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— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

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(54) Title: COMMUNICATIONS SYSTEM RADIO COVERAGE RECONFIGURATION BASED ON AVAILABLE CAPACITY OF A COMPENSATION CELL

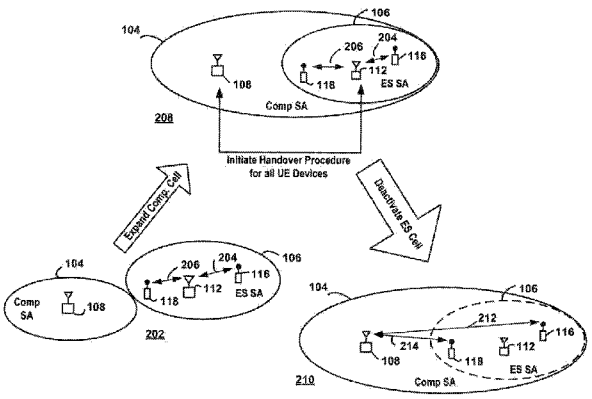

FIG. 2

(57) Abstract: In a cellular communication system, a coverage area configuration transition is performed when it is determined that the resources allocated to a compensation service area have sufficient available capacity to serve one or more UE devices being served by an energy saving service area, A coverage area configuration transition includes reducing the coverage of an energy saving service area and expanding the coverage of a compensation service area. A compensation communication station providing the compensation service area sends a request for a coverage area configuration transition to an energy saving communication station. The energy saving communication station may reject the coverage area configuration transition or may accept it and send an expansion notification to the compensation communication station, where the notification at least indicates that the compensation service area can be expanded.

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COMMUNICATIONS SYSTEM RADIO COVERAGE RECONFIGURATION BASED ON AVAILABLE CAPACITY OF A COMPENSATION CELL

PRIORITY

[0001] The present application claims priority to Provisional Application No. 61/864,474 entitled "Methods for Managing Resources for Transitions Between Cell Coverage Configurations", filed August 09, 2013, assigned to the assignee hereof, and hereby expressly incorporated by reference.

FIELD

[0002] The invention generally relates to wireless communications and more particularly to apparatuses, systems, and methods for changing communications systems' radio coverage configuration based on available capacity of one or more compensation cells.

BACKGROUND

[0003] Many wireless communication systems employ transceiver stations or radio heads to provide service within geographical service areas, where the boundaries of a service area are determined by the radio coverage of its associated transceiver station. Wireless service is provided to user equipment (UE) devices over radio frequency carriers (carriers) within each service area, where a carrier is the modulated waveform that conveys the physical channels as specified by the associated wireless technology standard. These service areas are sometimes referred to as "cells".

[0004] Although the term "cell" sometimes refers to the geographical area where multiple uplink and downlink resources (e.g., pairs of uplink and downlink carriers) are used, increasingly the term "cell" is used to refer to the geographical service area where single uplink resource and a single downlink resource are used to communicate with the UE devices. For example, where Time Division Duplex (TDD) is used, a single frequency may be used for uplink and downlink at different times within the "cell". Where

Frequency Division Duplex (FDD) is used, a single uplink/downlink frequency pair (one uplink frequency and one downlink frequency) is used within a "cell".

[0005] As discussed herein, one or more resources (carrier pairs) may be used in a service area. As a result, a service area may be a single cell or may contain multiple cells. In one common arrangement, each service area is adjacent to several other service areas to provide ubiquitous coverage over a large geographical area.

[0006] Adjacent service areas may overlap slightly, but, for the following discussion, no service areas provide service within the same geographical area. In many situations, there may be an advantage to dynamically change the configuration of the service areas, such as by selectively reducing the size of some service areas and expanding the size of one or more other service areas to provide service within the area previously serviced by the service areas that were reduced. Such dynamic coverage area configuration transitions may allow for more efficient operation of the system.

[0007] For example, a service area with only a small number of UE devices may be reduced to zero by deactivating its associated transceivers, and an adjacent service area that is serving several UE devices but has available capacity may be expanded to provide radio coverage for the UE devices previously contained in the reduced service area. Therefore, a service area that is reduced may be referred to as an energy saving service area since the energy consumed by its associated transceivers is reduced or eliminated, and a service area that is reduced to zero may be referred to as a deactivated service area. A service area that is expanded in cooperation with a service area that is reduced may be referred to as compensation service area since its service area is expanded to compensate for a service area that is reduced.

[0008] UE devices being served by an energy saving service area may lose their connection with the network if they are not handed over to another service area before the energy saving service area is deactivated. If the energy saving service area and the compensation service area operate on the same frequency resources, UE devices being served by an energy saving service area may lose their connection with the network if the compensation service area is expanded before the UE devices are handed over to another service area because of the interference between the energy

saving service area and the compensation service area. As discussed below, management techniques are needed to control the dynamic coverage area configuration transitions.

SUMMARY

[0009] In a cellular communication system, a coverage area configuration transition is performed when it is determined that the resources allocated to a compensation service area have sufficient available capacity to serve one or more UE devices being served by an energy saving service area. In reconfiguring the coverage areas of the system, the compensation service area is expanded to cover at least a portion of an energy saving service area of an energy saving cell and the energy saving service area is at least partially deactivated. A compensation communication station providing the compensation service area sends a request for a coverage area configuration transition to an energy saving communication station, and the energy saving communication station may reject the coverage area configuration transition or may accept it and send an expansion notification to the compensation communication station, where the notification at least indicates that the compensation service area can be expanded.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. 1 is an illustration of coverage areas in a cellular communication system.

[0011] FIG. 2 is an illustration of a coverage transition where the energy saving service area (ES SA) is deactivated and the compensation service area (Comp. SA) is expanded to provide wireless service within the geographical region of the energy saving service area.

[0012] FIG. 3 includes illustrations of a coverage area transition where the compensation service area is expanded to cover more than one energy saving service area.

[0013] FIG. 4 is a message flow diagram between the compensation communication station, the energy saving communication station, and the UE devices.

[0014] FIG. 5 is a method of operating the system shown in FIG. 1.

DETAILED DESCRIPTION

[0015] In a cellular communication system, a coverage area configuration transition is performed when it is determined that the resources allocated to a compensation service area have sufficient available capacity to serve one or more UE devices being served by an energy saving service area. In reconfiguring the coverage area of the system, the compensation service area (e.g., compensation communication station coverage area) is expanded to include at least a portion of an area covered by the energy saving communication station. For example, the expanded compensation service area would cover an energy saving service area of an energy saving cell and the energy saving service area is deactivated.

[0016] FIG. 1 is an illustration of coverage areas in a cellular communication system 100 where coverage area transitions are based on the available capacity of a compensation cell. For the example of FIG. 1, an energy saving communication station provides wireless service within a geographical service area represented by a circular area of an energy saving cell and a compensation communication station provides wireless service within a geographical service area represented by a circular area of a compensation cell. In typical implementations of the cellular communication system 100, several adjacent cells cover larger geographical regions. In the interest of brevity and clarity, however, FIG. 1 shows only two cells 104, 106. The circular shapes representing the service areas of the cells generally illustrate the relationships between the cells and do not necessarily depict the actual shapes of the service areas. The coverage area configuration transition management techniques discussed with reference to FIG. 1 may be applied to numerous coverage area configuration transition scenarios. For example, several energy saving cells may be deactivated and a compensation cell may be expanded to cover the geographical service areas of the multiple energy saving cells in accordance with the techniques discussed herein. The cells may have any of several shapes and sizes.

[0017] Communication stations 108, 112 transmit and receive wireless signals to provide the cells 104, 106. Each communication station 108, 112, which also may be referred to as an access node, access point, eNodeB, eNB, base station, and other terms, includes a transceiver and station controller. The controller in each communication station is configured to perform the various methods and operations described herein. The transceiver, or radio head, is typically collocated with the station controller although, in some situations, the station controller may be physically separated from the radio head. The radio head at least includes radio frequency (RF) transceiver equipment such as antennas, transmitters, and receivers, for transmitting and receiving wireless signals. Typically, radio heads do not include higher level processing and control functions which are performed by the associated station controller. For the illustration of FIG. 1, the radio heads are near a station controller where both the radio head and the controller may be implemented within a single apparatus. Since the location, shape, and size of the cell is determined at least in part by wireless transmission and reception with the communication station, the cell's location and coverage area is determined by the location and operation of the radio head. The compensation communication station 108 provides the compensation cell 104 and an energy saving communication station 112 provides the energy saving cell 106. Each communication station 108, 112, therefore, provides wireless communication services to wireless communication user equipment devices (UE devices) 114, 116, 118 within the cell where each cell covers a geographical service area. Communication stations typically provide several cells, but in the interest of brevity and clarity, communication stations 108 and 112 each provide one cell and the full radio and data processing capacity of communication stations 108 and 112 are applied to the service of the cell they provide. Accordingly, for the example shown in FIG. 1, the available capacity of a cell is equivalent to the available capacity of the communication station that provides the cell. As discussed herein, a communication station includes the equipment such as a station controller and radio head that provides a single cell. Accordingly, a communication station can be configured or adjusted to establish the size and shape of the service area of the cell. Several communication stations are typically interconnected through a backhaul (not shown) and to a network (not shown) to

provide several service areas to cover large areas. The backhaul may include any combination of wired, optical, and/or wireless communication channels. For the examples herein, the network includes the functionality of the Mobility Management Entity (MME) and the Packet Gateway (P-GW).

[0018] A cellular communication system is typically required to adhere to a communication standard or specification. The communication specification defines at least a data channel and a control channel for uplink and downlink transmissions and specifies at least some timing and frequency parameters for physical downlink control channels from a base station to a wireless communication device. The Third-Generation Partnership Project Long-Term Evolution (3GPP LTE) communication specification is a specification for systems where communication stations (eNodeBs) provide service to wireless communication devices (UE devices) using orthogonal frequency-division multiplexing (OFDM) on the downlink and single-carrier frequency-division multiple access (SC-FDMA) on the uplink. Although the techniques described herein may be applied in other types of communication systems, the exemplary systems discussed herein operate in accordance with an FDD 3GPP LTE communication specification.

[0019] Therefore, for the examples herein, the compensation communication station 108 includes a wireless transceiver that transmits downlink signals 120 to one or more UE devices 114 within the compensation cell 104 in accordance with 3GPP LTE and receives uplink signals 122 from one or more UE devices 114 within the compensation cell 104 in accordance with 3GPP LTE. The energy saving communication station 112 includes a wireless transceiver that transmits downlink signals 126 and 130 to one or more UE devices 116, 118 within the energy saving cell 106 in accordance with 3GPP LTE and receives uplink signals 124 and 128 from one or more UE devices 116, 118 within the energy saving cell 106 in accordance with 3GPP LTE.

[0020] The User Equipment (UE) devices 114, 116, 118 may be referred to as mobile devices, wireless devices, wireless communication devices, and mobile wireless devices, and UEs, as well as by other terms. The wireless communication devices include electronics and code for communicating with communication stations (eNBs) and, in some cases, with other devices including other UE devices. The UE devices include devices such as smart phones, cell phones, personal digital assistants (PDAs),

wireless modem cards, wireless modems, televisions with wireless communication electronics, and laptop and desktop computers, as well as other devices. The combination of wireless communication electronics with an electronic device, therefore, may form a wireless communication device. For example, a wireless communication device may include a wireless modem connected to an appliance, computer, or television.

[0021] In some instances, the compensation communication station 108 uses the same frequency channel to provide the compensation cell 104 as the energy saving communication station uses to provide the energy saving cell 106. For the example of FIG. 1, the same set of downlink/uplink frequency channel pairs may be assigned for the compensation cell 104 and the energy saving cell 106. In the cell configuration shown in FIG. 1, communications in the compensation cell do not interfere with communications in energy saving cell 106 when both cells use the same frequency channel since the service areas of the cells do not overlap. When the compensation cell and energy saving cell use the same frequency channel and the service area of the compensation cell is expanded as discussed below, the compensation cell will interfere with the UE devices served by the energy saving cell if not managed in some manner.

[0022] First, the compensation communication station 108 determines a traffic load of the compensation cell. As used herein, the term "traffic load" generally refers to an amount of communications resources of a particular cell that are being used by the UE devices that are being served by the cell. Traffic load can be expressed in an absolute terms or as a measurement relative to the total resources (e.g., capacity) of the cell.

[0023] Regardless of how the traffic load is expressed, if the traffic load of the compensation cell is below a first threshold level, the traffic load of the energy saving cell is determined. More specifically, the compensation communication station 108 transmits a request 132 for the traffic load of the energy saving communication station 112. The energy saving communication station responds by transmitting the traffic load indicator 134 that is indicative of the traffic load of the energy saving communication station to the compensation communication station 108. Based at least on the traffic load of the energy saving cell and the available capacity of the compensation cell, the compensation communication station 108 determines whether the compensation cell

can serve the UE devices 116, 118 being served by the energy saving communication station 112 if the compensation service area were to be expanded to include the energy saving service area. When determining whether the compensation cell can serve the traffic load of the energy saving cell, the compensation communication station may take into consideration the amount of the energy saving cell's traffic load that could be transferred to other cells. This information could be obtained from the energy saving communication station or from a centralized traffic management server, or it might be determined by the compensation communication station based on traffic load reports received from other communication stations. In response to a determination that the compensation cell can serve the UE devices 116, 118 being served by the energy saving cell, the compensation communication station 108 initiates a transition of the radio coverage area configuration.

[0024] In the example shown in FIG. 1, the coverage area configuration transition consists of expanding the compensation service area, handing over the UE devices being served by the energy saving cell, and deactivating the energy saving cell. In general, all of the UE devices being served by the energy saving cell are handed over to one or more compensation cells (or neighboring cells that do not expand their coverage area) before the energy saving cell reduces the amount of energy being used, and the compensation coverage area is expanded to include the entire area of the energy saving service area. However, in other instances, the energy saving cell's activity may only be partially reduced and a compensation service area may be expanded to include only a part of the energy saving service area. The energy saving cell may hand over one or more UE devices and still continue to serve one or more remaining UE devices. When the energy saving cell hands over all of its UE devices, the reduction of energy will generally include switching off or deactivating the energy saving cell 106. In other circumstances, the reduction of energy could include: reducing the size of the service area being served by the energy saving cell 106, reducing the broadcast strength of the signals 126, 130 being transmitted by the energy saving communication station 112, and/or reducing the number of UE devices being served by the energy saving cell 106.

[0025] FIG. 2 is an illustration of a coverage transition where the energy saving service area (ES SA) 106 is deactivated and the compensation service area (Comp.

SA) 104 is expanded to provide wireless service within the geographical region of the energy saving service area 106. In the example of FIG. 2, a coverage transition within the system of FIG. 1 is shown progressing through three stages. In the interests of clarity and brevity, two UE devices 116, 118, are shown in the example.

[0026] In the first stage 202, the UE devices 116, 118 are communicating over wireless communication links 204, 206 with the communication station 112 of the energy saving service area 106. For the example, the UE devices 116, 118 are at least receiving control signals and may also be transmitting control signals and exchanging data with the communication station 112 prior to the coverage transition. The coverage transition may be initiated in response to a determination that the energy saving service area 106 should be deactivated and the compensation service area 104 should be expanded. Such a determination may be based on any number of several factors and circumstances where some examples include the resource load on the energy saving service area 106 and the compensation service area 104. For example, the resource load of the energy saving service area may at least partly be based on the amount of time and frequency resources being used by all of the UE devices 116, 118 within the service area. The determination for deactivating the energy saving service area 106 may be based on whether the resources allocated to the compensation service area 104 have sufficient available capacity to provide service to the UE devices 116, 118 within the ES service area 106. As another example, the determination for deactivating an energy saving service area 106 may be based on a particular time, day, month, etc., where an operator has determined that the traffic load at this time can be managed without the energy saving service area 106. In response to the determination that the energy saving service area 106 should be deactivated, the coverage transition is initiated.

[0027] In FIG. 2, when it is determined that the compensation cell's traffic load may be sufficiently low to allow the deactivation of the energy saving cell 106, the compensation communication station 108 obtains the current traffic load of the energy saving cell 106. The compensation communication station 108 may already have this information because of previously received traffic load information or it may request the information based on existing methods. When the level of the traffic load of the energy

saving cell 106 does not exceed the available capacity of the resources allocated to the compensation coverage area 104, the compensation communication station 108 sends a message to the energy saving communication station 112 to request a cell coverage configuration transition. The energy saving communication station 112 sends a response message that indicates whether the request is accepted or not. For the purpose of this illustration, the cell coverage configuration transition would consist of the expansion of the coverage area 104 of the compensation cell to include the energy saving coverage area 106 and the deactivation of the energy saving service area 106.

[0028] When the compensation communication station 108 receives a response message from the energy saving communication station 112 with an "accept" indication, the coverage transition may be initiated, which is the second stage 208. The compensation communication station 108 initiates the expansion of the compensation service area and the energy saving communication station 112 initiates the handover procedures for the UE devices 116, 118 currently receiving wireless service from the energy saving communication station 112. The UE devices 116, 118 are handed over from the energy saving cell to other cells according to the typical LTE handover procedures. UE devices 116, 118 may be handed over to the compensation cell 104 when the compensation cell's coverage of the energy saving service area 106 allows it to be a suitable handover target for the UE.

[0029] After the compensation cell expansion is complete, the compensation communication station 108 notifies the energy saving communication station 112. After the energy saving communication station 112 receives notification that the compensation cell expansion is complete and all of the UE devices 116, 118 are handed over to other cells, at the third stage 210 of the transition procedure, the energy saving service area 106 is deactivated. The circle representing the energy saving service area 106 is shown with a dashed line to indicate that the cell is no longer active. As a result, the energy saving communication station (eNB) 112 does not provide wireless service within the energy saving service area 106 by transmitting or receiving wireless signals. For the example herein, the energy saving communication station 112 is turned off and consumes little or no power, and the UE devices 116, 118 are

communicating over wireless communication links 212, 214 with the compensation communication station 112 of the expanded compensation service area 104.

[0030] FIG. 3 includes illustrations 300, 301 of a coverage area transition where the compensation service area is expanded to cover more than one energy saving service area. The circular shapes representing the service areas generally illustrate the relationships between the service areas and do not necessarily depict the actual shapes of the service areas. In addition, the service areas may overlap in some regions more than in other regions. The open areas shown between the circular shaped service areas in the figure do not necessarily indicate that no service is available in these areas and are merely a product of illustration utilizing simple shapes to represent a more complicated relationship between service areas. Further, the service areas may contain holes of coverage where service is unavailable. In the interests of clarity and brevity, such features are not illustrated in the figures.

[0031] For the example of FIG. 3, the region 102 includes the geographical areas of several smaller service areas 104, 106, 302, 304, 306, 308, 310 including the compensation service area 104 and three energy saving service areas 106, 302, 304. In state 300 before the compensation area is expanded, the energy saving service areas 106, 302, 304 have coverage areas adjacent to the compensation service area 104. In state 301 after the compensation service area is expanded, the compensation service area 312 has a coverage area that includes the original coverage area of the compensation service area 104 and at least portions of the coverage areas of the energy saving service areas 106, 302, 304. The expanded compensation service area 312, therefore, is the compensation service area 104 with a larger coverage area. The energy saving service areas are shown with dashed lines in the coverage state 301 to illustrate that the service areas have been deactivated. The coverage area transition procedure for multiple energy saving service areas is similar to the transition procedure for a single energy saving service area discussed above. In one example, the compensation service area expands to cover each energy saving service area serially. In other words, the compensation service area is expanded to cover a first energy saving service area before a second energy service area. In such an example, all UE devices in the first energy saving service area are handed over to the compensation

service area, the compensation service area is expanded to cover the first energy saving service area, and the UE devices are transferred to the compensation service area prior to the procedure being performed for next energy saving service area. In the examples discussed below, however, the compensation service area is expanded to cover multiple energy saving service area areas in a single coverage area transition procedure. In this example, all UE devices from all energy saving service areas are handed over to the compensation service area, the compensation service area is expanded, and all the UE devices complete the handovers to the compensation service area. In some circumstances, some UE devices may be transferred to neighboring small service areas (306, 310) instead of the compensation service area. In these instances, the small service areas 306, 310 may act as additional compensation communication stations and may remain the same size or may expand/reduce their respective compensation service areas, as needed.

[0032] In some situations, a first compensation service area (e.g., first compensation communication coverage area) is only expanded to cover a portion of the energy saving service area, and one or more additional compensation communication stations each expand their respective coverage areas to include any portion of the energy saving service area that is not covered by the expanded first compensation communication station coverage area.

[0033] FIG. 4 is a message flow diagram 400 between the compensation communication station 108, the energy saving communication station 112, and the UE devices 116, 118. For the example, the communication stations are eNBs that communicate through the backhaul over an X2 link in accordance with LTE communication standards. Other communication techniques can be used in some circumstances. More specifically, the communication stations could communicate wirelessly in some circumstances.

[0034] For the example shown in Fig. 4, in response to determining that the traffic load of the compensation cell is below a first threshold level, the compensation communication station (compensation cell eNB) 108 sends a request 402 to the energy saving communication station (ES eNB) 112 for the traffic load of the energy saving cell. In response to the request, the energy saving communication station 112 transmits 404

a traffic load indicator (e.g., indicator 134 from Fig. 1) indicative of its current traffic load to the compensation communication station 108. Based at least on the traffic load of the energy saving cell and the available capacity of the compensation cell, the controller of the compensation communication station 108 determines whether the compensation cell can serve the UE devices 116, 118 that are being served by the energy saving communication station 112.

[0035] If it is determined that the compensation communication station 108 can serve the UE devices 116, 118 being served by the energy saving cell, the compensation communication station 108 sends a request to the energy saving communication station 112 to initiate a transition of the cell coverage configuration for the energy saving cell. In the example shown in FIG. 4, this request is a Cell Status Change Request 406. The energy saving communication station 112 sends a response to the compensation communication station 108 accepting or rejecting the request to initiate a transition of the cell coverage configuration for the energy saving cell. In this example, the response is a Cell Status Change Response 408. The Cell Status Change Response 408 is an example of the Expansion Notification and indicates to the compensation communication station 108 that the compensation service area can be expanded. In one example, the Cell State Change messages 406/408 are part of a dedicated procedure for this feature that is added to a standard specification. In other circumstances, the Cell State Change messages 406/408 functions may be incorporated into messaging structures and procedures currently defined by a communication standard, such as the Load Management or eNB Configuration Update procedures contained in the LTE communication standard. In either case, modifications of the LTE communication standard can facilitate the communication.

[0036] A part of the transition of the cell coverage configuration is that the compensation cell is reconfigured such that its coverage area is expanded to include the coverage area being served by the energy saving cell. The expansion of the compensation service area is initiated by the compensation communication station 108 after receiving the Cell Status Change Response 408 with an indication that the energy saving communication station 112 accepts the request for a transition of the cell coverage configuration for the energy saving cell. The compensation communication

station 108 increases transmission power and performs other known techniques for expanding the compensation service area to cover the energy saving service area. For example, techniques such as antenna tilting and antenna beam forming may be used to provide an expanded service area of the compensation cell that covers the original service area of the energy saving service area as well as the original service area of the compensation service area.

[0037] Where multiple energy saving service areas are deactivated, the compensation service area is expanded to cover those service areas. In one example, the parameters for establishing the expanded coverage area are determined at the time of equipment deployment. For example, signal quality measurements may be made and the parameters may be determined using the signal measurements at the time of or after equipment installation. Accordingly, the compensation communication station applies stored values or values it has received from an Operations and Maintenance (OAM) system to expand the service area to cover the areas of the energy saving service areas that have been deactivated.

[0038] The UE devices 116, 118 are handed over from the energy saving cell to other cells according to the typical LTE handover procedures. A UE device may be handed over to the compensation cell when the compensation cell's coverage of the energy saving service area allows it to be a suitable handover target for the UE. As illustrated in FIG. 4, handover messages 410 for the first UE device 116 are exchanged between the communication stations 108, 112 and handover messages 412 for the nth UE device 116 are exchanged between the communication stations 108, 112. When all of the UE devices 116, 118 are handed over to other cells and the compensation cell has completed its coverage expansion to include the energy saving service area, the energy saving service area 106 is deactivated. As discussed herein, a service area is "deactivated" when it no longer transmits downlink signals to UE devices and does not receive or process uplink signals from UE devices. Therefore, a deactivated service area cannot provide wireless service to UE devices. The communication station that provides the energy saving service area still includes active functions and is not turned off. For example, the communication station is still capable of communicating with other communication stations and/or the network.

[0039] In some circumstances, a communication station configuration update message may be sent from the energy saving communication station 112 to other communications stations indicating that the energy saving service area is no longer active. The other communication stations include at least the neighbor stations of the energy saving service area and may include other communication stations that require information regarding the status of the energy saving service area. For example, this functionality could be added to the LTE X2 interface eNB Configuration Update message that communication stations use to notify other communication stations about configuration changes of their service areas (cells).

[0040] Also, in some circumstances, a communication station configuration update message may be sent from the compensation communication station 108 to the other communications stations indicating that the compensation service area has been expanded. The other communication stations include at least the neighbor stations of the energy saving service area and the compensation service area and may include other communication stations that require information regarding the status of the compensation service area. For example, this functionality could be added to the LTE X2 interface eNB Configuration Update message that communication stations use to notify other communication stations about configuration changes of their service areas.

[0041] FIG. 5 illustrates a method 500 of operating system 100. At step 502, a controller of the compensation communication station 108 determines a traffic load of the compensation cell. At step 504, if the traffic load of the compensation communication station 108 is below a first threshold level, the compensation communication station 108 transmits a request 132 for the traffic load of the energy saving communication station 112. The energy saving communication station 112 responds by transmitting the traffic load indicator 134 indicative of the traffic load of the energy saving communication station 112 to the compensation communication station 108.

[0042] At step 506, based at least on the traffic load of the energy saving cell and the available capacity of the compensation cell, the compensation communication station 108 determines if the compensation cell can serve the UE devices 116, 118 being served by the energy saving cell. In some circumstances, determining whether the

compensation cell can serve one or more of the UE devices 116, 118 being served by the energy saving cell includes determining whether the traffic load of the energy saving cell is less than or equal to the available capacity of the compensation cell.

[0043] If it is determined that the compensation cell cannot serve the UE devices 116, 118 being served by the energy saving cell, the compensation communication station 108 transmits a request to the energy saving communication station 112 that the energy saving communication station 112 transmits a traffic load report or other indication to the compensation communication station 108 when the traffic load of the energy saving cell falls below a second threshold level.

[0044] In some situations, the determination that the compensation cell cannot serve the UE devices 116, 118 being served by the energy saving cell includes determining that the traffic load of the energy saving cell is more than a capacity threshold based on the available capacity of the compensation cell. For example, the capacity threshold could be 80% of the available capacity of the compensation cell. . Of course, the capacity threshold could be any suitable threshold amount, based on system capabilities, requirements, expected traffic demands, and any other pertinent criteria. When it is determined that the traffic load of the energy saving cell is more than the capacity threshold based on the available capacity of the compensation cell, the compensation communication station 108 transmits the request to the energy saving communication station 112 that the energy saving communication station 112 transmits a report to the compensation communication station 108 when the traffic load of the energy saving cell falls below a second threshold level. In some situations, the second threshold level may be updated as the traffic load of the compensation cell changes.

[0045] Regardless of the exact method used to determine that the compensation cell cannot serve the UE devices 116, 118 being served by the energy saving cell, the energy saving communication station 112 transmits, at step 508, the requested report to the compensation communication station 108 when the traffic load of the energy saving cell falls below the second threshold level. In response to a determination that the compensation cell can serve the UE devices 116, 118 being served by the energy saving cell and the energy saving communication station 112 accepting the request for a transition of the cell coverage configuration for the energy saving cell, the

compensation cell is reconfigured, at step 510, such that its coverage is expanded to include the coverage area being served by the energy saving cell. The UE devices 116, 118 are handed over from the energy saving cell to other cells according to the typical LTE handover procedures. A UE device may be handed over to the compensation cell when the compensation cell's coverage of the energy saving service area allows it to be a suitable handover target for the UE. When all of the UE devices 116, 118 are handed over to other cells and the compensation cell has completed its coverage expansion to include the energy saving service area, the energy saving service area 106 is deactivated. . In the example shown in FIG. 1, the reduction of energy includes switching off or deactivating the energy saving cell 106. In other situations, the reduction of energy includes: reducing the size of the service area being served by the energy saving cell 106, reducing the broadcast strength of the signals 126, 130 being transmitted by the energy saving communication station 112, and/or reducing the number of UE devices being served by the energy saving cell 106.

[0046] Clearly, other modifications and manners of practicing this invention will occur readily to those of ordinary skill in the art in view of these teachings. The above description is illustrative and not restrictive. This invention is to be limited only by the following claims, which include all such modifications and manners of practice when viewed in conjunction with the above specification and accompanying drawings. The scope of the invention should, therefore, be determined not with reference to the above description, but instead should be determined with reference to the appended claims along with their full scope of equivalents.

CLAIMS

1. A method comprising:

determining a traffic load of a first compensation communication station;

if the traffic load of the first compensation communication station is below a first threshold level, determining a traffic load of an energy saving communication station;

determining, based at least on the traffic load of the energy saving communication station and an available capacity of the first compensation communication station, whether the first compensation communication station can serve one or more user equipment devices (UE devices) being served by the energy saving communication station;

in response to determining that the first compensation communication station can serve one or more UE devices being served by the energy saving communication station, reconfiguring the first compensation communication station such that the first compensation communication station can serve the one or more UE devices being served by the energy saving communication station;

handing over at least one of the UE devices from the energy saving communication station to the first compensation communication station; and

reducing an amount of energy used by the energy saving communication station.

2. The method of claim 1, wherein the determining whether the first compensation communication station can serve one or more UE devices being served by the energy saving communication station comprises:

determining whether the traffic load of the energy saving communication station is less than or equal to the available capacity of the first compensation communication station.

3. The method of claim 1, wherein reconfiguring the first compensation communication station comprises:

expanding a first compensation communication station coverage area to include at least a portion of an area covered by the energy saving communication station.

4. The method of claim 3, wherein expanding the first compensation communication station coverage area comprises:

expanding the first compensation communication station coverage area to include all of the area covered by the energy saving communication station.

5. The method of claim 3, wherein one or more additional compensation communication stations expand their respective coverage areas to include any portion of the area covered by the energy saving communication station that is not covered by the expanded first compensation communication station coverage area.

6. The method of claim 1, wherein handing over at least one of the UE devices comprises:

handing over all of the UE devices being served by the energy saving communication station to the first compensation communication station.

7. The method of claim 1, wherein reducing the amount of energy used by the energy saving communication station comprises:

deactivating the energy saving communication station.

8. The method of claim 1, further comprising:

if the traffic load of the energy saving communication station is more than a capacity threshold based on the available capacity of the first compensation communication station, requesting that the energy saving communication station transmits a report to the first compensation communication station when the traffic load of the energy saving communication station falls below a second threshold level; and

transmitting the requested report to the first compensation communication station when the traffic load of the energy saving communication station falls below the second threshold level.

9. The method of claim 1, further comprising:

transmitting a request to initiate a transition of a cell coverage configuration;

transmitting a response to the request to initiate a transition of the cell coverage configuration; and

if the response is an acceptance, initiating a transition of the cell coverage configuration.

10. A compensation communication station, comprising:

a controller configured to determine a traffic load of the compensation communication station; and

a transmitter configured to transmit a request for a traffic load of an energy saving communication station if the traffic load of the compensation communication station is below a first threshold level,

wherein the controller is further configured to:

determine, based on at least the traffic load of the energy saving communication station and an available capacity of the compensation communication station, whether the compensation communication station can serve one or more user equipment devices (UE devices) being served by the energy saving communication station,

in response to determining that the compensation communication station can serve one or more UE devices being served by the energy saving communication station, reconfigure the compensation communication station such that the compensation communication station can serve one or more UE devices being served by the energy saving communication station, and

receive at least one of the UE devices being handed over from the energy saving communication station to the compensation communication station.

11. The compensation communication station of claim 10, wherein the controller is configured to determine that the compensation communication station can serve one or more UE devices being served by the energy saving communication station if the traffic

load of the energy saving communication station is less than or equal to the available capacity of the compensation communication station.

12. The compensation communication station of claim 10, wherein the controller is further configured to:

expand a compensation communication station coverage area to include at least a portion of an area covered by the energy saving communication station.

13. The compensation communication station of claim 12, wherein the controller is further configured to:

expand the compensation communication station coverage area to include all of the area covered by the energy saving communication station.

14. The compensation communication station of claim 10, wherein the controller is further configured to:

receive all of the UE devices being handed over from the energy saving communication station to the compensation communication station.

15. The compensation communication station of claim 10, wherein the controller is further configured to:

if the traffic load of the energy saving communication station is more than a capacity threshold based on the available capacity of the compensation communication station, request that the energy saving communication station transmits a report to the compensation communication station when the traffic load of the energy saving communication station falls below a second threshold level.

16. A system, comprising:

a compensation communication station, comprising:

a controller configured to determine a traffic load of the compensation communication station, and

a transmitter; and

an energy saving communication station, comprising:

a receiver configured to receive a request, transmitted by the compensation communication station, for a traffic load of the energy saving communication station if the traffic load of the compensation communication station is below a first threshold level, and

a transmitter configured to transmit the traffic load of the energy saving communication station to the compensation communication station,

wherein the controller is further configured to:

determine, based on at least the traffic load of the energy saving communication station and an available capacity of the compensation communication station, whether the compensation communication station can serve one or more user equipment devices (UE devices) being served by the energy saving communication station,

in response to determining that the compensation communication station can serve one or more UE devices being served by the energy saving communication station, reconfigure the compensation communication station such that the compensation communication station can serve one or more UE devices being served by the energy saving communication station, and

receive at least one of the UE devices being handed over from the energy saving communication station to the compensation communication station.

17. The system of claim 16, wherein the controller is configured to determine that the compensation communication station can serve one or more UE devices being served by the energy saving communication station if the traffic load of the energy saving communication station is less than or equal to the available capacity of the compensation communication station.

18. The system of claim 16, wherein the controller is further configured to:

expand a compensation communication station coverage area to include at least a portion of an area covered by the energy saving communication station.

19. The system of claim 18, wherein the controller is further configured to:

expand the compensation communication station coverage area to include all of the area covered by the energy saving communication station.

20. The system of claim 18, wherein one or more additional compensation communication stations expand their respective coverage areas to include any portion of the area covered by the energy saving communication station that is not covered by the expanded compensation communication station coverage area.

21. The system of claim 16, wherein the controller is further configured to:

receive all of the UE devices being handed over from the energy saving communication station to the compensation communication station.

22. The system of claim 16, wherein the energy saving communication station is configured to deactivate after handing over at least one of the UE devices.

23. The system of claim 16, wherein the controller is further configured to:

if the traffic load of the energy saving communication station is more than a capacity threshold based on the available capacity of the compensation communication station, request that the energy saving communication station transmits a report to the compensation communication station when the traffic load of the energy saving communication station falls below a second threshold level; and

receive the requested report when the traffic load of the energy saving communication station falls below the second threshold level.

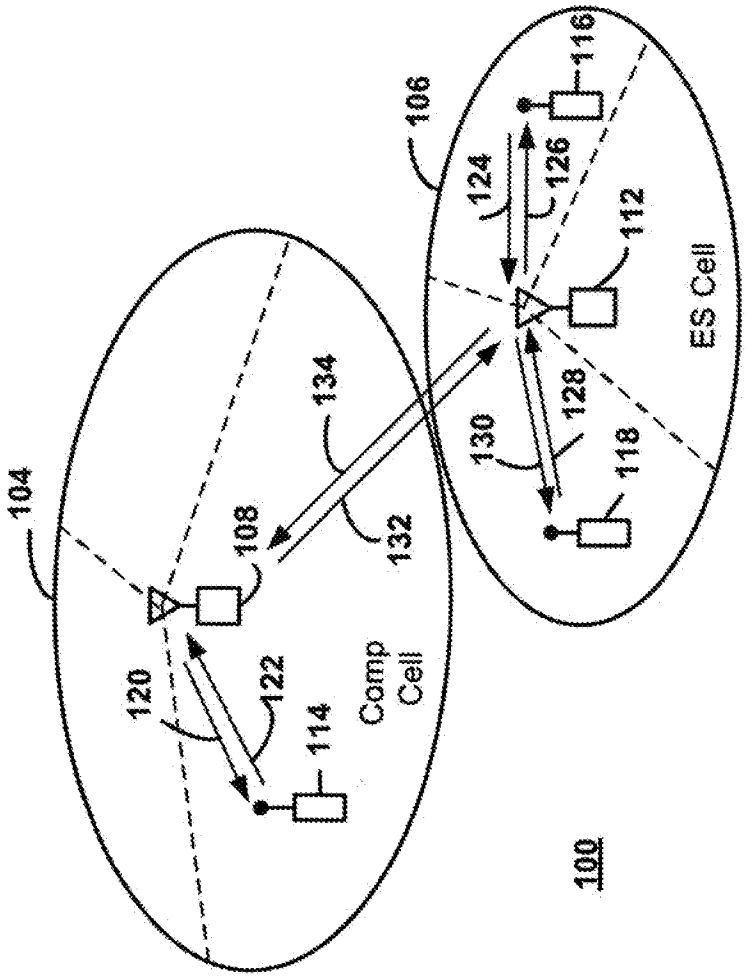

104
106
108
112
114
116
118
120
122
124
126
128
130
132
134
Comp Cell
ES Cell
100

FIG. 1

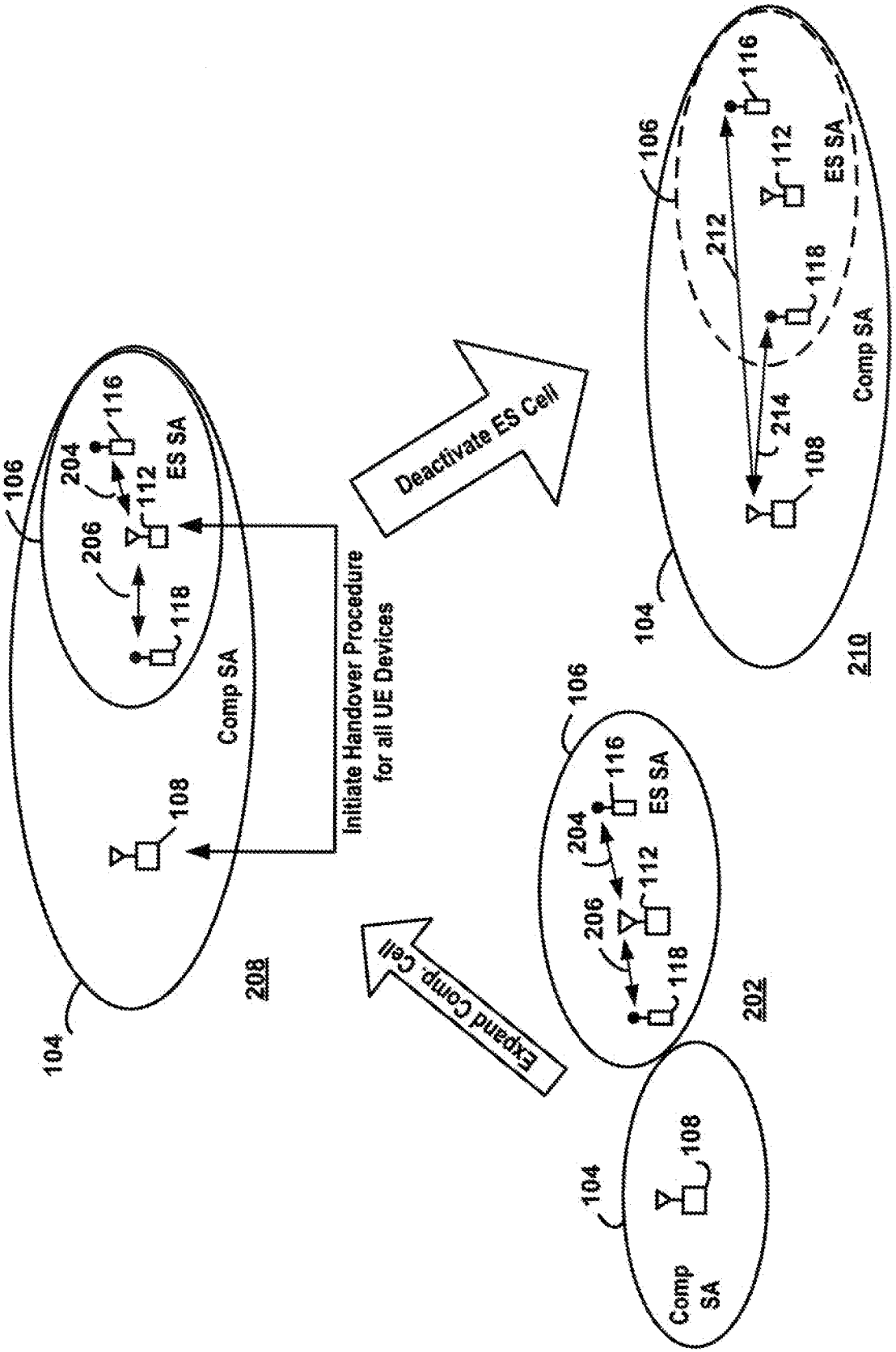
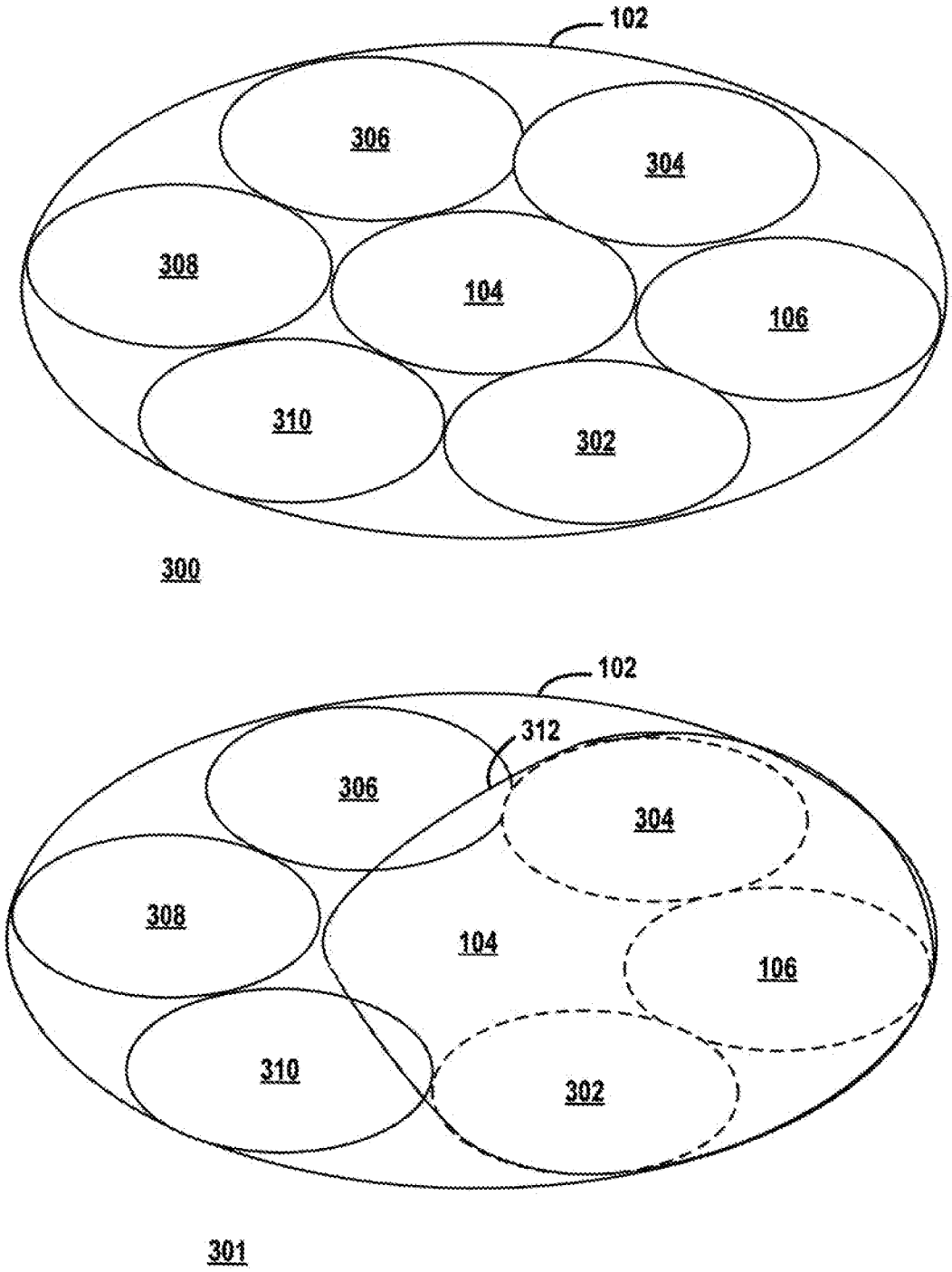

106
204
116
ES SA
112
206
118
Comp SA
108
104
208
Initiate Handover Procedure
for all UE Devices
Deactivate ES Cell
Expand Comp. Cell
106
116
ES SA
204
112
206
118
202
104
108
Comp
SA
106
116
ES SA
112
212
118
Comp SA
214
108
104
210

FIG. 2


102
306
304
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106
310
302
300
102
312
306
304
308
104
106
310
302
301

FIG. 3

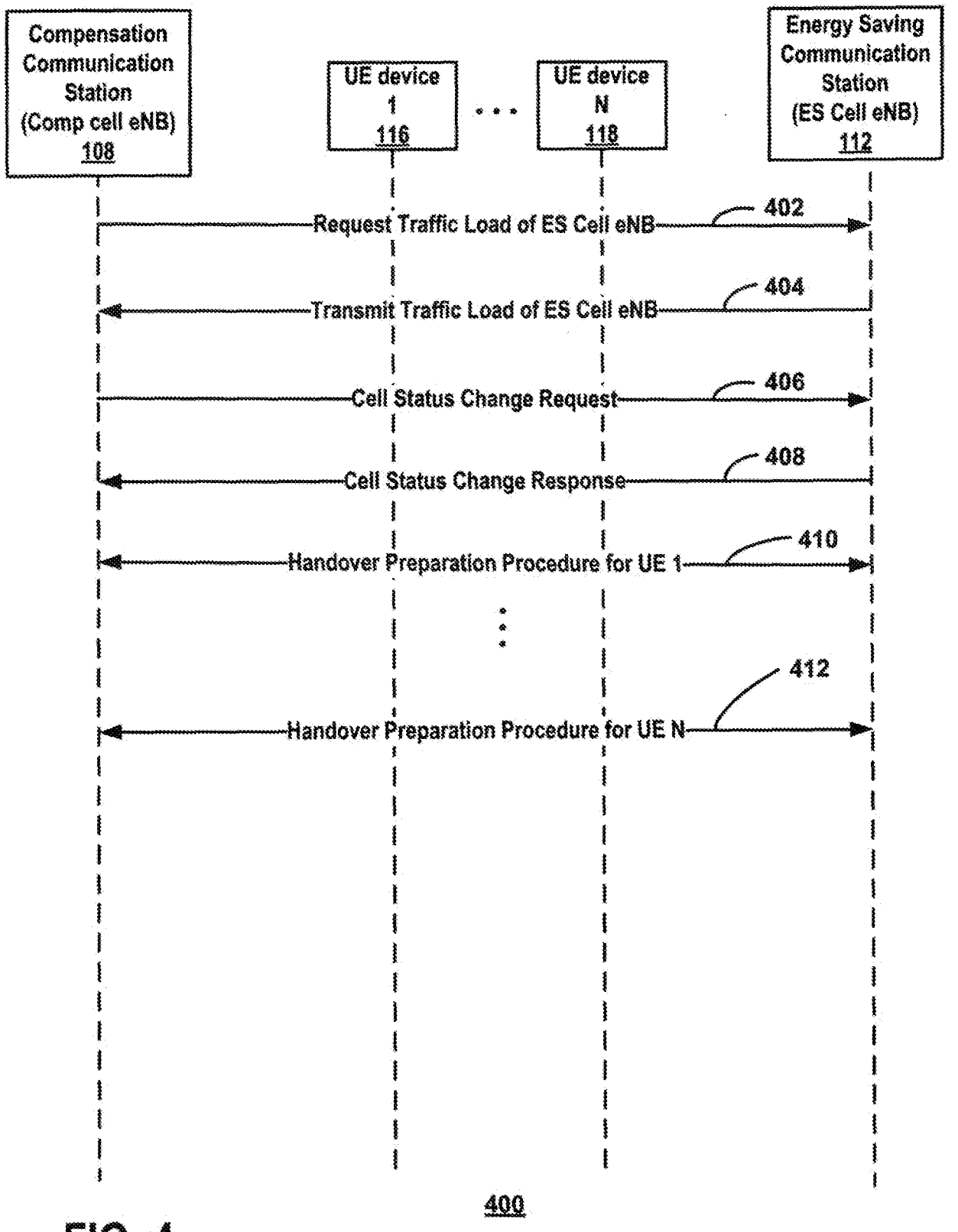
Compensation Communication Station (Comp cell eNB) 108
UE device 1 116
UE device N 118
Energy Saving Communication Station (ES Cell eNB) 112
Request Traffic Load of ES Cell eNB
402
Transmit Traffic Load of ES Cell eNB
404
Cell Status Change Request
406
Cell Status Change Response
408
Handover Preparation Procedure for UE 1
410
Handover Preparation Procedure for UE N
412
400

FIG. 4

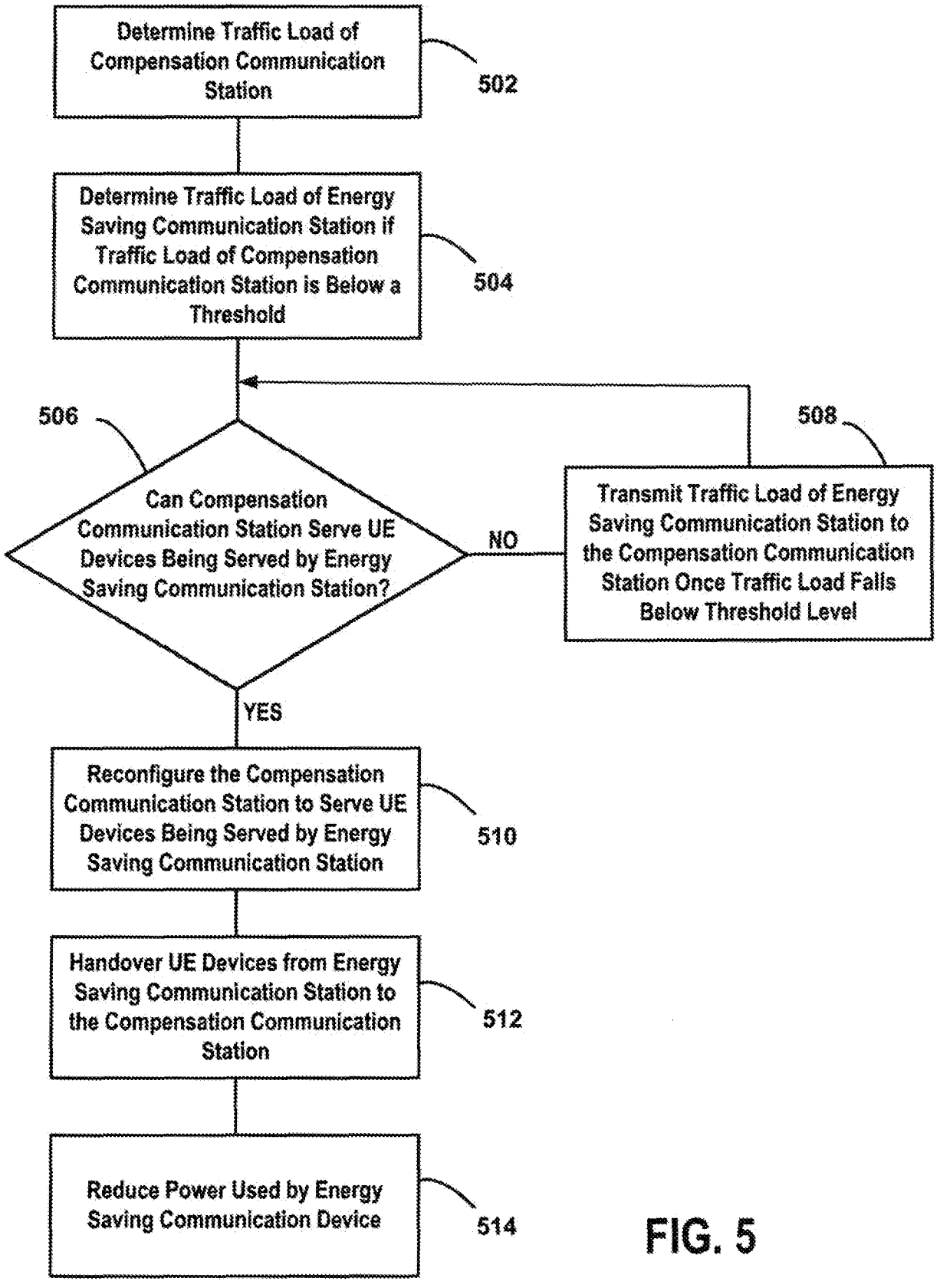
Determine Traffic Load of Compensation Communication Station
502
Determine Traffic Load of Energy Saving Communication Station if Traffic Load of Compensation Communication Station is Below a Threshold
504
506
Can Compensation Communication Station Serve UE Devices Being Served by Energy Saving Communication Station?
NO
508
Transmit Traffic Load of Energy Saving Communication Station to the Compensation Communication Station Once Traffic Load Falls Below Threshold Level
YES
Reconfigure the Compensation Communication Station to Serve UE Devices Being Served by Energy Saving Communication Station
510
Handover UE Devices from Energy Saving Communication Station to the Compensation Communication Station
512
Reduce Power Used by Energy Saving Communication Device
514

FIG. 5