UE Counting Mechanism for MBMS Considering PtM Macro Diversity Combining Support in UMTS Networks

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Abstract—Multimedia Broadcast and Multicast Services (MBMS) specified in 3GPP Release 6 are expected to be transmitted to large groups of users within the cell range. MBMS Counting Mechanism intends to analyse whether it is more economic to transmit the multimedia services in a Point-to-Point (PtP) or Point-to-Multipoint (PtM) mode, evaluating in terms of radio resources management whether it is preferable to use a single common channel reaching down the cell edge or single dedicated channels allocated to each user which convey identical MBMS content. MBMS Counting Mechanism was initially developed without consideration of Macro Diversity Combining (MDC) and users were only counted in each cell individually which can result in a waste of radio resources. With the introduction of MDC techniques users need to be counted in several cells so that they can successfully receive the MBMS services at the cell edge.

Index Terms—Macro Diversity Combining, MBMS Counting Mechanism

I. INTRODUCTION

The MBMS feature, introduced by 3GPP in Release 6 is proposed to more efficiently use network and radio resources for the transmission of multimedia services both in the core network and, most importantly, in the air interface of UTRAN (UMTS Terrestrial Radio Access Network), where the bottleneck is placed to a large group of users.

One of the most important properties of MBMS is resource sharing among many User Equipments (UE’s), meaning that many users should be able to listen to the same MBMS content present in the cell, but not useful on small number of users. PtP is useful on small number of users, but not useful on large number of users because of radio capacity. It’s just a trading-off relationship. So, even though initially one transmission method of the two is used, it may or may not change to the other transmission method sooner or later. The criteria for the decision of the threshold value will be based on the required cell transmitted power.

Furthermore, in view of the fact that it seems very difficult to predict, when PtP channels or one PtM channel should be used in a cell, it should be made visible how it would be possible to improve system capacity, if switching between PtP and PtM channels is available.

In this paper macro diversity combining fundamentals and techniques are introduced in section II. Section III presents the MBMS counting mechanism algorithm. In section IV an approach of how to integrate the PtM macro diversity support in the counting process is presented. Some simulation results are shown in section V, and finally some conclusions are drawn in section VI.

II. MACRO DIVERSITY COMBINING

Macro Diversity Combining (MDC) is proposed as an enhancement to the UMTS 3GPP Release 6 MBMS. In a point-to-multipoint MBMS service the transmitted content is expected to be network specific rather than cell specific, i.e. the same content is expected to be multicast/broadcasted through the entire network or through most of it. Therefore, a natural way of improving the physical layer performance is to take advantage of macro diversity.

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 and decode the same content from multiple transmitters simultaneously.

Basically the diversity combining concept consists of receiving redundantly the same information bearing signal over two or more fading channels, and combine these multiple replicas at the receiver in order to increase the overall received SNR.
In macro diversity the received signals from different paths have to be processed using some sort of combining algorithm. Two different combining procedures referred in [1] are considered to be introduced in MBMS to support simulcast transmissions, namely Selective Combining (SC) and Maximal Ratio Combining (MRC).

A. Selective Combining

With SC the multi-path channel yielding the highest SNR is always selected. In order to guarantee that the receiver uses the best quality channel, a simultaneous and continuous monitoring of all multi-path channels is required.

B. Maximal Ratio Combining

The Maximal ratio combining, although being a more complex combining technique, is the optimum way (in terms of at least BER/BLER) to combine the information from the different multi-path channels. The receiver corrects the phase rotation caused by the fading channel and then combines the received signals of different paths proportionally to the strength of each path. Since each path undergoes different attenuations, combining them with different weights yields an optimum solution under an AWGN channel.

III. MBMS COUNTING MECHANISM

The MBMS counting function specified in [2] includes a mechanism by which the UTRAN can prompt users interested in a given service; the UE counting is processed making use of the RACH channel in the UL. If a MBMS Multicast session is going to be started, an indication to the UE’s interested in receiving the multicast session shall be done. Each UE wishing to be counted for that particular service should transmit a RACH notification reporting their interest during the counting procedure. Since it is desirable to avoid bringing a large number of UE’s for counting purposes at the same time (RACH load), some RRM procedures may be taken such as setting an “access probability” factor for each of the interested UE’s. The RNC may use notification to indicate counting during an ongoing MBMS session (re-counting).

The counting process will be initiated by receiving the RACH notification of each interested UE. If the counting result is over the predefined PtM threshold the UTRAN shall initiate a PtM channel establishment in the cell, otherwise PtP transmission modes should be used to provide the same MBMS content.

IV. MBMS COUNTING MECHANISM WITH MDC SUPPORT

MBMS Counting Mechanism was initially developed without considering the possibility of exploiting SC or MRC techniques, and MBMS users are counted in each cell individually. With the introduction of SC and MRC users need to be counted in several cells so that they can successfully receive the MBMS services at the cell edge.

Not considering the possibility of exploiting macro diversity combining for MBMS Counting Mechanism may result in a waste of resources since mobile users, especially at cell edge where the interference levels are higher will not take advantage of macro diversity combining since the neighbour cells will not be providing the same MBMS content in a PtM mode.

With the introduction of MDC in the counting process the UTRAN needs to identify what cells are, or should be used for selective/maximal ratio combining. This can be done by composing a “window” for each UE identifying the cells from which the UE receives the strongest signals (in this study this window is composed by the three strongest cells). Based on these reports, and knowing which cells are already transmitting de MBMS service, the UTRAN is able to determine/redefine the cells, or part of the cells where PtM or PtP transmission modes should be used.

As mentioned in the previous section a number of UE’s threshold is used to set the PtP or PtM transmission mode in the cell. The criteria for the decision of the threshold value will be based on the required transmitted power from the cell, determining how many PtP dedicated channels are “equivalent” to a common PtM channel.

In a PtM transmission the cell transmitted power requirement will decrease when UE’s can perform macro diversity combining with the neighboring cells. Therefore the UTRAN can set a lower threshold value for switching from PtP to PtM and vice versa, adjusting at the same time the common channel transmitted power of the cells involved.

V. SIMULATION RESULTS

In this study the presented results were obtained for a CBR 64 kbps service with a TTI of 80 ms and 1% BLER. Cells were placed with a site to site distance of 1000 meters, having omni-directional antennas with a maximum transmission power of 33 dBm. The fading channel model considered was ITU Vehicular A at a speed of 3 km/h.

Figure 1 shows the comparison between the transmitted power over PtP DCH’s and PtM FACH channels. The estimates for the transmitted power over DCH’s were calculated by uniformly distributing the UE’s in cell C (as shown in Figure 2) with a given random mobility inside the cell radius. The simulation was repeated several times with and without other cells interference, the average result was then plotted in Figure 1 to be compared with the fixed transmit power cell fraction for the FACH common channel presented in [3].

![Figure 1: Average cell Tx power vs Number of UE’s per cell]

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From Figure 1 it was set the threshold from switching from PtP and PtM and vice versa. Results presented show not only the comparison between PtP and one radio link (RL) PtM, but also the comparison with PtM connections when it is possible to perform macro diversity combining with two or three cells either using selective or maximal ratio combining at the receiver side.

The results presented further in this paper will only address selective combining as the macro diversity combining technique used. The threshold values for the number of users per cell taken from Figure 1 are as follow:

- Threshold 1: 7 (PtP $\iff$ PtM-1RL $\iff$ PtM-1RL $\iff$ PtP)
- Threshold 2: 5 (PtP $\iff$ PtM-2RL $\iff$ PtM-2RL $\iff$ PtP)
- Threshold 3: 3 (PtP $\iff$ PtM-3RL $\iff$ PtM-3RL $\iff$ PtP)

In [3] it is shown that SC requirements are less much restricted in terms of cells transmission synchronization than MRC, and therefore can be more easily performed at the receiver side (in [3] it is also referred that the UE should perform MRC if it can and SC otherwise). Inside the same MBMS group whenever macro diversity combining is available there could be some UE’s that can perform MRC and others only SC. For this reason it was considered SC as the macro diversity combining technique used, MRC would give to much optimistic results, since it would decrease the reference switching thresholds which is translated in lower average transmitted power.

In the next sub-sections the studied scenarios and the obtained results are presented. Scenario 1 represents a simple case were MBMS counting mechanism operates in one cell separately. In scenario 2 macro diversity combining is introduced in the MBMS counting mechanism and UE’s need to be counted in several cells.

**A. Scenario 1:**

In this scenario (Figure 2) UE’s are randomly placed in cell C, each UE will then receive the session in a time interval of 190 seconds where the session duration is equal to 2800 seconds. During each session UE’s move randomly inside cell C radius.

The oscillation line in the top graph of Figure 3 indicates the case when the cell is transmitting in a PtP mode over DCH’s with power control, the constant line corresponds to the PtM case with a fixed transmitted power.

When analysing Figure 3 is very important to follow the number of UE’s in cell C above depicted. Taking as reference the elapsed time and comparing both graphs one can notice that cell C is transmitting the service in a PtP mode until the threshold 1 (7 UE’s) is reached.

In the time interval between 1200 and 5400 seconds the cell is transmitting in the common PtM channel while the number of user’s remains equal or higher than the threshold. After this period while the number of users continues to leave the MBMS group the number of UE’s falls down the threshold and PtP dedicated channels are set for the remaining UE’s in the cell.

**B. Scenario 2:**

A scheme of scenario 2 is shown in Figure 4. In this scenario 24 UE’s are placed static in cell C but close to the borders of cells A and D. When all UE’s are turned on in cell C a group of 8 UE’s move towards cell A, after reaching cell A another group of 8 UE’s move now to cell D. The simulation ends with groups of 8 UE’s in cells A, C and D.
Below Figure 5 captures the cell C statistics during the simulation period.

![Cell C Stats](image)

**Figure 5: Cell C Stats (Scenario 2)**

As can be see from Figure 5 in the beginning of simulation the service is being transmitted in PtP radio channels until the number of UE’s reach the threshold 1 (7 UE’s). The transmitted power remains constant during the rest of the simulation being adjusted around the 6000 and 9600 seconds when cell A and cell D start transmitting in a PtM mode being the UE’s that are located in cell C able to perform selective combining with 2 and 3 radio links respectively.

Figure 6 shows the statistics obtained for cell A. In this case the switching point reference will be threshold 2 since cell C is already transmitting in PtM mode and UE’s in cell A will have the possibility of exploiting selective combining with the PtM radio link of cell C if the same MBMS service is provided over a PtM channel in cell A. As can be seen from Figure 6 cell A moves from PtP to PtM transmission mode when the number of UE’s in cell reaches 5.

![Cell A Stats](image)

**Figure 6: Cell A Stats (Scenario 2)**

Figure 7 present the similar statistics results for cell D. In this case cell transmission mode goes from PtP to PtM when the number of UE’s in cell reaches 3 (threshold 3). All the UE’s now can perform selective combining with cells A, C and D.

![Cell D Stats](image)

**Figure 7: Cell D Stats (Scenario 2)**

In Figure 8 is depicted the mean transmitted power of the cells involved in the transmission of the MBMS service during the simulation. The three transitions on the average transmitted power correspond to the scenario presented, were the PtM transmission starts in cell C (1 RL), later on continues in cell A (2 RL-SC) and later on continues in cells C, A and D all transmitting in PtM mode (3 RL-SC). The oscillation in the average transmitted power occurs when the service is being transmitted in a PtP mode in any of the cells. Analysing Figure 8 it is possible to notice an increase on the mean transmitted power just before any of the cells that is transmitting the MBMS service in PtP connections shift to PtM mode. Notice that when a new cell starts transmitting in a PtM mode and macro diversity is available between cells the transmitted power in the involved PtM channels decreases.

![Cells Mean Tx Power](image)

**Figure 8: Cells mean transmitted power (Scenario 2)**

C. **Scenario 3:**

This scenario, depicted in Figure 9, can be seen as a continuation of scenario 2. In this scenario it is proposed to use both modes of transmission (PtM and PtP) in cell C.

The simulation starts with cells A, C and D transmitting the MBMS service in a PtM mode. At half of simulation time 8 UE’s in cell C, in the vicinity of cells E and B (where no MBMS transmission is available), start receiving the same MBMS service in a PtP mode since macro diversity combining isn’t available between cells E and B.
Figure 9: Scenario 3

Figure 10 presents the statistics obtained for cell C during the simulation period. The fixed transmitted power, illustrated as a reference, in the second half of the simulation period represents the case where the service is being provided in a PtM mode in cell C and the Threshold 1 is applied (macro diversity support cannot be assumed for all the MBMS group in cell C).

![Figure 10: Cell C Stats (Scenario 3)](image)

Analysing Figure 10 we can observe that for this case combining the PtM (3RL-SC) connection with other five PtP dedicated channels requires less power than setting one PtM channel to cover all the UE’s in the cell.

In conclusion for some particular cases and whenever macro diversity is available for a considerable number of UE’s of the same MBMS group, setting a PtM connection for these UE’s that can perform macro diversity and use a limited number of PtP dedicated channels for the rest of the UE’s in the group can be a reasonable approach to transmit the service in an efficient mode.

**VI. CONCLUSIONS**

In this paper some radio resources management methods concerning the efficient usage of the UMTS radio resources for broadcast/multicast kind of services proposed in 3GPP Release 6 were analysed.

MBMS counting mechanism should be used to decide whether the identical MBMS service contents should be transmitted in a PtP or PtM mode to a group of users. The decision proposed was based taking as cost function the total transmitted power in a cell.

Macro diversity combining for PtM connections is crucial for MBMS, since it improves significantly the received signal quality in the UE and therefore allows a substantially decrease in the necessary transmitted power in the common channels to deliver the requested QoS. In a multi-cell transmission, instead of avoiding interference at the cell border, all the neighbouring cells are used for transmission of the same information to the UE thus reducing inter-cell interference as well as improving the overall available transmit power.

MBMS counting mechanism was initially designed to count UE’s in each cell independently, but with the introduction of macro diversity some changes need to be made in the counting process and UE’s need to be counted in several cells in order to exploit the benefits of macro diversity combining.

Despite MBMS main purpose is to transmit the multimedia services in a PtM mode, it was shown that PtM is useful when large numbers of users are present in the cell and PtP could work better on small number of users because of radio capacity. Therefore, determining the transmission mode in each cell it was shown to be just a trading-off relationship in terms of radio resource management.

When the MBMS transmission is ongoing in a neighbour cell the UE should inform the UTRAN of which cells transmitting the MBMS service in a PtM mode it proposes to combine, or what are it strongest neighbouring cells. With this information the UTRAN should use the appropriate thresholds for switching, or start a transmission in a PtP or PtM mode.

The MBMS counting mechanism can also be set to order the cell to transmit the same service in both PtM and PtP modes to the users belonging to the MBMS group. This would happen whenever the majority of the UE’s in the cell can perform macro diversity combining with they neighbouring cells, and there exists a relatively small number of UE’s located close the vicinity of different neighbor cells that are not transmitting the same MBMS service in a PtM mode.

However, this would only be valid if the transmitted power in the common channel (decreased due to the possibility of exploiting macro diversity) plus the transmitted power of the dedicated channels isn’t higher than setting the cell common channel transmission power to cover all UE’s in the cell.

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