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Power Control based Resource Allocation in LTE Uplinks

K L V Sai Prakash Sakuru and Mushunuri Visali

Abstract—**Uplink power control is essential in 3GPP Long Term Evolution (LTE) to reduce interference caused by adjacent cell users and extending the user equipment (UE) battery life. In open loop power control, no feedback is given by the base station to the user equipments whereas in closed loop power control, feedback for power control is given by eNodeB to UE. Resource scheduling algorithm with power control technique is proposed in this paper, which considers channel characteristics and minimum power requirement at the base station for successful reception of a signal. Simulation results show that (i) the RBs are allocated to maximum UEs based on SINR and power control, (ii) the interference caused by the UEs in the adjacent cell is reduced thereby maximizing the uplink data rate.**

***Index Terms*— Power Control, Resource Blocks, SINR, Transmit Power, Uplink**

I. Introduction

Long Term Evolution introduced by Third Generation Partnership Project (3GPP) for high data rate applications, uses Single Carrier Frequency Division Multiple Access (SC-FDMA) for uplink access as it lowers the high Peak to Average Power Ratio (PAPR) caused by using OFDM access mechanism. Thus, lower PAPR helps in reducing the battery power consumption of User Equipments (UE) thereby also reducing intra-cell interference due to the orthogonality of subcarriers. But as LTE is designed for a frequency reuse factor 1, the inter-cell interference caused by other cell users, as shown in Fig. 1, is present and cannot be neglected.

The power control in LTE uplink mitigates the UE transmission through fading channels and also the inter-cell interference caused by the other cell users. It also helps in maximizing data rates by optimizing SINR. LTE uplink power control is a combination of Open Loop Power Control (OLPC) and Closed Loop Power Control (CLPC). In OLPC, the power is set at the UE by the eNodeB using downlink path loss value

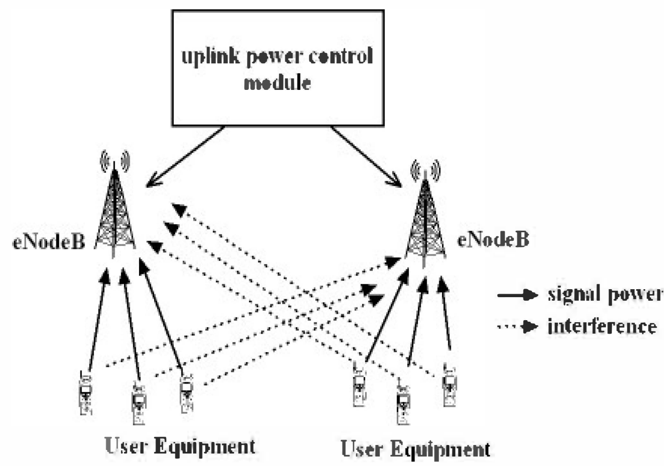

Fig. 1. Power Control in LTE

and channel configuration. No feedback is sent to the UE by eNodeB in case of OLPC. The slow varying path gain and shadowing are compensated by OLPC. In CLPC, the eNodeB gives feedback (power control commands) to UE to control its transmit power. Thus, the uplink power control is used to prolong the battery life of UE and helps in reducing inter-cell interference caused by users in the adjacent cells.

The proposed algorithm in this paper schedules users by controlling the UE transmit power based on the channel path loss measurements and minimum signal to interference plus noise ratio (SINR) requirement at the base station for successful reception of signal transmitted by the UE. Cost 231 Hata Model is considered as a path loss model and the minimum power required for transmission is set, based on the transmission power requirement of cell edge users as they have to transmit signal with more power to achieve good SINR requirement.

The paper is organized as follows. Section II gives the related work in the area of power control mechanisms of LTE. The LTE uplink power control mechanism is given in section III. Section IV explains the proposed algorithm for uplink power control. Section V deals with the parameters used for the simulation and discusses the results obtained. Section VI concludes the paper.

II. Related Work

Uplink power control is used to reduce inter-cell interference while maximizing the desired signal strength. It is

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required to reduce the unwanted interference at the base station from other cell users. In [1], the overview and performance of LTE uplink power control mechanism are presented and compared with two other default mechanisms. It is shown that LTE power control mechanism is better compared to the other two reference mechanisms in terms of cell edge bit rate and capacity improvement.

RY Kim et al in [2] explained the power saving mechanisms in the next generation wireless networks, IEEE 802.16 and 3GPP LTE. The idle mode and sleep mode mechanisms for IEEE 802.16m and DRX mechanisms for 3GPP LTE provide advanced power saving for users thus extending their battery life. In [3], the closed form expression and upper limit for dynamic receive power range are derived and open loop transmit power control parameters are α and P_o are derived.

A load adaptive power control algorithm is proposed in [4] that adjusts the transmit power of users to adapt to the variations and bandwidth. It is shown that this method provides coverage gains that can provide 60% coverage gains while maintaining comparable cell throughput. In [5], the open loop and closed loop power control schemes for uplink for LTE and LTE-A standards are explained. The proposed schemes perform better compared to the existing fractional power control schemes for LTE in terms of cell average throughput and cell edge throughput. In [6], the single carrier FDMA scheme is explained and is compared with OFDMA in terms of PAPR. The sub-carrier mapping techniques namely Localized FDMA (LFDMA) which allocates resources that are adjacent to each other and Interleaved FDMA (IFDMA) which allocates alternate resources to users are also discussed.

A new open loop power control method is proposed in [7] which schedules users and controls power based on channel conditions. Both the resource allocation and power control are done taking channel characteristics into account that can provide a number of resource blocks to the users with good channel conditions. The proposed method has better spectral efficiency and efficient power control. In [8], the closed-loop power control is evaluated with fractional path loss compensation. It is shown that the fractional path loss compensation has performed better compared to full path loss compensation with an improvement in mean bit rate.

In [9], a low complexity scheduling algorithm is proposed and evaluated with the proposed interference mitigation schemes with and without power control. The proposed approach with cooperative power control outperforms the approach without power control.

III. Uplink Power Control In LTE

The power control in Long Term Evolution consists of both Open Loop Power Control (OLPC) and Closed Loop Power Control (CLPC). The OLPC is used for compensating the slow varying path gains and shadowing. CLPC is used for directly controlling the UE transmit power by using explicit power control commands.

There are two possibilities of controlling power in uplink LTE. One method is to use the power control mechanism as a part of the scheduling decision. The commands can be sent during downlink assignment (PUCCH) or uplink grant (PUSCH). The other method is to use separate power control commands (DCI Format 3/3A). The OLPC is used for the power control in Random Access Channel (PRACH) and Shared Channel (PUSCH) and Control Channels (PUCCH). The CLPC is used for the controlling power on Shared Channels (PUSCH) and Control Channels (PUCCH).

IV. Proposed Scheduling Algorithm

The proposed scheduling algorithm used power control technique for scheduling users in uplink. The resources were allocated on demand to random users and the signal to interference plus noise ratio was calculated for the allocated resource blocks. Initially the transmit power was the same for all the users independent of their position relative to the eNodeB denoted by P_t. If the Signal to Interference plus Noise Ratio (SINR) is found to be greater than the required SINR, then resource blocks are given to the random users on demand.

If the received power of the i^{th} user P_i is greater than the minimum power required at base station P_{th} for successful reception of the signal, then the transmit power Pt_i of the UE is reduced to the required level. The minimum required SINR is set based on the transmission power requirement of cell edge users as they have to transmit with more power to achieve good signal to noise ratio requirement. Thus, the users near the base station can transmit signal with lesser power compared to the users far away from the base station as they have better SINR conditions.

The allocation of resources is such that, the number of users accommodated in the system is maximized by effectively controlling the power transmitted by each user and allocating resources based on their channel characteristics.

Let N be the total number of users in the system and M be the total number of resource blocks. Let the updated transmit power of an i^{th} user UE_i is Pt_i. The received power of the i^{th} user UE_i is denoted as P_i. The resource blocks j allocated to the i^{th} user is given by $RB_{i,j}$ where $j = 1 \ldots k,\ k \subset M$. BW is the total bandwidth available in the system. P_{max} be the maximum power transmitted by all users in the system given by NP_t. Thus, the scheduling methodology is given as follows.

$$Max(\sum_{i=1}^{N} UE_i(\sum_{j=1}^{k} RB_{i,j})), \quad k \le M \tag{1}$$

Such that

$$\sum_{i=1}^{N}\sum_{j=1}^{M} RB_{i,j} = BW \tag{2}$$

and

$$\sum_{i=1}^{N} Pt_i = \sum_{i=1}^{N} P_i * L(d_i) \le P_{\max} \tag{3}$$

The pseudo code for the proposed scheduling algorithm is given in Algorithm 1. The terminologies used in the algorithm are

- M – Total number of resource blocks
- $RB_{i,j}$ – resource blocks j assigned to the i^{th} user, $j=1\ldots k$ and $i=1\ldots N$
- $SINR_i$ – Signal to Interference plus Noise Ratio of the i^{th} user
- $SINR_{th}$ – Threshold SINR
- P_{th} – Threshold received Power

The path loss model used for characterizing each zone is Cost 231 Hata propagation model given by

$$L(d_i) = L_{const} + 10a\log_{10}(d_i) \tag{4}$$

where L_{const} is the system dependent parameter that depends on the system frequency, height of the base station and mobile station etc. a is the path loss exponent and d_i is the distance of an i^{th} user from eNodeB.

Algorithm 1 Power Control Algorithm

Assign equal transmit power Pt to all the users
Generate a random user in a cell i
$M \leftarrow 50$
while $M > 0$ **do**
  if SINR of user i $SINR_i > SINR_{th}$ **then**
    Assign 1 RB $RB_{i,j}$
    if power received $P_i > P_{th}$ **then**
      Reduce the transmit power Pt_i of user i
    end if
  end if
  Update received power P_i
  Update SINR $SINR_i$
end while

An equal transmit power P_t is assumed for all the users initially. The received powers can be calculated using

$$P_i = \frac{P_t}{L(d_i)} \tag{5}$$

The Signal to Interference plus Noise Ratio SINR is calculated initially using

$$SINR_i = \frac{P_i}{N+I} = \frac{P_t}{L(d_i)(N+I)} \tag{6}$$

where N is the thermal noise component at the base station and I is the interference from other cell users.

The transmit powers are updated as Pt_i by giving feedback from the base station if the received powers are above the threshold value. Thus, by reducing the transmit powers Pt_i, the received powers at the base station can be minimized, thereby the interference to other cell users can be brought down effectively without compromising on the required SINR at the base station for successful reception.

V. Simulation Parameters

The simulations for uplink scheduling with power control mechanism incorporated were performed in Matlab. The parameters taken for the simulation are as follows. The cell consists of 10 circular zones. A bandwidth of 10 MHz is taken and hence the number of resource blocks available for the allocation is 50. An equal power of 1 mW is taken initially for all the users. The maximum transmit power of the system P_{max} is limited to 50 mW.

As the number of active users in the system was increased from 10 to 50 as shown in Fig. 2, the users allocated with RB's were maximized. For a maximum of 50 users, as the number of resource blocks available are 50, on an average 35 users were given complete set of resources and rest of the users were deprived of resources based on their channel conditions.

The total transmit power of the system, with an increase in the number of users, is shown in Fig. 3. The total transmit power increases with an increase in the number of users in the system. The maximum power transmitted, with 50 users in the system, is only 40 mW with all the 50 resource blocks allocated. Initially, with a 1 mW power and 50 resources blocks, without power control mechanism, the total power that is transmitted would be 50 mW. But with power control mechanism, the total transmit power has decreased to about half for less number of users in the system. This rises as the number of users present increases well within the limits.

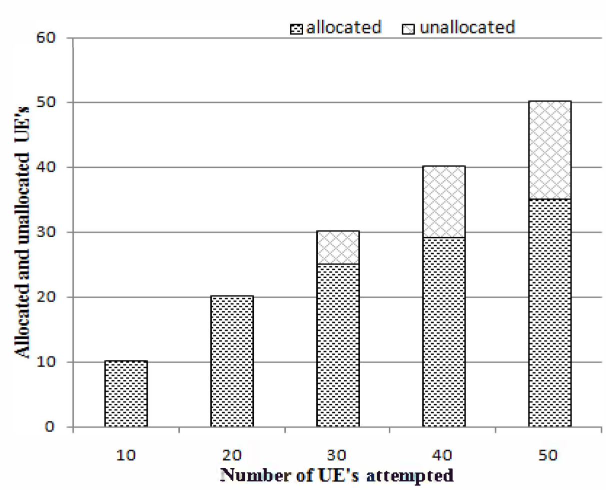

Fig. 2. Allocation with increase in number of users

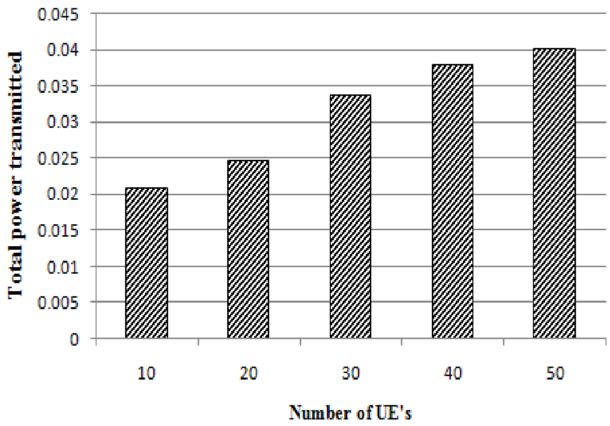

Fig. 3. Total transmit power with an increase in the number of users

VI. CONCLUSIONS AND FUTURE WORK

The scheduling in uplink for long term evolution networks is done based on fading channel characteristics with power control mechanism incorporated as a part of scheduling. In the proposed approach, it can be observed that more number of users are accommodated by considering power control mechanism. For lower loads, almost all the users are scheduled without any user deprived of resources and the total transmit power is also less. But, for the higher loads, with an increase in the number of users in the system, the RBs were allocated to maximum number of users with some users left unallocated based on their fading channel conditions and the power requirements. The total transmit power at eNodeB was kept within the limits even with an increase in the number of transmitting users.

Applying game theory for allocation of RB's considering inter-cell interference through fading channels and maximizing data rate by controlling eNodeB received power is our research interest and future work.

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