

Improving the Uplink Capacity of a Long Term Evolution Network Using Power Control Technique.

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ABSTRACT: The recent advancement of mobile terminals, the ever-increasing number of mobile users and the growing need for mobile data, without the corresponding increase in radio frequency allocation, have led to the deployment of compact mobile networks. As a result, many mobile network operators have chosen Long Term Evolution (LTE) standards which is a complete IP network to meet the increasing data requests of cellular network users. A key feature of LTE networks is the adoption frequency reuse factor of 1 leading to severe interference that creates limitations in terms of average user throughput and system performance. In fact, many recent works focus on reducing ICI and power consumption in multi-user OFDMA networks. In this paper, we proposed a power control algorithm that aims to minimize the total interference experienced in LTE systems. We also study the effect of power control algorithms on the SINR and system performance. The simulation results show that the proposed algorithm largely enhances the network system performance in terms of the received data rate as well as reduces the level of inter-cell interference (ICI) experienced in the network.

KEYWORDS: Long Term Evolution, OFDMA, power control, resource block, Inter-Cell Interference, QoS

I. INTRODUCTION

For wireless networks of the future, the demand for higher data rates with full frequency reuse results in interference-limited systems, which cannot achieve full potential without the implementation of one or more viable interference

mitigation/cancellation/coordination techniques. Furthermore, through the implementation of orthogonal frequency division multiple access (OFDMA) in the downlink and single carrier frequency division multiple access (SC-FDMA) in the uplink as multiple access schemes, future systems will provide orthogonality between Resource Blocks (RBs) in both directions, and hence also between all users within a cell (Boudreau et al, 2009). Thus, system performance is mainly limited by co-channel interference (CCI) originating from users in neighbouring cells, which can be harmful to the signal-to-interference-plus-noise ratio (SINR) and throughput performance of mobile stations (MSs) using the same RBs (Hosein, 2007). A typical solution is to force interferers to leave those RBs inactive. However, this severely reduces the trunking efficiency of the network (Uyungelen et al. 2011). Therefore, suppression transmission is clearly sub-optimal, and thus power control and inter-cell interference coordination (ICIC) are necessary to achieve the desired sum and individual throughput.

Power is an essential resource in communication systems. Transmission power control involves optimizing the power of base stations (BS) and mobile stations (MS) to increase system capacity through interference management, management of cell coverage, or improving MS battery life (Madan and Ray, 2011). In wireless networks, bandwidth is considered a finite resource, thus channels are reused for different transmissions. Wireless systems such as LTE use frequency reuse, which means that all available resource blocks in the system are reused in each

cell that is part of the network. An RB defines the basic time-frequency unit in LTE networks. Reusing resource blocks increases the capacity per sector but at the same time generates co-channel interference. Due to co-channel interference, the signal to noise ratio (SINR) can fluctuate in the range of 20-30dB at the receiver side. This is counterproductive for all users across the cell, but especially for users close to the cell border. Therefore, implementation of viable interference mitigation/cancellation/coordination techniques has been envisioned to improve the system performance. Power allocation is used as an appropriate way to counter these harmful effects, as the transmitted power can be controlled to maintain a certain link quality and reduce co-channel interference. Existing power control schemes can be classified as: centralized or distributed, downlink or uplink, open or closed loop, etc. (Han & Liu, 2008). The design of power control schemes is no trivial task as there are several trade-offs and practical constraints that must be considered:

- Increasing the transmission power increases the SINR on the receiver side. Nevertheless, it also increases the interference level of co-channel mobile stations (Han & Liu, 2008).
- Distributed methods are preferred over centralized methods for power allocation in uplinks. However, the convergence time of distributed schemes must be fast enough to deal with the changing nature of channel timing.
- Distributed methods must be able to allocate power with only local information to reduce the communication overhead of the network.

II. RELATED WORKS

(Kurda R. 2021) To reduce inter-cell interference in the function, a partial self-operated control scheme executed on each femtocell user was introduced. This study analyzed a scheme with optimal power value that provides a compromise between unwanted interference and the uplink signal provided to increase the spectral efficiency in terms of throughput within the noise ratio. In particular, the maximum transmit power to the user equipment in the uplink direction was reviewed as a major contributor to interference for the small cell. However, these fixed masks may not adapt to the service-dependent requirements of neighboring cells, potentially wasting bandwidth. Power control Schemes for Interference Management in LTE-Advanced Heterogeneous Networks is presented in (Amandeep et al, 2019), where various power control schemes based on fixed, constant Femto Base Station and Targeted SINR was used. These power control schemes were applied to the network

topology with increment in the size of femto cell range and number of femto and macro user in increment order. These fixed, constant Femto Base Station cannot, however, adapt to the service-dependent requirements of the neighbouring cells, potentially wasting bandwidth. Due to this, however, many users may not achieve their SINR targets, and hence user throughput could suffer. (Amir et al, 2018), examined open-loop transmit power control parameters for homogeneous and heterogeneous small-cell uplinks. A mathematical model was obtained to calculate the transmit power, power received at eNodeB, interference ratio on the user equipment. However, this task is mathematically cumbersome. (Yang et al, 2018) examined the problems of sum power minimization and sum rate maximization for multi-cell networks with non-orthogonal multiple access. Obtained a closed-form solution for the optimal power allocation strategy and then successfully transformed the original problem into a linear one with very small size, which can be optimally solved using the standard interference function. However their work could not be applied to orthogonal frequency division multiple access and broadcast channels. The work of (Samer et al, 2014) proposed a distributed heuristic power control algorithm that aims to reduce the total downlink power of an LTE system. The impact of the power control algorithm on ICI and system performance was also investigated. Simulation results showed that the proposed algorithm substantially reduces downlink power consumption without degrading system performance in addition to increasing the mean throughput for cell-edge users primarily affected by ICI problems. The work considered downlink direction which is less challenging than uplink due to distributed nature of power control. Research In (Dhillon et al, 2012) presented a distributed uplink power allocation technique based on maximum sum rate optimization, which yields better results in terms of average system throughput, although it ignored tradeoff between cell-edge performance and overall spectral efficiency.

III. SYSTEM MODEL

In a wireless system, the quality of each link is determined by the SINR at the intended receiver. If all SINR requirements can be met simultaneously, this will reduce the communication power of the users, thereby reducing interference for neighboring users. Therefore, in this task a power control algorithm was developed based on the variation of SINR, where each ms increases power when its SINR is less than its target and

decreases power when its SINR is greater than its target.

The SINR of UE_k at its serving base station eNB1 is given by

$$\Gamma_{1,k} = \frac{P_{1,k} \mathbf{g}_{1,k}}{\sum_{a \in \mathcal{I}_k} P_{1,a} \mathbf{g}_{1,a} \partial_{1,k} + \sigma_{1,k}^2} \quad (1)$$

where $p_{1,k}$ is the transmit power of UE_k, $\mathbf{g}_{1,k} \in \mathbb{C}^{N \times 1}$ is the channel (including fading and shadowing) between UE and eNB, $\mathbf{g}_{1,a}$ denotes the interfering channel between the desired UE and the interfering set, $\partial_{1,k}$ is a binary variable indicating that users in neighboring cells share the same RB or not, $\partial_{1,k} = 1$ indicates that the user is scheduled with the same RB as our desired user and $\partial_{1,k} = 0$ otherwise. $\sigma_{1,k}^2$ is the noise power

In this work, we assume that channels are known in ENB, therefore, this work will not be concerned with the issue of channel estimates. Equally, we are also not concerned with the beamforming design, so we assume that the beamforming vectors obtained are already designed and known by ENB. To specify a range of acceptable performance, let the system specify the values of the maximum and minimum SINRs as Γ_{\max}^k and Γ_{\min}^k , respectively. At any time t , a serving ENB may use a sub-channel for transmission and to ensure correct decoding of the transmitted symbol, the condition $\Gamma_{1,k} \geq \Gamma_{\min}$ must be satisfied. From (3.5), the maximum attainable SINR Γ_{\max} is given as

$$\Gamma_{\max}^k = \frac{P_{1,k} \mathbf{g}_{1,k}}{I_{k,\max}^1 + \sigma_{1,k}^2} \quad (2)$$

Similarly, the minimum interference attainable at Γ_{\min} is given as

$$\Gamma_{\min}^k = \frac{P_{1,k} \mathbf{g}_{1,k}}{I_{k,\min}^1 + \sigma_{1,k}^2} \quad (3)$$

Where $I_{k,\max}^1$ and $I_{k,\min}^1$ are the interference experience by the UE at maximum and minimum SINR respectively. Since the SINR cannot be improved by increasing transmission from all cell sites, increasing the transmission power may increase the received signal strength, but will also create stronger inter-cell interference to other cells. Therefore, it is necessary to guarantee that $\Gamma_{\min}^k \leq \Gamma_{1,k} \leq \Gamma_{\max}^k$ is always fulfilled through the use of power control techniques. In order to meet the minimum SINR requirement for the desired user ($\Gamma_{1,k} \geq \Gamma_{\min}^k$) the serving BS controls the transmit power of the UE by scaling it up using an interference margin factor f , ($\forall f \in \{\mathbb{R}^+, f > 1\}$). This scaling factor is used to compensate for the expected interference when neighboring UEs are

sharing the same RB to avoid excessive power loss. From (3.5), the transmit power control solution to achieve the minimum SINR target becomes

$$\bar{P}_{1,k} \geq f \Gamma_{\min}^k \left(\frac{\sum_{a \in \mathcal{I}_k} P_{1,a} \mathbf{g}_{1,a} \partial_{1,k} + \sigma_{1,k}^2}{\mathbf{g}_{1,k}} \right) \quad (4)$$

$$P_{1,k}^{\min} \leq \bar{P}_{1,k} \leq P_{1,k}^{\max} \quad (5)$$

Where $P_{1,k}^{\min} / P_{1,k}^{\max}$ are the transmit power limits of the respective minimum and maximum UEs as per 3GPP standard requirements and $\bar{P}_{1,k}$ is the average transmitting power of the UE for the RB.

III.1 POWER CONTROL ALGORITHM

The interference range is a function of the number of base-stations that reuse the same frequency for transmitting units of the UE and their transmitting power. In general cases, the transmitting power of all base stations is regulated at a constant value, except in scenarios that employ dynamic power allocation. At each TTI, the eNB scheduler receives buffer status reports and channel status information from the UEs, and calculates SINR values. In addition, the transmission power allocated for RBs with low SINR values is increased to guarantee better utilization of the available spectrum.

1. The maximum and minimum SINR target for the UE are declared as Γ_{\max}^k and Γ_{\min}^k

2. The eNB calculates $\Gamma_{1,k}$ and correlates it with the SINR target

if $\Gamma_{1,k} \geq \Gamma_{\max}^k$, the maximum allowable transmit power (MATP) for the UE is adapted using

$$P_{1,k} = \frac{\Gamma_{\max}^k}{\Gamma_{1,k}} \bar{P}_{1,k} \quad (6)$$

This will lead to a reduction in transmitting power as the UE requires less power due to an increase in its desired channel gain, and therefore may result in less interference.

3. If $\Gamma_{1,k} < \Gamma_{\min}^k$, the maximum allowable transmit power (MATP) for the UE is adapted using

$$P_{1,k} = \frac{\Gamma_{\min}^k}{\Gamma_{1,k}} \bar{P}_{1,k} \quad (7)$$

and subsequently its MATP is increased as it will require more power to achieve its Quality of Service (QoS) requirement.

IV. SIMULATION ENVIRONMENT

We studied the performance of our proposed power control algorithm by carrying out LTE system level simulations developed in MATLAB and we compared its performance with other power control strategies. We choose our

previously developed scheduler, called the adaptive SINR-based scheduling scheme, to implement the proposed power control algorithm, and compared its performance against Maximum Throughput (MT) Scheduling algorithm and Blind Equal Throughput Scheduling algorithm. SINR calculations were

made to ensure that the condition, $\Gamma_{\min}^k \leq \Gamma_{1,k} \leq \Gamma_{\max}^k$ is always guaranteed.

V. RESULTS

Figure 1 shows the data rate obtained as a function of SNR for the considered schedulers.

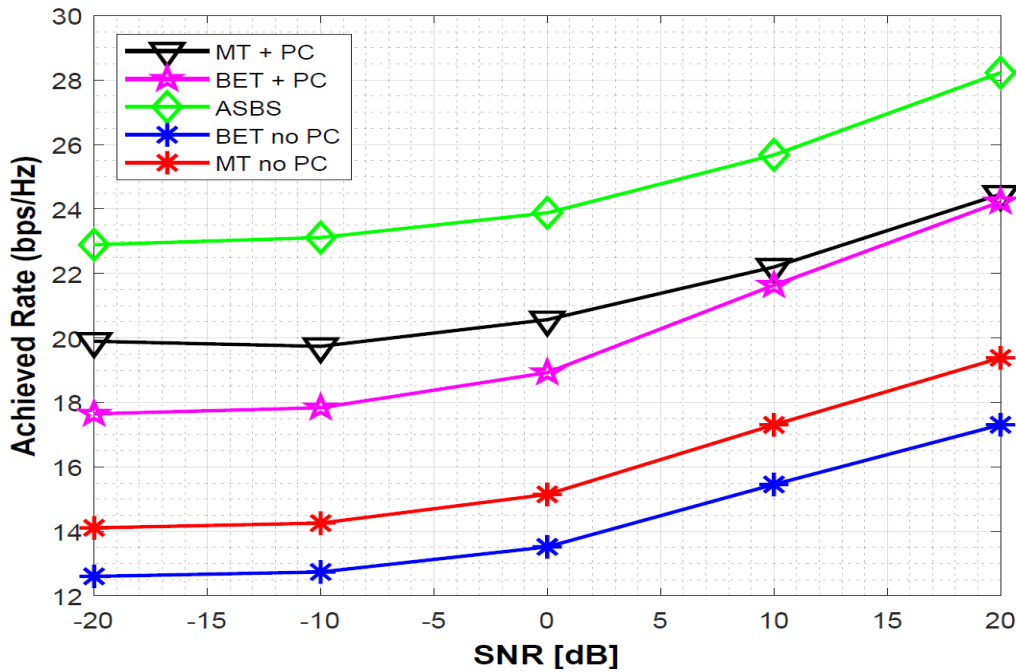


Figure 1: Achieved rate at different SNR

From the output, it is observed that the scheduler without power control performs very poorly with respect to power control and our developed ASBS algorithm. For instance, at SNR of 10dB for K=4 users, the developed ASBS which is a hybrid recorded a data rate of about 25.7bps/hz while MT achieved a rate of about 22.5 bps/hz with power control and a rate of 17.2 bps/hz without power control. BET on the other hand recorded a

rate of about 21.5 bps/hz with power control and a rate of 15.5 bps/hz without power control. The results demonstrated the importance of power control in scheduling. In Figure 2, we examined the performance of the scheduler with power control with an increased number of UEs in a cell, the output is expected as the schedulers support more users to be scheduled in the system and thus the rate attainable do increase.

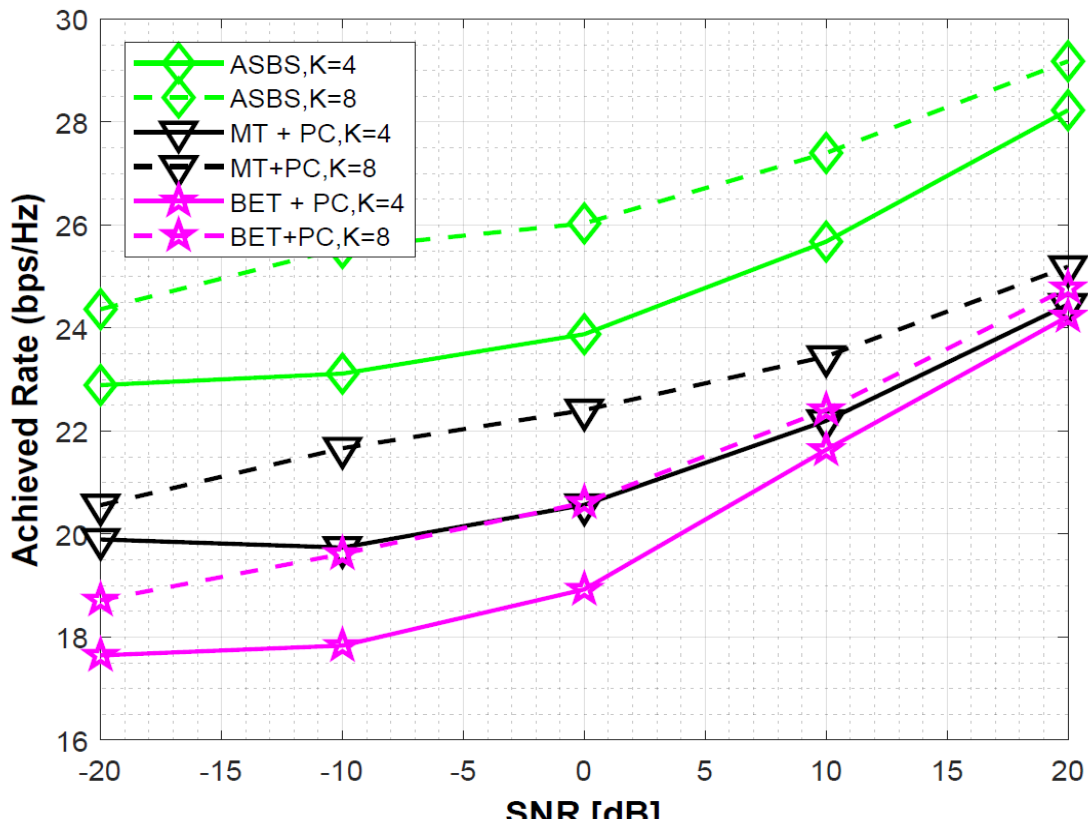


Figure 2: Rate obtained at different SNR, K= [4, 8]

At SNR of 10dB, our developed ASBS recorded an achieved data rate of 25.7bps/hz for K=4 users and 27.5bps/hz for K=8 users. BET on the other hand achieved a data rate of 21.5bps/hz for K=4 users and 22.5bps/hz for K=8 users. Whereas MT recorded a data rate of 22.5bps/hz for K=4 users and 23.5bps/hz for K=8 users. This proved that even with increased number of users, the schedulers performed better with power control.

VI. CONCLUSION

We have developed and implemented a power control algorithm to improve the uplink capability of LTE networks. The power control algorithm was based on the SINR variation in the cell. The proposed power control scheme was implemented in a system level simulator designed for LTE network simulation and used the well-known maximum throughput (MT) and blind equal throughput (BET) schedulers as benchmarks to compare the performance of our proposed scheme. The obtained results demonstrated the importance of power control in scheduling as schemes without power control performed poorly compared to schemes with power controls. Without proper power control of all users sharing the same time and frequency resources, the quality of service

(QoS) will deteriorate and the network may occasionally have network outages.

VII. RECOMMENDATION FOR FUTURE WORK

This work can be continued by implementing a distributed approach, where neighboring eNBs share information about scheduling and power control between them. This will enable eNB of cells that cause severe interference to users of the cell edge in a particular cell to control the transmission power of their user or a separate resource, thereby causing less interference to other users in other cells. To pursue such a study, eNBs must examine the backhaul connections required to communicate with each other, the amount of overhead resulting from sharing this information, and the computational complexity of the implementation.

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