A NEHO based MBMS Handover Control Approach

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Abstract—Handover Control is one of the essential means to guarantee the continuity of mobile services to a user traveling in a cellular infrastructure, without interruption. In previous work we illustrated that using the current 3GPP specified handover control algorithm to provide continuity of MBMS (Multimedia Broadcast Multicast Service) services to a user crossing cell boundaries results either in capacity or QoS inefficiencies and proposed a new MEHO (Mobile Evaluated Handover) based MBMS handover control algorithm that compensated for them. This algorithm, although effective in terms of capacity and QoS, has some limitations concerning the way certain parameters are handled for the efficient MBMS handover execution are estimated. In this paper, using a different approach (Network Evaluated Handover (NEHO)), we enhance previous work and propose a different method, that eliminates all of its predecessor’s deficiencies while achieving the same capacity and QoS efficiencies.

Keywords—MBMS; Network Evaluated Handover Control; RRM

I. INTRODUCTION

With MBMS (Multimedia Broadcast Multicast Service) services [1], the Radio Network Controller (RNC), for radio resource efficiency (see [2]) can use either Point-to-Point (P-t-P) or Point-to-Multipoint (P-t-M) transmission mode (but not both at the same time) to distribute the MBMS content within a cell (see Figure 1). If a P-t-M transmission mode is selected, one FACH (Forward Access Channel) is established covering the whole cell’s area and commonly shared by all the MBMS users within, otherwise, one Dedicated Channel (DCH) is established for each MBMS user within. Thus, a user that is on the move and receives an MBMS service may have to handover between P-t-P (DCH) and P-t-M (FACH) transmission mode cells, when crossing the cells’ boundaries (we refer to these types of handovers as “MBMS Handovers”).

Figure 1. Point-to-Point & Point-to-Multipoint transmission mode cells

In previous work [3] we show that using the current 3GPP specified handover control algorithm [4] to provide continuity of MBMS bearer services to a user traveling between a P-t-M and a P-t-P transmission mode cell can result either in capacity or QoS inefficiencies, due to the specific design of the FACH which offers capacity benefits and bounded coverage range. Therefore, in [3], by taking full advantage of FACH’s capacity benefits and considering its bounded coverage range characteristic, we proposed a specific MBMS handover control algorithm that addressed the aforementioned inefficiencies, and achieved enhanced capacity and more seamless handovers (i.e. service interruption avoidance) by executing the MBMS Handover on the FACH’s coverage limit (see Figure 1). This is a point as close to the P-t-P Base Station (BS) as possible, thus reducing the total downlink power in the P-t-P cells to the minimum required, and inside FACH’s guaranteed coverage area, thus avoiding any QoS degradation during handover.

The algorithm we proposed in [3], which followed a Mobile Evaluated Handover (MEHO) approach (i.e. the handover decision making is prepared by the User Equipment (UE)), although effective in terms of capacity and QoS, has some limitations concerning the way certain parameters are handled for the efficient MBMS handover execution are estimated. In this paper, using the same idea (i.e. execute the MBMS handover on the FACH’s coverage limit) but a different approach (Network Evaluated Handover (NEHO); i.e. the handover decision is prepared by the RNC), we enhance previous work addressing all of its predecessor’s deficiencies, while at the same time achieving the same capacity and QoS efficiencies. It is worth mentioning that an MBMS handover algorithm addressing the deficiencies of [3] has also been proposed in [5] but following a MEHO approach. The major benefit of the NEHO approach proposed in this paper compared with the MEHO proposed in [5] is that it keeps things simple in the UE since all the processing load concerning the handover decision making is passed to the RNC. A more comprehensive evaluation of the NEHO approach we propose here and the MEHO approach proposed in [5], highlighting the advantages and disadvantages of each approach, is left for future work.

The paper is organized as follows. In section II the deficiencies of the previously proposed MBMS handover algorithm [3] are highlighted. The enhanced MBMS handover control algorithm following a NEHO approach is described in section III and evaluated in section IV. Finally in section V we provide our conclusions.

II. DEFICIENCIES OF PREVIOUSLY PROPOSED APPROACH

The MBMS handover control algorithm we proposed in [3] although achieving significant transmission power savings and seamless handovers during the MBMS service provision, has some limitations concerning the way the MBMS Handover
Trigger Threshold (MHTT) is estimated (i.e. the threshold value that indicates the exact time of MBMS handover triggering in order to be efficiently executed on the FACH’s coverage limit). More specifically:

- A GPS (Global Positioning System) receiver (or a similar approach) is required to be installed on the UE, since for the accurate estimation of the MHTT, the instantaneous location and the mobility pattern (i.e. speed, direction) of the MBMS user is required.
- The UE is burdened with some extra processing effort for the estimation of the MHTT.
- The MCCH (MBMS P-t-M Control Channel [1]) is required to be enhanced to accommodate some fields.

The new NEHO based MBMS Handover control approach, addressing all the aforementioned is described in detail below.

III. PROPOSED NEHO BASED MBMS HANDOVER CONTROL

The algorithm we propose here using a NEHO approach, enhances previous work in order to achieve efficient MBMS Handover execution and address its predecessor’s deficiencies referred in section II . The new approach, instead of having the UE to continuously estimate and decide by itself the exact time of handover triggering (MEHO approach), the responsibility of this activity is passed to the RNC (NEHO approach). Before continuing, it is worth mentioning that the main input in making the MBMS handover decision is only the Common Pilot Channel (CPICH) Ec/No signal strength received from the BS in the P-t-M cell (P-t-M BS’s CPICH). The algorithm we propose here consists of three main phases. These are the measurement, the decision and the execution phase.

Measurement Phase:

During this phase, the MBMS users continuously measure the CPICH Ec/No signal strength of the current and neighboring cells, and report to the RNC the results (i.e. pairs of <Cell ID, Instantaneous CPICH Ec/No Signal Strength received>, etc.). In order to reduce signaling traffic, the measurement reporting will be controlled by a set of rules; i.e. the UEs will start sending the reports when the measured CPICH Ec/No signal strength of the Current cell reaches a threshold value. This threshold will be set by the RNC and send to the UE via Layer 3 signaling. A similar approach is used with the current 3GPP handover algorithm [4]. Although, what is new here is that some of the information included in the reports is stored in a record created at the RNC for the associated MBMS user in the “MBMS Handover Information Table (MHIT)” (see Table I). The MHIT will later assist the algorithm to identify if an MBMS user is likely to execute an MBMS Handover and facilitate the efficient MBMS handover execution (see the Decision phase). It is important to indicate that the RNC creates one MHIT for each cell that belongs to at least one MBMS Service Area (the area in which a specific MBMS session is made available and is represented by a specific group of cells). The MHIT includes the following info:

- **CELL ID:** Uniquely identifying the cell which the respective MHIT belongs to.

- **MBMS Services supported:** Includes all the MBMS services that can be supported in this cell. Each MBMS service is identified by its TMGI (Temporary MBMS Group Identity). For each MBMS service, the type of transmission mode used in that cell for its provision is indicated (either P-t-P or P-t-M). In case the MBMS service is provided using P-t-M transmission mode (i.e. MBMS content is provided using FACH), the FACH’s coverage limit is indicated by specifying the minimum P-t-M BS’s CPICH Ec/No signal strength required to be received by the MBMS user for achieving a reliable reception of the respective MBMS service content using FACH (i.e. with the requested Bit Error Rate).

- **One record for each MBMS user within the cell that is likely going to execute an MBMS Handover:** Each record is associated with the UE’s IMSI (International Mobile Subscriber Identity uniquely identifying the MBMS user) and includes information concerning the instantaneous CPICH Ec/No signal strength and CPICH Ec/No alteration rate experienced by the Current and Best Monitored cells during the MBMS user’s mobility. The CPICH Ec/No alteration rate indicates how fast (dB/sec) the measured CPICH Ec/No signal strength is increasing (i.e. moving towards the cell’s BS) or decreasing (i.e. move away from the cell’s BS) during its mobility.

As indicated above, the MHIT does not include one record for each MBMS user within the cell but one record for each MBMS user that is likely going to execute an MBMS Handover. This is done in order to avoid any redundant use of memory in the RNC (for storing any irrelevant information in the MHIT) and achieve processing effort efficiency (reduce the number of records included thus achieving faster searching, updating and decision making procedures). An MBMS user is likely going to execute an MBMS Handover if he is:

- Currently located in a P-t-P cell and the Best Monitored cell is a P-t-M cell, OR, Currently located in a P-t-M cell and the Best Monitored cell is a P-t-P cell (indicated using the info included in the MHITs).

<table>
<thead>
<tr>
<th>Table I. MBMS Handover Information Table (MHIT)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CELL ID (Identify the Cell that this MHIT belongs to)</strong></td>
</tr>
<tr>
<td><strong>MBMS Services supported:</strong></td>
</tr>
<tr>
<td><strong>Type</strong></td>
</tr>
<tr>
<td><strong>P-t-M or P-t-P</strong></td>
</tr>
<tr>
<td><strong>Type</strong></td>
</tr>
<tr>
<td><strong>P-t-M or P-t-P</strong></td>
</tr>
<tr>
<td><strong>UE_1 IMSI</strong></td>
</tr>
<tr>
<td><strong>UE_2 IMSI</strong></td>
</tr>
</tbody>
</table>

As indicated above, the MHIT does not include one record for each MBMS user within the cell but one record for each MBMS user that is likely going to execute an MBMS Handover. This is done in order to avoid any redundant use of memory in the RNC (for storing any irrelevant information in the MHIT) and achieve processing effort efficiency (reduce the number of records included thus achieving faster searching, updating and decision making procedures). An MBMS user is likely going to execute an MBMS Handover if he is:
AND, the user lies in an area, inside which the MBMS handover is most likely to happen. We refer to this area as the “MBMS Handover Activation Area (MHAA)”.

The size of the MHAA area [3] will depend on the value set for a parameter called “Activation Hysteresis (AH)” (measured in dB) which is decided by the Network Operator. This value is highly affected by the propagation environment used (e.g. higher value for vehicular environment, lower value for pedestrian environment). The higher the AH value the larger the MHAA’s size. The value of this parameter should be fixed to that much that will provide enough space for facilitating an accurate estimation of the MHTT and thus achieving accurate MBMS handover triggering, but not too high so as to introduce unnecessary processing (see the decision phase) to the RNC. Having in mind that the main input in making the MBMS handover decision is only the CPICH Ec/No signal strength received from the P-t-M BS we define the MHAA as:

- The area between the FACH’s coverage limit and the point where the measured P-t-M BS’s CPICH Ec/No signal strength is equal to (=) the minimum CPICH Ec/No required for reliably receiving the MBMS Service using FACH (indicated in the Best Monitored cell’s MHIT) minus (−) the AH, if the MBMS user is moving from a P-t-P towards a P-t-M transmission mode cell (see Figure 2).

Figure 2. “MBMS Handover Activation Area” when the MBMS user is moving from a Point-to-Point towards a Point-to-Multipoint cell

- The area between the FACH’s coverage limit and the point where the measured P-t-M BS’s CPICH Ec/No signal strength is equal to (=) the minimum CPICH Ec/No required for reliably receiving the MBMS Service using FACH (indicated in the Current cell’s MHIT) plus (+) the AH, if the MBMS user is moving from a P-t-M towards a P-t-P transmission mode cell (see Figure 3).

Figure 3. “MBMS Handover Activation Area” when the MBMS user is moving from a Point-to-Multipoint towards a Point-to-Point cell

Every time a measurement report is received from an MBMS user, the RNC checks if there is a record already created for him in the MHIT of his cell of attachment:

- If yes, this means that the MBMS user is likely going to execute an MBMS Handover (i.e. lies within the MHAA) and the RNC updates the values, concerning the instantaneous CPICH Ec/No signal strength and CPICH Ec/No alteration rate experienced by the Current and Best monitored cells, based on the latest measurement report received. Upon updating, the RNC needs to check again if the latest measurement report received indicates that the MBMS user is still inside the MHAA. If not, its record is deleted after a period of C seconds. The value of C is a subject of further research and aims to avoid frequent record’s deletion and creation for user following a zigzag trajectory.

- If there is not a record created for him, the RNC, based on the information included in measurement report received and the MHITs of the Current and Best Monitored cells, checks if this MBMS user is likely going to execute an MBMS Handover (i.e. entered the MHAA). If yes, the RNC creates a record for this MBMS user in the MHIT of the Current cell and fills in the instantaneous CPICH Ec/No signal strength experienced by the Current and Best Monitored cells. Since this is the first measurement report received after creating the record, the Current and Best Monitored cells’ CPICH Ec/No alteration rate experienced cannot be estimated. These will be estimated after the second and subsequent measurement reports from the MBMS user are received and then updated accordingly.

The measurement phase is an essential part of the MBMS handover procedure since it provides to the “decision phase” the main input for making the handover decision triggering. Thus any measurement errors can highly affect the efficient execution of the MBMS handover resulting in inefficiencies, due to signaling (caused due to unnecessary handovers), or capacity (due to inefficient use FACH’s capacity benefits), or QoS (due to executing the handover outside of the FACH’s guaranteed coverage area). Since the signal strength of the radio channel may vary drastically due to fading and signal path loss, resulting from the cell environment and user’s mobility, it is important to apply filtering on the handover measurements to average out and minimize the effect of the aforementioned impairments. Appropriate filtering can increase the performance significantly. As long filtering periods can cause delays in the handovers, the length of the filtering period has to be chosen as a trade-off between measurement accuracy and handover delay. Also the speed of the user matters: the slower the user equipment is moving the longer the measurement periods can cause delays in the handovers, the length of the filtering period has to be chosen as a trade-off between measurement accuracy and handover delay. Thus any measurement errors can highly affect the efficient execution of the MBMS handover resulting in inefficiencies, due to signaling (caused due to unnecessary handovers), or capacity (due to inefficient use FACH’s capacity benefits), or QoS (due to executing the handover outside of the FACH’s guaranteed coverage area). Since the signal strength of the radio channel may vary drastically due to fading and signal path loss, resulting from the cell environment and user’s mobility, it is important to apply filtering on the handover measurements to average out and minimize the effect of the aforementioned impairments. Appropriate filtering can increase the performance significantly. As long filtering periods can cause delays in the handovers, the length of the filtering period has to be chosen as a trade-off between measurement accuracy and handover delay. Also the speed of the user matters: the slower the user equipment is moving the longer it is to average out the effects of fast fading. Often a filtering period of 200ms is chosen.

**Decision Phase:**

Assuming that the MHITs of all the cells are continuously updated by the RNC during the “measurement phase”, the MHITs will always include the latest information concerning which MBMS users are likely going to execute an MBMS handover at any specific point in time. Thus the RNC during this phase will continuously monitor these MHITs and decide, based on the instantaneous assessment of each MBMS user’s
QoS connection and a comparison with certain QoS criteria, if an MBMS handover should be triggered.

As indicated above, the aim of our algorithm is to take full advantage of FACH’s capacity benefits, and execute the MBMS handover on the FACH’s coverage limit. Since some delay is caused from the time the handover is triggered until the UE switches channels (Handover Delay time), triggering the handover on the FACH’s coverage limit, will result in the switching of channels at some distance away from it (we refer to this as the “Handover Delay Distance”). Thus, to accommodate this delay and execute the MBMS Handover on the FACH’s coverage limit, a “Pre-Trigger Predictor (PP)” parameter is used. The estimation of the PP parameter (see equation (1)) depends on parameters that vary through time and thus should be continuously estimated by the algorithm. The value of this parameter depends on three parameters:

- **Handover delay time**: The value of this parameter is estimated by the RNC and provided to the algorithm.

- **Instantaneous P-t-M BS’s CPICH Ec/No Alteration Rate (AR) experienced**: This parameter’s value is indicated in the record created for the associated MBMS user in the MHIT of the Current cell.

- **Safety Margin (SM) (measured in dB and \( \geq 0 \))**: Although filtering is performed on the handover measurements, still some minor errors might occur resulting in the MBMS handover execution slightly outside of the FACH’s guaranteed coverage area (this might result in some packet loss). Thus, this parameter by slightly shifting the MBMS handover execution point inside the FACH’s guaranteed coverage area, it aims to lessen any possibility of MBMS service QoS degradation during the MBMS handover. If the user is likely going to handover from a P-t-P to a P-t-M cell, the SM is added (+), otherwise, it is subtracted (-).

The value for this parameter is constant and selected by the network operator, as a tradeoff between the QoS desired to be supported and the capacity gains desired to be achieved. For example, if maximum capacity gain is desired, the SM value will be 0 dB (i.e. execute the handover exactly on the FACH’s coverage limit).

\[
PP = |AR| \times \text{Handover Delay time} \pm SM \quad (1)
\]

Depending on the MBMS Handover type that is going to be executed, the decision of the MBMS handover triggering is handled partially differently. For example, if the MBMS user is likely going to handover from a P-t-P to a P-t-M cell (see Figure 4) AND the CPICH Ec/No alteration rate experienced by the Best Monitored cell is increasing (i.e. moving towards the monitored cell; indicated in the Current cell’s MHIT), the handover is triggered when:

- The Instantaneous P-t-M BS’s CPICH Ec/No signal strength (indicated in MBMS user’s record created in the Current cell’s MHIT) becomes equal to or greater than (\( \geq \)) the minimum CPICH Ec/No required for guaranteeing a reliable reception of the MBMS content using FACH (indicated in the MBMS service’s record in the Best Monitored cell’s MHIT) minus (-) the PP.

Alternatively, if the MBMS user is likely going to handover from a P-t-M to a P-t-P cell (see Figure 5), AND the CPICH Ec/No alteration rate experienced by the Best Monitored cell is increasing, the handover is triggered when:

- The Instantaneous P-t-M BS’s CPICH Ec/No signal strength becomes equal to or less than (\( \leq \)) the minimum CPICH Ec/No signal strength required for guaranteeing a reliable reception of the MBMS content using FACH (indicated in MBMS service’s record in the Current cell’s MHIT) plus (+) the PP.

![Figure 4](image)

**Figure 4. MBMS Handover Triggering - The MBMS user is moving from a Point-to-Point towards a Point-to-Multipoint cell**

**Execution phase:**

Depending on the decision phase’s outcome, the MBMS handover procedure will be triggered by the RNC.

**IV. PERFORMANCE EVALUATION**

For the performance evaluation of the proposed scheme OPNET Modeller 11.0.A UMTS module [7] was used as a base for building the MBMS simulator [8]. For illustrating the feasibility, the gain and the usefulness of the proposed scheme the following scenario (see Figure 6) was used.

In the scenario depicted above, a total of 30 MBMS users, 15 in P-t-P cell (UE 1 – UE 15) and 15 in P-t-M cell (UE 16 – UE 30), are receiving a 64 Kbps MBMS streaming video and are moving with a vehicular speed (selected using a uniform distribution between 30 and 40 Km/h) following a trajectory towards the opposite cell. The **minimum CPICH Ec/No signal strength required** for guaranteeing a reliable reception of the MBMS content using FACH is ~5 dB. The coverage of the cells is 1000 meter and the distance between the BSs is 1850 meters (thus leaving 150 meters cell’s overlap). A vehicular environment is used and a log-normal shadow fading with 10
![Figure 5](image)

**Figure 5. MBMS Handover Triggering - The MBMS user is moving from a Point-to-Multipoint towards a Point-to-Point cell**

**Figure 6.** 15 MBMS users located in P-t-P (UE 1 – UE 15) cell and 15 in P-t-M cell (UE 16 – UE 30), moving with a vehicular speed (~40 Km/h) performing MBMS Handovers
dB standard deviation is assumed. A 20 ms TTI (Transmission Time Interval) and a convolutional channel coding with 1/3 coding rate is used. The downlink other-cell interference factor is 1.78. Two instances of the same scenario have been simulated; using the handover algorithm currently specified by 3GPP and our proposed algorithm respectively. The results collected relate to the capacity (power) requirements and the MBMS users’ QoS experienced by each algorithm.

From the results illustrated in Figure 7, Figure 8 and Table II, we observe that our approach achieved the following gains:

- **Significant transmission power savings:** By taking full advantage of FACH’s capacity benefits (i.e. execute the handover on the FACH’s coverage limit), the maximum downlink power used is reduced from 3.66 to 2.35 watts (that is 36% decrease – Figure 7), while the average downlink power used is reduced from 1.348 to 0.958 watts (that is 29% decrease – Figure 8).

- **Seamless Handovers:** By taking into consideration the FACH’s bounded coverage characteristic and executing the handover on the point where the P-t-M’s BS CPICH is received with the minimum Ec/No signal strength required for guaranteeing a reliable reception of the MBMS content using FACH, managed to avoid any service interruption as occurred with the current 3GPP specified handover algorithm (see Table II for UE’s 6, 7, 12, 22, 23, 24, 26 and 29 shaded with gray). Note that the **minimum CPICH Ec/No required for guaranteeing a reliable reception is -5dB**.

![Graph](image)

**Figure 7.** Actual downlink power required (watts) – Current 3GPP Specified Handover Approach Vs Proposed Handover Approach

![Graph](image)

**Figure 8.** Average downlink power used (watts) – Current 3GPP Specified Handover Approach Vs Proposed Handover Approach

V. CONCLUSIONS

In this paper we present a NEHO based handover approach for MBMS which addresses the deficiencies of the MEHO approach presented in earlier work [3], concerning the method utilized for the estimation of a number of parameters essential for the efficient MBMS handover execution. The new algorithm (running in the RNC) using the information included in the MHI vs as main input, continually monitor the MBMS users that are **likely going** to execute an MBMS handover and facilitate the efficient MBMS handover execution, achieving significant transmission power savings and more seamless handovers. For the presented scenario (using vehicular speeds), we observed a 29% decrease on the average downlink power (capacity) used, and the ability to provide continuity of mobile services during an MBMS handover without interruption. Also with approach, we **reduce** the processing load (which results also in **battery life extension**) and storage requirements in the UE, since the handover decision making procedure is now solely taken by the RNC. It is worth pointing out that in case HSDPA is used for the P-t-P transmission, the handover algorithm proposed in this paper can be used also for HS-DSCH to FACH and vice versa handovers providing similar gains. Future work will include a more detail description of the algorithm, a more comprehensive evaluation and comparison between the NEHO and MEHO [5] approaches and a sensitivity analysis of the proposed NEHO scheme.

![Table](image)

**TABLE II.** CPICH Ec/No SIGNAL STRENGTH RECEIVED BY EACH MBMS USER FROM THE P-T-M BS WHEN MBMS HANDOVER IS EXECUTED – CURRENT 3GPP SPECIFIED APPROACH VS PROPOSED APPROACH

![Graph](image)

**ACKNOWLEDGMENT**

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