COVERAGE AND PLANNING ASPECTS OF MBMS IN UTRAN

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Abstract

MBMS is a key element of the forthcoming Release-6 of the 3GPP UTRAN and GERAN standards. This paper outlines the expected network resource demands for providing MBMS in a UTRA FDD network. Proposed MBMS related enhancements in the physical layer specifications and their effects on resource requirements are examined in detail. Such improvements are dependent on deployment scenarios, but can yield up to a threefold reduction in resource demand.

1 Introduction

The Multimedia Broadcast and Multicast Service (MBMS) is being standardized in 3GPP UTRAN (UMTS Terrestrial Radio Access Network) Release-6. The goal of this effort is to support downlink streaming and download-and-play type services to large groups of users. From the radio perspective, MBMS includes a point-to-point (PtP) and point-to-multipoint (PtM) modes. The latter aims to overcome network congestion when a large number of users request the same content, e.g. a sporting event clip, news update, local entertainment information or weather forecast. For download-and-play type services, the PtM mode may be supplemented by an additional point to point repair mechanism for recovering lost packets.

This paper focuses on the coverage aspects of PtM MBMS, using FDD UTRAN Release-5 and Release-6 technology. Since fast power control is not applicable in PtM, the proportion of available DL TX power allocated to MBMS will essentially be fixed. We address the fundamental question of how much power resource is likely to be required to ensure good PtM MBMS coverage: Allocating excessive power is wasteful, both from the efficiency and interference point of view. Allocating insufficient power will lead to significant areas of the cell in which high BLER is experienced by MBMS users, leading to either a reduction in coverage or an overload of the repair mechanism.

This paper is organized as follows. Section 2 presents MBMS coverage achievable using Release-5 technology (considering different TTI lengths and open loop transmit diversity). In Section 3, it is shown how system performance is improved with Release-6 by introducing macrodiversity on a broadcast MBMS channel. Conclusions are drawn in Section 4, and detailed simulation assumptions are included in the Annex.

2 Current (Release-5) Coverage

Although UTRAN Release-5 makes no explicit provision for MBMS, it is instructive first to study MBMS performance using the existing technology. A flexible common channel, suitable for PtM transmission is already available, namely the Forward Access Channel (FACH), which is mapped onto the Secondary Common Control Physical Channel (S-CCPCH).

Before proceeding, it is useful to introduce the following terminology [1]:

I_{or}	The total transmit PSD of the downlink, measured at the base station antenna connector, integrated in the signal bandwidth and normalized to the chip rate.
E_c	Average energy per chip of a physical channel.
$\hat{I}_{or}$	The total received PSD of the downlink, measured at the receiver antenna connector, integrated in the signal bandwidth and normalized to the chip rate.
I_{oc}	The power spectral density of a band limited white noise source (simulating interference from other cells) measured at the receiver antenna connector, integrated in a noise bandwidth equal to the chip rate and normalized to the chip rate.
N_t	The effective noise PSD (at the receiver).

The carrier to noise and interference ratio or *geometry G* is defined as:

$$CNIR = G = \frac{\hat{I}_{or}}{I_{oc} + N_t}$$

The approach for estimating Release-5 coverage can be summarized as follows:

- The distribution of geometry throughout the cell is calculated. This indicates the worst case G_X for a given coverage target, X (i.e. X% of randomly distributed users experience a geometry G_X or higher).

- The link performance of FACH/S-CCPCH is obtained for the chosen G_X in terms of BLER vs. E_c/I_{or}. This indicates the fraction of power that must be allocated to MBMS to meet the target BLER at a receiver experiencing G_X; i.e. for the worst case user to experience no worse than the target BLER
- Under certain assumptions, the change in geometry can be compensated by a reciprocal change in E_c/I_{or}. Thus, it is possible to calculate the power required for other values of geometry, which directly translates into other coverage targets.

In general terms, therefore, as the worst case geometry increases, E_c/I_{or} correspondingly decreases and hence less resources are required for supporting PtM MBMS.

2.1 Geometry CDF in Different Environments

The cumulative distribution function (CDF) of geometry can be obtained through uniformly distributing a large number of mobile stations in a cellular environment and calculating the CNIR at each location using well-known path loss models [2]. Using this approach and simulation assumptions shown in the Annex, the geometry CDF was obtained for urban macrocell and urban microcell environments (figure 1). The following observations can be made:

- In the macrocell (hexagonal layout with 1000m base station spacing), 80% of users experience a geometry of -2.5 dB or better and 95% of users experience a geometry of -5.2 dB or better.
- The microcell (Manhattan grid with 360m base station spacing) is a more benign environment, with 80% of users enjoying a geometry of 2 dB or better and 95% a geometry of -2.5 or better.

It should be noted that the microcell is likely to be a more favourable environment not only due to a better geometry distribution, but also due to better propagation conditions (more line of sight propagation). It can be concluded that the macrocellular environment is the more challenging scenario for successful MBMS provision.

2.2 Link Level Performance

The S-CCPCH link performance was simulated in a number of standard channel models, as shown in figure 2. The geometry of -3 dB was assumed, which corresponds to coverage of approximately 85% of users (considering the macrocell scenario). Assuming a 1% block error rate (BLER) target, the E_c/I_{or} for 85% coverage can be obtained from the link performance. For example, assuming the vehicular A channel model and the mobile speed of 3 km/h, the required relative MBMS power is equal to -7.0 dB (20% of the base station power).

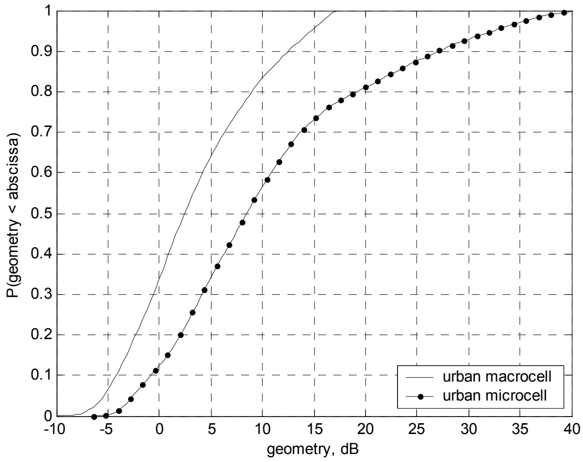

Figure 1 Geometry CDF.

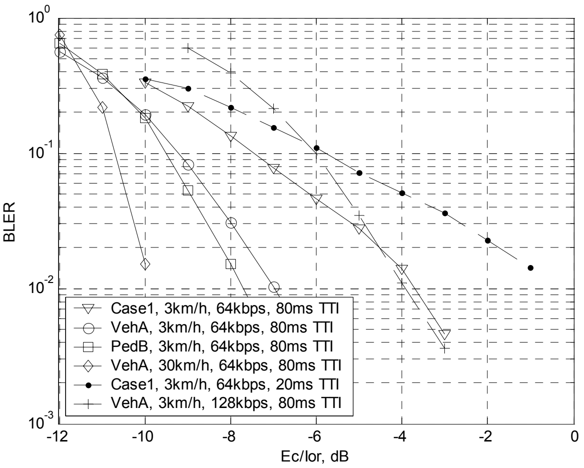

Figure 2 S-CCPCH link performance, G=-3 dB.

In can be observed from figure 2 that while the provision of 64 kbps MBMS seems viable, 128 kbps or higher may be problematic in the macrocell with Release-5 technology, in particular once practical implementation margins, which have not been considered in this analysis, are taken into account.

Another observation is the benefit of using long transmission time interval (TTI) values, as illustrated by the Case 1 result with a 20 and 80 ms TTI. Simply explained, a TTI is the interleaving period for an information block; 80 ms is the maximum supported by Release-5. Employing long TTI values requires large mobile receiver memory, but the time diversity gain justifies this cost.

2.3 Coverage Estimation

A coverage of 85% is likely to be insufficient in practice; a higher value of 95% may be required. Figure 3 shows the coverage of 64 kbps MBMS vs. relative MBMS transmit power. The results are only presented for the most relevant propagation channels. As can be verified, approximately 30-35% of the total power available to the base station is required for 95% coverage in the macrocellular environment.

Figure 3 was obtained by scaling the reference geometry and E_c/I_{or} values obtained from figure 2. This is justified because, when a small portion of the code tree is active, the link performance of WCDMA with a rake receiver is intercell interference limited at low geometry values (-3 dB or lower).

Although the geometry distributions were obtained assuming the high power base station class (43 dBm), the presented coverage is also applicable to other, lower base station classes. This is because intercell interference, rather than receiver noise is the limiting factor in the high coverage scenario.

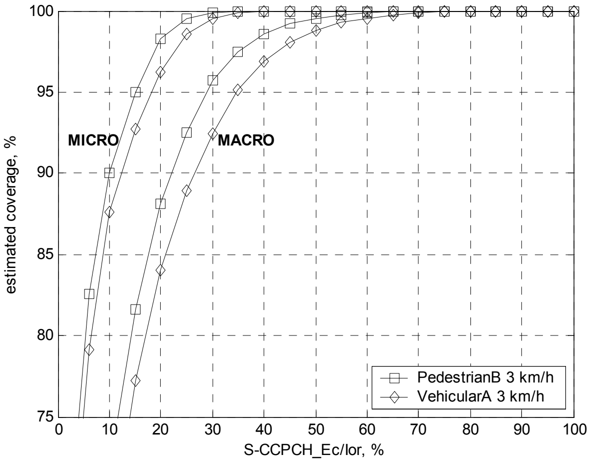

Figure 3 MBMS coverage vs. relative transmit power (64 kbps information rate, Release-5 FDD UTRAN).

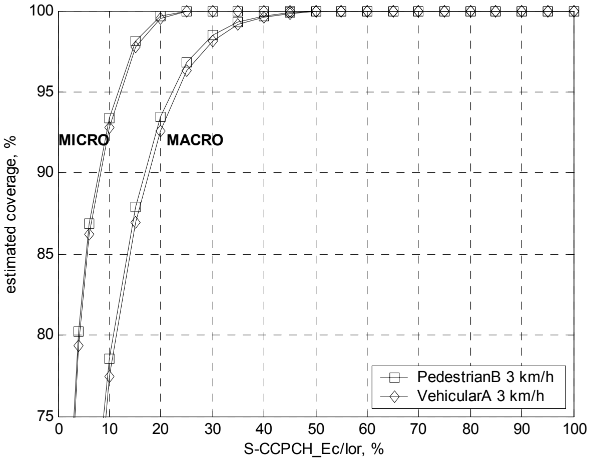

Figure 4 MBMS coverage vs. relative transmit power (64 kbps information rate, Release-5 FDD UTRAN, STTD)

2.4 Coverage Estimation with STTD

The S-CCPCH link performance can be improved by employing space-time transmit diversity (STTD) [3], which is part of UTRAN. Figure 4 shows the coverage benefits of STTD, based on simulation results from [4]. However, the support for STTD is optional in the standard, and the benefits of STTD may not materialize within a short time scale. Moreover, the results shown in figure 4 should be considered optimistic, as independent channels were assumed in the link level simulations.

3 Coverage Improvements through Exploiting Macrodiversity

The results presented in the previous section indicate that an MBMS bit rate of 64 kbps could be supported by Release-5 UTRAN in the macrocellular scenario. More advanced solutions are needed for higher bit rates. MBMS content is expected to be network specific rather than cell specific, i.e. the same content is expected to be available through the entire network or its large part. Therefore, a natural way of improving the physical layer performance is to take advantage of macrodiversity. On the network side, this means ensuring sufficient time synchronization of identical MBMS transmissions in different cells; on the mobile station side, this means the capability to receive the same content from multiple transmitters.

Macrodiversity for PtM MBMS cannot operate in the same manner as soft-handover for dedicated channels, due to the broadcast nature of the system. Two types of macrodiversity combining have been proposed for Release-6:

- *Selection Combining* (SC). The mobile receives two (or more) radio links in its physical layer independently. The decoded blocks are passed on to the radio link control (RLC) layer, which performs the CRC check, block selection and data reordering.
- *Maximum Ratio Combining* (MRC). This takes place in the physical layer prior to FEC decoding.

The proposed methods improve coverage performance using system-level and link-level mechanisms described below.

3.1 Geometry Improvements

Some insight into the achievable macrodiversity gain available from soft combining can be obtained by comparing the geometry corresponding to a 2-way soft handover (SHO) to the single radio link (RL) geometry discussed so far (figure 5). For the SHO case, maximum ratio combining was performed on the two strongest radio links, if their relative powers differ by no more than 3 dB. It is seen that, with a 2RL SHO, 95% of receivers experience a geometry of -2.5 dB, as opposed to -5.2 dB.

3.2 Link Level Gain

Apart from the system-level CNIR improvement, macrodiversity also brings a link-level diversity gain, which stems from the presence of two (or more) independently fading channels.

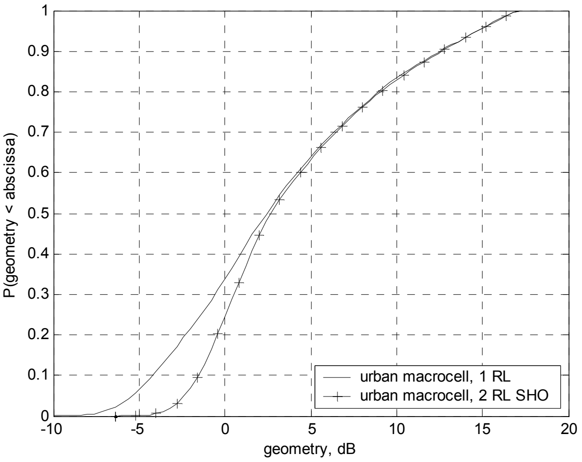

Figure 5 Geometry CDF (SHO benefit).

3.3 Simulation Methodology

The static geometry analysis does not fully describe the macrodiversity gain as, while accounting for the system-level CNIR improvement, it fails to capture the link level diversity gain. Therefore, the following approach was adopted in order to capture both the system and link level gains:

1. BLER vs. instantaneous SNIR (signal to noise and interference) curves are obtained through link level simulations. (Note these are different from the traditional long-term curves.)
2. At the beginning of the system level simulation, a large number of mobile stations are dropped into a macrocellular layout and affiliated to base stations. Affiliation is based on the received power, taking into account the macrocell propagation model and a handover margin. After affiliation, the next 1 or 2 strongest links are also noted for each mobile.
3. The system level simulation operates with a resolution of 1 TTI. In each TTI,
   - Both the propagation and fast fading channel models are taken into account in order to obtain an average SNIR during the TTI.
   - For maximum ratio combining, the SNIRs of the active links are summed up. A pass/fail is then randomly generated according to the link level BLER figures.
   - For selection combining, the BLER figure is obtained separately for each active link, based on individual SNIRs. A pass/fail is then generated for each link according to their respective BLERs, and then a logical OR of the results is performed.
4. The BLER over many TTIs is counted for each mobile station. A BLER threshold (of 1%) is then applied, with those mobiles whose BLER is below the threshold counted as being "in coverage".

3.4 Coverage Estimation, Macrodiversity

Coverage estimates using macrodiversity are shown in figures 6 and 7. For the 64 kbps service, the relative power requirement is equal to only 15-20% and 10-15% for SC and MRC respectively (95% coverage and 1% BLER). It is also observed that the 128 kbps service requires 40-50% of total power if SC is used; this reduces to only 30-40% with MRC.

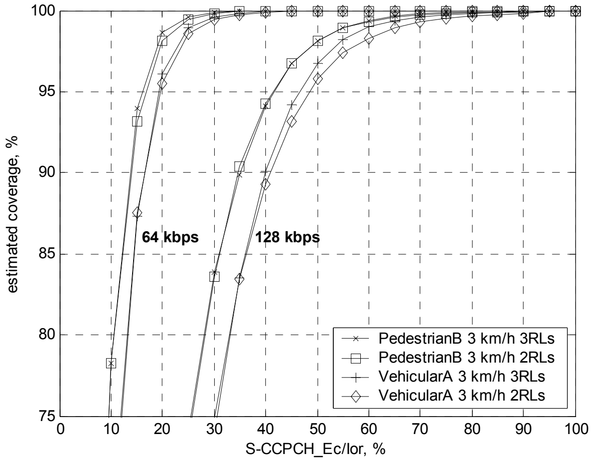

Figure 6 MBMS coverage vs. relative transmit power, SC.

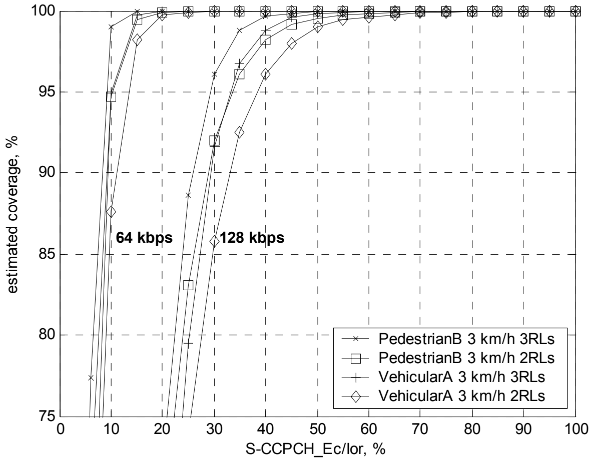

Figure 7 MBMS coverage vs. relative transmit power, MRC.

3.5 System Requirements for Macrodiversity Support

Supporting MBMS places a number of new requirements for both the network and the terminal. These can be summarised as follows:

- New channels MCCH/MICH (MBMS signalling channels), MTCH (MBMS traffic channel).
- For macrodiversity combining, some degree of synchronization between base stations is required. This is likely to be in the order of tens of milliseconds for selection combining, or up to 1ms for soft combining.
- Synchronization of content between base station elements that take part in macrodiversity.
- Inter-frequency and inter-system measurements pose an additional challenge for MBMS terminals. Since it is not

possible to schedule discontinuous transmission periods, terminals may have to cover data lost during measurements with higher layer error correction.

4 Conclusion

The simulation results indicate that, based on the functionality currently available in Release-5, 30-35% of the total base station power would be required for providing 64kbps PtM MBMS in the macrocellular environment. This can be reduced to 10-15% through the introduction of new techniques in the Release-6 physical layer, such as macrodiversity combining. Moreover, simulation results indicate that the provision of 128kbps PtM MBMS is likely to be viable with Release-6. Prerequisites for this gain, however, include a certain degree of content and timing synchronization in the network.

In the microcellular environment, improved geometry and propagation conditions lead to a significantly reduced resource demand, compared to the macrocell scenario.

It should be noted that, at the time of writing, the precise MBMS macrodiversity mechanism to be included in UTRAN Release-6 is still under discussion.

Annex Simulation Assumptions

For more details please refer to [4].

Parameter	Value
S-CCPCH slot format	10 (64 kbps, SF=32) 12 (128 kbps, SF=16)
Transport block size	1280 (64 kbps, 20ms TTI) 5120 (64 kbps, 80ms TTI) 10240 (128 kbps, 80ms TTI)
CRC length	16
# turbo decoding iterations	4
CPICH Ec/Ior	-10 dB
P-SCH Ec/Ior	-15 dB
S-SCH Ec/Ior	-15 dB
OCNS	varied to sum total Ec/Ior to 1
Number of rake fingers	equal to # of channel taps
Channel estimation	from pilots
Carrier frequency	2 GHz
Doppler spectrum	Jakes
Channel parameters pedestrian B	[0 200 800 1200 2300 3700] ns [0 -0.9 -4.9 -8.0 -7.8 -23.9] dB
vehicular A	[0 310 710 1090 1730 2510] ns [0 -1 -9 -10 -15 -20] dB
case 1	[1 976] ns [0 -10] dB

Table 1 Link level simulation assumptions.

Parameter	Value
cellular layout	hexagonal grid
number of rings around central site	4
sectorization	yes, 3 sectors/site
site to site distance	1000 m
base station antenna gain + cable loss	14 dBi
antenna front to back ratio	20 dB
horizontal antenna pattern	Gaussian
antenna beamwidth, -3 dB	70 degrees
propagation model	128.1+37.6*log(R) dB
std of shadow fading	10 dB
correlation between sites for slow fading	0.5
base station total transmit power	43 dBm
thermal noise	-174 dBm/Hz
mobile noise figure	9 dB
handover threshold	3 dB

Table 2 System level simulation assumptions, macrocell.

Parameter	Value
cellular layout	Manhattan grid
block width	75 m
road width	15 m
building to building distance	90 m
average building height	12 m
number of transmitters	84
transmitter placement	middle of the road
antenna height	12.5 m
sectorization	no
straight line distance between transmitters	360 m (4 blocks)
base station total transmit power	33 dBm
horizontal antenna pattern	omnidirectional
base station antenna gain	2 dBi
propagation model	Walfisch-Ikegami
std of shadow fading	NLOS: 10dB LOS: 4dB

Table 3 System level simulation assumptions, microcell (where different from macrocell).

Acknowledgement

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