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Abstract	This contribution provides contributions to the power control for Femtocell BS**.**
Purpose	For discussion and approval by IEEE 802.16m TG
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Proposed Text related to Downlink Power Control for Femtocell BS for the IEEE802.16m/D2 (15.4.12.1)

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NEC

1 Introduction

The downlink transmit power of Femtocell ABS shall be set appropriately so that quality of indoor communications or indoor coverage is maintained while mitigating the interference to outdoor macro/micro cell. In order to realize this, it is necessary for the Femtocell ABS to have the knowledge of isolation between the Femtocell and macro/micro cell through building penetration loss.

In this contribution, the maximum downlink transmit power setting of Femtocell ABS which takes into account the building penetration loss is provided and the enhancement is proved with system level simulation.

2 Downlink Power Control

2.1 Downlink Power Control Based on Penetration Loss

2.1.1 Measurement for Power Control

Femtocell ABS can measure the signal strength of carrier frequencies from surrounding cells for the interference mitigation via a DL or UL Receiver function. The DL Receiver function can periodically be switched from a DL transmitter function for the Femtocell ABS within one antenna. Some measurements shall also be collected through MSs attached to the Femtocell ABS.

The measurement items of Femtocell ABS shall be:

1) DL reception power of pilot subcarriers from macro/micro cells
2) UL reception power from MSs not attached to the Femtocell ABS
3) DL reception power of radio frequency from another radio system such as GPS

2.1.2 Power Control Algorithm

Each building has the different properties such as the penetration loss. When the transmit power of Femtocell BS set large while the penetration loss is small, the interference from Femtocell ABS to the macro/micro cell is increased. In opposite, the transmit power of Femtocell ABS set small while the penetration loss is large, the quality or coverage of indoor communications deteriorate (or could say becomes poor).

Femtocell ABS can detect and measure the radio frequency of surrounding macro/micro cells or another radio system such as GPS. The Femtocell ABS shall set its transmit power of pilot subcarriers based on the measurements. The Femtocell ABS can also set the maximum downlink transmit power in proportion to the transmit power of pilot subcarriers.

The Femtocell ABS shall set the transmit power of pilot subcarrier P_tx as follows:

P_tx (dBm) = MEDIAN(P_m + P_offset, P_tx_upp, P_tx_low) (1)

Where:
P_m (dBm) is the downlink reception power of pilot subcarrier from the surrounding macro/micro cell.
P_offset (dB) is the power offset and corresponds to the allowed indoor loss which consists of the indoor path loss between the Femtocell ABS and cell edge of Femtocell and the penetration loss.
P_tx_upp/P_tx_low (dB) is the upper/lower limit value of the transmit power.

As the reception power decreases, it means the Femtocell ABS is located closer to the edge of the macro/micro cell, the maximum downlink transmit power should be small in order to mitigate the DL interference to macro/micro cell.

Furthermore, P_offset is defined as follows:

P_offset = MEDIAN(P_offset_o + K1*L_E, P_offset_max, P_offset_min) (2)

Where:
P_offset_o (dB) is the power offset corresponding to the indoor path loss between the Femtocell ABS and cell edge of Femtocell.
K1 is the adjustable positive factor such as 1 or 2.
L_E (dB) is estimated value of the penetration loss.
P_offset_max/P_offset_min (dB) is the maximum/minimum value of the power offset.

If the penetration loss can be estimated, then the transmit power of the Femtocell ABS shall be set based on this.

In equation (2), the penetration loss is estimated and the power offset shall take this value into account. For buildings with small penetration loss such as 1 or 2 stories residential houses, the transmit power becomes small so that the interference to macro/micro cell can be mitigated. For buildings with large penetration loss such as an office building, the transmit power becomes large so that the indoor communication quality can be high. Fig1 shows the indoor communication quality becomes high because the transmit power is compensated by the penetration loss.

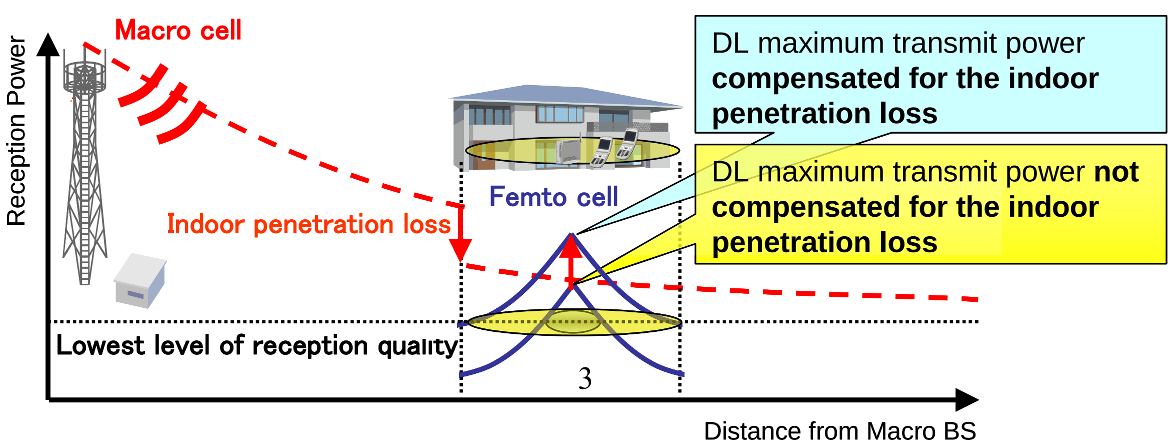

Fig.1: DL Maximum transmit power setting compensated by penetration loss

One method for estimating the penetration loss is to receive another radio system such as GPS. The penetration loss is the outdoor reception power minus indoor reception power. The outdoor one is constant in a broad area. The indoor one can be measured by the Femtocell ABS.

The penetration loss can be calculated as follows:

Penetration loss [dB] = Prx1[dBm] - Prx2[dBm] (3)

Prx1 [dBm] is the outdoor reception power, and can be
- of pilot signal from macro BS measured and reported by outdoor MS (need to be specified) or
- of pilot signal from macro BS previously known with network planning or something (implementation matter) or
- of signal from GPS previously known (implementation matter) or
- of signal from GPS measured and reported by outdoor MS (need to be specified)

Prx2 [dBm] is the indoor reception power, and can be
- of pilot signal from macro BS measured by Femtocell BS (implementation matter) or
- of pilot signal from macro BS measured and reported by indoor MS (need not to be specified) or
- of signal from GPS measured by Femtocell BS (implementation matter) or
- of signal from GPS measured and reported by indoor MS (need to be specified)

Another method for estimating the penetration loss is to use the estimated UL transmit power of a neighbor outdoor MS and the corresponding UL reception power from this MS. The Femtocell ABS can measure the UL reception power from the MS. The Femtocell ABS can estimate the UL transmit power of the neighbor outdoor MS using the DL propagation loss from the surrounding macro cell to the Femtocell ABS based on the assumption that UL power control is applied for both the neighbour outdoor MS and the Femtocell ABS as an MS. Then the penetration loss between the Femtocell ABS and the neighbor outdoor MS can be estimated by the UL transmit power of the MS minus the UL reception power from the same MS.

The penetration loss can be calculated as follows:

Penetraiton loss [dB] = Ptx - Prx – X (4)

X is propagation loss from outdoor to indoor other than penetration loss.

Ptx [dBm] is the outdoor transmit power, and can be
- of outdoor MS measuring and reporting (need to be specified)
- of outdoor MS estimated by Femtocell BS (implementation matter)

Prx [dBm] is the indoor reception power, and can be

- measured by Femtocell BS (implementation matter)

2.2 System Level Simulation for Downlink Power Control

2.2.1 Simulation Assumptions

Table 1 summarizes the simulation assumptions and parameters which are used in this contribution based on EMD. The parameters for Femtocell are assumed because these are currently not described in EMD.

Cell Radius	Macro cell: 1 km Femtocell: 10 m
Macro Cell Layout	Hexagonal grid, 7 cell sites, 3 sectors per site (wrap around)
Carrier Frequency	2.5 GHz
Operating Bandwidth	10 MHz for TDD
Basic Modulation	QPSK, 16QAM, 64QAM
BS Max Tx Power per sector	Macro BS: 46 dBm Femtocell BS: Setting with above algorithm
BS Antenna Pattern	Macro BS: $A(\theta) = -\min\left(12\left(\frac{\theta}{\theta_{3dB}}\right)^2, 20\right)$ dB, where $-180 \le \theta < 180$ θ_{3dB} is the 3dB beamwidth Femtocell BS： $A(\theta) = 0$
BS Antenna Gain	Macro BS: 17 dBi Femtocell BS: 2 dBi
MS Max Tx Power	23 dBm
Penetration Loss (PL)	Mixed with 5, 10, and 20 dB at equal probability
Path Loss Model	Macro BS to Macro MS

	Loss [dB] = 130.19 + 37.6Log$_{10}$(R) Macro BS to Femto MS Loss [dB] = 130.19 + 37.6Log$_{10}$(R) + PL Femtocell BS to Macro MS Loss [dB] = 148.18 + 36.8Log$_{10}$(R) + PL Femtocell BS to Femto MS Loss [dB] = 148.18 + 36.8Log$_{10}$(R) Another Femtocell BS to Femto MS Loss [dB] = 148.18 + 36.8Log$_{10}$(R) + 2PL R [km]: Distance from BS to MS PL [dB]: Penetration Loss
Lognormal Shadowing Std. Dev.	Macro cell: 8 dB Femtocell: 4 dB
Correlation Distance for Shadowing	50 m
Mobility	Macro MS: 3 km/h Femto MS: 0 km/h
Scheduling	Proportional Fairness
Link to System Mapping	RBIR
Power Control	Equal power per subcarrier
Traffic Model	Full Queue
Number of active MSs	10 per macro sector 1 per femtocell
MS Distribution in Macro Sector	Uniform
Number of Femtocell ABS per sector	10
Femtocell ABS Distribution in Macro Sector	Uniform
Upper Limit of Femtocell BS Max Tx Power	23 dBm
Lower Limit of Femtocell BS Max Tx Power	-20 dBm
P_offset_o	50 or 70 or 90 dB
K1	2

Table 1: Simulation Assumptions

2.2.2 Simulation Results

We compare two power control cases as below:

Case1: Penetration loss is not considered

- Open loop power control (Only reception power is considered)
- This case corresponds to K1=0

Case2: Penetration loss is considered and assumes ideal estimation

- L_E is ideally estimated to be 5, 10, or 20 dB

We define two performance criteria for evaluation:

- Cell Throughput [Mbps]: Total successfully transmitted bits per sector during simulation time
- Achievement Ratio of Peak Rate [%]: Percentage of achieving peak rate based on MCS derived by CDF of user throughput

Cell Throughput relates to operator satisfaction and Achievement Ratio of Peak Rate relates to customer satisfaction.

Fig.2 shows dependence of Cell Throughput on P_offset_o. According to Fig.2, the difference of Cell Throughput of macro cell between Case1 and Case2 is negligible. Both cases degrade by about 7% at P_offset_o=90 dB. Therefore we focus our analysis on two cases at P_offset_o=50 or 70 dB because it is important to keep Cell Throughput of macro cell without increasing interference from Femtocell to macro cell. Cell Throughput of Femtocell in Case2 is much higher than that in Case1 by 29% at P_offset_o=70 dB and 108% at P_offset_o=50 dB respectively. This is significant enhancement of the network due to the large gain in the femtocell environment.

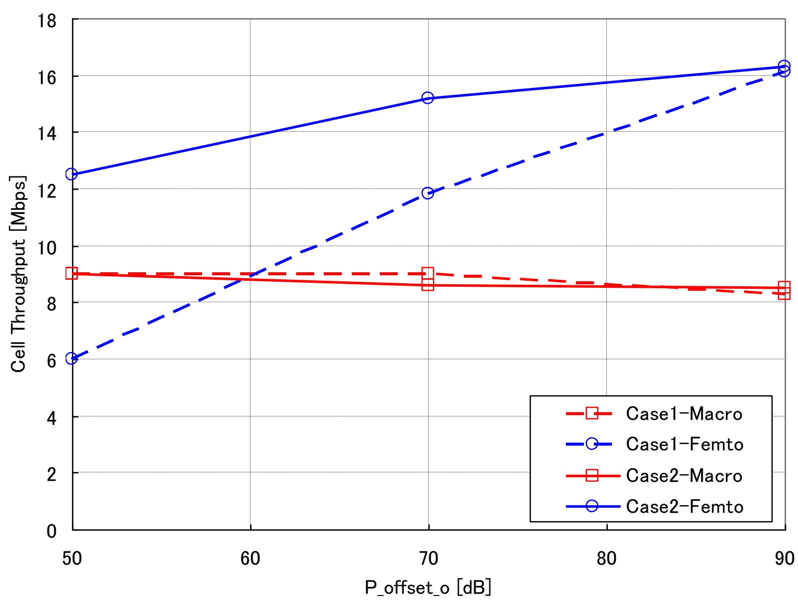

Fig.2 Dependence of Cell Throughput on P_offset_o

Fig.3 shows dependence of Achievement Ratio of Peak Rate on P_offset_o. According to Fig.3, difference of Achievement Ratio of Peak Rate of macro cell between Case1 and Case2 is small and both cases are degraded by about 12% at P_offset_o=90 dB. Therefore we focus our analysis on the two cases at P_offset_o=50 or 70 dB. Achievement Ratio of Peak Rate of Femtocell in Case2 is higher than that in Case1 by 27% at P_offset_o=70 dB and 33% at P_offset_o=50 dB respectively.

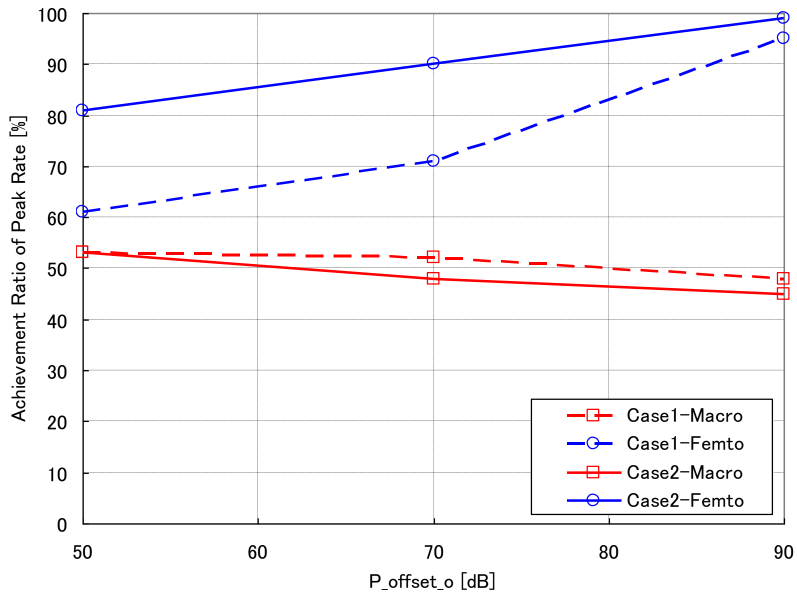

Fig.3 Dependence of Achievement Ratio of Peak Rate on P_offset_o

In conclusion, the power control based on penetration loss is more effective and useful than the power control based on the reception power from the surrounding macro/micro cell alone.

3 Proposed Text

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15.4.12.1. Downlink Power Control

The femtocell ABS shall set the maximum downlink transmit power and should take into account building penetration losses.

Femtocell ABS shall be able to detect and measure the radio frequency of surrounding macro/micro cells or another radio system such as GPS when propagation conditions allow it. The Femtocell ABS shall set the transmit power of pilot subcarriers based on the measurements. The Femtocell ABS shall also set the DL maximum transmit power in proportion to the transmit power of pilot subcarriers.

The Femtocell ABS shall set the transmit power of pilot subcarrier P_tx as follows:

$$P\_tx\ (dBm) = MEDIAN(\ P\_m + P\_offset,\ P\_tx\_upp,\ P\_tx\_low\ ) \quad (x)$$

Where:

P_m (dBm) is the DL reception power of pilot subcarrier from the surrounding macro/micro cell measured by the Femtocell ABS

P_offst (dB) is the power offset and corresponds to the allowed indoor loss which consists of the indoor path loss between the Femtocell ABS and cell edge of Femtocell and the penetration loss

P_tx_upp/P_tx_low (dB) is the upper/lower limit value of the transmit power.

Furthermore, P_offset is defined as follows:

$$P\_offset = MEDIAN(\ P\_offset\_o + K1 * L_E,\ P\_offset\_max,\ P\_offset\_min\ ) \quad (2)$$

Where:

P_offset_o (dB) is the power offset corresponding to the indoor path loss between the Femtocell ABS and cell edge of Femtocell .

K1 is the adjustable positive factor such as 1 or 2.

L_E (dB) is estimated value of the penetration loss.

P_offset_max/P_offset_min (dB) is the maximum/minimum value of the power offset.

One basic method for estimating the penetration loss is to receive another radio system such as GPS. The penetration loss is estimated based on the difference between the outdoor reception power and indoor reception power. The outdoor one may be constant in a broad area. The indoor one can be measured by the Femtocell ABS.

Another basic method for estimating the penetration loss is to use the estimated UL transmit power of a neighbor outdoor MS and the corresponding UL reception power from this MS. The Femtocell ABS can measure the UL reception power from the MS. The Femtocell ABS can estimate the UL transmit power of the neighbor outdoor MS using the DL propagation loss from the surrounding macro cell to the Femtocell ABS based on the assumption that UL power control is applied for both the neighbor outdoor MS and the Femtocell ABS as an MS. Then the penetration loss between the Femtocell ABS and the neighbor outdoor MS can be estimated based on the difference between the UL transmit power of the MS and the UL reception power from the same MS.

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