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Enhanced radio resource management algorithms for efficient MBMS service provision in UTRAN

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ABSTRACT

As currently specified by 3GPP, Multimedia Broadcast Multicast Service (MBMS) bearer services can be provided within a cell either by Point-to-Point (P-t-P) or Point-to-Multipoint (P-t-M) transmission mode, but not both at the same time. If P-t-P transmission mode is selected for a cell, one Dedicated Channel (DCH) is established for each user within the cell that joined the MBMS service. Otherwise, if P-t-M transmission mode is selected, one Forward Access Channel (FACH) is established covering the whole cell's area and commonly shared by all the UEs within. In this paper, we highlight the inefficiencies that can be caused with the aforementioned approach and introduce the "Dual Transmission mode cell" in which P-t-P and P-t-M transmissions (i.e. multiple DCHs and FACH) are allowed to coexist within the same cell. Hence, we propose a new radio resource allocation algorithm and solution to address them. Our proposed algorithm considers the instantaneous distribution and movement of the users within the cell and dynamically decides which users will use FACH and which DCH, in such a way that the requested Quality of Service (QoS) is supported with the least amount of transmission power (i.e. capacity) consumption. Moreover, with the "Dual Transmission mode cell", new types of intra-cell handovers are introduced which we also analyse and propose a new handover algorithm to address them. The performance evaluation carried out showed that our proposed "Dual Transmission mode cell" approach, provides considerable gains, as well as outperforming all other related approaches, such as "UE Counting", "Power Counting", "Rate Splitting", and "FACH with dynamic power setting", in terms of capacity and link performance efficiency.

1. Introduction

Driven by the need for efficient data distribution when a large number of users want to receive the same data, the 3rd Generation Partnership Project (3GPP) consortium introduced the Multimedia Broadcast Multicast Service (MBMS) system

Abbreviations: 3GPP, 3rd Generation Partnership Project; AH, Activation Hysteresis; AR, Alteration Rate; CCIT, Cell Context Information Table; CN, Core Network; CPICH, Common Pilot Channel; DCH, Dedicated Channel; FACH, Forward Access Channel; FACH_IT, FACH Information Table; HAA, Handover Activation Area; HAT, Handover Activation Threshold; HI_Table, Handover Information Table; HSDPA, High Speed Downlink Packet Access; HTT, Handover Trigger Threshold; IMSI, International Mobile Subscriber Identity; MBMS, Multimedia Broadcast Multicast Service; MCCH, MBMS Point-to-Multipoint Control Channel; MD, Mobile Device; NBAP, Node-B Application Protocol; PP, Pre-Trigger Predictor; P-t-M, Point-to-Multipoint; P-t-P, Point-to-Point; QoS, Quality of Service; RNC, Radio Network Controller; RRC, Radio Resource Control; RRM, Radio Resource Management; SM, Safety Margin; TMGI, Temporary Mobile Group Identity; TTI, Transmission Time Interval; UE, User Equipment; UMTS, Universal Mobile Telecommunications System; UTRAN, UMTS Terrestrial Radio Access Network; Δt, handover delay time.

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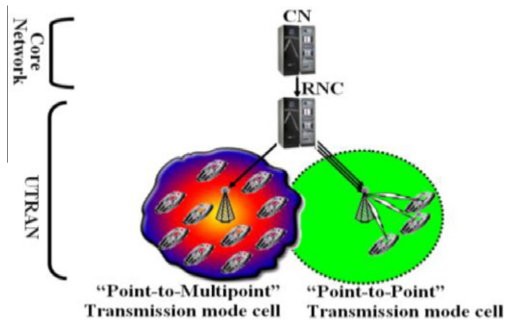

Fig. 1. Current 3GPP specified MBMS service provision approach.

[1,2] in Universal Mobile Telecommunications System (UMTS) Release 6 specifications [3]. MBMS system is considered as one of the most important steps of the UMTS network evolution since it provides it with a powerful tool to offer broadcast and multicast services efficiently. With MBMS system (see Fig. 1), the Core Network (CN) sends only one stream of data to the Radio Network Controller (RNC), irrespective of the number of Node-Bs (also known as Base Stations) or User Equipments (UEs) that want to receive it. Then, the RNC replicates and distributes, as efficiently as possible, the MBMS content to the UEs within the cells.

As currently specified by 3GPP in [2], MBMS bearer services can be provided within a cell either by Point-to-Point (P-t-P) or Point-to-Multipoint (P-t-M) transmission mode, but not both at the same time. If P-t-P transmission mode is selected for a cell, one Dedicated Channel (DCH) is established for each UE within the cell that joined the MBMS service. Otherwise, if P-t-M transmission mode is selected, one Forward Access Channel (FACH) is established covering the whole cell's area and commonly shared by all the UEs within. The decision of which transmission mode is going to be adopted is made by the RNC based on a radio resource efficiency criterion [2].

Although the service and technical requirements are complete for MBMS [1–6], still many design issues [7] need to be considered for MBMS services to be provided in a more efficient way, especially in the UMTS Terrestrial Radio Access Network (UTRAN) where the radio resources are limited. In this paper we focus our research on this issue. First, we highlight the inefficiencies that can be caused with the current 3GPP approach [2]. To address them and achieve efficient MBMS service provisioning, we motivate the need of allowing P-t-P (multiple DCHs) and P-t-M (one FACH) transmissions to coexist within the same cell (which we refer to as the "Dual Transmission mode cell"). Then, we built on this idea, which first appeared in a brief 3GPP report [8], and propose a new radio resource allocation algorithm to efficiently manage the radio resources of this new type of cell.

The radio resource allocation algorithm we propose, allows part of the cell's area (see Fig. 4) to be supported using FACH ("FACH supported area") while the rest of it is supported using DCHs ("DCH supported area"). Both at session initiation and also during the session, the size of these areas is dynamically adapted (shrinks or expands by adapting the transmission power devoted to FACH and by releasing or establishing DCH connections) according to the instantaneous distribution and movement of the users within the cell, aiming to always provide the MBMS service in the most efficient way (in terms of capacity and Quality of Service (QoS)). Moreover, with this new approach, mobility issues arise, in terms of intra-cell handovers between the FACH and the DCH supported areas, that must be considered in order for this scheme to work efficiently. Thus, we also analyse these new types of handovers and propose a new handover algorithm to efficiently address them.

The paper is organized as follows: In Section 2 the need for the "Dual Transmission mode cell" is motivated by emphasizing the gains that can be achieved compared to the current 3GPP specified MBMS service provision approach [2]. In Section 3 we present related research work performed on the efficient provision of the MBMS service. The "Dual Transmission mode cell" concept, the challenges we address in our design and the problem formulation are described in Section 4 together with our solutions in terms of new radio resource allocation and intra-cell handover algorithms. The performance evaluation of our proposed "Dual Transmission mode cell" approach is presented in Section 5, together with a comparative evaluation with other competing approaches, such as "UE Counting", "Power Counting", "Rate Splitting", and "FACH with dynamic power setting". Finally, in Section 6 we provide our conclusions and future work.

2. Motivation for "Dual Transmission mode cell"

In order to motivate the need for the "Dual Transmission mode cell" approach, the following scenario was investigated highlighting gains that can be achieved.

The scenario we use (see Fig. 2) considers the case where 30 stationary users, participating in a 3 min duration 64 kbits/s MBMS streaming video session, are uniformly distributed at distances closer than 600 m from the Node-B and two UEs (UE 1 and UE 2) located near the cell's edge, are leaving and re-joining the MBMS service every 20 s. The simulation parameters used are provided in Table 1. Two instances of this scenario were simulated, one using the current 3GPP [2] and the other the "Dual Transmission mode cell" approach. Results concerning the capacity requirements and processing effort introduced (in the RNC and Node-B) by each approach were obtained using OPNET Modeller and illustrated in Fig. 3 and Table 2. As can