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A Combined Open-Closed Loop Power Control for LTE Uplink

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Abstract— Long Term Evolution (LTE) is a new standard of the 3GPP, designed to increase capacity and improve service performance. Single Carrier FDMA is the multiple access technique used in the uplink, it avoids the intra cell interference typical of CDMA systems, but it is sensitive to inter-cell interference. This makes the power control functionality a vital issue. Power control needs to reduce inter-cell interference level and at the same time achieve a required SINR level. This paper proposes a combined open-closed loop algorithm component that enhances the uplink power control and set the power smartly for the user. The combined algorithm uses the fractional power control algorithm in the open loop and the conventional closed loop algorithm in the closed loop. In this paper the uplink power control schemes were analyzed and the results showed that the combined algorithm outperformed both the open and the closed loop algorithm since it features a cell autonomous mechanism that controls the interference and sets the UEs to transmit with a psd according to the gain in the throughput it would generate. Also, it introduces the possibility of setting the transmission power of the users to provide a minimum SINR.

Index Terms— Open loop power control, Closed loop power control, Fractional Power Control, Conventional Power control, combined open-closed loop power control

1 Introduction

Long Term Evolution (LTE) is a 3GPP standard, designed to increase the capacity and improve the service performance.

Power control in various forms has been one of the key system design features for past, current, and proposed wireless standards. The LTE power control mechanism is composed of a closed loop component operating around an open loop point of operation. The open loop component uses the fractional power control algorithm to compensate for the path loss and shadowing. The closed loop component uses the conventional closed loop algorithm to compensate for the fast variation in the channel, thus improving the system performance [1].

In this paper, a combined open-closed loop algorithm that enhances the uplink power control is proposed. The proposed algorithm uses the fractional power control in the open loop and the conventional power control in the closed loop. It sets the parameters (P0,α) so that the open loop reaches the desired SNR with a relatively large margin, and then uses the closed loop signaling (ΔUE) to more accurately control the power of the rather few UEs that generate the most interference.

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2 Related Work

Several researches have been done on the uplink power control schemes. The impact of the fractional power control scheme on the SINR and interference distribution was evaluated in [2] to provide a sub-optimal configuration tuned for both interference and noise-limited scenarios. In [3] the fractional power control scheme was investigated, the possible tunning of this algorithm and its impact on the service performance both on user experience and on system functionality was evaluated. In [4] a novel technique was proposed where the closed loop is considered to improve the initial performance of FPC by using information of user's potential generated interference. [5] Presents the performance of LTE power control schemes, the simulation results showed that the fractional power control is advantageous compared to the conventional open loop power control in terms of mean cell throughput. In [6] the performance of closed loop power control combined with fractional path loss compensation factor was investigated, the results showed that this mechanism improves the system performance in terms of the mean and cell-edge bit rates.

3 Power Control Schemes in LTE Uplink

Uplink power control is a key radio resource management function. It is used to maximize the power of the desired received signals while limiting the generated interference.

The setting of the UE transmits power Ptx for the uplink transmission in a given subframe is defined by

$$Ptx = \min\{Pmax, 10\log M + Po + \alpha.PL + \delta_{msc} + f(\Delta i)\} \quad (1)$$

Where

Pmax: is the maximum transmission power. It depends on the UE power class and has a value of 23 dBm
M: is the number of physical resource blocks [2, 4, 8, 16, 24, 48] per user in single user simulations.
Po: is a power offset cell/UE specific parameter signaled by Radio Resource Control (RRC).
α: is the path loss compensation factor [0-1]
PL: is the downlink path loss estimate.
δ_{msc}: MCS dependent offset. It is UE specific.
f(Δi): is the closed loop correction value.

The parameters Po and α are signaled from the eNB to the UEs as broadcast. While, Path loss is measured at the UE based on the reference symbol received power (RSRP) [7].

3.1 Open Loop Power Control

Open Loop Power Control is mainly implemented in the user equipment (UE). The UE measures the downlink signal status, compensates the uplink path loss and controls the interference in neighboring eNBs. With OLPC, the UE needs some static/semi-static configuration parameters to be signaled by the eNB and does not require short-term inputs. This saves the overall signaling overhead [8].
The transmission power required from the UE to the eNB can be obtained from Equation (2) by ignoring δ_{msc} and the closed loop correction factor.

$$\mathrm{Pol} = \min\{\mathrm{Pmax}, 10.\log 10\mathrm{M} + \mathrm{Po} + \alpha.\mathrm{PL}\} \quad (2)$$

1. *Fractional Power Control Algorithm*

This algorithm is related to the open loop power control. The standardized equation for this algorithm allows setting the user transmitting power according to the fraction of path gain (PG) that the user has to compensate for [9]. The parameters α and Po are set in order to have an operating point on which cell performance and outage are accordingly compromised. Depending on (FPC), equation (2) is written as

$$\mathrm{PSD_{tx}} = \mathrm{Po} + \alpha.\mathrm{PL} \quad (3)$$

Then equation (3) can be written in terms of path gain as

$$\mathrm{PSD_{tx}} = \mathrm{Po} - \alpha.\mathrm{PG} \quad (4)$$

And in term of the path gain in linear as

$$\mathrm{PSD_{tx}} = \frac{\mathrm{Po}}{\mathrm{pg}^{\alpha}} \quad (5)$$

The PSD is linearly dependent on Po, while α weight their dependencies with the path gain. The term (pg^{α}) varies for each UE according to its experienced path gain.

3.2 Closed Loop Power Control

Closed loop power control is the capability of the UE to adjust the uplink transmit power in accordance with the closed loop correction value also known as transmit power control (TPC) commands[11][12].. In a closed-loop power control system, the uplink receiver at the eNB estimates the SINR of the received signal, and compares it with the desired SINR target value. When the received SINR is below the SINR target, a TPC command is transmitted to the UE to request for an increase in the transmitter power. Otherwise, the TPC command will request for a decrease in the transmitter power [10].

1. *Fractional Closed Loop Power Control Algorithm*

The closed loop power control combined with fractional path loss compensation factor sets the SINR target based on the path loss of the users while the conventional closed loop uses a single SINR target for all the users in a cell.

2. *Conventional Closed Loop Power Control Algorithm*

This algorithm assumes that the level of interference is the same. In conventional closed loop power control the SINR target setting is the same for all users and is a trade-off between the cell-edge and mean bit rate; that is a high SINR target results in high mean user bit rate but lower cell-edge bit rate, while lower SINR target leads to low mean and high cell-edge bit rate.The SINR related to FPC is obtained from Equation (6)

$$SINR = Po + 10\log(M) + (1-a)PG - IoT - N \quad (6)$$

Where

- PG: The path gain to the BS from the UE =20dB.
- IoT: is the Interference over Thermal calculated as the ratio of interference plus thermal noise over thermal noise in the linear domain.
- N : The thermal noise =-174dBm/Hz.

If a constant level of interference and noise is assumed, a higher Po means an increase in SINR. But, in a real system, an increase in Po will increase the power of all users and hence the level of interference.

To determine the transmission power required from the UE to the eNB using the conventional closed loop mechanism, equation 7 is used.

$$\mathrm{P_{tr}} = \min\{\mathrm{Pmax}, \mathrm{Pol} + \mathrm{f}(\Delta i)\} \quad (7)$$

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Where

Pmax: is the maximum transmission power. It depends on the UE power class
Pol: is the uplink power set in the open loop point of operation
f(Δi): is the closed loop correction function and is defined by the expression

$$f(\Delta i) = f(\Delta i - 1) + \Delta i \qquad (8)$$

Δi : is the correction value, also referred as TPC command. The TPC commands are sent after the OLPC has set the initial transmit power using the desired α and Po values [13][14].

The closed loop correction value is obtained from the SINR difference as:
If difference ≤ -1 then -1 is sent,
else if -1 < difference ≤ 1 then 0 is sent,
else if 1 < difference≤ 5 then 1 is sent,
else if difference> 5 then 3 is sent

3.3 Proposed Combined Open-Closed Loop Power Control

A combined open and closed loop Power Control scheme with inter-cell interference mitigation is proposed for the LTE uplink. The Open loop is used to compensate for a fraction of long-term path loss based on the FPC algorithm while, the closed loop is used to correct the open loop power and to allow proprietary method to create open profile based on conventional algorithm. The algorithm sets the parameters (Po,α) so that the open loop reaches the desired SINR with a relatively large margin, and then use the closed loop signaling (ΔUE) to more accurately control the power of the rather few UEs that generate the most interference.

To determine the transmission power required from the UE to the eNB using this mechanism, the following equation was used:

$$P_{RB} = \min\{Po - \alpha \cdot PRxDL + \Delta UE + \Delta TF, Pmax_{RB}\} \qquad (9)$$

Where

- Po: a cell-specific parameter broadcast by the Node B
- α :a cell-specific partial compensation factor broadcast by the Node B
- PRxDL : the downlink signal strength, measured by the UE =from -105dBm to -15dBm.
- ΔUE : a UE-specific offset signaled by the Node B (e.g. as an option in the scheduling grant or on a separate channel)
- ΔTF: a transport format (TF) specific offset. For user plane data, the offset ΔTF, based on the selected transport format and QoS can be used. It is computed according to different power control. It ranges from -6 to 6 dBm
- $Pmax_{RB}$: the maximum allowed total power of the UE per resource block= Pmax / NRB in linear scale, where NRB is the number of resource blocks allocated to the UE =250mW = 43dB.

The UE measures and compensates for a fraction of the path loss according to the parameters Po, α, and ΔTF. Fine tuning (compensating for interference or link quality) is then performed by the NodeB and signaled individually to the UEs.

The parameters (Po and α) are broadcast. In order to limit the downlink overhead, the fine tuning done by the Node B may be sent only to a subset of the UEs.

4 Results and Discussion

The path loss compensation factor and the power offset were varied to test their effect on the UE transmission power using the FPC algorithm in the open loop, the conventional algorithm in the closed loop and the proposed combined open-closed loop power control. Table 1 show the different parameters used in the simulation

TABLE 1
SIMULATION PARAMETERS

Parameter	Value	Unit
Bandwidth of physical resource block	180	Hz
The power receivced from eNB (down link)	46	dB
Maximum Physical Resourse Block (M)	48	-
Maximum UE power	250	mW
Number of PRBs of UE	6	-
PC range	40	dB
Total Number of PRBs	48	-

Table 2 shows the simulation parameters used in the FPC algorithm

TABLE 2
FPC SIMULATION PARAMETERS

Parameter	Value	Unit
α	0.6	-
Po	-54.4	dB

Table 3 shows the simulation parameters used in the conventional closed loop algorithm

TABLE 3
CONVENTIONAL CLOSED LOOP SIMULATION PARAMETERS

Parameter	Value	Unit
α	1	-
Correction factor (Δi)	3	-
Po	-54.4	dB

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Table 4 shows the simulation parameters used in the proposed combined open-closed loop algorithm

TABLE 4

COMBINED OPEN-CLOSED LOOP SIMULATION PARAMETERS

Parameter	Value	Unit
Po	-54.4	dB
PRxDL	-66	dBm
ΔUE	100	-
PmaxRB	43	dB
ΔTF	-3	dB

1. Path Loss Compensation Factor Varied

Fig. 1 shows the result of varying the path loss compensation factor α on the UE transmission power.

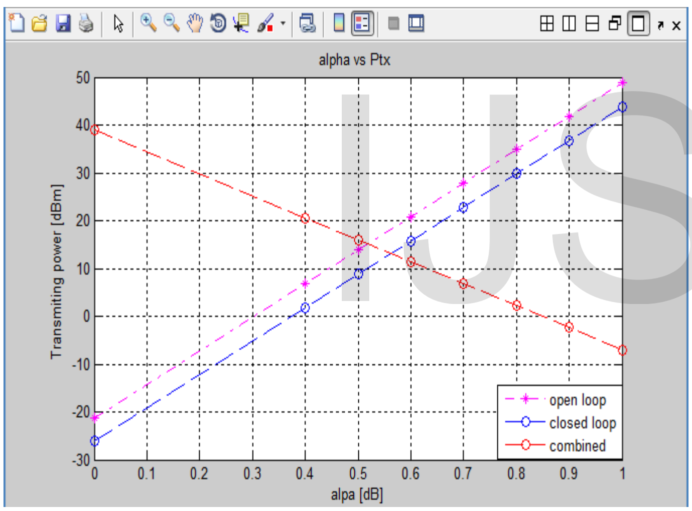

Fig.1 Path Loss Compensation Factor vs Power Transmission

The figure shows that an increase in α result in an increase in the transmission power of both the open and the closed loop power control. While, in the combined (open-closed) algorithm the power transmission decreases. This is due to the fact that the combined algorithm allows estimating the interference of each UE before setting the power. It introduces the possibility to set the Tx psd of the users to provide a minimum SINR.

2. Power Offset Varied

Fig. 2 shows the result of varying the power offset Po on the UE transmission power.

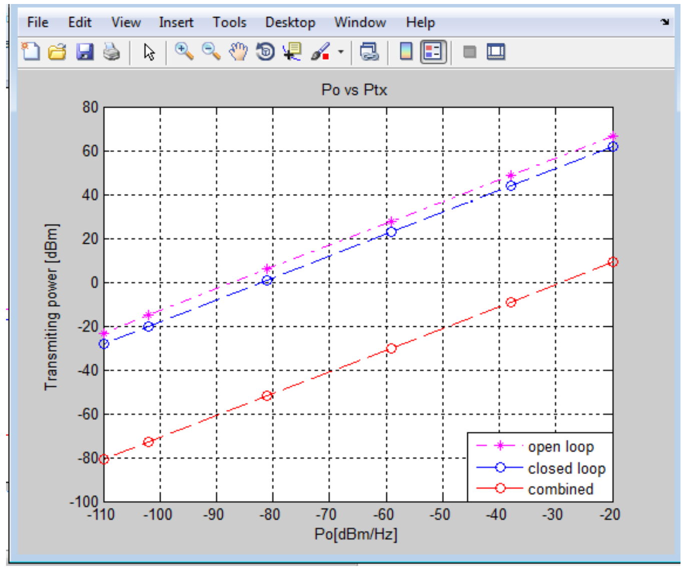

Fig.2 Power offset vs Power Transmission

Fig. 2 shows that an increase in the Po increases the transmission power of the users. Cell edge users will reach the maximum power limit beyond certain Po and then continue to transmit with the same power. The figure shows that the combined (open-closed) loop algorithm outperformed both the open and closed loop algorithms

4 CONCLUSION

In this paper a combined open-closed loop algorithm is proposed. The algorithm estimates the transmission power per resource block required from the UE to the eNB using the parameters Po, α and ΔTF in the open loop and ΔUE in the closed loop.

The fractional power control algorithm in the open loop, the conventional algorithm in the closed loop and the proposed combined open-closed loop algorithm were analyzed. The results showed that the parameters that affect the user transmission power were the path loss factor (α) and the power offset (Po). An increase in the path loss factor, both the fractional open loop and conventional closed loop power control showed an increase in the UE transmission power. The combined algorithm showed a decrease in the UE transmission power as this algorithm estimates the interference of each UE before setting the power. When varying the power offset (Po), the proposed combined (open-closed) loop algorithm outperformed both the open and closed loop algorithms.

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