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D3-1v2

SDMB ACCESS LAYER DEFINITION
(2nd version)

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Abstract:

The deliverable D3-1 aims at providing the definition of the access scheme engineered for the SDMB system, implemented in the SDMB Hub and terminal. This version provides an update of the SDMB access layers and functions defined in the first version based on the latest development and decisions regarding the support of MBMS within the access network in 3GPP. It is also aligned with the MAESTRO test bed Release 2 specifications. The constraints and requirements of the access scheme are first listed. The functions and procedures of layers 2 and 3 of the SDMB radio interface, comprising MAC, RLC, PDCP, and RRC sublayers, are then described in detail. This document also includes the specification of test bed Release 2 access scheme, whereby the differences with respect to the test bed Release 1 and the commercial implementation are highlighted. Finally, the key aspects of the access scheme that require further investigation via simulation are identified.

Keyword list: Satellite, MBMS, RRC, PDCP, RLC, MAC, radio resource management, packet scheduling, admission control, radio resource allocation, channel multiplexing.

EXECUTIVE SUMMARY

This document contains deliverable D3-1 of the IST Integrated Project MAESTRO – Mobile Applications & sErvices based on Satellite and Terrestrial inteRwOrking (IST Integrated Project n° 507023).

The MAESTRO project aims at studying technical implementations of innovative mobile satellite system concepts targeting close integration & interworking with 3G and Beyond 3G mobile terrestrial networks.

MAESTRO aims at specifying & 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 in the way they complement terrestrial solutions.

The main objective of Work Package 3 (WP3) is the definition of the Satellite Digital Multimedia Broadcast (SDMB) access scheme, namely the radio link layer (layer 2) and radio network layer (layer 3) of the satellite radio interface, the evaluation of key aspects of this scheme and the proposal of solutions for specific functions of this interface. The deliverable 3-1 encompasses the first 3 tasks in MAESTRO Work Package 3 – "Access". The task 3.1 is led by Alcatel Space and aims at the definition of the access scheme requirements and constraints. The task 3.2 concerns with the definition of the layers 2 and 3 of the satellite access scheme, while the task 3.3 builds on the tasks 3.1 and 3.2 in order to identify key aspects of the interface that require further investigation via simulation. The tasks 3.2 and 3.3 are led by the University of Surrey. All tasks have the support of WP3 partners.

The access scheme described in this document draws heavily on the Universal Terrestrial Radio Access (UTRA) Frequency Division Duplex (FDD) scheme deployed in T-UMTS, better known as Wideband Code Division Multiple Access (WCDMA). In fact, the SDMB access scheme presents maximum commonalities with the WCDMA radio interface in an attempt to achieve maximum reuse of software and hardware on both the network side and, most importantly, the terminal side. This is a fundamental requirement for a cost-effective, user-attractive terminal that will facilitate the penetration of the mass consumer market.

The deliverable 3-1 provides input to two different, though interrelated, activities:

- The definition of the commercial SDMB system architecture. In this respect, the document can be viewed as a working document. Its three versions within the duration of the project –D3-1v1, D3-1v2 and D3-1v3– capture the latest progress in the SDMB access scheme specification, in line with the progress and decisions made within 3GPP.

- The specification of the three SDMB test bed releases. There is one-to-one mapping between the deliverable version and the MAESTRO test bed release.

The current document, D3-1v2, describes the SDMB access scheme, in light of standardisation work within 3GPP up to November 2004, and specifies the access features of the MAESTRO test bed Release 2.

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ACRONYMS AND ABBREVIATIONS

2G / 3G	2nd / 3rd Generation
3GPP	3rd Generation Partnership Project
AC	Admission Control
ACK	ACKnowledged
AGCH	Access Grant CHannel
AM	Acknowledged Mode
APN	Access Point Name
ARQ	Automatic Repeat reQuest
B/M	Broadcast/Multicast
BA List	BCCH Allocation List
BCCH	Broadcast Control Channel (logical control channel)
BCH	Broadcast Channel (transport channel)
BE	Best Effort
BER	Bit Error Ratio
BLER	Block Error Ratio
BMC	Broadcast/Multicast Control
BM-SC	Broadcast Multicast Service Center in MBMS
BO	Buffer Occupancy
BS	Base Station
BSIC	Base Station Identity Code
CAC	Call Admission Control
CB	Cell Broadcast
CBCH	Cell Broadcast CHannel
CBS	Cell Broadcast Service
CCCH	Common Control CHannel
CCTrCH	Coded Composite Transport CHannel
CDMA	Code Division Multiple Access
CN	Core Network
C-PHY	Primitives for the control of the configuration of the physical layer

CPICH	Common Pilot CHannel
CRC	Cyclic Redundancy Check
CRLC	Control RLC
CRNTI	Control RNTI
CTCH	Common Traffic Channel
CTCH-BS	Common Traffic Channel Block Set
DCCH	Dedicated Control Channel (logical channel)
DCH	Dedicated Channel (transport channel)
DL	Downlink
DRX	Discontinuous Reception
DSCH	Downlink Shared Channel
DSF	Downlink Signaling Failure
DTCH	Dedicated Transport Channel
Eb/No	Energy per Bit over Noise power density ratio
Ec/No	Energy per chip over Noise power density ratio
ESA	European Space Agency
ETSI	European Telecommunications Standards Institute
FACH	Forward Access Channel
FCH	Frequency CHannel
FDD	Frequency Division Duplex (UMTS mode)
FEC	Forward Error Correction
FES	Fixed Earth Station
FIFO	First In First Out
FL	Forward Link
FSM	Finite State Machine
GEO	Geo-stationary Earth Orbit
GGSN	Gateway GPRS Support Node
GMM	GPRS Mobility Management.
GoS	Grade of Service
GPRS	General Packet Radio Service
GSM	Global System for Mobile communications
GSN	GPRS Support Node
GW	Gateway

HC	Handover Control
HFN	Hyper Frame Number
HLR	Home Location Register
ID	Identity
IE	Information Element
IETF	Internet Engineering Task Force
IMR	Intermediate Module Repeater
IMSI	International Mobile Subscriber Identity
IP	Internet Protocol
IPv4	Internet Protocol version 4
IPv6	Internet Protocol version 6
Kbps	Kilo bits per second
L1	Layer 1
L2	Layer 2
L3	Layer 3
LC	Load Control
LI	Length Indicator
LLr	Linked List of addresses of packets to be re-emitted
MAC	Medium Access Control
MAC-b	Medium Access Control broadcast
MAC-c	Medium Access Control common
MAC-d	Medium Access Control dedicated
MAC-sh	Medium Access Control shared
MBMS	Multimedia Broadcast Multicast Services
Mbps	Mega bits per second
Mcps	Mega chips per second
MCCH	MBMS point-to-multipoint Control CHannel
MICH	MBMS notification Indicator CHannel
MLP	MAC Logical channel Priority
MM	Mobility Management
MMI	Man Machine Interface
MS	Mobile Station
MSCH	MBMS point-to-multipoint Scheduling Channel

MT	Mobile Terminal
MTCH	MBMS point-to-multipoint Traffic CHannel
MUI	Message Unit Identifier
NAS	Non Access Stratum
NBAP	Node B Application Protocol
NI	Notification Indicator
NRT	Non Real Time
OVSF	Orthogonal Variable Spreading Factor
PC	Power Control
P-CCPCH	Primary Common Control Physical Channel
PCH	Paging CHannel
P-CPICH	Primary Common PIlot CHannel
PDCP	Packet Data Convergence Protocol
PDP	Packet Data Protocol
PDU	Protocol Data Unit
PHY	PHYsical layer
PI	Page Indicator
PICH	Paging Indicator Channel
PLMN	Public Land Mobile Network
PN	Pseudo Noise
PS	Packet Switched
PS	Packet Scheduler
PSC	Primary Synchronization Code
p-t-p	Point-to-Point
p-t-m	Point-to-Multipoint
QoS	Quality of Service
RAB	Radio Access Bearer
RACH	Random Access Channel
RAN	Radio Access Network
RANAP	RAN Application Part
RAT	Radio Access Technology
RB	Radio Bearer
RBAM	Radio Bearer Allocation and Mapping

Req.	Request
RL	Return Link
RLC	Radio Link Control
RM	Resource Management
RNC	Radio Network Controller
RNTI	Radio Network Temporary Identity
RRC	Radio Resource Control
RRM	Radio Resource Management
RT	Real Time
Rx	Receive
RXLev	Received Signal Level
SAP	Service Access Point
Sat	Satellite
SATIN	SATellite UMTS IP-based Network
SCCP	Signalling Connection Control Part
S-CCPCH	Secondary Common Control CHannel
SCH	Synchronisation CHannel
SDU	Service Data Unit
SF	Spreading Factor
SFN	System Frame Number
SGSN	Serving GPRS Support Node
SI	Status Indicator
SIB	System Information Block
SM	Session Management
SSN	SDMB Support Node
S-UMTS	Satellite UMTS
SW-CDMA	Satellite Wideband CDMA
T	Terrestrial
TB	Transport Block
TBS	Transport Block Set
TCTF	Transport Channel Type Field
TFC	Transport Format Combination
TFCI	Transport Format Combination Indicator

TFCS	Transport Format Combination Set
TFI	Transport Format Indicator
TFS	Transport Format Set
TM	Transparent Mode
TMGI	Temporary Multicast Group Identifier
TMSI	Temporary Mobile Subscriber Identity
TPC	Transmit Power Control
TrCH	Transport CHannel
TSTP	Time Stamp
TTI	Transmission Time Interval
T-UMTS	Terrestrial UMTS
TV	Virtual spacing Time
Tx	Transmit
UDP	User Datagram Protocol
UE	User Equipment
UM	Unacknowledged Mode
UMTS	Universal Mobile Telecommunications System
U-plane	User plane
URA	UMTS Registration Area
U-RNTI	UTRAN RNTI
UTRA	UMTS Terrestrial Radio Access (ETSI)
UTRA	Universal Terrestrial Radio Access (3GPP)
UTRAN	UMTS Terrestrial Radio Access Network
WCDMA	Wideband CDMA
WFQ	Weighted Fair Queuing
WP	Work Package

1 INTRODUCTION

The Satellite Digital Multimedia Broadcast (SDMB) system implements a satellite based broadcast layer over 2.5G and 3G terrestrial mobile cellular networks aiming at the increase of their content delivery capacity. Fundamental objective in the system design is the accommodation of 3G standardized handsets with negligible impact on terminal volume and cost, so that the system can address the mass consumer market.

In order to fulfill this objective, the approach taken in the system design is that of close integration with the terrestrial 3G networks, with respect to both the service offering and the network architecture. Therefore, the system will provide a subset of the services that are currently standardized under the 3GPP Multimedia Broadcast Multicast Service (MBMS) framework [1], adopting an architecture that is in close resemblance with the T-UMTS architecture. Due to the close synergy with the MBMS framework, note that throughout this document, the terms ‘MBMS’ and ‘SDMB’ are used interchangeably, i.e. whenever the term ‘MBMS’ is used when describing the SDMB system, its usage within the SDMB context is being referred to.

The document describes the access scheme engineered for the SDMB system, implemented in the SDMB Hub and handset (Figure 1). Its main features are the following:

- Maximum commonalities with the Universal Terrestrial Radio Access (UTRA) Frequency Division Duplex (FDD), hereafter called WCDMA [2], air interface. The 3GPP specifications have been the starting point for the access scheme definition. Adaptations and modifications to the satellite environment have been made where applicable.
- Given that the baseline architecture of the system is unidirectional, i.e. without a satellite return link, only the downlink direction of the WCDMA interface is of interest to SDMB [Note: A direct satellite return link is envisaged for the future evolution of SDMB systems to provide services related to public protection and crisis management (distress calls, search & rescue) and is addressed in WP9 of the project. Throughout this document, only the baseline architecture is considered].
- Due to the point-to-multipoint nature of the services, only the subset of WCDMA functionality required for the support of common/point-to-multipoint channels is relevant to the SDMB access scheme.

The main benefit expected out of this integrated system design approach on the target handheld terminal is the achievement of maximum hardware/software reuse, enabling cost-efficient and user-attractive design.

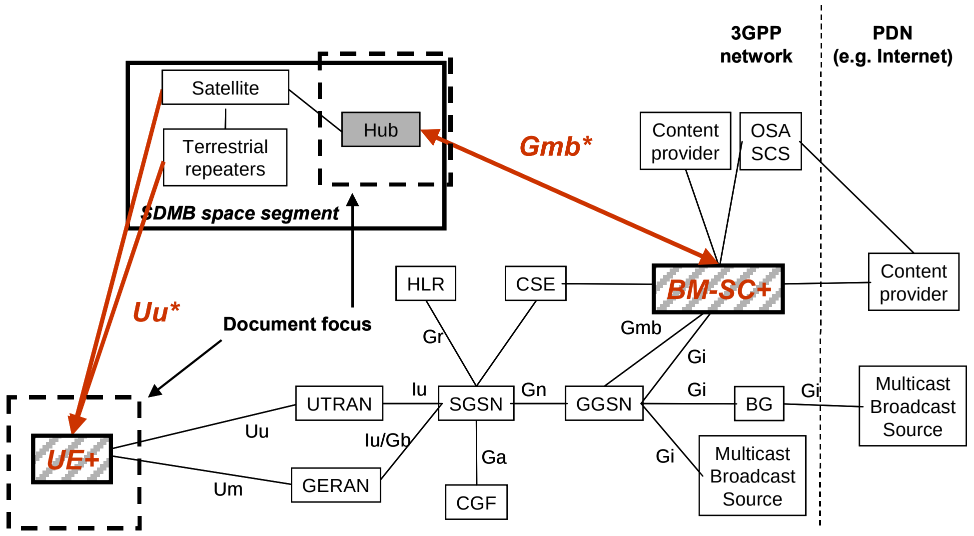

Figure 1: SDMB system, relevance to the T-UMTS architecture and deliverable focus

This document - the second version of D3-1 - is built upon the first version of D3-1 [3]. The SDMB access layer requirements, protocols and procedures defined in the first version are updated and refined based on the latest development and decisions made for MBMS from the ongoing standardization activities in 3GPP. Therefore, existing sections of the first version of D3-1 are maintained in this document but are subject to changes and additions, in light of new inputs from the parallel ongoing 3GPP MBMS standardization work. It is also noteworthy that the definition of the SDMB access layer functions draws on earlier work carried out in the context of EU IST SATIN (SATellite UMTS IP based Network) [4] and EU IST MoDiS (MObile DIgital broadcasting Satellite) [5] projects. On the other hand, the section in the first version of D3-1 on the access layer definition for the MAESTRO test bed is completely reprocessed to align with the Release 2 of the test bed specifications (carried out according to the scope of WP 6 and 7). This document is structured as follows:

Chapter 2 lists the requirements for the support of the SDMB services over the satellite radio interface, as defined in WP1. Starting point for their derivations are the MBMS requirements [6], filtered in the context of SDMB-specific considerations and architectural constraints, as derived from WP6 in the deliverable D6-1.2 (SDMB System technical requirement document).

Chapter 3 is the core of this document. It describes in detail the SDMB access scheme. The description is at the level of the layer/sub-layer functions, messages and primitives and points persistently to the relevant 3GPP Technical Specifications (TS) and Reports (TR) to avoid unnecessary repetition or reproduction of elsewhere-available texts. This chapter refers to the commercial system implementation, taking into account the latest progress made within the 3GPP MBMS standardisation framework; whenever reference is made to TSs and TRs, the version of the 3GPP MBMS related documents up to November 2004 is implied.

On the contrary, chapter 4 adapts the access scheme to the constraints of the MAESTRO test bed. The test bed implementation must be based on available equipment and functionality, which typically lags the current state-of-the art defined in standards. Basic MBMS features come under UMTS Release 6, whereas the complete specification of MBMS will be part of the next UMTS release (Release 7). In view of this, the second release of the MAESTRO test bed will take as reference the earlier release of UMTS, namely Release '99.

Chapters 3 and 4 of the document take advantage of the information exchange with WP6 deliverables D6-3.2 (UE SDMB specification document) and D6-5.2 (SDMB Hub specification document). Chapter 3, in particular, considers the requirements described in document D6-2.1a (System design definition file for commercial system), while chapter 4 takes into account the access layer functionality to be implemented in MAESTRO test bed Release 2, as described in the deliverable D7-1 (test bed integration plan).

Chapter 5 identifies the main aspects of the access scheme that will be evaluated further via simulation campaign (the access layer simulation platform and results from the simulation campaign will be reported in the deliverable D3-2: SDMB Access Layer Evaluation). These aspects cover:

- Radio interface procedures as a whole
- Trades-off relevant to the configuration of individual layers or functions that are part of a procedure

Finally, in support of the tasks addressed in chapters 3 and 5, a series of appendices are given in the end of the document. Appendices A and D summarize the heritage from earlier research activities on SDMB with respect to radio resource management functions of the SDMB radio interface, whereas appendices E and F review the current understanding and decisions within 3GPP standardisation groups regarding access layer mechanisms that can enhance the reliability of data delivery over the SDMB radio interface. Based on these, Appendix G provides analytical approximations with regard to the use of data repetitions and outer coding in SDMB, either applied at the SDMB RAN or at the application layer, in order to give a quick insight to the performance advantages and overheads related to these available reliable transport mechanisms.

2 ACCESS SCHEME REQUIREMENTS AND CONSTRAINTS

This section will list the requirements of the access schemes needed for the support of MBMS over SDMB. As can be seen in Figure 2, the access layer resides in both the UE and the SDMB RAN (Hub). A more detailed definition of the access layer can be found in section 3.1.

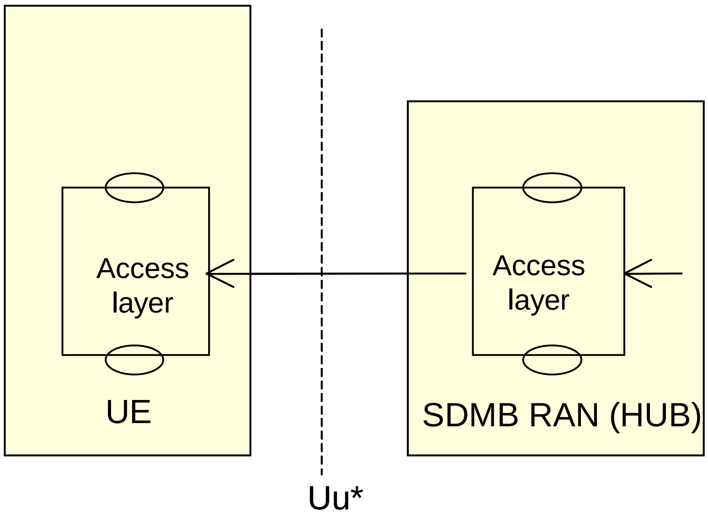

Figure 2: Perimeter of the access layer definition within SDMB

From the network side there is no inter-working at access layer between the SDMB system and the terrestrial GSM/UMTS system.

2.1 Requirements inherited from the 3GPP MBMS framework

This section is based on 3GPP TR 25.992 [7].

2.1.1 SDMB RAN requirements for the support of MBMS over SDMB

The following requirements have been identified with respect to the support of MBMS services over the SDMB RAN:

1. SDMB data transfer shall be downlink only.
2. Only the MBMS Broadcast mode shall be supported at RAN level with the four subsequent procedures: session start, MBMS notification, data transfer and session stop[1]. Multicast services and their relevant procedures such as subscription and group joining are part of upper layers (network and application).
3. During SDMB data transmission it shall be possible to receive paging messages via both satellite and terrestrial networks.

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[1] In other words, the functions performed by the SDMB RAN for the support SDMB services are the same with those performed by the UTRAN for the support of MBMS broadcast services

4. Simultaneous reception of SDMB and non-SDMB services shall depend upon UE capabilities.
5. Simultaneous reception of more than one SDMB services shall depend upon UE capabilities.
6. A notification procedure shall be used to indicate the start of SDMB data transmission. This procedure shall contain MBMS Radio Bearer information. The MBMS notification requirements are listed in sub-clause 2.1.1.1.
7. The SDMB UE broadcast subscription shall be transparent to SDMB RAN.
8. Reception of the SDMB signal is not guaranteed at SDMB RAN level. The SDMB system does not support individual retransmissions at the radio link layer, nor does it support retransmissions based on feedback from individual subscribers at the radio level. This does not preclude the periodic repetitions of the SDMB content based on operator or content provider scheduling or retransmissions based on feedback at the application level[2].
9. No specific mechanisms in SDMB RAN for the communication of per-UE feedback on the achieved QoS (e.g. link quality measurements) to the SDMB RAN are required.
10. UE controlled “service based” cell/spot selection/reselection shall not be permitted.
11. Guaranteed ‘QoS’ linked to a certain initial downlink power setting is not required.
12. To-be-adopted solutions for enhancing SDMB signal reception should minimise the impact on the MBMS physical layer and maximise reuse of existing physical layer and other MBMS RAN functionality, having as reference 3GPP TS 25.346 [11].
13. SDMB charging (i.e. end-user charging) should be transparent to the SDMB RAN.
14. SDMB should allow for low UE power consumption.
15. Header compression should be used.
16. No specific mechanism aiming at minimizing data loss during spot change (e.g. spot handover) is required.
17. It is not required to replicate SDMB data streams at SDMB RAN level. The working assumption is to have a mono-spot/cell service area.

[2] Within 3GPP RAN working groups, proposals have been made from time-to-time for the introduction of mechanisms in the RAN that can enhance the data reception quality. These proposals and their relevance to the SDMB system are reviewed in Appendices E and F

Note: The Operation and Maintenance requirements are not treated here. They will be analysed within MAESTRO WP6 (system architecture). Furthermore the requirements dealing with internal interfaces (inside the hub or even between the hub and the IMR) will not be listed.

2.1.1.1 MBMS Notification Requirements

The following requirements for MBMS notification mechanism(s) have been identified:

1. MBMS notification shall be transmitted within the SDMB service area.
2. MBMS notification shall be sent so that it can be received by all UEs with an activated SDMB service, regardless of their RRC states or the lack of an RRC connection.
3. MBMS notification should maximise the reuse of existing channels.
4. MBMS notification should allow terminals to minimise their power consumption, meaning that UEs with an activated SDMB service should not listen permanently, but at regular intervals to SDMB notification.
5. Reception of MBMS notification cannot be guaranteed.
6. UEs may receive MBMS notification and simultaneously monitor other occasions, e.g. UE dedicated paging and Cell Broadcast Service (CBS) messages. The avoidance of collisions between terrestrial and satellite signalling cannot be guaranteed. If collisions occur, the UE dedicated paging has higher priority (UE requirement).

2.1.2 SDMB RAN functions relevant to the support of MBMS over SDMB RAN

Two categories of functions have been identified in this context:

1. Functions relevant to the establishment and control of MBMS services:
   - Admission control for MBMS services
   - Assignment of resources and selection of parameters for MBMS radio bearers
   - Establishment and release of radio bearers for MBMS services
   - Announcement of the physical, transport and logical channel parameters (radio bearer configuration) with which particular MBMS services are transmitted in each cell to UEs
   - Alerting UEs that MBMS data is to be transmitted
   - Power Allocation/Control for the MBMS radio bearers
2. Functions relevant to the transmission of MBMS data:
   - Transfer of MBMS data

The functions, in more detail, are:

2.1.2.1 Admission Control

The SDMB RAN shall contain functionality that enables it to determine how to respond to requests for the provision of radio bearers for individual MBMS services (data streams) made by the SDMB network layer. This admission procedure may take into account the capacity required, quality of service and priority of the requested service and the resources that are available for MBMS services within the cell/spot.

2.1.2.2 Selection, Assignment and Establishment and Release of Radio Bearers

The SDMB RAN shall assign radio resources to bearers for MBMS services within the cells/spots of broadcast areas.

2.1.2.3 Announcement of MBMS radio bearer parameters to UEs

The SDMB RAN shall provide mechanisms whereby the RAN indicates to UEs the physical, transport and logical channel parameters that are associated with radio bearers that carry specific MBMS data streams within specific spots/cells.

2.1.2.4 Alerting UEs that MBMS data is to be transmitted

For discontinuous MBMS services radio bearers may be established only during those periods when there is data to be transferred. The RAN shall be required to alert the UE that the service is about to be re-established.

2.1.2.5 Power Allocation/Control

The power level shall be set at p-t-m bearer activation and re-scheduled at bearers modification (for e.g. MBMS bearer service addition).

NOTE: It is an open issue whether feedback control for p-t-m radio bearers is practical. (FFS)

2.1.2.6 Maintenance of MBMS Context

The SDMB RAN shall maintain internal records of the MBMS services that are active in each cell/spot.

2.1.2.7 Transfer of MBMS Data

The SDMB RAN shall provide the required layer 1 and layer 2 processes for the preparation and transfer of MBMS data over the Uu and Um interfaces. These encompass the functions of:

- header compression
- segmentation/concatenation
- multiplexing and
- coding

Depending on the service characteristics and the reception capability of the UE, it has to be evaluated how several data streams are multiplexed.

2.2 Additional SDMB specific requirements for the support of MBMS over the SDMB RAN

2.2.1 System information broadcasting

This function provides the mobile station with the access stratum and non-access stratum information, which are needed by the UE for its operation within the network. Specific parameter configuration (comparison PLMN/spot beam identity) is required for the SDMB system.

The basic control and synchronisation of this function is located in SDMB RAN.

2.2.2 UE dual mode behaviour

The specific SDMB activities shall not impact the UTRAN or GERAN procedures performed by the UE. All the constraints defined in 3GPP TSs (for example, [12]) shall be respected even if they have negative impact on the SDMB reception, leading to loss of SDMB data.

The UE behaviour will be as if it camps over two cells, the basic UMTS/GPRS cell and the complementary SDMB spot.

For UE dual mode equipment implementing two separate receiver chains for terrestrial and satellite reception, synchronisation with both systems shall be maintained in parallel by the UE.

For UE dual mode equipment implementing single receiver chain, synchronisation with both systems is sequential, i.e., UE restarts the CPICH and SCH acquisition procedures when switching reception from one system to the other.

2.3 User service QoS requirements and mapping to UMTS traffic classes

The SDMB system supports three types of point-to-multipoint user services: streaming, download and Groupcast services [8]

These services, called user services in TS 22.246 [10], will make use of the three types of SDMB transport services, namely streaming, hot and cold download and will be mapped into two traffic classes within the SDMB transport network, namely streaming and background, which are almost identical to the respective UMTS traffic classes defined in TS 23.107[3].

The relevant attributes of these traffic classes and their range of values within the SDMB RAN are listed in Table 1.

[3] The main difference is with regard to the attribute range of values rather than the applicable attributes themselves.

Traffic class	Streaming	Background
Maximum bit rate (kbps)	< 384[1]	< 384
Delivery order	No	No
Maximum SDU size (bytes)	1500	1500
Delivery of erroneous SDUs	No (TBC)[2]	No
Residual BER	TBD	TBD
SDU error rate	10^{-2} (TBC)	10^{-2} (TBC)[3]
Transfer delay (ms)	250-maximum value (TBC)	N/A
Guaranteed bit rate (kbps)	< 384	N/A
Allocation/Retention priority	1,2,3	1,2,3

Table 1: Range of values for attributes of the traffic classes supported over the SDMB RAN

Note 1: 384 kbps is the maximum user bit rate defined at the FACH (i.e. between layer 1 and layer 2), which includes the relevant UDP/IP/RLC/MAC headers. The maximum bit rate, which is defined to be the maximum number of bits delivered by the radio access network and to the radio access network at a Service Access Point (SAP) within a period of time, divided by the duration of the period [21], is therefore less than this value (by the exclusion of the PDCP/RLC/MAC headers), whereby the exact value will also be dependent upon the size of the IP datagram (a larger IP datagram size will lead to the segmentation at the RLC level) and whether the PDCP header is used, among other things.

Note 2: The RLC may forward erroneous RLC SDUs to higher layers, rather than discarding them, since these segments may be of some use in the upper layers for streaming services. The option should be combined with de-activation of UDP checksum or explicit adoption of UDP-Lite at UDP level.

Note 3: The SDU error rate values in Table 1 are the lowest defined in TS 23.107. However, additional losses are expected in the case of the SDMB network, because the terminal intermittently listens to the terrestrial network. D5.1 roughly estimates these losses to increase the information error rate up to 20%. In summary, and given the use of application-level FEC, it is expected for the SDU error requirements in the SDMB network to be more relaxed with respect to the standard values listed in TS 23.107.

3 ACCESS SCHEME DEFINITION

In the following we describe the radio link layer and the radio network layer of the satellite radio interface both at user-plane and control-plane. The description of the physical layer (layer 1) of the SDMB radio interface is the subject of D2.1, which is under the responsibility of WP2.

As already mentioned in section 1, the radio access scheme heavily draws on the WCDMA air interface; having said that, the description text is kept minimal, in that we attempt to describe in detail only aspects that are different with respect to 3GPP specifications, pointing to the latter where applicable to avoid text duplication. In the following, whenever reference to a technical specification (TS) or a technical report (TR) is made, we imply a 3GPP TS and a 3GPP TR respectively, unless explicitly stated otherwise.

3.1 SDMB air interface architecture

3.1.1 SDMB access scheme layers

The SDMB access scheme covers two layers:

- The radio link layer or layer 2 of the radio interface
- Part of the radio network layer or layer 3 of the radio interface

Note that the layer numbering is inline with the UMTS RAN architecture and layer numbering. It simply reflects their relative position in the satellite radio interface, without strict mapping on the respective layers of the ISO protocol stack [9].

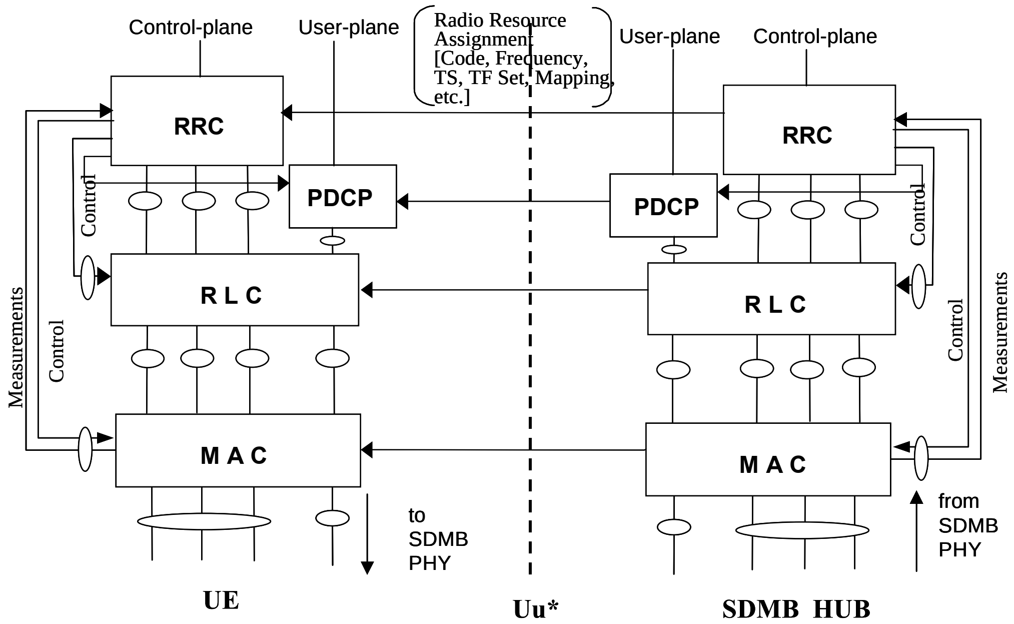

Figure 3: SDMB access scheme

Layer 2 in turn consists of three sub-layers, the Medium Access Control (MAC), the Radio Link Control (RLC) and the Packet Data Convergence Protocol (PDCP) sub-layers. The first two exist in both the user-plane and the control-plane, whereas PDCP is only relevant to the user-plane.

The network layer is part of the control plane and is also organised in sub-layers, the main one being the Radio Resource Control (RRC) sub-layer. The user and control-plane layers of the SDMB access scheme are summarized in Figure 3.

3.1.2 SDMB access scheme channels

The functionality of the SDMB radio interface layers is organized into the concept of channels, each one grouping a specific set of functions at the data and/or control planes. The SDMB set of channels is a subset of the WCDMA set of channels, including the following downlink common channels:

3.1.2.1 Logical channels

The SDMB-relevant WCDMA logical channels are:

- MBMS point-to-multipoint Traffic Channel (MTCH)
- MBMS point-to-multipoint Control Channel (MCCH)
- MBMS point-to-multipoint Scheduling Channel (MSCH)
- Broadcast Common Control Channel (BCCH)

MTCH, MCCH and MSCH are channels that have been introduced specifically for the support of MBMS and they are described in TS 25.346 [11]. The BCCH carries fundamental signalling information in UTRAN and its reception is mandatory for all terminals.

3.1.2.2 Transport channels

The SDMB-relevant WCDMA transport channels are:

- Forward Access Transport Channel (FACH)
- Broadcast Channel (BCH)

The channels are described in both TS 25.301 [23] and TS 25.321 [15]. Their use in SDMB does not introduce additional considerations.

3.1.2.3 Physical channels

The SDMB-relevant WCDMA physical channels are:

- Primary Common Control Physical Channel (P-CCPCH)
- Secondary Common Control Physical Channel (S-CCPCH)
- Synchronisation Channel (SCH)
- Common Pilot Channel (CPICH)
- MBMS Notification Indicator Channel (MICH)

The WCDMA physical channels that are applicable to SDMB are treated in more detail in Deliverable D2-1.1 (Part 1).

The channels of relevance to SDMB are summarized in Figure 4.

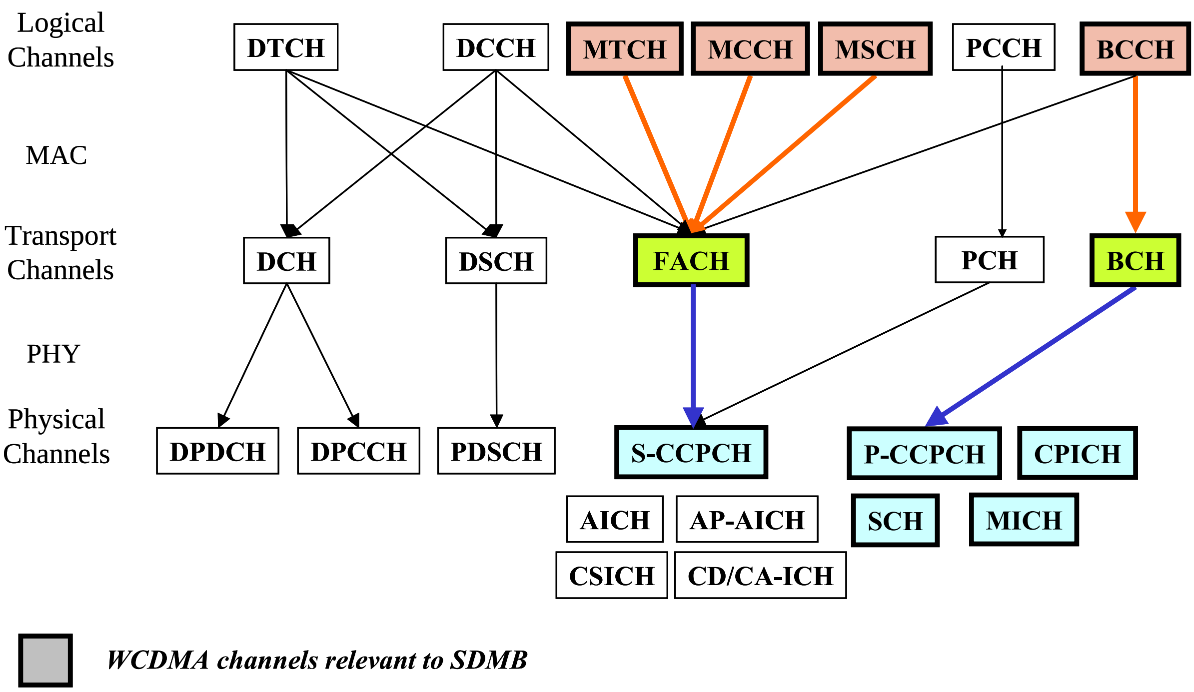

Figure 4: WCDMA channels and relevance to SDMB

3.2 Procedures for the support of MBMS within the SDMB RAN

In this section, the executed procedures within the SDMB RAN for the delivery of MBMS services are described. Given that the services considered in SDMB are push-type in nature, only a subset of those MBMS procedures described in TS 25.346 [11] is pertinent to SDMB.

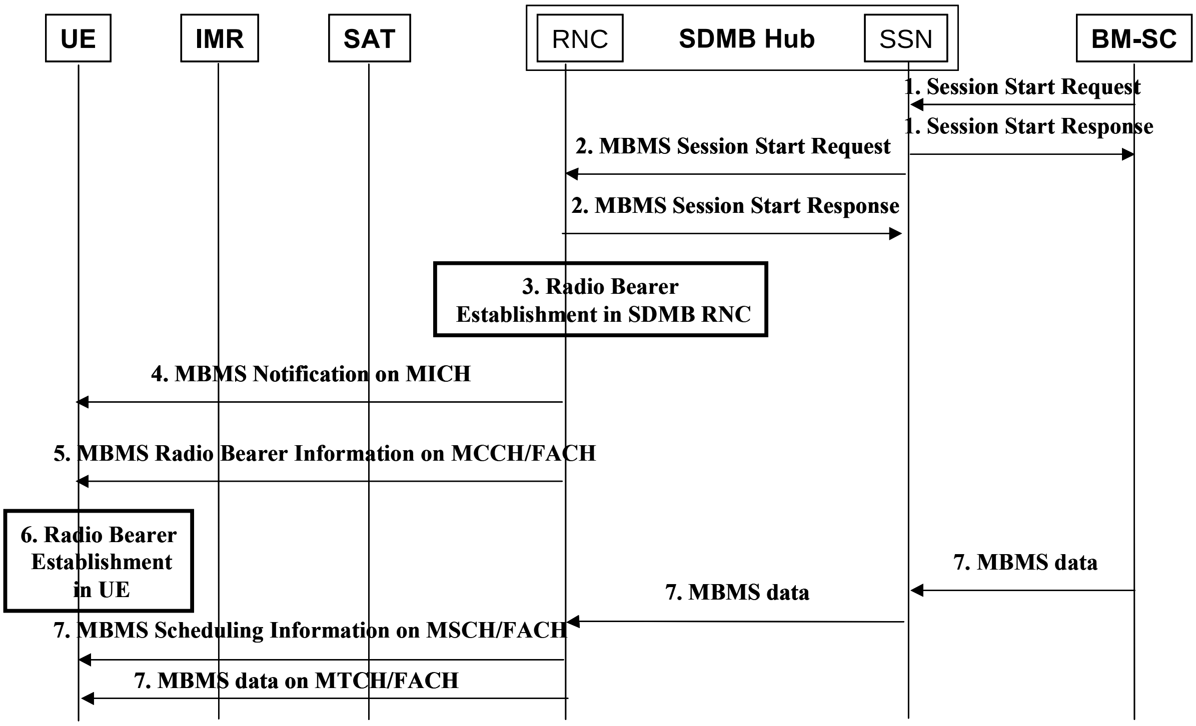

Figure 5: MBMS Notification, RB Setup and Data Transfer procedures

Figure 5 summarizes the three main procedures for the delivery of the MBMS services within SDMB RAN –notification, radio bearer establishment and data transfer– triggered by the session-start procedure of BM-SC. It is assumed that the UE is already logged onto the P-CCPCH, and is able to receive the MBMS system information transmitted on the BCCH logical channel, which carries the MCCH schedule information as well as the radio bearer configuration for MCCH reception (refer to section 3.4.2).

1. The BM-SC initiates the MBMS Session Start procedure to notify the impending start of the transmission and to provide the session attributes (QoS, estimated session duration…) so that all the necessary bearer resources in the network can be activated for the transfer of MBMS data. The reception of the Session Start request in the registered SDMB support node (SSN) changes the state attribute of its MBMS Bearer Context[4] (also known as the MBMS Service context in TS 23.246 [11]) to 'Active' mode and the SSN sends back a Session Start Response message to the BM-SC.
2. The SSN sends an MBMS Session Start Request message including the MBMS Service ID (which identifies all MBMS services that are potentially available), and optionally the MBMS Session ID, and the session attributes to the SDMB RNC. The arrival of the Session Start message will create the MBMS bearer context for the specific service in the SDMB RAN, if one has not been created. It also provides the MBMS Iu Data Bearer Establishment

[4] The MBMS bearer context contains all information describing a particular MBMS bearer service and is created in each node involved in the delivery of the MBMS data [6].

functionality. The SDMB RNC then responds with an MBMS Session Start Response to the SSN. In case the RNC does not have the required radio resources, it will notify the SSN accordingly. Note that for the case the MBMS sessions are repeated by the BM-SC (i.e. identical content is sent multiple times), the MBMS session ID together with MBMS service ID is used to identify specific MBMS service and session, upon which the UE can determine if it chooses to receive the MBMS session repetitions for the case when the UE has missed a complete session transfer (e.g. due to the intermittent switching to the terrestrial network to perform measurements and receive calls) or to ignore the MBMS session repetitions if it has received the session completely from previous transmission.

3. The SDMB RNC configures the MTCH for the transfer of MBMS data to the interested UEs. It also updates the MCCH (MBMS Radio Bearer Information). Note that the MBMS Service Information as specified in TS 25.346 is not required since the MBMS bearers over SDMB RAN are p-t-m only.
4. The SDMB RAN sets the correct MBMS Notification Indicator (NI), which is sent on the MICH (the MBMS-specific PICH described in TS 25.346 [11]), to inform UEs not receiving MBMS service(s) on MTCH of an upcoming change in the critical MCCH information, i.e. the MBMS Radio Bearer Information. MBMS Change Information is also transmitted on the MCCH in the beginning of each modification period[5] to notify UEs already receiving MBMS service(s) on MTCH of the modification to the MCCH information.
5. Upon DRX wakeup, the UEs not receiving MBMS service(s) on MTCH evaluate the MBMS NI corresponding to services of their interest and if set, read the MBMS Change Information from MCCH at the beginning of the modification period. UEs already receiving MBMS service(s) shall read the MBMS Change Information directly. If the service ID and the Session ID of activated MBMS service is indicated in the MBMS Change Information, the UEs shall continue to read the rest of the MCCH information to acquire the MBMS Radio Bearer Information. The MBMS Radio Bearer Information includes the MBMS Service ID, logical channel, transport channel and physical channel information per MBMS service.
6. With this information, the UEs set up the MBMS radio bearer (MTCH/FACH/S-CCPCH) and create the MBMS context on the UE side.
7. The data transfer phase may then begin, and MBMS data can be delivered to the UEs. At the same time, MTCH Scheduling Information is transmitted on the MSCH to UEs receiving MTCH, to enable UEs to perform discontinuous reception of MTCH based on the information provided. This scheduling information, which includes for each service the MBMS service Id, beginning and duration of MBMS data transmission, and indication of no MBMS data

[5] The modification period is defined as an integer multiple of the repetition period, which in turn is defined as the periodic transmission of the entire MCCH information [11].

transmission for either this period or several consecutive periods, is signalled on each MSCH repetition period[6]. Hence the scheduling information basically allows to cover different periods for different MBMS services.

NOTE: The signalling flows between the SSN and the RNC are internal to the hub.

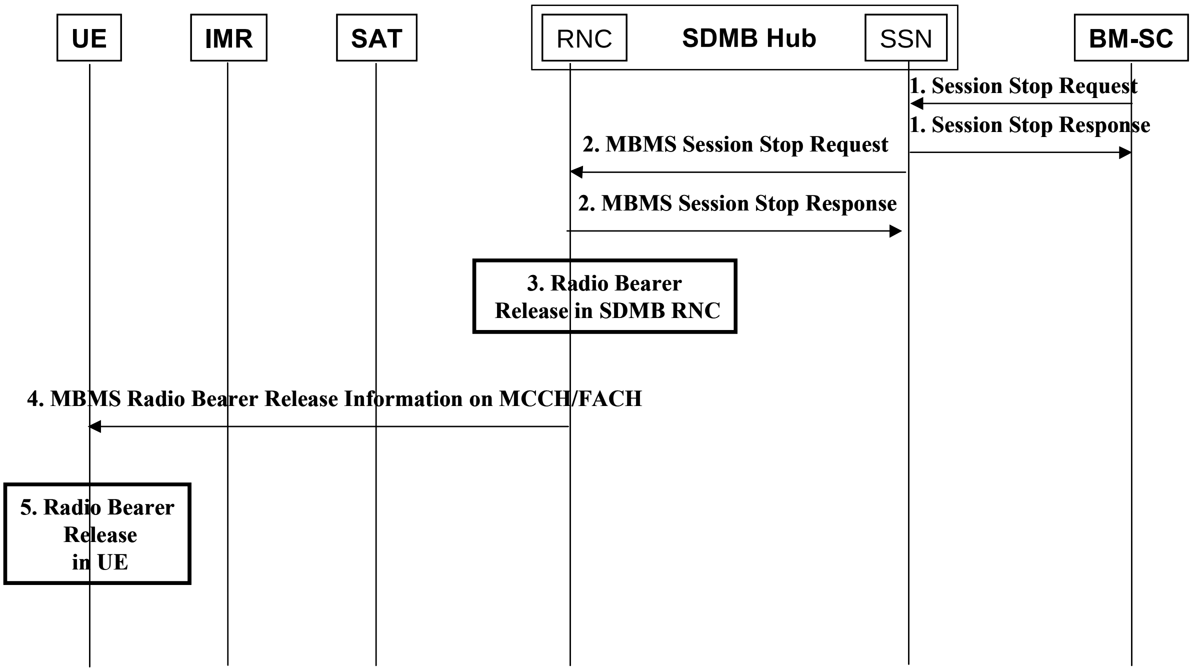

Figure 6: MBMS Notification and RB Release procedure involved in Session Stop

Figure 6 depicts the overall procedures for the termination of MBMS session when there is no more MBMS data expected to be transmitted for a sufficiently long period of time to justify a release of bearer plane resources in the network. The Session Stop procedure leads to the execution of the radio bearer release procedure within the SDMB RAN.

1. The BM-SC sends a Session Stop Request message to the SSN of the affected MBMS Bearer Context to indicate that the MBMS session is terminated and the bearer plane resources can be released. The BM-SC sets the state attribute of its MBMS Bearer Context to ‘Standby’. The SSN sends back a Session Stop Response message to the BM-SC.
2. The SSN releases its MBMS bearer plane resources and sends an MBMS Session Stop Request message to the SDMB RNC, which provides the MBMS lu Data Bearer Release functionality. The SDMB RNC responds with an MBMS Session Stop Response to the SSN.

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[6] The MSCH repetition period and the offset from the MCCH modification period are indicated on MCCH [11].

3. The RNC releases the affected radio and Iu resources. It updates the MCCH to indicate the MBMS RB release. Either the MBMS Radio Bearer Release Information or the MBMS Radio Bearer Information can be utilized, of which the first option is shown here.
4. The SDMB RAN sends the MBMS Change Information and the MBMS Radio Bearer Information including service ID and radio bearer release indicator
5. The UEs in idle mode as well as those receiving an MBMS service read the MBMS Change Information at the beginning of each modification period. If the service Id of activated MBMS service is indicated in MBMS Change Information, the UEs continue to read the rest of the MCCH information. Upon receiving the MBMS Radio Bearer Release Information, the UEs release the MBMS RB.

Note that the radio bearer release mechanism that has been described so far is for the explicit MBMS RB Release. An implicit MBMS RB Release can also be used, whereby no message is given by the SDMB RAN, but instead the radio bearer is released based on a timer given by the SDMB RAN [11].

NOTE: Step 2 signalling flows between the SSN and the RNC are internal to the hub.

Overall, it can be seen that the following procedures as specified in TS 25.346 [11] are not required:

- **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 that he/she is willing to receive multicast mode data of a specific MBMS bearer service becomes irrelevant to the SDMB RAN.
- **Counting/Recounting**: This procedure is used in terrestrial radio access networks (UTRAN, GERAN) to determine the optimal MBMS transmission mode, namely 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 for the MBMS service in SDMB, the counting/recounting procedure is not relevant to SDMB.
- **RNC Registration/Deregistration**: In terrestrial 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 per-service basis and assumes awareness about the existence of PMM-connected UEs in the area under the RNC control. In SDMB, there is one-to-one relation between SDMB RNC and SSN (the simplified SDMB Core Network) 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 terrestrial 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 (refer to section 2), the concept of combining from multiple cells is not applicable to SDMB.

NOTE: 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, whereby these signals from the satellite and IMRs are later selective combined at the UEs[7].

Table 2 summarizes the relevance of MBMS UTRAN principles described in TS 25.346 (sections 5.1 and 5.2) to the SDMB context.

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	

[7] The work on selective combining within SDMB is currently under investigation within WP9.

UTRAN MBMS procedures/principles	Applicability to SDMB	Remarks
MBMS Service Prioritisation	X	

Table 2: Relevance of UTRAN MBMS procedures/principles as specified in [11] to SDMB RAN

3.3 SDMB Radio Link Layer definition

In the following sub-sections, each of the layer 2 protocols in SDMB, i.e. MAC, RLC, and PDCP are described in more detail. The BMC sub-layer as specified by 3GPP in TS 25.324 [13] is not relevant within SDMB and thus is not defined herein.

3.3.1 MAC sub-layer

The MAC sub-layer provides logical channels to the RLC and maps the BCCH and MTCH/MCCH/MSCH logical channels onto BCH and FACH transport channels respectively. MAC has the overall responsibility of controlling the communications over the WCDMA transport channels provided by the physical layer. In order to be able to share the capacity of the transport channels among the set of users, the MAC protocol uses transport blocks as units of transmission. MAC is responsible for selecting an appropriate transport format (TF) for BCH and FACH, which depends on the instantaneous source rate of the respective logical channels mapped to them. On FACHs, the MAC provides addressing of user equipment and scheduling of protocol data units (PDUs). MAC also collects statistical information about the traffic to be used by the RRC layer. These MAC measurements include local measurements such as buffer occupancy, in terms of both mean value and variance.

3.3.1.1 SDMB MAC entities

Figure 7 shows the MAC architecture within SDMB RAN, which is a subset of the full set of MAC entities defined for the terrestrial UMTS ([11], [15]).

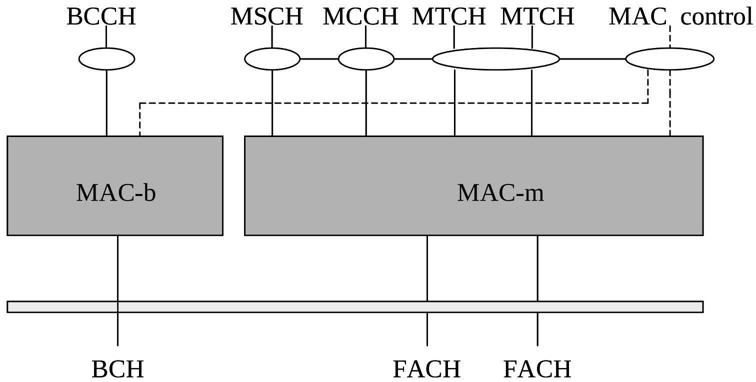

Figure 7: SDMB MAC architecture

As can be seen, given the unidirectional nature of SDMB with no satellite uplink, the MAC architecture consists of only two logical entities:

- MAC-b – the entity responsible for the broadcast channel (BCH)
- MAC-m – the entity defined to support MBMS user and control plane specific functions. It is responsible for the mapping of three logical channels considered for point-to-multipoint transmission, i.e. MCCH, MSCH and MTCH onto FACH

The MAC Control SAP is used to transfer Control information to each MAC entity. In the SDMB RAN, there is one MAC entity (MAC-b and MAC-m) for each spot. There is also one MAC entity (MAC-b and MAC-m) for each UE[8]. Note that the dual-mode UE, however, will feature the full set of MAC functionalities (depending on its class) that will allow it to receive the point-to-point services via the terrestrial network.

3.3.1.1.1 MAC-m architecture: SDMB RAN side

Figure 8 shows the MAC-m entity in the SDMB RAN side, needed to transmit MBMS data and control information over a common transport channel (FACH).

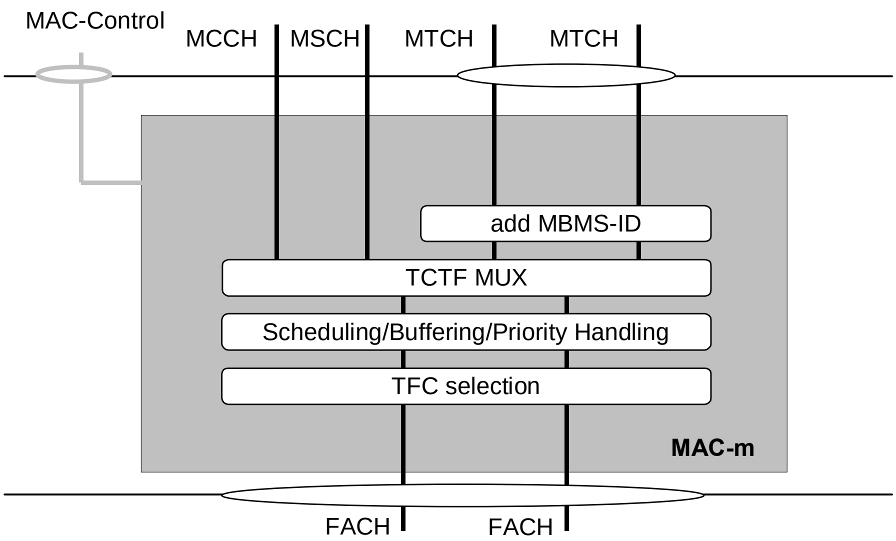

Figure 8: SDMB RAN side MAC-m architecture

The following functionalities are covered:

- ***Addition of MBMS-ID:*** For p-t-m type of logical channels, the MBMS-ID field in the MAC header is used to distinguish between MBMS services.
- ***TCTF Multiplexing:*** This function handles insertion of the Target Channel Type Field (TCTF) field in the MAC header and also the respective mapping between logical channels (i.e. MTCH, MSCH and MCCH) and transport

[8] Note that in the case of selective combining, there are several MAC-m entities in each UE.

channels. The TCTF field indicates which type of logical channel (i.e. MTCH, MSCH and MCCH) is used.

- ***Scheduling/Buffering/Priority Handling:*** This function manages common transport resources between MBMS data and control information according to their priority.
- ***TFC selection:*** Transport format combination selection is done for a common transport channel (FACH) mapped to MTCH, MSCH and MCCH.

3.3.1.1.2 MAC-m architecture: UE side

Figure 9 shows the MAC-m entity in the UE side, needed to receive MBMS data and control information over a transport channel (FACH).

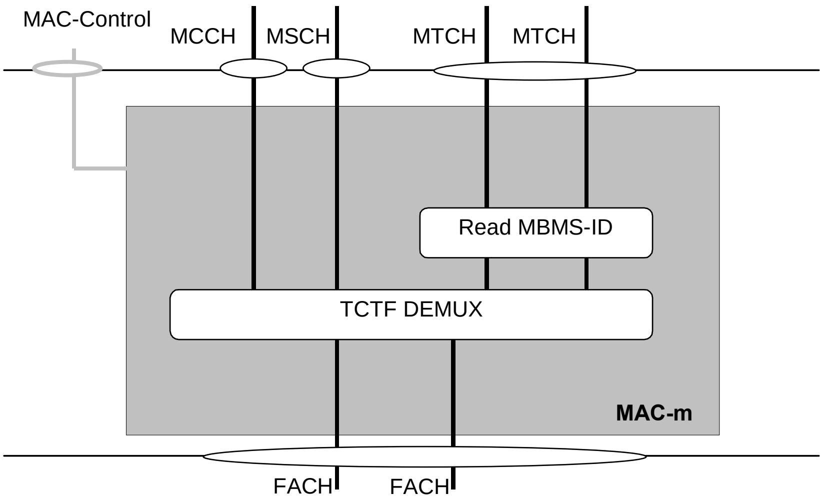

Figure 9: UE side MAC-m architecture

The following functionalities are covered:

- ***Reading of MBMS-ID:*** The MBMS-ID identifies data to a specific MBMS service.
- ***TCTF DEMUX:*** This function handles detection and deletion of the TCTF field in the MAC header, and also the respective mapping between logical channels (i.e. MTCH, MSCH and MCCH) and transport channels. The TCTF field indicates which type of logical channel (i.e. MTCH, MSCH and MCCH) is used.

3.3.1.2 Relation between MAC Functions and Transport Channels

3.3.1.2.1 Relation between MAC Functions and Transport Channels in SDMB RAN

The relevance of MAC sub-layer functions to the SDMB channels on the SDMB RAN side is summarized in Table 3.

Logical Channel	Transport Channel	TF Selection	Priority handling between services /groups of users	Scheduling	Mux/Demux on common TrCH	Identification of MBMS service
BCCH	BCH			X		
MCCH	FACH	X		X	X	
MSCH	FACH	X		X	X	
MTCH	FACH	X	X	X	X	X

Table 3: SDMB RAN MAC functions corresponding to the (downlink) transport channels

3.3.1.2.2 Relation between MAC Functions and Transport Channels in UE

The relevance of MAC sub-layer functions to the SDMB channels on the UE side is summarized in Table 4.

Logical Channel	Transport Channel	Mux/Demux on common transport channels	Identification of MBMS service
BCCH	BCH		
MCCH	FACH	X	
MSCH	FACH	X	
MTCH	FACH	X	X

Table 4: UE MAC functions corresponding to the (downlink) transport channels

3.3.1.3 Services to and from other layers

The SDMB MAC layer provides the following services to the upper layers:

- Data transfer: unacknowledged transfer of MAC SDUs between peer MAC entities, with no data segmentation (in the SDMB RAN to UE direction)
- Reallocation of resources and change of MAC parameters on request from RRC (only applicable on the SDMB RAN side)
- Reporting of local measurements to RRC (only applicable on the SDMB RAN side)

On the other hand, the physical layer offers information transfer services to the MAC layer.

3.3.1.4 Primitives

The interaction between the MAC layer and other layers are described in terms of primitives, where the primitives represent the logical exchange of data and control information between the MAC layer and other layers. The primitives shall not specify or constrain implementations. The MAC is connected to the physical layer (L1), the RLC sub-layer and RRC layer. The following sub-sections describe the primitives between these layers.

3.3.1.4.1 Primitives between layers 1 and 2

The primitives for local communications between MAC and L1 are shown in Table 5.

Generic Name	Parameter			
	Request	Indication	Response	Confirm
PHY-Data	Transport Format Indicator (TFI), Transport Block Set,	TFI, Transport Block Set, Cyclic Redundancy Check (CRC) result	Not Defined	Not Defined
PHY-Status	Not Defined	Event value	Not Defined	Not Defined

Table 5: Primitives between MAC layer and Physical layer

The definition for each of the primitives as well as the associated primitive parameters can be found in sections 10.1 and 10.3 of TS 25.302 [16].

3.3.1.4.2 Primitives between MAC and RLC

The primitives between MAC layer and RLC layer are shown in Table 6.

Generic Name	Parameter			
	Request	Indication	Response	Confirm
MAC-DATA	Data, Buffer Occupancy (BO), RLC Entity Info	Data, No_TB, Error indication		
MAC-STATUS		No_PDU, PDU_Size, TX status	BO, RLC Entity Info	

Table 6: Primitives between MAC layer and RLC layer

The definition for each of the primitives as well as the associated primitive parameters can be found in section 8.2 of TS 25.321 [15].

3.3.1.4.3 Primitives between MAC and RRC

The primitives between MAC and RRC are shown in Table 7.

Generic Name	Parameter			
	Request	Indication	Response	Confirm
CMAC-CONFIG	Radio Bearer (RB) information elements, Transport Channel (TrCH) information elements MBMS information elements			
CMAC-MEASUREMENT	Measurement information elements	Measurement result		
CMAC-STATUS		Status info		

Table 7: Primitives between MAC layer and RRC

The definition for each of the primitives as well as the associated primitive parameters can be found in section 8.3 of TS 25.321 [15].

3.3.1.5 MAC PDU Format

A MAC PDU consists of an optional MAC header and a MAC Service Data Unit (MAC SDU). Both the MAC header and the MAC SDU are of variable size. The content and the size of the MAC header depends on the type of the logical channel, and in some cases none of the parameters in the MAC header are needed. The size of the MAC-SDU depends on the size of the RLC-PDU, which is defined during the radio bearer set-up procedure.

The MAC PDU format for the 4 logical channels relevant within SDMB, i.e. BCCH, MTCH, MSCH and MCCH, is described in the following sub-sections.

3.3.1.5.1 MAC PDU format for BCCH

In SDMB, BCCH is only mapped to BCH, hence no MAC header is needed.

Figure 10: MAC PDU formats for BCCH

3.3.1.5.2 MAC PDU format for MTCH, MSCH and MCCH channels

MAC headers of MTCH, MSCH and MCCH channels consist of the following header fields:

- The **TCTF field** provides identification of the logical channel class (i.e. MTCH, MSCH or MCCH) on FACH. New TCTF values with respect to the current ones defined in section 9.2 of TS 25.322 [17] need to be introduced for MTCH, MSCH and MCCH.
- The **MBMS-Id field** provides an identifier of the MBMS service on FACH. The MBMS service identifier is the m-RNTI (Radio Network Temporary

Identifier). The MBMS-Id field is not part of the MSCH/MCCH MAC header because messages on MSCH/MCCH should be identified by an MBMS identity in a higher layer message.

The MAC PDU format for MTCH is shown in Figure 11.

a) MTCH mapped to FACH:

TCTF field is included in the MAC header

b) MTCH mapped to FACH, where MTCH is the only channel.

No TCTF field is included in the MAC header

Case a):

TCTF	MBMS-Id	MAC SDU

Case b):

MBMS-Id	MAC SDU

Figure 11: MAC PDU format for MTCH

The MAC header for MCCH/MSCH is shown in Figure 12.

a) MCCH/MSCH mapped to FACH:

TCTF field is included in the MAC header

b) MCCH/MSCH mapped to FACH, where MCCH/MSCH is the only channel.

No TCTF field is included in the MAC header

Case a):

TCTF	MAC SDU

Case b):

MAC SDU

Figure 12: MAC PDU format for MCCH/MSCH

3.3.2 RLC sub-layer

The RLC sub-layer [TS 25.322] provides the data transfer service of higher layer PDUs as RLC SDUs. On the control plane, the RRC layer for signalling transport uses the RLC services, known as the Signalling Radio Bearers. On the user plane, the RLC services are known as the Radio Bearers only if the PDCP is not used, otherwise the RB service is provided by PDCP.

3.3.2.1 Model of the SDMB RLC sub-layer

Figure 13 depicts the SDMB RLC sub-layer architecture, which is basically a subset of the ones defined in TS 25.322 [17]. Since there is no return link via the satellite in SDMB and due to the requirement that individual retransmissions are not supported at the radio link layer, only the transparent mode (TM), and unacknowledged mode (UM) RLC entities are applicable.

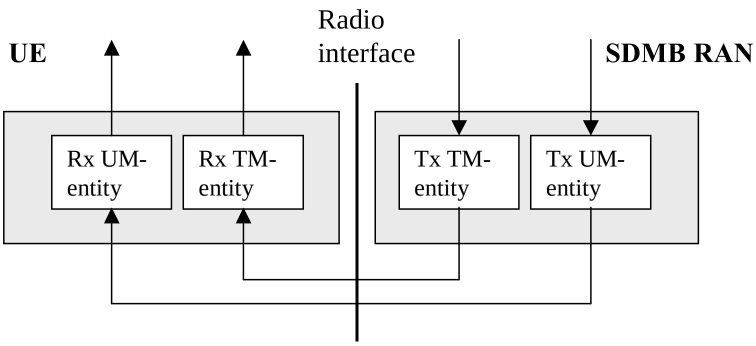

Figure 13: Overview model of the SDMB RLC sub-layer

Note that the TM and UM RLC entities are defined to be unidirectional, i.e. they can be configured to act either as transmitting or as receiving entities, of which the transmitting entity is known as the Sender and the receiving entity as the Receiver. Within SDMB, since the data flow is from SDMB RAN to the UEs, the transmitting entities only reside at the SDMB RAN side, while at the UE side, the TM-and UM-RLC entities act only as Receivers. In the SDMB RAN, there is one RLC entity for each MBMS service in each cell, while in the UE side, there is one RLC entity for each MBMS service. Each RLC entity exchanges data PDUs via use of the BCCH, MTCH, MSCH and MCCH logical channels.

Note that the models shown for the RLC entities are only related to the SDMB interface, and since it is expected that a SDMB terminal will be a fully T-UMTS compatible terminal, it shall have the full RLC functionality for interfacing with T-UMTS and accessing services not provided by SDMB.

3.3.2.1.1 Transparent mode(TM) RLC entities

Figure 14 depicts the model of two transparent mode peer RLC entities as well as the logical channel used to communicate with the lower layer. The only logical channel making use of the RLC TM service is the BCCH. The transmitting TM RLC entity in SDMB RAN receives RLC SDUs from upper layers through the TM-SAP and these are forwarded to the MAC layer on the BCCH logical channel. The RLC SDUs must be a multiple of one of the valid TM data (TMD) PDU lengths.

On the receiving part, the UE TM-RLC entity collects the TMD PDUs from the lower layers and forwards them to the upper layers via the TM-SAP.

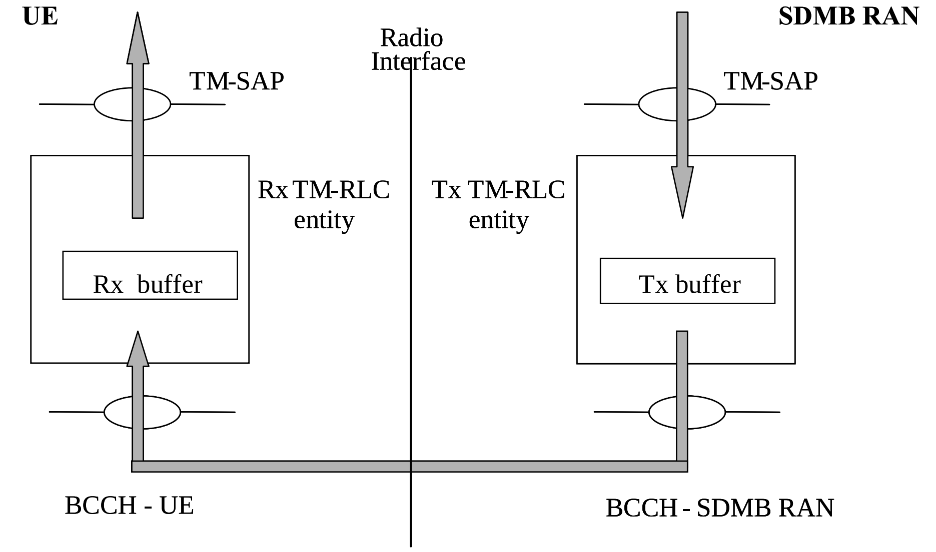

Figure 14: Model of two transparent mode peer entities

3.3.2.1.2 Unacknowledged mode (UM) RLC entities

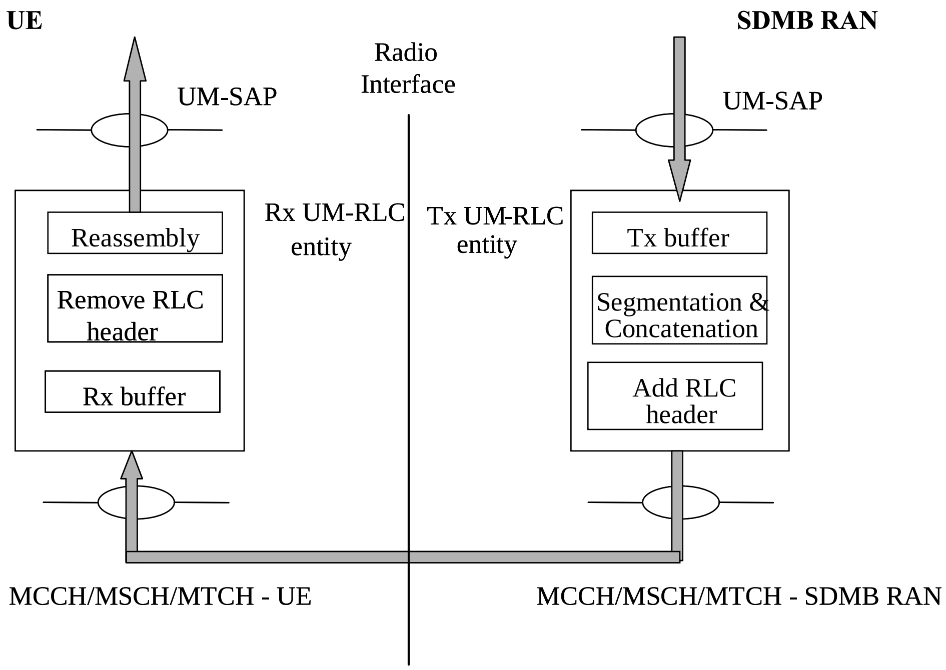

Figure 15: Model of two unacknowledged mode peer entities in SDMB

Figure 15 depicts the model of two unacknowledged mode peer RLC entities as well as the logical channels used to communicate with the lower layer. The logical channels used for communication with the MAC sub-layer are the MCCH, MSCH and MTCH.

Contrary to the TM-RLC PDU, an UMD PDU may contain segmented and/or concatenated RLC SDUs. Padding may also be applied to impose a valid length on the PDU. Moreover, length indicators are used to define boundaries between RLC SDUs within the same PDU, in case of concatenation. Similar indicators dictate the use or not of padding within the UMD PDU.
On the receiving part, the UE UM-RLC entity removes the RLC headers added at the transmitting side, and reassemble RLC PDUs into SDUs, if the respective features (segmentation/concatenation) have been activated at the transmitting side. The UM SAP at the UE side is used for passing the RLC SDUs to the upper layers.

3.3.2.2 Functions

The SDMB RLC sub-layer offers a subset of the full RLC functionalities described in TS 25.322 [17]. The functions provided are:

- ***Segmentation and reassembly:*** This function performs segmentation/reassembly of variable-length upper layer PDUs into/from smaller RLC PDUs. The RLC PDU size is adjustable to the actual set of transport formats.
- ***Concatenation:*** If the contents of an RLC SDU cannot be carried by one RLC PDU, the first segment of the next RLC SDU may be put into the RLC PDU in concatenation with the last segment of the previous RLC SDU.
- ***Padding:*** When concatenation is not applicable and the remaining data to be transmitted do not fill an entire RLC PDU of given size, the remainder of the data field shall be filled with padding bits.
- ***Transfer of user data:*** This function is used for conveying data between users of RLC services. Within SDMB, RLC supports unacknowledged and transparent data transfer. All services within SDMB (user plane) make use of the UM transfer.
- ***Sequence number check:*** This function is used in unacknowledged mode and guarantees the integrity of reassembled PDUs and provides a mechanism for the detection of corrupted RLC SDUs through checking sequence number in RLC PDUs when they are reassembled into a RLC SDU.
- ***SDU Discard:*** This function is used by the Sender to discharge RLC PDUs from the RLC PDU buffer to avoid buffer overflow, when the transmission of the RLC PDUs does not succeed for a period of time.
- ***Out of sequence SDU delivery***: This function is required for the transmitting RLC to transmit, on demand, copies of PDUs that were transmitted earlier. In the case of MCCH, this applies to MCCH critical information (all MCCH messages other than MBMS Access Information), which is repeated each repetition period within a modification period. MCCH non-critical information (MBMS Access Information) is not repeated.

3.3.2.3 Services provided to upper layers

The list of services provided by the SDMB RLC sub-layer to the upper layers depend on the RLC operation mode and are listed below:

- ***Transparent data transfer service:*** The only function provided is the transfer of user data.
- ***Unacknowledged data transfer service:*** The functions provided are segmentation and reassembly, concatenation, padding, transfer of user data, sequence number check, and SDU Discard.

The following tables show the applicability of services and functions to the logical channels in the transfer of data from SDMB RAN to UE (downlink). A '+' in a column denotes that the service/function is applicable for the logical channel in question whereas a '-' denotes that the service/function is not applicable.

Service	Functions	BCCH	MCCH	MSCH	MTCH
Transparent Service	Applicability	+	-	-	-
	Reassembly	-	-	-	-
	Transfer of user data	+	-	-	-
Unacknowledged Service	Applicability	-	+	+	+
	Reassembly	-	+	+	+
	Sequence number check	-	+	+	+
	Transfer of user data	-	+	+	+
	Out of sequence SDU delivery	-	+	-	-

Table 8: RLC modes and functions in UE downlink direction

Service	Functions	BCCH	MCCH	MSCH	MTCH
Transparent Service	Applicability	+	-	-	-
	Segmentation	-	-	-	-
	Transfer of user data	+	-	-	-
	SDU Discard	-	-	-	-
Unacknowledged Service	Applicability	-	+	+	+
	Segmentation	-	+	+	+
	Concatenation	-	+	+	+
	Padding	-	+	+	+
	Transfer of user data	-	+	+	+
	SDU Discard	-	+	+	+
	Out of sequence SDU delivery	-	+	-	-

Table 9: RLC modes and functions in SDMB RAN downlink direction

3.3.2.3.1 Primitives between RLC and upper layers

Given the absence of acknowledged mode entities from the RLC sub-layer within SDMB and with no ciphering performed at RLC layer, the (reduced) list of primitives between RLC and upper layers available is shown in the following table:

Generic Name	**Parameters**			
	Request	**Indication**	**Response**	**Confirm**
RLC-UM-DATA	Data, DiscardReq, Message Unit Identifier (MUI)	Data	Not Defined	MUI
RLC-TM-DATA	Data, DiscardReq, MUI	Data, Error_Indicator	Not Defined	MUI
CRLC-CONFIG	E/R, Stop (UM only), Continue (UM only), TM_parameters (TM only), UM_parameters (UM only),	Not Defined	Not Defined	Not Defined
CRLC-SUSPEND (UM only)	N	Not Defined	Not Defined	VT (US) (UM only)
CRLC-RESUME (UM only)	No Parameter	Not Defined	Not Defined	Not Defined
CRLC-STATUS	Not Defined	Event Code (EVC)	Not Defined	Not Defined

Table 10: Primitives between RLC and upper layers in SDMB

The definition for each of the primitives as well as the associated primitive parameters can be found in section 8 of TS 25.322 [17].

3.3.2.4 RLC PDU Format

There are 2 formats of the RLC PDU applicable for SDMB:

- Transparent Mode Data (TMD) PDU

The TMD PDU is used to convey RLC SDU data without adding any RLC overhead. The TMD PDU is used by RLC when it is in transparent mode. The data length is not constrained to be a multiple of 8 bits.

Data

Figure 16: TMD PDU

- Unacknowledged Mode Data (UMD) PDU

The UMD PDU is used to convey sequentially numbered PDUs containing RLC SDU data. UMD PDUs are used by RLC when it is configured for unacknowledged data transfer. The length of the data part shall be a multiple of 8 bits. The definition of the header fields can be found in section 9.2.2 of TS 25.322 [17].

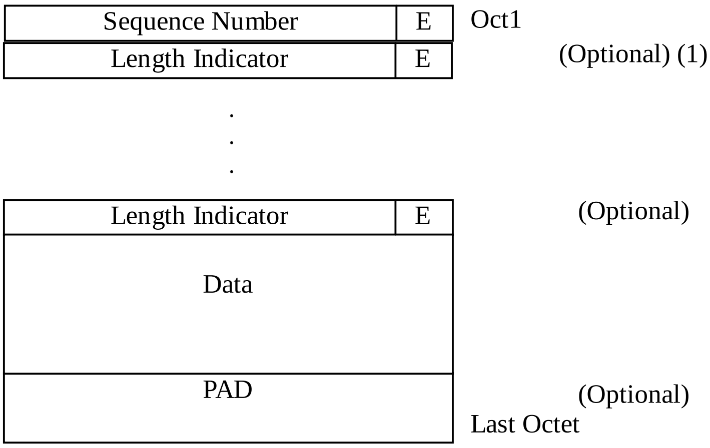

Figure 17:UMD PDU

3.3.3 Packet Data Convergence Protocol (PDCP) sub-layer

The PDCP sub-layer [TS 25.323] exists only in the user plane and is defined for the PS domain only. The PDCP contains compression methods needed for better spectral efficiency for delivery of IP packets over the radio interface and since MBMS traffic is encapsulated in IP datagrams, the PDCP sub-layer has an essential role in MBMS service provisioning. The services envisaged over MBMS are supposed to be multimedia, for example video streaming, which unlike VoIP, the RTP packet size could be quite big in comparison with the combined RTP/UDP/IPv6 headers size. Nevertheless, it has been shown in [19] that significant gain is still achievable with header compression even for multimedia services.

3.3.3.1 SDMB PDCP Sub-layer Architecture

Figure 18 shows the model of the PDCP within the radio interface protocol architecture. As can be seen, the PDCP resides in both the SDMB RAN and the UE side. In the SDMB RAN side, there is one PDCP entity per cell supporting SDMB services. In the UE side, there is one PDCP for each SDMB service.

The PDCP entity at the SDMB RAN side performs header compression upon reception of a PDCP SDU from upper layers and submits the PDCP PDU to the UM RLC entities (as stated in section 3.3.2, UM is the only RLC mode envisaged for MBMS traffic), while the PDCP entity at the UE side performs header decompression upon receiving the PDCP PDU from the UM RLC entities and delivers the PDCP SDU to the upper layers. This structure is in accordance with the SDMB architecture with the transmitting entities residing at the SDMB RAN and the receiving entities at the UE side only.

Every PDCP entity uses zero, one or several different header compression protocol types. The PDCP sub-layer is configured by the RRC through the PDCP-C-SAP.

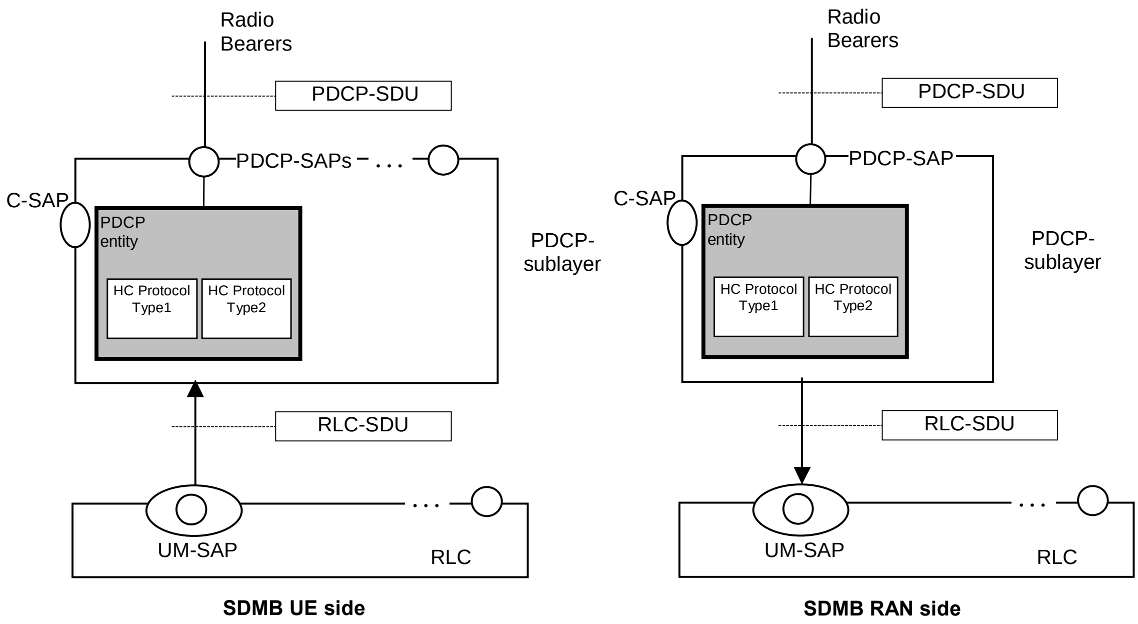

Figure 18: SDMB PDCP structure

3.3.3.2 PDCP Functions

The functions of PDCP within SDMB are:

- Header compression and decompression of IP data streams at the transmitting and receiving entity, respectively.

The PDCP sub-layer may operate with the RObust Header Compression (ROHC) protocol. ROHC is the only header compression protocol supported by 3GPP that is capable of compressing the RTP header and this is required for MBMS since the main MBMS user services are multimedia streaming applications, which provide RTP/UDP/IP packets. The detailed operation of the ROHC protocol is specified in RFC 3095 [20].

There are three modes of operation specified for ROHC, i.e. Unidirectional (U-mode), Bidirectional Optimistic (O-mode), and Bidirectional Reliable mode (R-mode). The U-mode is the only mode of operation supported in SDMB since the packets are sent only in one direction, 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). This mode of operation is also the only valid option within 3GPP MBMS [11] since the other two modes require feedback links. With the U-mode, transitions between compressor states are performed only on account of periodic timeouts and irregularities in the header field change patterns in the compressed packet stream. Due to the periodic refreshes and the lack of feedback for initiation of error recovery, the compression in this mode will be less efficient and have a slightly higher probability of loss propagation compared to the bi-directional modes [20].

- Transfer of user data

This function is used for conveying data between users of PDCP services.

The support for loss-less SRNS relocation (normally a function of PDCP for point-to-point transmission within UTRAN) is not required since SRNS relocation is not applicable within SDMB and also due to the fact that a MBMS RAB cannot be relocated due to its multicasting characteristics.

The service provided by PDCP to upper layers is the transfer of user data while the service expected from the RLC layer is unacknowledged data transfer service.

3.3.3.3 Primitives between PDCP and upper layers

Given that SRNS relocation is not supported by the PDCP within SDMB, and hence the PDCP sequence numbering is not needed, the (reduced) list of primitives between PDCP and upper layers that is relevant to SDMB is shown in Table 11.

Generic Name	Parameter			
	Request	Indication	Response	Confirm
PDCP-DATA	Data	Data	Not Defined	Not Defined
CPDCP-CONFIG	PDCP-Info, RLC-SAP, R/I	Not Defined	Not Defined	Not Defined
CPDCP-RELEASE	RLC-SAP	Not Defined	Not Defined	Not Defined

Table 11: Primitives between PDCP and upper layers

The primitives as well as the associated primitive parameters are detailed in section 7.1 of TS 25.323 [18].

3.3.3.4 PDCP PDU Format

There are two PDU formats for PDCP defined for SDMB, i.e. the PDCP-No-Header PDU (Figure 19) and the PDCP Data PDU (Figure 20). The PDCP-No-Header PDU does not introduce any overhead to the PDCP SDU with its use configured by the upper layer. The PDCP Data PDU introduces 2 overheads – the 'PDU type' field which indicates the PDCP Data PDU type and the 'PID (Packet Identifier)' field which indicates the used header compression and packet type or a context identifier. The PDCP Data PDU is used to convey data containing an uncompressed PDCP SDU; header compression related control signalling; or data that has been obtained from PDCP SDU after header compression. More details can be found in section 8.2 of TS 25.323 [18].

Figure 19: PDCP-No-Header PDU format

PDU type	PID
Data	

Figure 20: PDCP Data PDU format

3.4 SDMB Layer 3 definition (RRC)

The RRC performs the functions listed below. A more detailed description of these functions is provided in TS 25.301 [23]:

- Broadcast of information related to the non-access stratum layers, exchanged between UE and the Core Network
- Broadcast of information related to the access stratum layers, exchanged between SDMB RAN and UE
- Establishment, reconfiguration and release of Radio Bearers
- Initial spot selection

The RRC sub-layer implements algorithms for:

- Power allocation for common channels
- Radio admission control
- Radio resource allocation control

These tasks come under the more generic term of radio resource management (RRM) and are elaborated further in section 3.5.

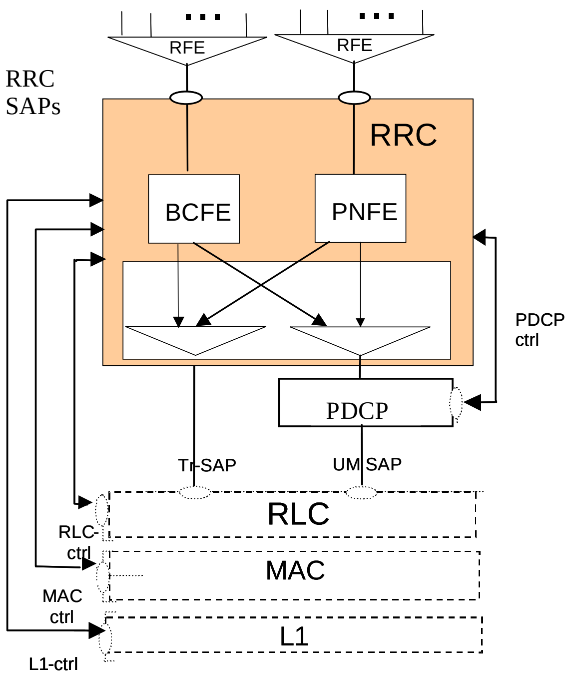

Figure 21: SDMB RRC entities

The RRC functional entities, which are applicable to SDMB are:

- Broadcast Control Function Entity (BCFE): for delivering system broadcast information,
- Paging and Notification Function Entity (PNFE): for notifying UEs of system information modification. This can be useful for informing UEs, which receive SDMB service on a MTCH/FACH and are not capable of decoding simultaneously the BCCH/BCH/P-CCPCH.

The RRC sub-layer implements the following methods:

- **Broadcast of non-MBMS system information** to all UEs in the spot, periodically repeated. This system information is spot specific.
- **Broadcast of MBMS system information** to all UEs in the spot, periodically repeated. This system information is spot specific.
- **Broadcast of MBMS Notification**: This is initiated on request from higher layers on the network side.
- **Control of requested QoS**: This includes the allocation of a sufficient number of radio resources.

3.4.1 Broadcast of system information

System information is segmented in blocks. The SIBs (System Information Blocks) relevant to SDMB and the information they carry are:

- Master Information Block (MIB): CN information (such as PLMN type and identity), and SIBs scheduling information,
- SIB 1: Non Access Stratum (NAS) system information as well as UE timers and counters to be used in idle mode,
- SIB 2: Radio Access Network identity,
- SIB 3: parameters for cell selection and re-selection in idle mode,
- SIB 5: parameters for the configuration of the common physical channels in the cell,
- SIB 7[9]: fast changing parameters UL interference and Dynamic persistence level,
- SIB 11: measurement control information to be used in the cell.

The tables below show the SIB contents for use in the SDMB system based on 3GPP format. The assumption is that the supported PLMN type is GSM-MAP.

[9] If the UE does not receive system information block 7, the cell is considered as barred (as specified in 3GPP release 99 RRC specification)

Information Element	Type and reference	SDMB value
Other information elements		
MIB Value tag	Integer (1…8)	
CN information elements		
Supported PLMN types	Enumerated (GSM-MAP, ANSI-41, GSM-MAP and ANSI-41)	GSM-MAP
PLMN Identity Mobile Country Code (MCC) Mobile Network Code (MNC)	 3*Integer (0…9) 2/3*Integer (0…9)	 Note 1 SDMB Network Code (see Note 2)
References to other SIBs		

Table 12: Master Information Block

Note 1: Code of the country where is installed the gateway which controls the spot coverage area.

Note 2: It is assumed SDMB doesn't belong to a terrestrial mobile operator.

Information Element	Type and reference	SDMB value
CN common GSM-MAP NAS system information	Octet string (1…8)	
CN domain system information CN domain identity GSM-MAP NAS system info CN domain specific DRX cycle length coefficient	 Enumerated (CS domain, PS domain) Octet string (1…8) Integer (6…9)	 PS domain TBD (WP4 specs)
UE timers and constants in idle mode T300 N300 T312 N312	 Integer (100) Integer (0) Integer (0) Integer (1)	Values are not meaningful (their purpose is for RRC connections) but are inserted for UE compatibility
UE timers and constants in connected mode T301 N301	 Integer (0) Integer (0)	Values are not meaningful (no connected mode) but are inserted for UE compatibility

Table 13: System Information Block 1

Information Element	Need	Multi	Type and reference	SDMB value
URA identity	MP		Bit string (16)	Spot identity (Note 1)

Table 14: System Information Block 2

Note 1: Registration Area on a spot by spot basis.

Information Element	Type and reference	SDMB value
SIB4 Indicator	Boolean	False (No SIB4 broadcast in the cell)
Cell identity	Bit string (28)	Spot identity
Cell selection and re-selection info		
Quality measure	Enumerated (CPICH Ec/No,CPICH RSCP)	TBD
Qhyst1s	Integer (0…40 by step of 2 dB)	TBD
Qhyst2s	Integer (0…40 by step of 2 dB)	
Treselection	Integer (0…31)	
Maximum allowed UL TX Power	Integer (-50..33)	-50 dBm : inhibit UL access
Power		TBD
Cell Access Restriction		
Cell Barred	Enumerated (not barred, barred)	Barred
Intra-frequency cell re-selection Indicator	Enumerated (not allowed, allowed)	Allowed
Tbarred	Integer (10,20,40,80,160,320,640,1280) s	TBD
Cell reserved for operator	Enumerated (reserved, not reserved)	Not reserved
Cell reservation extension	Enumerated (reserved, not reserved)	Not reserved

Table 15: System Information Block 3

Information Element	Type and reference	SDMB value
SIB6 Indicator	Boolean	False (No SIB6 broadcast in the cell)
PICH Power offset	Integer (-10…+5) dB	
AICH Power offset	Integer (-22..+5)	
Primary CCPCH info		
Tx Diversity indicator	Boolean	False
PRACH system information list		See TR 102 058
Secondary CCPCH system information		
STTD indicator	Boolean	False
Spreading factor	Integer (4,8,16,32,128,256)	TBD (marketing + capacity simulation : max nb of FACHs+TF)
Code number	Integer (0..SF-1)	TBD: service data rate and protection
TFCI existence	Boolean = True	TBD: service data rate and protection
Fixed or flexible position	Enumerated (fixed, flexible)	Flexible
Timing offset	Integer (0..38144 by step of 256)	Default value : 0
TFCS		
FACH information		
TFS		
Transport channel identity		
CTCH indicator	Boolean	True
CBS DRX Level 1 information		
Period of CTCH allocation	Integer (1…256	TBD (service definition is missing)
CBS frame offset	Integer (0…255)	TBD (service definition is missing)

Table 16: System Information Block 5

Information Element	Type and reference	SDMB value
UL interference	Integer (-110..-70)	Not used
PhyCH information elements		
PRACHs listed in system information block type 5 Dynamic persistence level	1 to<maxPRACH>	Not used
Expiration Time Factor	Integer(1..8)	Not used

Table 17: System Information Block 7[10]

Information Element	Type and reference	SDMB value
SIB12 Indicator	Boolean	False (No SIB12 broadcast in the cell)
Measurement control system information Use of HCS	Enumerated (Not used, used)	TBD (depending on IMR scrambling code allocation strategy)
Cell selection and reselection Quality measure	Enumerated (CPICH Ec/N0, CPICH RSCP)	TBD

Table 18: System Information Block 11

3.4.2 MBMS configuration

Based on [11]:

[10] The values for the SIB 7 are currently specified as 'unused' as the current assumption is that there is no direct satellite return link in the baseline architecture (as described in Chapter 1).

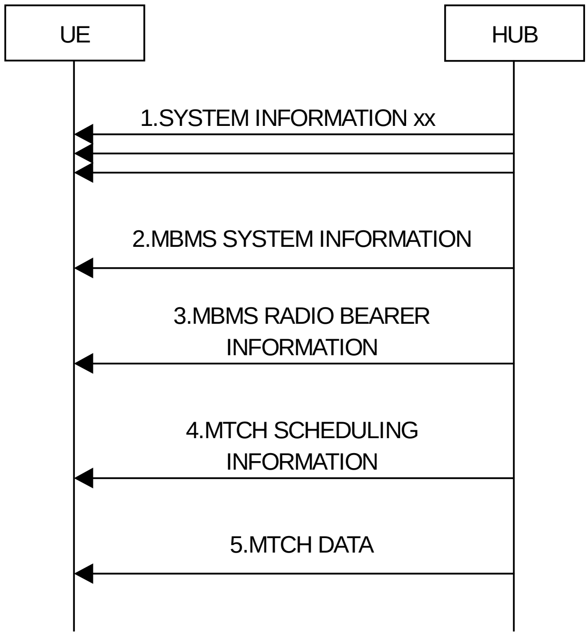

Figure 22: Sequence of procedures related to the support of MBMS over the SDMB RAN

(1) The System information Blocks are broadcast on the BCCH. They contain standard indications and parameters.

(2) The MBMS system information[11] is transmitted on the BCCH to give information about the MCCH.

(3) The MBMS RADIO BEARER INFORMATION is transmitted on the MCCH to give information about the MTCHs carrying data.

(4) The MTCH SCHEDULING INFORMATION is transmitted on the MCCH, and in the case of in-band notification, this information may be carried on MTCHs, to give information on the next MBMS services to be broadcast.

(5) The MTCH DATA is the data flow transmitted on the MTCH containing the downloaded/streamed multimedia content.

3.4.3 SDMB RRC states

After SDMB activation, the UE stays in SDMB Idle Mode. The SDMB RAN has no information of its own about the individual SDMB Idle Mode UEs and it can only address all UEs in a cell or all UEs monitoring a specific paging occasion.

The UTRA RRC Connected Mode is entered when the RRC Connection is established with the UTRAN. When the UE is in UTRA RRC Connected Mode, it automatically switches to the SDMB Disabled Mode.

[11] The work on MBMS system information coding is ongoing in stage 3 within 3GPP; when this is more mature, the actual MBMS SIB content will be incorporated in the relevant SIB table.

After leaving the UTRA RRC Connected Mode, the UE enters the UTRA Idle Mode and comes back to SDMB Idle Mode.

When in SDMB Idle mode, the Inter-RAT (Radio Access Technology) monitoring sub state is entered, where the UE shall perform paging monitoring and neighbour UMTS/GSM cells measurements. These are the usual GSM/UMTS Network monitoring actions performed by a classical 3GPP R99 UE when in UTRA Idle mode. It is required that while downloading the SDMB services, the UE still performs all UTRA Idle mode procedures. In order to do so, specific SDMB/UMTS dual mode modules of the stacks are activated in that state to perform the related processing. Once done, the UE returns to the SDMB Idle mode.

In particular, after SDMB service interruption for listening of terrestrial network paging (e.g. GPRS), UE should perform acquisition of the synchronisation of the SDMB frequency carrier in less than 10 ms.

The following table gives the duration of the activities that can occur when in the Inter-RAT state.

Activity	Period
Paging block decoding	DRX cycle: 2 to 9 51-multiframe or 0.5 to 2.1 seconds
GSM/UMTS adjacent Cell measurement	Same as DRX cycle
GSM/UMTS System information decoding	30 seconds
Search and confirmation of Base Station Identity Code (BSIC) adjacent cells	30 seconds
GSM/UMTS adjacent cells System Information decoding	5 minutes
HPLMN search if national roaming	6 minutes to 6 hours
PLMN search	At user request

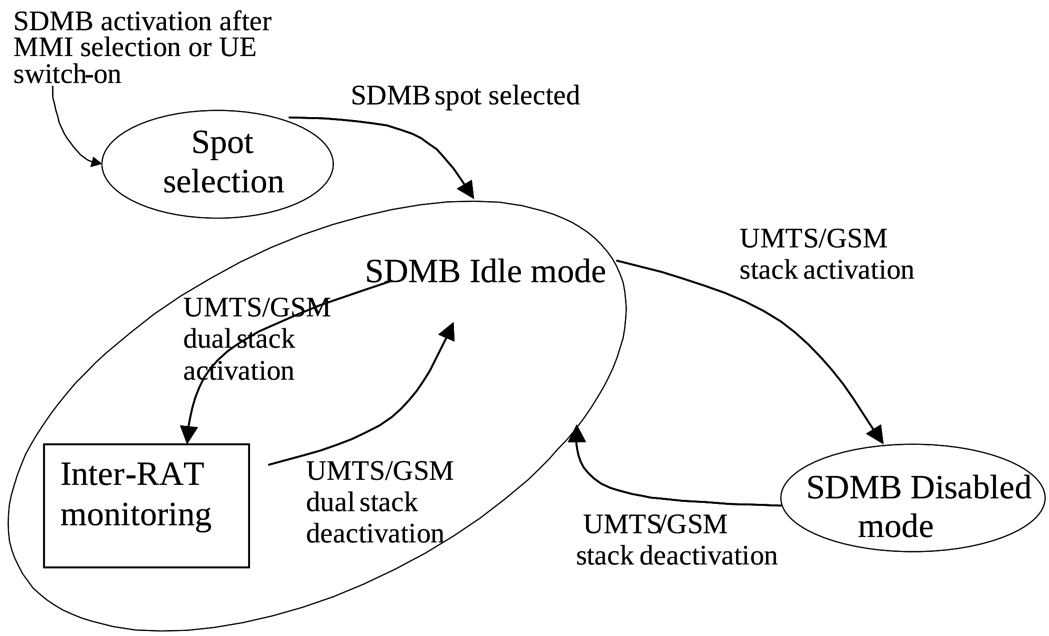

Figure 23: SDMB RRC state diagram

3.4.3.1 Spot selection

This procedure is compliant with the 3GPP cell selection procedure.

3.4.3.2 SDMB Idle Mode

When camped normally on an SDMB spot, the UE shall perform the following tasks:

- select and monitor the indicated MICH of the spot
- monitor relevant System Information
- perform necessary measurements for the spot reselection evaluation procedure
- execute the spot reselection evaluation process on the following occasions/triggers:

  1) UE internal triggers,

  2) When information on the BCCH used for the spot reselection evaluation procedure has been modified

3.4.3.2.1 SDMB Inter RAT monitoring

Based on registration information, the UE will perform periodic inter RAT power measurements and paging monitoring on the terrestrial cell it is registered on.

3.4.3.3 SDMB Disabled mode

This mode corresponds to no SDMB RRC activity in the UE. It could be either caused by disabling the SDMB mode by user choice or by prior activities such as GSM/UMTS connection.

3.5 Radio Resource Management

Radio resources in satellite networks such as bandwidth, transmit power and codes are generally limited due to the physical and regulatory restrictions as well as the interference-limited nature of CDMA networks. In order to support high user densities in CDMA networks, while maintaining high quality in the wireless links, radio resource management is essential. Radio Resource Management (RRM) comprises a set of algorithms that control the usage of radio resources. The RRM functionality is aimed to maximize the overall system capacity in the CDMA network. Future RRM schemes have to be intelligent enough to adapt dynamically to the changing traffic and interference levels of the satellite networks.

3.5.1 SDMB RRM constraints and features

In comparison with the standard unicast T-UMTS network, the SDMB RRM features two additional constraints:

- the absence of a direct satellite return link
- the point-to-multipoint service nature

The net result of the first constraint, which is a hard limitation, is the absence of real-time user feedback that could assist the management of radio resources. The main functions that are affected are the packet scheduling and the power-control functions, namely the short-term radio resource management functions, which have to operate without information on the radio link quality.

In any case, the point-to-multipoint service nature means that, even if user feedback were available, it would have to be used in a non-standard manner. Individual radio bearers address user groups rather than individual users, hence the management of the transmit power has to consider the quality of multiple links corresponding to the users that have activated and receive a data flow.

In conclusion, the short-term radio resource management functions become less relevant for SDMB much as the case is with standard MBMS. In fact, power-control is not applicable to the system at all, whereas power scheduling can affect the reception quality of the end users but has a less detrimental impact on the system throughput than in the standard unicast T-UMTS.

On the contrary, longer-term RRM functions gain in importance and present the SDMB system operator with significant trades-off.

The basic RRM can be classified into the following modules: Packet scheduler, Admission Control, and Radio Resource allocation.

3.5.2 SDMB RRM modules

3.5.2.1 Packet scheduler

The packet scheduler is responsible for two functions in the SDMB access scheme, which are executed with a period equal to the Transmission Time Interval (TTI):

- Time-multiplexing flows with different QoS requirements into fixed SF physical channels, in a way that can satisfy these requirements. The higher priority streaming services feature delay-jitter and rate requirements: the higher the delay jitter values the larger the playout buffer at the mobile terminal has to be. On the contrary, download services may be organized into data carousels that only require the provision of a constant, in long-term, mean rate that will guarantee some target download time.
- Adjusting the transmit power of the physical (code) channels carrying the data flows. Criteria for the power allocation may be the packet/transport block size to be served or knowledge of the expected audience distribution within the beam. This power adjustment is not therefore of the same granularity of the conventional fast power control mechanism but rather limited to a small set of values.

The packet scheduler interacts primarily with the resource allocation module (RRA) that configures the radio bearers over the SDMB radio interface.

The scheduler treats independently at TTI level each physical channel. The exact number of physical channels at a specific time instance and the corresponding mapping of logical/transport channels onto the transport/physical channels are defined by the Radio Resource Allocation (RRA) module.

Let $TBS\ size_{ij}(k)$ denote the kth Transport Block Set (TBS) size of the j^{th} FACH, $1 \le j \le N_i$, mapped to the i^{th} S-CCPCH, $1 \le i \le M$. $N(i)$ is the number of FACHs mapped to the i^{th} S-CCPCH, while K_{ij} is the TF size of the j^{th} FACH mapped to the i^{th} S-CCPCH. We assume that the TBS sizes corresponding to the TFs of each FACH are sorted in increasing order, namely

$$TBS\ size_{ij}(k) \le TBS\ size_{ij}(k+1) \quad 1 \le k < K_{ij} \tag{1}$$

Each Transport Format Combination (TFC) corresponds to a certain number of bits R_l passed from the scheduler to the Layer 1, upper-limited by the maximum allowed data rate of the physical channel. The scheduler is given L TFCs per S-CCPCH, obeying the limitations of 3GPP standards[12]. The task of the scheduler is to select every TTI and for each S-CCPCH i some “appropriate” TFC l, $1 \le l \le L$, featuring a certain TBS size –*TBS (l,m),* $1 \le m \le N(i)$– for each one of the $N(i)$ FACH channels mapped to it. The actual context of the term “appropriate” is

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[12] 3GPP TS 25.302, 25.133/ 25.306

dictated by several factors, like the service QoS requirements and the physical channel utilization efficiency, and differentiates the one scheduler from the other. This differentiation is summarized in the term scheduling discipline, i.e. in the way the semi-statically fixed capacity of S-CCPCHs is time-shared among the different FACHs.

3.5.2.2 Admission Control

3.5.2.2.1 Introduction

The Admission Control (AC) process is an essential and critical procedure for any QoS enabled IP network. AC is responsible for accepting or rejecting new or re-negotiated connections aiming at preserving the required QoS/GoS while making efficient utilisation of the network resources. Especially in the context of W-CDMA mobile data networks Admission Control becomes more critical due to the interference-limited nature of radio interfaces, along with the stringent and diverse QoS requirements of the supported services. On the one hand, Admission Control, being responsible for the admittance of new session requests, limits the traffic load carried over the radio interfaces, guaranteeing that the link level (BER, interference conditions at the physical layer) performance/quality of all established radio connections is maintained, fulfilling the appropriate QoS targets. On the other hand, AC also limits the traffic load on the queuing system (RLC queues, MAC layer), guaranteeing that the packet level performance of the admitted traffic flows is also kept (in a statistical nature) inside the predefined QoS bounds.

In the context of the SDMB access system and service scenarios, the Admission Control procedure is considered to be one of the critical network functionalities. Particularly, the WCDMA technology that is used in the SDMB air interface introduces the concept of soft capacity, enabling various trade offs between capacity, utilisation and achieved end-user QoS. This flexibility in the air interface can be handled efficiently using intelligent algorithms to control/regulate the establishment of new radio bearers over the air-interface, namely Admission Control Algorithms. Additionally, the definition of efficient AC strategies becomes a critical issue for SDMB and MBMS systems, in general, due to the nature of the supported streaming multimedia applications. The great sensitivity of these services in terms of QoS, calls for a more careful control of the interference levels along the radio interfaces and also control of the load on the queuing system.

3.5.2.2.2 SDMB access scheme constraints and requirements on Admission Control

The access layer architecture adopted in the SDMB system poses new limitations and requirements on the design of Admission Control procedures. SDMB access layer relies on a unidirectional radio interface, where there is no return link and consequently, no real time feedback information from the UE-side is available to the SDMB RAN-side of the access system. This major characteristic of the SDMB access layer architecture differentiates MBMS Admission Control functionality with those algorithms defined for the standard UTRAN radio interface. Particularly, the absence of a real time return link means that no information related to the radio link quality (channel state conditions, bit error rate…) or perceived QoS is available at the SDMB RAN. As a result, it is not possible to facilitate any kind of resource allocation adjustment/reconfiguration (in terms of power/data-rate/SIR target allocation) depending on the system evolution (user mobility, changing propagation conditions and interference levels). From this point of view, the Admission Control procedure becomes particularly challenging, being the only procedure responsible for the long-term resource reservation and power allocation. Finally, within the SDMB access layer architecture fast short-term RRM procedures are either constrained (e.g. less information available for optimisation of the packet scheduling procedure, impossible to implement reactive load control/congestion relief algorithms) or cancelled (i.e. power control). Consequently, medium and long-term functions such as Admission control become more important and call for higher than average precision.

3.5.2.2.3 Admission Control functions

3.5.2.2.3.1 Signaling Exchange between SDMB RNC and SDMB SN

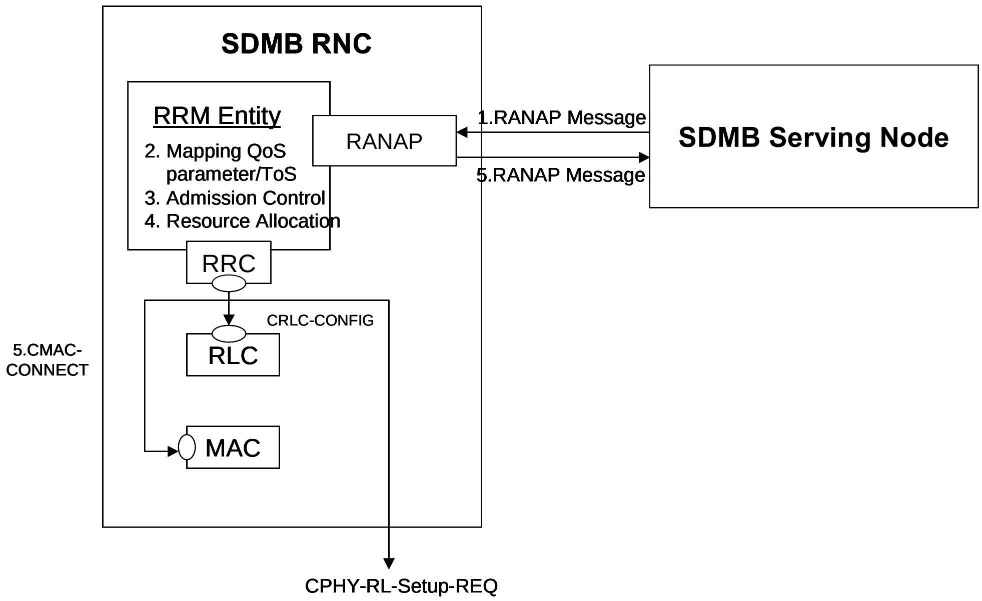

Figure 24: AC performed in SDMB RNC

Admission Control is executed during the session establishment process, i.e. following the MBMS Session Start Request [(step 2) with respect to the flow diagram in Figure 5]. The main signaling exchange for Admission Control establishment is carried over the RANAP signaling protocol.

A session set-up procedure involves the RANAP protocol through the following steps as also illustrated in Figure 24:

1. The SDMB SN (Serving Node) requests from the SDMB RNC to establish a p-t-m RAB indicating QoS parameters.

2. According to QoS parameters the requested service is assigned a type of service.
3. AC is performed according to the type of service.
4. Resources are allocated according to the result of AC.
5. Acknowledgement is sent back to the SDMB SN according to the result of AC. Sub-layers are configured accordingly by the RRC

RANAP, being the main signalling protocol running over the Iu interface, connects SDMB RAN to the SDMB SN. It is essential for overall RAB management, including set-up, modification and release of RABs.

RANAP is involved in the Admission Control process through the Elementary Procedures and Messages shown in Table 19.

The purpose of the RAB Assignment procedure is to establish new RABs and/or to enable and/or release of already established RABs for a given MBMS service. The procedure uses connection-oriented signalling.

Elementary Procedure	Initiating Message	Response Message
RAB Assignment	RAB ASSIGNMENT REQUEST	RAB ASSIGNMENT RESPONSE
	RAB MODIFY REQUEST	NONE
	RAB RELEASE REQUEST	NONE

Table 19: **RANAP Elementary Procedures and Messages involved in Admission Control Process**

The SDMB SN initiates the procedure by sending RAB ASSIGNMENT REQUEST message. When sending the RAB ASSIGNMENT REQUEST, message the SDMB SN shall start the $T_{RABAssgt}$ timer (in order to abort the session set-up procedure at timer expiration).

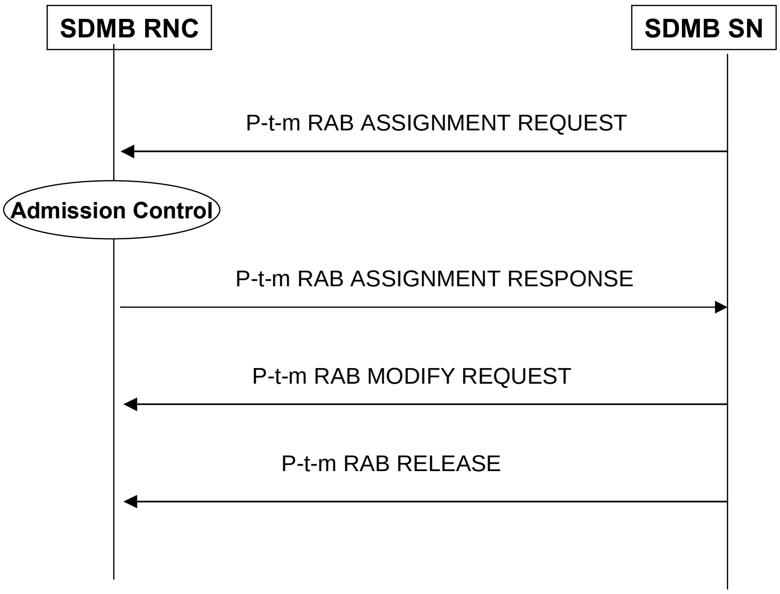

Figure 25: AC related RANAP signalling

The SDMB SN may request the SRAN to:

- establish
- modify
- release

one or several RABs with one RAB ASSIGNEMENT REQUEST message.

The message shall contain the information required by the SRAN to build the new RAB configuration, such as:

- list of RABs to establish or modify with their bearer characteristics
- list of RABs to release

For each RAB requested to be established the message may contain several parameters among them RAB ID, NAS Synchronisation Indicator, RAB parameters, User Plane information, Transport Layer information, PDP Type information, Data Volume Reporting Indication.

For each RAB, whose release is requested, the message shall contain:

- RAB ID
- Cause

The most essential Information Element (IE) relevant to the Admission Control process is the "*RAB Parameters*".

The purpose of *RAB parameters IE* group is to indicate all RAB attributes (as defined in 3GPP 23.107 [21]). Among these parameters, those listed in the following table are used at AC stage.

RAB Parameters	IE Reference	Usage on AC
Traffic Class	Conversational, streaming, interactive, background, ...	Defines relative priority of RABs
Maximum Bit Rate	Maximum bit rate requested	Maximum BW requirements
Guaranteed Bit Rate	Guaranteed bit rate for the connection	Minimum BW requirements
Allocation/Retention Priority		Defines RAB pre-emption strategy

Table 20: **RAB Parameters**

For a more detailed description of RAB parameters the reader may refer to TS 25.413 [22].

3.5.2.2.3.2 RNC Internal interfaces

The RRC protocol is the key protocol within SDMB RAN. It supports all RRM functionalities, coordinating the execution of resource control requests, which result from the decisions made by the RRM algorithms. In order to implement this functionality, RRC has the overall responsibility for the configuration of all other lower layer entities including RLC, MAC and Physical Layer. Additionally, Admission Control being the only long-term load control procedure in the context of SDMB, needs information related to the actual instantaneous radio resource allocation, in order to optimise and adopt its decision according to the estimated interference conditions, resource consumption and queuing load in the RLC queues.

RRC-MAC is an internal protocol interface and consequently precise standardisation is not needed. However, some general aspects of this interface are analysed in this section.

First of all, the RRC–MAC interface is bi-directional. The RRC configures the MAC sub-layer (e.g. maximum and minimum QoS levels for each admitted traffic flow) and the latter reports appropriate measurements and statistics (e.g. RLC buffer size, TFCS usage) to the RRC. Hence two unidirectional interfaces can be identified:

- RRC to MAC
- MAC to RRC

RRC to MAC interface

Admission Control is an event driven RRM procedure being executed whenever a new MBMS session set up request arrives at the SDMB RNC. In turn, the Admission Control checks the availability of radio resources to serve the new request according to the session's QoS profile submitted to AC via RANAP signalling. In case the user group's QoS profile enables QoS negotiation, it is possible that AC admits the specific traffic flow with reduced QoS attributes. Hence, AC returns a boolean value indicating its decision (accept/reject the new request) and also defines the QoS bounds (e.g. min, max bit rate) for the delivery of the service flow over the satellite radio interface. These QoS bounds are essential to configure the MAC layer, since short-term resource allocation (decided by MAC) cannot exceed the maximum data rate negotiated during Admission Control procedure.

MAC to RRC interface

Admission Control optimisation and adaptation to current system load, requires feedback information regarding the instantaneous system load. This information includes instantaneous data rate, instantaneous power allocation, RLC buffer size and it is submitted to AC through the MAC-RRC interface.

AC State machine

This section describes the internal working of the AC Functional Block by means of a Finite State Machine (FSM).

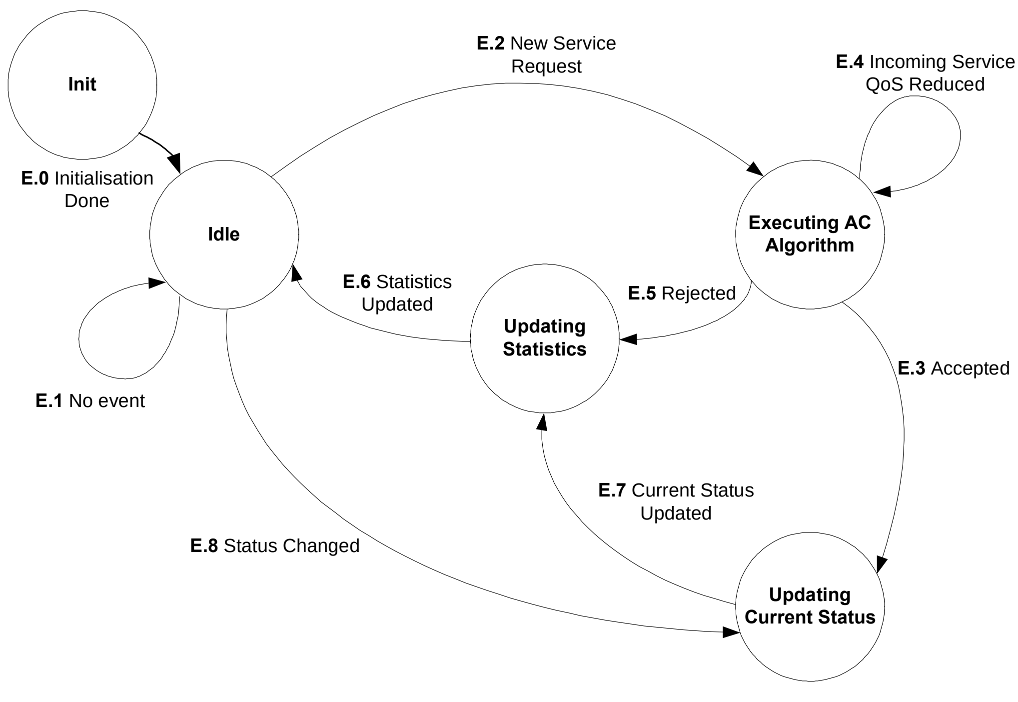

Figure 26: The Finite State Machine (FSM) of the AC functional block

Description of states

- **Init:** all functions to initialise the AC block are performed during this state.
- **Idle:** state at which external requests and notifications are expected.

- **Executing AC Algorithm:** during this state the AC algorithm is being executed and the relevant criteria are being examined, after the arrival of a new service request. More detail can be found in Appendix A
- **Updating Current Status:** during this state the view of the current status is updated to depict the changes following the acceptance of a service request or changes performed by the packet scheduler and/or load control.
- **Updating Statistics:** at this state the AC-specific statistics are updated.

Event-name	Parameters	Description
E.0		All initialisation tasks have been completed.
E.1		There is no service request; the system remains in the IDLE state.
E.2	QoS parameters, Service ID	This event indicates that a new service request has arrived.
E.3	QoS parameters, Service ID	This event indicates that the incoming service request has been accepted.
E.4		This event indicates that the AC algorithm will be repeated with reduction of the required QoS.
E.5	Service ID	This event indicates that the service request cannot be admitted in the system due to lack of resources.
E.6		This event indicates that the necessary statistics were updated and the service requestor has been informed of the rejection.
E.7		This event indicates that the current status has been updated successfully.
E.8	Resource allocation configuration	This event indicates a change in the status due to actions taken by the Packet Scheduler or Load Control.

Table 21: AC FSM State Transitions

3.5.2.3 Radio Resource allocation

We have chosen to discuss the Radio Resource Allocation function as a separate module, although its role is intermingled with the other modules and the border among them is often blur. The RRA module, in our context, is responsible for the radio bearer configuration. This task refers to the channel mappings across the layers of the SDMB radio interface and the parameterisation of PDCP/RLC/MAC functions as well as RRM entities. The decisions of the RRA function are communicated to both the AC and PS modules, so that they can be taken into account in these modules' own decisions.

The channel mappings concern both the control and user planes, whereby the RRA has to decide whether and how to multiplex logical channels (MTCHs/MSCH/MCCH) over transport channels (FACHs) and then, in turn, FACHs onto fixed spreading factor physical channels (S-CCPCHs). Figure 27 depicts an example of the different configurations of channel multiplexing, which essentially consists of logical channel multiplexing performed at Layer 2 (where MTCH 1 and MTCH 2 are multiplexed onto FACH 1, while MTCH 4 and MTCH 5 are multiplexed onto FACH 5), and the transport channel multiplexing performed at Layer 1 (where FACHs 1 to 4 are multiplexed onto S-CCPCH 1, while FACHs 5 and 6 are multiplexed onto S-CCPCH 2).

For logical channel multiplexing, it has to be made sure that the information carried on both the logical channels have similar characteristics and QoS requirements; otherwise, the radio resources would be used inefficiently. The advantage of having logical channel multiplexing is the reduction in the size of the TFCS. Transport channel multiplexing would, on the other hand, enable the use of transport blocks matched to the individual requirements of signalling as well as user data. Furthermore, the gain in performing transport channel multiplexing is the reduction in the codes utilized. However a higher number of multiplexed flows at the physical layer will result in the quick growth of the TFCS in order to efficiently track the packet-level dynamics of the flows.

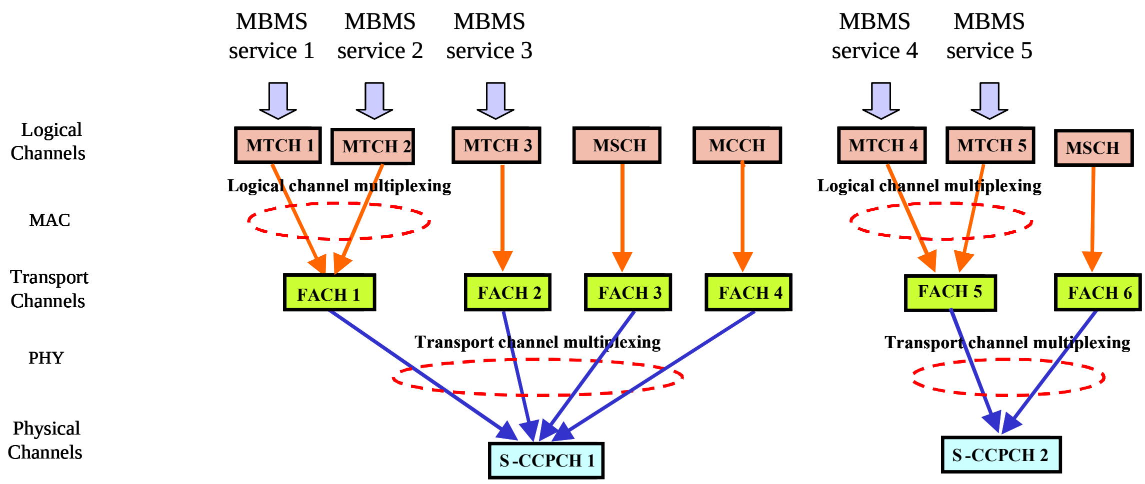

Figure 27: Channel multiplexing example

One of the main issues regarding the multiplexing options from the aspect of RRM is the placement of the MSCH and MCCH. For MSCH, it has been agreed that the MSCH is always mapped onto a separate FACH than MTCH due to their different tolerance to data loss [56]. Since MSCH carries the 'Service transmission schedule' that indicates when and what MBMS service is expected to be transmitted on an MTCH (this information can be used by the UE to perform DRX for battery saving purposes), it is transmitted on each of the S-CCPCH that carries the MTCH [11].

For MCCH, it is to be decided whether it should be:

i. carried on the same S-CCPCH as MTCHs or

ii. carried separately on a standalone S-CCPCH,

where both options are currently permitted by TS 25.346 [11].

According to the first option, the MCCH is always mapped on a separate FACH from MTCH, whereby the physical TFCI field is used to identify the respective FACH each logical channel is mapped to. This separation is mainly because the information carried on the MCCH has different characteristic and requirements compared to that carried on the MTCH. For instance, the signalling messages on MCCH are typically smaller compared to the user data on the MTCH, and the transport format for the radio bearer of MTCH changes for every occurrence of new MBMS service while the MCCH would have quite constant transmission bit rate (the transport format for the radio bearer of MCCH is pre determined with its configuration defined in SIB). Note that with the first option, the TFCS reconfiguration will happen frequently since the transport format for the radio bearers carrying MTCHs is redetermined whenever a new MBMS service flow (MTCH) is added to the same physical channel.

On the other hand, when the MCCH is placed on a standalone S-CCPCH with the second option, any changes to the radio bearer upon addition/removal of a FACH (MTCH) will not affect the TFCS of the S-CCPCH carrying the MCCH. Nevertheless, with the second option, the UE will need to receive an additional S-CCPCH simultaneously, which may not be possible depending on UE capabilities. Note that in T-UMTS, this second option is used when soft-combining is employed, whereby the MCCH is mapped to a separate S-CCPCH than the MTCH [11].

It must be noted that the discussions on the alternatives for these logical and transport channel multiplexing for MBMS are still going-on within 3GPP at the time of writing. A summary of the channel multiplexing options as adopted within the SATIN project can be found in Appendix D.

4 SUBSET OF ACCESS SCHEME FUNCTIONALITY RELEVANT TO MAESTRO TEST BED RELEASE 2

In this chapter, we describe the access scheme functionality that will be implemented in the test bed Release 2. The description is relative, namely we highlight the aspects of the scheme that change with respect to the test bed Release 1 implementation described in [3] as well as to the system commercial implementation described in chapter 3.

4.1 MAESTRO test bed Release 2 overview

The Release 2 of MAESTRO test bed aims at validating the feasibility of the MAESTRO SDMB system. In the scope of Release 2, MAESTRO study includes setting up two platforms representative of an SDMB system. One of these platforms will be dedicated to laboratory trials while the other one will be used for field trials.

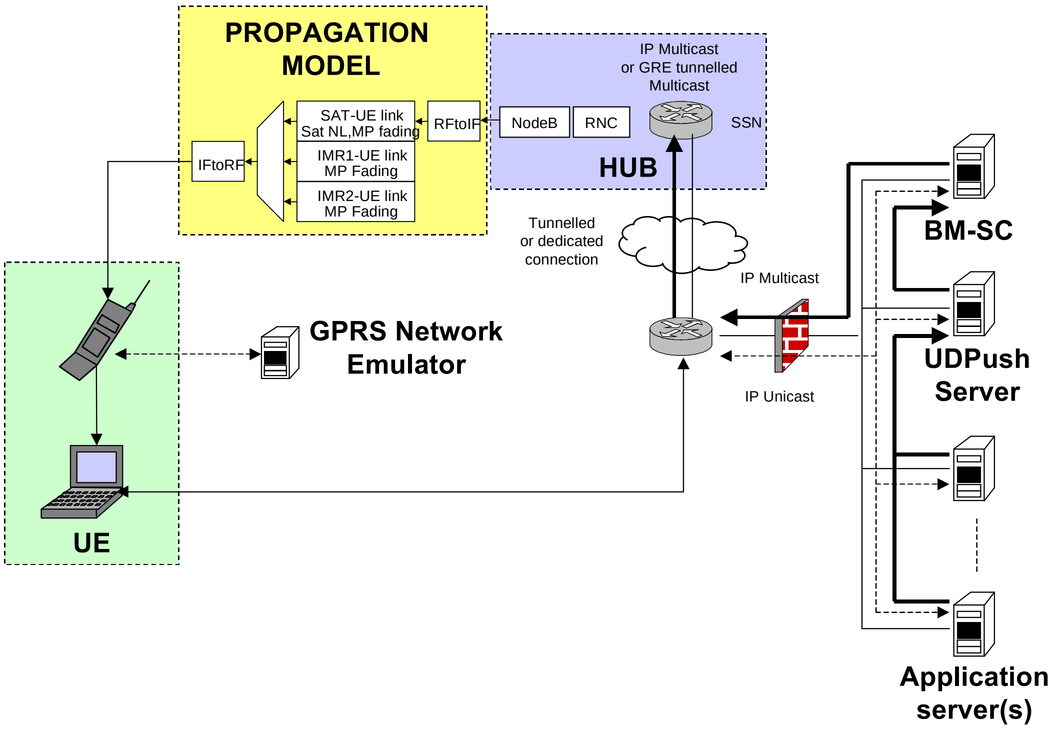

Figure 28: Lab propagation test bed

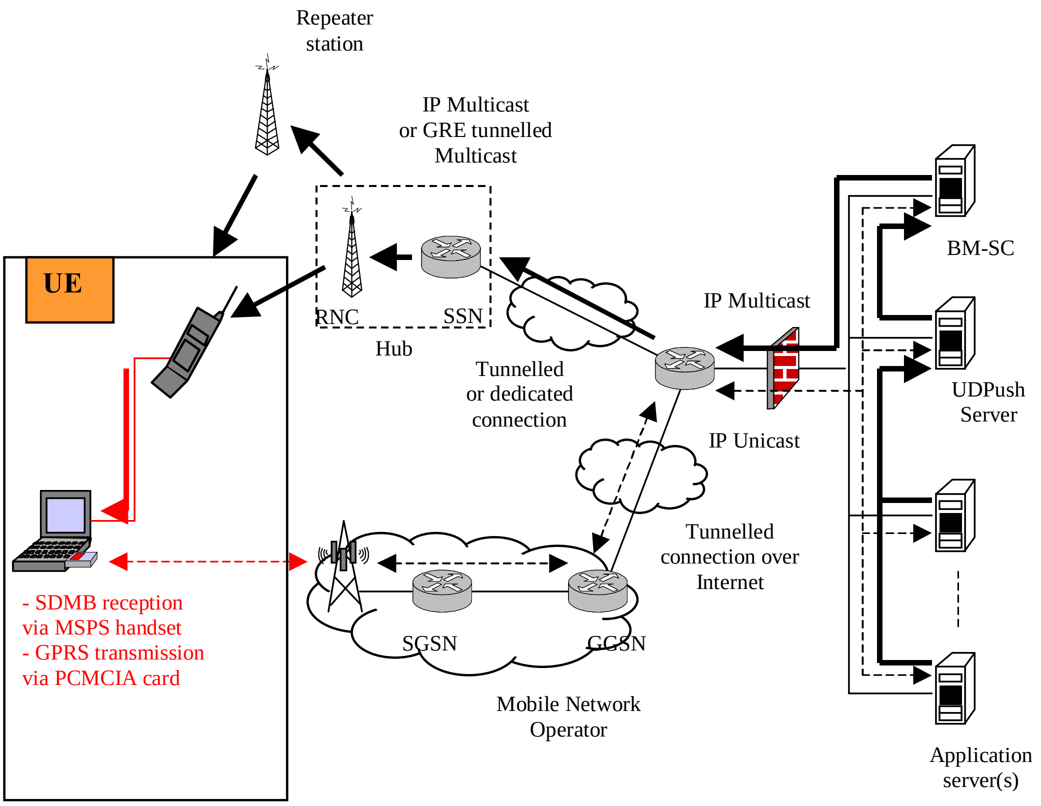

Figure 29: Field propagation test bed

The Release 2 test beds will be built on the Release 1 ones. The main upgrades will consist in integrating both the BM-SC and a 2G terrestrial network to the existing platforms.

The goal of the laboratory test bed is to provide a platform to consolidate simulation results. Therefore, one of the key features of that platform is to allow reproducibility.

As in MoDiS, the goal of the field test bed is to demonstrate the feasibility of the SDMB system but using a terminal built on a commercial UE which features a higher integration level and a complete UMTS/GPRS protocol stack.

4.1.1 Description

The aim of the test bed is to prove the SDMB concept via the validation of:

- GPRS Idle camp
- Calibration of appropriate DRX period
- SDMB downlink only UE setup

In test bed R2, no UMTS idle mode procedures as specified in the commercial version of SDMB will be taken into consideration. The initial UE UMTS stack will be converted to an ‘SDMB Release 2’ stack.

4.1.2 Test bed scope with respect to access layer

Basic features to test at the 2G access layer are:

- 2G registration and camp
- Neighbouring cells power measurements and best cells decoding
- Selected cell paging monitoring

Basic features to test at the SDMB 3G access layer, while doing 2G Idle mode procedures mentioned above, are:

- Reception of system information blocks over BCCH in UE SDMB idle mode
- Reception of several data-rate downlink FACHs
- PC post-processing (versus UE Man Machine Interface)

The addition of both of these activities must be tested.

4.2 Access layer in Release 2 MAESTRO test bed

Compared to Release 1 which focused on a 3G only environment, the Release 2 test bed both interacts with a 2G network and synchronizes with an SDMB spot. In the test bed Release 1, the SDMB spot search and download procedure was triggered at UE power up. In the test bed Release 2, the Dual Mode UE first registers on a 2G network before starting SDMB related procedures. It also monitors the 2G selected and neighbouring cell information as per 3GPP. The SDMB activity is therefore time multiplexed with common 2G idle mode activities.

4.2.1 Release 2 Access layer

In UMTS release terms, the Release 2 MAESTRO test-bed is based on the 3GPP Release 99 specifications (August 2002 version).

Release2 MAESTRO test-bed is built with the introduction of GPRS features at the UE side for GPRS paging listening.

GPRS paging listening is specified as a first priority in the UE receiver regarding SDMB service reception.

Thus, for the UE, the main differences between Release 1 and Release 2 test-bed lie in the:

- SDMB service reception coexisting with GPRS paging listening
- SDMB data blocks recovering after reception interruption.

At the SDMB infrastructure side, the difference lies in the service transmission (periodical) repetition. Service retransmission is managed by the BM-SC. The BM-SC labels each SDMB session with a session identifier to allow UEs to distinguish the SDMB session retransmissions.

Going into details, the SDMB Release 2 protocol module roles can be split in the following way:

Role 1: It hosts a downlink only SDMB signal receiver, based on slight 3G stack modifications of a 3GPP Release 99 compliant commercial UE. The goal is to keep these modifications as minimal as possible in order to reduce the potential implementation effort of SDMB features in a future 3GPP phone.

Role 2: The main functionality of the UE is still its 3GPP usual activities. In the scope of test bed Release 2, these are reduced to registering on a 2G PLMN, selecting a cell, camping on it in GPRS Idle mode.

a. Once this is achieved, between two paging blocks, instead of saving battery lifetime, the UE shall proceed as an SDMB signal receiver, i.e. it should download SDMB data broadcast by satellite/IMR as long as possible.

b. The UE shall also perform its usual neighbouring cell monitoring procedures: power measurements, system information decoding, etc.

Role 3: When a 2G incoming call occurs, the UE shall stop all SDMB activities and indicate to the user by a tone that an incoming call has been triggered. The call should not be handled by the UE in the scope of Test bed Release 2.

Role 4: On trigger of the Reliable Transport Layer, the UE shall be able to interrupt all SDMB activity and establish a data transfer with the 2G network. The purpose of this data transfer is to request the content provider database shared between terrestrial and satellite network to retransmit the packets[13] that were lost during satellite transmission.

4.2.1.1 Engine stack overview

The figure below gives an example of 3GPP dual mode engine stack architecture. This figure represents 2G and 3G modules separately, although design and implementation can clearly assume in one module both RAT functionalities.

The sections below go into the details of the four engine stack roles listed above.

[13] Retransmission will be through the terrestrial network.

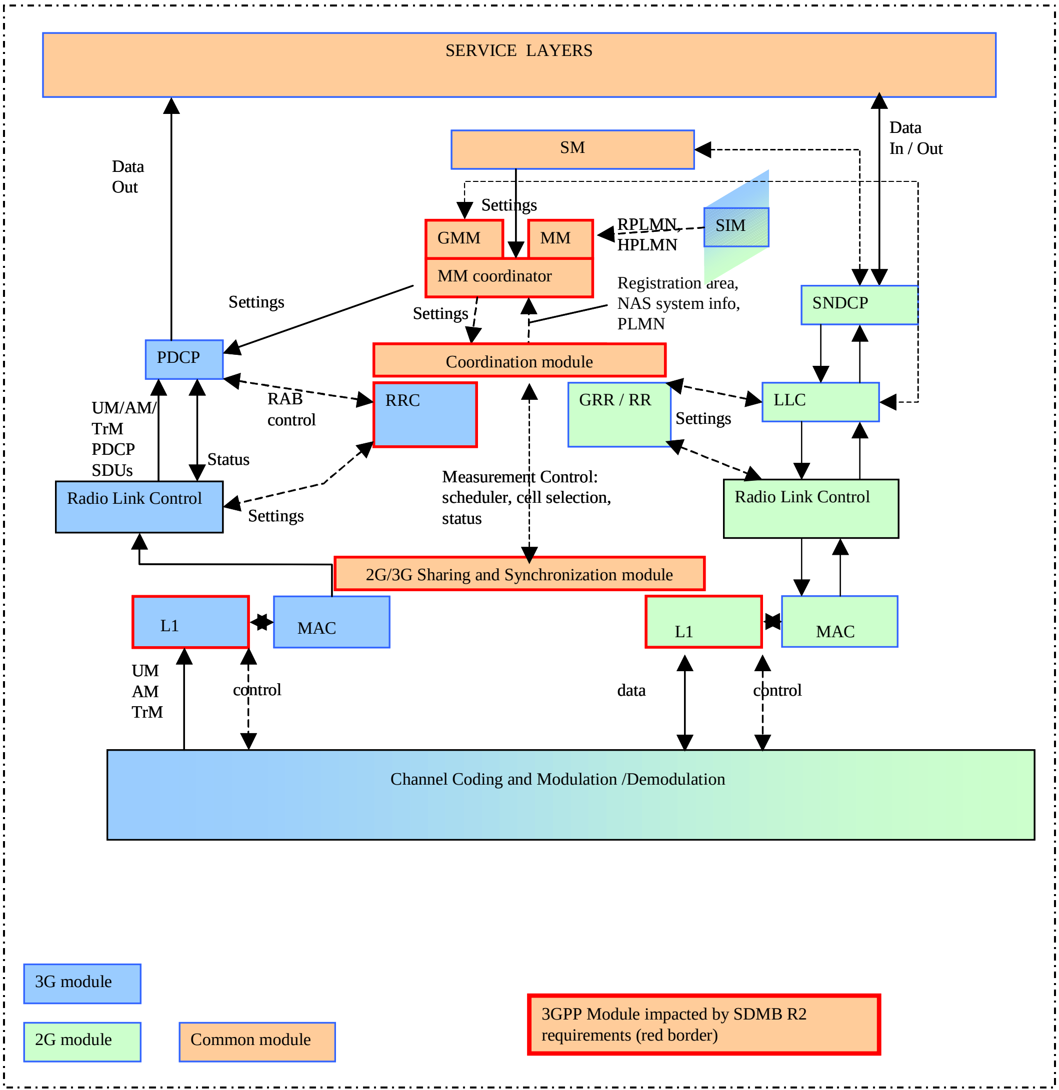

Figure 30: UE 2G/3G module decomposition

It is interesting to separate 2G and 3G modules to point out which specific 2G or 3G module the Test Bed Release 2 specifications impacts. The synchronization modules between 2G-3G at L1 and RR level must be changed. For instance, any 2G monitoring when in 3G is useless, since 3G has been modified to download SDMB only purposes. Also, any inter RAT cell reselection or handover must be frozen. On the other hand the synchronization modules need to be modified in order to activate SDMB download processing during 2G low processing periods.

4.2.1.2 GPRS idle mode capability

4.2.1.2.1 Idle Mode environment

This section focuses on the actual GSM 3GPP compliant activity set that the SDMB UE will execute in the scope of Test Bed Release 2. Basically, the UE's GSM activity is compliant to the Release 97 specifications in GSM/GPRS Idle mode. The goal of listing these is to capture the potential "no processing" periods when the UE can perform SDMB downloads. For more details on each point mentioned, please refer to 3GPP specifications.

There are 4 different phases in the Idle Mode lifetime of the UE:

- Camped phase (camped on a cell, listens to its paging sub channel, monitors neighbouring cells)
- Reselection (perform cell reselection, camp on a cell after having released a dedicated channel)
- *RACH (establishment of a dedicated channel): this will not occur as long as SDMB stack is active.*
- *PLMN search: in the scope of Release 2, PLMN search shall be performed once at power up, or when any connection to the network is lost.*

Another way to describe the Idle mode activity is to list the main tasks performed by the UE:

- Serving cell management
- Neighbouring cells management
- Reselection Management
- *Establishment of a dedicated channel: does not occur if SDMB stack is active*
- *PLMN search: occurs once at most of the time*
- *Power saving management*

To achieve these, the UE monitors mainly the following logical channels in IDLE Mode:

- FCH / SCH : Frequency / Synchronization CHannel :

- BCCH : Broadcast Control CHannel

- PCH : Paging CHannel

- AGCH : Access Grant CHannel

- CBCH : Cell Broadcast Channel

In the scope of Release 2, the tasks of interest while camping as Idle 2G and performing SDMB download are serving cell, neighbouring cells and reselection management.

4.2.1.2.2 Idle Mode Scheduler Principle

The 2G processing periods are identified below.

4.2.1.2.2.1 Serving cell management

- Measures Received Signal Level (RXLev) of serving cell (measurements are made on each paging blocks).

- Listen to FCCH/SCH channels at least every 3 seconds.
- Listen to BCCH channel at least every 30 seconds.
- Listen to PCH channel:
- Normal paging: reads PCH block from the paging channel,
- Paging reorganization: listen to full CCCH and BCCH channels.
- Manages the downlink signaling failure (DSF) counter.
- Listen to CBCH channel.

Compute C1 and C2 criteria at least each 5 seconds.

Actions	Module involved	Frequency
Power Measurement	L1	On each paging block
System Information (BCCH)	RR and L1	Every 30 seconds
Frequency Correction	L1	Every 3 seconds
Timing Synchro	L1	On each paging block

Table 22: Serving Cells Actions

4.2.1.2.2.2 Neighboring cells management

- Measures RXLev of the RF carriers given by the network (BA list).
- Listen to FCCH/SCH channels (of the 6+ list) at least every 30 seconds.
- Listen to BCCH channel (of the 6+ list) at least every 5 minutes.
- Update the list of 6 strongest RF carriers (6+ list).
- Compute C1 and C2 criteria (for the 6+ list) at least each 5 seconds.

Actions	Module involved	Frequency
Power Measurement	L1	According to network parameters. Located around the paging blocks
Frequency Synchronization (FCH)	L1	When the cell enters in the 6 best cell group
SCH +BCCH decode	L1	Every 30 seconds
Refresh the 6 best cell group	L1	specific

Table 23: Neighbouring Cells Actions

C1: C1 serving_cell < 0 (for 5 seconds)
C2: C2 adjacent_cell > C2serving_cell (for 5 seconds)
DSF: too many decode errors on PCH blocks
Cell Barred: serving cell becomes barred
PLMN changed: PLMN of the serving cell is not the HPLM

Table 24: Reselection criteria

The information above shows that in IDLE mode, events frequency is very low (~ 1s for each paging block). The UE will use the idle time to do 3G SDMB content download.

4.2.1.2.2.3 Reselection management

2G reselection occurs as per 3GPP release 99 specifications.

4.2.2 Release 2 Access layer modifications[14]

Since the MAESTRO test-bed Release 2 is based on the 3GPP Release 99 specifications (August 2002 version), the following differences with respect to the commercial implementation could be pointed out:

4.2.2.1 SDMB air interface architecture and radio link layer description

Most aspects of the interface remained unchanged, namely the organisation of the interface in layers/sub-layers. The main difference is related to the access scheme channels:

- At the RLC layer, there are no MBMS specific channels, namely the MTCH and MCCH are absent. The Dedicated Traffic Channel (DTCH) is used for MBMS data transfer instead. The Common Control Channel (CCCH) would be the analogue of MCCH for MBMS signaling.
- Likewise, the MBMS notification indication Channel (MICH) is not available. Although the notification of idle-mode users for changes of the transmitted data could be envisaged on the unused bits of the Paging Indication Channel (PICH), the limited scope of this test bed release makes this feature redundant.

Therefore, the channels that are relevant to SDMB 3G modules in the MAESTRO test bed Release 2 can be summarized by the figure below.

[14] Note that the access layer described here is similar to the ones defined for the test bed Release 1 [3].

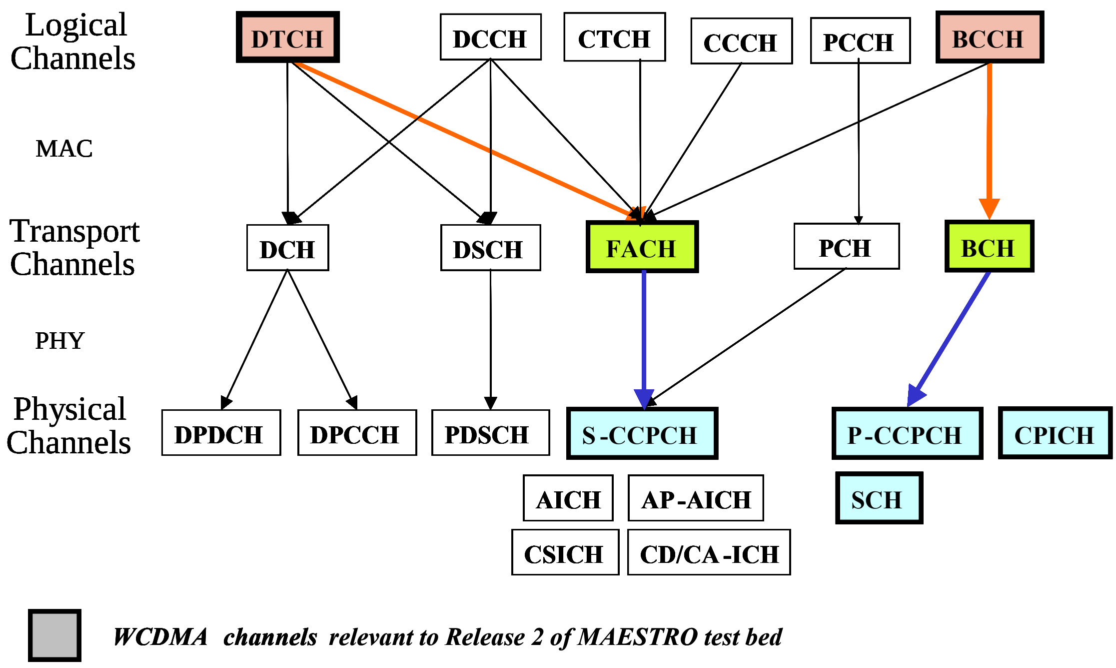

Figure 31: WCDMA channels relevant to Release 2 test bed

As a result, the individual layer functions described in section 3.3 are the same for the physical layer and the RLC layer.

There are minor differences in the MAC functions, namely the addition of the MBMS id on the SDMB RAN side and its reading on the UE side are not implemented.

Finally, the PDCP functionality in section 3.3.3 will not be tested in the test bed.

The service repetition required for Release 2 test-bed is managed at BM-SC level, i.e. it is transparent to SDMB Radio Access Network. Consequently, SDMB air interface architecture and radio link layer are not modified for Release 2.

4.2.2.2 Procedures for the support of MBMS within the SDMB RAN

The first release of the test bed mainly focuses on the evaluation of access layer and radio layer features [24]. Therefore, only a small subset of the procedures described in section 3.2 will be implemented. These procedures are described in section 4.2.2.3.

Due to the fact of that service repetition occurs at the BM-SC, the Release 2 of the test-bed does not cause any impact at the SDMB RAN side.

4.2.2.3 Radio Resource Control Layer (RRC)

4.2.2.3.1 SDMB 3G test bed procedures on the SDMB 3G RAN side

This paragraph gives the summary of the procedures that will be implemented regarding the SDMB 3G aspects of the test bed from the SDMB 3G RAN point of view, whereas section 4.2.2.3.2.1 deals with the procedures that are to be dealt within the 3G modules in the UE.

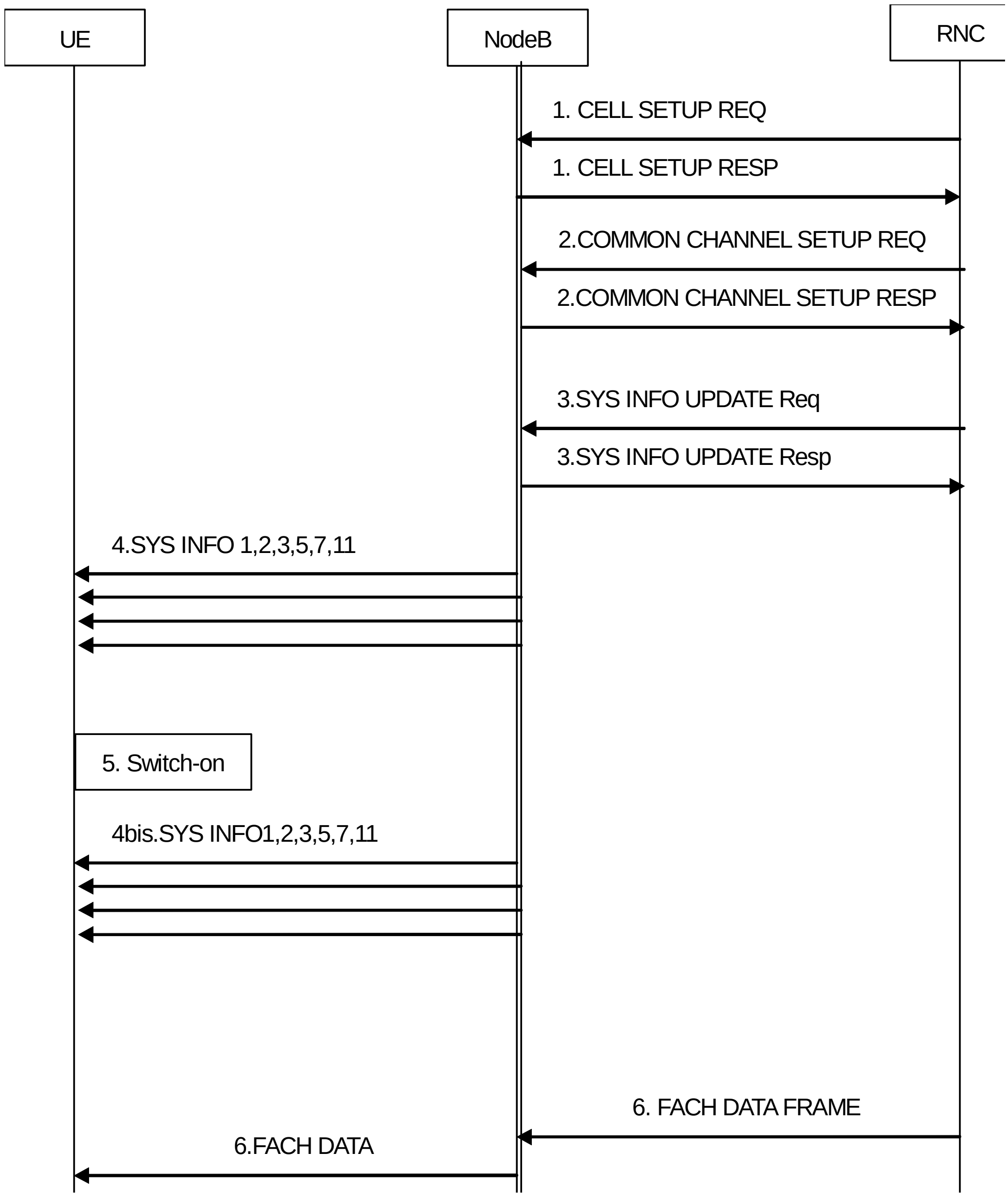

Figure 32: FACH initialization and MBMS data transfer in the MAESTRO Release 2 test bed

1. At system initialisation the RNC requests the cell/spot configuration from the Node B. The Node B performs the configuration of the cell/spot. CPICH(s), Primary SCH, Secondary SCH, and Primary CCPCH become available.
2. The Node B sets up the common channel on request from RNC. Now, the user plane for the DTCH/FACHs is established (1 for each FACH).
3. The RNC compiles all the SIBs using the Node B Application Part (NBAP) system information update procedure(s) [TS 25.433].
4. The node B periodically broadcasts the configured SIBs.

5. The UE switches-on and executes the cell synchronisation procedure. The UE receives all the required SIBs. System Information Block 5 is broadcast containing the FACH configuration for the UE. A mechanism shall inhibit the first UE RRC connection request and fake the network attachment for the upper layers. The UE is in the “camped normally” RRC state of the idle mode (see TS 25.304). The UE is able to receive data sent on the configured FACH.
6. The data are sent by the RNC on the FACHs and received by the terminal.

For more details about the content of SIBs, see Appendix C.

4.2.2.3.2 UE 3G module actions for support of test bed procedures

The following scenario has been proposed as a rational implementation that satisfies the requirements. The actions are discussed in the chronological order of procedures that are undertaken from the UE standpoint, and give a picture of the tradeoffs that have been introduced in the context of the second test bed release.

4.2.2.3.2.1 Cell selection and Camping

The RNC simulator shall provide the required physical channels for the UE to camp: SCH, CPICH, P-CCPCH.

Using these channels, the UE will perform the classical power scan on the usual 3GPP frequencies, synchronise and read information about the PLMN of the RNC simulator (BCCH).

REQUIREMENT: The PLMN value listed in the MIB must be a Preferred PLMN for the UE USIM.

At this point, the UE is considered to be ”normally camped” on the serving cell.

4.2.2.3.2.2 IMSI Attach

The next step that is normally undertaken is location update or routing area update triggered by the MM layer in the UE. However, this procedure will be bypassed in the following manner:

- the UE MM layer sends a Location Update/Routing Area Update primitive to the UE RRC layer.
- the UE RRC then sends a reply primitive to UE MM (without establishing the RRC connection as specified in 3GPP), giving the appropriate value to MM for the TMSI as it would have been assigned by UTRAN, in the context of the standard IMSI attach procedure described in TS 24.008.

At this point, the UE is considered as registered in the SDMB RAN.

4.2.2.3.2.3 “RRC Connection Establishment”:

The next step in the 3GPP procedure is for the UE to enter a state in which it can be paged in case of incoming calls, or initiate a PS or CS connection with the network.

In both cases, the UE has to set up an RRC connection. However, this implies uplink signalling on the RACH, which is not possible in the SDMB case due to the absence of return link. The proposal for the Release 2 test bed is to bypass this procedure as well, by performing a fake RRC connection establishment using only System Information read on the BCCH to configure the UE SDMB stack.

After reading the respective SIB (SIB 5), the UE RRC layer will receive a primitive as if it has received the RRC_CONNECTION_SETUP message from UTRAN, and then configure its physical, MAC, RLC and PDCP layers. This solution is indeed rational, as the same FACH on which the UMTS stack is configured to read the RRC_CONNECTION_SETUP message is to be used for the subsequent data transfer for the test bed.

REQUIREMENT: The System Information Blocks must be properly set for the FACH download. Only one S-CCPCH will be used to carry the FACH(s). Current UE capabilities ([8]) state that a DL384k class mobile needs to receive only one SCCPCH/DPCH at a time. However, the multiplexing of FACH(s) on the S-CCPCH remains to be defined . The response should also indicate to the RRC layer that it should enter the CELL_FACH state, using the Information Element of the RRC State Indicator field.

Important Note: the RRC state transition diagram for Release 2 is different from the commercial one. The following diagram shows the SDMB 3G aspect of the use case for Release 2.

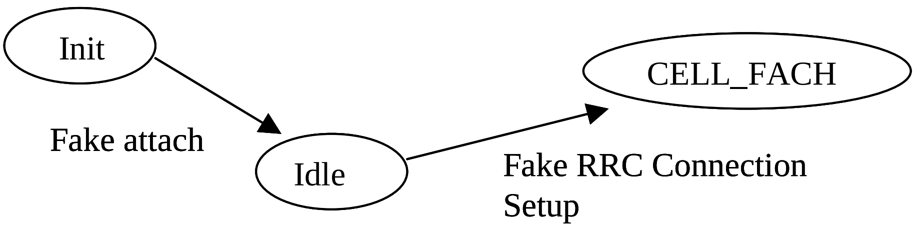

Figure 28: RRC state diagram in the MAESTRO Release 2 test bed

4.2.2.3.2.4 Data Transfer:

Now that after the RRC connection establishment is “set up”, the UE is in the proper state to perform data transfer. However, the NAS protocols, namely the Session Management (SM), IP, UDP, still need to be configured properly to perform end-to-end data transfer.

- Normal procedure: the UE SM entity sends a PDP CONTEXT ACTIVATE REQUEST message to its peer, and receives a PDP CONTEXT ACTIVATE ACCEPT in the positive case. Meanwhile, the UTRA RRC sends a RADIO BEARER SETUP to configure all layers up to PDCP for data transfer on the appropriate RAB/RB mapping.

- Proposed amendment: Hard code some of the values that are to be used for PDP context activation in the UE (this is out of scope of WP3 - access layer), and then the UE RRC configures L1, MAC, RLC and PDCP layers of the SDMB stack using System Information broadcast.

All the protocol stacks are correctly configured to perform the data transfer.

4.2.2.3.2.5 System Information change

When the handset is in CELL FACH mode and a change of SIB occurs, a SYSTEM INFORMATION CHANGE INDICATION message is handled on the BCCH mapped on the BCH on the Primary CCPCH in the cell.

4.2.2.4 Radio Resource Management

No radio resource management procedures are within the scope of the Release 2 MAESTRO test bed.

5 IDENTIFICATION OF FEATURES FOR EVALUATION

The chapter identifies functions of the access scheme that require further investigation. The respective trades-offs are presented and the possible alternatives for evaluation are listed.

5.1 RRM modules optimisation

5.1.1 Packet scheduler

5.1.1.1 Time scheduling function

5.1.1.1.1 Trade-off description

The trade-off is mainly relevant to streaming services. The scheduler decisions resolve a fundamental trade-off between the QoS perceived by end users in terms of transfer delay and delay variation and utilisation of the radio resource –in this respect, the code channel on which the data flow is mapped. The trade-off is affected by the Transport Format Combination Set size, when service data flows are multiplexed over the SDMB RAN. The per-TTI allocations of the scheduler may be more “generous” towards the flows leading to better delay/delay variation scores at the expense of reduced utilisation. The trade-off is also affected by the RRA decisions.

5.1.1.1.2 Trade-off evaluation

Different scheduling disciplines resolve the trade-off with different efficiency. Starting from the evaluation that took place in the context of the IST FP5 SATIN project, different time scheduling disciplines will be compared with regard to their efficiency in managing the trade-off. The size of the TFS/TFCS that is required in each case will be one of the comparison criteria.

5.1.1.2 Power scheduling function

5.1.1.2.1 Trade-off description

The fundamental trade-off is between capacity and coverage. Higher transmit power allocations allow services on a given code channel to reach users in the areas of the spot-beam that are worse illuminated by the satellite antennas. On the other hand, the consumed power increases, letting less space for other services.

5.1.1.2.2 Trade-off evaluation

Optimum power settings will be searched for, under realistic scenarios for the distribution of users in the beam and their interest in certain services. Relevant to the trade-off are non-access stratum protocols, such as the reliable multicast transport protocol that will be applied at transport/application layer at the BM-SC. The combined setting of the protocol redundancy and the transmit power will be part of this evaluation.

5.1.2 Radio Resource Allocation

5.1.2.1.1 Trade-off description

The RRA may decide to follow a one-to-one mapping strategy between MTCH-FACH-SCCPCH or multiplex more than one MTCH onto a single S-SCCPCH. The multiplexing may happen at transport channel level, i.e. more than one MTCH on a single FACH/S-CCPCH, at code channel level, i.e. more than one MTCH/FACH over a single S-CCPCH, or at both levels. The decision affects:

- The transmit power usage. It is favourable to have channel mappings that minimize the power consumption, although this might mean higher processing complexity with respect to one-to-one mapping.
- The time multiplexing trade-off described in section 5.1.1.1, in particular when variable-rate streaming services of some burstiness are involved. Statistical multiplexing gain could be achieved by multiplexing efficient number of data flows over a single S-CCPCH. On the other hand, the size of the TFCS that can follow the dynamics of all flows efficiently grows quickly with the number of multiplexed flows.

5.1.2.1.2 Trade-off evaluation

Optimum channel mapping strategies/algorithms will be explored. The main comparison criterion will be the achieved system capacity under the different mappings.

5.1.3 Admission Control

5.1.3.1 Resource Reservation Strategy

5.1.3.1.1 Trade off description

The interaction between long-term and short-term resource allocation functions has an impact on overall system performance. In this context, the interworking of Admission Control (AC) and Packet Scheduling (PS) needs to be investigated and the various tradeoffs evaluated (Admission Probability - Packet Delay). The key concept affecting this trade off will be the resource reservation strategy adopted during Admission Control procedure. High bandwidth reservation will favour the packet level performance (delay/jitter) at the expense of higher blocking probability and lower resource (code channel) utilisation.

5.1.3.1.2 Trade off evaluation

Optimum resource reservation strategies during Admission Control procedure (mean rate, effective rate, etc) will be explored. The main comparison criterion will be a combination of admission probability, perceived QoS of the flows (delay) and achieved system throughput. Trade offs described before can be handled through appropriate setting of Transport Formats for each Transport Channel.

5.1.3.2 Parameter-Based vs. Measurement-Based Admission Control

5.1.3.2.1 Trade off description

A parameter-based AC scheme bases its decisions entirely on the declared QoS profile of the new session request (e.g. mean data rate, guaranteed data rate). On the other hand a measurement-based AC scheme utilises real time information from lower layers in order to obtain the actual system status (transmitted power, load factor, buffer occupancy). Measurement-based approaches are expected to provide better efficiency at the expense of higher complexity in the RRM strategy design and possibly higher response time of the AC algorithm.

5.1.3.2.2 Trade off evaluation

Using the AC simulator, parameter-based and measurement-based approaches can be compared in terms of overall system capacity (throughput), stability (overload probability) and perceived packet level QoS (delay/jitter). The comparison will be carried out for different scenarios in terms of service characteristics (mean rate, burstiness), traffic mix scenarios and TrChs multiplexing approaches. Finally, the possibility to develop a hybrid approach utilising both parameter-based and measurement-based logic will be investigated.

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[45] R1-040067, “Outer Coding in the Presence of DRX for PtM MBMS (FDD)”, Siemens, 3GPP TSG RAN WG1 Ad Hoc, January 2004

[46] R1-040072, “Advanced interleaver for outer coding in MBMS (FDD)”, Samsung, 3GPP TSG RAN WG1 Ad Hoc, January 2004

[47] R1-040314, “Use of outer coding for MBMS”, Vodafone Group, 3GPP TSG RAN WG1 meeting #36, February 2004

[48] RP-040014, “Status Report for WI to TSG”

[49] R1-021407, “Time diversity gain for MBMS”, NTT DoCoMo, 3GPP TSG RAN WG1 meeting #29, November 2002

[50] GMBMS-030007, “On MBMS bearer definition”, Siemens, 3GPP TSG-GERAN MBMS Workshop, August 2002

[51] R2-040509, “Layer 2 quick repeat”, Qualcomm, 3GPP TSG RAN WG” meeting #41, February 2004

[52] R2-040779, “Radio link retransmissions for MBMS”, Philips, 3GPP TSG RAN WG2 MBMS adhoc, Budapest, Hungary, 20-22 April 2004

[53] R2-040808, “Support of RLC level retransmissions for MBMS“, Philips, 3GPP TSG RAN WG2 MBMS adhoc, Budapest, Hungary, 20-22 April 2004

[54] R2-040822, “Radio link retransmissions for MBMS (update)”, Philips, 3GPP TSG RAN WG2 MBMS adhoc, Budapest, Hungary, 20-22 April 2004

[55] R2-040812, “Load control for MBMS data repair”, Motorola, TSG-RAN 2 MBMS Ad-hoc, Budapest, Hungary, 20–22 April 2004

[56] R2-042275, “Reply to MBMS capability and Multiplexing options for MBMS”, Motorola, 3GPP TSG RAN WG” meeting #44, Sophia Antipolis, France, 4-8 October 2004

[57] R1-041030, ”Baseline for finalization of MBMS soft combining”, Qualcomm, 3GPP TSG RAN WG1 meeting #38, Prague, Czech Republic, August 2004

[58] R1-040885, ”Soft combining aspects”, Qualcomm, 3GPP TSG RAN WG1 meeting #38, Prague, Czech Republic, August 2004

[59] R2-042568, ” Email agreement CR 265 to 25.322 [Rel-6] on out of sequence SDU delivery”, Siemens, December 2004

APPENDIX A – ADMISSION CONTROL STRATEGIES FOR SDMB ACCESS LAYER

The design and definition of efficient Access Control schemes for SDMB systems relies on the consideration that the interference limited WCDMA satellite radio interface is the capacity bottleneck of the whole satellite network. Following the assumption that the system routes traffic from core network (content provider) towards mobile/nomadic users over point-to-multipoint connections, we consider only the downlink case of a typical Admission Control Algorithm. Subsequently, the proposed Admission Control Strategies in this section reflect direct adaptation of well known downlink AC algorithms, with respect to the limitations, and requirements imposed by the SDMB specifications analysed in section 3.5.2.2.2

In any QoS enabled IP network Admission Control performance and efficiency is measured using the following key parameters:

- Implementation and operation cost of the algorithm-feasibility of the implementation
- Achieved Network Utilisation and QoS support

The feasibility of the implementation is the first issue that has to be addressed, during the design and analysis of AC strategies. In order to be feasible an AC algorithm has to fulfil two major requirements. First, the signalling exchange between various protocol entities should be kept at reasonable levels in order to avoid capacity reduction and session set-up latency due to signalling overhead. Secondly, the decisions of the Admission Control algorithms should be based on easily obtainable parameters. These parameters should cover a wide variety of QoS prerequisites and furthermore should be representative of the current status of the satellite network.

In general, AC relies its decision to grant or reject a specific service request on 3 different types of information. Information related to the *default network and protocol entities configuration,* information representative of the *current status/load of the network* and information regarding to the *new session QoS profile*.

First of all, the *default network and protocol entities* related information covers all aspects of the configuration of the SDMB RNC, RANAP protocol and threshold values used during Admission Control procedure. This information for example may include threshold values used to define the capacity limits of the network or the quality of individual radio connections (e.g. downlink load threshold), or RNC, SSN timers (e.g. $T_{queuing,}$ $T_{inactivity}$) used during the whole RAB management in SDMB RAN and Core Network.

Secondly, *new session QoS profile* information includes the QoS parameters according to the traffic contract of the specific MBMS group. These QoS parameters are included in the RAB parameters Information Element (IE) submitted to RNC via Session Set Up Request (RANAP signalling protocol). The attributes of RAB parameters IE and their impact on Admission Control procedure are summarised in Table 20.

The *current status/load of the network* information is the most important one. The type of information collected to represent the current network status and also the collection and processing mode that is used, reflect in fact the various Downlink Admission Control strategies analysed so far in the related literature.

Regarding the method used to obtain the current system load and assign the appropriate resources, two broad categories of Admission Control algorithms can be identified: *Parameter Based* and *Measurement Based Admission Control Algorithms.*

The *Parameter Based AC* considers the user specified flow characteristics and QoS requirements to decide whether the network has the required resources to accommodate the new request. In particular the specified resources (submitted to the network during call set up procedure) of all existing connections are summed up and they are used (along with default link budgets and link Eb/No requirements) to represent the current system load. Despite the fact that this method is the simplest one in its implementation, it also has two major shortcomings. The first one is that it requires an accurate statistical characterisation of the requested traffic flow and huge computational effort to compute the effective bandwidth that has to be assigned to the flow. On the other hand, the algorithm has to be designed for the worst case of source location and propagation distributions, which are not under the SRAN control so the bandwidth utilisation can be far from optimum. Simplifications of this general method are the peak rate allocation or mean rate allocation strategies: the first one reserves bandwidth at the peak data rate and the second at the average bit rate of the source flow during its lifetime. These methods suffer from low resource utilisation and hence there is a waste in capacity especially for bursty Variable Bit Rate (VBR) traffic streams.

The *Measurement Based* approach for the Admission Control problem relies on appropriate network measurements to estimate the current load of existing traffic, instead of computing the traffic characteristics out of the user specified connection's parameters. It has no prior knowledge of the traffic statistics and makes admission decision based on the measured current system state. Given that source behaviour is not static in general, service commitments made by such measurement based AC Algorithms can never be absolute. The QoS requirements of each traffic flow can be guaranteed in a statistical nature (e.g. packet delay <x msec for the 95% of the packets). The estimation of the load over the radio interface can be based on various, standardised within 3GPP, measurements. These measurements, conducted in the RAN side include Received Total Wideband Power, SIR, SIR_{error}, Transmitted Carrier Power, Transmitted Code Power, Transport Channel BER, and Physical Channel BER. Additionally traffic volume measurements, buffer occupancy reported by MAC layer to RRC layer can also be employed.

Several criteria that represent the current load in a typical WCDMA network have been proposed in the literature. These criteria are used on both Parameters Based and Measurement Based AC and actually reflect the fundamental capacity limits due to the WCDMA-based multiple access technique. Some of them are listed below:

- Total Transmitted Power
- Multiple Access Interference levels
- Number of codes used
- Number of Active channels
- Load or Noise Rise
- Total Throughput

In the context of unidirectional MBMS access system, the feasibility of Measurement Based Admission Control is actually restricted. Particularly, due to the absence of return link no feedback information from UE it is possible to be transmitted back to the SRAN. As a result, information related to the quality of individual connections or the load in the downlink direction of the radio interface is not available at the RNC in order to be exploited/used during Admission Control procedure. The only measurements that are possible to be conducted and fed to AC are the Total Downlink Transmitted Power and Total Throughput. Additionally, Admission Control procedure is located in SDMB Hub and frequent, over the air signalling, (for measurements report) is also required in the case of a measurement based AC scheme. Hence, under these limitations imposed by the unidirectional nature of the SDMB access scheme, Parameter based Admission Control Algorithms seems to be more suitable.

Appendix B – Combinations of UE Radio Access Parameters for DL

Reference combination of UE Radio Access capability parameters in DL	12 kbps class	32 kbps class	64 kbps class	128 kbps class	384 kbps class
Transport channel parameters					
Maximum sum of number of bits of all transport blocks being received at an arbitrary time instant	640 (FDD) 1280 (TDD)	1280	3840	3840	6400
Maximum sum of number of bits of all convolutionally coded transport blocks being received at an arbitrary time instant	640	640	640	640	640
Maximum sum of number of bits of all turbo coded transport blocks being received at an arbitrary time instant	NA (FDD) 1280(TDD)	1280	3840	3840	6400
Maximum number of simultaneous transport channels	4 NOTE 4	8 NOTE 4	8 NOTE 4	8 NOTE 4	8 NOTE 4
Maximum number of simultaneous CCTrCH (FDD)	1 NOTE 3	1 NOTE 3	2/1 NOTE 2 NOTE 3	2/1 NOTE 2 NOTE 3	2/1 NOTE 2 NOTE 3
Maximum number of simultaneous CCTrCH (TDD)	1 NOTE 3	2 NOTE 3	3 NOTE 3	3 NOTE 3	3 NOTE 3
Maximum total number of transport blocks received within TTIs that end at the same time	4	8	8	16	32
Maximum number of TFC	16	32	48	96	128
Maximum number of TF	32	32	64	64	64
Support for turbo decoding	No (FDD) Yes (TDD)	Yes	Yes	Yes	Yes
Physical channel parameters (FDD)					
Maximum number of DPCH/PDSCH codes to be simultaneously received	1	1	2/1 NOTE 2	2/1 NOTE 2	3
Maximum number of physical channel bits received in any 10 ms	1200	1200	3600/240	7200/480	19200

Reference combination of UE Radio Access capability parameters in DL	12 kbps class	32 kbps class	64 kbps class	128 kbps class	384 kbps class
interval (DPCH, PDSCH, S-CCPCH).			0 NOTE2	0 NOTE2	
Support for SF 512	No	No	No	No	No
Support of PDSCH	No	No	Yes/No NOTE 1	Yes/No NOTE 1	No/Yes NOTE 1
Maximum number of simultaneous S-CCPCH radio links	1	1	1	1	1
Support of dedicated pilots for channel estimation	Yes/No NOTE 1	Yes/No NOTE 1	Yes/No NOTE 1	Yes/No NOTE 1	Yes/No NOTE 1

Table 25: UE radio access capability parameter combinations, DL parameters

NOTE 1: Options represent different combinations that should be supported with Conformance Tests

NOTE 2: Options depend on the support of PDSCH. The highest value is required if PDSCH is supported.

NOTE 3: The given number does not contain the BCH CCTrCH of the current cell nor of the neighbour cells.

NOTE 4: The given number does not contain the BCH of the neighbour cell.

The full table and related information can be found in TS 25.306.

APPENDIX C – "DETAILS OF SYSTEM INFORMATION BLOCKS FOR MAESTRO TEST BED RELEASE 2"

The tables below detail SIB contents for use in MAESTRO Release 2.

NOTE: Due to input from WP6, the list may be extended, but the following list is the minimal set of parameters to be included in SIB.

Information Element	Type and reference	Release 2 value
Other information elements		
MIB Value tag	Integer (1…8)	
CN information elements		
Supported PLMN types	Enumerated (GSM-MAP, ANSI-41, GSM-MAP and ANSI-41)	GSM-MAP
PLMN Identity Mobile Country Code (MCC) Mobile Network Code (MNC)	 3*Integer (0…9) 2/3*Integer (0…9)	 Same value as the HPLMN of the test USIM
References to other SIBs		

Table 26: MIB

Information Element	Type and reference	Release 2 value
CN common GSM-MAP NAS system information	Octet string (1…8)	
CN domain system information CN domain identity GSM-MAP NAS system info CN domain specific DRX cycle length coefficient	 Enumerated (CS domain, PS domain) Octet string (1…8) Integer (6…9)	 PS domain TBD if discontinuous reception is implemented
UE Timers and constants in idle mode T300 N300	 Integer (100)	Values are not meaningful in the SDMB system/test bed case (their purpose is for RRC connections) but are inserted for UE

T312 N312	Integer (0) Integer (0) Integer (1)	compatibility
UE Timers and constants in connected mode T301 N301 ….	 Integer (0) Integer (0) …	Values are not meaningful in the SDMB system/test bed case (no connected mode) but are inserted for UE compatibility

Table 27: SIB 1

Information Element	Need	Multi	Type and reference	Release 2 value
URA identity	MP		Bit string (16)	TBD

Table 28: SIB 2

Information Element	Type and reference	Release 2 value
SIB4 Indicator	Boolean	False (No SIB4 broadcast in the cell)
Cell identity	Bit string (28)	Spot identity
Cell selection and re-selection info Quality measure Qhyst1s Qhyst2s Treselection Maximum allowed UL TX Power	 Enumerated (CPICH Ec/No,CPICH RSCP) Integer (0…40 by step of 2 dB) Integer (0…40 by step of 2 dB) Integer (0…31) Integer (-50..33)	 TBD TBD 31 s -50 dBm : inhibit UL access
Cell Access Restriction Cell Barred Intra-frequency cell re-selection Indicator Tbarred Cell reserved for operator use Cell reservation extension	 Enumerated (not barred, barred) Enumerated (not allowed, allowed) Integer (10,20,40,80,160,320,640,1280) s Enumerated (reserved, not reserved) Enumerated (reserved, not reserved)	 Barred Allowed TBD Not reserved Not reserved

Table 29: SIB 3

Information Element	Type and reference	Release 2 value
SIB6 Indicator	Boolean	False (No SIB6 broadcast in the cell).
PICH Power offset	Integer (-10…+5) dB	-15 dB
AICH Power offset	Integer (-22..+5)	-22 dB (not meaningful for SDMB but kept for UE compatibility)
Primary CCPCH info		
Tx Diversity indicator	Boolean	False
PRACH system information list	TBD	Information is configured for PRACH inhibition
Secondary CCPCH system information		TBD (for release 2)
STTD indicator	Boolean	False
Spreading factor	Integer (4,8,16,32,128,256)	TBD : service data rate and protection
Code number	Integer (0..SF-1)	TBD : service data rate and protection
Pilot symbol existence	Boolean = True	TBC
TFCI existence	Boolean = True	
Fixed or flexible position	Enumerated (fixed, flexible)	Flexible
Timing offset	Integer (0..38144 by step of 256)	0
TFCS		TBD
FACH information		TBD
TFS		TBD
Transport channel identity		TBD
CTCH indicator	Boolean	True
CBS DRX Level 1 information		
Period of CTCH allocation	Integer (1…256)	Not used
CBS frame offset	Integer (0…255)	

Table 30: SIB 5

Information Element	Type and reference	Release 2 value
UL interference	Integer (-110..-70)	Not used
PhyCH information elements		
PRACHs listed in system information block type 5 Dynamic persistence level	1 to<maxPRACH>	Not used
Expiration Time Factor	Integer(1..8)	Not used

Table 31: SIB 7

Information Element	Type and reference	Release 2 value
SIB12 Indicator	Boolean	False (No SIB12 broadcast in the cell)
Measurement control system information		
Use of HCS	Enumerated (Not used, used)	Not used
Cell selection and reselection quality measure	Enumerated (CPICH Ec/N0, CPICH RSCP)	TBD

Table 32: SIB 11

APPENDIX D – CHANNEL MAPPING AND MULTIPLEXING: THE SATIN APPROACH

Within the scope of the SATIN project, only channel multiplexing at the physical layer was considered for the support of multiple services. Therein there is a one to one correspondence between the multicast/broadcast services and the RABs, whereby the services are mapped one-to-one on the Common Traffic Channels (CTCHs) at the RLC sub-layer at a given time. The CTCHs are then mapped one-to-one on the FACHs on the MAC sub-layer, which are then multiplexed at physical layer on S-CCPCHs. There can be a maximum of 8 FACHs multiplexed per S-CCPCH. The spreading factor of the physical channels is considered fixed (in a static or semi-static manner) and the FACHs (hence the services and corresponding CTCH) are mapped to them according to their respective peak aggregate rates. By semi-static it is meant that the SF of the channel may change over large time periods but not during the transfer phase of the specific services. The service mapping on radio resources is made to reduce service announcement signalling, whereby a separate S-CCPCH of low rate, called "master S-CCPCH" is reserved for signalling related to service notification. On the whole, there can be up to a maximum of 32 of Radio Bearers per satellite beam (including the bearer to be used for service signalling, i.e. the "Master S-CCPCH").

An example of the transport channel multiplexing scenarios adopted in SATIN is shown in Figure 33.

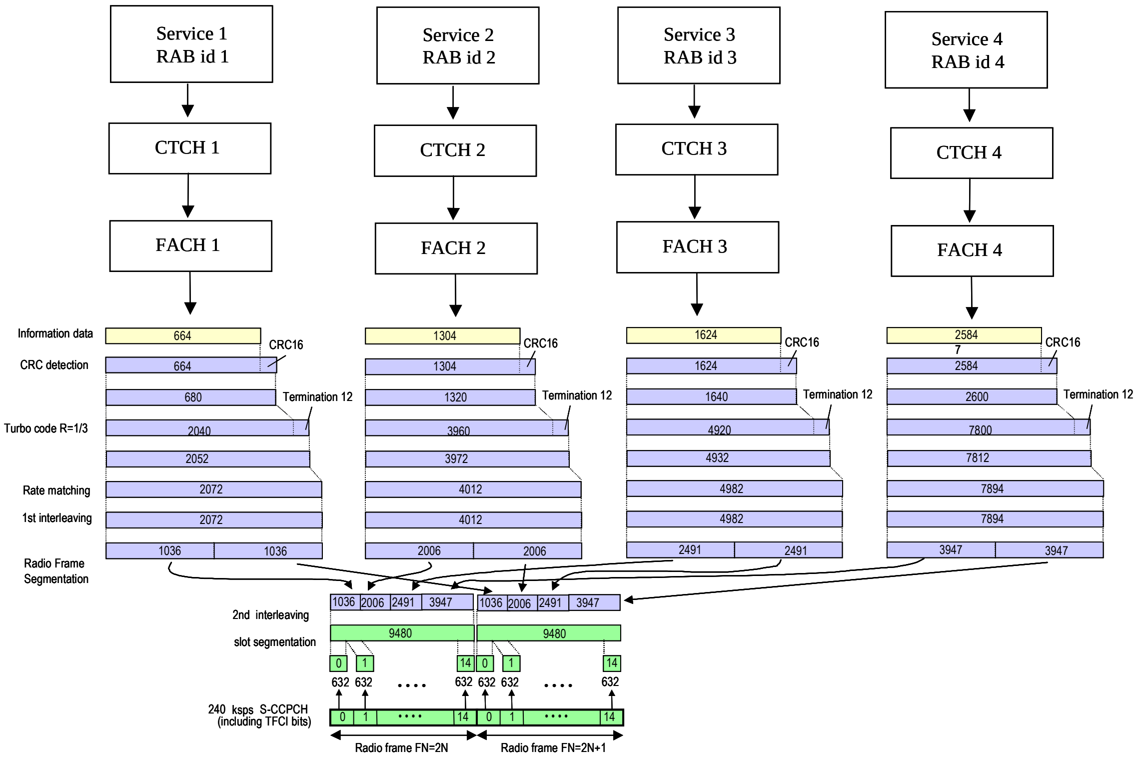

Figure 33: Multiplexing at physical layer

It must be noted that from the simulation campaign carried out in SATIN [25], it has been found the FACH performance, BER=f(Eb/No) is independent from the multiplexing scenarios, i.e. it does not matter whether a FACH is transmitted alone on a S-CCPCH or together with other FACH channels.

APPENDIX E - OUTER CODING IN RAN: A REVIEW OF THE CURRENT STATUS OF WORK IN 3GPP

According to the current MBMS specifications [1][11], the UTRAN will use the RLC Unacknowledged Mode (RLC-UM) to deliver MBMS content over the air interface, i.e. the UTRAN does not guarantee the MBMS content delivery over the air interface. Hence, different mechanisms have been proposed to enhance the reliability provided by UTRAN in MBMS delivery. The proposed mechanisms include the following:

1. Outer Coding (OC) - [26]
2. Link-level data retransmissions - [27]
3. Selective Combining (SC) - [28]
4. High inter-frame interleaving (i.e. high TTI values) - [29]
5. Link-level data repetition - [30]
6. Use of time diversity techniques - [31]
7. Soft combining – [57]

From these mechanisms, only Selective Combining was previously agreed in 3GPP to be a mandatory UE functionality for Release-6 MBMS, but more recently in October 2004, RAN WG2 has also approved the use of full soft combining and partial soft combining in Release 6 [56] to provide higher reliability to p-t-m content over terrestrial WCDMA systems, whereby this decision has been captured in the latest version of TS 25.346 [11]. There are different options to implement this layer 1 soft combining, which includes rake combining, and Log-Likelihood Ratio (LLR) combining at the physical layer [58].

This appendix focuses on the use of outer coding for MBMS delivery, providing a brief review of all contributions that have been made within 3GPP on this mechanism and the decisions taken there. Given the increased data loss in the SDMB Radio Access Network, the use of outer coding is one promising alternative for deployment over the SDMB RAN. The work and findings within 3GPP form the starting point in this direction.

E.1 Introduction

During the initial stages of the release 99 specifications [32] for “services provided by physical layer“, in 3GPP they had envisaged two coding stages as part of the physical layer functions. They were called inner coding and outer coding; inner coding refers to the bit-level Forward Error Correction (FEC) schemes, such as convolutional or turbo coding, which provide error protection to the physical layer bit stream. Outer coding in the form of a Reed Solomon based coding scheme was considered for the protection of the Transport Blocks (TB), but the 3GPP physical layer working group finally dropped this option, excluding it from physical layer functional definition.

With the introduction of MBMS services within UTRAN, the necessity to provide higher reliability to the content over UTRAN was identified as a major concern among MBMS specification group members. Because of this, MBMS research communities have again begun investigating the advantages of OC for MBMS content delivery. Qualcomm have pioneered this work for UTRAN and Siemens for GERAN. OC was mainly considered as a mitigation technique for bursty data losses due to fading, UE being out of coverage, monitoring paging instances, RAT measurement occasions and user mobility (during the handover process).

E.2 Proposed technique

According to the Qualcomm proposal [26], the OC is applied at the RLC protocol sub-layer and FEC is performed serially between RLC PDUs as shown in Figure 34. The main advantage of introducing OC at RLC level is that the FEC encoder is aware of erroneous PDUs and this improves the error correction capability of the FEC code, namely the code has to cope with erasures rather than errors.

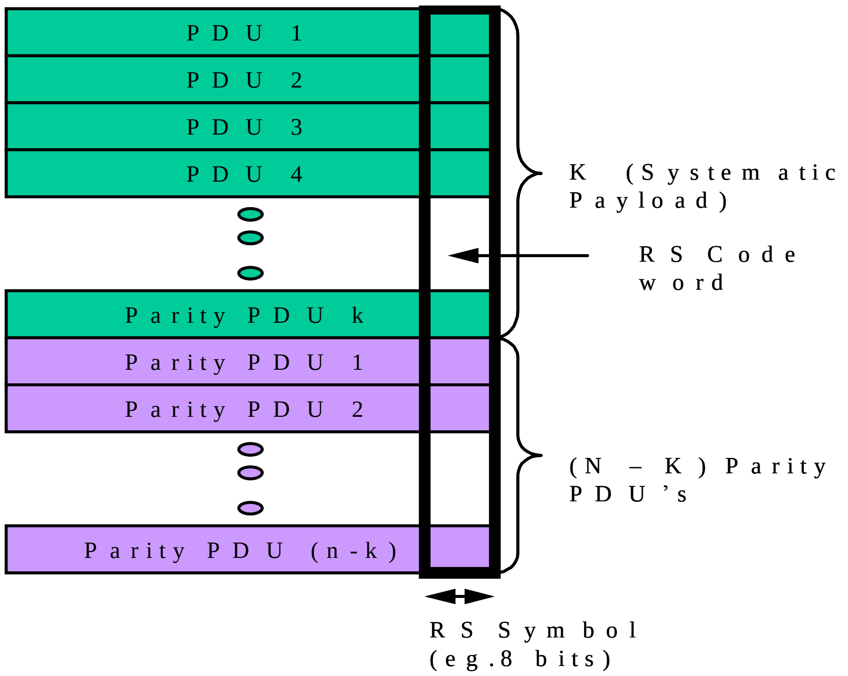

Figure 34: Systematic OC scheme based on RS codes

Outer coding implies new functions for the RLC sub-layer. On the UTRAN side, RLC PDUs have to be buffered row-wise within the buffer memory stacks till the buffer length reaches the required number of PDUs (k). Data are then released to the FEC encoder. The FEC encoder performs coding along the columns of the conceptual matrix and one byte (8 bits) from each row is used as the Reed-Solomon codeword. The same coding process is carried out L times, where L equals the PDU length in bytes. After generating the parity packets the outer coding header will be added to all the encoded PDUs and they will be forwarded to the MAC layer.

At the receiving end, if the user receives k original PDUs correctly, the decoding function is not required. The decoder will forward the original PDUs and will discard the received parity PDUs. When the decoder does not receive all the original PDUs correctly, the decoder will have to perform the decoding function. In order to successfully decode the original PDUs, the encoder has to receive at least *k* PDUs correctly. If this does not happen, the encoder will forward the correctly received PDUs and will discard the correctly received parity PDUs[15].

Since the outer coding technique is new functionality for the UTRAN, specification groups have been mainly interested in analysing the performance gain in terms of reduced required Node B transmit power to achieve a target BLER, such as 1%, as well as the additional complexity related to outer coding. Furthermore, they have been looking at the relative performance of the OC when compared with less complex alternative techniques such as high interleaving depths.

E.3 Performance

Six major companies have presented simulation results to the RAN MBMS specification groups (Qualcomm, Siemens, Motorola, Samsung, Vodafone, and IPWireless). Out of them Qualcomm [36][38][39] and Siemens [40] have shown that the transmit power gain achieved by introducing outer coding is significant when compared to the one without OC; on the contrary, according to Motorola [37][41][42], the performance gains achieved by outer coding are not that significant. The following tables show some of the results presented by those 3 companies.

Outer Code Gain over 80ms interleaving, Vehicular A Channel			
Inner TTI size (ms)	20	40	80
Gain at 3 kmph (dB)	-0.6	0.3	1.1
Gain at 30 kmph (dB)	-1.2	Not tested	-0.4
Gain at 120 kmph (dB)	-1.3	Not tested	-0.8

Performance at 3kmph in Vehicular A			
TTI size (ms)	20	40	80
Ec/Ior at 1% FER (dB) with outer coding	-6.2	-7.0	-7.7
Ec/Ior at 1% FER (dB) without outer coding	-7.1	-8.0	-8.8

Table 33: Results presented by Motorola [42]

15 The description in this paragraph refers only to systematic erasure codes.

Simulation Parameters	
Information Rate	64.2 kb/s
Spreading Factor	32
Channel condition	Vehicular A
UE speed	3, 30, 120 kmph
TTI Length	20, 40, 80 ms
Outer coding	RS (16,12)
RS symbol size	8 bits
Geometry	-3 dB
Channel Estimation	Ideal
Turbo Decoder	Max Log MAP

Table 34: Motorola Link layer simulation parameters [42]

The gains shown in Table 33 were calculated by comparing required E_c/I_{or} to achieve 1% FER for 80ms TTI without outer coding and for different TTI values with outer coding. By using those results, Motorola derived the following conclusions:

at 3 kmph, the outer code outperforms 80 ms TTI by 0.3 to 1.1 dB when the inner TTI is 40 ms or more, although there is a loss of 0.6 dB for 20 ms inner TTI.

There is a loss at vehicular speeds over 80 ms TTI of 0.4 to 1.2 dB at 30 kmph, and by 0.8 to 1.3 dB at 120 kmph.

Channel	**% Tx Power without outer coding**	**% Tx power with outer coding**
Case 1 – 3 kph	42.2 %	25.1 %
Case 2 – 3 kph	17.8 %	15.0 %
Veh-A – 3 kph	23.2 % (-6.8dB)	17.8 % (7.5dB)

Table 35: OC Qualcomm results (1% BLER TTI 80ms, (16,12) OC) [39]

Parameter	**Value**
CPICH Ec/Ior	-10 dB
P-SCH Ec/Ior	-15 dB
S-SCH Ec/Ior	-15 dB
Inner TTI	80 ms
S-CCPCH slot format	10
SF	32
Information Rate	64 kbps
Outer Code Rate	0.75
Channel Estimation	Non-ideal

Power Control	Off
Geometry	-3 dB
Channels	Case 1, Case 2, Veh-A
UE speed	3 kph
Number of Tx antennas	1

Table 36: Qualcomm Link layer simulation parameters [39]

According to the Qualcomm simulation results for the same TTI (80ms), outer coding provides a gain of .7dB when 1% BLER is targeted (Motorola found this to be 1.1 dB with respect to 1% FER). However, for a given TTI, the use of outer coding introduces higher memory requirements. Therefore, when comparing the performance gain for similar memory requirements, outer coding provides gains only in certain channel conditions.

All the above results were derived for (16,12) RS code; Siemens have presented simulation results for different RS code parameters. According to Table 37, the performance gain for some of the channels increases with respect to the number of blocks (TB) within the outer code block. When the number of blocks within the outer code block increases, the memory requirements also increase linearly. For example, with the 80 ms TTI and the (32,24) RS code, additional storage for 1.92 seconds (24*80 ms) of data would be required for the outer code frames. This translates to 20 kilobytes (32*1280*4/8) of memory.

Channel	Bit rate, kbps	TTI, ms	Ec/Ior			
			no outer coding dB, (%)	outer coding RS (16,12) dB, (%)	outer coding RS (32,24) dB, (%)	outer coding RS (64,48) dB, (%)
PedA, 3 km/h	64	20	>-1.0 (>79)	*-1.0 (79)*	*-2.7 (54)*	-3.2 (48)
PedA, 3 km/h	64	80	-2.9 (51)	-4.4 (36)	-5.2 (30)	*-5.7 (27)*
Case1, 3 km/h	64	20	*-1.0 (79)*	-3.0 (50)	-4.2 (38)	-4.8 (33)
Case1, 3 km/h	64	80	-4.3 (37)	-6.5 (22)	-6.9 (20)	-7.1 (19)
PedB, 3 km/h	64	20	-6.5 (22)	-6.6 (22)	-7.2 (19)	-7.6 (17)
PedB, 3 km/h	64	80	-8.1 (15)	-7.9 (16)	-8.5 (14)	*-8.9 (13)*
VehA, 30 km/h	64	20	-8.4 (14)	-8.3 (15)	-8.6 (14)	-8.8 (13)
VehA, 30 km/h	64	80	-10.3 (9)	-9.7 (11)	-9.7 (11)	-9.7 (11)

Table 37: Required Ec/Ior for 1% BLER by Siemens [44]

According to the results presented by different companies it can be concluded that when the performance comparison is done between TTI 80ms without outer coding and TTI 20ms with outer coding, for some channel conditions the E_c/I_{or} requirements are higher for the latter scenario than the former one [42], but the combination of interleaving within OC block has yielded better performance [46].

Siemens have evaluated the outer coding performance in the presence of DRX for p-t-m MBMS [45] and they have highlighted the necessity to investigate powerful RS code performance for long measurement occasions. Samsung have presented extensive simulation results comparing performance with and without OC for different channel conditions [43].

In the Vodafone contribution [47], they highlight that outer coding is useful for handling service outage due to mobility and they have suggested that the outer coding functionality should reside at the application level in order to enable the UE to recover in the inter-RNC/RAT case and for architectural simplicity. According to the document such a requirement would implicitly enable the UE to recover from any outage caused by DRX during inter-frequency/RAT measurements. Hence their view is that there is not necessity to introduce an outer coding scheme at the RAN level.

E.4 Associated Complexity

The complexity of the outer coding technique is mainly analysed based on the additional memory requirements and operations required to perform OC. The memory requirements for OC have been compared with buffer requirements for higher TTI values and the reference document [33] by Qualcomm provides some initial results. From their initial results they have indicated that the outer coding approach offers a better overall performance/resource ratio than the very long TTI (higher interleaving) approach and OC should be introduced in order to support MBM services.

In a subsequent technical document [34], Qualcomm have provided the comparison across schemes, such as data repetition at the UTRAN and longer TTIs with respect to the memory requirements, number of computations and the impact of UE capability. The objective of the document was to compare different schemes to mitigate the average power requirement for transporting MBMS on S-CCPCH, whereby the following conclusions were reached:

1. The buffer requirements for outer coding are minimal compared to what is needed for long TTI or repetition schemes.
2. The number of computations required for outer coding is small.
3. Outer coding relies on resources that are available in Rel-5 UE classes, or which can be re-used for other functionality within the terminal.

Another document presented by Qualcomm [35] has outlined the outer code design and gave a detailed explanation of the OC decoding procedure. The associated erasure decoder complexity was shown to be minimal, with required total number of computations less than 0.1 Mcps (for RS (15,12) and (15,11)). According to the document, the decoding function will be able to use trivial software decoder implementation, without necessitating hardware changes.

E.5 Current Status of Outer coding in 3GPP

The RAN working groups working on MBMS have recently decided that there is no necessity to introduce outer coding at the UTRAN level, therefore work on OC has been stalled [48].

Link gains achieved by longer TTI and/or Selective Combining compared to OC link gains were not felt large enough to require the use of RAN-level outer coding.

Drawbacks that have been invoked within technical documents in RAN1 group include the following:

- Use of outer code can degrade performance. For example, the degradation in vehicular conditions can be as much or more than the gains observed at pedestrian speeds.
- Outer coding is not suitable for delay intolerant or interactive services.
- The results discussed so far in RAN1 are applicable to streaming services. Benefits of the outer code for applications such as store and play have yet to be addressed.

E.6 Implications for SDMB

As mentioned earlier, the increased data loss in the SDMB Radio Access due to the need to attach to the terrestrial mobile network creates new motivations for the re-examination and evaluation of the scheme within the SDMB context.

APPENDIX F– RLC REPETITIONS AND RETRANSMISSIONS IN 3GPP

Since the beginning of the MBMS specification effort, the baseline assumption has been that the radio access network does not provide guaranteed reception and any desire to provide such guarantees should be pursued at the application layer.

This assumption is clearly stated in [1]: "*Reception of multicast services cannot be guaranteed over the access network. For many applications and services guaranteed data reception may be carried out by higher layer services or applications, which make use of MBMS*". Further reference to it is made in [7], where some more detail is given on the possible mechanisms at application layer: "*Reception of MBMS shall not be guaranteed at RAN level. MBMS does not support individual retransmissions at the radio link layer, nor does it support retransmissions based on feedback from individual subscribers at the radio level. This does not preclude the periodic repetitions of the MBMS content based on operator or content provider scheduling or retransmissions based on feedback at the application level"*. Finally, in the main 3GPP TS related to MBMS [11], it is stated clearly that the MBMS transfer over the UTRAN will make use of the RLC Unacknowledged Mode (RLC-UM).

Nevertheless, there have been proposals that deviate from this direction in that they introduce additional mechanisms at the radio access network that aim at enhancing the reliability of the data transfer whilst preserving the power resource of the system. These proposals have attracted the interest of the 3GPP RAN working groups at different time periods: first, the data repetition mechanism and, more recently, the data retransmission mechanism. This appendix reviews these proposals and the impact they have had on the standardisation procedure.

F.1 Data repetition at the RAN

F.1.1 Description

Data repetition implies the transmission of the same TB *n* times at the transmitter side (UTRAN) and their soft combining at the receiver side (UE). It is one of the three ways that *time diversity* can be obtained –the other two are outer coding and extension of TTI lengths [31].

F.1.2 Performance

Contributions to the 3GPP on the data repetition have been by NTT DoCoMo, Siemens and Qualcomm. In the contributions of NTT DoCoMo [31], [49], the possibility for repetition of TBs is presented as an alternative to the introduction of higher interleaving depths (TTIs > 80ms). Nevertheless, only the second option is evaluated, to derive a gain of 1.5-2dB when TTIs of 320ms are considered for 64/128kbps information rate in Vehicular-A channels with UE velocity of 3kmph and geometries spanning from –6 to 0 dB.

Results obtained with the TB repetition scheme are reported in [30]. The transport channel rate is 64kbps and each transport block is repeated twice (*n*=2) in one of the two following options:

- Individual TBs are channel encoded separately, transmitted sequentially and combined softly at the receiver.
- Individual TBs are concatenated and encoded together to form a 128kbps bearer using rate matching.

These two alternatives are again investigated in conjunction with the TTI length (20 and 80ms) and use of space-time transmit diversity (STTD). The schemes are tested under two channels, the Pedestrian B at 3 kmph and the Vehicular A at 30 kmph. Gains of 0.1-0.9 dBs, on top of the gain provided by STTD and 80ms interleaving are measured depending on the channel and the TTI/STTD configuration, the gain due to the first implementation option for data repetition being 0.1-0.7dB higher than the repetition using rate matching.

A more complete analytical investigation of the data repetition mechanism is provided by Siemens in the context of GERAN in [50]. With respect to [30], they consider only the first implementation option, namely TBs are encoded, transmitted sequentially and combined softly at the receiver. However, they compare the repetition of MAC/RLC blocks in the GERAN (Eq. 1) with repetition of application data units at the application layer (Eq. 2), in terms of correct decoding probability to find out that the former performs better, achieving one order of size better results than the latter.

$$P_{RAN} = 1-\left(1-P_{BLER}^{n}\right)^{N}$$

$$P_{BM-SC} = \left[1-\left(1-P_{BLER}\right)^{N}\right]^{n}$$

The performance gap increases with both number of repetitions *n* and number of RLC/MAC blocks *N* fitting within a higher layer packet.

According to the same contribution, repeated blocks may be sent either sequentially or each replica can follow the previous one after a certain number of blocks.

Qualcomm in [51] argue in favour of data repetitions in RAN, this time having MBMS control messages in mind. In their contribution, they compare the probability of correct decoding of RRC control messages when the message is repeated at RLC layer (with the possibility to handle out-of-order TBs at RLC UM) against the message repetition at RRC layer. They find it easily to prove that the former, given by:

$$P_{RLC} = \left(1-p^{k}\right)^{n} \qquad (1)$$

is always less or equal than the latter, given by

$$P_{RRC} = 1 - \left(1 - (1-p)^k\right)^n \qquad (2)$$

where *n* is the number of repetitions of the message and *k* is the number of TTIs required for the transmission of the whole message.

F.1.3 Associated complexity

An evaluation of the complexity related to the data repetition mechanism is given in [34] by Qualcomm.

They estimate the memory requirements introduced by data repetition, comparing them with the respective requirements due to outer coding and longer interleaving depths. Data repetition and high interleaving depths are shown to require the same buffering space at the terminal and the network, which is clearly higher than the memory required by outer coding. The potential use of data repetition is also hindered by the UE release 5 capabilities, namely the constraint on the maximum number of bits that terminal of certain classes can receive over a given TTI.

F.2 Data retransmission at the RAN

F.2.1 Description

With the data retransmission mechanism implies, contrary to the data repetition mechanism, only transport blocks/packets that were lost are retransmitted over the radio interface rather than all data. The retransmissions are triggered by user feedback at the uplink reporting loss of MBMS data.

Notably, the details of the retransmissions at the downlink are not given, whether they will be in p-t-p or p-t-mp mode, what are the added functions required at RAN level etc. Instead, the bulk of contributions focuses on the how the user feedback can be provided in a scalable manner at the uplink.

Therefore, Philips in [52], [53] and [54] describe a mechanisms that enables UEs to use the RACH channel for providing negative acknowledgments for individual packets. The mechanisms introduce small changes in the way the RACH is used and allows the UEs to report a packet loss in a way that reduces the interference at the uplink.

Motorola on the other hand in [55], have focused on the signalling and the procedures at the RAN that enable the latter to control dynamically the activation of mechanisms such as the aforementioned one by Philips, depending on the load the RAN experiences at a given instant. This way the network exercise a form of MBMS-specific load control.

F.2.2 Performance and complexity

No results evaluating the performance or the complexity of this technique have been retrieved.

F.3 Current Status of data repetitions and data retransmission in 3GPP

Regarding data repetitions, it has been agreed to use this mechanism for MCCH critical information, i.e. all MCCH messages other than the MBMS Access Information, whereby the repetition is performed in each repetition period within a modification period as part of the RLC-UM ‘Out of sequence SDU delivery’ functionality [59]. As for data retransmissions, the discussion was initiated in the early part of 2004, but come the second half of the year, the input on this has becoming less that there is no further contribution on this in 3GPP.

F.4 Implications for SDMB

The data retransmission, even if it makes progress in the standardisation arena, is not appropriate for SDMB given the unidirectional nature of the system and the absence of return link. The disadvantages of the data repetition mechanism with respect to buffering requirements and capacity overhead need to be weighed against the need to combat higher loss at the SDMB RAN than the ones in the UTRAN.

APPENDIX G– APPROXIMATE ANALYSIS OF DATA REPETITIONS AND OUTER CODING IN THE CONTEXT OF SDMB

G.1 Introduction

This appendix contains analytical approximations with regard to the use of data repetitions and outer coding in SDMB, either applied at the SDMB RAN or at the application layer. It is, effectively, an exercise giving quick insight to the performance advantages and overheads related to available reliable transport mechanisms.

The study recalls well-known generic formulas that relate the information error rate (called SDU error rate in related 3GPP standard documents), achieved via use of the mechanisms of data repetitions and outer coding, to the error rate experienced at the level of Transport Block (*BLER*). The formulas are then fed with values pertaining to potential SDMB operational conditions to yield an insight to the expected performance gain in numerical terms.

G.2 Analytical approximations

G.2.1 Notation

The following notation is adopted hereafter:

L size of a packet (in bytes)

L_{TB} size of the TB (in bytes)

$N_{B(P)}$ number of TBs fitting in a packet $N_B = \left\lceil \frac{L}{L_{TB}} \right\rceil$, when $L \geq L_{TB}$ or

number of packets contained in one TB $N_P = \left\lceil \frac{L_{TB}}{L} \right\rceil$, when $L \leq L_{TB}$

BLER Block Error Rate, namely the error rate experienced at the Transport Block (TB) level

P_x^y resulting packet error rate, after application of the mechanism *x* at level/layer *y.* For example, P_{rep}^{app} denotes the error rate experienced after applying data repetitions at the application layer (namely, the minimum repeated data unit is the packet).

p packet error rate when no protection measure is taken. Under the assumption of independent errors at the TB level, *p* is given by

$$p = 1 - (1 - BLER)^{N_B} \text{, when } L \geq L_{TB}$$

and $p = 1 - (1 - BLER)^{1/N_P}$, when $L < L_{TB}$ (G-1) *k* number of repetitions of data (either at packet or at transport block level)

M, H original and redundant data units within a block of coded data resulting from FEC and outer coding. The overhead ratio, defined as

$$\frac{M+H}{M}$$

is the metric of the overhead introduced by FEC and outer coding

G.2.2 Formulas

In light of the notation introduced in G.2.1, the following formulas may be used to yield the packet error rate:

G.2.2.1 No protection above physical layer

$$P = p$$

There is some minimum protection at the physical layer. Physical layer mechanisms may have a dramatic impact on the achieved BLER. We focus on measures at Layer 2 and above, assuming that the physical layer is dimensioned for a given BLER.

G.2.2.2 Data repetitions at the application layer (repeated data unit: packet)

$$P_{rep}^{app} = \left[1-(1-BLER)^{N}\right]^{k}$$

Packets are repeated at SDMB server *k* times instead of once.

G.2.2.3 Data repetitions at the RAN level (repeated data unit: Transport Block)

$$P_{rep}^{ran} = 1-\left(1-BLER^{k}\right)^{N}$$

Transport blocks, originating from the packets, are now repeated *k* times instead of once. As in the previous case, the rate of the resulting radio bearer is increased by a factor approximately equal to *k.* The overhead-related gain over the previous case has to do with the savings of capacity over the SDMB server-Hub link.

G.2.2.4 Forward Error Correction at the application layer (packet level)

$$P_{FEC}^{app} = p \cdot \left(\sum_{j=H}^{M+H-1} \binom{M+H-1}{j} \cdot p^{j} \cdot (1-p)^{M+H-j-1} \right)$$

The assumed code is a block, erasure code.

G.2.2.5 Outer coding at the RAN level (Transport Block level)

We can proceed in two steps:

First we can compute the BLER resulting from application of outer coding

$$BLER_{OC} = BLER \cdot \left(\sum_{j=H}^{M+H-1} \binom{M+H-1}{j} \cdot BLER^{j} \cdot (1 - BLER)^{M+H-j-1} \right)$$

and then we interpret it into packet error rate according to Eq. (G-1)

$$P_{OC} = 1 - (1 - BLER_{OC})^{N}$$

G.2.2.6 Selective combining

We consider combining of blocks at RLC layer. In that case, from analytical point of view, selective combining ends up being a special instance of data repetitions with $k=2$[16].

In SDMB, selective combining may be enabled by the use of two satellites or the use of gap fillers, which regenerate the signal and input it to the terrestrial Node B with a different scrambling code than the original satellite signal.

$$P_{sc} = 1 - (1 - BLER^{2})^{N}$$

G.2.2.7 Selective Combining coupled with data repetitions

$$P_{sc,rep} = 1 - (1 - BLER^{2k})^{N}$$

Superimposing data repetitions on selective combining, we introduce excess diversity at the Transport Block reception level.

G.2.3 Numerical, SDMB-specific inputs

The following inputs are considered in producing the numerical results in section G.3.

G.2.3.1 Target packet error rate

The target packet (SDU) error rate is in line with the values in TS 23.246, namely 10^{-2} and 10^{-1} for background and streaming QoS classes respectively.

G.2.3.2 BLER

The achieved BLER at the SDMB RAN is worse than the usually assumed at the UMTS RAN (1%). Namely, irrespective of the physical layer dimensioning (coding,

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[16] Network resource efficiency considerations introduce a first “soft” constraint on the number of paths considered for selective combining. A harder constraint comes from the terminal processing capabilities.

use of higher TTIs, STTD etc.), there is significantly higher loss due to the pre-emption of SDMB reception by terrestrial network signalling and data transfer activities. The average value of data loss at SDMB RAN has been computed to be 20% in D5.1. We will consider below three cases:

- Ideal case: no additional data loss due to the pre-emption from the terrestrial mobile network - BLER = 1%
- Average case – BLER 20%
- Negative extreme case – BLER 30%

NOTE: the simplifying assumption behind the analysis is that loss is random. This is definitely not the case; when the SDB reception is pre-empted, the use of RAN mechanisms like repetitions, which have short time diversity scope, will probably benefit SDMB reception less than the formulas predict.

G.2.3.3 Packet size L, TB size L_{TB}

These values are imported from Tdoc S4-040348, where guidelines for MBMS-specific simulations are provided (the numerical values there are termed “meaningful”). The values are given for TTI = 80ms, which is also the reference for the SDMB radio bearers.

The following tables are quoted from the specific doc.

SDU sizes (including header) [bytes] - *L*: 200, 300, 500, 800, 1400

RAN-Scenario	RLC data block length[1] [bytes]	Data rate [kbps]
16 kbps service, 80 ms TTI	160	< 16
32 kbps service, 80 ms TTI	320	< 32
64 kbps service, 80 ms TTI	640	< 64
128 kbps service, 80 ms TTI	1280	< 128

Note 1: the term RLC data block length is synonym to the Transport Block size L_{TB}, at least in the context of this study

Therefore the resulting N_B and N_P parameters are given in the following two tables respectively:

	Packet size *L* (bytes)				
	200	300	500	800	1400
16 kbps	2	2	4	5	9
32 kbps			2	3	5
64 kbps				2	3
128 kbps					2

Table 38: Possible values for the number of TBs N_B originating from a single SDU

	Packet size *L* (bytes)				
	200	300	500	800	1400
16 kbps					
32 kbps	2	1			
64 kbps	4	2	2		
128 kbps	7	3	3	2	

Table 39: Possible values for the number of packets N_P fitting in a single RLC PDU

In other words, N_B may vary from 2 to 9 and N_P may vary in the range [2..7].

G.3 Numerical results

G.3.1 Ideal case - BLER = 0.01

G.3.1.1 Target SDU error rate = 10^{-1} (streaming QoS class)

	Number of TBs in an SDU (N_B)								
	N_B=1	N_B=2	N_B=3	N_B=4	N_B=5	N_B=6	N_B=7	N_B=8	N_B=9
Repetitions at the application layer	1	1	1	1	1	1	1	1	1
Repetitions at the RAN	1	1	1	1	1	1	1	1	1
Selective combining+repetitions	1	1	1	1	1	1	1	1	1

Table 40: Required number of repetitions *k* for achieving the target SDU error rate

	Number of TBs in an SDU (N_B)								
	N_B=1	N_B=2	N_B=3	N_B=4	N_B=5	N_B=6	N_B=7	N_B=8	N_B=9
Application layer FEC (M=10)	1	1	1	1	1	1	1	1	1
Application layer FEC (M=30)	1	1	1	1	1	1	1	1	1
RAN outer coding (M=10)	1	1	1	1	1	1	1	1	1
RAN outer coding (M=30)	1	1	1	1	1	1	1	1	1

Table 41: Required overhead ratio for achieving the target SDU error rate

G.3.1.2 Target SDU error rate = 10^{-2} (background QoS class)

	Number of TBs in an SDU (N_B)								
	N_B=1	N_B=2	N_B=3	N_B=4	N_B=5	N_B=6	N_B=7	N_B=8	N_B=9
Repetitions at the application layer	2	2	2	2	2	2	2	2	2
Repetitions at the RAN	1	2	2	2	2	2	2	2	2
Selective combining+repetitions	1	1	1	1	1	1	1	1	1

Table 42: Required number of repetitions *k* for achieving the target SDU error rate

	Number of TBs in an SDU (N_B)								
	N_B=1	N_B=2	N_B=3	N_B=4	N_B=5	N_B=6	N_B=7	N_B=8	N_B=9
Application layer FEC (M=10)	1.1	1.1	1.1	1.2	1.2	1.2	1.3	1.3	1.3
Application layer FEC (M=30)	1.033	1.033	1.067	1.1	1.133	1.133	1.167	1.2	1.2
RAN outer coding (M=10)	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
RAN outer coding (M=30)	1.033	1.033	1.033	1.067	1.067	1.067	1.067	1.067	1.067

Table 43: Required overhead ratio for achieving the target SDU error rate

G.3.2 Average case - BLER = 0.2

G.3.2.1 Target SDU error rate = 10^{-1} (streaming QoS class)

	Number of TBs in an SDU (N_B)								
	N_B=1	N_B=2	N_B=3	N_B=4	N_B=5	N_B=6	N_B=7	N_B=8	N_B=9
Repetitions at the application layer	2	3	4	5	6	8	10	13	16
Repetitions at the RAN	2	2	3	3	3	3	3	3	3
Selective combining+repetitions	1	1	2	2	2	2	2	2	2

Table 44: Required number of repetitions *k* for achieving the target SDU error rate

	Number of TBs in an SDU (N_B)								
	N_B=1	N_B=2	N_B=3	N_B=4	N_B=5	N_B=6	N_B=7	N_B=8	N_B=9
Application layer FEC (M=10)	1.4	2	2.7	3.7	4.9	6.4	8.3	10.8	14
Application layer FEC (M=30)	1.3	1.767	2.333	.3.067	3.967	5.133	6.567	8.433	10.733
RAN outer coding (M=10)	1.3	1.4	1.5	1.5	1.6	1.6	1.6	1.6	1.7
RAN outer coding (M=30)	1.267	1.333	1.367	1.4	1.4	1.433	1.433	1.433	1.467

Table 45: Required overhead ratio for achieving the target SDU error rate

G.3.2.2 Target SDU error rate = 10^{-2} (background QoS class)

	Number of TBs in an SDU (N_B)								
	N_B=1	N_B=2	N_B=3	N_B=4	N_B=5	N_B=6	N_B=7	N_B=8	N_B=9
Repetitions at the application layer	3	5	7	9	12	16	20	26	32
Repetitions at the RAN	3	4	4	4	4	4	5	5	5
Selective combining+repetitions	2	2	2	2	2	2	3	3	3

Table 46: Required number of repetitions *k* for achieving the target SDU error rate

	Number of TBs in an SDU (N_B)								
	N_B=1	N_B=2	N_B=3	N_B=4	N_B=5	N_B=6	N_B=7	N_B=8	N_B=9
Application layer FEC (M=10)	1.7	2.5	3.4	4.5	6	7.8	10.1	13.1	16.8
Application layer FEC (M=30)	1.5	2.033	2.667	3.5	4.5	5.8	7.433	9.5	12.1
RAN outer coding (M=10)	1.7	1.8	1.8	1.8	1.9	1.9	1.9	1.9	1.9
RAN outer coding (M=30)	1.467	1.5	1.533	1.533	1.567	1.567	1.567	1.567	1.6

Table 47: Required overhead ratio for achieving the target SDU error rate

G.3.3 Extreme case – BLER = 0.35

G.3.3.1 Target SDU error rate = 10^{-1} (streaming QoS class)

	Number of TBs in an SDU (N_B)								
	N_B=1	N_B=2	N_B=3	N_B=4	N_B=5	N_B=6	N_B=7	N_B=8	N_B=9
Repetitions at the application layer	3	5	8	12	19	30	46	72	111
Repetitions at the RAN	3	3	4	4	4	4	5	5	5
Selective combining+repetitions	2	2	2	2	2	2	3	3	3

Table 48: Required number of repetitions *k* for achieving the target SDU error rate

	Number of TBs in an SDU (N_B)								
	N_B=1	N_B=2	N_B=3	N_B=4	N_B=5	N_B=6	N_B=7	N_B=8	N_B=9
Application layer FEC (M=10)	1.9	3.5	6	10.10	16.5	25.7	43	68.9	109.9
Application layer FEC (M=30)	1.733	2.967	4.867	7.687	12.6	20.067	31.767	50.2	79.067
RAN outer coding (M=10)	1.8	1.9	2	2.1	2.1	2.2	2.2	2.2	2.2
RAN outer coding (M=30)	1.667	1.733	1.8	1.833	1.833	1.867	1.867	1.9	1.9

Table 49: Required overhead ratio for achieving the target SDU error rate

G.3.3.2 Target SDU error rate = 10^{-2} (background QoS class)

	Number of TBs in an SDU (N_B)								
	N_B=1	N_B=2	N_B=3	N_B=4	N_B=5	N_B=6	N_B=7	N_B=8	N_B=9
Repetitions at the application layer	5	9	15	24	38	59	92	143	221
Repetitions at the RAN	5	6	6	6	6	7	7	7	7
Selective combining+repetitions	3	3	3	3	3	4	4	4	4

Table 50: Required number of repetitions *k* for achieving the target SDU error rate

	Number of TBs in an SDU (N_B)								
	N_B=1	N_B=2	N_B=3	N_B=4	N_B=5	N_B=6	N_B=7	N_B=8	N_B=9
Application layer FEC (M=10)	2.4	4.4	6.4	12.2	19.8	31.8	50.7	80.6	127.7
Application layer FEC (M=30)	1.967	3.367	5.5	8.867	14.167	22.433	35.4	55.667	87.333
RAN outer coding (M=10)	2.3	2.4	2.5	2.5	2.5	2.6	2.6	2.6	2.6
RAN outer coding (M=30)	1.9	1.967	2	2.033	2.067	2.067	2.067	2.1	2.1

Table 51: Required overhead ratio for achieving the target SDU error rate