The Improvement of Power Control Mechanism based on Interference in LTE Network

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Abstract

The performance of uplink channel power control method is pathloss distribution dependent. Power control algorithms in LTE systems give better performance on the locations where UE is less likely to be power limited. The baseline parameter settings of fractional pathloss power control is valid for some cases, however, it is a key issue to improve cell edge throughput in real environment (mix of indoor and outdoor UE case). In this paper, another power control mechanism based on interference is proposed, which takes into account an estimate of the amount of interference generated by UEs to other cells. The simulation results show that it is able to further improve the throughput for UE located at the position with high pathloss, and also leads to interference reduction from other UEs at positions with low pathloss.

1. Introduction

In LTE network, the uplink power control is based on both signal-strength measurements done by the terminal itself (for open-loop power control), as well as measurements by the base station (closed-loop power control). The later measurements are used to generate power control commands that are subsequently fed back to the terminals as part of the downlink control signaling. The 3GPP standard power control mechanism provides a possibility for the eNodeB to configure the cell specific pathloss compensation factor for uplink power control performed in the UE. This mechanism is also called fractional pathloss power control.

With fractional pathloss power control in a live network, it aims to compensate for distance dependent pathloss and shadowing while reducing the interference generated towards neighboring cells and it will be easier to set power control parameters that will enable UL peak rate in the serving cell without sacrificing cell-edge performance too much.

2. INTERFERENCE BASED POWER CONTROL MECHANISM

In fractional pathloss power control, UE with low pathloss is allowed to boost the transmit PSD without causing too much interference. This is widely used in homogeneous environment at present. take PUSCH for example, the UE uses parameter α (pathloss compensation factor) to set UE transmit power for uplink channel in subframe i as:

$$P_{\mathrm{PUSCH}}(i) = \min\{P_{\mathrm{CMAX}}, 10\log_{10}(M_{\mathrm{PUSCH}}(i)) + P_{\mathrm{O\_PUSCH}} + \alpha \cdot PL + \Delta_{\mathrm{TF}}(i) + f(i)\} \text{ [dBm]}.$$

With pathloss compensation factor α< 1.0, eNodeB allows UEs to be received with variable PSD (power spectrum density) depending on their pathloss i.e. the UE with small pathloss will be received with high PSD. The closed-loop power control performed in the eNodeB shall take the configured value of α to calculate the received PSD target as:

$$P_{\mathrm{PUSCH}}(i) = P_{\mathrm{O\_PUSCH}} - (1-\alpha) \cdot PL$$

However, LTE is an interference limited system with the frequency re-use 1 configuration, plot pollution and cell overlapping are the key reasons to cause high interference to the cell edge areas and high degradation of data throughput. Especially in mix indoor and outdoor case, boosting power of outdoor UE which have relatively low pathloss might cause strong interference to neighbor cell indoor UE which have relatively high pathloss. It is really harmful to indoor UE because most likely the indoor UEs are power limited when they are on cell border and have no power to increase SINR. Interference based power control is a mechanism that takes into account an estimate of the amount of interference generated by UE to other cells. This can be estimated as an interference factor to determine the appropriate received PSD target for the UE. The closed-loop power control function shall be used to make adjustments according to interference. Interference based power control enables further improvement of throughput for high pathloss UEs and also leads to reduced interference from low pathloss UEs.

For interference based power control, interference strength can be introduced to enable interference awareness. Interference strength factor is defined relatively based on downlink path-gain and interference from neighbor cells, and can be used in uplink at eNodeB for power control. A measurement of how far the victim UE is isolated from its neighbors in terms of the amount of interference it could cause when transmitting data. It is usually defined as SINR and can be calculated as:

$$UE_{\text{SINR}} = S/(I+N) = \frac{G_{serving\_cell}}{Noisefloor + \sum_i G_{neighboring\_cell,i}}.$$

In a live network, the serving i and neighboring cell's RSRP can be reported from the victim UE and the SINR can also be calculated as:

$$SINR_i = RSRP_i / (\sum_{j \neq i} RSRP_j + Noisefloor)$$

So, the interference strength factor for victim UE can be defined as:

$$F_{Interferencestrength} = (\sum_{j \neq i} RSRP_j + Noisefloor) / RSRP_i$$

As we know, low interference strength suggests low interference to neighbor cells and high interference strength will cause high interference to neighbor cells. In the paper, we suppose that the closed-loop power control performed in the eNodeB shall take the estimated SINR and configured values of α and β to calculate the received PSD target as:

$$P_{\text{PUSCH}}(i) = P_{\text{O\_PUSCH}} - (1-\alpha) \cdot PL + \beta \cdot F_{Interferencestrength}$$

where β is the weight of interference strength factor.

With interference based power control mechanism, we can avoid such issues. Uplink transmit power will be boosted only if interference of the UE is not high enough, which means no significant interference will be generated.

3. SIMULATION AND RESULT

Lots of studies we have done and shown large potentials of either capacity or coverage gain from fractional pathloss power control and interference based power control. Purpose of this paper is to evaluate fractional pathloss power control and interference based power control performance in a live LTE network. Table 1 shows some of the most important parameters of the simulation parameter configuration.

Table 1 Basic Parameter settings in simulation

Cellular Layout	19 sites, 3 cells/site
Inter-site distance	500 m (Case 1)
Bandwidth	10 MHz
Carrier Frequency	1.9GH
UE distribution	Uniformly distributed
Maximum UL power	24 dBm
Channel model	EPA, 3 km/h
Indoor loss	20 dB
Buffer Status	Full buffer
Indoor uses and outdoor UEs ratio	1:1

Fig.1 gives pathloss distribution used in the simulation.

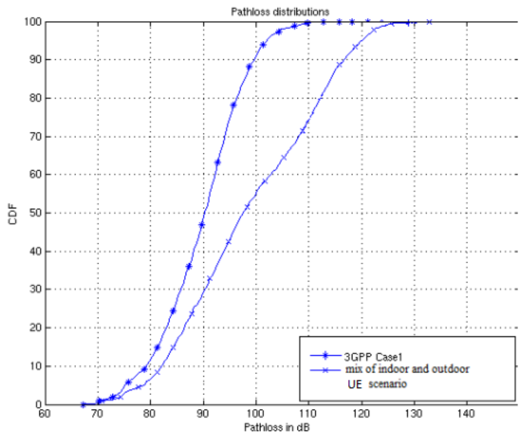

Fig.1 Pathloss distribution of 3GPP case1, 3GPP case 1 with 50% indoor UEs,

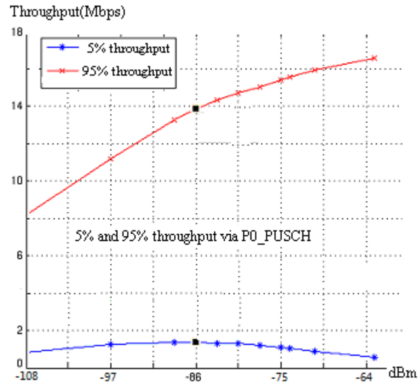

Fig.2 In mix of indoor and outdoor UE scenario, α=0.8

(1) Selection of P0_PUSCH

Basically with a fixed α, selection of P_{0_PUSCH} is a trade-off between cell edge performance and cell center performance. The reason is that as P_{0_PUSCH} increases, both eNodeB received power and interference will increase. Interference from neighboring cells will have more impact on cell edge UE than UE at cell center. In mix of indoor and outdoor UE scenario, when P_{0_PUSCH} increases up to a threshold value, the increase of power can not compensate the increase of interference, the average SINR starts to reduce and total throughput goes down. So basically for each scenario, there should one optimal P_{0_PUSCH} which can give best cell edge performance. Fig.2 gives the relationship between 5th, 95th percentile throughputs versus P_{0_PUSCH} for α 0.8. 95th percentile throughput is used to indicate cell center performance and 5th percentile for cell edge performance. From Fig.2, we can see that for an optimal cell edge throughput, best P_{0_PUSCH} is really pathloss distribution dependent. Under 3GPP case1 with mix of indoor and outdoor UE scenario (for example, 50% each), the range of P_{0_PUSCH} between -108 to -96 dBm is optimum in a live network.

(2) Fractional pathloss power control

In mix of indoor and outdoor UE scenario, outdoor UEs have relatively low pathloss therefore could have high received power target according to the principle of fractional pathloss power control, thus may cause strong interference to the UEs (i.e. indoor) of neighboring cells that have large pathloss and low received power target. The situation becomes even worse when both the outdoor UE and indoor UE are on cell border where it is most likely the indoor UE will get power limited. So, fractional pathloss power control will have problem on cell edge performance in mix of indoor and outdoor UE scenario. Due to the fact, we can see in Fig.3, there is no cell edge gain under different P_{0_PUSCH}. With (P_{0_PUSCH} = -86dBm, α=0.8), the throughput loss is around 3% compared with baseline setting: full pathloss compensation power control with P_{0_PUSCH} equal to -103dBm. Summary of performance targeted for the best cell edge performance gain is shown in Table 2.

Table 2 Performance targeted for the best cell edge performance gain under fractional pathloss power control mechanism

fractional pathloss power control	parameters	5th percentile	95th percentile
mix of indoor and outdoor UE scenario	(P_{0_PUSCH} = -103dBm, α=1)	0%	0%
	(P_{0_PUSCH} = -86dBm, α=0.8)	-3%	-2.8%.

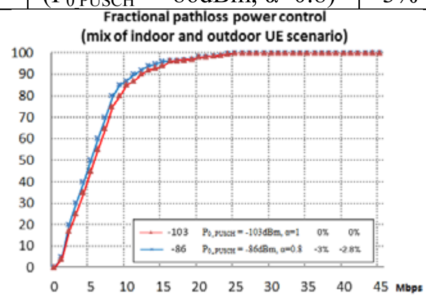

Fig.3 Throughput distribution under mix of indoor and outdoor UE scenario

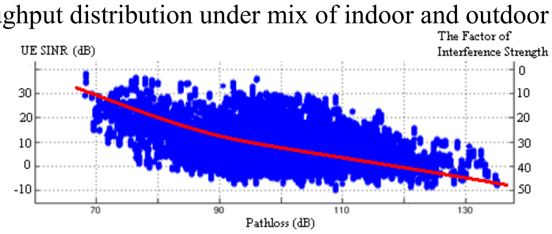

Fig.4 UE SINR and the factor of interference strength distribution for mix of indoor and outdoor UE scenario

(3) Interference based power control

In mix of indoor and outdoor UE scenario of a live network, usually the SINR of UEs is distributed over [-5, 35] dB, and 50% of them are no more than 10dB, thus we can deduce the factor of interference strength is distributed over [0, 50], and 10% of them are no more than 40, as shown in Fig.4.

Summary of throughput gain targeted to the best cell edge performance is shown in Table 3.

Table 3 performance targeted for the best cell edge performance gain under interference based power control mechanism

interference based power control	parameters	5th percentile	95th percentile
mix of indoor and outdoor UE scenario	($P_{0\ PUSCH}$ = -103dBm, α=1)	0%	0%
	($P_{0\ PUSCH}$ = -86dBm, α=0.8)	-3%	-2.8%.
	($P_{0\ PUSCH}$ = -108dBm, α=1.0, β=0.5)	12%	8.9%.

Compared with fractional pathloss power control, interference based power control shows better performance significantly in mix of indoor and outdoor UE scenario. We can see in Fig.5, with (P_{0_PUSCH} = -108dBm, α=1.0, β=0.5), the throughput gain is around 12% cell edge performance gain and at least 8% cell center performance gain compared with baseline setting.

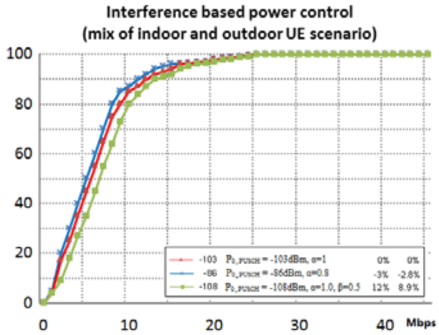

Fig.5 Throughput distribution under mix of indoor and outdoor UE scenario

4. Conclusion

As we know, the performance of uplink power control is pathloss distribution dependent. Power control algorithms give better performance in the scenarios where UE is less likely to be power limited. There exist an optimal P0_PUSCH that can provide best cell edge performance when configure the fixed parameter α. A more aggressive P0_PUSCH is able to bring higher cell center throughput but it will cost cell edge performance.

As compared to fractional pathloss power control with the baseline parameter setting in the paper, it shows problem on cell edge throughput in mix of indoor and outdoor UE case. 3% or more cell edge performance loss is observed.

As expected, interference based power control is able to provide relative gains in mix of indoor and outdoor UE case. Interference based power control based exact UE SINR shows great potentials on improving both cell center and cell edge performance in the mix scenario. Interference based power control is able to provide more than 12% cell edge performance gain together with at least 8% cell center performance gain.

In general, performance of power control shows strong dependency on deployment scenarios. It would be useful to have some self-organized network function intelligently tuning of power related parameter for each scenarios in order to guarantee a perfect performance.

5. References

1 3GPP TS 36.104 Base Station（BS）radio transmission and reception.

2 3GPP TS 36.213: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures".

3 3GPP TS 36.214: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer – Measurements".

4 “TD-LTE Pre-Planning and analysis platform” Design Guideline, Design Institute of Chinamobile