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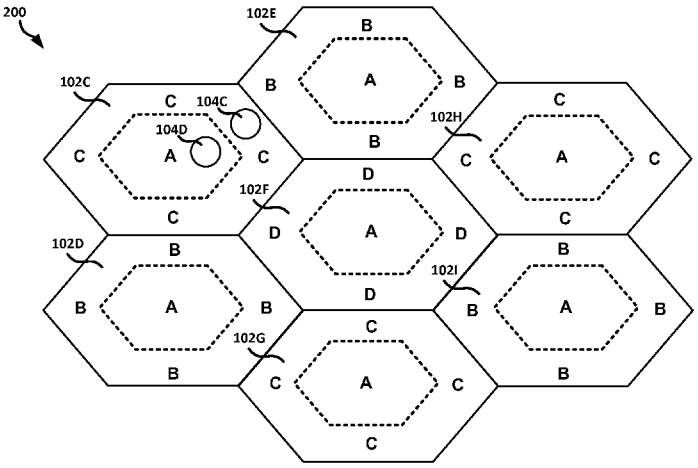


FIG. 2

(57) **Abstract**: Generally discussed herein are systems and apparatuses that can implement Physical Cell Identity assignments that reduce collision or confusion of small cell identities at User Equipment and techniques for using the same. According to an example apparatus a device can be configured to estimate a location of the small cell eNodeB based on at least one of Global Positioning System (GPS) coordinates of the location of the small cell eNodeB and an RSRP measured at the small cell eNodeB, determine if the location of the small cell eNodeB is within a first region or a second region of a large cell transmission area, wherein the first and second regions do not overlap, and in response to determining which region the small cell eNodeB is deployed in, assign a PCI code from a respective group of available PCI codes to the small cell eNodeB.

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PCI PARTITION AND ALLOCATION FOR CELLULAR NETWORK

RELATED APPLICATION

This application claims priority to United States Provisional Application serial number 61/721436, filed November 1, 2012, which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

Examples generally relate to Physical Cell Identity (PCI) and more specifically to avoiding collision or confusion between User Equipment (UE) or base stations in a cellular network (e.g., a Long Term Evolution (LTE) network).

TECHNICAL BACKGROUND

PCI can help UEs distinguish different cells from each other by distinguishing different transmitters. In LTE, each cell is assigned a PCI upon deployment. The range of PCI is currently from 0-503. Assigning PCI to a large number of cells can create a problem because no two cells in range of a UE should be assigned the same PCI. If a UE receives communications from two cells with the same PCI, a PCI confusion or PCI collision can occur. These confusions or collisions can render the UE unable to identify the cell correctly. The number of small cells (e.g., micro, pico, or femto cells) is expected to increase in the future, thus exacerbating the problem.

A collision can occur when a UE is within range of two cells that each has the same PCI assigned and are simultaneously broadcasting to the UE. A confusion can occur when the UE is within range of two cells that each have the same PCI and the UE cannot distinguish between the two cells. Thus, to avoid or reduce the number of collisions a PCI should be unique in the area that a given cell covers, and to avoid or reduce the number of confusions a cell should not have neighbor cells with identical PCIs. Confusion can cause handover procedures from one cell to another cell to fail.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings, which are not necessarily drawn to scale, like numerals may describe similar components in different views. Like numerals having different letter suffixes may represent different instances of similar components. The drawings illustrate generally, by way of example, but not by way of limitation, various embodiments discussed in the present document.

FIG. 1 illustrates an example of a Heterogeneous cellular Network (HetNet).

FIG. 2 illustrates an example of a partitioned HetNet that is configured to reduce collisions or confusions.

FIG. 3 illustrates an example of a technique for reducing the number of confusions or collisions experienced by a UE in a cellular network.

FIG. 4 is a schematic of an example of an electronic system, such as can be used in an LTE device, such as a large or small cell eNodeB, an Operations, Administration, or Maintenance (OAM) device, or a UE.

DESCRIPTION OF EMBODIMENTS

Examples in this disclosure relate to apparatuses and systems that include collision or confusion avoidance in a cellular network (e.g., an LTE network). Examples also relate to techniques of using and implementing the collision or confusion avoidance mechanisms.

The following description includes terms, such as first, second, etc. that are used for descriptive purposes only and are not to be construed as limiting. The examples of an apparatus or article described herein can be manufactured, used, or shipped in a number of positions and orientations.

Allocating PCI with only 504 unique PCI identifiers in a cell without a collision occurring can be challenging. With the number of small cells expected to be deployed in future generations of cellular networks (e.g., LTE Rel-12 and beyond) increasing, allocating PCI with only 504 unique PCI identifiers in a cell without a collision occurring can be challenging.

FIG. 1 shows an example of how a collision can occur. In the example of FIG. 1, a HetNet 100 can include two large cells 102A and 102B

(e.g., macro cells or Primary cells (Pcells)), with each large cell 102A and 102B including a respective small cell 104A and 104B (e.g., micro cells, pico cells, or femto cells, or Secondary cells (Scells)). Each of the large cells 102A and 102B and small cells 104A and 104B can include a respective base station 110A, 110B, 110C, and 110D (e.g., enhanced Node B (eNodeB)). The HetNet 100 can include an Operations, Administration, and Maintenance device 108 communicatively coupled to the base stations 110A-110D. The small cells 104A or 104B can be communicatively coupled to the OAM 108 through the nearest, respective large cell 102A and 102B, such as to communicate to the OAM 108 by transmitting a communication from a base station 110C or 110D to a base station 110A or 110B, respectively, which can forward the communication to the OAM 108.

The small cells 104A and 104B are physically close to each other and each has the same PCI code of "1" in this example. The UE 106 situated between the two small cells 104A may not be able to distinguish between the two small cells 104A and 104B if it is within range of both small cells 104A and 104B simultaneously, because they have the same PCI. This is what is known as PCI collision.

As used herein, "large cell" refers to what is commonly known as a macro cell. Macrocells can have a transmission area of between about 1 kilometers and 30 kilometers, or even larger. As compared to "small cells", large cells require more electric power to operate. As used herein, "small cell" refers to what are commonly known as microcells, picocells, and femtocells, or cells that are not considered "large cells" because of their transmission area or power requriements. A microcell can have a transmission area of between about 200 meters and 2 kilometers, a picocell can have a transmission area of between about 4 and 200 meters, and a femtocell can have a transmission area even smaller than that of a picocell. The large cell can provide the main coverage area of the cellular network and the small cell can complement the coverage area, such as to extend the coverage area or provide hot spots with relatively good cellular network connectivity and bandwidth in their transmission area.

Thus, a small cell can reside within the large cell and can serve an area that is substantially smaller than the area served by the large cell.

In the current Third Generation Partnership Project (3GPP) specification, there are two PCI selection mechanisms: 1) centralized PCI assignment and 2) distributed PCI assignment. In centralized PCI assignment, the OAM device 108 signals a specific PCI value and a base station 110 (note that 110 as used herein, refers to base stations generally) can assign this value to the given cell. In distributed PCI assignment, the OAM device 108 signals a list of PCI values and the base station 110 can restrict this list by removing PCIs that are or have been reported by a UE 106 or are or have been reported by as used by a neighboring base station 110, such as over an x2 interface. Then the base station 110 can select a PCI value for the cell (e.g., randomly) from the remaining list of PCIs.

This disclosure proposes a number of PCI partitioning and allocation schemes that can reduce collisions or confusions. Available PCI codes can be split into N groups, such as an integer number of equal or unequal size groups. For example, assume there are 504 codes available for allocation to small cells 104 (note that 104 as used herein refers to small cells generally) in a given large cell transmission area. In a partition of N=4 groups, the 504 codes, {0-503}, can be split into group 1={0-150}; group 2={151-303}, group 3={304-403}; and group 4={404-503}. When a small cell 104 is deployed, the PCI assignment can be based on (e.g., a function of) a Reference Signal Received Power (RSRP) measured at a small cell 104 base station 110. The reference signal can be sent from a large cell 102. Note that "102" as used herein refers to large cells generally. As used herein "when" can mean "at or around the time", "after", or "in response to" as is appropriate for the context of usage.

A large cell 102 can include an RSRP map (e.g., a map that depicts generally the different areas of the large cell 102 transmission area that include relatively weak, and relatively strong, etc. RSRP). An OAM device 108 can be responsible for dictating the partitioning of the PCI codes relative to the RSRP map. Each partition of the PCI codes can map to a region on the RSRP map. When a small cell 104 is deployed, the map can be used to help determine the

PCI code assignment. A PCI code can be picked at random for assignment or a fixed assignment protocol can be used (e.g., the PCI codes can be assigned in a predetermined order, such as alphabetical, numerical, alpha-numeric, or other order). A Global Positioning System (GPS) can help verify that the small cell 104 is in a particular location. Alternatively, the GPS can be used to determine the location of the deployed small cell 104, instead of using the RSRP value measured at the small cell 104 base station 110.

FIG. 2 shows an example of a network 200 that can include a number of large cells 102C, 102D, 102E, 102F, 102G, 102H, and 102I, some of which are contiguous with one another. In this example, all large cells 102C-102I have a region "A" (the region of the large cell 102C-102I that extends from the center of the respective large cell 102C-102I to the dotted line in the respective large cell 102C-102I). It is assumed, for simplicity, that a base station 110 (see FIG. 1) is positioned at the center of each large cell 102. Region "A" can correspond to a region in which a small cell 104 deployed therein is likely to measure an RSRP that is relatively high (e.g., an RSRP signal that is greater than one or more specified thresholds). This can be due to the base station 110 being relatively close to the small cell 104 when the small cell 104 is deployed in region "A". Note that small cell 104D is deployed in region "A" of large cell 102C.

The small cells 104 located in the outer region, the region from the respective dotted line to the respective outer edge of the large cell 102 (e.g., region "B" of large cell 102D, 102E, and 102I; region "C" of large cell 102C, 102G, and 102H; and region "D" of large cell 102F) are likely to measure a relatively low RSRP (e.g., an RSRP that is less than or equal to a specified threshold or generally less than an RSRP measurement made from a base station 110 deployed in a region "A"). Note that small cell 104C is located in the outer region "C" of large cell 102C. A small cell 104 located in these large cells 102C-102I can be assigned, for example, a PCI code from the code group "1" if they are determined to reside in region "A", a PCI code from the code group "2" if they are determined to reside in region "B", group "3" if they are determined to reside in region "C", group "4" if they are determined to reside in region "D".

In the example of FIG. 2, no two neighboring large cell 102C-102I regions (e.g., edges) are allocated the same group of PCI codes. The PCI allocation in this example can be relatively collision free, such as if the PCI codes are only used once.

Other configurations can be used in other examples. For example, each cell can be partitioned into fewer or more regions. The fewer or more regions can each correspond to specific ranges of RSRP values received at the base station 110, specific GPS coordinates received, or a combination thereof. It can be advantageous to configure two neighboring regions to be disjoint (e.g., non-overlapping) or be allocated PCI groups that are disjoint (e.g., do not overlap or contain a same element). Using such a configuration can help reduce collisions or confusions experienced by a UE 106.

The allocation or assignment of PCI codes can be geographically based, such as by using GPS coordinates to allocate or assign PCI codes based on geographic location. A combination of GPS coordinates corresponding to a location of a small cell 104 and RSRP received at the base station can be used to allocate to a small cell 104 a PCI code from a specific group of PCI codes.

In one or more embodiments, a base station 110 (e.g., a large cell eNodeB or a small cell eNodeB) or OAM 108 can determine if the RSRP value is greater than a specified threshold. In response to determining the RSRP is greater than the threshold, the base station 110 or OAM 108 can choose a PCI code (e.g., randomly or otherwise) from a group of available PCI codes and the base station 110 or OAM 108 can assign a specific PCI code to the deployed small cell 104 base station 110.

In the example of FIG. 2, after, or during, small cell 104 deployment and in response to determining the RSRP is greater than a specified threshold, the base station 110 or OAM 108 can determine that the small cell 104 is in region "A" (i.e. the region from the center of the large cell 102C, 102D, 102E, 102F, 102G, 102H, or 102I to the dotted line within the respective cell) and can assign a PCI code from a predetermined set of PCI codes allocated for that region to the small cell 104. In the example of FIG. 2, all regions labeled "A" can have small cells 104 with PCI codes allocated from the same group of PCI codes. That is,

for example, region "A" of large cell 102C can include small cells allocated with a PCI code from group "1", region "A" of large cell 102B can include small cells allocated with PCI codes from group "1", and so on.

If the received RSRP measurement is less than the specified threshold, the respective large cell 102C-102I can assign a PCI value from a different group of PCI codes that corresponds to a region further from the center of the cell or outside of region "A". In FIG.2 each of these regions is labeled "B", "C", and "D". These regions each extend from the dotted line to the periphery of their respective large cell 102C-102I. Note that RSRP can be used to accomplish this assignment because the RSRP generally decreases as the reference signal received traverses a further distance, which generally corresponds to the cell being further from the base station.

By allocating different PCI code groups to the outer regions (e.g., "B", "C", and "D") and configuring adjacent outer regions to include different PCI code groups (e.g., in FIG. 2, region "B" is not contiguous with any other region "B", region "C" is not contiguous with any other region "C", and region "D" is not contiguous with any other region "D"), the likelihood of having a collision or confusion at a UE can be reduced. The likelihood can be further reduced by having a minimum distance between two regions that are allocated the same PCI code group. In the example of FIG. 2, the minimum distance between like PCI code groups is a large cell edge length.

In one or more embodiments, if a small cell 104 is determined to be within the region "A" of large cell 102C, 102G, or 102H, a PCI code from the group including PCI codes from groups "1", "2", and "4" can be selected and assigned to the small cell base station. In these embodiments, group "3" can be assigned to small cells 104 deployed in the outer region "C" of the large cells 102C, 102G, and 102H. Similar PCI group allocations and assignments can be made in the other large cells 102D, 102E, 102F, and 102I. If a small cell 104 is determined to be within the region "A" of large cell 102D, 102E, or 102I, a PCI code from the group including PCI codes from groups "1", "3", and "4" can be selected and assigned to the small cell 104 base station 110. In these embodiments, group "2" can be assigned to small cells 104 deployed in the outer

region "B" of the large cells 102D, 102E, and 102I. If a small cell 104 is determined to be within the region "A" of large cell 102F a PCI code from the group including PCI codes from groups "1", "2", and "3" can be selected and assigned to the small cell 104 base station 110. In these embodiments, group "4" can be assigned to small cells 104 deployed in the outer region "D" of the large cell 102F.

Since no two neighboring (e.g., contiguous or adjacent) large cells 102, of the example shown in FIG. 2, have the same group of available PCI codes assigned to outer regions thereof, the system can be relatively or completely collision and confusion free, such as in an ideal case (e.g., where there are no large cells that are reusing PCI codes because there are too many small cells deployed therein).

When the group of available PCI codes has become the empty set, previously assigned PCI codes may be used again. In such cases, a collision or confusion may occur. By mapping where each PCI code is assigned, such as in the OAM 108 or a base station 110, a repeat PCI code can be intelligently selected so as to reduce the risk of collision or confusion. One such technique of assigning a repeat PCI code is to assign a PCI code previously assigned to a small cell 104 that is outside the transmission area or a small cell 104 that is a minimum distance away from the small cell that is being deployed.

There could be several approaches to allocating a PCI code to a small cell 104. The approach can vary depending on which entity determines the PCI code for the small cell 104.

If a large cell 102 base station 110 assigns the PCI code to the small cell 104 base station 110, then the following techniques can be used. After the small cell 104 powers on, it can operate as if it is a normal UE. The small cell 104 base station 110 can attach to a nearby large cell 102 (e.g., the closest large cell 102). In one or more embodiments, a relay can be used. The small cell 104 base station 110 can indicate to the large cell 102 base station 110 that it is the small cell 104 base station 110.

The small cell 104 base station 110 can measure an RSRP of a reference signal received from the large cell 102. RSRP can be determined based on a

single received reference signal, an average of a plurality of received reference signals, or other method of determining RSRP. Measuring the RSRP can be done in a way so as to account for an anomaly in the received reference signal. The small cell 104 base station 110 can send a measurement report including RSRP of the reference signal(s). If possible, the small cell 104 base station 110 can also send the measurement report including RSRP of the neighboring small cells 104.

The large cell 102 can use the RSRP map and determine the PCI group based on the RSRP value received from the small cell 104. The large cell 102 can send the PCI code (e.g., randomly chosen from the group) to the small cell 104. Alternatively, the large cell 102 can send a list of available PCI codes to the small cell 104. The small cell 104 base station 110 can choose one of the PCI codes (e.g., randomly). The small cell 104 can indicate to the large cell 102 which PCI code was chosen. The large cell 102 can mark the PCI as used. The large cell 102 can relay to the OAM 108 which PCI code was used. The PCI code that was chosen may not be used again until all the PCI codes in the respective group have been used. The small cell 104 base station 110 can reconfigure and operate as a base station 110 (e.g., instead of as a UE 106) with the assigned PCI code.

If a small cell 104 base station 110 assigns the PCI code to itself, then the following techniques can be used. After the small cell 104 base station 110 powers on, it can register to OAM 108. The small cell 104 base station 110 can send its location information to the OAM 108. Alternatively, the small cell 104 can measure RSRP from multiple large cell 102 base stations 110 and determine which base station 110 is the closest or has the highest RSRP measurement.

The OAM 108 can provide a group of available PCI codes that correspond to the location information the small cell 104 has sent. The group of available PCI codes in each group can be PCI codes not yet assigned to other small cells 104. The OAM 108 can provide one or more thresholds to the small cell 104. The OAM 108 can indicate to the small cell 104 which group of available PCI codes corresponds to a respective range of locations or a respective range of RSRP measurements. For example, the OAM 108 can

indicate that if the RSRP measurement is less than a first threshold, then the small cell 104 is to choose a PCI code from group "1", and if the RSRP measurement is greater than or equal to the first threshold, then the small cell is to choose a PCI code from group "3".

The small cell 104 can measure an RSRP of a reference signal from the large cell 102. Based on the measurement result, the small cell 104 can select the appropriate group of available PCI codes. If there are multiple PCIs in the selected group, the small cell 104 can choose one of them randomly. The small cell 104 can measure the RSRP when it has dual Radio Frequency (RF) capability to receive the reference signal from the large cell 102 base station 110 or when the small cell 104 base station 110 operates its own frequency carrier. If the small cell 104 base station 110 does not have the dual RF capability or the ability to operate its own frequency carrier, the small cell 104 base station 110 can select the group, and the corresponding PCI code, based on an RSRP measurement from a neighboring cell, such as from a UE 106 or base station 110 within the transmission area of the small cell 104 base station 110 that can measure the RSRP of the neighboring cell. Alternatively, the small cell 104 base station 110 can estimate the RSRP based on its location (e.g., GPS coordinates) or the location of a large cell 102 base station 110.

If an OAM device 108 assigns the PCI code to the small cell 104 base station 110, then the following techniques can be used. When the small cell 104 base station 110 powers on, the small cell 104 can send RSRP information to OAM 108. If the small cell 104 cannot measure RSRP, the small cell 104 can send its GPS location to the OAM 108. The OAM 108 can look up the small cell 104 location relative to the large cell 102 that the small cell 104 base station 110 will be communicating, either directly or indirectly, with. A group of available PCI codes can be selected from a mapping table. The OAM 108 can send a PCI code from the group of available PCI codes to small cell 104, such as a randomly selected PCI code. The OAM 108 can mark which PCI code was used, such as to help avoid another small cell 104 base station 110 being assigned the same PCI. If the small cell 104 base station 110 does not have GPS capability, an RF chain (e.g., the capability to measure RSRP), or other means of

determining its location, the OAM 108 can assign an unused PCI code from any of the groups of available PCI codes. The OAM 108 can send the selected PCI code to the large cell 102 base station 110, which can forward the PCI code to the small cell 104 base station 110.

Due to imperfect beam shape, there may be some overlapping that can cause a PCI collision. In that case, the regular procedure to resolve the PCI collision in the current specification can be performed. Such resolutions can include a UE 106 reporting the collision or confusion to a base station 110 and the base station 110 assigning a different PCI code to the small cell 104 or the base station 110 forwarding the collision or confusion report to the OAM 108 and the OAM 108 assigning a different PCI code to the small cell 104.

FIG. 3 is a block diagram of an example of a technique 300 to help reduce the number of PCI collisions or confusion in a cellular network. The method can include a PCI code to a small cell base station as a function of a location of the small cell base station. At 302, a location of a small cell base station can be estimated. The location estimation can be based on GPS coordinates of the small cell base station or an RSRP measured at the small cell base station. Estimating the location of the small cell base station can include comparing the RSRP to a first threshold. Estimating the location of the small cell base station can include comparing the RSRP to a second threshold. The second threshold can be less than the first threshold.

At 304, it can be determined if the location of the small cell base station is within a first region or a second region of a large cell transmission area. The first and second regions of the large cell transmission area can be disjoint or non-overlapping. The technique can include determining if the location of the small cell base station is within a third region of the large cell transmission area. The first, second, and third regions can be disjoint or non-overlapping. The first region can be a region of the large cell transmission area extending outward from a base station of the large cell. The second region can be a region of the large cell transmission area extending outward from an outer edge of the first region. The third region can be a region of the large cell transmission area extending outward from an outer edge of the second region.

At 306, if the small cell base station is determined to be in the first region, a PCI code from a first group of available PCI codes can be assigned to the small cell base station. The small cell base station can be determined to be within the first region if it is determined that the measured RSRP is greater than (or equal to) the first threshold. Assigning the PCI code from the first group of available PCI codes can include randomly choosing a PCI code from the first group of available PCI codes and assigning the randomly chosen PCI code to the small cell base station.

At 308, if the small cell base station is determined to be within the second region, a PCI code from a second group of available PCI codes can be assigned to the small cell base station. The first and second groups of available PCI codes can be disjoint. The small cell base station can be determined to be within the second region if it is determined that the measured RSRP is less than (or equal to) the second threshold. The small cell base station can be determined to be within the second region if it is determined that the measured RSRP is greater than (or equal to) the second threshold and less than the first threshold.

The small cell base station can be determined to be within the third region if it is determined that the RSRP is less than (or equal to) the second threshold.

The technique can include registering the small cell base station to an OAM device. The technique can include receiving the first threshold value from the OAM. The technique can include receiving the first and second sets of available PCI codes from the OAM. The technique can include indicating to the OAM device which PCI code was assigned.

FIG. 4 is a block diagram of a computing device, according to an example embodiment. One or more of the foregoing examples of UEs 106, base stations 110, OAMs 108, or other devices that is configured to allocate or partition PCI codes, may include a computing system, such as computing system 400 of FIG. 4. In one or more embodiments, multiple such computer systems are utilized in a distributed network to implement multiple components in a transaction based environment. An object-oriented, service-oriented, or other architecture may be used to implement such functions and communicate between

the multiple systems and components. One example computing device in the form of a computer 410 may include a processing unit 402, memory 404, removable storage 412, and non-removable storage 414. Memory 404 may include volatile memory 406 and non-volatile memory 408. Computer 410 may include – or have access to a computing environment that includes – a variety of computer-readable media, such as volatile memory 406 and non-volatile memory 408, removable storage 412 and non-removable storage 414. Computer storage includes random access memory (RAM), read only memory (ROM), erasable programmable read-only memory (EPROM) & electrically erasable programmable read-only memory (EEPROM), flash memory or other memory technologies, compact disc read-only memory (CD ROM), Digital Versatile Disks (DVD) or other optical disk storage, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices, or any other medium capable of storing computer-readable instructions. Computer 410 may include or have access to a computing environment that includes input 416, output 418, and a communication connection 420. The computer may operate in a networked environment using a communication connection to connect to one or more remote computers, such as database servers. The remote computer may include a personal computer (PC), server, router, network PC, a peer device or other common network node, or the like. The communication connection may include a Local Area Network (LAN), a Wide Area Network (WAN) or other networks.

Computer-readable instructions stored on a machine-readable storage device are executable by the processing unit 402 of the computer 410. A hard drive, CD-ROM, and RAM are some examples of articles including a non-transitory computer-readable medium. For example, a computer program 425 capable of providing instructions, which when executed by the processing unit 402 or other machine capable of executing the instructions, cause the processing unit to perform allocation or assignment of PCI based on a location of a small cell, such as a small cell that is being deployed. The instructions can be saved on a CD-ROM and loaded from the CD-ROM to a hard drive of the computer 410. The computer-readable instructions can allow the computer 410 (e.g., the processing unit 402) to implement the partition or assigning algorithm.

EXAMPLES AND NOTES

The present subject matter may be described by way of several examples.

Example 1 can include or use subject matter (such as an apparatus, a method, a means for performing acts, or a device readable memory including instructions that, when performed by the device, can cause the device to perform acts), such as can include or use an LTE device configured to assign a PCI code to a small cell eNodeB based on a location of the small cell eNodeB, wherein the LTE device can be configured to: (1) estimate a location of the small cell eNodeB based on at least one of Global Positioning System (GPS) coordinates of the location of the small cell eNodeB and an RSRP measured at the small cell eNodeB, (2) determine if the location of the small cell eNodeB is within a first region or a second region of a large cell transmission area, wherein the first and second regions do not overlap, (3) in response to determining the small cell eNodeB is within the first region, assign a PCI code from a first group of available PCI codes to the small cell eNodeB; and (4) in response to determining the small cell eNodeB is within the second region, assign a PCI code from a second group of available PCI codes to the small cell eNodeB, wherein the first group of PCI codes and the second group of PCI codes are disjoint.

Example 2 can include or use, or can optionally be combined with the subject matter of Example 1, to optionally include or use wherein the device is configured to perform at least one of: (1) estimate the location of the small cell eNodeB based on the RSRP measured at the small cell eNodeB, (2) compare the RSRP to a threshold, (3) in response to determining the RSRP is less than or equal to the threshold, determining the small cell eNodeB is within the second region, and (4) in response to determining the RSRP is greater than the threshold, determining the small cell eNodeB is within the first region.

Example 3 can include or use, or can optionally be combined with the subject matter of at least one of Examples 1-2, to optionally include or use wherein the LTE device is a large cell eNodeB.

Example 4 can include or use, or can optionally be combined with the subject matter of at least one of Examples 1-2, to optionally include or use

wherein the LTE device is the small cell eNodeB, and the small cell eNodeB is further configured to perform at least one of: (1) register to an Operations, Administration, and Maintenance (OAM) device, receive the threshold value from the OAM, and receive the first and second sets of available PCI codes from the OAM.

Example 5 can include or use, or can optionally be combined with the subject matter of at least one of Examples 1-2, to optionally include or use wherein the LTE device is an Operations, Administration, and Maintenance (OAM) device.

Example 6 can include or use, or can optionally be combined with the subject matter of at least one of Examples 1-5, to optionally include or use wherein the assigned PCI code is chosen randomly from the respective first and second groups of available PCI codes.

Example 7 can include or use, or can optionally be combined with the subject matter of at least one of Examples 1-6 to optionally include or use wherein the location of the small cell eNodeB is estimated base on the GPS coordinates.

Example 8 can include or use, or can be optionally be combined with the subject matter of at least one of Examples 1-7, to include subject matter (such as an apparatus, a method, a means for performing acts, or a device readable memory including instructions that, when performed by the device, can cause the device to perform acts), such as can include or use at least one of (1) estimating a location of the small cell eNodeB based on at least one of Global Positioning System (GPS) coordinates of the location of the small cell eNodeB and an RSRP measured at the small cell eNodeB, (2) determining if the location of the small cell eNodeB is within a first region or a second region of a large cell transmission area, wherein the first and second regions do not overlap, (3) in response to determining the small cell eNodeB is within the first region, assigning a PCI code from a first group of available PCI codes to the small cell eNodeB, and (4) in response to determining the small cell eNodeB is within the second region, assigning a PCI code from a second group of available PCI codes to the small cell eNodeB, wherein the first group of PCI codes and the second group of PCI codes are disjoint.

Example 9 can include or use, or can optionally be combined with the subject matter of at least one of Examples 1-8 to optionally include or use at least one of: (1) comparing the RSRP to a threshold, in response to determining the RSRP is less than or equal to the threshold, determining the small cell eNodeB is within the second region, and in response to determining the RSRP is greater than the threshold, determining the small cell eNodeB is within the first region.

Example 10 can include or use, or can optionally be combined with the subject matter of at least one of Examples 1-9 to optionally include or use at least one of: (1) registering the small cell eNodeB to an Operations, Administration, and Maintenance (OAM) device, (2) receiving the threshold value from the OAM, and (3) receiving the first and second sets of available PCI codes from the OAM.

Example 11 can include or use, or can optionally be combined with the subject matter of at least one of Examples 1-10 to optionally include or use wherein assigning the PCI code from the first group of available PCI codes includes randomly assigning the PCI code from the first group of available PCI codes.

Example 12 can include or use, or can optionally be combined with the subject matter of at least one of Examples 1-11 to optionally include or use communicating to an Operations, Administration, and Maintenance device which PCI code was assigned.

Example 13 can include or use, or can optionally be combined with the subject matter of at least one of Examples 1-12 to optionally include or use wherein the first region corresponds to a region of the large cell extending outward from an eNodeB of the large cell and the second region corresponds to a region of the large cell extending outward from an outer edge of the first region.

Example 14 can include or use, or can optionally be combined with the subject matter of at least one of Examples 1-13 to optionally include or use wherein the threshold is a first threshold, wherein determining if the location of the small cell eNodeB is within the first region or the second region further includes determining if the location of the small cell eNodeB is within a third region of the large cell transmission area, wherein the first, second, and third

regions do not overlap. Example 14 can optionally include or use at least one of: (1) comparing the RSRP to a second threshold, the second threshold less than the first threshold, in response to determining the RSRP is less than or equal to the second threshold and less than the first threshold, determining the small cell eNodeB is within the third region, and wherein determining the small cell eNodeB is within the second region includes further determining that the RSRP is greater than the second threshold and less than or equal to the first threshold.

The above detailed description includes references to the accompanying drawings, which form a part of the detailed description. The drawings show, by way of illustration, specific embodiments in which methods, apparatuses, and systems discussed herein can be practiced. These embodiments are also referred to herein as "examples." Such examples can include elements in addition to those shown or described. However, the present inventors also contemplate examples in which only those elements shown or described are provided. Moreover, the present inventors also contemplate examples using any combination or permutation of those elements shown or described (or one or more aspects thereof), either with respect to a particular example (or one or more aspects thereof), or with respect to other examples (or one or more aspects thereof) shown or described herein.

In this document, the terms "a" or "an" are used, as is common in patent documents, to include one or more than one, independent of any other instances or usages of "at least one" or "one or more." In this document, the term "or" is used to refer to a nonexclusive or, such that "A or B" includes "A but not B," "B but not A," and "A and B," unless otherwise indicated. In this document, the terms "including" and "in which" are used as the plain-English equivalents of the respective terms "comprising" and "wherein." Also, in the following claims, the terms "including" and "comprising" are open-ended, that is, a system, device, article, composition, formulation, or process that includes elements in addition to those listed after such a term in a claim are still deemed to fall within the scope of that claim. Moreover, in the following claims, the terms "first," "second," and "third," etc. are used merely as labels, and are not intended to impose numerical requirements on their objects.

The above description is intended to be illustrative, and not

restrictive. For example, the above-described examples (or one or more aspects thereof) may be used in combination with each other. Other embodiments can be used, such as by one of ordinary skill in the art upon reviewing the above description. The Abstract is provided to comply with 37 C.F.R. §1.72(b), to allow the reader to quickly ascertain the nature of the technical disclosure. It is submitted with the understanding that it will not be used to interpret or limit the scope or meaning of the claims. Also, in the above Detailed Description, various features may be grouped together to streamline the disclosure. This should not be interpreted as intending that an unclaimed disclosed feature is essential to any claim. Rather, inventive subject matter may lie in less than all features of a particular disclosed embodiment. Thus, the following claims are hereby incorporated into the Detailed Description as examples or embodiments, with each claim standing on its own as a separate embodiment, and it is contemplated that such embodiments can be combined with each other in various combinations or permutations. The scope of the invention should be determined with reference to the appended claims, along with the full scope of equivalents to which such claims are entitled.

What is claimed is:

1. A Long Term Evolution (LTE) device configured to assign a Physical Cell Identity (PCI) code to a small cell eNodeB based on a location of the small cell eNodeB, wherein the LTE device is configured to:

estimate a location of the small cell eNodeB based on at least one of Global Positioning System (GPS) coordinates of the location of the small cell eNodeB and an RSRP measured at the small cell eNodeB;

determine if the location of the small cell eNodeB is within a first region or a second region of a large cell transmission area, wherein the first and second regions do not overlap;

in response to determining the small cell eNodeB is within the first region, assign a PCI code from a first group of available PCI codes to the small cell eNodeB; and

in response to determining the small cell eNodeB is within the second region, assign a PCI code from a second group of available PCI codes to the small cell eNodeB, wherein the first group of PCI codes and the second group of PCI codes are disjoint.

2. The LTE device of claim 1, wherein the device is configured to:

estimate the location of the small cell eNodeB based on the RSRP measured at the small cell eNodeB;

compare the RSRP to a threshold;

in response to determining the RSRP is less than or equal to the threshold, determining the small cell eNodeB is within the second region; and

in response to determining the RSRP is greater than the threshold, determining the small cell eNodeB is within the first region.

3. The LTE device of claim 2, wherein the LTE device is a large cell eNodeB.

4. The LTE device of claim 2, wherein the LTE device is the small cell eNodeB, and the small cell eNodeB is further configured to:

register to an Operations, Administration, and Maintenance (OAM) device;

receive the threshold value from the OAM; and

receive the first and second sets of available PCI codes from the OAM.

5. The LTE device of claim 2, wherein the LTE device is an Operations, Administration, and Maintenance (OAM) device.

6. The LTE device of claim 2, wherein the assigned PCI code is chosen randomly from the respective first and second groups of available PCI codes.

7. The LTE device of claim 1, wherein the location of the small cell eNodeB is estimated base on the GPS coordinates.

8. A method of assigning a Physical Cell Identity (PCI) code to a small cell eNodeB as a function of a location of the small cell eNodeB, the method comprising:

estimating a location of the small cell eNodeB based on at least one of Global Positioning System (GPS) coordinates of the location of the small cell eNodeB and an RSRP measured at the small cell eNodeB;

determining if the location of the small cell eNodeB is within a first region or a second region of a large cell transmission area, wherein the first and second regions do not overlap;

in response to determining the small cell eNodeB is within the first region, assigning a PCI code from a first group of available PCI codes to the small cell eNodeB; and

in response to determining the small cell eNodeB is within the second region, assigning a PCI code from a second group of available PCI codes to the small cell eNodeB, wherein the first group of PCI codes and the second group of PCI codes are disjoint.

9. The method of claim 8, wherein estimating the location of the small cell eNodeB based on the RSRP measured at the small cell eNodeB includes:

comparing the RSRP to a threshold;

in response to determining the RSRP is less than or equal to the threshold, determining the small cell eNodeB is within the second region; and

in response to determining the RSRP is greater than the threshold, determining the small cell eNodeB is within the first region.

10. The method of claim 9, further comprising:

registering the small cell eNodeB to an Operations, Administration, and Maintenance (OAM) device;

receiving the threshold value from the OAM; and

receiving the first and second sets of available PCI codes from the OAM.

11. The method of claim 10, wherein assigning the PCI code from the first group of available PCI codes includes randomly assigning the PCI code from the first group of available PCI codes.

12. The method of claim 8, further comprising:

communicating to an Operations, Administration, and Maintenance device which PCI code was assigned.

13. The method of claim 8, wherein the first region corresponds to a region of the large cell extending outward from an eNodeB of the large cell and the second region corresponds to a region of the large cell extending outward from an outer edge of the first region.

14. The method of claim 9, wherein the threshold is a first threshold, wherein determining if the location of the small cell eNodeB is within the first region or the second region further includes determining if the location of the small cell eNodeB is within a third region of the large cell transmission area, wherein the first, second, and third regions do not overlap, and the method further comprises:

comparing the RSRP to a second threshold, the second threshold less

than the first threshold;

in response to determining the RSRP is less than or equal to the second threshold and less than the first threshold, determining the small cell eNodeB is within the third region; and

wherein determining the small cell eNodeB is within the second region includes further determining that the RSRP is greater than the second threshold and less than or equal to the first threshold.

15. A non-transitory computer readable storage device comprising instructions stored thereon, the instructions, which when executed by a machine, cause the machine to perform operations comprising:

estimating a location of a small cell eNodeB based on at least one of Global Positioning System (GPS) coordinates of the small cell eNodeB and an RSRP measured at the small cell eNodeB;

determining if the location of the small cell eNodeB is within a first region or a second region of a large cell transmission area, wherein the first and second regions do not overlap;

in response to determining the small cell eNodeB is within the first region, assigning a PCI code from a first group of available PCI codes to the small cell eNodeB; and

in response to determining the small cell eNodeB is not within the first region, assigning a PCI code from a second group of available PCI codes to the small cell eNodeB, wherein the first group of PCI codes and the second group of PCI codes are disjoint.

16. The storage device of claim 15, further comprising instructions stored thereon, which when executed by the machine, cause the machine to further perform operations comprising:

comparing the RSRP to a threshold;

in response to determining the RSRP is less than or equal to the threshold, determining the small cell eNodeB is within the second region; and

in response to determining the RSRP is greater than the threshold,

determining the small cell eNodeB is within the first region.

17. The storage device of claim 16, further comprising instructions stored thereon, which when executed by the machine, cause the machine to further perform operations comprising:

registering the small cell eNodeB to an Operations, Administration, and Maintenance (OAM) device;

receiving the threshold value from the OAM; and

receiving the first and second sets of available PCI codes from the OAM.

18. The storage device of claim 16, wherein the instructions for assigning the PCI code from the first group of available PCI codes include instructions for randomly assigning the PCI code from the first group of available PCI codes.

19. The storage device of claim 16, further comprising instructions stored thereon, which when executed by the machine, cause the machine to further perform operations comprising:

communicating to an Operations, Administration, and Maintenance device which PCI code was assigned.

20. The storage device of claim 19, wherein the first region corresponds to a region of the large cell extending outward from an eNodeB of the large cell and the second region corresponds to a region of the large cell extending outward from outer edge of the first region.

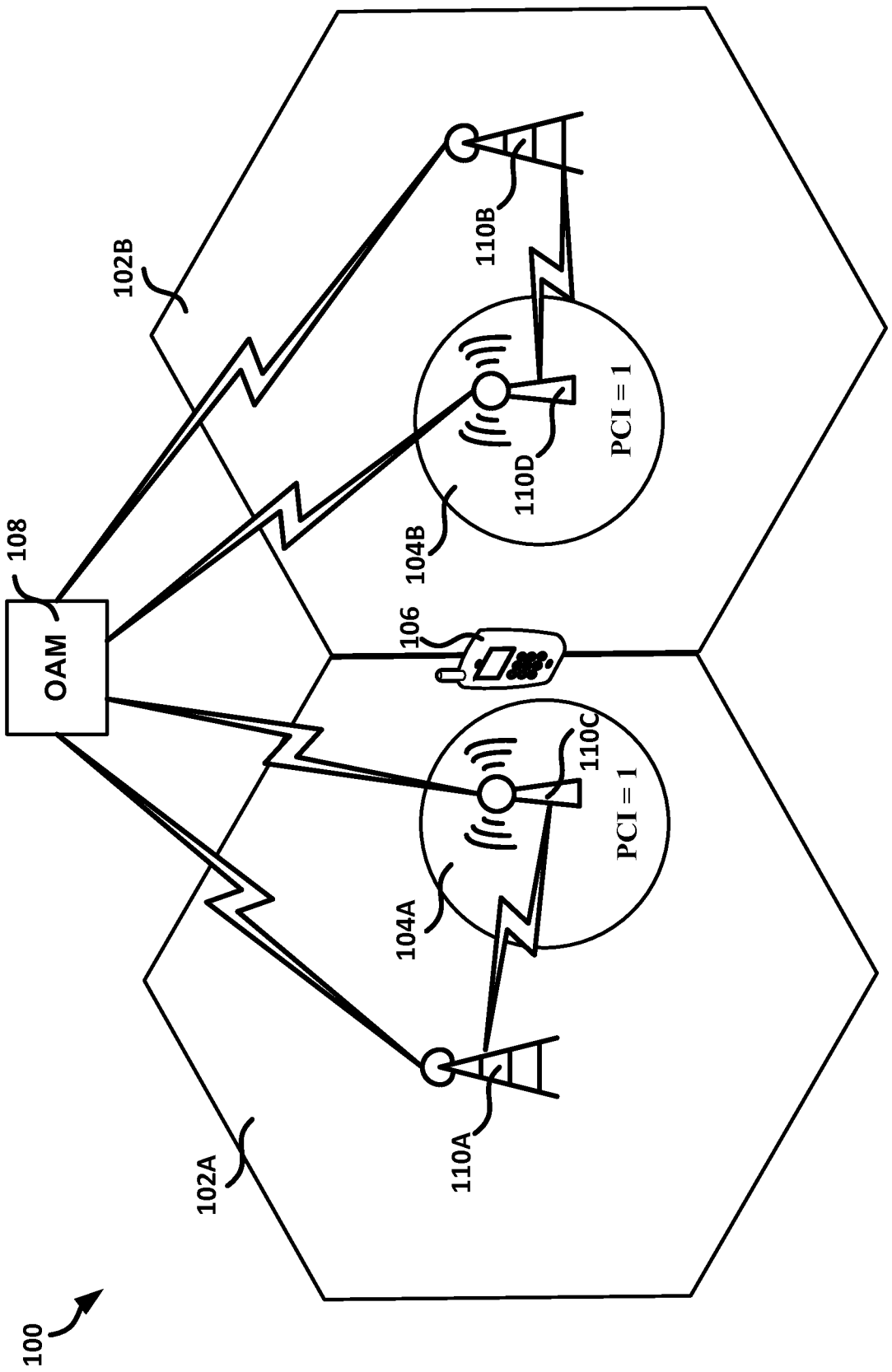

100
102A
102B
108
OAM
104A
104B
106
110A
110B
110C
110D
PCI = 1
PCI = 1

FIG. 1

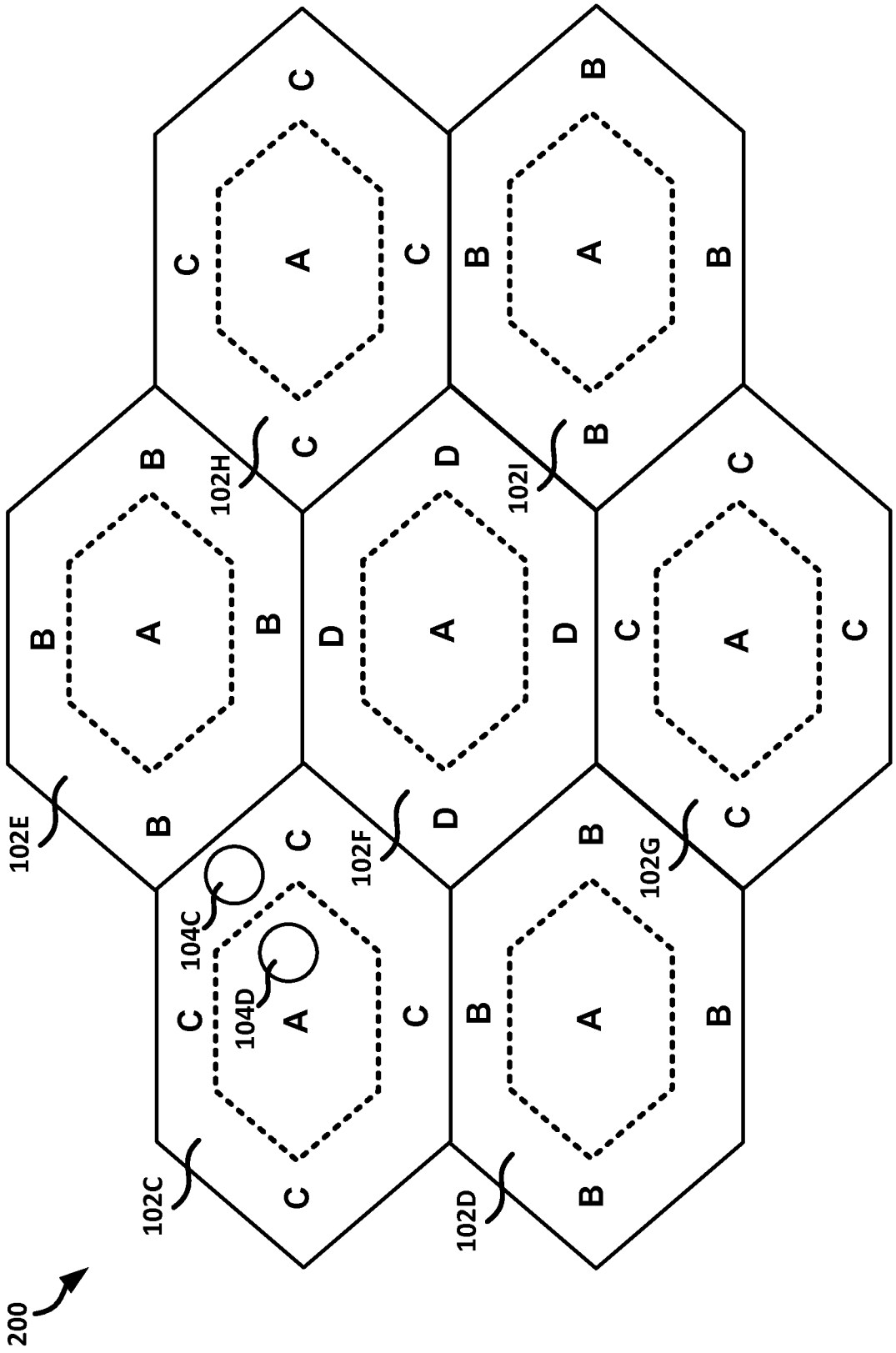


FIG. 2

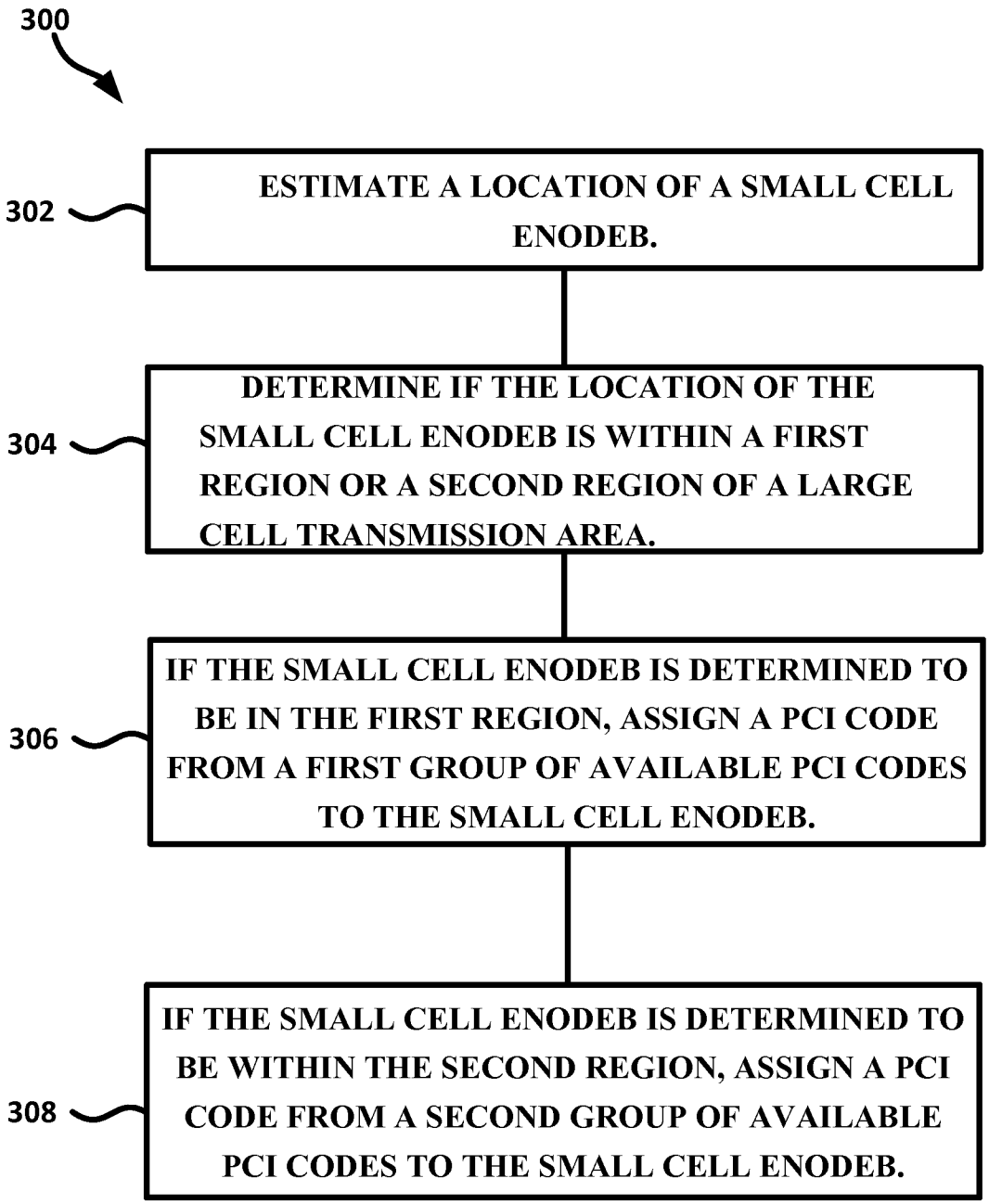

300
302
ESTIMATE A LOCATION OF A SMALL CELL ENODEB.
304
DETERMINE IF THE LOCATION OF THE SMALL CELL ENODEB IS WITHIN A FIRST REGION OR A SECOND REGION OF A LARGE CELL TRANSMISSION AREA.
306
IF THE SMALL CELL ENODEB IS DETERMINED TO BE IN THE FIRST REGION, ASSIGN A PCI CODE FROM A FIRST GROUP OF AVAILABLE PCI CODES TO THE SMALL CELL ENODEB.
308
IF THE SMALL CELL ENODEB IS DETERMINED TO BE WITHIN THE SECOND REGION, ASSIGN A PCI CODE FROM A SECOND GROUP OF AVAILABLE PCI CODES TO THE SMALL CELL ENODEB.

FIG. 3

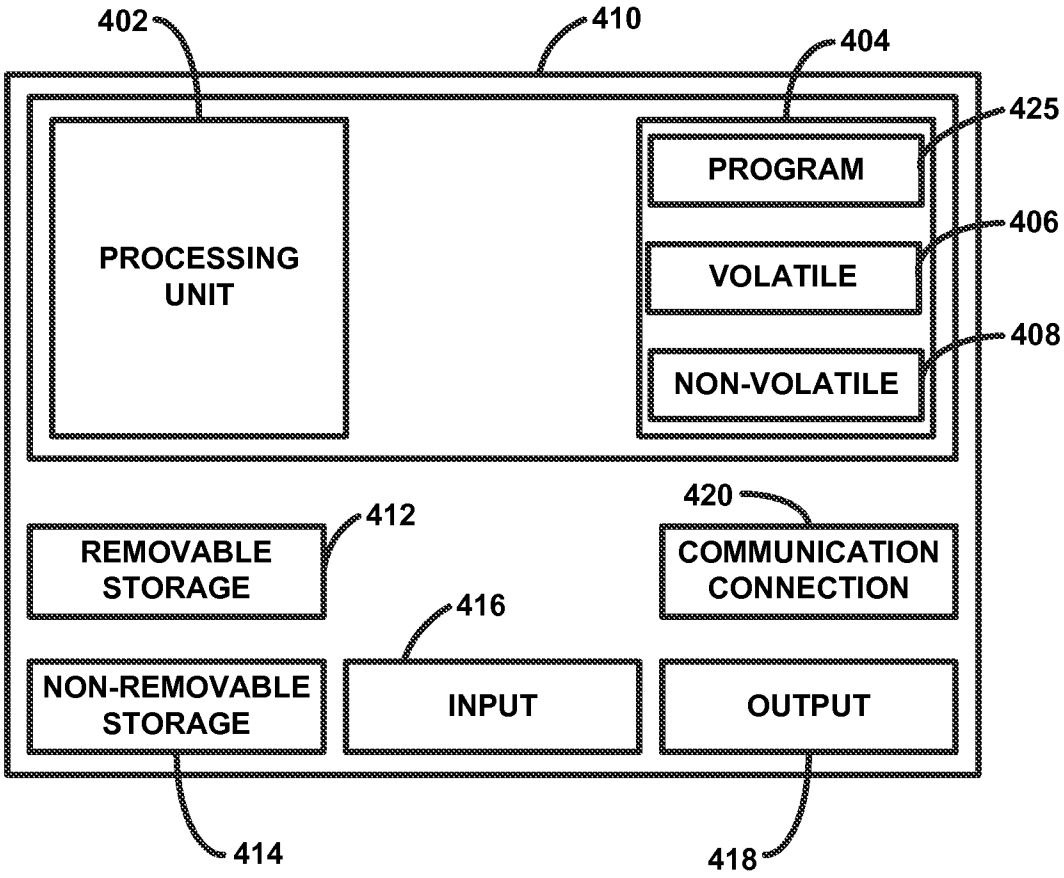

402
410
404
425
PROGRAM
406
VOLATILE
408
NON-VOLATILE
PROCESSING UNIT
420
412
REMOVABLE STORAGE
COMMUNICATION CONNECTION
416
NON-REMOVABLE STORAGE
INPUT
OUTPUT
414
418

FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2013/067575

A. CLASSIFICATION OF SUBJECT MATTER

H04W 16/18(2009.01)i, H04W 16/24(2009.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04W 16/18; H04L 1/00; H04W 4/00; H04W 72/00; H04W 16/24

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: PCI (Physical Cell Identity) code, small cell eNodeB, large cell eNodeB, location, GPS, RSRP (Reference signal Received Power)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2011-0059744 A1 (JEONG-JAE WON et al.) 10 March 2011 See paragraphs [0038], [0042], [0067], [0098]; figures 2, 6; and claim 1.	1-2,4-12,15-19
A		3,13-14,20
Y	US 2011-0038326 A1 (RICHARD L. DAVIES et al.) 17 February 2011 See paragraphs [0018]-[0019], [0022], [0027], [0029]; figures 1A, 1C, 2; and claim 4.	1-2,4-12,15-19
A	US 2011-0149728 A1 (CHAN YONG LEE) 23 June 2011 See paragraphs [0053]-[0055]; and figure 4.	1-20
A	US 2011-0190000 A1 (JONG-HYUNG KWUN) 04 August 2011 See paragraphs [0070]-[0075]; and figures 5A-5B.	1-20
A	US 2011-0110347 A1 (SEUNG-CHEOL MUN) 12 May 2011 See paragraph [0081]; and figure 6.	1-20

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
21 February 2014 (21.02.2014)	**21 February 2014 (21.02.2014)**

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Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/US2013/067575

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		US 8422472 B2	16/04/2013