Comparison of Point to Point and MBSFN transmissions in Next Generation Mobile Networks

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ABSTRACT

Multicast/Broadcast Multicast Service over Single Frequency Network (MBSFN) technology has introduced advanced broadcast capabilities to cellular systems. In Long Term Evolution Advanced (LTE-A) systems, MBSFN transmission accommodates multicast groups in search of the same data. In this paper we compare the traditional Point-to-Point (PTP) communication with the MBSFN services through simulation experiments for various femtocell distributions and network configurations. The comparison takes into account the average throughput, overhead cost, energy consumption and capacity gain, concluding that MBSFN through multicast transmission may guarantee performance improvement even for users in the cell boundaries.

Keywords

Point-to-point; multicast transmission; mbsfn; femtocells; modulation and coding scheme; next generation mobile networks.

1. INTRODUCTION

Nowadays, mobile networks have evolved in a way that can, apart from voice services, offer multimedia services in high speeds. To this direction, the initial research in the area of multimedia transmission methods led the 3rd Generation Partnership Project (3GPP) to standardize the Multimedia Broadcast/Multicast Service (MBMS) as a method for multicast. The same data can be provided through MBMS over Single Frequency Network (MBSFN) or through Point-To-Point (PTP) transmissions [1]. To satisfy the need for resources that cannot be achieved by utilizing only the macrocell infrastructure, femtocells can also participate in multicast transmissions to improve the total performance.

A rapid service launch could be achieved by initializing a user topology with both macrocell and femtocell users. This could be suitable only for multimedia services which have low traffic and low quality. However, three or more connections could reduce the total performance and saturate the whole system, making it impossible for the network to serve all the unicast users. The selection of the transmission method depends on various factors such as the topology and the deployment or the type of data would like to deliver [2].

The utilization of the MBMS over femtocells is proposed to provide multimedia services to subscribed users in order to achieve high bit rate using lower power, while simultaneously the use of the macrocell infrastructure is kept low. When delivering a broadcast multimedia service the radio access network transmits the same information stream from several nearby cells. The impact of MBSFN performance is visible not only at the improvement of Signal to Interference plus Noise Ratio (SINR), but also to the total throughput and Spectral Efficiency.

Contrary to previous works, which study the MBSFN transmissions in case of femtocells resources by selecting the ideal Modulation Coding Scheme (MCS) for the transmission, in this work we compare and find the ideal transmission method between MBSFN and the traditional PTP communication. To this direction, we propose a mechanism that selects the MCS for the delivery of both the MBSFN and PTP data, extending our algorithm from work [1], highlighting that the increased performance, the throughput optimization, overhead and energy consumption may save the available resources.

The paper is structured as follows: in Section 2 we describe the PTP and multicast transmissions through MBSFN service; while in Section 3 we provide the simulation results of the comparison between the two transmission schemes. The conclusions and planned next steps are briefly described in Section 4.

2. MCS SELECTION IN PTP AND MULTICAST TRANSMISSION

According to MBSFN, the suitable MCS should be selected in order to transmit the same signal to synchronized adjacent cells. In fact, the best MCS is selected according to the SINR of the recipient of MBSFN information in order to meet a specific target of MBSFN transmissions and improve its performance in terms of throughput, overhead and energy consumption.

Starting our experiment, the SINR of PTP transmission is mapped into each Channel Quality Indicators (CQI) and we get the throughput of each user before we calculate the total overhead and energy consumption. All CQIs, refer to different MCS with

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different rates. In PTP transmission each user depends on bandwidth (BW) and has different MCS based on the different distance between base stations (BS) and mobile terminals for both macro and femto users.

It is very helpful to ensure that, all users in the cell will get the service for MBSFN. So our analytical model is summarized in the algorithm below in which we will study the two transmissions [3].

Algorithm MCS Selection in PTP and MBSFN case

```
Step 1 : % SINR calculation for all users
for i = 1:total_users
Calculate SINR(i) using the suitable eq. from (1) & (4)
end
Step 2: SINR and CQI matching based on transmission
Step 3 : MCS that corresponds to the minimum SINR
        selected_MCS = f_MCS (min_SINR)
Step 4 : % Metrics Calculation for the selected MCS
for i = 1:total_users
    user_throughput(i) = f_throughput(BW, selected_MCS,
        min_SINR)
    energy_consumption(i) = f_energy(sum(Power_loses))
    capacity(i) = f_capacity(BW,α,SINR)
end
average_throughput = sum(user_throughput)
        /total_users
```

2.1 PTP Transmission

In basic configuration of PTP transmission, the active User Equipments (UEs) always report their conditions as CQI to the serving base station and based on this CQI we extract the SINR of each user. Based on these SINR values from different users the base station can choose the most suitable MCS which can be used in order to transmit the multicast service to the subscribed users.

2.1.1 SINR Calculation

In order to calculate the SINR in PTP transmission we use the formula below depends on vector of user *r*:

$$SINR(\vec{r}) = \frac{P / q_0}{\sum_{i=1}^{n} X_i \frac{P}{q_i} + N_0} \quad (1)$$

where P is the power emitted by the base station which is constant and N_o is the background noise. In the formula above, q_i is the path loss between base station i and the corresponding receiver. The Xi parameter is equal to 1 if there is interference between UE and the interferer and equals 0 if we don't have any interference in the whole topology.

For the throughput calculation, we use the capacity of a user i on a specific subcarrier n, which can be estimated via the SINR from the following equation:

$$C_{i,n} = W \cdot \log_2 (1 + aSINR_{i,n}) \quad (2)$$

where W is the available bandwidth for subcarrier n divided by the number of users that share the specific subcarrier and α is a constant for a target bit error rate (BER) defined by $\alpha = -1.5 / \ln(5BER)$. Here we set BER to 10^{-6}.

So the expression of the total throughput of the multicast service is:

$$T_M = \sum_i \sum_n p_{i,n} C_{i,n} \quad (3)$$

where $p_{i,n}$ is an assignment index variable with $p_{i,n} = 1$ implying that subcarrier n is assigned to user i and $pi,n = 0$ otherwise. In the specific paper the study is done for LTE systems, which means each subcarrier can be only occupied by one user in the same cell in each time slot.

2.2 Multicast Transmission

In MBSFN operation, due to multipath, the signals of the cells arrive to the receiver by M different paths and the SINR of a single user at a given point m of the MBSFN area is expressed as in Eq. 4, assuming the area consists of N neighboring cells [4]:

$$SINR(m) = \frac{\sum_{i=1}^{N} \sum_{j=1}^{M} \frac{w(\tau_i(m) + \delta_j) P_j}{q_i(m)}}{\sum_{i=1}^{N} \sum_{j=1}^{M} \frac{(1 - w(\tau_i(m) + \delta_j)) P_j}{q_i(m)} + N_0} \quad (4)$$

with:

$$w(\tau) = \begin{cases} 1 & 0 \le \tau < T_{CP} \\ 1 - \frac{\tau - T_{CP}}{T_u} & T_{CP} \le \tau < T_{CP} + T_u \\ 0 & otherwise \end{cases} \quad (5)$$

where P_j is the average power associated with the j path, $\tau_i(m)$ the propagation delay from the macro or femtocell i, δ_j the additional delay added by path j, $q_i(m)$ the path loss from base station i, T_{cp} the length of the cyclic prefix (CP), T_u the length of the useful signal frame and N_0 the noise power.

To estimate the throughput achieved equation (6) is used, in which the BW is the total system bandwidth , e(SINR) is effective code rate of the selected coding scheme and BLER(SINR) the block error rate:

$$Throughput = BW \cdot e(SINR) \cdot (1 - BLER(SINR)) \quad (6)$$

The mathematical analysis presented previously will be the basis for the implementation that will help us to evaluate the best mechanism can be used for our MBSFN services [5].

3. PERFORMANCE EVALUATION

In this section we provide the simulation results of PTP and MBSFN in case of our femtocell topology changes. In general, throughput, overhead and energy efficiency are some metrics that can give us a better perspective for monitoring how efficiently the transmission of our system is utilized. To extract these metrics we start by computing the SINR in each case.

The parameters used in the simulation described below:

Table 1. Simulation parameters

Parameter	Value
Cellular Layout	5 x 5
Femtocells Density	Max 100 femtocells per cell
Users Density	Max 100 users per cell
Inter Site Distance	500m
Carrier Frequency	2.000MHz
System Bandwidth	1.4MHz
Femtocells Transmission Power	2Watt
Macrocells Transmission Power	20Watt
Channel Mode	3GPP Typical Urban
Cyclic prefix	16.67μsec
Useful signal frame length	66.67μsec
Frames to be sent	100000

After calculating the SINR for each user, we can use this value to choose which MCS will be selected for supporting all users' needs in PTP or multicast service transmission. Each MCS is mapped to a predefined CQI value [6].

3.1 Comparison of Average Throughput in PTP and Multicast Transmission

We start our experiment by analyzing the average throughput benefit in two different transmissions. We start our simulation utilizing an MBSFN area consisting of 25 macrocells, 100 users and 1250 femtocells. During our simulation we gradually increase the number of hybrid femtocells from 0 to 300 per macrocell.

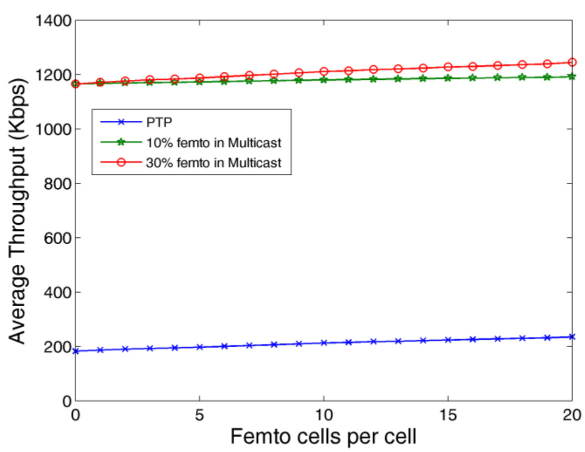

Figure 1. Average throughput vs number of femtocells per cell for different values of femtocell bandwidth allocated to non-authorized users for both PTP and multicast transmission

Figure 1 displays the average throughput for different number of femtocells per cell and different portions of femtocell bandwidth allocated to non-authorized users. As we can see, the average throughput achieved in case of Multicast Transmission is higher, in comparison with the traditional PTP transmissions. This is due to the fact that multicasting offers the transmission of a data flow to multiple destinations where only one data stream is sent regardless of the number of non-authorized users. More analytically, the case of PTP transmission is the same with the 0% femto influence on multicast transmission. From the above chart we export that the femto influence as we use the 10 and 30% of femtos respectively, give us better and higher average throughput [7].

3.2 Comparison of Overhead in PTP and Multicast Transmission after femtocell density

By viewing overhead as the cost of constraints imposed on a system, information-theoretic techniques can be used to obtain fundamental limits on system performance.

Therefore, investigating the overhead required to transmit some frames over channel we consider each frame transmitted to the authorized user inserts an overhead of 1 bit, per frame. The number of users is kept constant to 100 and we start by increasing the number of femtocells from 0 to 300 per macrocell. As we can see from our results, the total overhead in multicast transmission increases when we have the impact of all femtocells for our transmission to the total users.

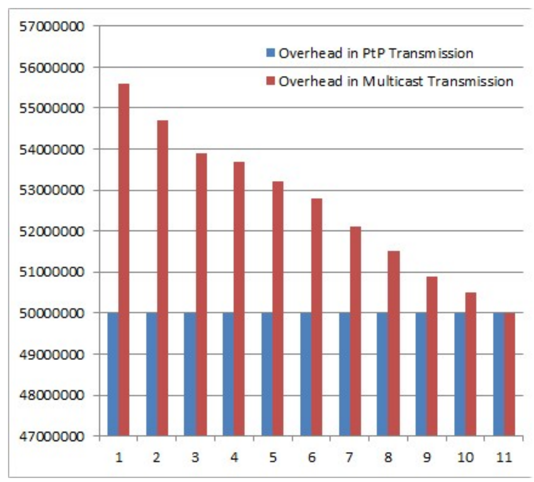

Figure 2. Bits overhead vs femtocells per cell

From Figure 2 it is obvious that when the femtocells' density changes, the overhead tends to be the same in both transmissions. This imports an improvement in case of overhead through our transmission in our whole topology starting from 55600000 bits to 50000000 bits. This happens because of the fact that in multicast transmission the BS sends less data, from a BS to each mobile terminal, in contrast with the PTP case where the BS must send one stream per user data [8].

3.3 Comparison of System Capacity in PTP and Multicast Transmission Scenarios

In this ideal model, the bit rate between a pair of transmitter and receiver is represented by the Shannon capacity for a point-to-point Gaussian channel. The channel capacity of a wireless system is the maximum number of users possible in the system. For this reason, we start our experiment by analyzing the theoretical formula of Shannon Capacity which has been described above. Based on this formula and taking into account that we want to transmit 100000 frames, we continued by calculating the total capacity in each packet sent for all users in our MBSFN topology in the two different transmissions.

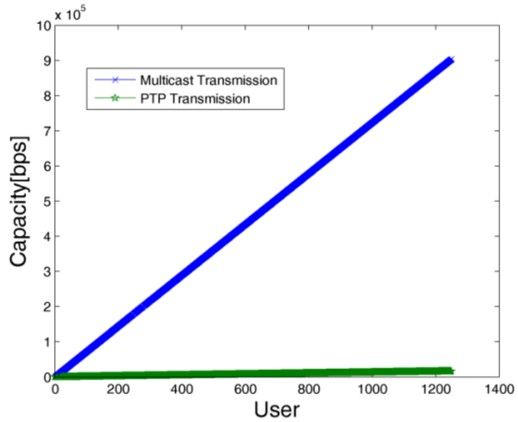

Figure 3. Capacity in two transmissions vs user density

From Figure 3 we see that the scenario of multicast transmission for MBSFN services give us a greater capacity as a linear function in comparison to the traditional PTP transmission where the total capacity in our system seems to be constant. This is justified by the fact that for PTP transmission the BS has to send all data to non-authorized users forcing each user to still consume all the available bandwidth, including those unused. Otherwise in multicast transmission the losses seem to be minimal without affecting the total capacity [9].

3.4 Comparison of Energy Consumption in PTP and Multicast Transmission Scenarios

The energy was calculated as a sum of the Power Losses for all the frames we wanted to send. In our case we set the number of frames to be 100000.

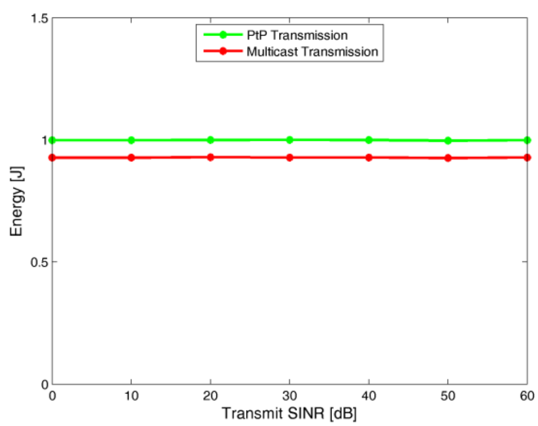

Figure 4. Energy consumption vs transmit SINR

The above chart is normalized relative to the maximum power for easy comparison and better display sizes. We see that the multicast transmission scenario needs less total energy compared to the PTP transmission scenario, regardless of the different parameters in communication. This method is more efficient because the user with the maximum power required would take the same amount of power and unicast transmission. This transmission power will be enough for all other users of the group saving about 15%, as Figure 4 shows, ensuring simultaneously reliable reception of MBSFN data [10].

4. CONCLUSIONS AND FUTURE WORK

In the current work we compared the traditional PTP transmission with the multicast transmission in terms of average throughput, system capacity, total overhead and energy efficiency. We proposed a mechanism for both transmissions which is able to select the best MCS that should be used for multicast services transmissions, in order to serve all the users in our MBSFN topology. The results indicate that PTP transmission normally has performance issues compared to the multicast transmission in multicast services. In every case, multicasting may to lead to increased average throughput, better energy efficiency, significantly increase of system capacity and improvement on overhead per frame transmission as the femtocell density increases, transmitting the MBSFN data to neighboring cell.

For future work, our mechanism could be extended to support more metrics (for example air interface cost or interference), with minimal changes as the topology changes.

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