# Coverage Optimization in Self-organizing Small Cells

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**Abstract.** Heterogeneous two-tier network with hybrid deployed small cells and macrocells is a promising solution for fifth generation (5G) wireless networks. However, with the higher and higher spectrum band used in 5G, the coverage and capacity of indoor environment is not good enough for the users' increasing demand. In this paper, we proposed a self-organizing capacity and coverage optimization scheme using power adaptation to enhance the capacity and improve the coverage. Simulation results show that the proposed self-organizing scheme can effectively improve the capacity and coverage.

**Keywords:** Small cells · Coverage optimization
Capacity optimization · Self-organizing network

## 1 Introduction

In recent years, the mobile data usage has grown by 70–200% per annum. More worryingly, the bursty nature of wireless data traffic makes traditional network planning for capacity obsolete. Currently, heterogeneous small cell network with overlay femtocells and macrocell is a most promising solution for the wireless cellular communications of the future [1]. The use of femtocell, which is considered a promising technique, can provide an effective solution to tackle the challenges in this respect [2,3]. In heterogeneous small cell network, low power small cells (such as picocell, relay and femtocell) together with macrocells, can improve the coverage and capacity of cell-edge users and hotspot by exploiting the spatial reuse of spectrum [2]. Small cells can also offload the explosive growth of wireless data traffic from macrocells [3–5]. For example, in an indoor environment WiFi and femtocells can offload most of the data traffic from macrocells [5–7]. For mobile operators, small cells such as femtocells can reduce the capital expenditure (CAPEX) and operating expenditure (OPEX) because of the self-installing and self-operating features of femto basestations [7,8]. The femtocell combined with cognitive radio can further improve the system performance [9,10]. Resource allocation of small cells was studied in [9,10]. The authors addressed many critical issues on femtocells, such as interference mitigation, spectrum access, resource allocation, and quality-of-service (QoS) provisioning [11–13].


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In the Long Term Evolution (LTE) system, with the demand of home eNB (HeNB) deployment within the residual area, the interference between macro eNB and HeNB becomes major obstacle for operators to deploy HeNB. Figure 1 illustrates a result we simulate the coverage of Macro and home eNB with unsuitable transmit power [7]. In this figure, the red zone is covered by Macro eNB and the green zone is covered by HeNB. We can see there are three apartments which are supposed to be covered by Macro eNB covered by a neighbor HeNB in zone 1. As a result, the UE is in the three apartments can't work normally because they aren't the members of the closed subscriber group (CSG) HeNB and can't connect to Macro eNB neither. On the other hand, in zone 2 we can see that HeNB can't cover the whole apartment and that means the end-user who buys HeNB can't get the advantage from HeNB. From the above description, we can summary the main issues of HeNB from the coverage aspect as following:

– If transmit power of HeNB is large, non-CSG UEs which is supposed to connect to MeNB will be affected.
– If transmit power of HeNB is small, some place can't be covered by HeNB and CSG UEs will be affected.

The number of HeNB involved in a wide-scale deployment will be orders of magnitude more than the numbers commonly associated with cells used in macro eNB deployments. With such large numbers, the conventional manual approach to cell-planning and deployment of base stations would not be feasible due to the resulting prohibitively high costs. HeNBs therefore have to be deployed by the end-users themselves, and the HeNB must be able to auto-configure all the required parameters and self-optimize them during operation with minimal human intervention. In this paper, a detail coverage and capacity optimization (CNC) solution will be proposed which includes the self configuration and the self optimization. Both of two parts will adjust the transmit power to optimize the coverage of HeNB in the different stage of HeNB running.

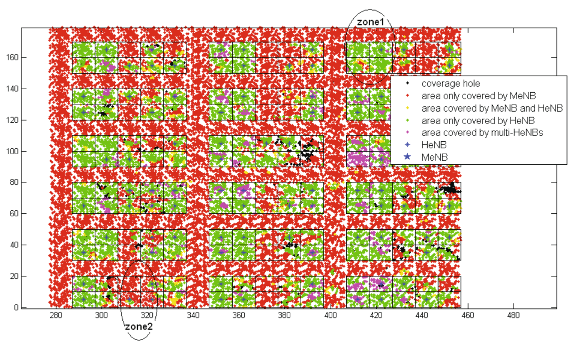


**Fig. 1.** Coverage overview in dense-urban scenario.

# 2 Detailed Algorithm

## 2.1 Self Configuration

After power on, HeNB can detect the wireless environment with a downlink receiver. HeNB can get the RSRP of Macro eNB and its neighbor HeNBs from this detection. Self configuration process will use the detection result to configure a suitable transmit power for the HeNB.

- HeNB has a small coverage area and the boundary is defined as the place that is x2 dB away from HeNB.
- A close-by MUE or HUE has similar RSRP as the detection of HeNB.
- The SINR of a HUE received from the HeNB is more than x3 dB means HUE is covered by a HeNB.
- The SINR of a MUE received from the Macro eNB is more than x1 dB means MUE is covered by a Macro eNB.

With the above assumption, the basic concept of algorithm in self configuration process can be described as following:

- Maintain an SINR is less than x3 dB for a HUE located more than X2 dB away from HeNB
- Maintain an SINR is more than x1 dB for a MUE located more than x2 dB away from HeNB

Figure 2 illustrates how to determine the transmit power of a HeNB [7]. The left figure shows the suitable transmit power of HeNB is supposed to guarantee the HUE is on the boundary has a SINR that is less than x3 dB, thus the HeNB can't affect the MUE. The right figure shows the suitable transmit power of HeNB is supposed to guarantee the MUE which is on the boundary has a SINR that is more than x1 dB.

Here is the detail algorithm.

Figure 3 is the flowchart about self configuration process.

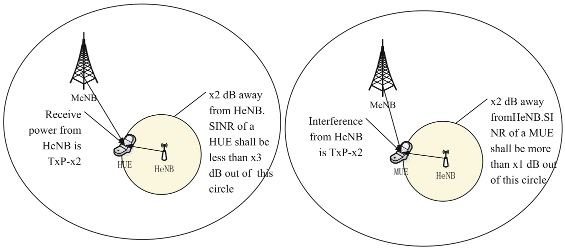


**Fig. 2.** How to determine the transmit power of a HeNB.

**Algorithm 1.** Accumulated-Payoff Based Snowdrift Game

1: **Input** The RSRP of Macro eNB and the neighbor HeNB detected by the considered HeNB Process:
2: **Calculate** the RSRP of a HUE which is on the boundary from HeNB: $TxP_{HeNB}1-x2$
3: **Calculate** the interference of the HUE from the Macro eNB and the neighbor HeNB $\sum_{i=1}^{N_2} 10^{RxP_i/10}$
Where: $N_2$is the number of the Macro eNB and the all neighbor HeNB $RxP_i$is the RSRP of the i-th Macro eNB or HeNB. The unit is dBm
4: **Calculate** the SINR of the HUE $(TxP_{HeNB}1-x2)-10*\log_{10}(\sum_{i=1}^{N_2} 10^{RxP_i/10}+noise)$
Where: is the basic noise and its unit is mW.
5: **Guarantee** this SINR is less than x3 dB

$$(TxP_{HeNB}1 - x2) - 10 * \log_{10}(\sum_{i=1}^{N_2} 10^{RxP_i/10} + noise) < x3 \tag{1}$$

.
6: **Calculate** the RSRP of a MUE which is on the boundary from Macro eNB: $RxP_{MeNB}$
Where: the unit of $RxP_{MeNB}$ is dBm.
7: **Calculate** the interference of the MUE from the HeNB $10^{(TxP_{HeNB}2-x2)/10}$
Where: the unit of $TxP_{HeNB}2$ is dBm
8: **Calculate** the interference of the MUE from the Macro eNB and the neighbor HeNB $\sum_{i=1}^{N1} 10^{RxP_i/10}$
Where: $N_1$ is the number of the Macro eNB and the all HeNB except the considered HeNB $RxP_i$ is the RSRP of the i-th Macro eNB or HeNB. The unit is dBm
9: **Calculate** the SINR of the MUE $RxPMeNB - 10 * \log 10(10^{(TxP_{HeNB}2-x2)/10} + \sum_{i=1}^{N1} 10^{RxP_i/10} + noise)$
10: **Guarantee** this SINR is more than x1 dB $RxPMeNB - 10 * \log 10(10^{(TxP_{HeNB}2-x2)/10} + \sum_{i=1}^{N1} 10^{RxP_i/10} + noise) > x1$
11: **Get** the minimum of these two TxP $Txp_{HeNB} = \min(Txp_{HeNB}1, Txp_{HeNB}2)$
12: **Output:** $Txp_{HeNB}$

## 2.2 Self Optimization

**Boundary Algorithm.** In the self configuration process, the boundary is fixed, actually in real environment, the size of an apartment or a house is various, we are supposed to get the real boundary of every HeNB coverage area. In the self configuration process, SON system can't get any information but the RSRP of Macro eNB and neighbor HeNBs. According to the detection we can't determine the exactly boundary. In the self optimization process, there are HUEs work in the coverage area of HeNB, we can use the measurement of HUE to determine the boundary. Since when HUE enter an apartment, its RSRP from HeNB will have a big change because of the penetration loss of wall, we can use the path-loss form HeNB as the radius of the HeNB coverage. Although according to the position of a HeNB, this kind of radius isn't an concise value, i.e. when HeNB is near to the window (left in Fig. 4), or in the corner (right in Fig. 4). But when the HeNB is in the central of apartment (in Fig. 5), the boundary is suitable. And we know that this kind of boundary depends on the real size of apartment or house, it's better than a fixed boundary, also, we can optimize the transmit power in next optimization process.

About this adaptive boundary, there is another thing to be considered. The measurement report will be sent to eNB only when A3 event occur. However, when UE enter or go out the door, A3 event doesn't occur always. So, we need a new trigger for it. Here we define a threshold $\text{Thres}_{\text{boundary}}$, and a event $B_T$ that the change of RSRP from HeNB between successive two measurements is more than $\text{Thres}_{\text{boundary}}$. Once $B_T$ occurs, the measurement the bigger RSRP is in will be sent to HeNB. For boundary determination, a measurement period T is needed, boundary is supposed to be determined in two successive T. once occurs, HeNB will determine the boundary with the RSRP reported by UE from the this event $B_T$. The fixed boundary will be the initial value of the boundary. If SON server gets a boundary from HeNB, use it in the self optimization process, if not, use the initial value, namely, the fixed boundary. Figure 6 is the relationship between boundary process and the self optimization process. Before $t_0$, there is no boundary is calculated, self optimization process will use the fixed boundary; when $B_T$ occurs at time 3T, SON server will calculate a boundary

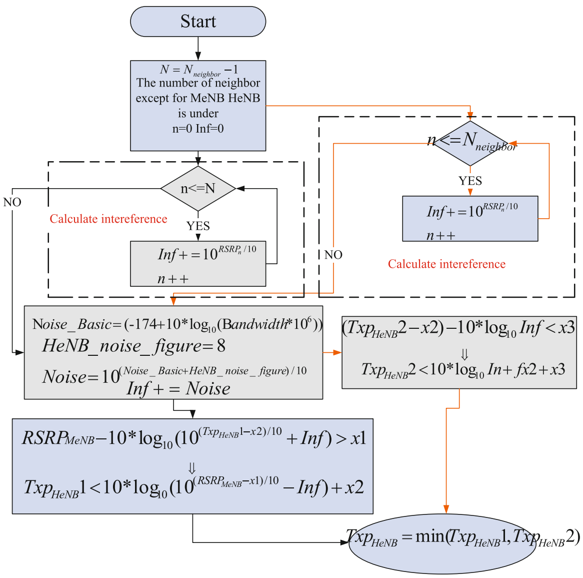


**Fig. 3.** Self configuration flowchart.

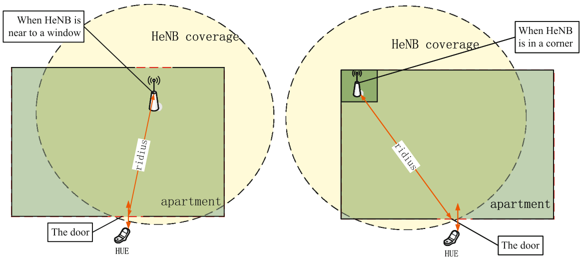


**Fig. 4.** Unsuitable position of HeNB.

with two successive measured RSRP, hence when $t_0$ comes, the boundary has been calculated, self optimization can use the new boundary.

Here is the algorithm.

## Simulation Plan

- Run simulation in every position in Fig. 5.
- Run simulation with same penetration loss of outdoor wall and separating wall, the penetration loss can be 10 and 20 dB.
- Compare the performance of our CNC solution and other similar CNC solution.

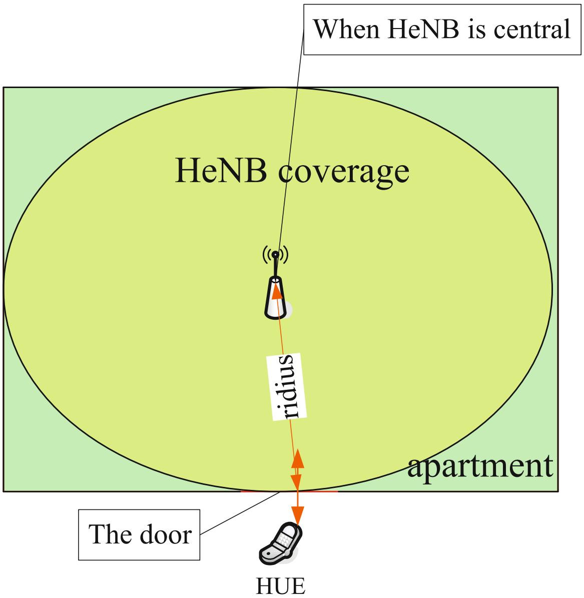


**Fig. 5.** Suitable position of HeNB.

**Algorithm 2.** Boundary Algorithm

1: **Input** The RSRP measured by HUE.
2: In T time, get the average RSRP, and regard it as RSRPi, in next T time, get the average RSRP, and regard it as RSRPi+1. If the change between this measurement RSRPi+1and the previous measurement RSRPi isn't more than the $\mathrm{Thres}_{\mathrm{boundary}}$, do nothing; if crosses it, record the bigger RSRP. $|RSRP_i - RSRP_{i+1}| > Thres_{boundary}$ $RSRP_{boundary} = \max(RSRP_i, RSRP_{i+1})$ Where: $RSRP_i$ is the averaged RSRP of HUE in ith T time period $RSRP_{boundary}$ is the RSRP used to calculate house boundary
3: **Get** the $RSRP_{boundary}$ and report the $RSRP_{boundary}$ to HeNB. If there is no $RSRP_{boundary}$ can be got, doesn't report anything to HeNB.
4: When HeNB get the report from HUE, it will calculate the boundary with its transmit power and sends the path-loss to SON server. HeNB will save the boundary for further self optimization. If SON server doesn't receive any boundary, use the fixed boundary and enter the next T time to get a suitable boundary. $boundary = TxP_{HeNB} - RSRP_{average}$
If don't get a boundary: $boundary = boundary_{fixed}$ Where: the unit of *boundary* is dB
5: **Output:** Output: *boundary*

## 2.3 Shadowing Fading Model

Log-normal shadowing will be applied in our simulation. The standard deviation for HeNB is assumed to be 10 dB, for Macro eNB, it is assumed to be 8 dB. The auto-correlation distance for Macro eNB is assumed to be 50 m and for HeNB, it is 3 m.

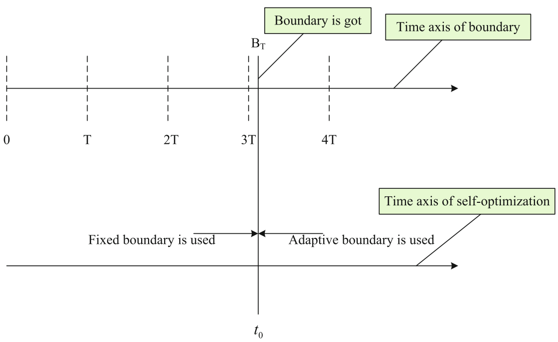


**Fig. 6.** The relationship between boundary process and the self optimization process.

# 3 Simulation Result

## 3.1 Coverage and Capacity

In this simulation, the blocks will be put into Position 1, Position 2 and Position 3 and get the coverage ratios of Macro eNB and HeNB. When simulator running, the penetration loss of wall will be set to 10 dB or 20 dB. But in each simulation, the penetration loss is a fixed value.

**Simulation Results in Position 1.** The optimized coverage ratio value of macro eNB and HeNB and comparisons with coverage ratio value of macro eNB and HeNB with fixed power of HeNB when penetration loss = 10 dB is shown in the following table and figure (Table 1).

The distribution of optimized transmitted power of HeNB is shown in the following figure where Y axis is the number of HeNB with the same optimized transmitted power and the X axis is the transmitted power of each HeNB. The average transmit power is −16.66 dBm.

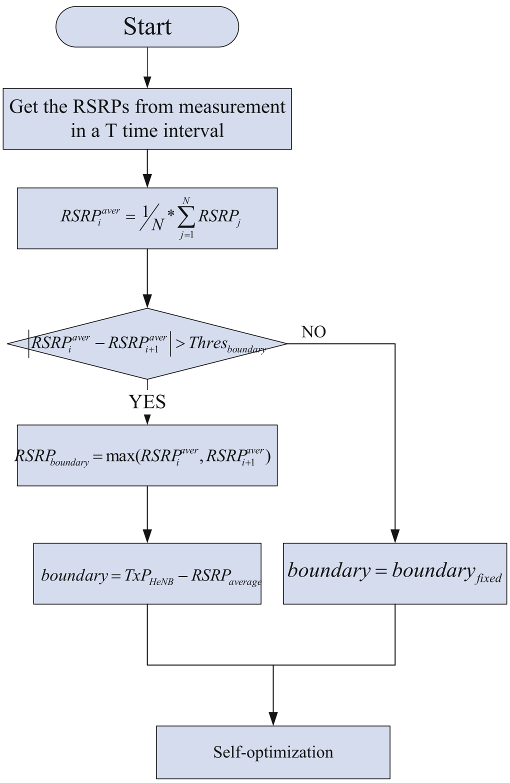


**Fig. 7.** Boundary flowchart.

**Table 1.** Parameters assumption.

| | | | Optimized | 20 dBm | 0 dBm | −10 dBm | −20 dBm |
|---|---|---|---|---|---|---|---|
| Position1 | 10 dB | MeNB coverage ratio | 90.99% | 20.17% | 59.72% | 83.66% | 96.34% |
| | | HeNB coverage ratio | 75.63% | 95.76% | 94.90% | 90.18% | 74.06% |
| | 20 dB | MeNB coverage ratio | 90.05% | 35.23% | 72.12% | 84.23% | 92.59% |
| | | HeNB coverage ratio | 91.88% | 96.44% | 96.17% | 95.17% | 91.52% |
| Position2 | 10 dB | MeNB coverage ratio | 89.70% | 15.47% | 48.95% | 74.46% | 91.50% |
| | | HeNB coverage ratio | 82.27% | 95.86% | 95.69% | 92.92% | 81.69% |
| | 20 dB | MeNB coverage ratio | 87.33% | 28.09% | 65.88% | 80.59% | 89.46% |
| | | HeNB coverage ratio | 93.37% | 95.96% | 95.97% | 95.52% | 92.81% |
| Position3 | 10 dB | MeNB coverage ratio | 90.22% | 16.97% | 53.80% | 78.10% | 93.36% |
| | | HeNB coverage ratio | 91.56% | 96.20% | 95.73% | 93.04% | 82.77% |
| | 20 dB | MeNB coverage ratio | 89.94% | 31.85% | 67.86% | 81.56% | 91.78% |
| | | HeNB coverage ratio | 93.22% | 96.32% | 96.26% | 95.66% | 93.09% |

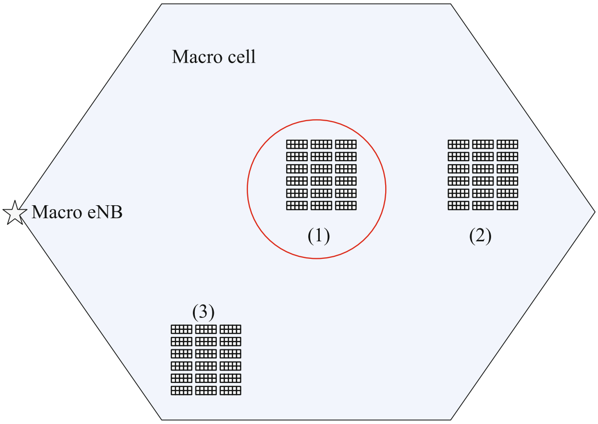


**Fig. 8.** The position of HeNB blocks

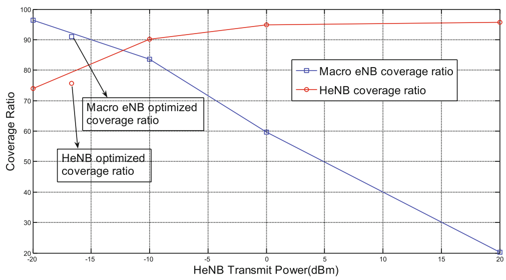


**Fig. 9.** Comparisons of coverage ratio of macro eNB and HeNB with optimized and fixed power of HeNB.

## 4 Conclusion

Our optimized target is that, first, the coverage ratio of macro eNB is more than required coverage ratio, then, maximize the coverage ratio of HeNB. The following table gives the summary results for CNC. From the table list above, We can see that the optimized coverage ratio of macro eNB is very near the required coverage ratio of macro eNB 90%. The optimized coverage ratio of HeNB is very big than that of the most fixed transmitted power when macro eNB meets coverage target. From the above results, we can see that the optimized coverage ratio is similar to that of −20 dBM, this is because the HeNB in our simulation conditions is still densely deployed, so the inter-interference among HeNB is high, as a result, the transmitted power of HeNB after optimization shall not be high, if the HeNB is sparse deployed, the optimized power of HeNB shall be higher than −20 dBM.

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