Development of Technology to Control Radio Signal Interference for LTE Femtocell Base Stations to Achieve Stable Communications Quality Anywhere

MORITA Motoki, NOBUKIYO Takahiro, HAMABE Kojiro

Abstract

Demand is accelerating for reliability that mobile communications services can be used in a stable way. In order to cope with the increasing data traffic volume of mobile communications, there is a growing need to install more femtocell base stations covering small indoor areas, in addition to macrocell base stations covering large outdoor areas. This paper introduces a technology to maximize communications speeds by controlling the transmission power of radio signals for femtocell base stations in accordance with the data traffic volume. This is a radio signal interference control technology that minimizes the degradation of communications quality, which happens due to radio signal interference with macrocell base stations, even under the condition of a high-density installation of femtocell base stations. Moreover, we introduce a technology that makes it possible to control transmission power for each femtocell base station and to minimize the radio signal influence of heavy users who carry out high-volume data transmission.

Keywords

mobile communications, femtocell, macrocell, radio signal interference, transmission power control, data traffic, heavy user, LTE

1. Introduction

In recent years, mobile communications services have spread throughout people's everyday lives as well as business activities. They are now considered to be as important as social lifelines such as water and electricity. In this society, reliability for stable use of mobile communications is demanded. Moreover, the dissemination of LTE for high-capacity and high-speed mobile communications has recently accelerated. LTE allows users of mobile communications services to transmit large volumes of data, such as movies, and therefore the growth of data traffic volumes is expected to continue. In order to cope with such conditions of the wireless access networks supporting mobile communications, there is a growing need to install more femtocell base stations (hereinafter referred to as "femto base stations") covering small indoor areas such as homes, offices, etc. where many people use mobile communications services, in addition to demand for the installation of macrocell base stations (hereinafter referred to as "macro base stations") covering large outdoor areas.

However, the high-density installation of femto base stations to deal with data traffic increases may cause radio signal interference between closely installed femto base stations and macro base stations. This may result in the degradation of communications quality (comfortable connectivity and transmission speed) in some places (Fig. 1). Moreover, high-volume and continuous data transmission by a few heavy users may cause a constant degradation of communications quality, which can be an obstacle to providing stable mobile communications ser-

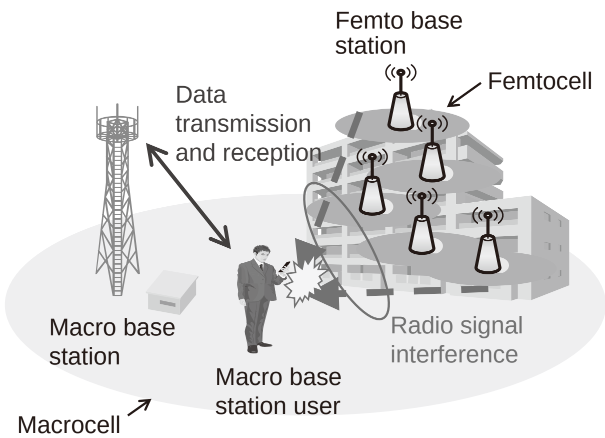

Fig. 1 Radio signal interference between femtocells and macrocells.

vices to general users. Therefore, it is a social issue to achieve stable mobile communications services anywhere, also in the near future with the drastic increase of data traffic volumes.

To solve these social issues, NEC has developed technologies that control radio signal interference for femto base stations. Section 2 in this paper describes a technology to minimize the reductions in communications speed due to radio signal interference even when data traffic volumes increase drastically. Section 3 explains a technology to minimize the reductions in communications speed even when heavy users are continuously transmitting a large volume of data via femto base stations.

2. Transmission Power Control in Accordance with Data Traffic Volume

2.1 Developed Technology

Our developed transmission power control technology is outlined in this section. Fig. 2 illustrates power control for an uplink in which radio signals are transmitted from a mobile device to a base station. First, femto base stations set the standard value of the target received power for the desired signals that determine the uplink transmission power, so that the uplink interference power of an individual user's terminal carrying out data transmissions with femto base stations (hereinafter referred to as a "femto terminal") can be maintained below a set level. Next, femto base stations measure the transmission volume of their data traffic (hereinafter referred to as data transmission volume) and calculate power adjustment volumes for collective femto terminals in response to the data transmission volumes of all the femto base stations that are installed within the coverage area of a macro base station (hereinafter referred to as a "macrocell"). The target received power at each femto terminal can be determined by deducting the adjustment volume from the standard value.

As shown in Fig. 2, when the overall data transmission volume of all femto base stations increases, the transmission power of each femto terminal is restrained by increasing the power adjustment volume. This makes it possible to keep the total uplink interference power for the macro base station within tolerance levels, so that degradation of the communications speeds of the user terminals connected to a macro base station (hereinafter referred to as a "macro terminal") can be minimized. Moreover, the power adjustment volume is reduced when overall data transmission volume is low, so that the transmission power for each femto terminal will be increased relative to when overall data transmission volume is high. Therefore the transmission speed of each femto terminal can be increased.

2.2 Performance Evaluation

This section introduces the evaluation results of the developed technology. Based on the evaluation conditions regulated by 3GPP (3rd Generation Partnership Project), an international organization for mobile phone system standardization, we have conducted a simulation test with an LTE system. This simulation test was conducted within the parameters that a single femto terminal is assumed to be connected to a single femto base station. Three different conditions were prepared in order to compare performance: (1) setting the power adjustment volume to zero (No power adjustment), (2) calculating the power adjustment volume based on the number of femto base stations (Power adjustment based on the number of femto base stations) and (3) calculating the power adjustment volume

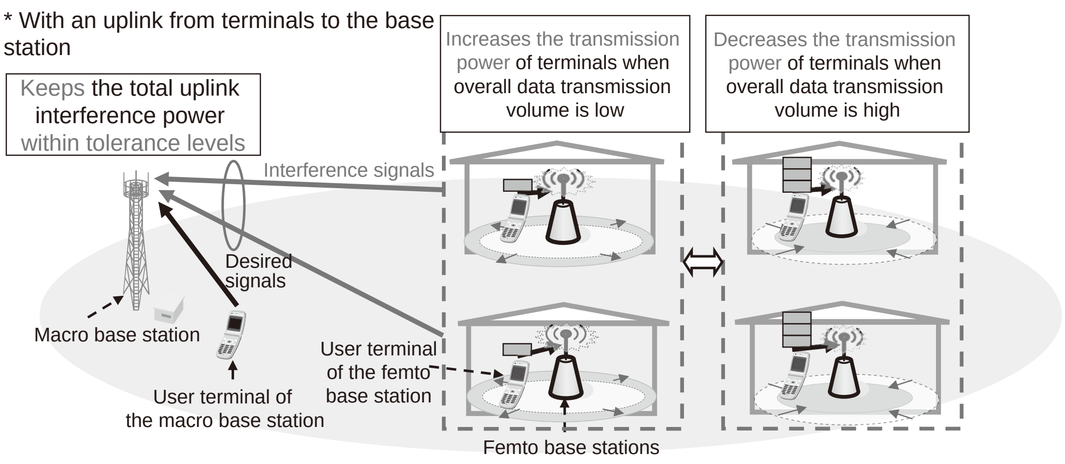

Fig. 2 Transmission power control in response to the overall data transmission volume of all femto base stations.

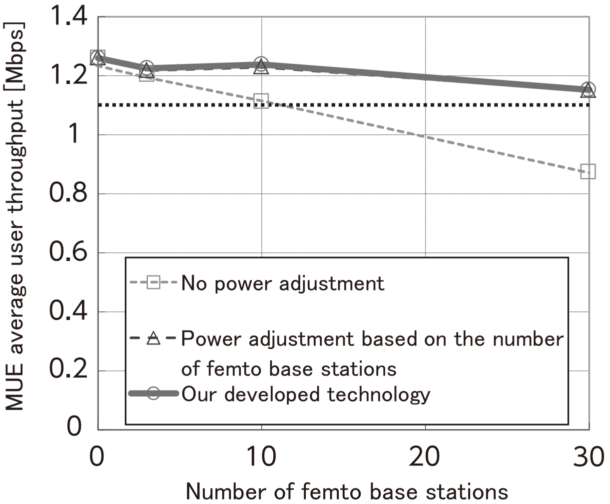

Fig. 3 Properties of the macro terminal (MUE) throughput during times of high data transmission volume at each femto base station.

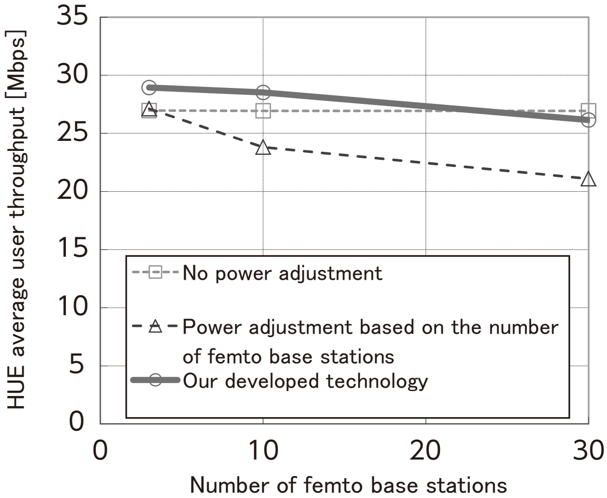

Fig. 4 Properties of the femto terminal (HUE) throughput during times of low data transmission volume at each femto base station.

based on the overall data transmission volume of all femto base stations (Our developed technology). "MUE" (Macro User Equipment) represents a macro terminal and "HUE" (Home User Equipment) represents a femto terminal. The user throughput value is acquired by dividing transmission data volume by transmission time. This value represents the speed that a user feels when they are operating their devices.

Fig. 3 shows the average MUE user throughput with different numbers of femto base stations. These stations are installed in the macro cell area and a large volume of data transmission at each femto base station can be expected. Fig. 3 indicates the influence on the macro terminal (MUE) when data transmission volume is high. This figure also indicates that our developed technology curbs the degradation of the average MUE user throughput even under conditions of high-density installation of femto base stations. This enables femto base stations to be installed at three times greater density while maintaining the present average MUE user throughput (see the dotted line at the level of 1.1 Mbps in Fig. 3).

Fig. 4 shows the average HUE user throughput with different numbers of femto base stations. These stations are installed in the macro cell area and a small volume of data transmission at each femto base station can be expected. Fig. 4 indicates the influence on the femto terminal (HUE) when data transmission volume is low. The figure also shows that when the number of femto base stations is 30, our developed technology increases the average HUE user throughput to 1.2 times greater than that achieved by the power adjustment technology that relies on the number of femto base stations.

As explained above, with appropriate use of our developed technology, more femto base stations can be installed while curbing radio signal interference at the macro base station. Our technology also achieves superior femto terminal (HUE) average throughput during times of low overall data transmission volume at all femto base stations.

3. Transmission Power Control for Femto Base Stations to Minimize the Radio Signal Influence of Heavy Users

3.1 Developed Technology

This section outlines our developed transmission power control technology. Fig. 5 illustrates the power control for a downlink in which signals are transmitted from a base station to a mobile device. First, the technology measures the data transmission volume at each user's terminal over a set period to judge whether they are heavy users or general users and then identifies the femto base stations that are continually being accessed by heavy users. Next, it reduces the transmission power of radio signals at the femto base stations being accessed by heavy users. At the same time, it increases the transmission power of the femto base stations of general users, while keeping the radio signal interference power at the macro terminal (MUE) within tolerance levels.

3.2 Performance Evaluation

This section introduces the evaluation results of the developed technology through a simulation test conducted with an LTE system. Three different conditions were prepared in order to compare performance: (1) no heavy users exist (all MUEs and HUEs are owned by only general users), (2) some HUEs are owned by heavy users and our developed technology is not applied and (3) some HUEs are owned by heavy users but our

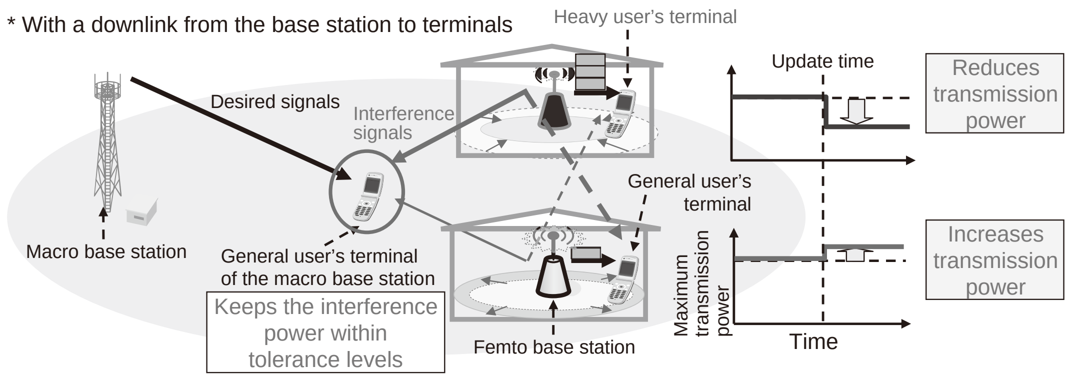

Fig. 5 Power control for heavy users of femto base stations.

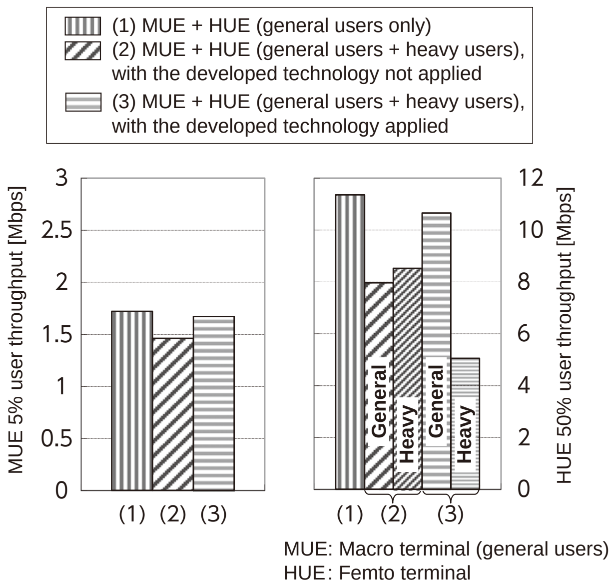

Fig. 6 Influences on throughput performance due to heavy users.

developed technology is applied. For both (2) and (3), it was assumed that approximately 3% of the HUEs are owned by heavy users, who each use almost 25 times the data traffic of a general user (together making up almost half of the total HUE traffic). User throughput values are evaluated using the CDF (Cumulative Distribution Function).

The left-hand chart in Fig. 6 shows the bottom 5% of MUE user throughput. The figure indicates the influence on the macro terminal (MUE) whose data transmission speed degrades due to radio signal interference from a femto base station. The right-hand chart in the figure shows the bottom 50% (median) of HUE user throughput. It indicates the influence on the femto terminal (HUE) due to the power control. The left-hand chart in Fig. 6 shows that the bottom 5% of MUE user throughput degrades 15% without our developed technology applied, but only degrades 3% with our developed technology applied, even when some HUEs are owned by heavy users. Moreover, the right-hand chart in Fig. 6 indicates that our developed technology also significantly curbs the degradation of the HUE user throughput of general users.

As explained above, with appropriate use of our developed technology, degradation of both the femto terminal (HUE) and the macro terminal (MUE) throughput for general users can be curbed even if heavy users access the femto base stations.

4. Conclusion

This paper introduces technologies to minimize radio signal interference for femto base stations to achieve stable mobile communications services anywhere even under conditions in which data traffic is high or heavy users are continually transmitting large volumes of data. NEC will proceed in our research and development of these technologies to put them to practical use so that they will contribute to improving the reliability of mobile communications services for stable use.

* LTE and 3GPP are registered trademarks of European Telecommunications Standards Institute (ETSI).

Reference

1) Motoki Morita, Takahiro Nobukiyo, Kojiro Hamabe, "Uplink Power Control Method for LTE Femtocells Based on Resource Usage Aggregation," in Proc. IEEE PIMRC (Personal Indoor and Mobile Radio Communications) 2012, pp.442 – 447, Sept. 2012
2) 3GPP TR 36.814 v9.0.0, Further advancements for E-UTRA physical layer aspects, 2010.3

Authors' Profiles

MORITA Motoki
Assistant Manager
Green Platform Research Laboratories

NOBUKIYO Takahiro
Principal Researcher
Green Platform Research Laboratories

HAMABE Kojiro
Assistant General Manager
Green Platform Research Laboratories

Information about the NEC Technical Journal

Thank you for reading the paper.
If you are interested in the NEC Technical Journal, you can also read other papers on our website.

Link to NEC Technical Journal website

Japanese | English

Vol.8 No.1 Solving Social Issues Through Business Activities

Vol.8 No.1
September, 2013

Special Issue TOP