Adaptation of MBMS Architecture and Protocols for SDMB

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ABSTRACT

The Satellite Digital Multimedia Broadcast (SDMB) system implements a satellite based broadcast layer to enhance the 3G and beyond 3G systems in the efficient delivery of the Multimedia Broadcast Multicast Service (MBMS). Designed to accommodate 3G standardised handsets with low cost impact and no form factor modifications, the SDMB system is based on the 3GPP standardised technology and utilizes the IMT2000 frequency band. This paper describes the differences and the adaptations made in SDMB with respect to MBMS, and highlights their impact on the MBMS architecture and protocols.

Keywords – MBMS, SDMB, UMTS, WCDMA

I INTRODUCTION

Multimedia Broadcast Multicast Service (MBMS) is currently under standardization in various groups within the 3rd Generation Partnership Project (3GPP) with the first phase set to be finalised as part of the Release 6 standard [1]. By enhancing the UMTS system with broadcast and multicast mode capability, the main aim of MBMS is to efficiently support, in terms of radio and network resources, simultaneous distribution of identical rich multimedia content (streaming and download-and-play type services) to large user groups.

To complement this effort, a hybrid mobile satellite broadcast system, also known as the Satellite Digital Multimedia Broadcast (SDMB) system [2], has been defined to provide a dependable and cost effective broadband transmission capacity for multimedia services such as mobile TV and video services for mobile services over a pan-European coverage. In addition to utilizing the 3GPP standardised technology (where possible), the SDMB system makes use of IMT2000 satellite frequency bands and high power geostationary (GEO) satellite(s) combined with terrestrials gap-fillers in order to accommodate low cost 3G handsets with outdoor as well as indoor reception. Based on this concept of a hybrid satellite/terrestrial architecture, SDMB takes advantage of the natural assets of satellite systems, while ensuring maximum interoperability with terrestrial UMTS (T-UMTS) standards in order to encourage multimedia usage take-up in Europe and contribute to the successful deployment of 3G. Such hybrid architectures have proven to be business-successful in USA, as demonstrated by the popular XM Radio/Sirius mobile satellite broadcasting systems.

Although achieving maximum hardware/software reuse on the network side and at the terminal side is the main design aim of the SDMB system, there are some differences foreseen with respect to UMTS in general, and MBMS in particular, due to the specific requirements and characteristics of SDMB to implement its specific features. Hence this paper describes these differences and the adaptations made in SDMB with respect to MBMS, whereby their impact on the MBMS architecture and protocols and procedures as defined in 3GPP is also highlighted. The work presented here is based on the current output from the IST MAESTRO (Mobile Applications & sErvices based on Satellite and Terrestrial inteRwOrking) integrated project [3].

The paper is organised as follows. In section II, after briefly illustrating the overall SDMB architecture, the respective SDMB entities and components are described in more detail with regard to their modifications and/or add-ons with the impact foreseen to the MBMS architecture. This is followed by a description of the differences in SDMB with respect to the MBMS protocols and procedures and their expected impact. Section IV concludes the paper.

II IMPACT OF SDMB ON MBMS ARCHITECTURE

The SDMB system architecture is depicted in Figure 1, whereby the satellite link is unidirectional, with the interactive link provided by the standard terrestrial 2G/3G mobile network (note that a direct satellite return link is envisaged in the future evolution of the SDMB system). The system is compliant with the broadcast mode of the 3GPP defined MBMS standard, allowing the support of open services platforms as defined in the Open Mobile Alliance (OMA).

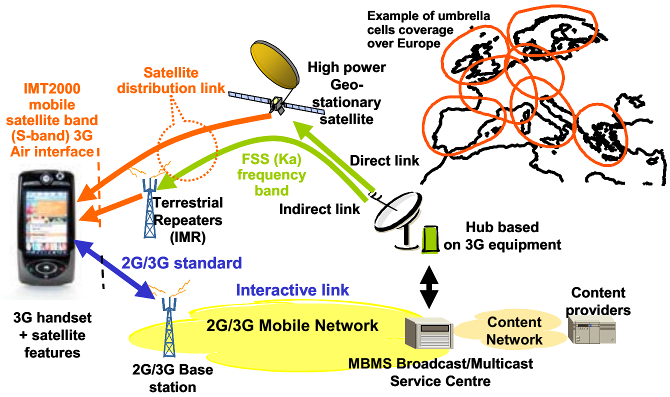

Figure 1: SDMB system architecture and its interworking with terrestrial network

Each of the SDMB entities and components shown in Figure 1 is described in more detail in the following subsections.

A. User equipment (UE)

The UE is a 3GPP compliant dual mode GSM/UMTS terminal, with frequency band extension. It is able to perform parallel idle mode, i.e. maintaining either GSM activity or UMTS activity during SDMB reception. The basic type does not have a dedicated receiver for SDMB and is then required to switch from UMTS terrestrial to SDMB satellite reception. The enhanced type has a dedicated reception chain for SDMB and is then able to receive SDMB data flow without interruption.

One of the goals of the SDMB system is to have the lowest possible cost impact on the UE, starting with an UE that is compliant with the UMTS Terrestrial Radio Access Network (UTRAN) standards. This implies that the UE must have little hardware and software changes to be able to receive contents through the SDMB system. So SDMB re-uses as much as possible the existing protocols and air interfaces defined in UTRAN.

Nevertheless remaining adaptations of the UE are needed. One element of SDMB with regards to MBMS is the use of the downlink only: during the attach procedure and the transfer of data for SDMB, in order to save current drain in the UE, no uplink transfer to the satellite is recommended. One possible solution is to use the 3G terrestrial networks to perform a “classical” (as defined in 3GPP) attachment procedure, then handover to the satellite in order to receive the data transfer from the SDMB system. The drawback to this solution is the need for cooperation between terrestrial and satellite operators. An alternative solution would be to modify the attachment procedure to avoid the terminal sending information to the satellite and thus receive directly all the required information to establish a data transfer.

During the data transfer, the UE should not send a request for missing blocks to the satellite directly. This could be avoided by using the terrestrial networks (through requests for missing packets at higher level, IP for instance) or by using techniques such as data carousels or adapted Forward Error Correction (FEC) algorithm.

Another change is due to the difference in the channel propagation properties between the satellite and terrestrial networks. To ensure optimum reception quality for SDMB, more fingers (12) should be allowed for the recombination of the signal compared to the number of fingers used in the terrestrial environment (usually up to 8). Since mobile manufacturers mainly implement rake receivers by using a hardware accelerator, this would imply a hardware change in the UE to increase the number of fingers.

The last constraint considered herein is the need of a wider window for re-combining the received signals at the rake receiver level in the case of SDMB. This could be done with hardware or software modifications depending on the implementation of the rake receiver. Note that the extension of the combining window has a lower impact on the received signal quality than the need of more fingers to re-combine it. The cost of either change is expected to be minimal.

B. Intermediate Module Repeater (IMR)

The IMR receives signal from the space segment and re-amplifies it. Basically, IMRs will be deployed in urban/suburban areas, to offer deep indoor coverage and increase throughput where the satellite signal is not 100% available. They can be co-located with T-UMTS Node Bs.

The SDMB architecture allows the deployment of several types of IMRs :

- Frequency conversion repeater: receives the SDMB signal from the SDMB satellite in High Density Fixed Satellite Systems (HDFSS) frequency bands, amplifies and retransmits in Mobile Satellite Service (MSS) band. Tx antenna gain is typically 15 dB (sectored antenna), total Tx power ranges from 30 to 35 dBm.
- On-channel repeater: receives the SDMB carriers from the SDMB satellite in MSS band, amplifies them and retransmit them on the same frequency slot(s). Tx antenna gain is typically 15 dB (sectored antenna), while total Tx power is 30 dBm. Due to required isolation between Rx and Tx antenna, this solution targets limited coverage such as in-building, tunnel, and underground.
- Node B-based repeater: receives the SDMB signal from the SDMB satellite in HDFSS frequency bands, amplifies and retransmits in MSS band. Tx antenna gain is typically 15 dB (sectored antenna), while total Tx power is up to 43 dBm. It is built with 3GPP standardised Node B. IMR is managed by the Radio Network Controller (RNC) of the Hub for radio resource allocation and transmission synchronisation. It is under the control of the RNC of the Hub, via Iub interface over the satellite radio link. This link is unidirectional, thus adaptation of Iub protocols must be implemented. This type of IMR can be integrated inside a T-UMTS Node B.

IMRs are equipped with O&M modules and a wireline/less modem for site supervision and equipment monitoring.

When IMRs repeat the satellite signal with the same scrambling code, UE Rake receiver maximum window length introduces high synchronisation constraints on IMR signal transmission and also fixes IMR coverage radius limitations.

The 3rd type of IMR, Node B based repeater, will eventually allow implementation of signal repetition with a scrambling code different from the one on the satellite signal. In this way, soft and/or selective combining as specified by 3GPP can be introduced in SDMB. Another advantage is the re-use of 3GPP flexibility such as enlarged UE reception window, thus decreasing synchronisation constraints on the IMR signal transmission.

C. Space Segment

The space segment is based on a high power transparent GEO satellite with large deployable reflectors. It provides European coverage through several spot beams (from 2 to 6 spots), each of nation-wide size.

For the direct downlink (satellite to UE), the satellite down-converts the Wideband Code Division Multiple Access (WCDMA) carrier in FSS bands coming from the Hub, amplifies them and retransmits each carrier in the corresponding spot beam in MSS bands.

Depending on the selected on-board configuration, the range of EIRP per spot beam should be in the range 60 to 72 dBW. An average antenna C/I of 12 dB is envisaged.

For the indirect downlink (satellite to frequency conversion or node B-based repeaters), the satellite down-converts the WCDMA or DVB-S carriers in FSS bands coming from the Hub, amplifies them and retransmits each carrier in the corresponding spot/global beam in MSS or HDFSS bands.

The SDMB architecture is flexible enough to integrate one or several satellites (1 to 3 satellites). Six orbital slot locations have been identified as potential candidates for the SDMB system (15°W, 1°W, 6°E, 10°E, 27.5°E, 32.5°E). Considering a feeder link in C-band or in Ka-band, the most favourable orbital slots are 15°W, 10°E and 32.5°E.

The feeder uplink coverage roughly represents European coverage, as depicted in Figure 2.

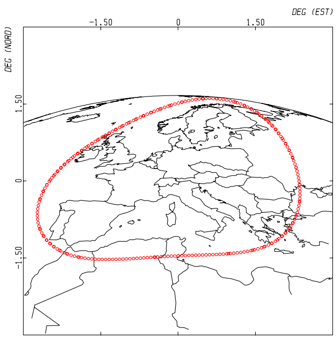

Figure 2: Typical feeder uplink coverage

The SDMB service downlink coverage will be an area from 10°W to 30°E longitude and 35°N to 65°N latitude, as depicted in Figure 3.

Figure 3: Typical S-band service downlink coverage

D. Hub

In the SDMB architecture, the Hub sends the content data received from the Broadcast Multicast Service Center (BM-SC) to the satellite. The radio emission between the Hub and the satellite uses the UMTS waveform.

The Hub is composed of 4 parts:

- the Node B part, which handles modulation. It is based of a commercial Node B configured for using the S-UMTS band.
- the RNC part, which configures and delivers the data to the Node B.
- the SDMB Support Node (SSN) part, which handles Gi/Gmb interface, and can be integrated together with the RNC part.
- a radio transmitter in charge of forwarding the radio signal to the satellite.

Compared to MBMS architecture, the SSN part replaces both the SGSN and GGSN equipment. In MBMS, a large number of RAN, fed by several SGSN, may broadcast or multicast data. Therefore in MBMS, activation of multicast/broadcast transmission must be done on demand by each SGSN (through MBMS Context Request), and RAB are established when needed to save bandwidth. These issues do not arise in SDMB since for a given beam, a single source is used with a dedicated bandwidth. This allows simplification of the architecture because a single SGSN and GGSN can be grouped together to form the SSN.

Similarly, for the RNC part, the MBMS Iu bearers can be permanently set up with the SSN, and mapped to specific FACH channels on Iub. The RNC part of the hub otherwise behaves like a standard 3GPP RNC since the set of functions it implements is a subset of the functions required by a 3GPP RNC. Its main tasks consist of configuring the Node B; setting up the beams, which are seen at this level as cells with common transport channels; broadcasting the system information to the mobiles and relaying payload data from the SSN to the Node B.

Most of these tasks are done using standard 3GPP protocols. The overall architecture of the hub provides, for broadcast services only, similar Gi and Gmb references points.

E. Broadcast Multicast Service Centre (BM-SC)

The BM-SC is a functional entity within the MBMS architecture that provides a range of functions related to the provision of the MBMS service. For example, the BM-SC controls user access to services, authorises and initiates bearer services within the network, and schedules and transmits MBMS data across the network. The functionality of the BM-SC in MBMS is defined in [4].

An obvious impact of SDMB on the BM-SC is that SDMB is intended to be a 'broadcast' system. As a result, the BM-SC is only required to support MBMS Broadcast Mode and not Multicast Mode. A BM-SC that is dedicated to SDMB is therefore only required to support a subset of the functionality defined by 3GPP. However, it is quite possible that SDMB could operate alongside an MBMS-capable 3G network in which case the full MBMS functionality would be required in the BM-SC.

Operation alongside an MBMS-capable 3G network actually then opens up the potential for the BM-SC to apply policy based routing between terrestrial MBMS and satellite SDMB. This policy could, for example, be based on some form of least-cost algorithm.

However, perhaps the most significant impact of SDMB on the MBMS architecture with respect to the BM-SC that has been identified to date relates to where the BM-SC will be located. Two key models have been identified within the MAESTRO project:

- Mobile Network Operator (MNO) centric model

Here the BM-SC will be located within the MNO network and will be dedicated to serving subscribers to that network.

- Aggregator centric model

Here the concept of an external entity (the aggregator) is introduced which may serve subscribers from multiple networks (MNOs).

No major issues arise out of the MNO centric model as this case is closely aligned with the standard MBMS reference architecture (defined in [4]).

However, this is not the case for the aggregator centric model and a range of potential issues arise as a result. Primary amongst these from the BM-SC perspective is the question of ownership of subscribers and sharing of subscriber information. MNOs are likely to insist on retaining full control of subscriber management, and hence an AAA interface is likely to be required between the aggregator and MNO systems to permit authentication of the subscribers, authorisation of service, and forwarding of accounting records. The current MBMS specifications have provisions for authentication (bootstrapping architecture) but do not define this interface for authorisation and accounting purposes.

III IMPACT OF SDMB ON MBMS PROTOCOLS AND PROCEDURES

A. Access Layer

The SDMB radio access scheme draws heavily on the WCDMA air interface in an attempt to achieve maximum commonality with the T-UMTS. Towards that end, the 3GPP specifications have been the starting point for the SDMB access scheme definition, and where applicable, adaptations and modifications have been made to suit the satellite environment. In particular, given that the baseline SDMB system is unidirectional in nature and the point-to-multipoint (p-t-m) services it provides, only the downlink direction of the WCDMA interface is of interest to SDMB. Thus only a subset of WCDMA functionality is required for the support of common/p-t-m channels, and this subset of WCDMA set of channels relevant to SDMB is shown in Figure 4.

Accordingly, the SDMB radio layer protocols comprising the Radio Resource Control (RRC), the Packet Data Convergence Protocol (PDCP), the Radio Link Control (RLC) and the Medium Access Control (MAC) sub-layers implement a subset of those functionalities defined in T-UMTS. The RRC, for example, is responsible for the broadcast of information related to the non-access stratum layers and access stratum layers; the establishment, reconfiguration and release of Radio Bearers; and the initial spot selection, but does not implement any of the functions related to RRC connection given that there is no direct satellite return link in the baseline architecture. For the broadcast of system information, the RRC includes specific parameter configuration required for the SDMB system.

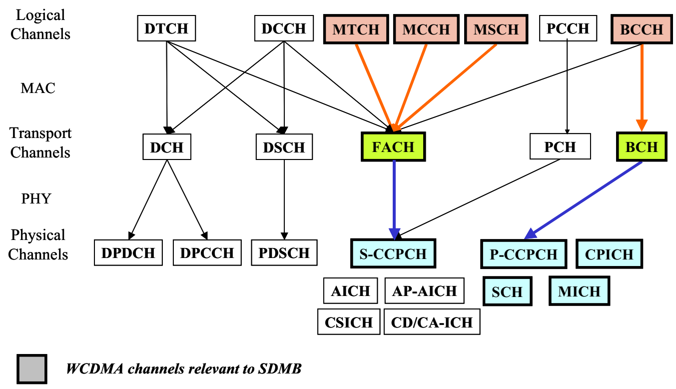

Figure 4: Applicability of UMTS channels to SDMB

The PDCP provides header compression and decompression of IP data streams, but the support for loss-less Serving Radio Network Subsystem (SRNS) relocation (normally a function of PDCP for p-t-p transmission within UTRAN) is not required since SRNS relocation is not applicable within SDMB. Similar to MBMS, the Unidirectional (U-mode) of the RObust Header Compression (ROHC) protocol is the only mode of operation supported in SDMB since the packets are sent in one direction only from the SDMB RAN to the UE, and there is no return path from the decompressor (located at the UE) to the compressor (located at the SDMB RAN). As for the RLC, only the transparent mode (for BCCH) and unacknowledged mode (for the three newly defined MBMS logical channels – MCCH, MSCH and MTCH) are applicable, which includes support for the added RLC-UM functionality defined for MBMS such as out of sequence SDU delivery. All the newly defined functionalities associated with MAC-m for MBMS such as buffering, and the addition and reading of MBMS-ID are also supported in SDMB.

Given the unique nature of the SDMB system and that only the MBMS broadcast mode is supported, only a subset of those MBMS UTRAN procedures described in [5] is pertinent to SDMB. Table 1 summarizes the relevance of these MBMS UTRAN procedures to the SDMB context. Those procedures not required in SDMB are explained in more detail as follows:

- **Joining**: With no satellite uplink available, this procedure by which a subscriber joins (becomes a member of) a multicast group by indicating to the network the desire to receive multicast mode data of a specific MBMS bearer service becomes irrelevant to the SDMB RAN.

- **Counting/Recounting**: This procedure is used in UTRAN to determine the optimal MBMS transmission mode, namely point-to-point (p-t-p) versus p-t-m bearer, taking into account the number of UEs expected to receive the service. With only p-t-m bearers being employed in SDMB, the counting/recounting procedure is not relevant to SDMB.
- **RNC Registration/Deregistration**: In T-UMTS, each SGSN has under its control a number of RNCs. Those RNCs with users interested in a specific service have to register with the Core Network. Registration is performed on a per-service basis and assumes awareness of the existence of PMM-connected UEs in the area under the RNC control. In SDMB, there is one-to-one mapping between the SDMB RNC and SSN and, most importantly, the SDMB RAN does not maintain any connection with UEs. Hence, the feature is not applicable to SDMB RAN.
- **Channel Switching**: As only p-t-m bearers are relevant to SDMB, channel switching between dedicated channel and common channel is not relevant.
- **UE Linking/Delinking**: The linking procedure is used to link a UE, which has joined the MBMS service, to an MBMS service context in the RNC (or to remove a specific UE from one or several MBMS service context in the RNC for the delinking procedure) and is only applicable for UEs in PMM-CONNECTED mode. With no PMM state defined in SDMB, this procedure is therefore not relevant to SDMB.
- **Selective Combining**: In T-UMTS, the UE may take advantage of MBMS transmissions in neighbouring cells belonging to the same MBMS service area and perform selective combining. Within the context of the mono-spot architecture defined for SDMB, the concept of combining from multiple cells is not applicable to SDMB. It is foreseen nevertheless that the feature of selective combining can still be applied within SDMB by having the IMRs applying a different scrambling code to the signal coming from the satellite, whence these signals can be selectively combined at the UEs.

B. Physical Layer

Besides introducing selective combining, where the UE combines transport blocks after the physical layer at the RLC level, 3GPP Release 6 also introduces soft combining of common physical channels (S-CCPCH) over which MBMS services are carried. Soft combining means the UE receiver combines signals at the physical layer level, before the channel decoder. These mechanisms which enhance the UE capability to combine S-CCPCHs from several cells (each carrying the same data content over distinct scrambling codes) are introduced to allow for consistent radio capacity improvement and for added reliability. Note that as with selective combining, soft combining is applicable only to regenerative IMRs (for e.g. Node B based repeater), i.e. for IMRs repeating with a scrambling code different than the satellite. Every UE that is compliant to 3GPP Release 6 should implement S-CCPCH combining.

Table 1: Relevance of UTRAN MBMS procedures/principles to SDMB RAN

UTRAN MBMS procedures/principles	Applicability to SDMB	Remarks
MBMS Session Start/Stop	X	SDMB RNC receives a single Session Start request (no Iu flex)
MBMS Iu bearer	X	No Iu flex applicable and no need to set multiple MBMS RBs per MBMS Iu bearer
MBMS Iub bearer	X	Standard FACH transport mechanism is applicable
Mapping of MBMS Iu bearers to p-t-p and p-t-m connections	X	Mapping is on p-t-m bearers by default
MBMS UE Linking/De-linking	N/A	
RNC registration/deregistration	N/A	Could be implemented for compatibility purposes, though not required
CN deregistration	N/A	
MCCH information scheduling	X	Carries only MBMS Radio Bearer Information (no MBMS Service Information, no MBMS neighbouring Cell information)
MBMS notification	X	
MBMS counting/recounting	N/A	Only p-t-m bearers supported in SDMB RAN
MBMS radio bearer release in UE	X	
MBMS Session Repetition	X	
MBMS Service Prioritisation	X	

IV CONCLUSIONS

In this paper, the differences and the adaptations made in SDMB with respect to the MBMS architecture and protocols are described. These adaptations are necessary to cater for the unidirectional nature of the SDMB baseline architecture and the support of only the MBMS broadcast mode. As SDMB is engineered to achieve maximum commonality with T-UMTS so as to optimise market entry and penetration, the impacts have been shown to be minimal.

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