

LTE Cell Planning Support Tool (CELPLA L)

With the introduction of NTT DOCOMO's LTE "Xi" (Crossy) service, we have developed an LTE cell planning support tool (CELPLA L) to enable the quick and automatic generation of cell planning parameters essential to the design and construction of an LTE area. This tool enables the automatic design of optimal parameters independent of the cell planner's level of technical skills and helps to maintain a stable level of LTE service quality. It can also shorten planning time, significantly reduce the risk of design errors, and facilitate smooth expansion of the LTE coverage area.

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1. Introduction

NTT DOCOMO launched Japan's first LTE service in December 2010 to provide its customers with higher transmission speeds, greater capacity and lower delay. Since then, we have been expanding the LTE coverage area. As of the end of July 2011, approximately 1,700 LTE base stations (evolved Node Bs (hereinafter referred to as "eNodeBs")) have been installed, and we are currently aiming to have about 7,000 or more installed by the end of fiscal year 2011.

The work of putting LTE eNodeBs into operation consists of a variety of processes. In addition to choosing an area for deployment, selecting the type of eNodeB equipment to be used, and

performing infrastructure studies and consulting, there is also a need to determine optimal cell planning parameters for those eNodeBs. Given the amount of work involved, it is essential that these processes be optimized for maximum efficiency. An efficient process for studying cell planning parameters should have a major effect on LTE deployment considering the complexity and labor usually associated with such planning.

Cell planning parameters are generally selected based on operation policies and design policies that attempt to maximize the advantages of the LTE system. Moreover, by applying unique parameters to individual base stations, the quality of service is improved.

These parameters, however, consist of a diverse number of items as shown in **Table 1**. In addition to the Random Access Channel (RACH) Root Sequence (RRS)^{*1} [1] and Neighbor Relation Table (NRT)^{*2}, there is also the Physical Cell ID (PCI)^{*3} [1] parameters consisting of local ID^{*4}, cell-group ID^{*5} and hopping pattern^{*6} that interact with each other. The manual design of these parameters can consequently be quite difficult. Unsuitable parameter design, moreover, can lead to faults in the quality of the service such as drops in throughput^{*7}, and in the worst-case scenario, it can even disrupt communications resulting in a major impact on users.

With the aim of resolving these

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*1 **RRS**: A single sequence for generating a Random Access Channel (RACH) preamble. As a common channel in the uplink, RACH is used for transmitting control information and user data.

issues, we have developed an LTE cell planning support tool (CELPLA L: CELPLAnning for Lte). This article provides an overview of CELPLA L functions and describes the technique for determining LTE cell planning parameters with this tool.

2. Overview of CELPLA L

CELPLA L is a tool for quickly and automatically generating necessary parameters for LTE area design. As shown in **Figure 1**, the parameter design method for cell planning consists of three steps: 1) input base-station information, 2) calculate parameters, and 3) output calculation results.

1) Input eNodeB Information

In this step, W-CDMA and LTE base-station information (latitude, longitude, antenna height, direction of radio wave radiation, etc.) and base-station configuration parameters (type of base-station equipment, jurisdiction^{*8}, propagation-delay correction value^{*9}, high-speed-flow flag^{*10}, etc.) are input to the design database management section via the design database input section and stored in the base-station information management section and parameter management section. Here, the W-CDMA base-station information consists of items that are needed for handover^{*11} processing in neighboring cell planning^{*12}.

2) Calculate Parameters

Next, optimal values for the PCI,

Table 1 Comparison of 3G and LTE cell planning parameters

LTE parameters		W-CDMA parameters	Purpose
PCI	Local ID	PSC*	Cell identification
	Cell-group ID		
	Hopping pattern		
RRS		Unnecessary	Signal for establishing radio uplink
NRT (LTE⇒LTE) (LTE⇒W-CDMA) (W-CDMA⇒LTE)		ZT (W-CDMA⇒W-CDMA)	Neighboring cell planning required for handover processing

*PSC (Primary Scrambling Code) : Cell identification in W-CDMA

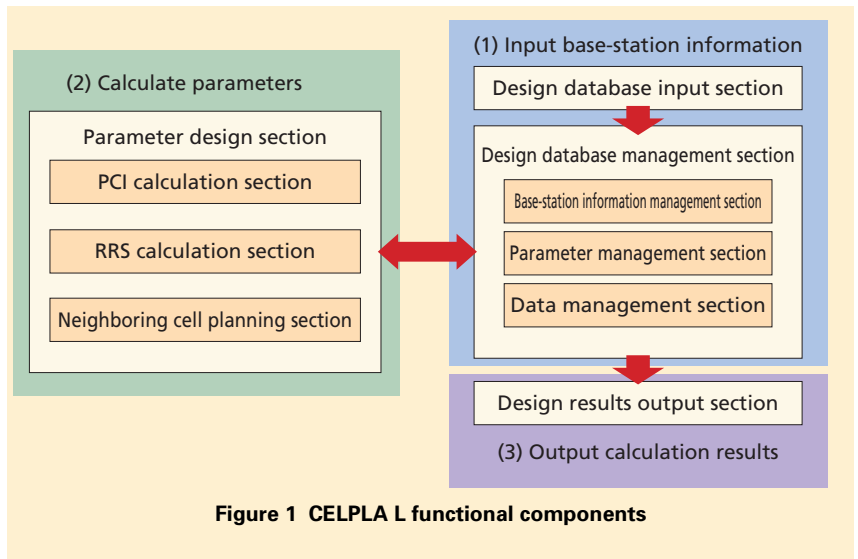


Figure 1 CELPLA L functional components

RRS and NRT parameters required for cell planning are automatically calculated by the parameter design section based on the base-station information and parameters input in the previous step. Manual adjustments may also be performed for an individual eNodeB depending on its installation environment.

3) Output Calculation Results

Finally, the parameters for LTE eNodeB equipment automatically designed by the parameter design sec-

tion are output by the design results output section. A function is available for outputting only those parameters that differ from existing base-station parameters.

Among the various parameters needed for LTE cell planning, we here focus on PCI and RACH in explaining the CELPLA L design method.

3. PCI Design

3.1 PCI Overview

To identify the eNodeB sector that

*2 **NRT**: A table used by an LTE eNodeB for determining a handover candidate.

*3 **PCI**: An ID for identifying cells in LTE.

*4 **Local ID**: Specifies transmission timing of the downlink Reference Signal (RS) using three reused values from 0 – 2. RS is used for esti-

mating radio-transmission quality.

*5 **Cell-group ID**: Uses 168 reused values from 0 – 167 grouping together local IDs.

*6 **Hopping pattern**: Specifies a transmission-timing group for the uplink RS using 17 reused groups numbered from 0 – 16.

*7 **Throughput**: Effective amount of data transmitted without error per unit time.

*8 **Jurisdiction**: Indicates the area that a base station belongs to; used for design in units of areas.

the User Equipment (UE) is communicating with, each sector is assigned with an ID in the range of 0 – 503 making for a total of 504 IDs. This ID is the PCI. PCI-related parameters are shown in **Figure 2**. The 504 different values of the PCI must be reused across the LTE area and must be sufficiently isolated to avoid duplicating a PCI value among neighboring sectors. A PCI, moreover, is uniquely determined by three IDs: cell-group ID, local ID and hopping pattern. These IDs must also be reused according to the total number of allocated sectors in the LTE area. One issue with reusing the PCI and these IDs is that insufficient isolation between identically identified sectors can cause interference leading to drops in communication quality. To efficiently prevent this issue from occurring, the CELPLA L PCI assignment technique groups together a maximum of 30 neighboring sectors (uplink (UL) sequence shift in fig. 2) under the same hopping pattern so that the amount of interference in the uplink from the UEs detected on the eNodeB side can be controlled. Additionally, to reduce the amount of downlink interference from neighboring sectors, this technique assigns the local IDs of neighboring sectors so that they are not duplicated within the same hopping pattern and groups together local IDs under cell-group IDs. Repeating this group-forming process for each ID enables PCIs and IDs to be assigned in an optimal

PCI		0	1	2	3	4	5	..	27	28	29	..	480	481	482	..	501	502	503	
DL	Cell-group ID	0			1			..	9			..	160			..	167			
	Local ID	0	1	2	0	1	2	..	0	1	2	..	0	1	2	..	0	1	2	
UL	Hopping pattern	0										..	16							
	Sequence shift	0	1	2	3	4	5	..	27	28	29	..	0	1	2	..	21	22	23	

Figure 2 PCI-related parameters

manner.

3.2 Configuration of PCI Assignment Function

The configuration of the PCI assignment function in CELPLA L is shown in **Figure 3**. Using the eNodeB information stored in the base-station information management section, this function determines the sector representative point, group representative point, and block representative point described below in respective functional sections and assigns the corresponding group IDs (local ID, cell-group ID and hopping pattern). The ID assignment section assigns the PCI corresponding to these representative points.

3.3 PCI Assignment

As shown in fig. 3, the PCI assignment function is broadly divided into two procedures: determination of representative points and assignment of group IDs and PCIs.

- 1) Determination of Representative Points

The flow for determining each

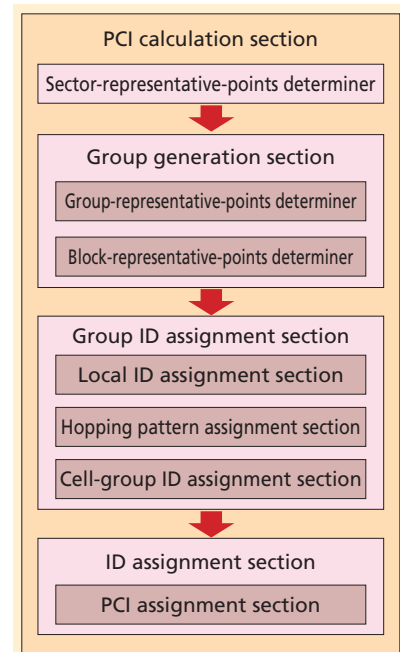


Figure 3 Configuration of PCI assignment function

type of representative point is shown in **Figure 4** and described below.

- Determine sector representative points

For each sector, the center point of the actual sector area is determined as the sector representative point based on data included in the base-station information management section such as latitude and

*9 **Propagation-delay correction value:** A value that corrects for the time taken for a signal transmitted from a base station to arrive at the UE.

*10 **High-speed-flow flag:** A flag identifying a base-station sector serving a high-speed-flow

area that includes, for example, a bullet train corridor.

*11 **Handover:** The process of switching the base station connected to the UE.

*12 **Cell planning:** The task of determining how to cover a desired service area using multiple

cells, where the area corresponding to one base station constitutes a single cell.

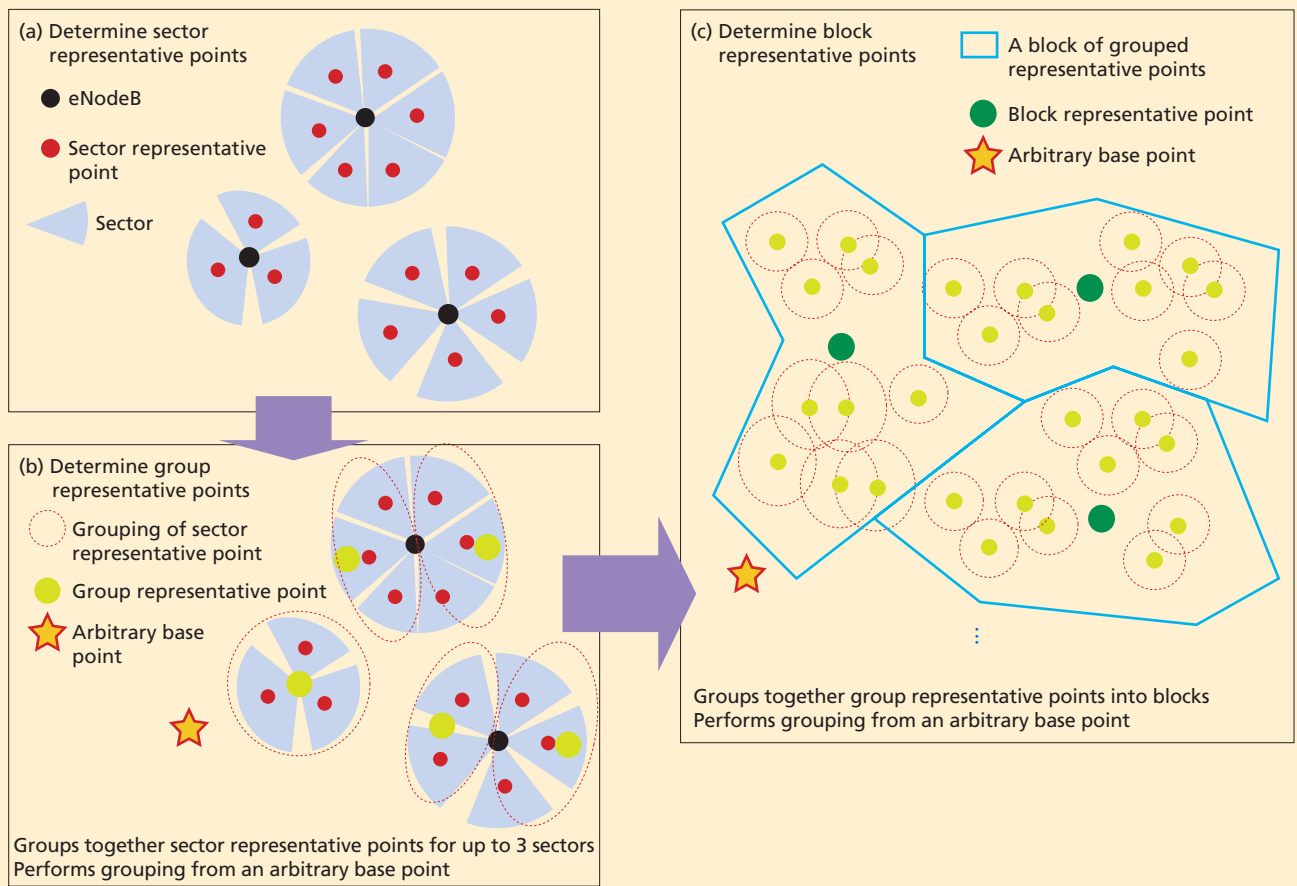


Figure 4 Flow for determining representative points

longitude, elevation, antenna height, signal arrival direction, and direction of radio wave radiation (fig. 4 (a)).

- Determine group representative points

First, necessary data is read, such as the latitude and longitude of an arbitrarily established base point^{*13} and grouping settings from the parameter management section and the positions of the sector representative points from the data management section. Then, on the

basis of this data, groups of up to three sector representative points are formed in order from the sector nearest the base point and a group representative point is determined for each such group of sector representative points (fig. 4 (b)).

- Determine block representative points

A block representative point is determined as the center point of each group of group representative points for up to 30 sectors in order from the sector nearest the base

point. A group of group representative points is called a “block.” Once determined, the positions of the block representative points are stored in the design database management section. In CELPLA L, blocks are determined using a Voronoi diagram^{*14}, which makes it possible to divide group representative points into areas and to easily recognize neighboring sectors. As a result, there is no need to calculate the distance from the base point to each group representative point,

*13 **Base point:** In this article, a reference point for grouping representative points starting with those nearest that reference point.

*14 **Voronoi diagram:** A diagram that divides a certain space of arbitrarily positioned points into areas by determining groups of points closest to certain points in that space.

which makes for efficient determination of block representative points (fig. 4 (c)).

2) Assignment of Group IDs and PCIs

• Step1: Assign local IDs

After determining representative points as described above, it's time to assign group IDs in order. To begin with, a local ID is assigned to each of the three or less sectors grouped together by a group representative point starting with the sector group nearest the base point and continuing on. Within any one sector group, local IDs are assigned in the order of 0 – 2 starting with the sector whose orientation is closest to 0 degrees and proceeding clockwise. For a group of two or less sectors, the local IDs of neighboring sectors are first examined and the sectors in question are assigned local IDs having the most separation in value from those neighboring local IDs.

• Step2: Assign hopping patterns

First, the latitude and longitude of the base point used in determining the block representative points is obtained from the parameter management section. Next, hopping-pattern numbers are assigned in a consecutive manner to blocks starting with the block representative point nearest the base point.

• Step3: Assign cell-group IDs

Similar to the assignment of hopping patterns, the latitude and

longitude of the base point used in determining group representative points is obtained from the design database management section. Then, starting with the sectors nearest the base point, cell-group IDs are assigned in a consecutive manner while grouping local IDs.

This process of assigning group IDs as described in steps 1 – 3 above is depicted in **Figure 5**.

• Step4: Assign PCIs

Once the assignment of local IDs, hopping patterns, and cell-group IDs is completed, PCIs are assigned to all sectors based on the assigned values of each type of group ID.

The above technique for assigning group IDs and PCIs makes for efficient and appropriate PCI assignment. A screen presenting the results of PCI assignment in CELPLA L is shown in **Figure 6**.

4. RACH Design

4.1 RACH Overview

When commencing communications, a mobile terminal transmits a RACH Preamble^{*15} as a signal on the uplink. The signal sequence for generating this RACH Preamble is the RRS, and appropriate RRSs and an appropriate number of these RRSs must be assigned for each sector. In RRS assignment, if the same RRS is assigned to different sectors, a certain distance must be established between those sectors for the following reason. If the same RRS should be assigned to neighboring sectors, there is the possibility that UEs parked in those sectors will transmit the same RACH Preamble based on the same RRS. If so, the same RACH Preamble may be received by an eNodeB from UEs inside and outside that eNodeB's sector resulting in signal collision and an inability to communicate.

Important elements in RRS design

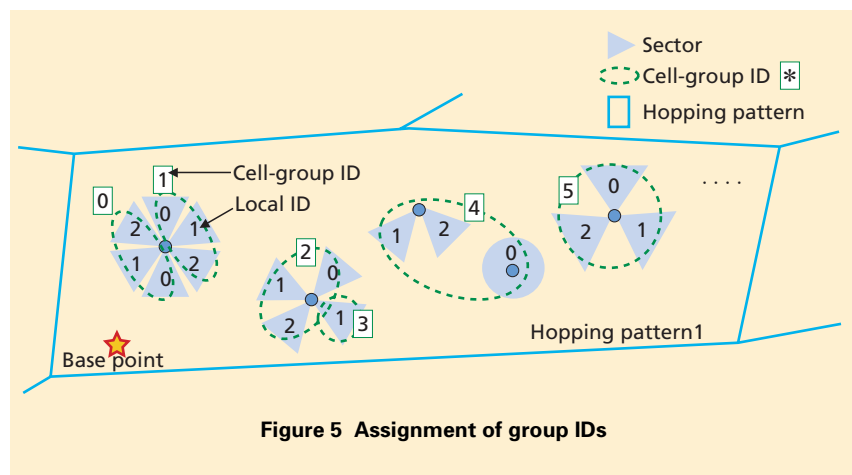


Figure 5 Assignment of group IDs

*15 RACH Preamble: Signal used by UE for connecting to an eNodeB by random access.

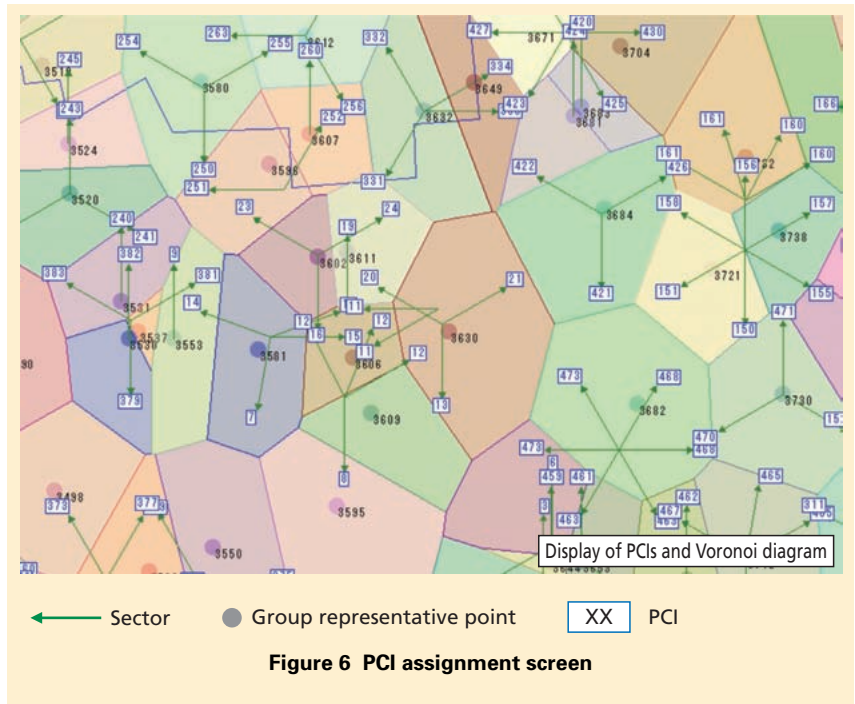
are RRS assignment in accordance with area radius, RRS assignment for high-speed-flow eNodeBs, and isolation of sectors with the same RRS.

Similar to the case of PCIs described in Chapter 3, RRS assignment requires that appropriate RRSs and an appropriate number of these RRSs be assigned according to cell radius, and for high-speed-flow eNodeBs, that the number of RRSs assigned be a multiple of that assigned for ordinary eNodeBs to alleviate the effects of Doppler shift^{*16}. For example, given an area radius of 10 km, six RRSs would be required for an ordinary eNodeB while 18 would be required for a high-speed-flow eNodeB.

Again, similar to PCIs, there are only a finite number of RRSs available for use, specifically, 838, which means that they must be reused while ensuring a prescribed distance between sectors assigned with the same RRS. Thus, when assigning a certain number of RRSs to a sector, the number of calculated RRSs should be no more than needed to make the distance between sectors with the same RRS as long as possible.

4.2 RRS Assignment

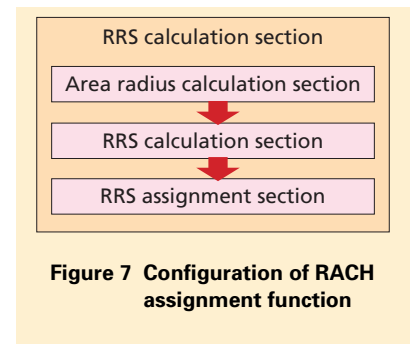
The configuration of the RRS assignment function in CELPLA L is shown in **Figure 7**. This function first calculates the area radius based on eNodeB information stored in the base-station information management



section. It then calculates the number of RRSs needed based on the calculated area radius and assigns RRSs in a manner that ensures a prescribed distance between sectors with the same RRS.

1) Calculation of Area Radius

The basic method for calculating the area radius for RACH use is to calculate the range of signal arrival according to the same logic as used in establishing PCIs. This radius, however, must be corrected taking into account area factors (such as multipath delay^{*17}) stored in the parameter management section (**Figure 8**). This is because the RACH Preamble—in contrast to the PCI—is an uplink signal, which means that RACH design must be



carried out while estimating delay caused by environmental factors so that this signal can be adequately supplemented on the LTE eNodeB side.

Calculating the area radius in accordance with actual environmental factors in this way enables only the minimal required number of RRSs to be assigned making for efficient RACH design given a limited number

*16 **Doppler shift:** Shift in carrier-wave frequency due to the Doppler effect.

*17 **Multipath delay:** Reception of transmitted waves in the form of delay waves caused by the arrival of waves along different paths owing to reflection or diffraction caused by buildings or topography.

of available RRSs.

2) Calculation and Assignment of RRSs

Based on the area radius for RACH use determined in step 1), the function now calculates the required number of RRSs and assigns the RRSs. The RRS assignment process is performed in order from the sector nearest an arbitrarily established base point. If the prescribed isolation between sectors with the same RRS cannot be achieved, the sector furthest away from the sector assigned with a RRS to be duplicated is assigned with that RRS.

Furthermore, as shown in **Figure 9**, RRSs for high-speed-flow will be assigned to certain sectors based on the high-speed-flow flag stored in the data management section.

The above methods maintain communications quality by assigning reused RRSs in a way that prevents RRSs from being duplicated in neighboring areas and that separates as much as possible sectors assigned with the same RRS. A screen presenting the results of RRS assignment in CELPLA L is shown in **Figure 10**.

5. Improving Efficiency of Design Technique

The techniques described in Chapters 3 and 4 for assigning PCIs and RRSs by CELPLA L enable independent cell planning in units of coverage

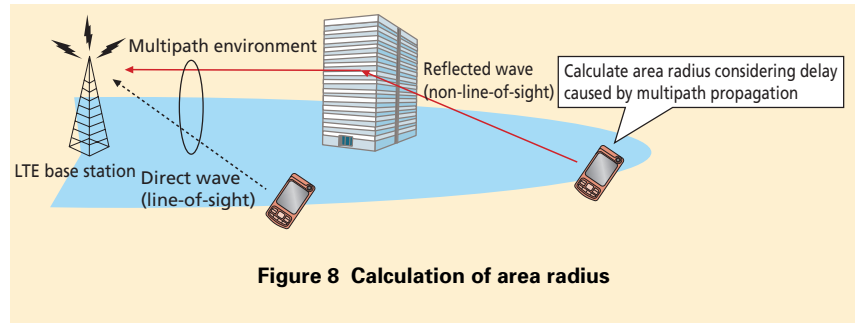


Figure 8 Calculation of area radius

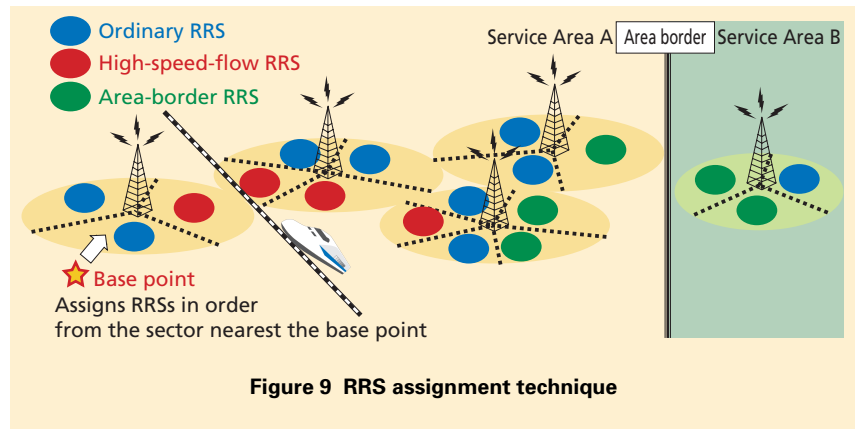


Figure 9 RRS assignment technique

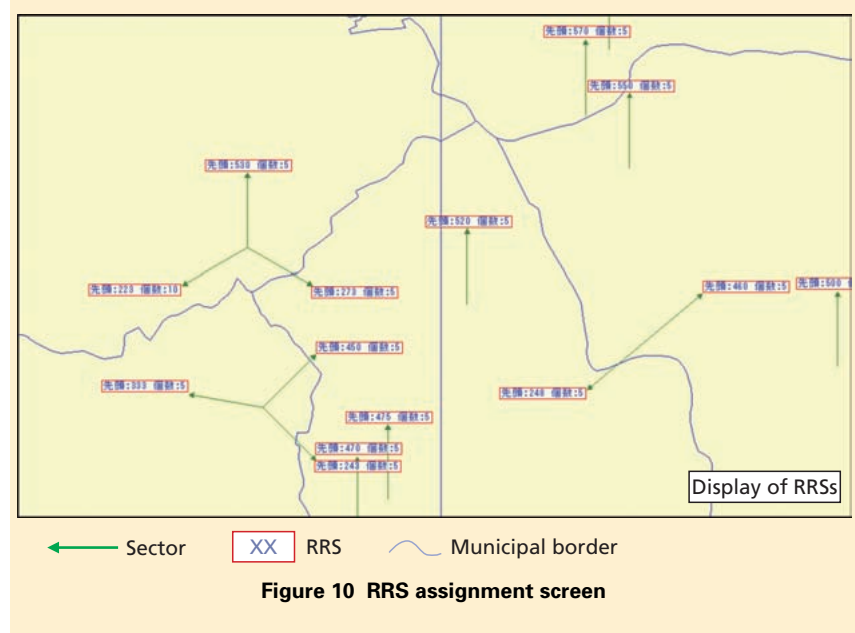


Figure 10 RRS assignment screen

areas (such as prefectures).

Usually, when a designer is per-

forming cell planning for multiple coverage areas in parallel, the possibility

exists of assigning the same PCIs or RRSs across those areas, but as shown in fig. 9, this can be prevented by assigning PCIs and RRSs for area-border use to sectors located near borders. In CELPLA L, combinations of area-border PCIs and of area-border RRSs that prevent duplication at area borders are stored in the data management section for assignment to border sectors.

This assignment method makes for efficient assignment of PCIs and RRSs for multiple coverage areas in parallel.

The CELPLA L tool also provides for the automatic design of neighboring cells as required for handover. This design work is based on base-station information (latitude, longitude, antenna height, direction of signal radiation,

etc.) found not only in the LTE-related NRT but also in the Zone Table (ZT)^{*18} parameter used in W-CDMA cell planning.

Although accurate cell planning while checking the peripheral environment has been difficult considering the existence of parameters unique to each base station, CELPLA L enables large-scale design on a level of several ten-thousand sectors to be completed in a matter of days.

6. Conclusion

This article outlined the functions of an LTE cell planning support tool (CELPLA L) and described the technique for determining LTE cell planning parameters using this tool.

CELPLA L helps to maintain a stable level of LTE service quality independent of the cell planner's level of technical skills, contributes greatly to making the traditionally difficult process of parameter design more efficient, and enables a smooth expansion of the LTE coverage area. Looking forward, we plan to pursue a flexible approach to adding and modifying cell planning parameters in response to future functional enhancements in LTE services.

REFERENCE

- [1] 3GPP TS.36.211 V8.9.0: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical Channels and Modulation (Release 8)," Feb. 2009.

*18 ZT: Information on neighboring cells required for adding a radio circuit.