International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-3 Issue-3, February 2014

Uplink Power Control Schemes in Long Term Evolution

Mrs. Sonia, Nisha Malik, Preet Kanwar Singh Rekhi, Sukhvinder Singh Malik

Abstract*— in multi user environment, number of users share the same radio resources. The shared channels cause the signal intended for a certain user to reach other users and introduce interference in their path and degrade the signal quality. Power control needs to reduce inter-cell interference level and at the same time achieve a required SINR level. To achieve this SINR level eNodeB sends Transmit Power Control (TPC) Command in Downlink in PDCCH and UE sends Power Head Room (PHR) stating how more it can transmit to reach maximum power. In this paper, authors have worked upon the PUSCH Power control, LTE power control mechanism, TPC Command and Power Headroom Reporting. They also found the optimum value of Path Loss Compensation Factor "α".

Index Terms*— LTE, Uplink, Open Loop Power Control, Close loop Power Control, Fractional Power Control, and Inter-Cell Interference.

I. Introduction

Long Term Evolution (LTE) have been introduced by 3GPP with an objective of high-data-rate, low-latency and packet-optimized radio access technology. LTE is also referred to as EUTRA (Evolved UMTS Terrestrial Radio Access) or E-UTRAN (Evolved UMTS Terrestrial Radio Access Network).

LTE uses new multiple access schemes on the air interface namely OFDMA (Orthogonal Frequency Division Multiple Access) in Downlink and SCFDMA (Single Carrier Frequency Division Multiple Access) in Uplink. Usage of SC-FDMA in uplink eliminates intra-cell interference. However since LTE is designed for Frequency reuse 1, inter cell interference persists. Since both data and control channels are sensitive to inter cell interference there should be Power Control (PC) functionality in uplink to minimize the effect of inter cell interference

In LTE, the standardized uplink power control formula contains an open loop component and a closed loop component. In open loop power control (OLPC), the transmitting power is set at the user equipment (UE) using parameters and measures obtained from signals sent by the base station and no feedback is sent to the UE regarding the power to be used for transmission. The closed loop component is considered to improve the performance of FPC by compensating fast variations in channel. In closed loop power control (CLPC) the base station sends feedback to the UE, which is then used to correct the transmitting power.

Qualifying the power control technique as open loop and closed loop helps to have an anticipated idea of the implementation complexity and expected level of performance. For example, it is presumed that a closed loop power control scheme would require high signal overhead of transmission but at the same time it would provide with a fast mechanism to compensate for interference and channel conditions. On the other hand, an open loop power control would result in simpler implementation and low signaling but would be unable to compensate for channel variations for individual users.

The rest of the paper is organized as follows: Section II provides the Role of Power Control. Section III describes the PUSCH power control followed by Power Control Schemes in Section IV. Section V adds the simulations and results. Section VI, VII and VII provide the Conclusion and Future Work, Acknowledgement and References respectively.

Manuscript published on 28 February 2014.
***** Correspondence Author (s)
Mrs. Sonia, Department of Electronics and Communication Engineering, Bhagwan Parshuram College of Engineering, Gohana Sonepat, Haryana, India
Nisha Malik ,Department of Electronics and Communication Engineering, Bhagwan Parshuram College of Engineering, Gohana Sonepat, Haryana, India
Preet Kanwar Singh Rekhi , LTE Test Engineer, Bangalore, Karnataka, India
Sukhvinder Singh Malik LTE Test Engineer, Bangalore, Karnataka, India

II. Role of Power Control

A. Increase Spectral Efficiency

In a multi user environment a number of users share the same radio resources. Due to limited availability of radio channels in the network, same channels have to be assigned to many users. Thus a signal intended for a certain user will reach other users and introduce interference to their connection, and degrade the quality.

A user with very good quality may consider using a low power and still having acceptable quality. The advantage is that it will disturb other users less, and thereby their quality is improved. Power control is essentially to do the same thing but in a controlled manner.

To maximize spectral efficiency, 3GPP LTE is designed for frequency reuse both for downlink and uplink, which means that all cells in the network use the same frequency bands. Thus with frequency reuse 1, both data and control channels are sensitive to inter-cell interference. The cell edge performance and the capacity of a cell site can be limited by the inter-cell interference.

Therefore the role of closed loop power control becomes decisive to provide the required SINR to maintain an acceptable level of communication between the eNodeB and the UE while at the same time controlling interference caused to neighboring cells.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

B. *Battery power consumption*

Battery power is a scarce resource for portable devices like notebooks, ultra-portables, gaming devices and video cameras. In the coming years these devices will operate over mobile broadband technology such as LTE. Therefore to minimize consumption of battery power and use the available power efficiently, power control will prove to be helpful.

III. LTE PUSCH POWER CONTROL

Power control refers to set output power levels of transmitters, Base stations or eNodeBs in the downlink and UEs in the uplink. The 3GPP specification 36.213 defines the setting of the UE transmit power for PUSCH by the following equation:

P_{PUSCH} = min {P_{max}, Po_PUSCH + 10*Log (PUSCH_M) + α*PL + δmcs + f (Δi)} ……………………………. (1)

- *P*max is the maximum allowed transmit power. It depends on the UE power class.
- PUSCH_*M* is the number of physical resource blocks (PRBs) allocated to the UE.
- P_0 is cell/UE specific parameter signalled by radio resource control (RRC). In this thesis study, it is assumed that *P*0 is cell-specific.
- α is the path loss compensation factor. It is a 3-bit cell specific parameter in the range [0, 1] signalled by RRC.
- *PL* is the downlink path loss estimate. It is calculated by the UE based on the reference symbol received power (RSRP).
- δ*mcs* is cell/UE specific modulation and coding scheme defined in the 3GPP specifications for LTE.
- *f* (Δi) is UE specific and is a closed loop correction value . f is a function to select the accumulated or absolute correction value.

Po_PUSCH is the nominal power which is calculated as

Po_{PUSCH}= α *(SNR_i + RB_n) + (1- α)*(Pmax-10*Log (PUSCH_M)…………………………………………… (2)

- SNR_i is the open loop SNR target.
- RB_n is the noise power per PRB.
- PUSCH_*M* defines the number of PRBs for which the SNR target is reached with full power.

A. *PUSCH power control signaling*

Some of the parameters in equation (1) are broadcasted by the eNodeB i.e. same for all the users in a specific cell. The figure shown below clarifies the parameters signalled by the eNodeB towards the UEs.

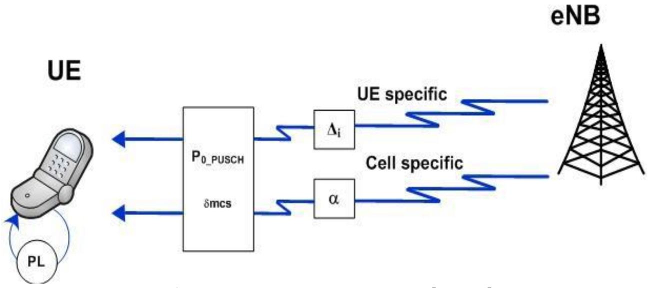

Figure 1. PUSCH power control signaling.

Figure 1 shows that the UE received parameters namely α, δmcs, Δi and Po_PUSCH from the eNodeB. Path Loss PL is calculated by the UE based on reference symbol received power (RSRP). Cell specific parameters vary from UE to UE. Cell specific parameters indicate that they are same for all the UEs in that specific cell.

B. *Power spectral density - PSD*

UE sets its initial transmission power based on received parameters from the eNodeB and path loss calculated by the UE. It is worthwhile to note that Δi is signalled by the eNodeB to any UE after it sets its initial transmit power i.e. Δi have no contribution in the initial setting of the UE transmit power. The expression, based on which a UE sets its initial power can be obtained from equation (1) by ignoring δmcs and the closed loop correction.

While power limitation can be neglected since it corresponds to the UE to respect it.

PPUSCH =10∗Log *(PUSCH_M)* + *P*0_PUSCH +α ·*PL* [dBm] …………………………………………… (3)

Where PUSCH_*M* is the total number of PRB scheduled by the eNodeB. The power assignment for transmission at the UE is performed on the basis of PRB and each PRB contains equal amount of power. Thus by neglecting *M*, the expression used by the UE to assign power to each PRB is given by

PSDTx= *P*0+α ·*PL* [dBm/PRB] …………………………………….. (4)

The equation (3) represents transmit power spectral density (PSD) of a PRB expressed in dBm/PRB. PSDTx is a helpful means to explain the basic difference between conventional and fractional power control. This is discussed in next section.

The power control scheme can be categorized based on the value of α in equation (3).

Figure2. Path loss compensation

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

Using α = 1 (full compensation of path loss) leads to conventional power control. 0 < α < 1 (fractional compensation of path loss) turns to fractional power control, while α = 0 (no compensation of path loss) leads to no power control i.e. all users will use maximum allowed transmission power.

IV. Power Control Schemes

A. Conventional power control scheme

Using α= 1, Po_PUSCH is given below
Po_PUSCH= SNRi + RBn [dBm]………………….. (v)
And thus the PSDTx is given by
PSDTx = Po_PUSCH – PL = (SNRi + RBn + PL) [dBm/PRB] …………………………………………… (6)

Taking into account the path loss, received PSD at the eNodeB is given by
PSDRx = (SNRi + RBn) = Po_PUSCH [dBm/PRB] … (7)

It is important to note that the received PSD at the eNodeB is equal to P0_PUSCH, thus equation (7) illustrates that a conventional PC scheme steers all users with equal power spectral density. This scheme is widely used in cellular systems which do not use orthogonal transmission scheme in the uplink such as CDMA based systems. One of the advantages of this power control scheme is that it removes near-far problem as of typical CDMA systems, since it equalizes power of all UEs before receiving at the base station. The received PSD is plotted for users of different path loss.

B. Fractional power control scheme

The fractional power control scheme allows user to be received with variable PSD depending on their path loss i.e. the user with good radio conditions will be received with high PSD. Using 0 < α < 1, PSD is given by below equation

PSDTx= Po_PUSCH + α*PL = α* (SNRi + RBn) + (1-α)*(Pmax) +α*PL ………………………… (8)

In contrast to conventional power control which allows full compensation of path loss, fractional power control compensates for the fraction of the path loss, and this is the reason that it is named as fractional power control. The received PSD can be found by taking path loss in to account and is given by

PSDRx = P0_PUSCH + PL*(α-1) ……………………… (9)

By comparing equation (8) and equation (9), since received PSD in case of conventional power control scheme results in P_0 while in case of fractional power control scheme it also have an additional term . As both P_0 and □ are cell specific broadcasted towards the UEs by the eNodeB, meaning that they are same for all the UEs thus PL is the key factor in the equation (9) that allows users to be received with different power spectral density. This behavior can be explained with the help of figure obtained using equation (9)

C. Open loop power control

Open loop power control is capability of the UE transmitter to set its uplink transmit power to a specified value suitable for receiver. This setting as discussed in III.B is based on equation (iii), rewriting it as

P_{PUSCH} =10*Log *(PUSCH_M)* + P_0_PUSCH +α ·*PL* [dBm] ………………………………………………….... (10)

OL Power is the uplink power, set by open loop power control. The choice of α depends on whether conventional or fractional power control scheme is used. Using α = 1 leads to conventional open loop power control while 0 < α < 1 leads to fractional open loop power control.

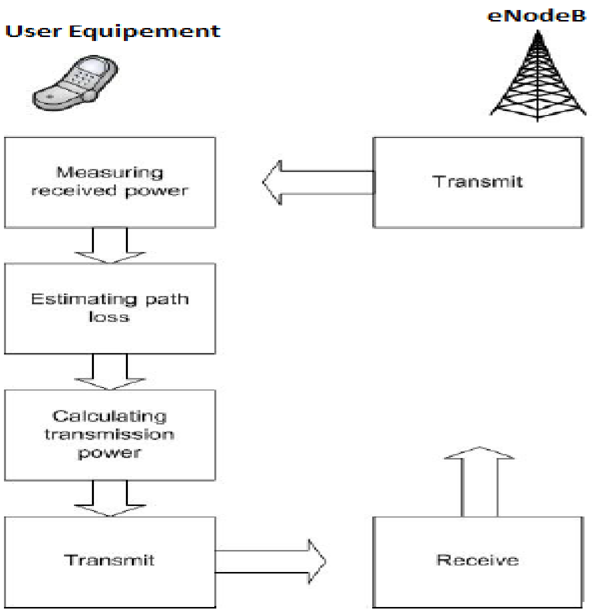

Figure 3. Open Loop Power Control

The Figure shows a block diagram of the steps involved in setting the uplink transmit power using the open loop power control. Estimate of the path loss is obtained after measuring reference symbol received power (RSRP) and then the calculation for transmission power is performed based on equation (10). The transmit block in the eNodeB represents the broadcast of parameters involved in equation (10), namely P_o_PUSCH and α.

D. Closed loop power control

Closed loop power control is 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. TPC commands are transmitted, by the eNodeB towards the UE, based on the closed loop signal-to-interference and noise ratio (SINR) target and measured received SINR. In a closed-loop power control system, the uplink receiver at the eNodeB estimates the SINR of the received signal, and compares it with the desired SINR target value.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

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 transmit power.

The LTE closed loop power control mechanism operates around open loop point of operation. As discussed earlier the UE adjusts its uplink transmission power based on the TPC commands it receives from the eNodeB when the uplink power setting is performed at the UE using open loop power control. The closed loop power control mechanism around open loop power of operation is presented in figure below:

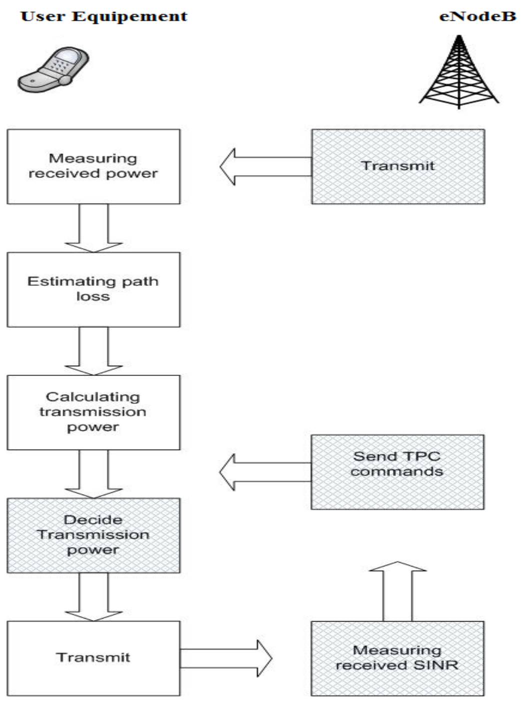

Figure 4. Closed Loop Power Control

The shaded blocks indicate the closed loop power control components. As shown above, the closed loop correction value is applied after calculating the transmission power using the open loop power control. It is worthwhile to note that, conventional and fractional power control indicates the choice of value of α, while open loop and closed loop power control indicate the method of setting the transmission power.

E. Power Headroom Report

The power headroom report can be used by the eNodeB to calculate the path loss for the users which is then used in setting of SINR target. The setting of SINR target is based upon the path loss experienced by users to achieve the particular modulation. Power headroom report is sent by the UE to the eNodeB which indicates how much power UE is left with to start using full power. In other words, it is the difference between the UE transmit power and the maximum UE transmit power.

$$P_h = P_{max} - P_{PUSCH} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (11)$$

The following trigger should apply to the power headroom reporting

- The path loss has changed by a threshold value, since the last power headroom report is sent. The threshold value can be [1, 3, 6, infinity] dB.
- The time elapsed from previous power headroom report is more than Y transmission time intervals (TTIs). The parameter Y can take values [10, 20, 50, 200, 1000, infinity] TTIs.

A power headroom report can only be sent when the UE has an UL grant. If one or several triggers are fulfilled when the UE does not have a grant the UE should send the report when it has received the grant again.

V. Simulation and Results

We performed simulation for conventional power control and fractional power control and results are shown below.

Conventional power uses α=1 where path is fully compensated. The Figure (5) shows conventional power control which illustrates the received PSD is same for all users independent of their path loss for given SINR target. It is worthwhile to note that the 'knee point" indicates the power limited region i.e. users at this point and beyond will start to use Pmax, in other words it shows the maximum path loss which results in uplink power equal to Pmax by the user. The knee point drifts to the left by increasing the SNR target, this means that users will be power limited more quickly. High SNRi mostly favors users close to the eNodeB while lower SNRi favors users at the cell-edge.

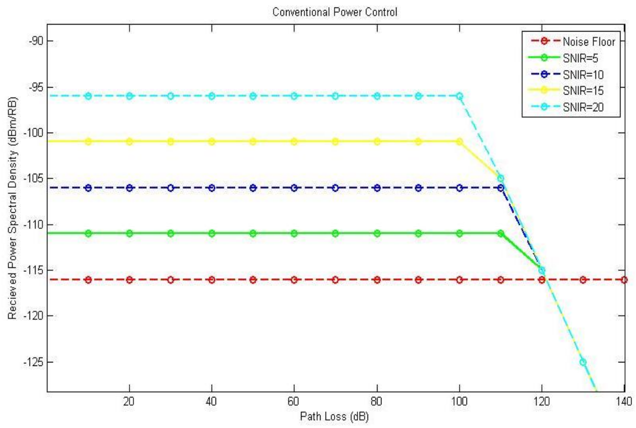

Figure 5. Conventional Power Control

Figure (6) show fractional power control where we plotted the result for different values of α. The result show here are for SINR value of 15 dB and number of PUSCH RB is 50. The noise floor considered is -116 dB.

α = 1(full compensation) and α = 0 (no compensation) shows Conventional and No Power control scheme respectively. For 0 < α< 1 users receive variable PSD depending on their path loss. The "knee point" drifts towards left by decreasing α and increasing SNRi.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

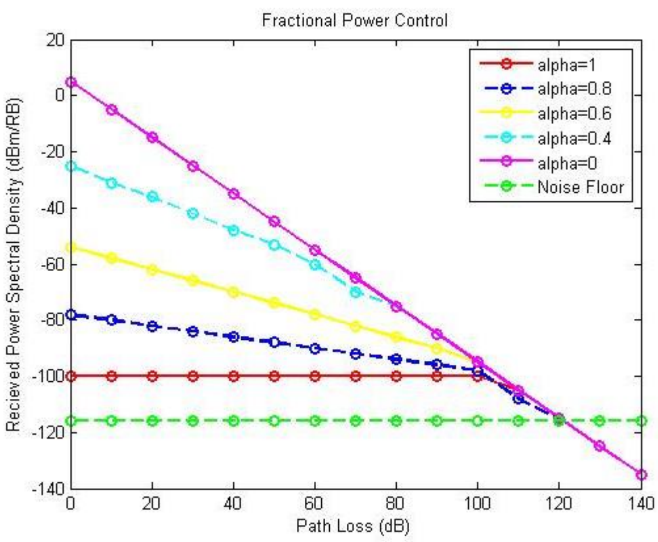

Figure 6. Fractional power control with different value of alpha

VI. Conclusion And Future Work

The simulation results indicated that conventional Closed Loop Power Control can be replaced by the Closed Loop Power Control with Fractional compensation and thus improving the system performance in terms of the spectral efficiency as it reduces the Inter cell Interference and saves UE Battery Power Consumption. For lower path loss, the user will transmit less power in comparison to conventional Power Control. For value of Path Loss Compensation Factor (α) =1, receiver may get saturated on the lower end and for α =0, receiver may get saturated on the upper end. So, the optimum value of α for which the Inter Cell Interference for a receiver will be minimized is the mean of 0.6 and 0.8, that is α=0.7.

As a future work, simulations can be carried to find out how much is the improvement in cell edge bit rate in terms of percentage for different values of α .

VII. Acknowledgment

I owe many thanks to all the people who have helped and supported me throughout this paper. I would also like to express my thanks to Mrs Sonia for her guidance and support and making this possible.

I would also like to say thanks to my institution and my faculty members without whom this paper would have been in a distant state. I also extend my thanks to my family and all of my well-wishers.

References

[1] Lte - The Umts Long Term Evolution from Theory To Practice 2nd Edition by Stefania Sesia , Issam Toufik, Matthew Baker
[2] 3GPP TS 36.213 "Evolved Universal Terrestrial Radio Access (E-UTRA) Physical layer procedures".
[3] 3GPP TS 36.221 "Evolved Universal Terrestrial Radio Access (E-UTRA); Medium Access Control (MAC) protocol specification"
[4] R1-074850 "Uplink Power Control for E-UTRA – Range and Representation of P0"
[5] R1-073036 "Intra-cell Uplink Power Control for E-UTRA – Evaluation of Fractional Path Loss Compensation"
[6] 3GPP, TR 25.814 v7.1.0. Physical layer aspects for Evolved UTRA
[7] W. C. Jakes. Microwave mobile communications. John Wiley & Sons, New York, NY, USA, 1974
[8] R4-081162 "LS on power headroom reporting"

Author's Biographies

Mrs. Sonia M.tech, B.Tech is Electronics and Communication Engineering from MDU University. Working as Assistant Professor and Head of the Department in Electronics & Communication Engineering department at Bhagwan Parshuram College of Engineering and Research including Next Generation telecommunication technologies.

Nisha Malik B.Tech in Electronics & Communication Engineering from School of science and Engineering Khanpur Kalan , BPS Mahila University in 2012. She is pursing M.tech degree in Electronics & Communication Engineering from Bhagwan Parshuram College of Engineering,Deenbandhu Chhotu Ram University of Science & Technology Murthal University.

Preet Kanwar Singh Rekhi B.Tech in Electronics and Communication Engineering from GGSIPU in 2010 with Honours. Having more than 3 years of experience in LTE development industry in different fields i.e. Protocol testing, Quality Assurance etc.

Sukhvinder Singh Malik B.E. in Electronics and Communication Engineering from MDU Rohtak in 2010 with Honours. Having more than 3 years of experience in LTE development industry in different fields i.e. Radio, Protocol testing, Quality Assurance etc.