Efficient Multimedia Content Distribution to Mobile Communities

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Abstract. Mobile Operators have to meet the growing demand for multimedia services. The Social Networking trend and the Mobile TV are just a few examples of multimedia services that are seriously crowding the operators' infrastructure. Since the content is to be shared by large groups of users it makes sense to use a point-to-multipoint technology to convey the multimedia information. MBMS (Multimedia Broadcast and Multicast Service) and E-MBMS (Evolved MBMS) are the 3GPP systems used to delivery multimedia contents to mobile communities. But these technologies do not support power control which leads to an inefficient data distribution. This paper devises a mechanism that makes possible to reduce the transmitted power enabling an effective multimedia multicast data distribution to mobile groups leading to significant gains on the radio interface on next generation multimedia networks.

Keywords: E-MBMS, Efficiency, EPS, MBMS, Multicast, Multimedia, UMTS.

1 Introduction

The sudden increase of Web 2.0 platforms is changing our lives. A new mode of communication is modifying the way we face the world. Our social relationships are built on top of telecommunications networks where we can easily share multimedia contents with groups of mates that have common interests. Additionally, Mobile TV services comprising real-time TV channels, interactive TV, video on demand, are a winning bet done by Mobile Operators.

Multimedia services are typically major resource consumers, but Mobile Operators are still using dedicated connections for the content distribution even when targeting mobile communities. Sharing network resources is particularly efficient when the information is to be transmitted to large groups of users. MBMS (Multimedia Broadcast and Multicast Service) was defined in 3GPP Release 6 aiming at broadcast and multicast packet data on UMTS (Universal Mobile Telecommunication System) networks to mobile communities [1]. Furthermore, the Evolved MBMS (E-MBMS)

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was specified in 3GPP Release 9 to enable broadcast communication over the EPS (Evolved Packet System) architecture [2]. Hence, the MBMS and the E-MBMS usage makes possible an efficient unidirectional transportation of information from a source to several end-users.

The use of the MBMS and the E-MBMS systems is a cornerstone towards an efficient content distribution. But it can even be improved by adding power control mechanisms on the radio interface. By now, the radio links are configured to always reach the cell border assuring a specific quality of experience even when there are no users near the edge. This paper presents an innovative approach to decrease the transmitted power levels in the radio interface allowing an efficient multimedia multicast content delivery on next generation networks to mobile communities.

The rest of the paper is organized as follows: Section 2 provides the main motivation for the work carried out and related work; Section 3 details the proposed mechanism to overcome the power control problem; the most important results are presented in Section 4; finally, Section 5 summarizes the main conclusions.

2 Motivation

2.1 Multimedia World

Human socialization is nowadays done mostly behind a terminal. While on the move, users resort to mobile equipments to communicate between each other or to access their mobile services. They follow commentators on TV discussing the last model scandal while sharing their multimedia content through social network platforms. They share their favorite videos while playing games together. Multimedia sharing is not the future, multimedia sharing is the reality just right now.

In specific scenarios, where the services target groups of users intending to simultaneously receive the same content, a point-to-multipoint technology can play a major role since it makes the data delivery much more efficient due to the resource sharing. MBMS and E-MBMS are the 3GPP proposed technologies to support multimedia multicast and broadcast services. In crowded situations the bottleneck is still sited in the radio access, therefore it makes sense to improve it in order to efficiently cope with huge amount of multimedia content distribution. For multicast services, 3GPP resorts to the FACH (Forward Access Channel) channel to perform the content distribution. But FACH does not support power control, being its usage very inefficient. Therefore, the main motivation for this paper is the development of a process that improves the multimedia multicast data transmission over the air interface to groups of users reducing the transmission power.

2.2 Service Scenario

Today is the big day! The final football match has just started. All pubs are crowded with people watching the game. In addition, there are also a large number of fans who follow the game while driving on city streets. All of them have subscribed the service “My Team on Mobile Goal Replay”, which shows the game goals from different angles associated with expert comments.

Whenever a team scores a goal then all subscribers get to see the slow motion goal replay, whether driving or sitting in the pub.

2.3 Related Work

The increase trend of multimedia group communications requires evolved networking technologies to efficiently distribute rich-media content to groups of mobile users.

The C-MOBILE (Advanced MBMS for the Future Mobile World) project has evolved the MBMS system towards a converged, multi-bearer service architecture for supporting broadcast and multicast services [3]. Besides proposing the enhancement of the actual radio access network, it also considers new technologies for an efficient support of MBMS services. This work was developed in [4] and the main results were presented in [5]. The project however did not address in its research any mechanism for the common channel power control.

The C-CAST (Context Casting) project has evolved the mobile multimedia multicasting to make use of the increase integration of mobile devices with our daily physical world and environment [6]. The work carried out in [7] devises a framework that enables the collection of sensor data, the distribution of context information and the efficient control of context- aware multiparty data delivery. Although the C-CAST project made use of context information for radio access technology selection, it did not use it to improve the air interface.

The studies performed in [8] describe efficient radio resource management techniques to offer MBMS services to end-users. It was considered the non-uniform QAM constellations, multi-code and macro-diversity usage to assure the most favorable distribution of quality of service based on the mobiles location. Furthermore, the work described in [9] suggests a power control mechanism that by sharing the available power resources to all MBMS services running in the network leads to an effective MBMS session allocation in next generation networks. The proposed radio resource management techniques, however, do not consider the reduction of the FACH transmission power to improve the radio efficiency.

The research done in [10] devises an innovative mechanism for an efficient radio bearer selection during E-MBMS transmission over LTE networks. Nevertheless, the procedure requires a periodic check of the terminal context leading to a considerable increase in the uplink communication.

The work carried out in [11] introduces an integrated context-aware MBMS and IMS architecture which enables a wisely management of multimedia multiparty content distribution to mobile communities. It defends the context information usage to improve the radio resource management; however, it did not define any specific mechanism or algorithm to optimize the MBMS transmission.

3 Proposed Mechanism

3.1 The Problem

As described in [2], the MBMS and the E-MBMS systems allow the point-to-multipoint packet data transmission over UMTS and EPS networks. But the multicast services are, by now, only supported by the MBMS system being the topic considered for further study in what respects to the E-MBMS technology. Therefore, 3GPP resorts to the FACH usage running over the S-CCPCH (Secondary Common Control Physical Channel) channel for the point-to-multipoint downlink multimedia transmission to joined users [12]. But FACH channel, as described in [13], does not support power control being configured to permanently reach the cell border where the data needs to get to the entire users inside a cell. For that, during the radio network-planning phase, the FACH channel is configured to be transmitted with specific power level assuring specific quality. Fig 1 presents an example of a MBMS service running having two users inside a cell.

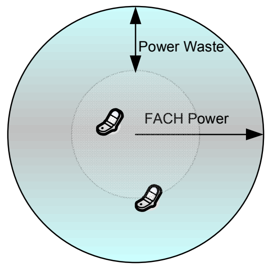

Fig. 1. FACH Power Waste

As can be seen, there are situations in which mobile users are far from the cell border. This means that the FACH power used, besides being worthless, leads to a decrease of the network capacity due to the noise created with this excessive transmitted power.

3.2 Proposed Solution

This paper presents a new approach to optimize the multicast transmission over the radio interface. It proposes a mechanism that allows to dynamically control the power being transmitted by the FACH channel taking into account the terminals radio conditions. To guarantee a specific data quality, the signal shall reach all terminals with, at least, a specific SIR (Signal-to-Interference Ratio) reference value regarding their position inside the cell. Note however that the overcome of this reference value does not bring additional quality benefits, which leads to radio power wastage. Therefore, the FACH transmission power shall be configured not to statically reach the cell border but to dynamically get to the terminal in worst radio conditions - called Token - respecting the SIR reference value requirements, leading to transmission power savings, as exemplified in Fig 2.

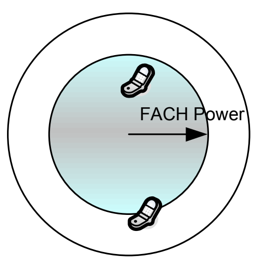

Fig. 2. Efficient FACH Power Control

To support the MBMS power control it is necessary to evolve the existing control mechanisms between terminals and radio access network. It is mandatory to create new information fields being periodically broadcasted to mobile terminals; furthermore it requires the creation of new messages sent from terminals towards the radio network controller reporting their SIR status, using, for instance, a random access procedure. The work here devised describes the proposed processes running on radio access network and on terminals to allow an efficient power control for multicast multimedia distribution.

3.3 The Mechanism

Two complementary processes are here proposed to manage the transmitted power on the air interface. One is performed by the terminal and, under specific circumstances, triggers the transmission of SIR related reports to the radio network manager, impacting the Token selection and the FACH transmission power. The other process runs in the radio network manager entity, which enables a shared power control in which the terminal in “worst” SIR conditions - the Token - influences the FACH transmitted power. The Token shall be changed by the radio network manager whenever a different terminal faces poorer SIR conditions.

The 3GPP standard has defined the MCCH (MBMS point-to-multipoint Control Channel) channel to carry downlink control plane information enabling terminals to tune the right service with the proper parameters [1]. Therefore, mobile terminals receive periodically control information about their related multicast services in cells having active MBMS services.

In order to support the proposed mechanism, the MCCH needs to be evolved to periodically transmit new relevant parameters related with the service being transmitted in each specific cell. These parameters are radio broadcasted and are used to identify the terminal directly impacting the FACH transmission power (Token) and its related SIR value – called Token_SIR - which shall be the lowest one from all terminals. Table 1 below presents the description of these parameters.

Table 1. MCCH Parameters Description

Name	Description
C_ID	Identification of the cell in which terminal is receiving the service
S_ID	The service identification
Token_SIR	The lowest received SIR of all received reports
Token	Identification of the terminal which has sent the lowest SIR value

Furthermore, the FACH transmitted power shall also be periodically adjusted taking into account the reports coming from terminals. The transmitted parameters and the adjusted FACH power are represented in Fig 3.

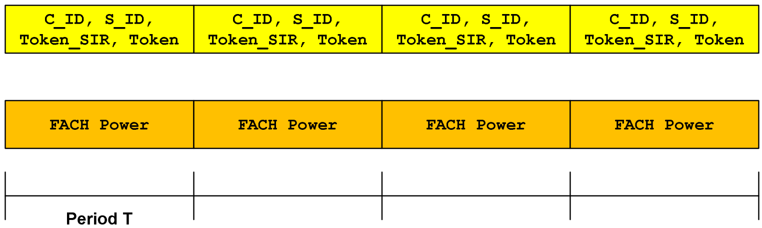

Fig. 3. Periodically Information Broadcasted and FACH Power Adaptation

In a preliminary phase, for each specific service, in each specific cell, the radio network manager starts by setting the initial control parameters – the ones presented in Table 1 - to be broadcasted by the MCCH to all terminals. It allocates a reference SIR value to the parameter Token_SIR. The Token_SIR value shall be previously computed to assure a specific quality for the service. Moreover, the radio network manager, in the initiation phase, has no information about the terminals SIR values; therefore, it will allocate a Null value to the Token field. Finally, the cell identity (C_ID) and the service identity (S_ID) parameters are configured with their respective identifications. The FACH transmission power is also set to a predefined value obtained during the network planning phase, which allows its correct reception in the entire cell. Note that a communication timeout can also force the radio network manager to set these initial values. The radio network manager shall then wait for reports coming from terminals. The new reports sent by the terminals towards the radio network manager encompass the parameters described in Table 2.

Table 2. Terminal Parameters Description

Name	Description
UE_ID	Identification of the terminal that sent the report
Measured_SIR	SIR measured by the terminal related with FACH channel
C_ID	Identification of the cell in which terminal is receiving the service
S_ID	The service identification

Terminal Process: Fig 4 below presents the algorithm running in the terminals.

Terminals with service active will start by reading the values broadcasted by the MCCH channel, more specifically the C_ID, the S_ID, the Token_SIR and the Token (1). Moreover, terminals will measure their SIR values associated to the FACH channel (2). They will then compare their measured SIR (Measured_SIR) values with the one broadcasted by the system (Token_SIR) (3) in order to check if they are facing worse SIR conditions.

If the measured SIR value is lower than the Token_SIR then the terminal shall inform the radio network manager, which leads to a correction in the FACH transmission power. For that, it shall send a report encompassing its identity (UE_ID) and its related SIR value read (Measured_SIR), besides the identification of the cell and of the service (4). Then the terminal shall wait for the next MCCH notification, while it receives the service.

But if the measured SIR value is higher than the Token_SIR then the terminal shall check if it is the Token (5). It can do that by comparing the Token value being broadcast with its own identity. If it is the Token, then it shall send a report to the radio network manager encompassing the terminal identity and the SIR value read (4), besides the cell and the service identification, impacting the FACH transmission power. Then the terminal waits for the next MCCH control message.

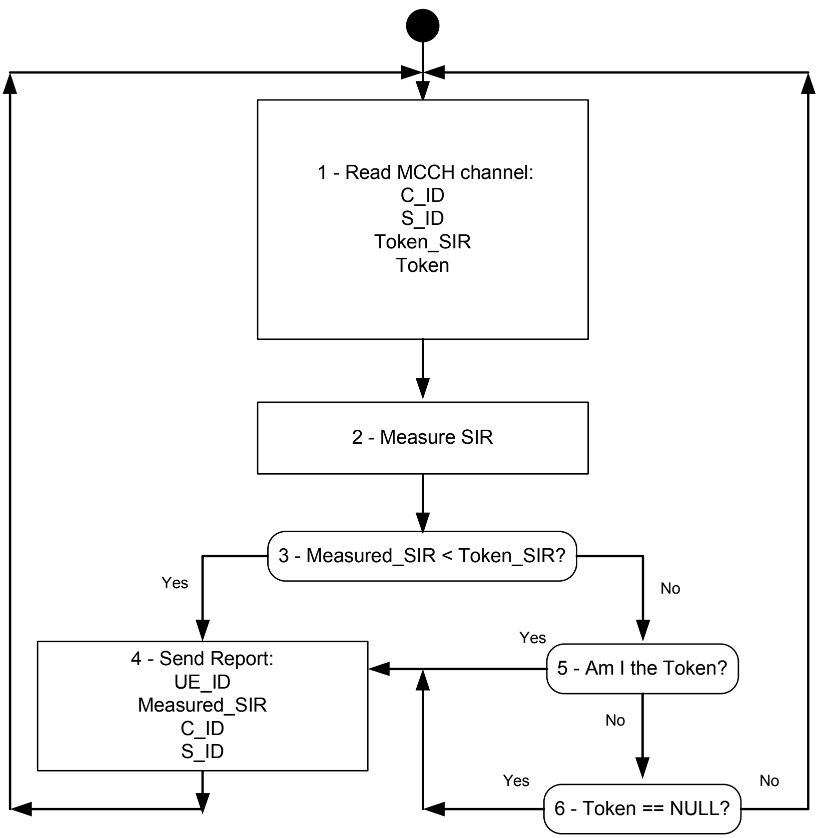

Fig. 4. Power Control Algorithm - Terminal Process

But if the user is not the Token it shall then check if there is any other Token (6). If the Token is Null then a report shall be sent to the radio network manager entity encompassing the UE_ID and its SIR value read, and also the cell and the service identification (4). The terminal shall then wait for the next control notification. In case there is already a Token (6) then the terminal just waits for the next MCCH message.

Radio Network Manager Process: Fig 5 presents the algorithm running on the radio network manager.

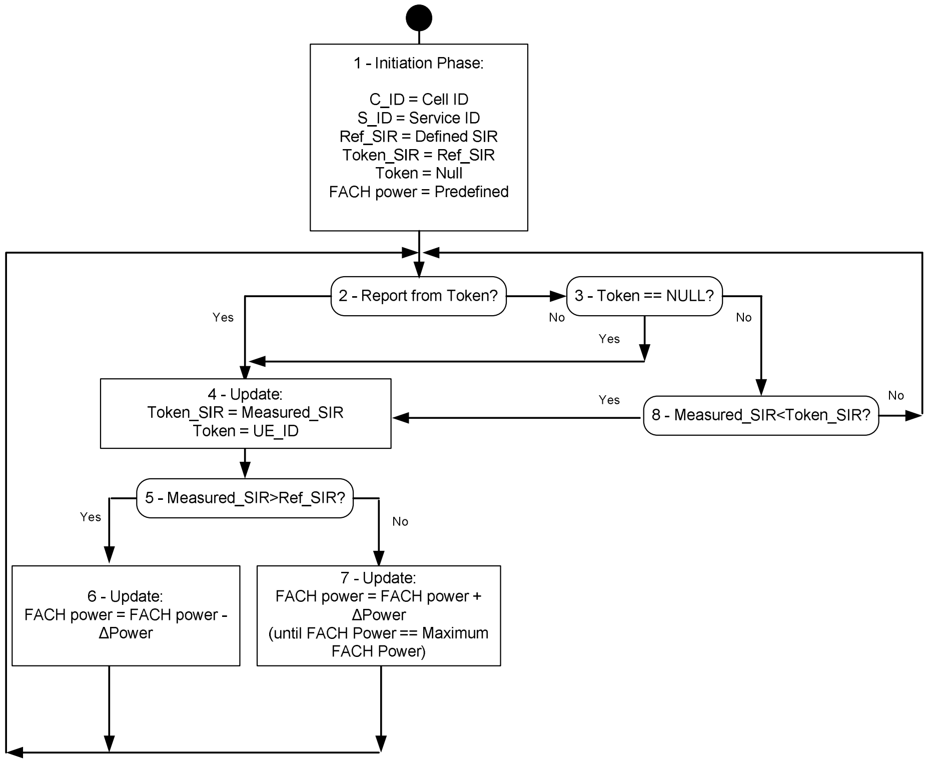

Fig. 5. Power Control Algorithm - Radio Network Manager Process

After setting the initial parameters (1), the radio network manager shall wait for reports coming from terminals, which provide information about their SIR values. The reception of a report can lead to the FACH transmission power adjustment and to a Token allocation process.

There are three different situations in which the radio network manager can receive the terminal reports. The first one takes place when the radio network manager is completely unaware about terminals SIR values and, therefore, there is no Token allocated. This can happen in the beginning of the service or just after a communication timeout, meaning the radio network entity has stopped receiving reports from the Token. The second situation occurs when there is already a defined Token, but the report comes from a different terminal. Finally, the last situation happens when the Token itself sends the report.

The first situation, as seen before, happens in the start of the service or after a communication timeout. The radio network manager shall just confirm that the report was not sent by the Token (2) and that there is no Token assigned (3). The radio network manager shall then set the Token_SIR value with the received measured SIR value; furthermore, the Token parameter shall also be set with the identification of the terminal that sent the report (4). It shall then proceed by comparing the terminal measured SIR reported (Measured_SIR) with a reference SIR fixed by the system to ensure a specific quality of service (5). A measured SIR higher than the reference value means that there is a waste on the FACH transmission power; therefore, the radio network manager shall decrease its output by a ΔPower value (6), reducing the transmission power. But if the terminal measured SIR is lower than the reference value then the radio network manager shall update the FACH power by increasing it by a ΔPower value, which leads to improved reception conditions (7). The FACH power cannot be higher than a predefined value in order to avoid signal interferences, which has a negative impact in the other users' quality of service; therefore the power increase process shall stop when it reaches the maximum allowed value.

The second situation arises when the received report comes from a non Token terminal (2) and there is already a Token selected (3). In these circumstances, the radio network manager shall compare the received measured SIR value with the one currently allocated to the Token_SIR (8). If the measured SIR is higher than the current Token_SIR then it shall not be updated any value since the Token, which has the lowest SIR value reported, controls the transmitted power. But if the measured SIR is lower than the Token_SIR then this means there is a new Token candidate, leading to a set of parameters update (4). Consequently, the radio network manager shall update the Token_SIR with the measured SIR value. The Token is also set with the terminal identification of the one who sent the report. Now it is time to check if the measured SIR is higher than the reference value for the service (5). If it is (6), the FACH transmission power shall be decreased, otherwise (7) the radio network manager shall update the FACH power by increasing it by a ΔPower value until it reaches the maximum allowed power

The last possibility happens when the Token itself sends the report (2). In this case, the radio network manager shall update the Token_SIR value with the one sent by the terminal (4). Furthermore, the radio network manager shall compare the terminal reported measured SIR with the reference SIR for the service (5). If the measured SIR is higher than the reference value then the FACH power shall be adjusted by decreasing it of a ΔPower value, saving power transmission (6). But if the Measured_SIR is lower than the reference value then the radio network manager shall update the FACH power by increasing it by a ΔPower value until it reaches the maximum power allowed (7). There is no need to update the Token since in these cases the Token itself sent the report. These values will then be broadcasted by the MCCH channel.

This process shall be repeated until the end of the multimedia service.

4 Evaluation

4.1 Scenario Environment

The mechanism presented in Section 3 aims at decreasing the noise caused by the FACH channel in the system by reducing its transmission power leading to energy efficiency improvements and inter-cell interference reductions, impacting the system capacity. This Section shows the main results achieved, by means of a system-level simulator, when applying the proposed mechanism. It evaluates the transmission power gains of the devised technique and assesses the Token update dependencies in what respects to the number of users accessing the service and to the frequency of the SIR analyses.

The characteristics of the scenario are depicted in Table 3. It considers an urban environment where the multimedia contents are distributed to mobile clients by means of point-to-multipoint system.

Table 3. Scenario Parameters

Parameter	Value
Cellular Layout Sectorization	3 sectors per cell
Site to site distance	2000 m
Maximum BS Transmission Power	20 W
Common Channel Power	1 W
Maximum BS Power allocated to MBMS	1 W
Propagation Model	Okumura Hata
Log-normal fading std	7 dB
Orthogonality factor	0.8
Eb/N0 target	9.4 dB

The scenario depicted has 19 cells, with a central one, and two rings of "interfering" cells around the central cell. The first ring has 6 cells and the second 12. Each cell has 3 sectors, and the study is implemented in one sector of the inner cell.

The propagation model used was the Okumura-Hata model with a log-normal fading standard deviation of 7 dB to describe urban environments. Then with the Eb/No and the orthogonally factor it is calculated the downlink performance. The orthogonally factor indicates how much of the serving base station transmission power causes interference in each terminal, where 1 means that all channels in the serving base station are orthogonal, so no interference occurs, and 0 meaning that the channels are not orthogonal and that all the transmission power of other channels interfere in the communications.

During the scenario creation phase it is calculated the pathloss matrices as a grid for all of the simulation area, which is constant for every iteration of the simulation. The location of each terminal is set as a vector position being updated during the user replacement. Based on the pathloss and on the interference it is applied the proposed algorithm to choose which of the terminals is the Token in the run. Then, based on the Token choice, the radio resources are allocated and the metrics are extracted for this iteration. After it, the users are replaced on the scenario and the process starts again, until the achievements of the stop criteria. The simulation method applied was the Monte-Carlo technique where 1000 runs of each scenario were made.

4.2 Scenario Evaluation

Transmission Power Savings Evaluation: The simulation environment created to estimate the achieved FACH power reduction considers groups of 5, 10, 20, 40 and 80 users randomly distributed in a MBMS cell and accessing a 64 kbps service. Fig 6 presents the mean transmission power when using the proposed mechanism in a MBMS cell. It also shows the mean FACH transmission power in a scenario without applied power control mechanisms.

It can be observed that the transmission power increases with the addition of new users since it is augmented the probability of having terminals in bad reception conditions. The proposed mechanism allows saving on average approximately 23% of transmission power for an 80 users scenario. Furthermore, the power reduction can reach about 55% of transmission power on average when decreasing the number of users accessing the service. The percentage of the power reduction, considering all the scenarios, was near 36%, which is a significant gain, which proofs the algorithm efficiency.

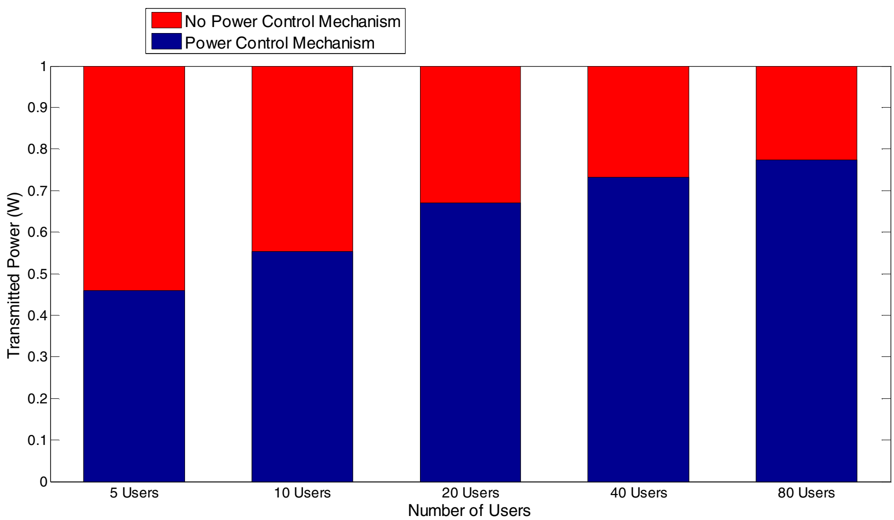

Fig. 6. Mean Transmitted Power With a and Without Enhanced Power Control

In this way it is concluded that even with a high number of terminals accessing the service it is an advantage the power control usage, allowing reducing expenditure costs and also intra and inter-cell interference caused by excessive transmission power.

Token Update Frequency Evaluation: As stated before, the Token is the terminal directly impacting the FACH transmission power, which can be changed over the time. The dependencies of the Token updates are here verified in what respects to the number of users and to the frequency of the SIR analysis. The Token update frequency is evaluated by considering sets of users driving at 50 km/h in an urban environment; to maintain the same number of terminals and keep up the simulation conditions, when a user arrive the extremity of the cell it is placed in the opposite symmetric position to the origin, maintaining the same movement characteristics. The simulation does not consider handover scenarios. In each TTI (Transmission Time Interval) the terminal position is updated and its SIR conditions are analyzed.

The results presented in Fig 7 demonstrate the existence of a relationship between the mean number of Token updates with the number of users that are simultaneously receiving the multimedia content. It was assessed the mean number of Token updates per second considering a scenario where 5, 10, 20, 40 and 80 users are driving in the MBMS cell. The increase in the number of terminals receiving the content generates an increased number of Token updates due to the higher probability of a terminal to move to the cell border where the reception conditions are worse. Therefore, for a 5 users' scenario the mean number of Token updates was slightly above the 0.5 times per second, while the number of Token updates reached the 1.1 times per second for an 80 users' environment.

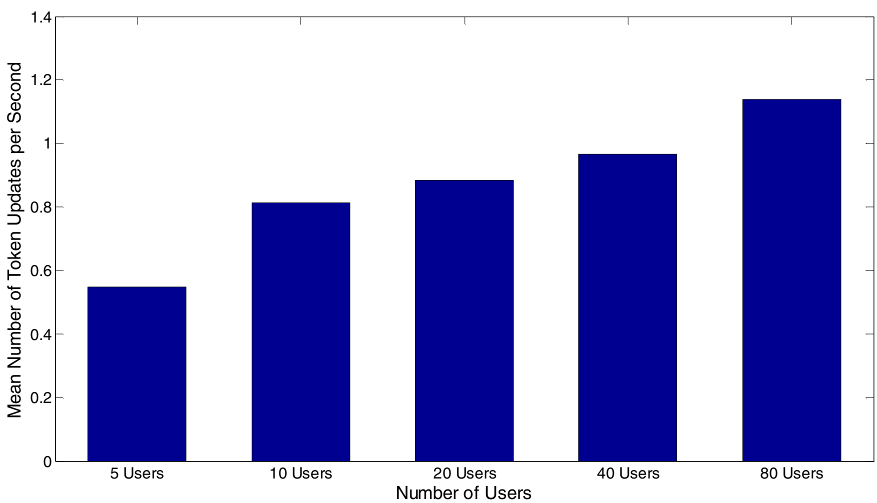

Fig. 7. Mean Number of Token Updates per Groups of Users per Second

It was also evaluated the Token update frequency for a 10 users' scenario driving in one cell. Five different TTI values were considered: 0.08, 0.16, 0.32, 0.64 and 1.28 seconds. Fig 8 presents the main results. It may be noted that the SIR analyses frequency impacts the number of Token updates. Thus, for a TTI with 1.28 seconds of duration, the mean number of Token updates does not reach the 0.4 units while for a 0.08 seconds TTI, the mean number of Token updates reaches the 0.7 units. This happens because an increase in the SIR analysis frequency leads to a more accurate power control algorithm which is done resorting to a higher number of Token updates per second. Fig 8 presents these results.

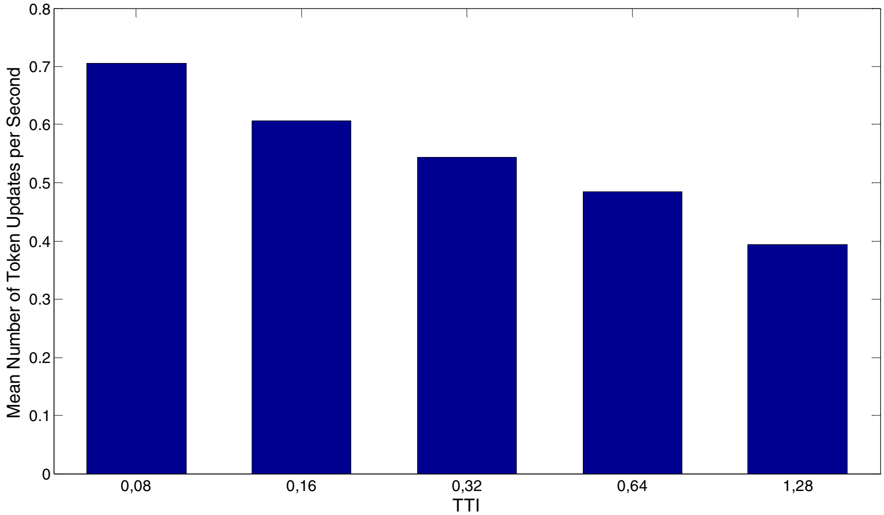

Fig. 8. Mean Number of Token Updates per TTI per Second

The simulation results show that there is a direct dependency between the Token update frequency and the number of users accessing the service. They also demonstrate the existence of a relationship between the number of Token updates and the frequency of the SIR analysis.

5 Conclusions and Future Work

Multimedia services are crowding the Mobile Operators' networks. The Social Networking fashion and the Mobile TV services are positioning the multimedia content on the centre of the human communications. Whenever the communication involves mobile communities, a point-to-multipoint technology shall be used to efficiently transport rich-media content from the source towards the end-users. Following this vision, the 3GPP organization has specified the MBMS and E-MBMS systems to distribute multimedia content to groups of users. These architectures enable an efficient resource usage by sending the same information simultaneously to all the receivers. But these technologies fail on power control support leading to an inefficient data distribution over the radio interface.

This paper has proposed a mechanism that allows significant gains on the radio interface by decreasing the transmitted power, up to 55%, in the downlink direction enabling an efficient multimedia multicast content transmission to groups of users on the next generation multimedia networks. It was also figured out that an increase on either the number of users or on the frequency of the SIR analysis leads to an increase number of Token updates.

As a future work it is envisaged the investigation of the E-MBMS system usefulness to carry out sensor information distribution. Studies are required to check the evolutions needed in order to support the specific dynamics of this type of information and to evaluate its impact in the radio resource management.

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