A Cell-Planning Model for HetNet with CRE and TDM-ICIC in LTE-Advanced

Shoji KANEKO, Takashi MATSUNAKA, and Yoji KISHI
Radio Access Network Laboratory
KDDI R&D Laboratories, Inc.
Saitama, Japan

Abstract*—Heterogeneous Network (HetNet) in 3GPP is a technique to increase network capacity. In order to further increase network capacity, Cell Range Expansion (CRE) and Time Domain Multiplexing Inter-Cell Interference Coordination (TDM-ICIC) have been discussed for LTE-Advanced. Since the parameter values for CRE and TDM-ICIC have a huge effect on network capacity expansion, in this paper, a cell-planning model for the downlink in HetNet with CRE and TDM-ICIC is presented in order to find the minimum number of installed pico BSs under the constraint of covering all user data traffic. The constraint condition is formulated by using an overload indicator for the cases of between normal subframes and muted subframes, because different interference sources are considered for these subframes by adopting TDM-ICIC. The appropriate parameter values of not only CRE and TDM-ICIC but also the location, transmission power, and antenna tilt for each pico BS are determined. Cell planning is conducted for traffic distribution generated by reference to realistic traffic distribution by a greedy algorithm based on the proposed cell-planning model. The result shows that the solution algorithm finds a good approximate solution which covers all data traffic by installing one pico BS with CRE bias value = 8 dB and setting the muted subframe ratio = 0.2.

Keywords- LTE-Advanced; Heterogeneous Network (HetNet); Cell planning; Pico BS; CRE; TDM-ICIC;

I. INTRODUCTION

Mobile data traffic has been increasing explosively with the popularization of functional mobile terminals such as smart-phones. One way to deal with this increase in mobile data traffic is to increase network capacity in cellular systems. Heterogeneous Network (HetNet) has been discussed as a way of improving the capacity of LTE (Long Term Evolution) systems in the 3rd Generation Partnership Project (3GPP) [1].

HetNet consists of macro base stations (BS) and a variety of local BSs, such as pico BSs and femto BSs, which have lower transmission power and smaller coverage areas compared with macro BSs. In HetNet, local BSs are located where a huge amount of data traffic arises such as downtown areas in the coverage area of a macro BS. The user data traffic is offloaded onto local BSs from the macro BS.

In order to further increase network capacity in HetNet, Cell Range Expansion (CRE) has been studied for LTE-Advanced. CRE is a method for expanding the coverage area of local BSs. When CRE is adopted, user equipment (UE) adds a predetermined bias value to the received power from the local BS, and the UE connects to the BS whose received power is highest, thus expanding the coverage of the local BS.

UE connected to a local BS by CRE suffers from severe interference from macro BSs because the received power from the local BS to which UE is connected is lower than that of any macro BS. Therefore, the Signal to Interference plus Noise Ratio (SINR) of the UE is low, and it is difficult to achieve sufficient throughput. Time Domain Multiplexing Inter-Cell Interference Coordination (TDM-ICIC) in combination with CRE has been studied in order to cope with this problem [2, 3]. In TDM-ICIC, the macro BS partially mutes the subframe in the time domain. UE connected to a local BS by CRE communicates with the local BS in the muted subframe.

There have been various studies on cell planning [4, 5, 6]. In [4], a cell-planning problem with capacity expansion was proposed, but interference from other BSs was not considered. In [5, 6], cell-planning models and algorithms for locating macro BSs in W-CDMA (Wideband Code Division Multiple Access) systems and LTE systems were proposed, but CRE and TDM-ICIC ware not considered. The parameter values for CRE and TDM-ICIC depend on data traffic distribution and the volume of data traffic. Therefore, in order to offload more data traffic, it is important to set the CRE bias value and the muted subframe ratio, which is the parameter for TDM-ICIC and the ratio of the muted subframe to all subframes per unit time, to the appropriate values.

In this paper, a cell-planning model for the downlink in HetNet with CRE and TDM-ICIC is proposed. This paper focuses on cell planning for outdoor areas. Therefore, the only local BS considered is a pico BS. The cell-planning model is formulated as an optimization problem. The objective function is to minimize the number of pico BSs, and the constraint condition is to cover all user data traffic. The service area covered by a pico BS is divided into the service area which the pico BS covers by CRE and the others. Muted subframes are assigned to the former and normal subframes are assigned to the latter. The constraint condition for the amount of data traffic covered is formulated by using an overload indicator in the case of muted subframes and normal subframes, because different interference sources are considered for these subframes by adopting TDM-ICIC. A greedy algorithm based on the cell-planning method is presented. The solution algorithm starts from the case where there are no pico BSs and stops when an achieved solution satisfies the constraint conditions, or the total amount of data traffic covered cannot be further improved. Cell-planning is conducted for traffic

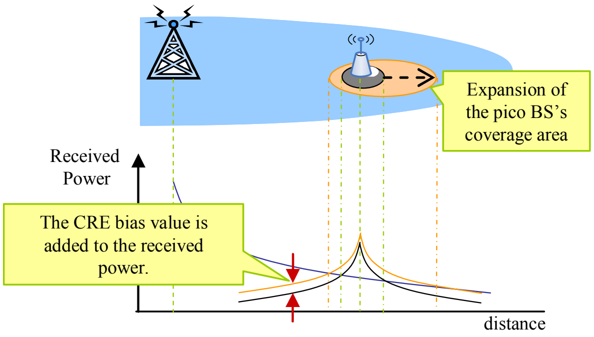

Figure 1. The coverage area of a pico BS with CRE

distribution generated by reference to a realistic traffic distribution by using the solution algorithm.

The rest of this paper is organized as follows. Section II describes the CRE and TDM-ICIC. In section III, the cell-planning model for HetNet is proposed. Section IV introduces a solution algorithm to solve the problem. A computational result obtained for traffic distribution and macro BS location generated by reference to realistic traffic distribution and macro BS deployment is reported in Section V. Finally, conclusions are summarized in section VI.

II. CRE, TDM-ICIC IN LTE-ADVANCED

CRE is one of the load balancing techniques used in LTE-Advanced. When CRE is adopted, the serving BS ID for the i th UE, $s(i)$, is given by

$$s(i) = \arg\max_{j} \left(\alpha_j P(j,i)\right), \tag{1}$$

where j indicates a BS index, α_j denotes a CRE bias value for BS j, and $P(j, i)$ is the received power from BS j at the i th UE. By setting the CRE bias value of a pico BS to a higher value than that of the macro BS, the CRE enables the offloading of a UE from the macro BS to the pico BS. Fig. 1 shows the coverage area of a pico BS when CRE is adopted. As shown in Fig. 1, the coverage area of the pico BS is expanded by CRE.

A UE connected to the pico BS by CRE suffers from severe interference from macro BSs. TDM-ICIC is proposed in 3GPP in order to mitigate the interference. In TDM-ICIC, the macro BS partially mutes the subframe, which is a resource unit in the time domain. Since the macro BS cannot assign radio resources in the muted subframe, the UE connected to the pico BS by CRE is saved from severe interference by transmitting data in the muted subframe. 3GPP specifies which subframe can be muted. As the aim of TDM-ICIC is to mitigate interference from macro BSs for UEs connected to pico BSs by CRE, the timing of the muted subframe is synchronized among all BSs.

III. CELL-PLANNING MODEL FOR HETNET

In this paper, a cell-planning model for the downlink in HetNet is proposed. The most severe case (all BSs transmit simultaneously) is assumed in order to achieve tolerant cell-planning. It is also assumed that there are no dead spots in the service area constructed by macro BSs. The cell-planning model for HetNet with CRE and TDM-ICIC is formulated as an optimization problem. The model has the objective function of minimizing the number of pico BSs and constraint conditions, which are to cover all user data traffic that arises in the coverage area of an overloaded macro BS.

A working area for cell-planning is divided into subareas. The subareas are defined on a grid, and each subarea is referred to as a test point (TP). A set of test points (TPs) I is also given. Each TP $i \in I$ can be considered as a centroid where a given amount of traffic w_i is requested. Note that TP corresponds to UE in this paper. It is also assumed that a set of candidate sites J where a pico BS can be installed is given. The locations of macro BSs are also given. A set of macro BSs is indicated by L and the set of sectors that a macro BS has is Σ.

To formulate the cell-planning problem, the following decision variables are introduced. Let x_j be the decision variable of J:

$$x_j = \begin{cases} 1 & \text{if a pico BS is installed in } j \\ 0 & \text{otherwise} \end{cases} \tag{2}$$

for $j \in J$. Let m_{ij} be the wireless connection between TP i and local BS j such that

$$m_{ij} = \begin{cases} 1 & \text{if TP } i \text{ is covered by pico BS installed in } j \\ 0 & \text{otherwise} \end{cases}. \tag{3}$$

Also, let $m_{il\sigma}$ be the wireless connection between TP i and the sector σ of the macro BS l such that

$$m_{il\sigma} = \begin{cases} 1 & \text{if TP } i \text{ is covered by the sector } \sigma \text{ of the macroBS } l \\ 0 & \text{otherwise} \end{cases} \tag{4}$$

for $\sigma \in \Sigma$ and $l \in L$.

The received power at TP i for the transmission of the pico BS installed in j, $P(j,i)$, is given by

$$P(j,i) = g_{ij} \cdot Ant_{pico(j)} \cdot Tx_{pico(j)} \cdot x_j, \tag{5}$$

where, g_{ij} denotes the propagation factor of the radio link between TP i and the pico BS installed in j, $Ant_{pico(j)}$ is the antenna gain of the pico BS installed in j and $Tx_{pico(j)}$ is the transmission power of the pico BS installed in j. Also, the received power at TP i for the transmission of sector σ of macro BS l, $P(\sigma,l,i)$, is described as

$$P(\sigma,l,i) = g_{il\sigma} \cdot Ant_{macro(l\sigma)} \cdot Tx_{macro}, \tag{6}$$

where, $g_{il\sigma}$ denotes the propagation factor of the radio link between TP i and the sector σ of the macro BS l, $Ant_{macro(l\sigma)}$ is the antenna gain of the sector σ of the macro BS l and Tx_{macro} is the transmission power of the macro BS.

TP i is covered by the BS (a macro BS or a pico BS) from which the received power is highest. Note that the CRE bias value is considered for the received power of pico BSs when CRE is adopted. When TP i is covered by the pico BS installed in j, the following inequality expressions are satisfied:

$$\alpha_j \cdot P(j,i) \cdot m_{ij} \geq \alpha_{j'} \cdot P(j',i) \cdot x_{j'} \tag{7}$$

$$\alpha_j \cdot P(j,i) \cdot m_{ij} \geq P(\sigma,l,i) \tag{8}$$

for $j' = 1,\cdots,|J|$, $l = 1,\cdots,|L|$ and $\sigma = 1,\cdots,|\Sigma|$ where, $|\bullet|$ denotes the cardinality of the set $\bullet$. In the same way, when

TP i is covered by sector σ of the macro BS l, the following inequality expressions are satisfied:

$$P(\sigma,l,i)\cdot m_{il\sigma} \ge \alpha_j \cdot P(j,i)\cdot x_j \quad (9)$$

$$P(\sigma,l,i)\cdot m_{il\sigma} \ge P(\sigma',l',i) \quad (10)$$

for $j=1,\cdots,|J|$, $l'=1,\cdots,|L|$ and $\sigma'=1,\cdots,|\Sigma|$.

In this paper, it is assumed that the radio resources in the muted subframe are only assigned to TP i that are connected to the pico BS by CRE, and the radio resources in the normal subframe are assigned to both TP i, which is connected to a pico BS without CRE, and TP i, which is connected to a macro BS. Fig. 2 shows an example of subframe assignment.

The derivation of SINR is divided between the case of normal subframes and the case of muted subframes because different interference sources are considered.

In the case of normal subframes, both macro BSs and pico BSs are considered as interference sources. When TP i is connected to the pico BS installed in j, the SINR_{ij} is given by

$$SINR_{ij} = \frac{P(j,i)\cdot x_j}{\sum_{\substack{j'\in J\\ j'\ne j}} P(j',i)\cdot x_s + \sum_{l\in L}\sum_{\sigma\in\Sigma} P(\sigma,l,i)+\eta} \quad (11)$$

where, η indicates the noise power. When TP i is covered by sector σ of the macro BS l, the $SINR_{il\sigma}$ is given by

$$SINR_{il\sigma} = \frac{P(\sigma,l,i)}{\sum_{j\in J} P(j,i)\cdot x_j + \sum_{\substack{l'\in L\\ l'\ne l}}\sum_{\sigma'\in\Sigma} P(\sigma',l',i) + \sum_{\substack{\sigma'\in\Sigma\\ \sigma'\ne\sigma}} P(\sigma',l,i)+\eta} \quad (12)$$

In the case of muted subframes, only the pico BS is considered as an interference source. When TP i is connected to the pico BS installed in j by CRE, the $SINR_{ij}^{pico}$ are obtained by the following equation:

$$SINR_{ij}^{pico} = \frac{P(j,i)\cdot x_j}{\sum_{\substack{j'\in J\\ j'\ne j}} P(j',i)\cdot x_s + \eta}\ . \quad (13)$$

Let d_{ij}^{normal} and $d_{il\sigma}$ be the expected throughput [bps] in TP i, which is connected to the pico BS installed in j without CRE, and TP i, which is connected to sector σ of the macro BS l. The expected throughputs, d_{ij}^{normal} and $d_{il\sigma}$, are described as follows:

$$d_{ij}^{normal} = d_{il\sigma} = \frac{(1-\beta)\cdot Eff_{mimo}\cdot \#RB\cdot \#Bit}{0.5\times 10^{-3}} \times (1-PER)\ . \quad (14)$$

Similarly, let d_{ij}^{muted} be the expected throughput in TP i, which is connected to the pico BS installed in j by CRE, such that

$$d_{ij}^{muted} = \frac{\beta\cdot Eff_{mimo}\cdot \#RB\cdot \#Bit}{0.5\times 10^{-3}} \times (1-PER)\ . \quad (15)$$

In (14) and (15), β denotes the ratio of the muted subframe to all subframes per one second. Eff_{mimo} is the efficiency of the throughput improvement by MIMO (Multiple Input Multiple Output) transmission. #RB represents the number of Resource Blocks (RB) in the frequency domain. #Bit denotes the number of data bits that can be transmitted per one RB. The #Bit is calculated from the transport block size in [7] based on the selected modulation and #RB. Note that the modulation for TP i is selected based on the SINR. The PER (Packet Error Rate) is obtained from the table for the relationship between SINR and PER. The denominator of (14) and (15) is the duration [sec] of one RB.

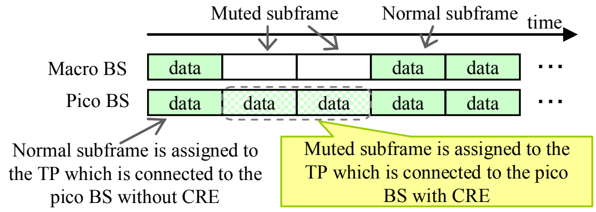

Figure 2. Example of subframe assignment

In this paper, the overload indicator is introduced in order to decide whether a BS (a macro BS or a pico BS) is overloaded or not. The overload indicator of sector σ of the macro BS l is given by

$$load_{(l\sigma)} = \sum_{i\in I} \frac{w_i}{d_{il\sigma}}\cdot m_{il\sigma}\ , \quad (16)$$

where, $w_i/d_{il\sigma}$ is the quantity of radio resources needed to cover the requested traffic in TP i connected to sector σ of the macro BS l. The overload indicator shows the quantity of radio resources required to cover all data traffic in the coverage area of a BS, and the overload indicator also takes the selected modulation in TPs into consideration.

When $load_{(l\sigma)} \le 1$, sector σ of macro BS l can cover all user data traffic that arises in the coverage area. Otherwise, sector σ of macro BS l is overloaded.

The overload indicator of a pico BS is defined for normal subframes and muted subframes. The overload indicator of the pico BS installed in j is represented by the following equations. For normal subframes:

$$load_{(j)}^{normal} = \sum_{i\in I_{pico}^{normal}} \frac{w_i}{d_{ij}^{normal}}\cdot m_{ij} \quad (17)$$

where I_{pico}^{normal} is a subset of I and the TP i belonging to I_{pico}^{normal} is connected to the pico BS without CRE, and w_i/d_{ij}^{normal} is the quantity of radio resources needed to cover the requested traffic in TP i, which is assigned as normal subframe in the pico BS installed in j. For a muted subframe:

$$load_{(j)}^{muted} = \sum_{i\in I_{pico}^{muted}} \frac{w_i}{d_{ij}^{muted}}\cdot m_{ij} \quad (18)$$

where I_{pico}^{muted} is a subset of I and the TP i belonging to I_{pico}^{muted} is connected to the pico BS by CRE, and w_i/d_{ij}^{muted} is the quantity of radio resources needed to cover the requested traffic in TP i, which is assigned muted subframes in the pico BS installed in j.

When both (17) and (18) are smaller than or equal to 1, the pico BS installed in j covers all user data traffic in the coverage area. Otherwise, the pico BS is overloaded.

The number of pico BSs installed is given by

$$\sum_{j\in J} x_j \; . \tag{19}$$

From the above, the cell-planning model for HetNet with CRE and TDM-ICIC can be formulated as follows:

$$\text{Minimize} \qquad \sum_{j\in J} x_j \tag{19}$$

Subject to:

$$m_{ij} \le x_j \;\; \text{for } i\in I ,\; j\in J \tag{20}$$

$$\sum_{i\in I}\sum_{j\in J} m_{ij} + \sum_{i\in I}\sum_{l\in L}\sum_{\sigma\in\Sigma} m_{il\sigma} = |I| \tag{21}$$

$$\sum_{j\in J} \alpha_j \cdot P(j,i)\cdot m_{ij} + \sum_{l\in L}\sum_{\sigma\in\Sigma} P(\sigma,l,i)\cdot m_{il\sigma} \ge \alpha_{j'}\cdot P(j',i)\cdot x_{j'} \tag{22}$$

$$\sum_{j\in J} \alpha_j \cdot P(j,i)\cdot m_{ij} + \sum_{l\in L}\sum_{\sigma\in\Sigma} P(\sigma,l,i)\cdot m_{il\sigma} \ge P(\sigma',l',i) \tag{23}$$

$$\text{for } i\in I \;\; j'\in J ,\; l'\in L \text{ and } \sigma'\in\Sigma$$

$$load_{(l\sigma)} \le 1 \quad \text{for } \; l\in L \text{ and } \sigma\in\Sigma \tag{24}$$

$$load^{normal}_{(j)} \le 1 \quad \text{for } \; j\in J \tag{25}$$

$$load^{muted}_{(j)} \le 1 \quad \text{for } \quad j\in J \tag{26}$$

Equation (20) means that TP i can be connected to the pico BS installed in j only if a pico BS is located in j. Equation (21) indicates that TP i is covered by one BS (a macro BS or a pico BS). Equations (22) and (23) are derived from (7) and (9), (8) and (10), respectively.

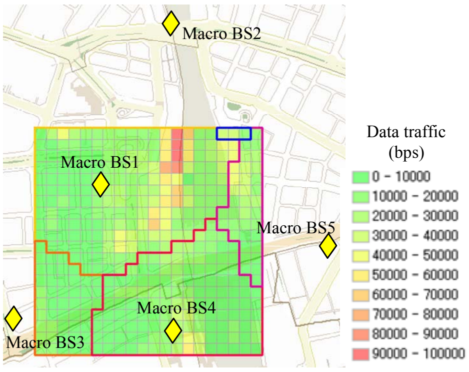

Figure 3. Traffic distribution and macro BS locations

TABLE I. PARAMETERS FOR CELL PLANNING

System bandwidth	10 MHz
Path loss	128.1+37.6log10(D) for macroBS, D in km 140.7+36.7log10(D) for pico BS, D in km
Transmission power	46 dBm for macro BS 24 or 30 dBm for pico BS
Antenna height	50 m for macro BS 10 m for pico BS
Antenna pattern	macro BS: Omni pico BS: Horisontal Omni Vertical $-\min\left[12\{(\theta - tilt)/\theta_0\}^2, A_n\right]$ $\theta_0 = 10\deg$, $A_n = 20dB$,$tilt$= 0,1,…,5
Antenna gain	0 dBi for macro BS, 5 dBi for pico BS
CRE bias value α	0, 4, 8 dB
Muted subframe ratio β	0.1, 0.2, 0.3, 0.4, 0.5

IV. Solution Algorithm

The cell-planning model for HetNet with CRE and TDM-ICIC is a special case of a set covering problem that is a well-known NP-complete problem. Therefore, a heuristic algorithm classified as a greedy algorithm based on the cell-planning model is presented to find an approximate solution. In this algorithm, not only pico BS locations, CRE bias values and the muted subframe ratio, but also the transmission power and the antenna tilt of pico BSs are variables.

Only the muted subframe ratio is a variable for macro BSs. The muted subframe ratio is set to the same value for all macro BSs in order to mitigate interference from macro BSs. Therefore, the muted subframe ratio is separated from the other parameters and the solution algorithm is executed for each muted subframe ratio.

The solution algorithm starts from the case where there are no pico BSs and iteratively adds pico BSs. This is done by evaluating the total volume of data traffic covered based on (24), (25) and (26) in the case where a pico BS is installed for each candidate site j. Let ξ be the coefficient based on the overload indicator. ξ is divided into three cases, $\xi_{l\sigma}$ for a TP covered by sector σ of the macro BS l , ξ^{normal}_j for a TP connected to the pico BS installed in j without CRE, and ξ^{muted}_j for a TP connected to the pico BS installed in j by CRE. For each ξ , $\xi = 1$ if $load \le 1$, otherwise, $\xi = load$. The total amount of data traffic covered, c_J , is defined as

$$c_J = \sum_{j\in J}\left(\frac{\sum_{i\in I} w_i \cdot m_{il\sigma} \cdot x_j}{\xi_{l\sigma}}\right) + \sum_{l\in L}\sum_{\sigma\in\Sigma}\left(\frac{\sum_{i\in I^{normal}_{pico}} w_i \cdot m_{ij}}{\xi^{normal}_j} + \frac{\sum_{i\in I^{muted}_{pico}} w_i \cdot m_{ij}}{\xi^{muted}_j}\right) \tag{27}$$

After the evaluations, site j is selected among J where c_J is the maximum and a pico BS is installed at the candidate site j, where $Tx_{pico(j)}$, $tilt_{(j)}$ and α_j of the pico BS are the values when c_J is maximum. This is iterated until the constraint conditions shown in (20) to (26) are satisfied or where the total volume of data traffic can no longer be increased even if a pico BS is installed.

The most appropriate solution is selected among the best values for each muted subframe ratio.

V. A Computational Result

In order to evaluate the performance of the solution algorithm based on the cell planning model, cell planning for a HetNet with CRE and TDM-ICIC was performed over a rectangular area of 500 m $\times$ 500 m. HetNet is a technique to increase a network capacity by locating pico BSs where a huge volume of data traffic arises in the coverage area of an overloaded macro BS, and the inter-site distance between macro BSs is 500 m in [8]. Therefore, the simulated area size is suitable for HetNet cell planning. All TPs are 25 meters square. The data traffic distribution and the location of macro BSs are generated by reference to realistic data from a dense urban area in Japan. Fig. 3 shows the traffic distribution and the location of macro BSs. In Fig.3, a diamond symbol indicates a macro BS. Only macro BS1 is overloaded, with an overload indicator (16) of 1.23. Therefore, the candidate site is the coverage area of macro BS1 and the target area for the optimization is the entire working area. The parameters of the experiment are shown in Table 1. In Table 1, the range of CRE bias values is determined by reference to [9], and the CRE bias values considered are 0, 4, and 8 dB, to limit the computational burden in this paper.

Table 2 shows the result of cell planning for each muted subframe ratio. In Table 2, $\beta = 0$ indicates the case where CRE and TDM-ICIC are not adopted. As shown in the Table 2, the overload indicator of macro BS1 is reduced to less than one for all the muted subframe ratios. In other words, macro BS1 is offloaded by the deployment of pico BSs. When $\beta = 0$, six pico BSs are installed. This is because the coverage area of the pico BSs is small due to severe interference from the macro BSs. It is shown that the number of pico BSs can be reduced further by adopting CRE and TDM-ICIC. When the muted subframe ratio is set to a higher value, the number of subframes allocated for macro BS decreases, resulting in an increase in the number of installed pico BSs because the volume of data traffic covered by macro BSs decreases. When β=0.1 and 0.2, the number of installed pico BSs is the minimum. As mentioned above, the overloaded indicator shows the radio resources required to cover the all data traffic, taking the selected modulation in TPs into consideration. In Table 2, the radio resources needed when β=0.2 is smaller than that for β=0.1. Therefore, β=0.2 is the best appropriate solution for cell-planning. Fig. 4 shows the deployment of the pico BS for the case of β=0.2. In Fig.4, the triangle indicates the pico BS and the purple line shows its coverage area. The pico BS is installed in the cell edge area of macro BS1, and there are TPs that have a large amount of data traffic in the cell edge of the pico BS. The reasons are as follows. Because of interference from macro BS1, a pico BS location in the cell edge area is preferable to the cell center area in terms of offloading. The TPs, which is in the cell edge area of the pico BS, are connected to the pico BS by CRE. These TPs can escape the severe interference from the macro BSs.

TABLE II. THE RESULT OF CELL PLANNING

β	Overload indicator of macro BS1	pico BS				
		# of pico	Pico Bs ID	α	Tx	tilt
0	0.994	6	1	0	24	0
			2	0	24	2
			3	0	30	2
			4	0	24	0
			5	0	24	0
			6	0	24	0
0.1	0.996	1	1	8	30	3
0.2	0.966	1	1	8	30	5
0.3	0.976	2	1	8	30	5
			2	8	30	5
0.4	0.994	3	1	8	30	5
			2	8	30	5
			3	0	24	0
0.5	0.986	6	1	8	30	5
			2	0	30	5
			3	8	30	5
			4	0	30	1
			5	8	30	5
			6	8	30	5

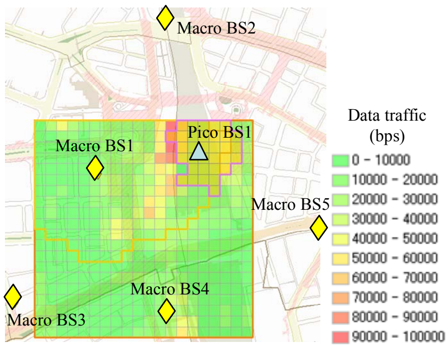

Figure 4. The deployment of pico BS

VI. CONCLUSIONS

This paper proposes a cell-planning model for downlink in HetNet with CRE and TDM-ICIC. The objective function is to minimize the number of pico BSs, and the constraint condition is to cover all user data traffic. TPs covered by a pico BSs, are divided into TPs connected to the pico BS by CRE, and others. The muted subframe is assigned to the former and the normal subframe is assigned to the latter. The constraint condition is formulated by using the overload indicator for the muted subframe and the normal subframe, respectively. A solution algorithm classified as the greedy algorithm is presented. Cell planning is conducted for a traffic distribution generated by reference to a realistic traffic distribution in order to evaluate the performance of the algorithm, and shows that the solution algorithm can find a good approximate solution.

ACKNOWLEDGMENT

We would like to thank Dr. Nakajima and Dr. Takeuchi of KDDI R&D Laboratories for supporting this research.

REFERENCES

[1] A. Khandekar, et al., ”LTE-Advanced: Heterogeneous Networks,” Proc. EWC 2010, pp. 978-982, Apr., 2010.

[2] 3GPP, R1-105622, “Discussion of time domain eICIC scheme for Rel-10,” Oct., 2010.

[3] S.Konishi, et al., “Downlink Performance Evaluation of HetNet with Pico Cells with Time Domain Interference Coordination Scheme,” IEICE Gen. Conf. 2011, B-5-73, Mar. 2011 (in Japanese).

[4] C. Y. Lee, et al., “Cell Planning with Capacity Expansion in Mobile Communications: A Tabu Search Approach,” IEEE Trans on Vehicular Technology, pp. 1678-1691, vol.49, No.5, Sept., 2000

[5] E. Amaldi, et al., “Optimization models and algorithms for downlink UMTS radio planning,” Proc. Wireless Communications and Networking, pp.827-831, vol.2, Mar., 2003

[6] K. Majewski, et al., “Conservative Cell Load Approximation for Radio Networks with Shannon Channels and its Application to LTE Network Planning,” Proc. Sixth Advanced International Conference on Telecommunication, pp.219-225, 2010

[7] 3GPP, TS 36.213 Ver.10.0.0.1, “Physical layer procedures,” Dec., 2010

[8] 3GPP, TR 36.814 Ver.9.0.0, “Future Advancements for E-UTRA Physical Layer Aspects,” Dec., 2009

[9] I. Guevenc, “Capacity and Fairness Analysis of Heterogeneous Networks with Range Expansion and Interference Coordination,” IEEE Communication Latters, pp.1084-1087, vol.15, No.10, Oct., 2011