A novel optimal small cells deployment for next-generation cellualr networks

by Nael Al-shareefi

Submission date: 13-Aug-2020 09:24PM (UTC+0300)

Submission ID: 1369239301

File name: ijece.docx (570.77K)

Word count: 1535

Character count: 8112

A novel optimal small cells deployment for next-generation cellualr networks

Nael A. Al-Shareefi[1]
[1]College of Biomedical Informatics, University of Information Technology and Communications (UOITC), Baghdad, Iraq

Article Info

Article history:

Received Jun 9, 2018
Revised Nov 20, 2018
Accepted Jan 11, 2019

Keywords:

SC deployment
NRS
Mobile station
CHP
Donor base station

ABSTRACT

Small−cell−deployments have pulled cellular operators to boost coverage and capacity in high-demand areas (for example, downtown hot spots). The location of these small cells (SCs) should be determined in order to achieve successful deployments. In this paper, we propose a new approach that optimizes small cells deployment in cellualr networks to achieve three objectives: reduce the total cost of network installation, balancing the allocation of resources, i.e. placement of each SC and their transmitted power, and providing optimal coverage area with a lower amount of interference between adjacent stations. An accurate formula was obtained to determine the optimum number of SC deployment (N_{SC}). Finally, we derive a mathematical expression to calculate the critical−handoff−point (CHP) for neighbouring wireless stations.

Corresponding Author:

Nael A. Al-Shareefi,
College of Biomedical Informatics,
University of Information Technology and Communications (UOITC), Baghdad, Iraq.
Email: dr.nael.al_shareefi@uoitc.edu.iq

1. INTRODUCTION

Outage in wireless services in the urban areas due to the poor coverage and the long geographical distance from the donor base station (D_{eNB}) and mobile stations (MS), is critical design challenge that radio planning engineers need to think about. Radio engineers have chosen to deploy more D_{eNBs} with a small radius to solve this issue. However, this solution is impractical scince it increases total cost of network and resources allocation [1]. SCs are miniature D_{eNB} that divides a cell into smaller geographical area. SCs have been appeared to save the energy consumption and raise the throughput in cellular scenarios [100]. The most common form of SCs is microcells, picocells and femtocells which can be installed indoor/outdoor [2]. Because of its easy deployment, low power and low cost, SCs provide a feasible and cost-effective way to boost cellular coverage, capacity and quality of service. Since wireless carriers seek to "condense" existing wireless networks to provide data capacity requirements for "5G", SCs are currently seen as a solution to allow the same frequency reuse and as an important means of raising mobile network throughput and quality with increased focus with 4G LTE A.

Some initial studies involved with CSs deployment were explored in [6-9]. Maveddat [6] showed the necessity of CS deployment. Chen [7] studied how to deploy small cells nested with macro cells, and improves overall network performance. Ranaweera [8] discussed the backhaul of small cells. The automated deployment of a small cell for heterogeneous cellular networks is addressed in [9]. However, the researchers did not identify the optimum SC deployment.

In this paper, we propose a new approach that can optimizes SC deployment and enhances coverage area by mitigate the amount of the interference between stations. An accurate and simple mathematical formula was obtained to determine the optimum number of SC deployment (N_{SC}).

2. THEORITCAL ANALYSIS

2.1. Critical−Handoff−Point

Cellular telecommunications define the handoff as a situation where two frequency channels are available, thereafter the cellular network selects one them []. It is activated either by crossing the cell boundaries or by degrading the signal quality. The cellular network searchs for the available channels and chooses which channel and cell to perform this operation [101]. Multiple Hops have been considered as supplementary technology in next generation cellular networks. To assess the CHP in multi-hop cellular networks, received signal strength (RSS) from SC and D_{eNB} need to be known. Consequently, MS selects the strongest in terms of RSS as depicted in Figure 1.

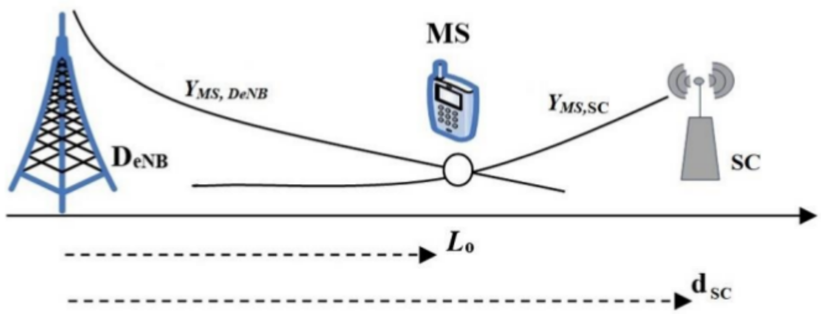


Figure 1. Critical−handover−point

In Figure 1, the distance between the D_{eNB} and SC is indicated by (d_{sc}). The distance from the D_{eNB} to MS is indicated by L_o. The distance from the SC to MS is indicated by (d_{sc} - L_o). Critical−handoff becomes clear when the RSS from the D_{eNB} to MS, ($Y_{DeNB, MS}$), is equal to the RSS from SC to MS ($Y_{SC, MS}$) []. Based on this relation the value of L_o can be evaluated and ($Y_{DeNB, MS}$) and ($Y_{SC, MS}$) can be mathematically written as:

$$Y_{D_{eNB},MS} = \sqrt{P_{D_{eNB}}} H_{D_{eNB}} X_{D_{eNB}} \quad (1)$$

$$Y_{SC,MS} = \sqrt{P_{SC}} H_{SC} X_{SC} \quad (2)$$

where P_{SC} and P_{DeNB} are the transmit power of the SC and D_{eNB}, respectively. H_{SC} is the channel gain from SC location to MS and H_{DeNB} is the channel gain form D_{eNB} to MS. X_{DeNB} and X_{SC} are RSSs from D_{eNB} and SC, respectively. At CHP, the received signal from D_{eNB} to MS equals to the received signal from SC to MS. This suitation can be written as

$$Y_{SC,MS} = Y_{D_{eNB},MS} \quad (3)$$

$$\sqrt{P_{D_{eNB}}} H_{D_{eNB}} X_{D_{eNB}} = \sqrt{P_{SC}} H_{SC} X_{SC} \quad (4)$$

$$P_{D_{eNB}}\left|H_{_{DeNB}}\right|^2 = P_{SC}\left|H_{SC}\right|^2 \tag{5}$$

For simplicity, H can be given by [10, 11]

$$|H| = d^{-\alpha} \tag{6}$$

$$\Rightarrow \left|H_{D_{eNB}}\right|^2 = L_o^{-\alpha}$$

$$\Rightarrow \left|H_{RS}\right|^2 = (d_{SC} - L_o)^{-\alpha} \tag{7}$$

where α is the path–loss exponents, typical values range between 1.5 and 5 [12]. Therefore, Equation (5) can be written as:

$$P_{D_{eNB}} L_o^{-\alpha} = P_{RS}(d_{SC} - L_o)^{-\alpha} \tag{8}$$

$$P_{D_{eNB}}^{(\frac{-1}{\alpha})} L_o = P_{SC}^{(\frac{-1}{\alpha})}(d_{SC} - L_o) \tag{9}$$

$$L_o = d_{SC} \Big/ \left(\left(\frac{P_{SC}}{P_{D_{eNB}}} \right)^{\frac{1}{\alpha}} + 1 \right) \tag{10}$$

2.2. Optimum Number of SCs deployment (N_{SC})

To to reduce the number of the deployed SCs and enhancing the coverage area with minimizing the interference between SC stations, the optimal number of SC stations (N_{SC}) should be computed. To compute **(N_{SC}), s**uppose that a MS exists in the middle between two SCs, and that *Lo* is the distance from SC to MS as demonstrated in Figure 2.

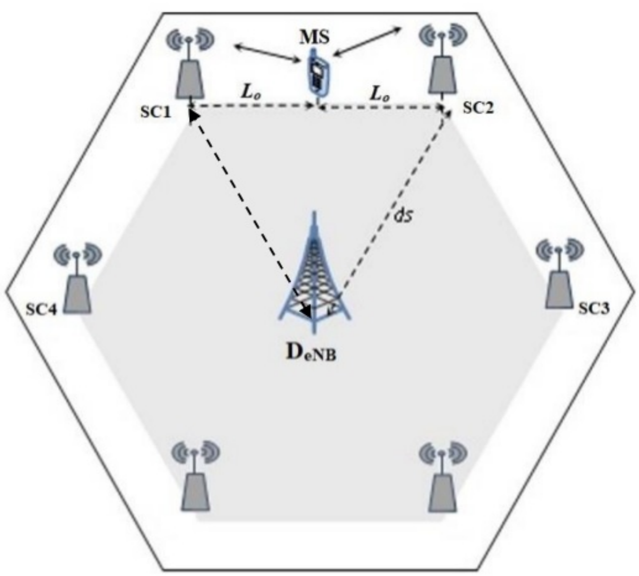


Figure 2. SCs deployment

In Figure 2, increasing the number of SCs can enhance coverage area. Nevertheless, it is also increasing interference between SCs [13]. This paper presents a solution to balance between increasing number of SCs, increasing interference between SCs and increasing resource allocation by derivation of N_{SC} based on the path loss from neighboring D_{eNB} and SCs [14, 15]. In Figure 2, RSS from two neighbouring RSs can mathematically expressed as:

$$Y_{MS1} = \sqrt{P_{SC1}} H_{SC1} X_{SC1} + \sigma_{MS} \tag{11}$$

$$Y_{MS2} = \sqrt{P_{SC2}} H_{SC2} X_{SC2} + \sigma_{MS} \tag{12}$$

σ_{MS} is Additive White Gaussian Noise for mobile station. The received signal from the donor can be mathematically expressed as:

$$Y_{D_{eNB},MS} = \sqrt{P_{D_{eNB}}} H_{D_{eNB}} X_{D_{eNB}} + \sigma_{MS} \tag{13}$$

At the location of MS, the interference power between neighboring SCs to MS be equal or stronger than interference power from $D_{eN}B$ to MS. Therefore, equations (11), (12), and (13) can be written as:

$$Y_{D_{eNB},MS} \leq Y_{MS1} + Y_{MS2} \tag{14}$$

$$P_{D_{eNB},MS} .(d_S)^{-\alpha} < P_{SC1}(L_o)^{-\alpha} + P_{SC2}(L_o)^{-\alpha} \tag{15}$$

$$P_{D_{eNB},MS} .(d_S)^{-\alpha} < 2P_{SC}(L_o)^{-\alpha} \tag{16}$$

As depicted in Figure 2, RSs deployed at cell boundaries around the D_{eNB} with radius d_S. Consequently, the distance between neighboring RSs is:

$$2L_o = \frac{2\pi d_S}{N_{SC}} \tag{17}$$

Substitution of Equation (17) into Equation (16) produces:

$$(d_S)^{-\alpha} < \frac{2P_{RS}}{P_{D_{eNB}}} \left(\frac{\pi d_S}{N_{RS}} \right)^{-\alpha} \tag{18}$$

Thus, the optimum number of SCs (N_{SC}) is:

$$N_{SC} < \pi \left(\frac{2P_{SC}}{P_{D_{eNB}}} \right)^{\frac{-1}{\alpha}} \tag{19}$$

Based on Equation (19), the optimum number of SCs (N_{SC}) depend on three factors: the distributed transmitted power of each SC (P_{SC}), D_{eNB} and α. These factors provide the maximum enhancement in capacity and coverage area and mitigate the interference between nodes (SCs, D_{eNB}).

3. NUMERICAL RESULTS AND DISCUSSIONS

The numerical results based on the above theoretical derivation coupled with simulation results using MATLAB R2019a and ICS telecom EV simulator from ATDI, are presented in this section.

Figure 3, shows the effect of optimum SC location on the N_{SC}. The highest N_{SC} can be obtained when the placement of SC from D_{eNB} is increased. The N_{SC} value degrades slowly with the decrement of the placement of SC from $D_{eNB.}$ This enhancement in N_{SC} is obtained by balancing the N_{SC} with optimal SC location.

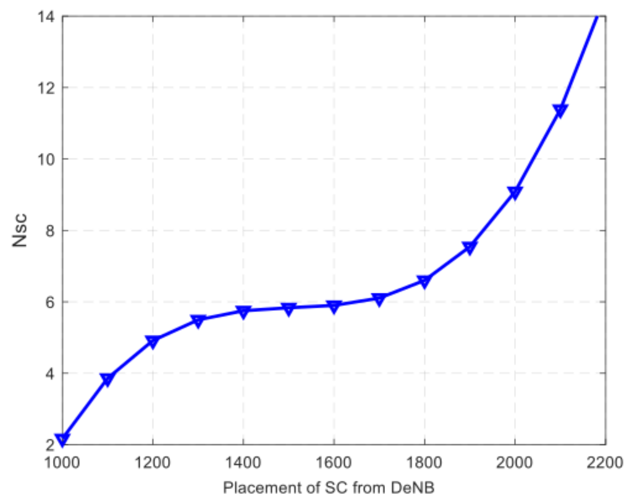


Figure 3. N_{SC} Vs. placement of SC from D_{eNB}

Figure 4, shows the relationship between power allocation of each SC and N_{SC}. The power allocation for each SC increases as N_{SC} decreases based on Equation (19) to avoid interference between neighboring RSs as well as balance the total power consumption for SCs with the N_{SC}.

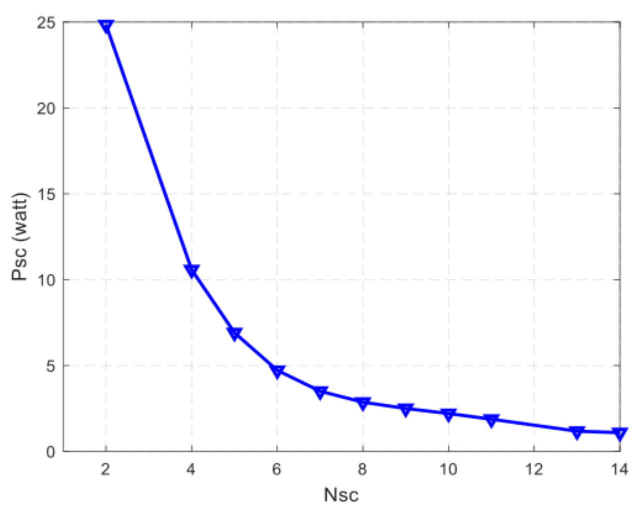


Figure 4. P_{RS} Vs. N_{SC}

Figure 5, shows the relationship between transmitted power allocation of each SC and their placement within the cell. This relation ensures the enhancement of spectral efficiency by balancing the power allocated for SCs with their locations. The power assigned for each SC is reduced whenever the location of SC from D_{eNB} is increased as shown in Figure 5.

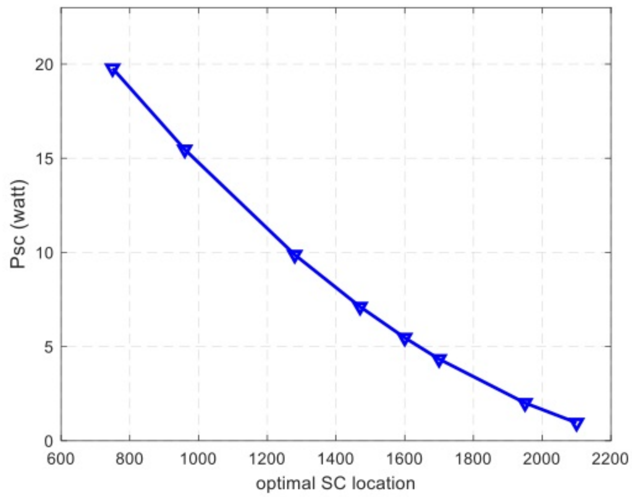
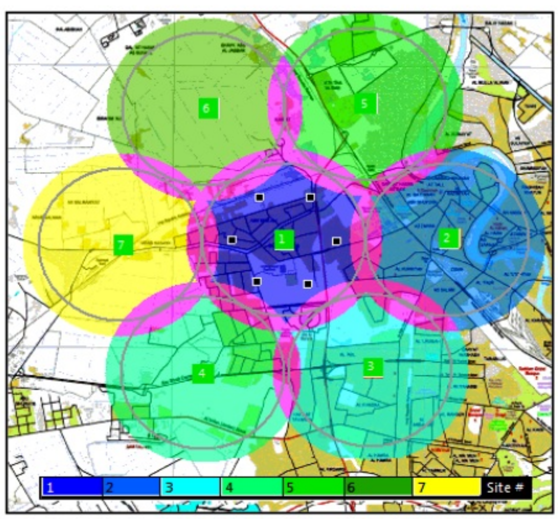
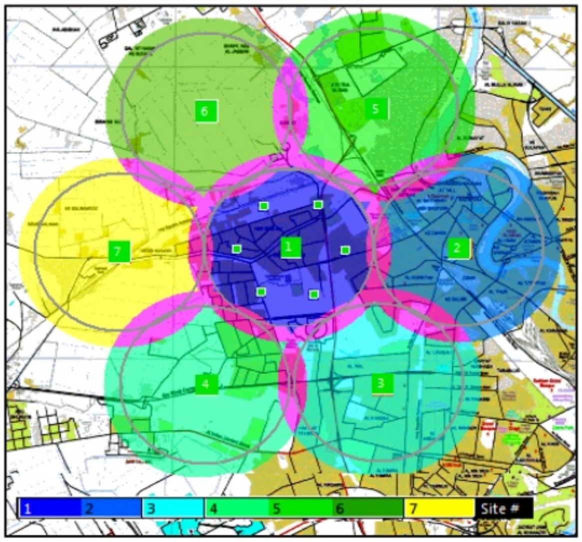


Figure 5. P_{SC} Vs. optimal SC location

Figure 6 depicts interference alleviation for the optimum SCs deployment based on our approach assuming the number of SCs (N_{SC}=6) and using ICS telecom EV simulator. The pink colour in figure 6 illustrates interference between deployed SCs at cell boundaries around the D_{eNB}, CSs inside cell boundaries of the D_{eNB} and D_{eNB}. Figure 6a shows the interference when SCs inside cell boundaries of the D_{eNB} are deactivated (SCs idle), while Figure 6b depicts the interference in case of activated SCs. Compared with Figure 6a, Figure 6b shows an interference alleviation and an enhancement in the coverage area.



(a)



(b)

Figure 7. Interference alleviation with deploying SCs

4. CONCLUSION

This paper investigates a new optimal small cells deployment technique that is developed to mitigate the interference level between adjacent SCs and the D_{eNB}, reduce the total cost of network installation, and providing maximize coverage area. The proposed technique involves more than one phase. These phases aim, firstly, to get accurate equations for critical−handoff−point and optimum number of small cell stations (N_{SC}). The deduced equations showed good accuracy with numerical simulation which represent the second phase. The paper assists radio planning engineers in determination N_{SC} and CHP without using licensed and expensive simulators to achieve maximum coverage area with a minium amount of interference between adjacent stations for next generation cellular networks.

A novel optimal small cells deployment for next-generation cellualr networks

ORIGINALITY REPORT

10%	7%	6%	10%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Submitted to Texas A&M University, College Station Student Paper	6%
2	Submitted to Universiti Teknologi MARA Student Paper	2%
3	Submitted to Universiti Malaysia Terengganu UMT Student Paper	1%
4	Submitted to College of Education for Pure Sciences/IBN Al-Haitham/ Baghdad University Student Paper	1%
5	Huda Kadhim Tayyeh, Mohammed Salih Mahdi, Ahmed Sabah Ahmed AL-Jumaili. "Novel steganography scheme using Arabic text features in Holy Quran", International Journal of Electrical and Computer Engineering (IJECE), 2019 Publication	<1%

Exclude quotes	Off	Exclude matches	Off
Exclude bibliography	Off		