Research Article

Power Level Assignment and Base Station Placement Using Simulated Annealing for 4G-LTE Femtocell Networks in Multi-floor Buildings

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Abstract
Femtocell Base Stations (FBSs) are widely used to improve data rates and cell coverage to the indoor service in Long Term Evolution (LTE) networks. With a proper network's design, a network deployment cost will be worth and a network performance will satisfy the users. Nevertheless, with an improper design, besides all of the foregoing will not achieve, an unpleasant problem such as a leakage signal from an indoor to outdoor area will occur. In this paper, we propose an optimization technique which is a collaboration between a Linear Programming (LP) and a Simulated Annealing heuristic technique (SA). We separate our optimization technique into two steps. In step one, we focus on minimizing the number of FBS to be installed by formulating a linear programming problem. In step two, we optimize the placement location and the transmit power level of installed FBS by using the SA heuristic. Our results show that the proposed technique can achieve a better performance trade-off between computation time and solution quality. Besides, when compared to linear programming technique, the proposed technique can reduce the summation of leakage signal up to 90%, the total power usage up to 45% and reduce a computation time more than 70%.

Keywords: Network planning, Power level assignment, Base station placement, Linear programming, Simulated annealing, 4G-LTE femtocell networks

1 Introduction

Nowadays, the growing number of smartphone and tablet users has led to very high mobile data traffic in the cellular networks and it has been observed that the most of the mobile data traffic generates from indoor. Hence, FBSs are installed to enhance the network performance inside the buildings to provide an access to indoor users at a low cost of deployment [1]. A femtocell is a low-power wireless base station for the in-building cellular access. In addition, the FBSs can help reduce the load and congestion of the macrocell base stations. Especially, they can help extend the service coverage to the indoor service areas where the radio signal from the outdoor base stations could be limited or unavailable due to the complicated structure of the indoor buildings. When we compare the outdoor base station placement problem and the indoor base station placement problem, the indoor base station placement problem needs to consider more factors such as the limitation of femtocell's capacity to support the indoor users, the leakage signal and the building structure. Therefore, the indoor base station needs to be deployed carefully and optimally.

Nevertheless, in the enterprise scenario, FBSs could be deployed with a non-optimal number and location. The non-optimal deployment of FBS led to some problems that could occur such as an outage

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area inside the building and a lack of FBS's capacity to support indoor users [2]. However, the existing works in literature have considered some of these issues.

Most researches in the existing works related to femtocell networks in a building and focus on base station placement and power level assignment. In [3], the authors proposed an energy-saving mechanism in LTE macrocell-femtocell networks while maintaining the required data rate. In [4], the authors presented the technique of a femtocell base station placement in a single-floor building by using several algorithms. The authors aim to place a minimum number of FBSs while maximizing the covered area based on the signal to interference plus noise ratio. In [5], the authors placing the femtocell base station in the optimal positions in a single-floor building and minimizing the total uplink power by using a Linear Programming. In [6], presented the technique to solve joint placement and power control problem by using Mixed Integer Programming which optimally tunes the power of femtocell base station, minimize the number of femtocell base station needed for the coverage of a single-floor building while guaranteeing a minimum signal to interference plus noise ratio to users. In [7], the authors presented the technique to deploy a base station in the presence of femtocell access points to optimize coverage and capacity of the network by using simulated annealing heuristic technique.

Although existing works have studied the base station placement and power level assignment to improve a performance of networks, there are only a few works considering about the leakage signal from the indoor FBS that could occur after deployed. In [8], the authors proposed a technique to optimize the femtocell network in a three-story building under the coverage and interference constraints by using a mixed integer programming with two objectives to maximizing the sum of femtocell base station's transmit power and maximizing Shannon's capacity in an indoor area while considered the leakage signal that emitted out of the building. In [9], the authors presented a placement and power control algorithm which optimally places and dynamically adjusts the transmission power of a femtocell base station by using mixed integer programming while guaranteed the signal to noise ratio for every indoor user and the degradation of outdoor users' signal to noise ratio.

Despite some existing works have studied the leakage signal from the indoor FBS, the literature has considered only in a single-floor building and not considered in some factor of real network environments such as an optimal number of installed FBS that can support the indoor users which expand around in the service area and the complex indoor structure of a multi-floor building. Therefore, this paper aims to present an optimization technique to optimize the number and the placement location of the FBSs and also the transmit power level of each installed FBS in a multi-floor building base on a received signal strength value, while simultaneous minimize the summation of leakage signal which occurs from the indoor FBSs to an outdoor area around the building. Especially, we take into account the penetration loss from the indoor obstacles (e.g. floors, walls) in the propagation signal calculation. In this paper, we use the LP to find a preliminary solution which includes a number and a placement location of FBSs to install and transmit power level of each FBS. All of the foregoing will be the initial input parameters for the SA heuristic technique which is effective and easy to use to optimize the placement location of each installed FBS and the transmit power level.

The rest of the paper is organized as follows. The methodology is presented in Section 2. The experimental setup is discussed in Section 3. Simulation results are presented and analysed in Section 4. Finally, conclusions are presented in Section 5.

2 Methodology

This section describes our proposed power level assignment and base station placement technique called Minimum Summation of Leakage Signal-SA (MSLS-SA). We have two steps to optimize the number, the placement location of the FBSs and also the power level of each installed FBS in a multi-floor building. In the first step, we formulate a linear programming problem with an objective to minimize the number of FBS under the network's constraints with an approximate placement location and transmit power level. Then, in the second step, we use a simulated annealing heuristic technique to optimize the placement location and the transmit power level of installed FBS which achieved from the previous step with an objective to minimize the sum of leakage signal from an installed FBS to an outdoor area around the building. For the comparison purposes, we implement two techniques include K-Means (KM) [10] clustering algorithm and Boundary Linear Programming (BLP) [11].

2.1 *MSLS-SA technique*

2.1.1 Linear programming

Linear Programming is a generalization of linear algebra. It is a mathematical technique designed which widely used to help planning and to make decisions relative to the trade-offs necessary to allocate resources. Linear programming uses a mathematical model to describe the problem of concern, linear programming problem may be defined as the problem of maximizing or minimizing a linear function subject to linear constraints which may be equalities or inequalities [11].

Table 1: Notations 1

Sets	
B	A set of candidate sites to install femtocell base stations (FBSs)
L	A set of transmit power level of femtocell base station
S	A set of signal test points (STPs)
T	A set of leakage signal test points (LTPs)
U	A set of users
Decision Variables	
r_i	A set of binary {0, 1} variable that equals 1 if the FBS is installed at site i, $i \in B$; 0 otherwise
a_{il}	A set of binary {0, 1} variable that equals 1 if the transmit power level l is assigned to FBS i, $i \in$ B and $l \in L$; 0 otherwise
s_{il}^h	A set of binary {0, 1} variable that equals 1 if the STP h is assigned to FBS i with transmit power level l, $h \in S$, $I \in B$ and $l \in L$; 0 otherwise
t_{il}^o	A set of binary {0, 1} variable that equals 1 if the LTP o is assigned to FBS i with transmit power level l, $o \in T$, $I \in B$ and $l \in L$; 0 otherwise
u_{il}^g	A set of binary {0, 1} variable that equals 1 if the user g is assigned to FBS i with transmit power level l, $g \in U$, $I \in B$ and $l \in L$; 0 otherwise
Constant Parameters	
pls_{hi}	Path loss (dB) between FBS i and STP h
pls_{oi}	Path loss (dB) between FBS i and LTP o
plu_{gi}	Path loss (dB) between FBS i and user g
Pt_{il}	The transmit power level l (dBm) of FBS i
P_{ths}	The received signal strength (dBm) threshold for STPs
P_{thu}	The received signal strength (dBm) threshold for users
G_t	The gain of the transmitting antenna
G_r	The gain of the receiving antenna

Although the LP method can obtain the optimal solution. But in the case of a large size and more complex problem, LP method is improper to solve the optimal solution since it takes too much time-consuming due to a brute-force algorithm which finds the best answer from all of the candidates answer in the feasible solutions. Therefore, in an experimental environment of this work which is a complex structure of a multi-floor building, we using LP to solve only a superficial result. In this step, the linear programming model aims to minimize the number of FBS to install in the service area by formulating a problem and network's constraints into a mathematical model.

Besides, the approximate placement location and the transmit power level of installed FBSs will be assigned from this step. In addition, the results from this step will become the initial input parameters for the next step of our optimization technique which is the SA heuristic technique.

Table 1 shows the notation of parameters used in this model. The objective function of LP can be written as an Equation (1). In addition, we incorporate the network design requirements into the mathematical model through nine of constraint Equations (2)–(10).

Objective function:

$$\text{Minimize} \sum_{i=1}^{B} r_i \tag{1}$$

Constraints:

$$\sum_{l=1}^{L} a_{il} = 1, \forall i \in B \tag{2}$$

$$a_{il} \le r_i, \forall i \in B, l \in L \tag{3}$$

$$\sum_{i=1}^{B} \sum_{l=1}^{L} s_{il}^h \ge 1, \forall h \in S \tag{4}$$

$$s_{il}^h \le a_{il}, \forall h \in S, i \in B, l \in L \tag{5}$$

$$s_{il}^h * [(Pt_{il} + Gt + Gr - pls_{hi}) - P_{ths} \ge 0, \ \forall h \in S, \ i \in B, \ l \in L \tag{6}$$

$$\sum_{i=1}^{B} \sum_{l=1}^{L} u_{il}^g \ge 1, \forall g \in U \tag{7}$$

$$u_{il}^g \le a_{il}, \ \forall g \in U, \ i \in B, \ l \in L \tag{8}$$

$$u_{il}^g * [(Pt_{il} + Gt + Gr - pls_{gi}) - P_{thu} \ge 0, \forall g \in U, \ i \in B, \ l \in L \tag{9}$$

$$\sum_{g=1}^{U} u_{il}^g \le 32, \forall i \in B, \ l \in L \tag{10}$$

Constraint Equations (2)–(3) ensure that each of the installed FBS *i* must have only one transmit power level *l*. Constraint Equations (4)–(6) ensure that the network can provide signal coverage in the service area by assessing the received signal strength at each STP *h* and specifying that the received signal strength received at STP *h* from FBS *i* must be greater than the threshold P_{ths}. Constraint Equations (7)–(9) ensure that the received signal strength of user u from FBS *i* must be greater than the threshold P_{thu} to be achieved the highest physical data rate. Constraint Equation (10) ensure that each FBS can support the users only with its limited capacity [12]. Besides, we define P_{ths} and P_{thu} equal to –103.535 dBm and –80.9348 dBm respectively to ensure that every STPs can reach the minimum modulation (QPSK 1/8) and every users can reach the maximum modulation (64 QAM 3/4) [13].

2.1.2 Simulated annealing

Firstly, annealing is referred to as tempering certain alloys of metal, glass, or crystal by heating above its melting point, holding its temperature, and then cooling it very slowly until it solidifies into a perfect crystalline structure. This physical/chemical process produces high-quality materials. The simulation of this process is known as Simulated Annealing (SA). SA is one of the heuristic techniques for optimization, which is a popular, effective and simple technique. This technique is used to reach a satisfying near-optimal solution for complex models [14], [15].

Since the large and complex experimental environment of this work, we prefer not to use LP method even if it can provide an optimal solution. In this second step, we use SA heuristic technique to prevent a time consuming. We use SA heuristic to solve a near-optimal solution which is still considered the network's constraint Equations (2)–(10). From the approximate solution in the previous step, we use it as input parameters include the number (N), the placement location and the transmit power level of installed FBSs (Sinitial) for SA heuristic technique's process. The SA model aims to minimize the summation of the leakage signal that emitted out of the building while the number of installed FBS which achieved from the first step will not change. In this step, the placement location will be more carefully optimized, from a thorough candidate location. Besides, the transmit power level of installed FBSs will be more accurately optimized with continuous value. The foregoing is called move operation in the SA process. Table 2 shows the notation of SA parameters. Table 3 shows the pseudo code of the SA heuristic technique in this work. In additions, from our quality evaluation of parameters testing, we define τ_{stop} to 0.01, φ to 0.9, $P_{a\_initial}$ to 0.8 and n_{worse_max} to 2000. Equations (11)–(14) show the expression of each parameter.

$$\tau_{initial} = -\frac{\overline{\Delta}E}{\ln(P_{a\ \ initial})} \tag{11}$$

$$P_a = e^{-(\frac{\Delta E}{\tau})} \tag{12}$$

$$\tau = \varphi\tau \tag{13}$$

$$Iter_{max} = \frac{Iter_{max}}{\varphi} \tag{14}$$

Table 2: Notation 2

SA parameters	
τ	The current temperature
$\tau_{initial}$	The initial temperature
τ_{stop}	The final temperature
$\overline{\Delta}E$	The average of the difference of the evaluation function in a preliminary test
P_a	The probability of a state change
$P_{a\_initial}$	The initial probability of a state change
φ	The control parameter which determines a decrease in temperature
$Iter_{max}$	The maximum value of iteration
$n_{worse\ max}$	The maximum value of no answer improvement

2.2 *K-Means clustering-SA technique (KM-SA)*

K-Means clustering algorithm is the simple algorithm that solves the clustering problem. This algorithm determines a set of n data points in real dimension into *k* cluster with a centroid of each cluster and minimizes the mean squared distance from each data point to its nearest centroid [10].

Table 3: Pseudo code of SA heuristic technique

Input	*N*, $S_{initial}$, φ, τ_{stop}, n_{worse_max}, ΔE, *STPs*, *Candidate FBSs*, *Users*, *path loss data*
Output	Solution of FBSs placement for multi-floor building (S_{final})
	Initialize *Iter* = 0, n_{worse} = 0
	Set Itermax = N
	Calculate τ = τinitial
	Calculate evaluation function *E*(*S*)
	Repeat
	Repeat
	Repeat
	Generate new assignment S_{new} from S (move operator)
	Check constraint Equations (2)–(10)
	Until all constraints pass
	Calculate evaluation function $E(S_{new})$
	Calculate $\Delta E = E(S) - E(S_{new})$
	Set Iter ++
	If $\Delta E > 0$
	$n_{worse} = 0$
	$S = S_{new}$
	$E(S) = E(S_{new})$
	Else $\Delta E < 0$
	Set n_{worse} ++
	Repeat
	If random [0,1] < $e^{-(\Delta E/\tau)}$
	$S = S_{new}$
	$E(S) = E(S_{new})$
	Until $n_{worse} = n_{worse\_max}$
	End SA Process
	Until *Iter* = $Iter_{max}$
	Reset *Iter* = 0
	Calculate $\tau = \varphi\tau$
	Calculate
	Until $\tau = \tau_{stop}$
	End SA Process
	$S_{final} = S$

Hence, for performance's comparison purpose with our proposed technique, we use this algorithm to solve the placement location of FBS problem. So, the users in each scenario are a set of data point which will be group into *k* cluster while *k* is the number of FBS that needs to be installed to reach the network's constraints. Then we use SA heuristic to optimize the transmit power level and the placement location of each installed FBS which achieved from the K-Means clustering algorithm.

2.3 *Boundary Linear Programming technique (BLP)*

Since the SA heuristic technique is used to reach a near-optimal solution, not an optimal solution. For performance's comparison purpose, we use the linear programming [11] with an objective to minimize the summation of leakage signal as shows in an Equation (15) with network's constraints and a fixed number of FBS to be installed which is equal to the number of FBS that achieved from step one of MSLS-SA technique.

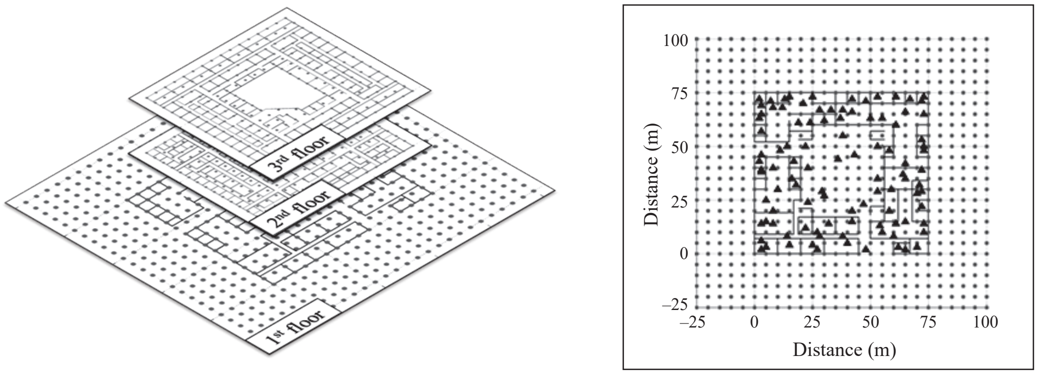
Objective function:

$$\text{Minimize} \sum_{i=1}^{B}\sum_{l=1}^{L} t_{il}^{o} * 10^{\left[\left(Pt_{il}+Gt+Gr-pls_{oi}\right)-P_{ths}\right]/10} \quad (15)$$

3 Experimental Setup

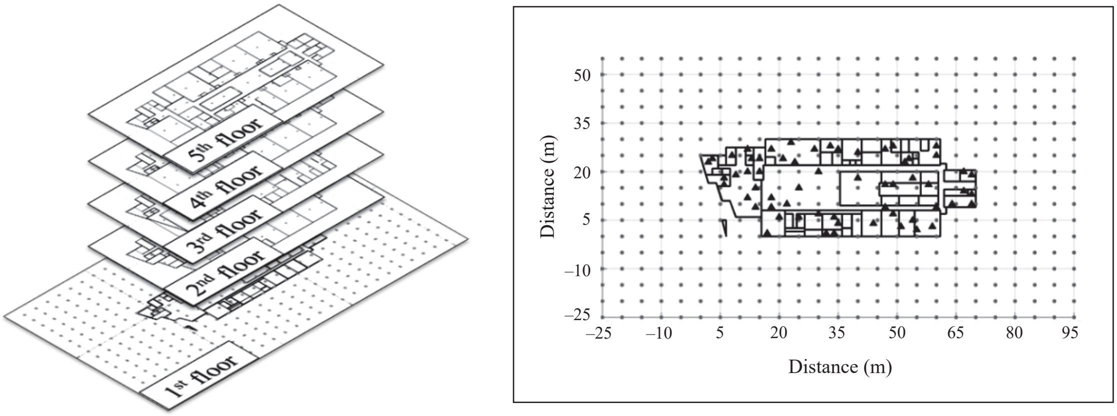
The experiments were setup in two buildings with different floor structures and different dimension area. The first building is a three-story office building with dimensions 75 m × 75 m, labeled Building A. The second building is a five-story office building with dimensions of approximately 70 m × 30 m, labeled Building B. The floor layouts of both buildings are illustrated in Figures 1 and 2, respectively. We consider that the target service area and the outdoor area is represented by a set of discrete grid points which the received signal strength is tested called Signal Test Points (STPs) and Leakage signal Test point (LTPs) respectively. The signal test point granularity of 5 m in an indoor area and the leakage signal test point granularity of 5 m in an outdoor area of 25 m around the building (represented by a gray dot in Figures 1 and 2). The candidate sites to install FBS are considered at the same location of STPs. We consider that the indoor user demand is modeled by user points which represent the geographic distribution of the expected user traffic in the service area, the indoor users which are represented by a black triangle. The setup parameters for the experiment are summarized in Table 4.

Besides, we conducted extensive experiments to evaluate the performance of our proposed technique. We considered two scenarios of the indoor femtocell networks in both buildings. In the first scenario, we deploy 150 users inside the service area and especially inside the room. In the second scenario, we increase the number of users from 150 users to 300 users inside the service area. Moreover, we consider that each FBS operates at the different frequency.



(a) (b)

Figure 1: Building A (a) The three-story structure. (b) Floor plan on the 1st floor with signal test point (● in and indoor area), leakage signal test point (● in an outdoor area) and indoor users (▲).



(a) (b)

Figure 2: Building B (a) The five-story structure. (b) Floor plan on the 1st floor with signal test point (● in and indoor area), leakage signal test point (● in an outdoor area) and indoor users (▲).

Table 4: Parameter uses in the experiments

Parameters	Values
Carrier frequency	2.6 GHz
Femtocell's transmit power	0–20 dBm
Femtocell's height	2 m
Signal test point's height	0.8 m
Femtocell's support channel	32 users
Transmitted antenna gain	3 dBi
Received antenna gain	1 dBi
Number of floors	3 (Building A) 5 (Building B)
Received signal strength threshold for STPs (P_{ths})	–103.535 dBm
Received signal strength threshold for users (P_{thu})	–80.9348 dBm

In addition, received signal strength from the femtocell base station is one of the key parameters indicative of the performance of network services. Therefore, the purpose of using the path loss model is calculating an attenuation of the signal. So, this work using the path loss model by 3GPP (The 3rd Generation Partnership Project) standard [16], [17], which is expressed by an Equation (16).

$$PL = 40.7412 + 20\log_{10} R + 0.7d_{2d,indoor} + 18.3^{((n+2)/(n+1)\text{-}0.46)} + qL_{iw} \quad (16)$$

Where R is a distance between STPs and FBSs. d_{2d}, indoor is a wall thickness (0.18 m). n denotes the number of floors crossed by the signal while propagating between FBSs to STPs. q is the number of walls crossed by the signal and Liw is a building's wall penetration loss. A typical value of wall loss (L_{iw}) is described in Table 5.

Table 5: Relative permittivity of materials [18]

Description	Value
Concrete	5.31 dB
Plasterboard	2.94 dB
Glass	6.27 dB
Reinforced concrete	18.3 dB

4 Results and Analysis

In this section, the performance of our proposed technique in each experiment scenario will be analysed and compared with others technique in terms of the number of installed FBS needed for the coverage of the building and serves the users, the computation time, the total power usage and the summation of leakage signal which emitted out of the building. Simulation results were conducted using: 1) MATLAB R2014a and 2) IBM ILOG CPLEX 12.7. Computations are performed on an Intel Core i5-6600 3.30 GHz 64-bit Operating System and 16.0 GB of RAM.

For Building A, Table 6 shows a number of installed FBS and computation time of the three techniques at Building A. From the objective function in Equation (1) which expected to minimize the number of FBS to be installed. MSLS-SA technique provides five FBSs to be installed for 150 users scenario.

Therefore, for performance's comparison purpose, the number of installed FBS of BLP technique is restricted to have five FBSs equal to the MSLS-SA. However, the KM-SA technique also provides five FBSs to be installed from its clustering algorithm. For 300 users scenario, the number of installed FBS of three techniques is all equal but rise from five FBSs to ten FBSs since the increase in the number of users in the building. The computation time of BLP technique is the highest for both scenarios due to the brute-force algorithm which searches all of the possible candidates for the best solution. In the meantime, the KM-SA technique has the lowest computation time since its simplistic algorithm which calculates a mean squared distance between each user and its nearest centroid and chooses it as a location to deploy FBSs. Then, MSLS-SA technique came in second place after the KM-SA technique by cause of the decision process for a proper initial solution in step one.

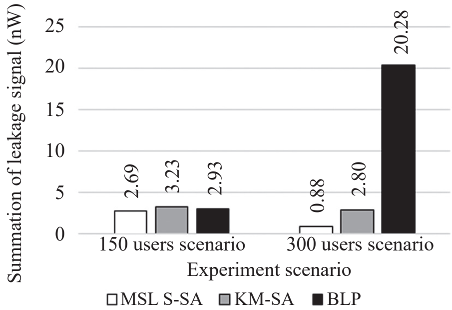


Figure 3: Summation of leakage signal (nW) of three techniques at Building A.

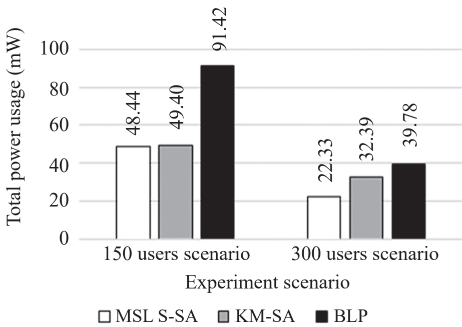


Figure 4: Total power usage (mW) of three techniques at Building A.

Figures 3 and 4 shows the summation of leakage signal and total transmit power usage of the three techniques at Building A. For 150 users scenario, The summation of the leakage signal of the MSLS-SA technique and the KM-SA technique is very close to the BLP technique which provides an optimal solution. Then, for 300 users scenario, it can be obviously seen

Table 6: Performance comparison of three techniques in Building A

Performance	150 Users Scenario			300 Users Scenario		
	MSLS-SA	KM-SA	BLP	MSLS-SA	KM-SA	BLP
Number of installed FBS	5	5	5	10	10	10
Computation time (minute)	7.6	2.77	83.63	38.45	8.31	6967.37

that the summation of leakage signal of the MSLS-SA technique and the KM-SA technique is far better than the BLP technique. Moreover, the MSLS-SA provides the best performance in both scenarios. In terms of total power usage, since the power level and placement location of FBS in BLP technique is selected approximately due to the restriction of the time-consuming. While the other techniques assign the power level more thorough with a continuous value and select the placement location more careful in SA step. The BLP technique uses more total transmitted power than the other techniques for both scenarios. In addition, it can be seen that although the number of installed FBS for the 300 users scenario is more than the 150 users scenario, the total power usage is less. Because of with the more number of installed FBS, each FBS can share more the burden of work to serves only the nearby users and transmit with a low power level.

When comparing both techniques between the MSLS-SA and the KM-SA which both techniques use the SA heuristic to assign the power level and select the placement location of each installed FBS. The results show that the MSLS-SA technique is better than the KM-SA technique in terms of the summation of leakage signal and total transmit power usage. Because of the initial solution of the MSLS-SA technique which includes the number, the power level and the placement location of each installed FBS was obtained from linear programming. So, the initial solution was optimally selected before beginning the SA process. While the initial solution of the KM-SA technique was obtained by the clustering algorithm. Thus, the FBS with its maximum power level will be deployed with a number that needed to reach the networks constraints at the centroid of each cluster which is mentioned previously. So, the initial power level of each installed FBS is set to a maximum value. Therefore, even if the computation time of the MSLS-SA technique is slightly longer than the KM-SA technique. It is still far better than the computation time of the BLP technique. Furthermore, the summation of the leakage signal and the total power usage of the MSLS-SA technique is the finest when compared to the other techniques.

For Building B, Table 7 shows a number of installed FBS and computation time of the three techniques at Building B. The results of the experiments at Building B are in the same direction with Building A in terms of a computation time. That is, the computation time of the BLP technique is the highest for both scenarios while the KM-SA technique has the lowest computation time. In addition, since the number of test points at Building B is less than Building A due to its size, it can be seen that the computation time of BLP technique at Building B is lower than Building A. While the computation time of the MSLS-SA technique and the KM-SA technique at Building B is more than Building A. Because of in the SA process, the move operator actually moves from the current solution to the neighbour solution. Building B has five floors which mean the number of neighbor solution to move is more than at Building A which has three floors. Furthermore, in terms of a number of installed FBS, the KM-SA technique uses significantly more than the other techniques. For 150 users, the KM-SA technique needs 19 FBSs to be installed while the other techniques only need five FBSs. For 300 users the KM-SA technique needs 22 FBSs to be installed while the other techniques only need ten FBSs. It can be seen that the KM-SA technique is unsuitable for a building with a lot number of floors since its clustering algorithm which mentioned previously.

Figures 5 and 6 shows the summation of leakage signal and total transmit power usage of the three techniques at Building B. Also, the results at Building B are in the same direction with Building A in both terms include the summation of leakage signal and total transmit power. The summation of the leakage signal of BLP technique is the highest for both scenarios while the MSLS-SA technique and the KM-SA technique is far better. Then, for the total power usage in 150 users scenario, it can be seen that the KM-SA technique can provide slightly better than the MSLS-SA technique since the number of installed

Table 7: Performance comparison of three techniques in Building B

Performance	150 Users Scenario			300 Users Scenario		
	MSLS-SA	KM-SA	BLP	MSLS-SA	KM-SA	BLP
Number of installed FBS	5	19	5	10	22	10
Computation time (minute)	12.64	8.16	49.22	60.91	11.16	442.81

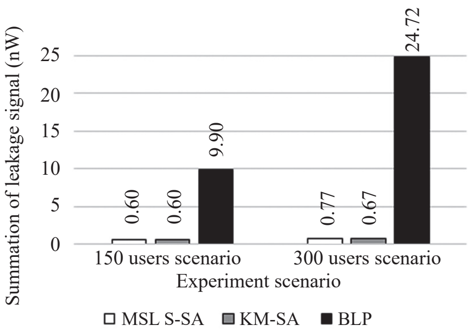


Figure 5: Summation of leakage signal (nW) of three techniques at Building B.

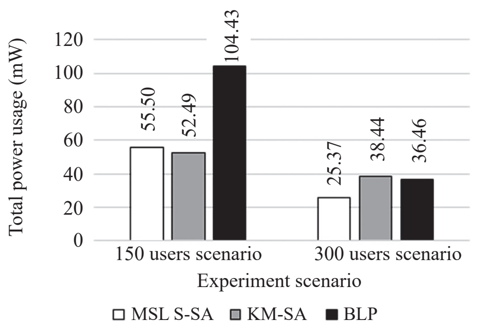


Figure 6: Total power usage (mW) of three techniques at Building B.

FBS of the KM-SA technique is quite a lot. So, each FBS can share the burden and the power level of each can be reduced to a very low level while it still can reach the network constraints includes the coverage of building and the user's service. For the total power usage in 300 users scenario, the MSLS-SA technique provides the finest performance compared to the others.

As a result of the experiments in two buildings, the MSLS-SA technique can achieve the better performance and solution quality while using much less computation time compared to the BLP technique. Moreover, when compared to the KM-SA technique, the total power usage of the MSLS-SA technique is lower. Furthermore, the number of FBS needed to be installed is much fewer when the number of floors increases.

5 Conclusions

In this paper, we present the power level assignment and base station placement using simulated annealing for 4G-LTE femtocell networks in multi-floor buildings. Extensive experiments were conducted to compare the performance of the proposed technique with the others. Experimental results showed that our proposed technique can efficiently solve the problem with the finest performance compared to the KM-SA technique and the BLP technique. While handling a trade-off between computation time and solution quality. The MSLS-SA technique needed a fewer number of FBS to be installed compared to the KM-SA technique. Moreover, in the case of an equal number of installed FBS, the MSLS-SA technique significantly reduces the summation of leakage signal and total power usage in all experiment. Furthermore, when compared to the BLP technique which provides an optimal solution, the MSLS-SA technique can reduce the summation of leakage signal up to 90%, the total power usage up to 45% and reduce a computation time more than 70%.

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