

CHAPTER THREE
PICO CELL RANGE EXPANSION

Chapter Three

Pico Cell Range Expansion

3.1 Pico Cell Range Expansion

Pico base stations (PBSs) are mostly considered, because they can improve the capacity and they usually have the same backhaul as macro base station (MBS). PBS can be placed near the hot spot where the amount of traffic is high to prevent much user equipment's (UE) from accessing the MBS. PBS has low transmission power, ranging from 23dBm to 30dBm, and serves tens of UE within a coverage range of up to 300 m. However, in the presence of MBS, PBSs ranges become smaller. MBSs transmit power is about 46dBm, and the difference of them is about 16dBm. This big difference causes PBSs ranges to fall within tens of meters, whereas MBS ranges are hundreds or thousands of meters. This is not the case for uplink (UL), in which the reference signal strengths (RSSs) from a UE at different base station mostly depend on the UE transmission powers [28]. Therefore, in this thesis we consider only downlink (DL).

If the range of the hot spot area is the same as that of the Pico cell, the PBS can serve UE within that area and improve coverage area. However, because the hot spot's location and amount of traffic change dynamically, Pico base stations cannot always cover the hot spot area and UE may have to access the MBS even if the PBS may be closer to them.

A major issue in heterogeneous network planning is to ensure that the small cells actually serve enough users that are done by adapting the appropriate cell selection scheme.

In 3GPP LTE, cell selection is performed according to two parameters measured by a User Equipment (UE): Reference Signal Received Power (RSRP) and Reference Signal Received Quality (RSRQ). RSRP is defined as the linear average over the power contributions of their source elements that carry cell-specific reference signals within the considered measurement frequency bandwidth.

RSRQ is calculated based on RSRP which provides additional information and reliable cell selection decision when RSRP is not sufficient. [23][24]

3.2 Conventional cells selection scheme

The traditional cell selection method User Equipment can select the serving Reference-signal-received-power-based (RSRP) cell selection scheme, whereby the selection procedure is triggered through the assessment of the strength of the pilot signal (reference signal) Using RSRP-based cell selection, UE compare the power of reference signal received from macro cell and Pico cell, and connect to the largest one (shown in (3-1)) [29].

The cell with the highest RSRP will be selected as the serving cell of User Equipment.

$$\text{Cell serving} = \text{argmax} \{ \text{RSRP} \} \quad (3-1) [25]$$

Cell selection based on the strongest downlink RSRP is not the best scheme because UE connect to a higher power node instead of the lower power nodes at the shortest path loss distance. Therefore, traffic load is distributed unequally which can lead to macro cells overloading.

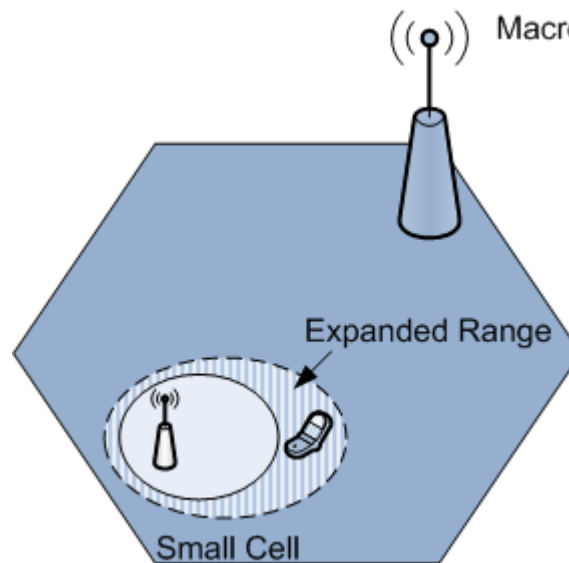


Figure 3-1: Cell Range Expansion

Cell range expansion (CRE), which is a technique that adds a non-negative bias value to Pico received power from Pico cell (shown in (3-2)) and bias is set to zero for the macro cell during the handover instead of increasing the power transmitted as if Pico cell range is expanded (shown in figure 3-1) [28][29][30].

CRE can make more UE to access the Pico cell even if the macro received power is stronger than the Pico received power. However, those UEs that access the Pico cell whose Pico received power is weaker than the macro received power are affected by a large amount of interference from macro cell; such UEs are referred to as expanded region (ER) UE [28].

Traditionally, UEs are set to use the same, fixed, bias value. [28][29][31]

One reason is the fact that varying the bias value would require the measurement of the UE distribution, which is hard to get. However, optimal bias values change depending on the location of UE and base station which differ from one another. [32]

With RE the serving cell of UE is selected from the set of neighbor cells according to the rule given as:

$$\text{Serving Cell} = \text{argmax} (\text{RSRP} + \text{bias}) \quad (3-2)$$

Where RSRP and bias are expressed in dB, this rule implies that UE do not necessarily connect to the base station that has the strongest DL received power. [33]

Considering two cases for user association:

- When UEs connect to MBS,

$$(\text{RSRP macro cell}) \text{ dB} > (\text{RSRP Pico cell}) \text{ dB} + (\Delta \text{ bias}) \text{ dB}$$

- When UEs connect to PBS,

$$(\text{RSRP macro cell}) \text{ dB} < (\text{RSRP Pico cell}) \text{ dB} + (\Delta \text{ bias}) \text{ dB}$$

In such a strategy if the bias value is not properly set, some problems will be introduced. [25]

If the bias is set low in this case, a large number of users won't access into the Pico cell because of the Pico cells' small coverage. The resources (e.g. frequency band/power) won't be fully exploited, which will lead to a bad system performance. And if the bias is set high In this case, the coverage of the Pico cells will be manually enlarged, which will admit more users.

Many of the users accessing into Pico cells will not be scheduled due to their long distance from the Pico cell band bad RSRP, which may lead to scheduling outage. Moreover, those who are relatively close to macro cell will suffer dramatic interference. Thus, the bias value for RE strategy should be carefully designed to get a good system performance. [25]

Given the relatively small footprint of low power nodes, even in the case of the most optimized placement, low power nodes may be underutilized due to geographic changes in data traffic demand. [27]

To determine the benefits of performing CRE, we must measure the bandwidth utilization, throughput, spectral efficiency and data rate.

3.3 Performance Metrics Equations:

3.3.1 Free Space path loss:

In telecommunication, free-space path loss (FSPL) is the loss in signal strength of an electromagnetic wave that would result from a line-of-sight path through free space (usually air), with no obstacles nearby to cause reflection or diffraction. [34]

$$Plf = \frac{-10 \times \log \omega^2 \times g}{(4 \times \pi \times d)^2} \quad (3-3)$$

Plf = free space path loss

W = wavelength

Fc = carrier frequency

D = distance

3.3.2 Path Loss:

Path loss (or Path attenuation) is the reduction in power density (attenuation) of an electromagnetic wave as it propagates through space, and it's usually expressed in dB.

$$L_p = Plf + Amu - Ght - Ghr - Garea \quad (3-4)$$

Lp = path loss

Plf = free space path loss

Amu = Median Attenuation

Ghr = receiver antenna height gain

Ght = transmitter antenna height gain

Garea = area gain

3.3.3 Noise:

Noise is any type of disruption that interferes with the transmission or interpretation of information from the sender to the receiver.

$$N = 10 \times \log_{10}(k \times t \times B) + NF \quad (3-5)$$

N = Noise

K = Boltzmann constant

(Is a physical constant relating energy at the individual particle level with temperature). [35]

B = Bandwidth used per user

NF = Noise figure (It is a number by which the performance of an amplifier or a radio receiver can be specified, with lower values indicating better performance). [36]

3.3.4 Received Power:

The amount of power that is actually received by receiver.

$$Pr = Pt + Gt + Gr - shadow - Lp - Lpen \quad (3-6)$$

Pr = received power

Gt = transmitter antenna gain

Gr = receiver antenna gain

Shadow = Shadowing is caused by obstacles in the propagation path between the UE and the eNodeB Shadowing is modeled as a random variable that is added to the propagation path loss. [37][38]

Lp = path loss

Lpen = penetration loss (absorption loss)

3.3.5 Signal to Interference Noise Ratio:

SINR refers to the amount of useful signal in any transmission divided by the interference combined with noise, averaged over the simulation time t , is measured in dB. [33]

$$SINR = Pr - N - I \quad (3-7)$$

SINR = Signal to interference to noise ratio

Pr = received power

N = noise

I = interference

3.3.6 Total System Bandwidth:

Describes the maximum data transfer rate of a network or internet connection, it measures how much data can be sent over specific connection in a given amount of time. [39]

$$\text{Total bandwidth} = \text{Pico cells bandwidth} + \text{macro cell bandwidth} \quad (3-8)$$

By performing cell range expansion, we can benefit from the entire Pico cells bandwidth, thus the total bandwidth will increase.

3.3.7 Bandwidth per user:

$$\text{Bandwidth per user} = \frac{\text{total bandwidth}}{\text{number of users}} \quad (3-9)$$

3.3.8 Bandwidth Utilization:

Bandwidth utilization is the wise use available bandwidth to achieve specific goals. [40]

$$\text{bandwidthutilization} = \text{usedbandwidth} / \text{totalbandwidth} \quad (3-10)$$

After performing cell range expansion, the used bandwidth will increase; accordingly the bandwidth utilization will increase.

3.3.9 Data Rate:

Data transfer rate is the average number of bits, characters or samples or blocks per unit time passing between equipment. [39]

3.3.10 Throughput:

Network throughput is the rate of successful message delivery over a communication channel. [41] Throughput is usually measured in bits per second, and sometimes in data packet per second. Throughput is the accumulated data rate, and the data rate will obviously increase due to the increasing in the bandwidth utilization; accordingly the throughput will increase.

$$Th = \sum \text{datarate/sec} \quad (3-11)$$

Th = Throughput

3.3.11 Spectral Efficiency:

Refers to the information rate that can be transmitted over a given bandwidth in specific communication system. It is a measure of how efficiently a limited frequency spectrum is utilized by the physical layer protocol and sometimes by the media access control. [40]

$$\text{Spectral efficiency} = \text{data rate} / \text{bandwidth} \quad (3-12)$$

According to the increasing in the bandwidth the data rate rata will increase. Thus the spectral efficiency will increase

3.4 Simulation Scenario:

MatLab programming language (numerical computing environment and 4G programming language, developed by Math Works) was used and construct the simulation code in the M-file.

Heterogeneous network scenario consists of one macro cell (total bandwidth 15 MHz) and one Pico cell (5 MHz) around it was considered, the number of users was increased gradually, the point where the macro cell was overloaded (the assumption is 40 user), and many unused resources in the Pico cell were available, the overall system performance was degrading.

At this point the system performance was measured through calculating used bandwidth per user, noise, shadowing per user, interference per user, path loss, power received and SINR. Taking in consideration (antenna height gain, area gain, coverage area, power transmitted and other physical constants), in order to calculate the performance metrics of the network.

To balance the load, more users were pushed into the Pico cell gradually by expansion the range of the Pico cell, the system performance was calculated in each cell range value and compared to the performance without range expansion.

The path losses, SINR values and other parameters that control network conditions were stabilized before and after the range expansion; the only varying parameters were used band width per user, bandwidth utilization, data rate, spectral efficiency and throughput.