connectable with a mobile station device (also called a terminal or UE (User Equipment)) are set to be partly overlapped with each other.

[0003]

In order to increase the frequency usage efficiency of the cells in the above-described cellular configuration, it is studied, as discussed in Non Patent Literature (NPL) 1 mentioned below, (i) to repeatedly utilize the same frequency by the individual cells, or (ii) to construct a heterogeneous network in which, in addition to a base station device (macrocell) having a cell radius of several hundred meters to over ten kilometers, other base station devices (each called a picocell, a femtocell, or Home eNodeB) having various cell radii are deployed such that ranges of the other base station devices entirely or partly overlap with the macrocell.

[0004]

Fig. 22 is a schematic view illustrating one example of a downlink in a radio communication system in which base station devices having different cell radii are deployed. A base station device 1000-2 is deployed with Single Frequency Reuse ~~one-cell frequency reuse~~ such that a cell 1000-2a (e.g., a picocell) of the base station device 1000-2 overlaps with a cell 1000-1a (macrocell) of a base station device 1000-1. A mobile station device is preferably controlled to be radio-

transmission or MIMO (Multiple Input Multiple Output) transmission.

[0055]

Fig. 3 illustrates a transmission frame format for a downlink of the base station device 100-1 in the radio communication system according to the first embodiment of the present invention. On frame is made up of ten plural types of subframes including Normal Subframes and resource-mapping limited subframes (hereinafter also referred to as "limited subframes"). An example of the resource mapping limited subframes is MBSFN (Multimedia Broadcast multicast service Single Frequency Network~~Multicast/Broadcast over Single Frequency Network~~) or ABS (Almost Blank Subframe).

[0056]

The term "Normal Subframe" implies a subframe for which resource mapping of the information data, the control data, and the reference signals, each transmitted from the base station device 100-1, in accordance with the above-described scheduling information is allowed. For example, the Physical Downlink Shared Channel, the Physical Downlink Control Channel, the Synchronization Signal, the Physical Broadcast Channel, the Cell-specific Reference Signal, the Channel State Information-Reference Signal, the paging signal, SIB-1, etc. can be mappeded to the Normal Subframe by resource mapping.

[0057]

thick lines), which is constituted by two resource blocks. Each resource block pair is made up of 168 resource elements that occupy frequencies indicated by 12 subcarriers and times indicated by 14 OFDM symbols. The control signals, such as the PDCCH, are mainly mapped in one to three areas at the beginning of the 14 OFDM symbols constituting the resource block pair. The remaining eleven to thirteen areas of the OFDM symbols are areas where the data modulation symbols, such as the PDSCH, are mainly mapped. The Cell-specific Reference Signal is mapped in predetermined ones (i.e., filled-in portions) of the resource elements constituting each resource block. It is to be noted that the resource element in which the Cell-specific Reference Signal is mapped is cyclically shifted in the frequency direction depending on the cell ID of the base station device 100-α.

[0065]

Using the subframe format illustrated in Fig. 4, the base station device 100-1 executes scheduling for the mobile station device 200-1 to perform resource mapping of the PDSCH and the PDCCH to only the Normal Subframes~~Frames~~, taking into consideration the feedback information. Thus, when the resource mapping unit 106 executes the resource mapping in accordance with the scheduling information, the base station device 100-1 can transmit the PDSCH and the PDCCH to the mobile

station device 200-1 by employing only the Normal Subframes~~Frames~~. On the other hand, in the resource-mapping limited subframe, a voided portion where the PDCCH, for example, is mapped by the resource mapping can be set such that any signal is not mapped there. As a result, the Inter-cell Interference with respect to the mobile station device connected to the base station device 100-2 can be mitigated in the resource-mapping limited subframe.

[0066]

Fig. 5 is a conceptual view illustrating another example of the subframe format according to the first embodiment of the present invention. The example illustrated in Fig. 5 represents one exemplary case where the base station device 100-α performs transmission by employing two antennas (antenna ports). In Fig. 5, the horizontal direction represents time, and the vertical direction represents frequency. The Cell-specific Reference Signal is mapped in predetermined ones (i.e., filled-in portions) of the resource elements constituting each resource block. In Fig. 5, the reference signal transmitted from one of the two antennas is mapped to a resource element 0 by the resource mapping. The Cell-specific Reference Signal transmitted from the other of the two antennas is mapped to a resource element 1 by the resource mapping. The subframe format for the base station device 100-α is given

[0082]

The base station device 100-2 obtains information related to downlink transmission of an adjacent base station device (i.e., the base station device 100-1) through the backhaul link 10 (S101). The information related to downlink transmission includes information regarding the transmission frame format.

[0083]

Next, the base station device 100-2 determines, based on the information related to downlink transmission, whether or not the subframe transmitted from the base station device 100-1 is the MBSFN (S102). If it is determined that the relevant subframe is not the MBSFN (NO in S102), the base station device 100-2 generates a control signal for notifying the necessity of the cancellation process to the mobile station device 200-u (u = 2 and/or 3 in the case of Fig. 1) (S104).

[0084]

On the other hand, if it is determined that the relevant subframe is the MBSFN (YES in S102), the base station device 100-2 generates a control signal for notifying the non-necessity of the cancellation process to the mobile station device 200-u (u = 2 and/or 3 in the case of Fig. 1) (S103). Thereafter, the base station device 100-2 transmits the control signal and a data signal (e.g.,

outputs the received OFDM signal in the carrier band to the reception unit 202. At that time, the reception antenna unit 201 further receives an OFDM signal in the carrier band, which is transmitted from the base station device 100-1, thus causing the Inter-cell Interference.

[0087]

The reception unit 202 down-converts the OFDM signal, input from the reception antenna unit 201~~2~~, to a frequency band where digital signal processing is executable, and further executes a filtering process of the down-converted signal to remove the unnecessary component (Spurious). In addition, the reception unit 202 executes (A/D: Analog to Digital) conversion of the signal, which has been subjected to the filtering process, from an analog signal to a digital signal, and outputs the converted digital signal to the channel estimation unit 203, the GI removing unit 204, and the control signal detection unit 211.

[0088]

The channel estimation unit 203 executes channel estimation by employing a reference signal contained in the signal output from the reception unit 202, thereby generating a channel estimation value. Then, the channel estimation unit 203 notifies the channel estimation value to the interference removing unit 206, the channel compensation unit 207, and the higher layer 210. The channel estimation

process is selected corresponding to the error correction coding, e.g., turbo coding or convolution coding, which has been executed in the base station device ~~transmission device~~ 100 as a transmission source. The error correction coding process may be executed with hard decision or soft decision. When the base station device transmits the interleaved data modulation symbols, the decoding unit 209 executes, prior to the error correction decoding process, a process of deinterleaving the input coded bit sequence corresponding to the interleaving in the base station device. The decoding unit 209 then executes the error correction decoding process on the signal that has been subjected to the deinterleaving process.

[0096]

The control signal generation unit 222 generates a control signal for transmitting feedback information (including the CQI, the RI, and the PMI) to the base station device. The feedback information is determined by the higher layer 210 based on the channel estimation value calculated by the channel estimation unit 203.

[0097]

The control signal generation unit 222 generates the control signal by executing error correction coding and modulation mapping on control data that represents the feedback information. The control signal corresponds to,

[0102] [Math. 2]

$$\tilde{R}_{k,l} = R_{k,l} - \hat{R}_{k,l} \quad \cdots(2)$$

[0103]

In the above formula, $R_{k,\ell}$ denotes a signal in the k-th subcarrier of the first OFDM symbol in the resource-mapping limited frame output from the DFT unit 205. $R_{k,\ell}$^ denotes an interference replica in the resource-mapping limited frame, and it is expressed by a formula given below. It is to be noted that the expressions "R^" and "R~" imply symbols, which correspond to alphabets "R" added respectively with "^" and "~" put above them, as expressed in the formula (2). Those expressions are similarly applied to "s^", "c^", and "H^" used below.

[0104] [Math. 3]

$$\hat{R}_{k,l} = \hat{H}_{k,l}\hat{s}_{k,l} \quad \cdots(3)$$

[0105]

In the above formula, $H_{k,\ell}$^ denotes a transfer function of the k-th subcarrier of the first OFDM symbol, which has been estimated by the channel estimation unit 203. $s_{k,\ell}$^ denotes a replica of a transmission signal in the k-th subcarrier of the first OFDM symbol, which has been generated by the transmission signal replica generation unit 241. The $s_{k,\ell}$^ is a replica that is made up of the known

necessity of the cancellation process by setting "1" in that area.

[0125]

Upon receiving the control signal that includes the information indicating the necessity or the non-necessity of the cancellation, the mobile station device 200-2 and/or the mobile station device 200-3 executes the cancellation process on the subframe based on the information indicating the necessity or the non-necessity of the cancellation.

[0126]

In another example, the information indicating the necessity or the non-necessity of the cancellation notifies the arrangement of the Normal Subframe, the MBSFN subframe, and the ~~Normal~~ ABS Subframe in the format transmitted from the base station device 100-1. The base station device 100-2 prepares, for example, a 2-bit area for indicating the information regarding the necessity or the non-necessity of the interference cancellation in the PDCCH or the RRC signaling, and it notifies the Normal Subframe by setting "01" in that area, the MBSFN subframe by setting "10" in that area, and the ABS by setting "11" in that area.

[0127]

The mobile station device 200-2 and/or the mobile station device 200-3 having received the control signal, which includes the information indicating the necessity or

Fig. 21 is a flowchart illustrating the generation of the feedback information in the fifth embodiment of the present invention. The control signal detection unit 211 of the mobile station device 200-2 extracts the control information related to the interference cancellation process from the downlink control signal transmitted from the base station device 100-1, and obtains the information indicating the necessity or the non-necessity of the interference cancellation process (S501). If the necessity of the interference cancellation process is notified (YES in S502), the mobile station device 200-2 sets the feedback information, such as the CQI and the RI, in consideration of not only the channel state, but also application of the interference cancellation process (S504).

[0156]

On the other hand, if the non-necessity of the interference cancellation process is notified (NO~~YES~~ in S502), the mobile station device 200-2 sets the feedback information, such as the CQI and the RI, based on the channel state (S503). The mobile station device 200-2 then notifies the set feedback information to the base station device 100-2 (S505). It is to be noted that the channel state is estimated from the reference signal, e.g., the CRS, transmitted from the base station device 100-2.

[0157]

Returning to Fig. 20, the base station device 100-2 sets, based on the feedback information, the MCS, the number of layers, etc. of a data signal transmitted to the mobile station device 200~~2~~-2, and generates the PDSCH by executing the coding process, the modulation process, the precoding process, etc. based on the above-mentioned parameters (S406). The base station device 100-2 further generates the Physical Downlink Control Channel (PDCCH) for notifying the MCS, the number of layers, etc. (S406). Thereafter, the base station device 100-2 transmits the PDSCH and the PDCCH to the mobile station device 200-2 (S407).

[0158]

Upon receiving the PDSCH and the PDCCH, the mobile station device 200-2 executes a PDSCH detection process (including the demodulation process and the decoding process) by applying the interference cancellation process based on the information, such as the MCS and the number of layers, which are set in the PDCCH (S408).

[0159]

According to the fifth embodiment of the present invention, as described above, the mobile station device generates the feedback information in consideration of not only the channel state, but also the necessity or the non-necessity of application of the interference cancellation process. The base station device transmits the data signal

reception unit, 203 channel estimation unit, 204 GI removing unit, 205 DFT unit, 206 interference removing unit, 207 channel compensation unit, 208 demodulation unit, 209 decoding unit, 210 higher layer, 211 control signal detection unit, 221 transmission antenna unit, 222 transmission unit, 223 control signal generation unit, 241 transmission signal replica generation unit, 242 interference replica generation unit, 243 subtracter, 251, 252 transmission frame formats, 1000-1, 1000-2 base station devices, and 2000-1, 2000-2, 2000-3 mobile station devices.

CLAIMS

[Claim 1]

A base station device communicating with a mobile station device,

wherein the base station device notifies, to the mobile station device by RRC signaling, a cell ID of another base station device different from the aforesaid base station device, number of antenna ports for a cell-specific reference signal in the aforesaid other base station device, and subframe information indicating MBSFN subframes that are reserved for MBSFN, which is used as an MBSFN by the aforesaid other base station device.

[Claim 2]

The base station device according to Claim 1, wherein the MBSFN subframes include an OFDM symbol area in which the cell-specific reference signal is mapped, and an OFDM symbol area in which the cell-specific reference signal is not mapped.

[Claim 3]

The base station device according to Claim 1, wherein the subframe information contains a bitmap indicating MBSFN subframe allocation in a predetermined number of subframes.

[Claim 4]

A mobile station device communicating with a base station device,

wherein the mobile station device receives, from the base station device by RRC signaling, a cell ID of another base station device different from the aforesaid base station device, number of antenna ports for a cell-specific reference signal in the aforesaid other base station device, and subframe information indicating MBSFN subframes that are reserved for MBSFN, which is used as an MBSFN by the aforesaid other base station device.

[Claim 5]

The mobile station device according to Claim 4, wherein the mobile station device employs the received information to mitigate interference suffered from the cell-specific reference signal that is transmitted from the aforesaid other base station device.

[Claim 6]

The mobile station device according to Claim 4, wherein the MBSFN subframes includes an OFDM symbol area in which the cell-specific reference signal is mapped, and an OFDM symbol area in which the cell-specific reference signal is not mapped.

[Claim 7]

The mobile station device according to Claim 4, wherein the subframe information contains a bitmap indicating MBSFN subframe allocation in a predetermined number of subframes.

[Claim 8]

A transmission method in a base station device communicating with a mobile station device, the transmission method comprising the step of:

notifying, to the mobile station device by RRC signaling, a cell ID of another base station device different from the aforesaid base station device, number of antenna ports for a cell-specific reference signal in the aforesaid other base station device, and subframe information indicating MBSFN subframes that are reserved for MBSFN, which is used as an MBSFN by the aforesaid other base station device.

[Claim 9]

The transmission method according to Claim 8, wherein the MBSFN subframes include an OFDM symbol area in which the cell-specific reference signal is mapped, and an OFDM symbol area in which the cell-specific reference signal is not mapped.

[Claim 10]

The transmission method according to Claim 8, wherein the subframe information contains a bitmap indicating MBSFN subframes allocation in a predetermined number of subframes.

[Claim 11]

A reception method in a mobile station device communicating with a base station device, the reception method comprising the step of:

receiving, from the base station device by RRC signaling, a cell ID of another base station device different from the aforesaid base station device, number of antenna ports for a cell-specific reference signal in the aforesaid other base station device, and subframe information indicating MBSFN subframes that are reserved for MBSFN, which is used as an MBSFN by the aforesaid other base station device.

[Claim 12]

The reception method according to Claim 11, wherein the received information is employed to mitigate interference suffered from the cell-specific reference signal that is transmitted from the aforesaid other base station device.

[Claim 13]

The reception method according to Claim 11, wherein the MBSFN subframes include an OFDM symbol area in which the cell-specific reference signal is mapped, and an OFDM symbol area in which the cell-specific reference signal is not mapped.

[Claim 14]

The reception method according to Claim 11, wherein the subframe information contains a bitmap indicating MBSFN subframe allocation in a predetermined number of subframes.

[Claim 15]

An integrated circuit incorporated in a base station

device communicating with a mobile station device,

wherein the integrated circuit notifies, to the mobile station device by RRC signaling, a cell ID of another base station device different from the aforesaid base station device, number of antenna ports for a cell-specific reference signal in the aforesaid other base station device, and subframe information indicating MBSFN subframes that are reserved for MBSFN, which is used as an MBSFN by the aforesaid other base station device.

[Claim 16]

The integral circuit according to Claim 15, wherein the MBSFN subframes include an OFDM symbol area in which the cell-specific reference signal is mapped, and an OFDM symbol area in which the cell-specific reference signal is not mapped.

[Claim 17]

The integral circuit according to Claim 15, wherein the subframe information contains a bitmap indicating MBSFN subframe allocation in a predetermined number of subframes.

[Claim 18]

An integrated circuit incorporated in a mobile station device communicating with a base station device,

wherein the integrated circuit receives, from the base station device by RRC signaling, a cell ID of another base station device different from the aforesaid base station

device, number of antenna ports for a cell-specific reference signal in the aforesaid other base station device, and subframe information indicating MBSFN subframes that are reserved for MBSFN, which is used as an MBSFN by the aforesaid other base station device.

[Claim 19]

The integral circuit according to Claim 18, wherein the received information is employed to mitigate interference suffered from the cell-specific reference signal that is transmitted from the aforesaid other base station device.

[Claim 20]

The integral circuit according to Claim 18, wherein the MBSFN subframes include an OFDM symbol area in which the cell-specific reference signal is mapped, and an OFDM symbol area in which the cell-specific reference signal is not mapped.

[Claim 21]

The integral circuit according to Claim 18, wherein the subframe information contains a bitmap indicating MBSFN subframe allocation in a predetermined number of subframes.