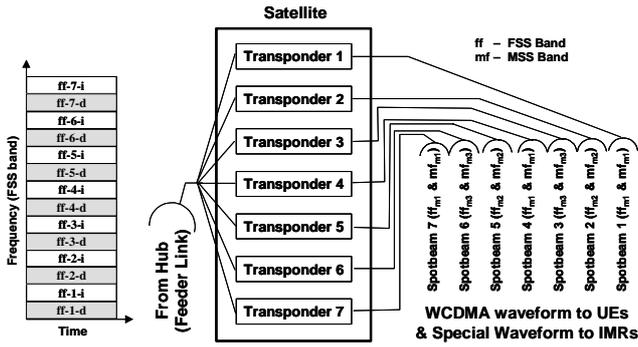


Figure 4: Simple Payload Arrangement

To achieve a European coverage, the space segment consists of few high power bent-pipe GEO satellites offering coverage with 7 spot beams. Each spotbeam covers approximately a linguistic area as depicted in Figure 3.

From a transmission point of view, the satellites shall be able to provide sufficient transmission power over the targeted spotbeam area assuming the reception of the S-DMB signal with 3G handsets having a gain to equivalent noise temperature ratio (G/T) performance of  $-29 \text{ dB/}^\circ\text{K}$ . In addition, such high-power GEO satellite requires also to implement large deployable reflector antenna of about 12 meters diameters similar to those already used in operational Mobile Satellite Systems (THURAYA, AceS).

The possible payload arrangement is shown in Figure 4. Here simple transparent payload can be used if the signal transmitted to different spotbeam carrier by feeder link with different carrier frequencies. The frequency reuse factor is assumed as 1/3.

### C. S-DMB hub

The S-DMB hub controls the broadcast transmission and provides this capacity to the S-DMB data servers. It is part of the satellite operator network and provides satellite bandwidth sharing to the Content Delivery Service Providers. The hub is responsible for the S-DMB transmission with an UTRA FDD W-CDMA waveform signal towards the satellite in a FSS frequency band. The system is designed to allow up to several hubs to share the system capacity. One hub is assumed to be installed per satellite spotbeam. The architecture of the S-DMB hub shall be inherited for the one of the UMTS network with an access network (AN = RNC + Node B) and a core network (CN). The hub includes:

- § One S-DMB Support Node (SSN)
- § One Radio Network Controller (RNC)
- § One or several UTRA FDD Node B.
- § One or several Hub-To-IMR transmitter (HTI Tx)
- § One RF front end and antenna subsystems
- § One time and frequency reference equipment.

The SSN interconnects the broadcast multicast service centre (BM-SC) [6] to a standard RNC. This S-DMB RNC controls several Node Bs each in charge of generating a W-CDMA signal, which shall be transmitted in a satellite spotbeam. It also routes data packets to the Node Bs on which the IMRs are built from.

It is connected to the IMR's Node B via the HTI Tx and HTI Rx. The HTI Tx converts the bi-directional Iub interface into a unidirectional interface. It generates all expected answers from the distant Node Bs.

The Hub's RF front end subsystem up-converts and amplifies the WCDMA signals generated by the spotbeam Node B and the signals generated by the HTI Tx and transmits them towards the Satellite in a FSS frequency band (the notation used is ff-x-y. where ff – FSS frequency band, x – targeted spotbeam number, y – direct (d) or indirect (i) case). Each feeder link interface signal has been modulated with different carrier frequencies (ff-x-y) and spread with different scrambling codes to separate the signals meant for different spotbeams as shown in Figure 5. Inside each spotbeams, different channelisation codes are used to separate different services. Different hubs like to transmit signal to the same spotbeam have to use the same carrier frequency and scrambling code. Only channelisation code varies from hub to hub to differentiate the services.

The hub (S-DMB RNC) in relation with the IMR (HTI Rx) ensures that both satellite W-CDMA signal and IMR's W-CDMA signal are received by the S-DMB enabled handset within its rake window to ensure coherent recombination. The S-DMB RNC delays the information/signal transmitted by the S-DMB Node B to take into account the maximum processing time of the HTI Tx + HTI Rx + 'enabled S-DMB' Node B. The HTI Rx will synchronise the information/ signal transmitted by the 'enabled S-DMB' Node B to achieve time alignment between both signals from the satellite and from the IMR at the UE side. For that, a cache memory is needed to absorb the worst case time difference.

The use of a common clock reference in the hub and in the IMR is required to adjust the IMR's node B modem time reference with regards to time reference sent by the HTI Tx/S-DMB RNC.

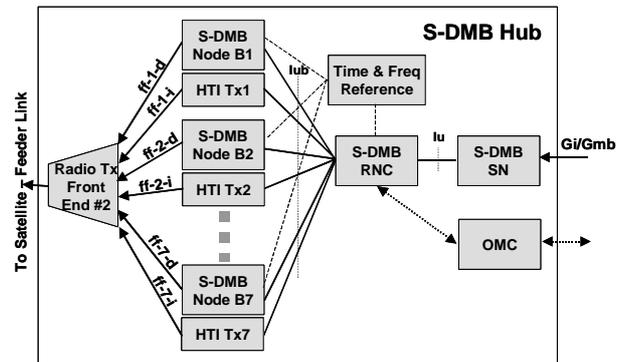


Figure 5: S-DMB hub architecture

#### D. S-DMB Terrestrial Repeater (IMR)

The IMR will enhance the signal availability in urban areas specially for indoor environment. It should be co-sited with 3G Base Station to prevent additional installation cost. Two types of IMR are envisaged:

*On channel repeater* providing only amplification of received signal. The coverage is restricted to hundreds of meter radius to achieve the required 80 dB isolation between repeater input and output.

*Active repeater* providing full processing of received signal. There is no restriction on the coverage. Two options are possible for the IMR architecture:

- A. FSS band reception, frequency transposal in MSS band, amplification
- B. FSS band reception, demodulation, decoding, processing, encoding, WCDMA modulation, amplification in MSS band.

The first option is the most simple solution but it has major drawbacks against two MNO requirements:

- § The transmission of satellite and IMR shall not interfere with network operation.
- § The Node B architecture shall not be modified for the terrestrial installation.

The first requirement would not be respected with option A since this external radio equipment needs a coupling equipment to share the antenna with the existing Node B leading to at least 3dB loss in the T-UMTS transmission power. The second requirement could not be achieved with option A since the internal 3G Base Station architecture is vendor specific and it seems difficult to impose at each vendor to combine an external RF signal in MSS band at the input of their base station.

Furthermore the option B has the advantage to fit easily in the 3G Base Station without impacting the equipment configuration and supervision performed by the MNO.

The Node B includes a set of UTRA FDD modems. Each modem is able to transmit and receive a W-CDMA signal modulated onto Terrestrial UMTS carriers. Although the detailed implementation differs from one BS manufacturer to the other, the modems are connected to RF Tx/Rx part which amplifies and filters the signal transmitted and received over the air interface via an antenna network. The Node B modem interconnects with the RNC via an equipment called Base Common Functions (BCF) that support the Iub protocol stack and a proprietary O&M protocol.

To avoid high transmission loss due to RF coupling, the option to have an IMR fully integrated to the Node B is preferred. Thus the IMR is based on a slightly adapted Node B and an HTI Rx module associated to a receiving hub antenna.

The “enabled S-DMB” Node B modem is used to transmit the downlink signal in the MSS frequency band. For this, it implements extended frequency agility to the MSS band.

The HTI Rx module receives the signals transmitted by the IMR Tx module in the hub forwarded by the satellite. It is interconnected to the “enabled S-DMB” Node B modem via an interface compatible with the Iub standard. The HTI Rx extracts the information transmitted by the HTI Tx and forwards it to the Node B modem so that they can be modulated onto the WCDMA downlink signal. It acts as RNC from 'S-DMB enabled' Node B point of view answering to all requests from the WCDMA modem. The HTI Rx shall insure that the transmit delay inside the IMR shall be kept fixed. The IMR offers the same coverage as 3G Node B.

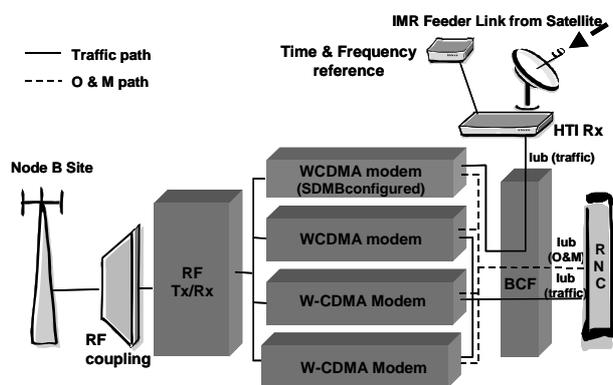


Figure 6: S-DMB enabled Node B

#### E. S-DMB Data Server

The S-DMB data server manages the interaction with content providers located inside the UMTS domain or outside and manages the delivery of formatted data towards final users. The S-DMB data server

- § acquires live contents or deferred contents
- § formats contents coding it in adapted format (e.g. MPEG-4)
- § describes it with adapted metadata (e.g. MPEG7 or XML)
- § delivers data towards final users using best delivery path (either terrestrial 3G network or satellite S-DMB network)
- § manages all the transport layer protection scheme from FEC to multiple transmissions
- § provides data collection for billing purposes

The S-DMB data server may be based on the BM-SC defined by the Multimedia Broadcast/Multicast Service (MBMS) 3GPP architecture, the BM-SC being responsible for service provisioning and delivery.

The S-DMB data server has mass memory storage, processor and interconnection equipment, it interacts with the MNW via standard interfaces, i.e Gi/Gmb with the 3GPP CN as defined in TR 23.846. One S-DMB data

server is assumed to be installed per country. The S-DMB server functional architecture is shown in Figure 7.

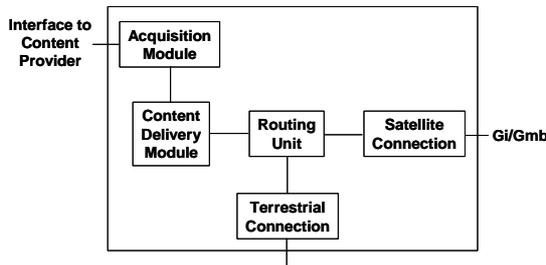


Figure 7: Architecture of S-DMB Server

### V S-DMB Experimental Platform

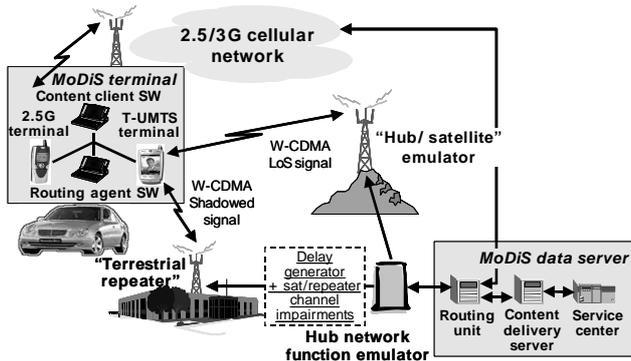


Figure 8: MoDiS Experimental Platform

The demonstration of the S-DMB system is achieved through trials performed within the MoDiS project. The experiment consists to set-up a representative network of the S-DMB system, as shown in Figure 8.

When comparing this platform with the S-DMB architecture, differences are the following:

- § The satellite and the transmission part of the hub have been replaced by an emulator. Due to the lack of existing satellite being able to provide enough power and bandwidth in the L/S frequency bands, it is proposed to replace a satellite by an equivalent transmitter located on an high altitude place (mountain, etc..). This transmitter will be set to have a transmit power equivalent to a satellite. For the Trial, transmission will be performed in IMT 2000 frequency band.

The Hub network function emulator performs the same function as defined for the S-DMB hub. Basically, the Hub network functions corresponds to a RNC simulator featuring broadcast/multicast support and adapted to MODIS platform constraints.

- § Terrestrial repeaters are directly fed by the hub network function emulator. In order to be able to cover both type of terrestrial gap-filler, and to avoid additional RF transmissions, the terrestrial repeater includes the same functions as the hub/satellite emulator, and is directly fed by the same hub network function emulator. A delay line and a channel impairment simulator of the

RF link between the satellite and the terrestrial gap-filler will be added.

- § The 3G network interactive link is provided with a 2.5G network. This configuration will be an operational S-DMB configuration when the system is operated outside 3G network, which will be mainly limited to urban areas. In addition, the system architecture is independent of the 3G network with respect to the DMB service in terms of transmission of the interactive link, so that there is no limitation in using a 2.5G network.

The experiment platform has three main goals

- § Demonstration of the hybrid satellite/intermediate module repeater transmission scheme.
- § Evaluate the potential of content push with reliable transport techniques in a satellite/terrestrial mobile environment.
- § Demonstration of some key features such as QoS based routing selection scheme between S-DMB and mobile network for transmission of a multicast stream, terminal cache management.
- § Some selected content push technology and real time streaming applications will be developed to give a flavour of the services offered by the S-DMB.

### VI CONCLUSIONS

In this document the S-DMB system architecture was presented and the functionality of its components (S-DMB enabled user terminal, satellite, terrestrial repeater, gateway/S-DMB hub and S-DMB data server) detailed. A set of architecture requirements has been defined:

- § Downlink Iub interface is supported on the satellite link between hub and terrestrial repeater/IMR, specific devices are required in the hub and in the IMR to fake the Iub interface at each side;
- § Integrated multimode GSM/ GPRS/ UMTS/ S-DMB terminal with few modifications in the UMTS part in order to receive the S-DMB signal whose frequency is adjacent to the T-UMTS band.
- § Direct connection between the S-DMB hub and the S-DMB data server at Gi.
- § Integration of the logical functionality of one or more Node Bs able to serve several spotbeams. with the RNC in the S-DMB Hub. Some functions of SGSN and GGSN are also included in the Hub as S-DMB support node (SSN).

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