(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
14 March 2013 (14.03.2013)

WIPO | PCT

(10) International Publication Number
WO 2013/033907 A1

(51) International Patent Classification:
H04W 24/08 (2009.01)

(21) International Application Number:
PCT/CN2011/079494

(22) International Filing Date:
9 September 2011 (09.09.2011)

(25) Filing Language: English

(26) Publication Language: English

(71) Applicant *(for all designated States except US)*: **RENESAS MOBILE CORPORATION** [JP/JP]; 6-2, Otemachi 2-chome, Chiyoda-ku, Tokyo 100-0004 (JP).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **HONG, Wei** [CN/CN]; Room 606, No. 8 Haidian North Second Street, Haidian, Beijing 100080 (CN). **WANG, Haiming** [CN/CN]; Room 1403, Unit 5, Building 101, Jiang Fu Jia Yuan, Jiang Tai Road, Chaoyang, Beijing 100015 (CN). **WEI, Na** [CN/CN]; Jing Ao Jia Yuan #609-2-303, Chaoyang, Beijing 100018 (CN).

(74) Agent: **KING & WOOD PRC LAWYERS**; 20th Floor, East Tower, World Financial Centre, No.1 Dongsanhuan Zhonglu, Chaoyang District, Beijing 100020 (CN).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM,

[Continued on next page]

(54) Title: METHODS AND APPARATUS FOR INTER-CELL INTERFERENCE COORDINATION

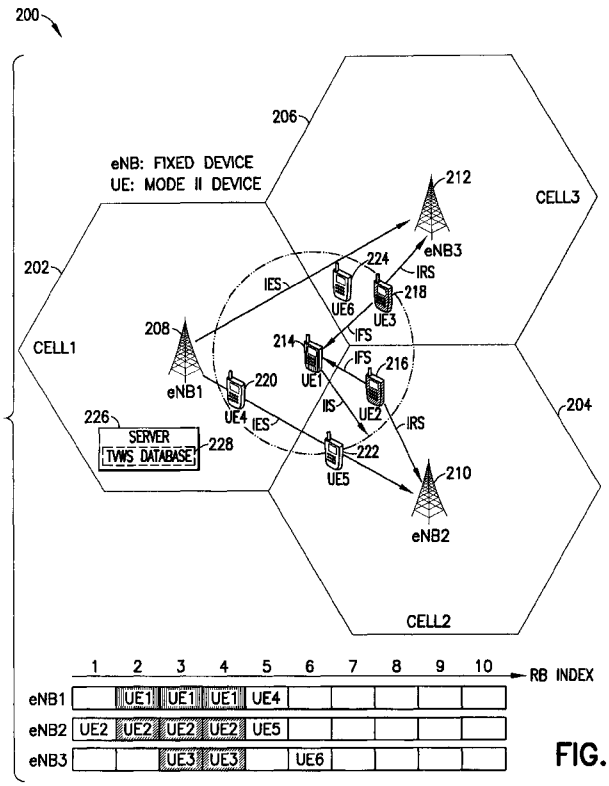

FIG.4

(57) Abstract: Systems and techniques for reducing or eliminating interference in licensed frequency bands. A device, such as a UE, upon recognizing that it is experiencing interference, transmits an inquiry using an unlicensed frequency band, such as a television white space (TVWS) band. A device that are potential sources of interference responds by transmitting a feedback signal providing information that can be used to identify it as an interferer. The device experiencing interference performs analysis to identify interferers, or simply transmits the feedback information to its base station. The base station, upon identification of one or more interferers, uses unlicensed frequencies, such as TVWS bands, to communicate with neighboring base stations to request reduction or elimination of interference. Neighboring base stations respond by taking actions that may include scheduling management or transmit power reduction to reduce interference by their served devices.

WO 2013/033907 A1

TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *of inventorship (Rule 4.17(iv))*

Published:

— *with international search report (Art. 21(3))*

METHODS AND APPARATUS FOR INTER-CELL INTERFERENCE COORDINATION

FIELD OF THE INVENTION

[0001] The present invention relates generally to wireless communication. More particularly, the invention relates to improved systems and techniques for the use of unlicensed bands to exchange interference information in order to perform improved interference coordination.

BACKGROUND OF THE INVENTION

[0002] The following abbreviations that may be found in the specification and/or the drawing figures are defined as follows:

3GPP	Third Generation Partnership Project
eNB	evolved Node B
HII	high interference indicator
IE	information element
IES	interference exchange signaling
IFS	interference feedback signaling
IIS	interference inquiring signaling
IRS	interference remind signaling
LTE	long term evolution
OI	overload indicator
UE	user equipment
TVBD	television band device
TVWS	television white space
WiMAX	worldwide interoperability for microwave access
WS	white space

[0003] Interest in wireless communication, particularly personal wireless communication, has increased more and more during the last few decades, and user demand for the ability to transmit and receive information wirelessly has proven insatiable. More and more users wish to spend more and more of their time communicating with one another, sharing data with others,

and receiving data made available to the public at large or to large groups of users, so that serving the simultaneous activities of these users while providing an acceptable quality of service to each user has proven more and more challenging. Manufacturers and operators of wireless communication systems such as cellular networks have gone to great lengths to increase the data that can be carried in the portion of the radiofrequency spectrum allocated to them. Continued advances in the efficient use of the radiofrequency spectrum to carry data have led from the first wireless transmissions in the 1800's to the ubiquitous presence of wireless data communication in every aspect of everyday life.

SUMMARY OF THE INVENTION

[0004] In one embodiment of the invention, an apparatus comprises a computer readable memory, at least one processor, and a program of instructions configured to, with the computer readable memory and the processor, cause an apparatus to perform actions comprising detecting interference on a licensed frequency band used by the apparatus broadcasting a interference inquiry signal on an unlicensed frequency band available to the apparatus. The interference inquiry signal provides information identifying the apparatus and requests interference feedback information from devices that may be a source of the detected interference. The actions further comprise, upon receiving the interference feedback information, transmitting interferer identification information to a base station. The interferer identification information can be used to identify the devices that are sources of the interference experienced by the apparatus.

[0005] In another embodiment of the invention, an apparatus comprises a computer readable memory, at least one processor, and a program of instructions. The program of instructions is configured to, with the computer readable memory and the processor, cause an apparatus to perform actions comprising receiving, over one or more unlicensed frequency bands, interferer identification information from a served device. The interferer identification information can be used to identify the devices that are sources of interference experienced by the served device, where the interference experienced by the served device interferes with use by the served device over one or more licensed frequency bands. Upon identification of one or more interferers, interference exchange information is transmitted over the one or more unlicensed frequency bands. The interference exchange information specifically identifies one

or more interfering devices presenting interference to the served device and requests reduction of interference by the interfering devices.

[0006] In another embodiment of the invention, a method comprises configuring at least one processor to cause an apparatus to perform actions comprising detecting interference on a licensed frequency band used by the apparatus and broadcasting an interference inquiry signal on an unlicensed frequency band available to the apparatus. The interference inquiry signal provides information identifying the apparatus and requests interference feedback information from devices that may be a source of the detected interference. The actions further comprise, upon receiving the interference feedback information, transmitting interferer identification information to a base station. The interferer identification information can be used to identify the devices that are sources of the interference experienced by the apparatus.

[0007] In another embodiment of the invention, a method comprises configuring at least one processor to cause an apparatus to perform actions comprising receiving, over one or more unlicensed frequency bands, interferer identification information from a served device. The interferer identification information can be used to identify the devices that are sources of interference experienced by the served device. The interference experienced by the served device interferes with use by the served device of one or more licensed frequency bands. Upon identification of one or more interferers, interference exchange information is transmitted over the one or more unlicensed frequency bands. The interference exchange information specifically identifies one or more interfering devices presenting interference to the served device and requesting reduction of interference by the interfering devices.

[0008] These and other embodiments and aspects are detailed below with particularity.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] Fig. 1 illustrates a cell served by a wireless network operating according to an embodiment of the present invention;

[0010] Figs. 2-5 illustrate a wireless network with elements performing procedures according to various embodiments of the present invention;

[0011] Fig. 6 illustrates hardware elements that may operate according to embodiments of the present invention; and

[0012] Fig. 7 illustrates a process of interference management according to an embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0013] Systems and techniques according to various embodiments of the present invention recognize that the radiofrequency spectrum specifically allocated to use by cellular communication systems is limited, and that the need to operate within a limited spectrum imposes significant constraints on the communication capacity of any system. As the number of users increases, and as the demands of users increase, the load on a system increases, and the difficulty of accommodating simultaneous users concurrently increases. System capacity can be increased by the deployment of new communications infrastructure, but such deployment is costly and in addition can only meet communication needs up to a certain point. If the radiofrequency spectrum available to users of a network is being used at full capacity by users within a geographic area, the addition of new infrastructure such as new base stations will not increase the capacity of the network within that area because the limitation is imposed not by the available infrastructure, but by the capacity of the available radiofrequency spectrum to carry data.

[0014] The radiofrequency spectrum allocated to systems such as cellular networks is determined by government licensing authorities, who need to manage allocation between numerous competing claimants. Licensing for particular uses is typically conducted after much analysis of the needs of various parties, and can be expected to be relatively fixed. Even when allocations change, there is no particular reason to believe that the result will be an increased allocation to users of cellular networks.

[0015] One problem affecting wireless communication is interference between users. One frequently occurring form of interference is inter-cell interference, which occurs when neighboring cells assign the same frequency bandwidth to different user equipments (UEs). To take an example, an exemplary network 100 comprises two adjacent cells, the cell 102A and the cell 102B. The network 100 may suitably be a long-term evolution (LTE) network, with the cells 102A and 102B each being served by a base station, with the base stations being implemented in the form of eNodeBs (eNBs) 104A and 104B. UEs 106A, 106B, 108A, and 108B are operating within the cells 102A and 102B, with the UEs 106A and 108A operating

within the cell 102A and with the UEs 106B and 108B operating within the cell 102B. Each of the UEs 106A and 106B is operating near the edge of its own cell, and a UE operating near the edge of its cell may be subject to inter-cell interference. The UEs 106A and 106B are near one another in space, but are served by the different eNBs 104A and 104B, so that interference can easily result if each of the eNBs 104A and 104B carries out communication with its own UE without taking into consideration the operation of its operation on communication between the eNB and the UE or UEs being conducted in the adjacent cell.

[0016] Therefore, eNBs and UEs such as those illustrated here may carry out inter-cell interference coordination to reduce the occurrence and effects of interference. LTE systems may use dynamic uplink (UL) inter-cell interference coordination (ICIC) techniques, whereby UEs in a cell are allocated frequency resources that are orthogonal to resources allocated to all or a portion of the interfering UEs in an adjacent cell. Such an approach aims to reduce inter-cell interference effects, particularly in the cell-edge area. 3GPP standards designate a number of standardized information elements (IE) that are exchanged between base stations in order to allow for coordination of operation between the base stations so as to reduce interference. One such IE is the overload indication (OI), which provides, per physical resource block (PRB) a report on interference overload. The OI can be used to request neighbor cells to refrain from scheduling UEs that have been detected to cause high interference on a particular band. For example, a source eNB, such as the eNB 104A, may detect high interference in a physical resource block and then send out an OI to its neighbor eNBs, such as the eNB 104B. The neighbor interfering eNBs, such as the eNB 104B, may suitably respond by attempting to determine if any of its UEs, such as the UE 106B, are interfering with the eNB 104B. For example, the eNB 104B may examine its scheduling history. Upon identifying an interfering UE, such as the UE 106B, the eNB 104B may suitably seek to reduce interference by scheduling the interfering eNB. For example, the eNB 104B may schedule the UE 106B on other PRBs, or may reduce its transmitting power.

[0017] Embodiments of the present invention recognize that the use of overload indicators or high interference indicators (HIIs) is subject to a number of difficulties. A target eNB, that is, an eNB identified by a source eNB as producing interference, may have difficulties identifying which UEs have interfered with or are interfering with the source eNB. One typical approach is to first divide the UEs into cell edge UEs and cell center UEs and then to coordinate

with other eNBs to avoid scheduling cell edge UEs from different cells in the same or adjacent physical resource blocks. Such an approach imposes significant scheduling constraints. Because of a lack of information identifying the exact UEs causing interference and the exact UEs scheduling interference, the simple division between cell center UEs and cell edge UEs requires avoidance of scheduling of all cell edge UEs in the same or adjacent resource blocks, even though these cell edge UEs may be distant from the UEs that are experiencing interference. In the present exemplary case, this approach would require avoiding scheduling the UE 108B in the same resource block as the UE 106A, even though the UE 108B is too far from the UE 106A to cause interference.

[0018] In addition, under current standards, OI and HII information elements are exchanged through an X2 interface, and the X2 interface delay is approximately 20ms. This delay may render OI and HII information elements obsolete by the time they are received.

[0019] Various embodiments of the invention recognize the availability of significant frequency resource that may be used to carry control information. One significant resource is found in television white space (TVWS) bands. TVWS bands can be found around and within the frequency ranges 54-60 MHz (TV channel 2), 76-88 MHz (TV channels 5 and 6), 174-216 MHZ (TV channels 7-13), 470-608 MHZ (TV channels 14-36) and 614-698 MHz (TV channels 38-51). The TVWS bands exist at gaps within the frequency ranges dedicated to television broadcast channels. For example, if no broadcaster in a region is operating using TV channel 2, the area dedicated to channel 2 is white space within that region. In addition, gaps separating channels represent white space. TVWS bands have been made available for communication by devices that follow constraints designed to prevent interference with users of the television broadcast channels. The TVWS frequencies exhibit highly favorable propagation characteristics as compared to the 2.4 and 5GHz bands, such as the ability to pass through buildings, weather, and foliage at lower power levels. Devices that take advantage of TVWS bands are referred to as TV band devices (TVBD). Different devices, subject to different constraints, are fixed devices, personal/portable devices, and sensing only devices. The requirements imposed on such devices are defined by the U.S. Federal Communications Commission (FCC) as follows:

Fixed device

a. Operating from fixed location registered to WS database.
b. Geo-location/database access and spectrum sensing required.
c. Max 1W transmission power (4 W radiated power (EIRP)).

d. Operating on unoccupied channels between 2 and 51.
e. Can't operate on the first adjacent channels to TV stations.

Personal/Portable devices – Modes II / Mode I

f. Operating on unoccupied channels between 21 and 51.
g. Max 100mW radiated power (EIRP). (40 mW close to TV station's service area).
h. Mode II: Geo-location/database access required.
i. Mode I: Geo-location/database access not required.
j. A Mode II device uses an internal geo-location capability and accesses to a TV bands database either through a direct connection to the Internet or through an indirect connection to the Internet by way of fixed TVBD or another Mode II TVBD, to obtain a list of available channels.
k. A mode II device may select a channel itself and initiate and operate as part of a network of TVBDs, transmitting to and receiving from one or more fixed TVBDs or personal/portable TVBDs.
l. A Mode II device must check its location at least once every 60 seconds while in operation

Sensing only device

m. Uses spectrum sensing to determine a list of available channels.
n. Max 50mW radiated power (EIRP). (40 mW close to TV station's service area).
o. Operating on unoccupied channels between 21 and 51.

[0020] Channels between 2 and 20, therefore, may be used only by fixed devices. In these channels, only eNB transmissions to other eNBs and to UEs are allowed. In the context of TVWS operation, these channels are referred to as uplink (UL) disable channels.

[0021] In appropriate circumstances, eNBs and UEs may operate at times as TVBDs, transmitting and receiving information on their allowed TVWS frequencies. Such information may include information identifying interfering and interfered UEs and control information exchanged between eNBs and between eNBs and UEs to allow for management of transmission so as to avoid interference.

[0022] According to one embodiment of the present invention, therefore, UEs are able to operate as Mode II devices and eNBs are able to operate as fixed devices in the TVWS bands. In addition, UEs and eNBs may also operate in their own licensed LTE bands. In the network 100 of Fig. 1, therefore, the eNBs 106A, 106B, 108A, and 108B are mode II devices and the eNBs 104A and 104B are fixed devices. In the present illustrated example, the UEs 108A and 108B do not have an immediate need to use the TVWS band because they are not sources of or subject to interference, but are able to use the TVWS bands as needed when their circumstances change. The UEs 106A is subject to interference caused by the UE 106B.

[0023] The UE 106A, operating in its licensed LTE band, detects a high degree of interference. It sends interference inquiring signaling (IIS) to neighbor TVBDs. The IIS may include information such as the device ID, it serving cell ID, PRBs for which it is experiencing interference, its location, and other relevant information. If neighbor UEs exist that are nearer to the cell edge than the UE 106A, these neighbor UEs may help to forward the IIS.

[0024] The UE 106B, upon receiving the IIS from the UE 106A, sends interference feedback signaling (IFS) to the UE 106A. The signaling may suitably include its device ID, its serving cell ID, interfering PRBs, its location, its transmitting power, and other relevant information. Again, if the UE 106A has neighbor UEs that are nearer to its cell edge than the UE 106A, these neighbor UEs may help to forward the IFS back to the UE 106A.

[0025] After receiving IFSs from all interfering UEs (in the present simplified case, only the UE 106B), the UE 106A may suitably identify the interfering UE or UEs based on the IFSs, or alternatively may forward all the IFSs to the serving eNB, which in the present case is the eNB 104A. The eNB 104A, upon receiving information identifying one or more interfering UEs, or interferers, or identifying the interfering UE through its own analysis of the IFSs received from the UE 106A, sends interference exchange signaling (IES) to the interfering eNB, which in the present case is the eNB 104B. The IES may be sent using a UL disable WS channel or other available WS channel. The IES may include the cell ID of the cell experiencing interference, that is, the cell ID of the cell 106A, the interfering device ID, PRBs subject to interference, the location of the UE experiencing interference, that is, of the UE 106A, and other relevant information.

[0026] In another embodiment of the invention, the UE 106B, upon receiving IIS from the UE 106A, may send Interference Remind Signaling (IRS) to the eNB 104B. The IRS may include, for the UE sending the IRS, the device ID of the device, location information for the device, interfered UE's serving cell ID, the interfered UE's location, interfered PRBs, and other relevant information. As a further alternative, the UE 106B may send IRS to its own serving eNB 104B as well as sending IFS to the UE 106A.

[0027] Fig. 2 illustrates an exemplary network 200 implementing an embodiment of the present invention. The network 200 comprises cells 202-206, served by eNBs 208-212, respectively. The UEs 214-224 are present in the cells 202-206, with the UEs 214 and 220 being present in the cell 202, the UEs 216 and 222 being present in the cell 204, and the UEs 218 and

224 being present in the cell 206. A server 226 is present in the network 200, hosting a TVWS database 228. The TVWS database 228 stores information specifying the TVWS frequencies available in each cell. Upon recognizing that it is experiencing a high level of interference, the UE 214 consults the TVWS database 228 to identify the available TVWS channels that are available among the most likely interfering adjacent cells. Suitably, the various eNBs are configured to be aware of the WS channels that are available, and the TVWS database 228 may suitably associate TVWS channels with cells or groups of cells. For example, channel 2 may be available for communication with cells 202 and 204, while channel 5 may be available for cells 202, 204, and 206. The various eNBs may be configured to communicate using the different TVWS frequencies that may be available, and a UE, such as the UE 214, is able to use the channels available for use with the cells with which it needs to communicate.

[0028] If TVWS is available, the UE 214 selects an available channel and transmits IIS, suitably including its device ID, PRBs experiencing interference, and location information. In the present example, the PRBs used by the UE 214 that are experiencing interference are PRB #2, #3, and #4. The IIS reaches the UEs 216-224, and upon receiving the IIS, the UEs check to determine if the PRBs they are using are the same as or part of PRBs experiencing interference. In the present example, the UE 216 is in the cell 204 and using PRBs #1, #2, #3, and #4. There is, then, a possibility that the UE 216 is causing inter-cell interference, affecting PRB #2, #3, and #4, so that the UE 216 will send IFS to the UE 214, with the IFS including the device ID, serving cell ID, location, identification of the possibly interfering PRBs #2, #3, and #4, and transmitting power of the UE 216.

[0029] The UE 218 is located in the cell 206 and using PRB #3 and PRB #4, so that it will send an IFS to the UE 214. The other UEs will not send IFSs to the UE 214. The UE 220 is in the same cell as the UE 214 and thus cannot cause inter-cell interference. The UE 222 is in the cell 204 and using the PRB #5, so that it cannot be interfering with the UE 214, and the UE 224 is in the cell 206 and using PRB # 6, so that it likewise cannot be interfering with the UE 214. The UEs 220-224 thus have no need to send IFSs to the UE 214.

[0030] Once the UE 214 has received IFSs from the UEs 216 and 218, it may forward the IFSs to the eNB 208. Fig. 2 illustrates this scenario. Upon receiving the IFSs from the UE 214, the eNB 208 identifies the UE or UEs presenting severe interference to the UE 214, taking into account the location and transmitting power of the UEs identified in the IFSs. In the present

example, the UE 216 is nearer to the UE 214 than is the UE 218, but the transmitting power of the UE 218 is higher than that of the UE 216. Accordingly, the eNB 208 may determine that both the UE 216 and the UE 218 are presenting severe interference to the UE 214.

[0031] Once the determination has been made, the eNB 208 may consult the TVWS database 228 to identify the WS channels available to it. If a UL disable channel WS is available, such a channel will be chosen for communication, and if no UL disable WS channel is available, the eNB will chose another available channel above channel 20. Suitably, the chosen channel may be a channel designated for use among the cells 202, 204, and 206, or, if not a specifically designated channel, a channel known beforehand to be usable by each of the cells 202, 204, and 206. Once the UEs 210 and 212 have received information identifying the interfering UEs and the location of the UE experiencing interference, they can take appropriate steps to reduce or eliminate the interference, such as adjusting scheduling of the UEs, reducing the transmit power of the UEs, or taking other appropriate steps. The specific information provided to the eNBs 210 and 212 identifying the interfering UEs, the UE experiencing interference, and details of the interference, allows for a targeted adjustment affecting the UEs presenting the interference, and the use of TVWS channels allows for the exchange of information needed to describe the interference without using the licensed frequencies. In addition, the specific use of TVWS channels employs frequencies with advantageous propagation properties as described above, so that the efficiency of transmission is relatively great.

[0032] Once a channel has been chosen, the eNB 208 may send IESs to the eNBs 210 and 212 over the chosen WS channel. The IES to the eNB 210 may include the cell ID of the cell 202, the device ID of the interfering device UE 216, the interfered PRB #2, #3, and #4, and the location of the UE 214. The IES to the eNB 212 may include the cell ID of the cell 202, the device ID of the interfering device UE 218, the interfered PRB #2, #3, and #4, and the location of the UE 214.

[0033] An approach according to an alternative embodiment of the present invention is illustrated in Fig. 3, which similarly shows the network 200, including the cells 202-206, the eNBs 208-212, the UEs 214-224, the server 226, and the TVWS database 228. In the example illustrated in Fig. 3, the UEs 216 and 218 may, after receiving the IIS from the UE 214, send interference remind signaling (IRS) to their respective eNBs. The IRS for the UE 216 may be sent to the eNB 210, and may include the device ID for the UE 216, the location of the UE 216,

the serving cell ID for the UE 214, that is, for the UE experiencing interference, and the interfered PRB #2, #3, and #4 of the UE 214. The IRS for the UE 218 may be sent to the eNB 212, and may include the device ID for the UE 218, the location of the UE 218, the serving cell ID for the UE 214, that is, for the UE experiencing interference, and the interfered PRB #2, #3, and #4 of the UE 214. After receiving the IRS from the UEs 216, the eNB 210 may avoid scheduling the UE 216 on the PRBs #2, #3, and #4, which are the PRBs on which the UE 214 is experiencing interference. Alternatively or in addition, the eNB 210 may reduce the transmitting power of the UE 216. The eNB 212 may follow similar procedures with respect to the UE 218.

[0034] A further alternative according to another embodiment of the invention is illustrated in Fig. 4, which similarly shows the cells 202-206, the eNBs 208-212, the UEs 214-224, the server 226, and the TVWS database 228. In the alternative illustrated here, each of the UEs 216 and 218 may send an IFS to the UE experiencing interference, that is, the UE 214, and may also send an IRS to its own serving eNB. Upon receiving the IFS, the UE 214 may follow the procedures described above with respect to Fig. 2, that is, identifying the interfering UE or forwarding the IFS to the eNB 208. The eNB 208 may then, in a manner similar to that described above, send an IES to eNBs serving UEs identified as presenting interference.

[0035] After receiving the IRS from the UE 216, the eNB 210 may wait for an interference exchange timer (IET) to wait for an IES from the eNB serving the UE experiencing interference, that is, from the eNB 208. If no IES is received by the time the IET expires, the eNB 210 may leave its scheduling strategy unchanged and take no action to prevent interference, because the lack of an IES is likely to indicate that the eNB 208 has solves the interference problem without a need to involve the eNB 210. If the eNB 210 has received an IES from the eNB 208 by the expiration of the IET, the eNB may follow the procedures described above with respect to Fig. 2, in order to minimize or reduce interference caused by the UE 216 to the UE 214. The eNB 212 behaves in a similar manner, that is, after receiving an IRS from the UE 218, the eNB 212 waits for an IES, and if no IRS is received during the time specified by the IET, the eNB 212 takes no action, while if an IES is received, the eNB 212 follows appropriate procedures to reduce or eliminate interference caused by the UE 218.

[0036] As noted above, it is possible for UEs to assist in the transfer of information. Fig. 5 illustrates an exemplary case according to another embodiment of the present invention, showing the network 200, , including the cells 202-206, the eNBs 208-212, the UEs 214-224, the

server 226, and the TVWS database 228. In the example shown here, the UE 220 is nearer the edge of the cell 202 than is the UE 214 that is experiencing interference. Therefore, the UE 220 is able to assist the UE 214 in sending and receiving information relating to interference originating from other cells. Specifically, the UE 220 receives the IIS transmitted from the UE 214 because the IIS is generally broadcast, and the UE 220 may be configured to pay attention to IISs from UEs in its own cell so that it may assist in relaying the IISs. Upon receiving the IIS, the UE 220 forwards the IIS by performing its own broadcast if the IIS, so that the IIS can extend further into the neighboring cells due to the closer proximity of the UE 220 to the edge of cell 202 and thus to cells bordering the cell 202. The UEs 216 and 218 respond to the IIS by transmitting IFSs, which are received and forwarded by the UE 220. The UE 214 may respond to the IFSs in a manner similar to that described above - for example, by identifying an interfering UE or UEs or by relaying the IFS to the eNB 208. The eNB 208 may then transmit an IES to the neighboring eNBs 210 and 212.

[0037] Fig. 6 illustrates details of an eNB 602 and a UE 604 that may be used in various embodiments of the present invention. The eNB 602 suitably comprises a transmitter 606, receiver 608, and radiocontroller 610, as well as an antenna 612. The eNB 602 further suitably comprises a processor 614, memory 616, and storage 618, communicating with one another and with the radiocontroller over a bus 620. The UE 604 may similarly comprise a transmitter 622, receiver 624, and radiocontroller 626, as well as an antenna 628. The UE 604 further suitably comprises a processor 630, memory 632, and storage 634, communicating with one another and with the radiocontroller over a bus 636.

[0038] Both the eNB 602 and the UE 604 suitably implement various mechanisms to allow them to recognize and deal with interference caused by cell-edge UEs in neighboring cells and to communicate information over TVWS channels in order to take actions to reduce or eliminate such interference. Such mechanisms, which may variously be used by one or the other, or by both, of the eNB 602 and the UE 604 may include such as transmitting messages requesting information from possible sources of interference, reporting information that may be used to identify the UE 604 as a possible source of interference, transmitting messages that can be used by neighboring eNBs to inform coordination of their own UEs to reduce or eliminate interference, or relaying transmissions to or from other UEs. To this end, the eNB 602 and the UE 604 suitably implement various software modules. In the case of the eNB 602, software

modules may reside in storage 618 and be transferred to memory 616 as needed for execution by the processor 614. In the case of the eNB 604, software modules may reside in storage 634 and be transferred to memory 632 for execution by the processor 630.

[0039] The software modules implemented by the UE 604 may include an interference detection module 638, an interference inquiry module 640, an interference analysis module 642, an interference feedback module 644, an interference reporting module 646, and an information relay module 648. The modules 638-648 may respectively perform procedures for recognizing that the UE 604 is being subjected to interference, procedures for selecting an available TVWS channel and broadcasting an inquiry requesting information from possible interfering UEs, procedures for analyzing information received by other UEs to identify interfering UEs, procedures for responding to an inquiry from another UE by providing information that may identify the UE 604 as an interfering UE, procedures for delivering information to the serving eNB of the UE 604 over TVWS channels, and procedures for relaying information to or from another UE that needs to transmit or receive interference information.

[0040] The software modules implemented by the eNB 602 may include a UE TVWS communication module 650, for communicating with the various UEs served by the eNB 602 over TVWS channels in order to receive interference information such as an identification of an interfering UE or information, such as one or more IFSs forwarded by its served UE, that can identify a UE as an interfering UE. The eNB 602 may implement an interference analysis module 652 for analyzing received interference information to identify interfering UEs, and an interference coordination module 654 for communicating with other eNBs to report the identity of interfering UEs in other cells, to receive information identifying interfering UEs in its own cells, and to perform procedures to reduce or eliminate interference by its own UEs. The various hardware components and software modules may suitably implement procedures described above with respect to Figs. 1-5. It will be recognized that the specific components illustrated and described here are exemplary only, and that numerous combinations of software and hardware components can be used to implement embodiments of the present invention.

[0041] Fig. 7 illustrates a process of interference management according to an embodiment of the present invention. At step 702, upon detection by a UE that it is experiencing excessive interference, the UE selects an available TVWS channel and broadcasts interference inquiring signaling (IIS). At step 704, UEs receiving the interference inquiring signaling

respond by determining if they may be sources of interference, for example, checking to see if they are in the same cell as the UE broadcasting IIS and checking to see if they are using one or more PRBs being used by the UE broadcasting IIS. Upon determining that it is a possible source of interference, a UE transmits interference feedback signaling (IFS), which may be accompanied by interference remind signaling (IRS). Interference feedback signaling is transmitted by a UE to the UE transmitting the interference inquiring signaling, and interference remind signaling is transmitted by a UE to its own serving base station. At step 706, a UE experiencing interference, upon receiving interference feedback signaling, performs appropriate analysis and communication. In one embodiment of the invention, the UE may analyze the interference feedback signaling and identify interfering UEs, transmitting the identification to its serving eNB, and in an alternative embodiment of the invention, the UE simply relays the received interference feedback signaling to its serving eNB.

[0042] At step 708, an eNB receiving information from its own UE indicating the identity of one or more interfering UEs performs appropriate steps to manage the interference. Depending on whether it has received an identification of one or more interfering UEs or has simply received forwarded IFS signaling, the eNB may or may not perform analysis to identify the interfering UE or UEs. Once the interfering UE or UEs have been identified for or by the eNB, the eNB selects an available TVWS channel for communication with neighbor eNBs. The selection may suitably be accomplished by consulting a TVWS database, with an uplink disable channel being chosen if available, and transmits interference exchange signaling to neighboring eNBs, identifying interfering UEs.

[0043] At step 710, an eNB serving an interfering or potentially interfering UE receives information that can be used to identify, or does positively identify, the interfering UE. The eNB may receive interference remind signaling from its own UE, at which point it sets an interference exchange timer, which alerts the eNB that its UE may be presenting interference, and alerts the eNB that interference exchange signaling may be forthcoming from a neighbor eNB.

[0044] At step 712, upon receiving interference exchange signaling from a neighbor eNB, whether or not preceded by interference remind signaling, the eNB takes appropriate steps to reduce or eliminate interference presented by the identified UE or UEs, such as adjusting scheduling in the physical resource blocks experiencing interference, reducing transmit power of the UE or UEs, or other appropriate measures.

[0045] While various specific embodiments of the invention are described above, it will be recognized that a wide variety of implementations may be employed by persons of ordinary skill in the art in accordance with the above description and the claims which follow below. In particular, it will be recognized that the advantages provided by embodiments of the present invention be realized in other environments other than an environment using TVWS for communication. Any available frequency range or ranges having desired properties and allowing communication without the use of licensed frequencies may be used, such as WiMAX.

WHAT IS CLAIMED IS:

1. An apparatus comprising:

a computer readable memory;

at least one processor;

a program of instructions configured to, with the computer readable memory and the processor, cause an apparatus to perform actions comprising:

detecting interference on a licensed frequency band used by the apparatus;

broadcasting interference inquiring signaling on an unlicensed frequency band available to the apparatus, wherein the interference inquiring signaling provides information identifying the apparatus and requests interference feedback information from devices that may be a source of the detected interference; and

upon receiving the interference feedback information, transmitting interferer identification information to a base station, wherein the interferer identification information can be used to identify the devices that are sources of the interference experienced by the apparatus.

2. The apparatus of claim 1, wherein the unlicensed frequency band comprises a television white space band.

3. The apparatus of claim 1 or 2, wherein the interferer identification information comprises specific identification of one or more interfering devices.

4. The apparatus of any of claims 1-3, wherein the interferer identification information comprises interference feedback information received from one or more potentially interfering devices.

5. The apparatus of any preceding claim, wherein the apparatus is a user equipment (UE) operating in a wireless network.

6. The apparatus of any preceding claim, wherein the actions further comprise relaying one or more of interference inquiring signaling, interference feedback information, and interferer identification transmitted from or needed by other similar apparatuses relaying to or from other UEs operating in the wireless network.

7. An apparatus comprising:

a computer readable memory;

at least one processor;

a program of instructions configured to, with the computer readable memory and the processor, cause an apparatus to perform actions comprising:

receiving, over one or more unlicensed frequency bands, interferer identification information from a served device, wherein the interferer identification information can be used to identify the devices that are sources of interference experienced by the served device, wherein the interference experienced by the served device interferes with use by the served device of one or more licensed frequency bands; and

upon identification of one or more interferers, transmitting, over the one or more unlicensed frequency bands, interference exchange information specifically identifying one or more interfering devices presenting interference to the served device and requesting reduction of interference by the interfering devices

8. The apparatus of claim 7, wherein the one or more unlicensed frequency bands comprise television white space bands.

9. The apparatus of claim 7 or 8, wherein transmission of the interference exchange information is performed using an uplink disable white space channel.

10. The apparatus of any of claims 7-9, further comprising receiving interference exchange information from a neighbor apparatus and, in response to the interference exchange information, controlling served devices identified as interferers in order to reduce or eliminate interference to devices served by the neighbor apparatus.

11. The apparatus of any of claims 7-10, wherein the apparatus is a base station operating in a wireless network and wherein the devices served by the apparatus and by neighbor apparatuses are user equipments (UEs) operating in the wireless network.

12. The apparatus of claim 11, wherein the apparatus is an evolved node B.

13. A method comprising:

detecting interference on a licensed frequency band used by an apparatus;

broadcasting interference inquiring signaling on an unlicensed frequency band available to the apparatus, wherein the interference inquiring signaling provides information identifying the apparatus and requests interference feedback information from devices that may be a source of the detected interference; and

upon receiving the interference feedback information, transmitting interferer identification information to a base station, wherein the interferer identification information can be used to identify the devices that are sources of the interference experienced by the apparatus.

14. The method of claim 13, wherein the unlicensed frequency band comprises a television white space band.

15. The method of claim 13 or 14, wherein the interferer identification information comprises specific identification of one or more interfering devices.

16. The method of claim 13 or 14, wherein the interferer identification information comprises interference feedback information received from one or more potentially interfering devices.

17. A method comprising:

receiving, over one or more unlicensed frequency bands, interferer identification information from a served device, wherein the interferer identification information can be used to identify the devices that are sources of interference experienced by the served device, wherein the interference experienced by the served device interferes with use by the served device of one or more licensed frequency bands; and

upon identification of one or more interferers, transmitting, over the one or more unlicensed frequency bands, interference exchange information specifically identifying one or more interfering devices presenting interference to the served device and requesting reduction of interference by the interfering devices.

18. The apparatus of claim 17, wherein the one or more unlicensed frequency bands comprise television white space bands.

19. The apparatus of claim 17 or 18, wherein transmission of the interference exchange information is performed using an uplink disable white space channel.

20. The apparatus of any of claims 17-19, further comprising receiving interference exchange information from a neighbor apparatus and, in response to the interference exchange information, controlling served devices identified as interferers in order to reduce or eliminate interference to devices served by the neighbor apparatus.

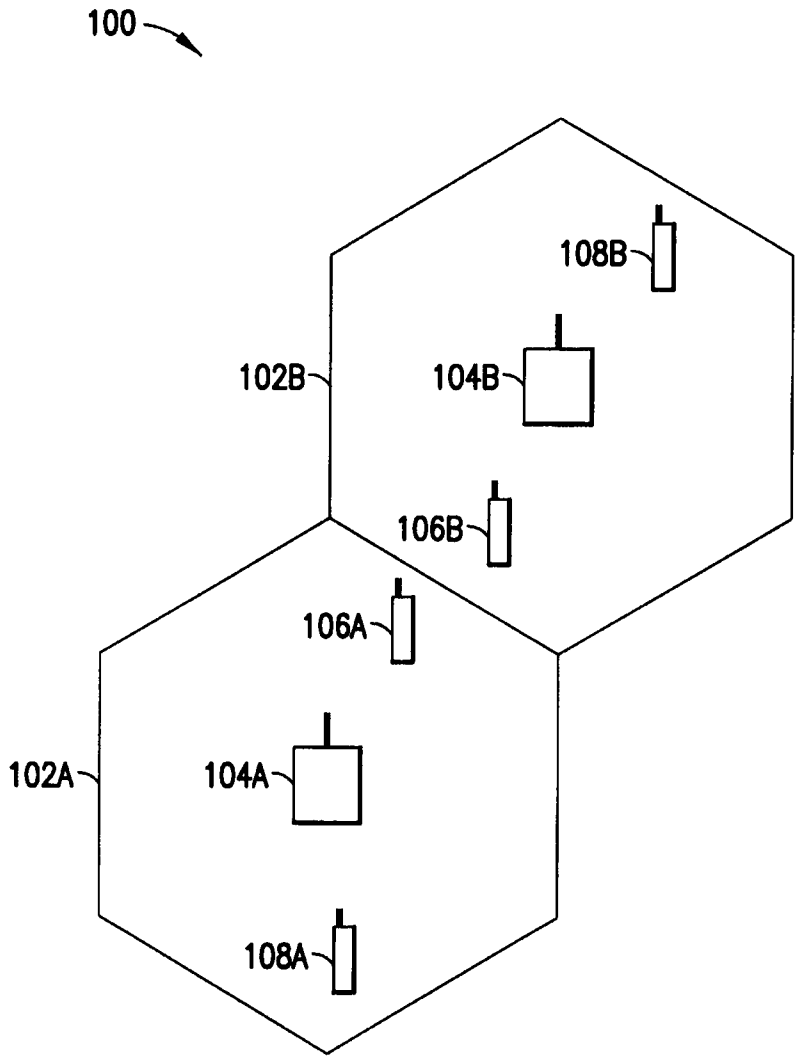

FIG. 1

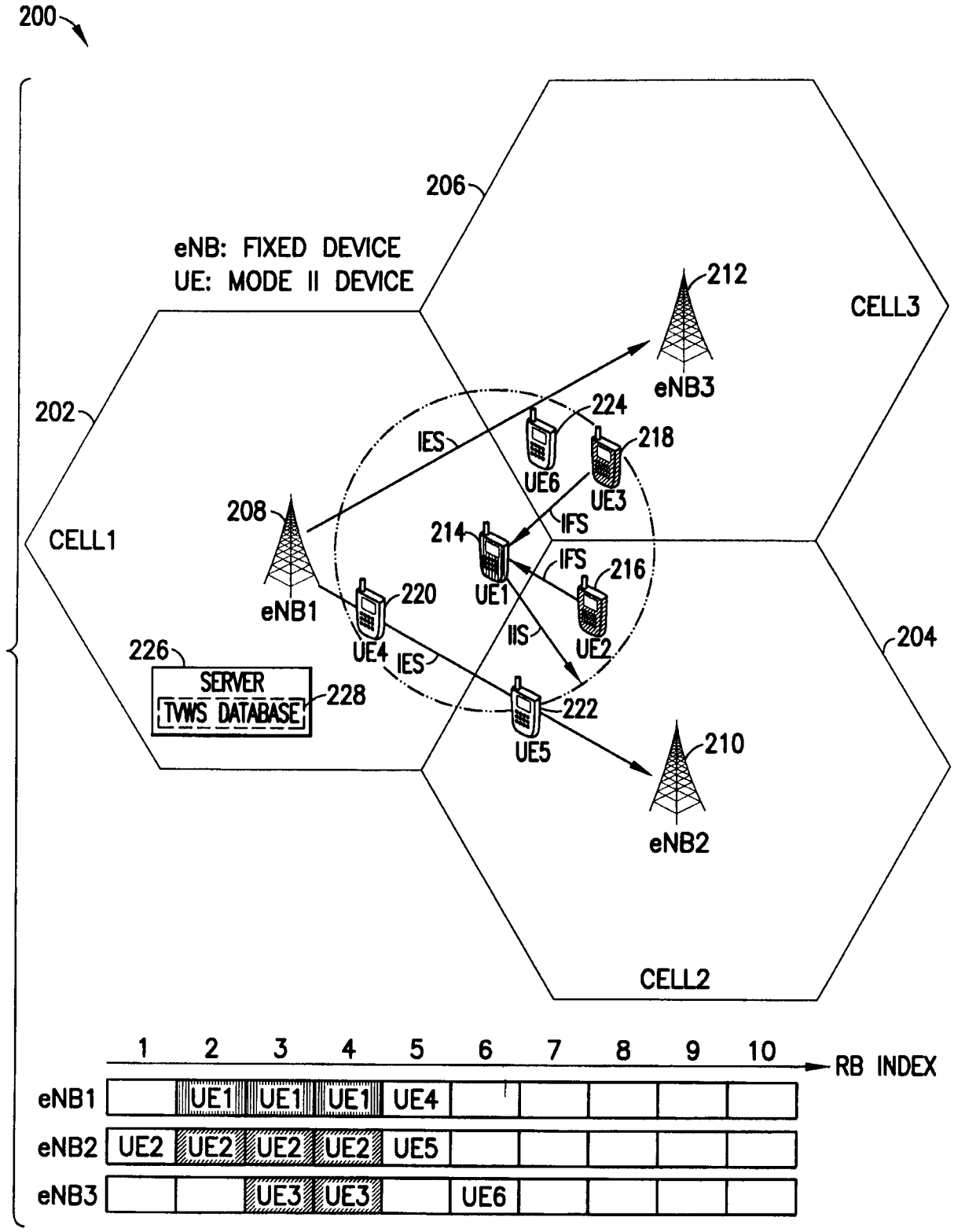
200
206
eNB: FIXED DEVICE
UE: MODE II DEVICE
212
CELL3
eNB3
202
224
IES
218
UE6
UE3
208
IFS
214
CELL1
IFS
216
eNB1
220
UE1
UE2
IIS
204
226
UE4
IES
SERVER
TVWS DATABASE
228
222
UE5
210
eNB2
CELL2
1 2 3 4 5 6 7 8 9 10
RB INDEX
eNB1 UE1 UE1 UE1 UE4
eNB2 UE2 UE2 UE2 UE2 UE5
eNB3 UE3 UE3 UE6

FIG.2

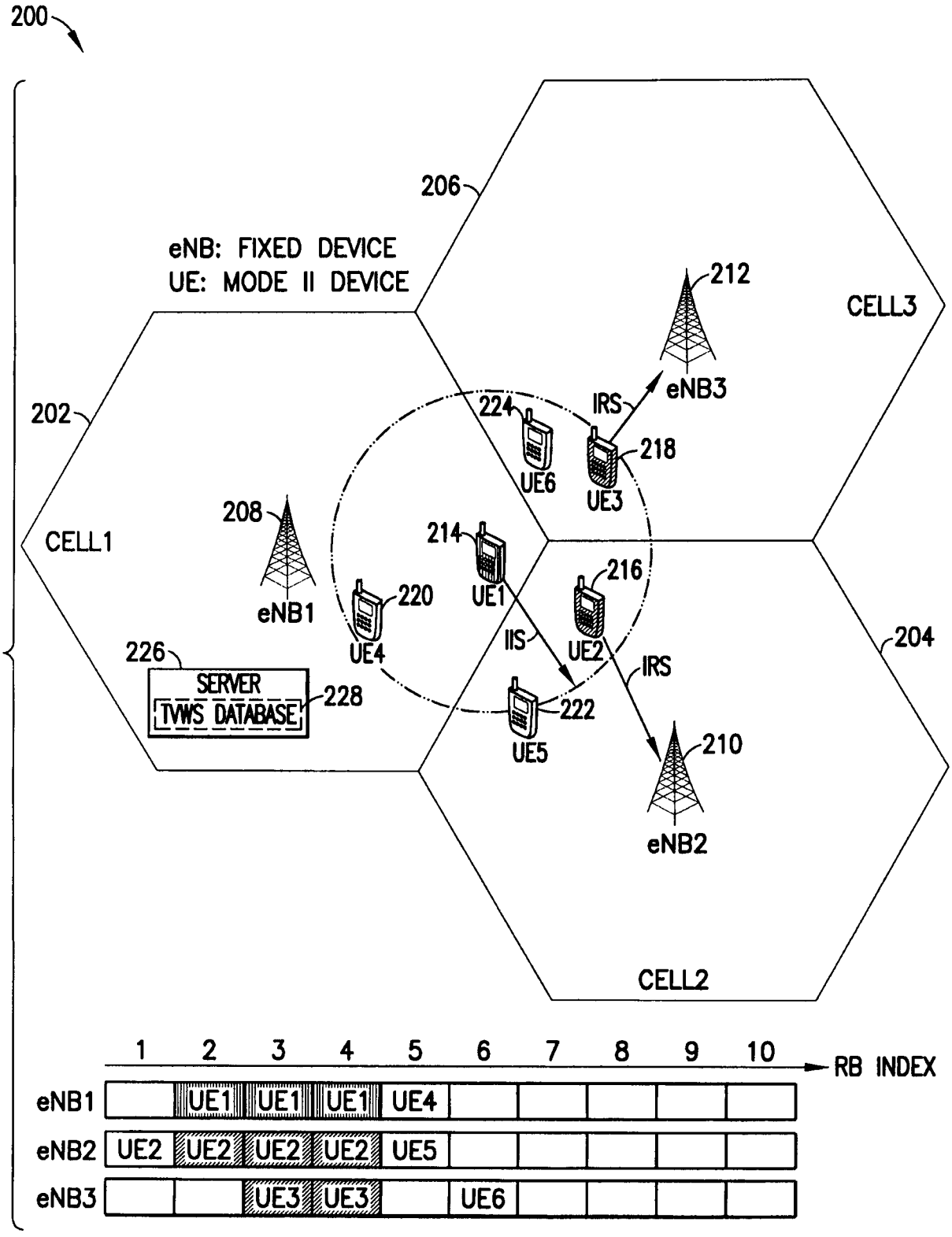
200
206
eNB: FIXED DEVICE
UE: MODE II DEVICE
212
CELL3
eNB3
202
224
IRS
218
UE6
UE3
208
214
CELL1
216
eNB1
220
UE1
UE2
204
226
IIS
IRS
SERVER
TVWS DATABASE
228
222
UE4
UE5
210
eNB2
CELL2
1 2 3 4 5 6 7 8 9 10
RB INDEX
eNB1 UE1 UE1 UE1 UE4
eNB2 UE2 UE2 UE2 UE2 UE5
eNB3 UE3 UE3 UE6

FIG.3

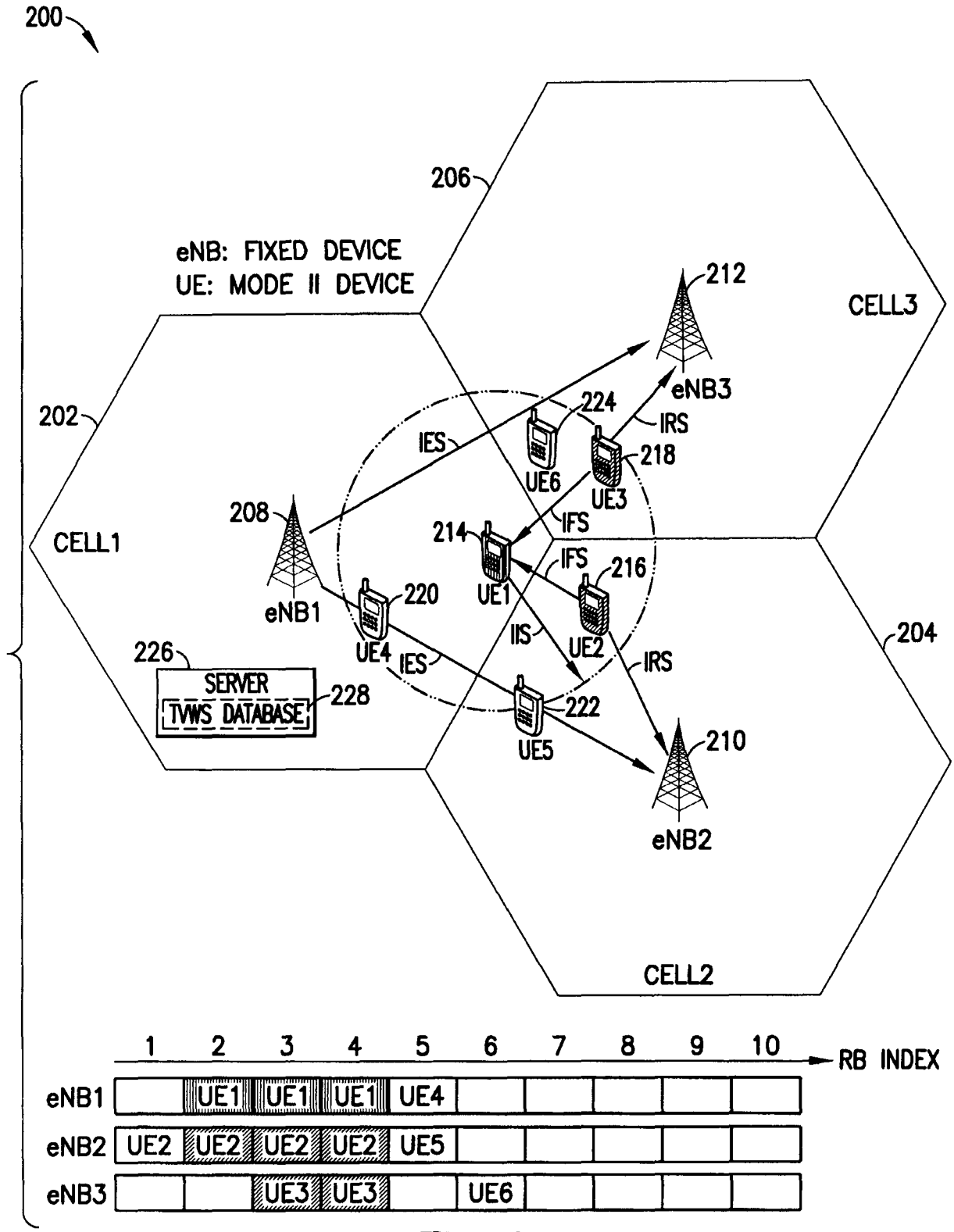
200
206
eNB: FIXED DEVICE
UE: MODE II DEVICE
212
CELL3
eNB3
224
IRS
IES
218
UE6
UE3
202
208
214
IFS
CELL1
IFS
216
eNB1
220
UE1
UE2
IIS
204
226
UE4
IES
IRS
SERVER
TVWS DATABASE
228
222
UE5
210
eNB2
CELL2
1 2 3 4 5 6 7 8 9 10
RB INDEX
eNB1 UE1 UE1 UE1 UE4
eNB2 UE2 UE2 UE2 UE2 UE5
eNB3 UE3 UE3 UE6

FIG.4

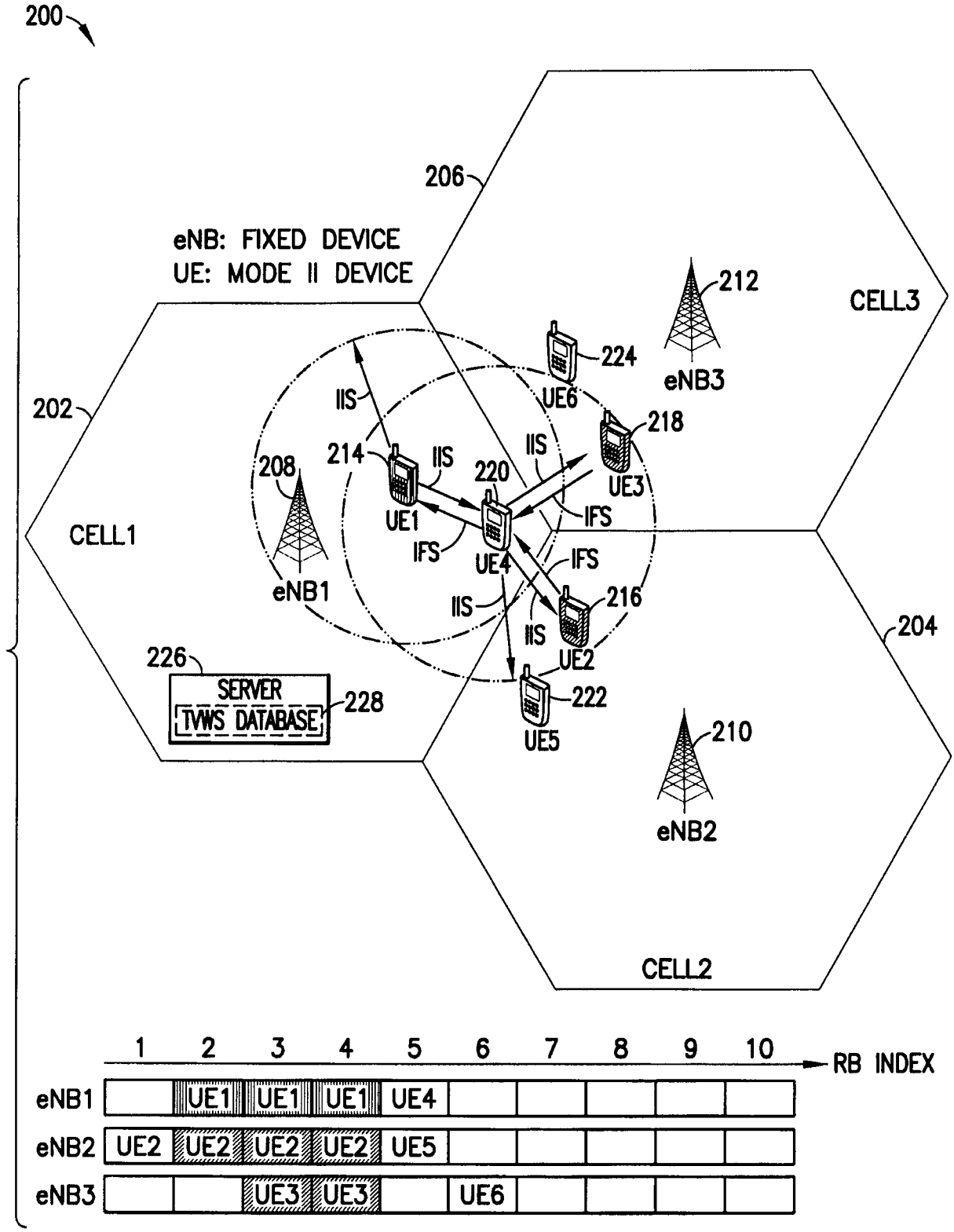
200
206
eNB: FIXED DEVICE
UE: MODE II DEVICE
212
CELL3
224
eNB3
UE6
202
218
IIS
214
IIS
220
IIS
208
UE3
UE1
IFS
IFS
CELL1
UE4
IFS
eNB1
IIS
216
204
IIS
UE2
226
222
SERVER
TVWS DATABASE
228
UE5
210
eNB2
CELL2
1 2 3 4 5 6 7 8 9 10
RB INDEX
eNB1 UE1 UE1 UE1 UE4
eNB2 UE2 UE2 UE2 UE2 UE5
eNB3 UE3 UE3 UE6

FIG.5

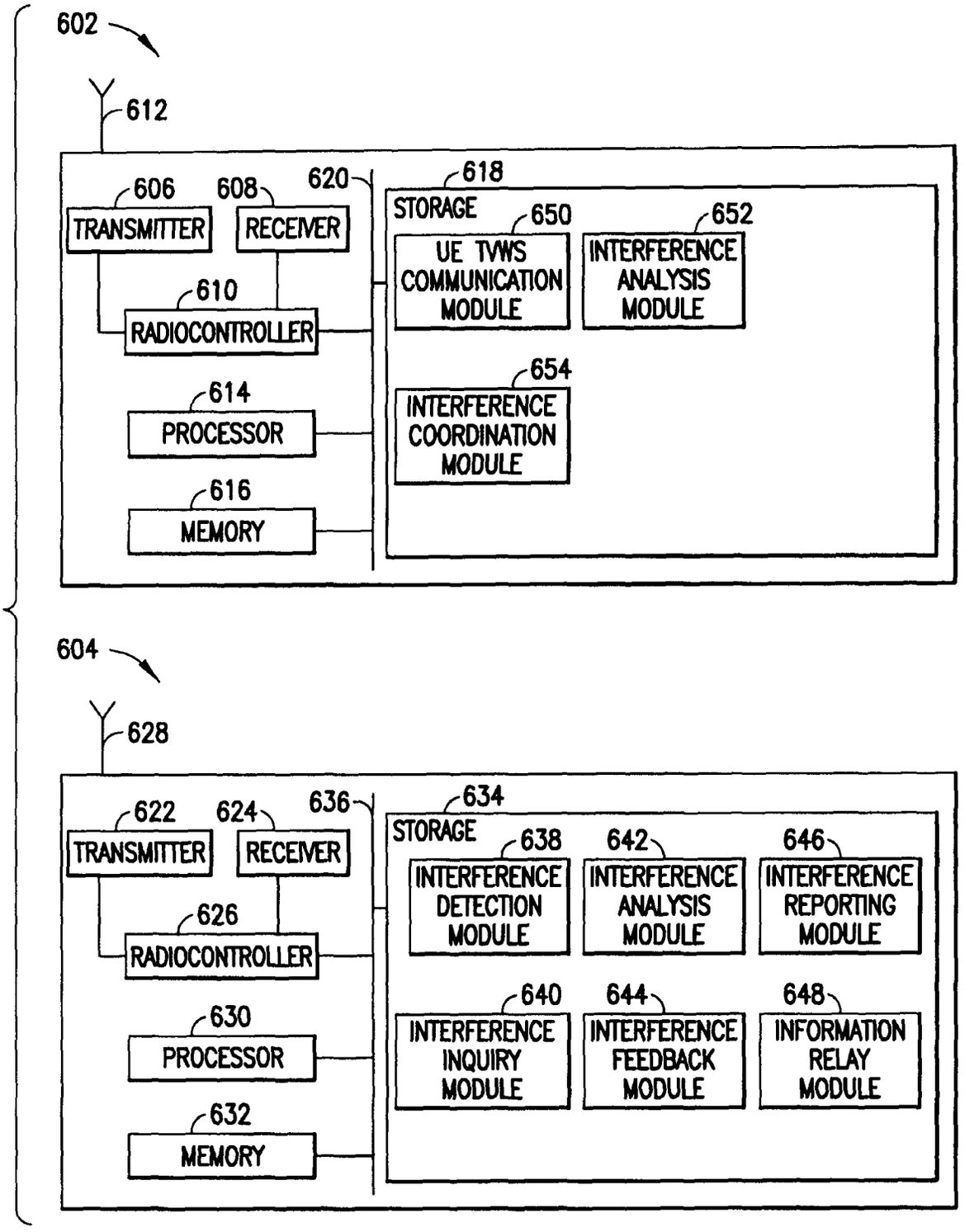
602
612
606
608
620
618
TRANSMITTER
RECEIVER
STORAGE
650
652
UE TVWS COMMUNICATION MODULE
INTERFERENCE ANALYSIS MODULE
610
RADIOCONTROLLER
654
INTERFERENCE COORDINATION MODULE
614
PROCESSOR
616
MEMORY
604
628
622
624
636
634
TRANSMITTER
RECEIVER
STORAGE
638
642
646
INTERFERENCE DETECTION MODULE
INTERFERENCE ANALYSIS MODULE
INTERFERENCE REPORTING MODULE
626
RADIOCONTROLLER
640
644
648
INTERFERENCE INQUIRY MODULE
INTERFERENCE FEEDBACK MODULE
INFORMATION RELAY MODULE
630
PROCESSOR
632
MEMORY

FIG.6

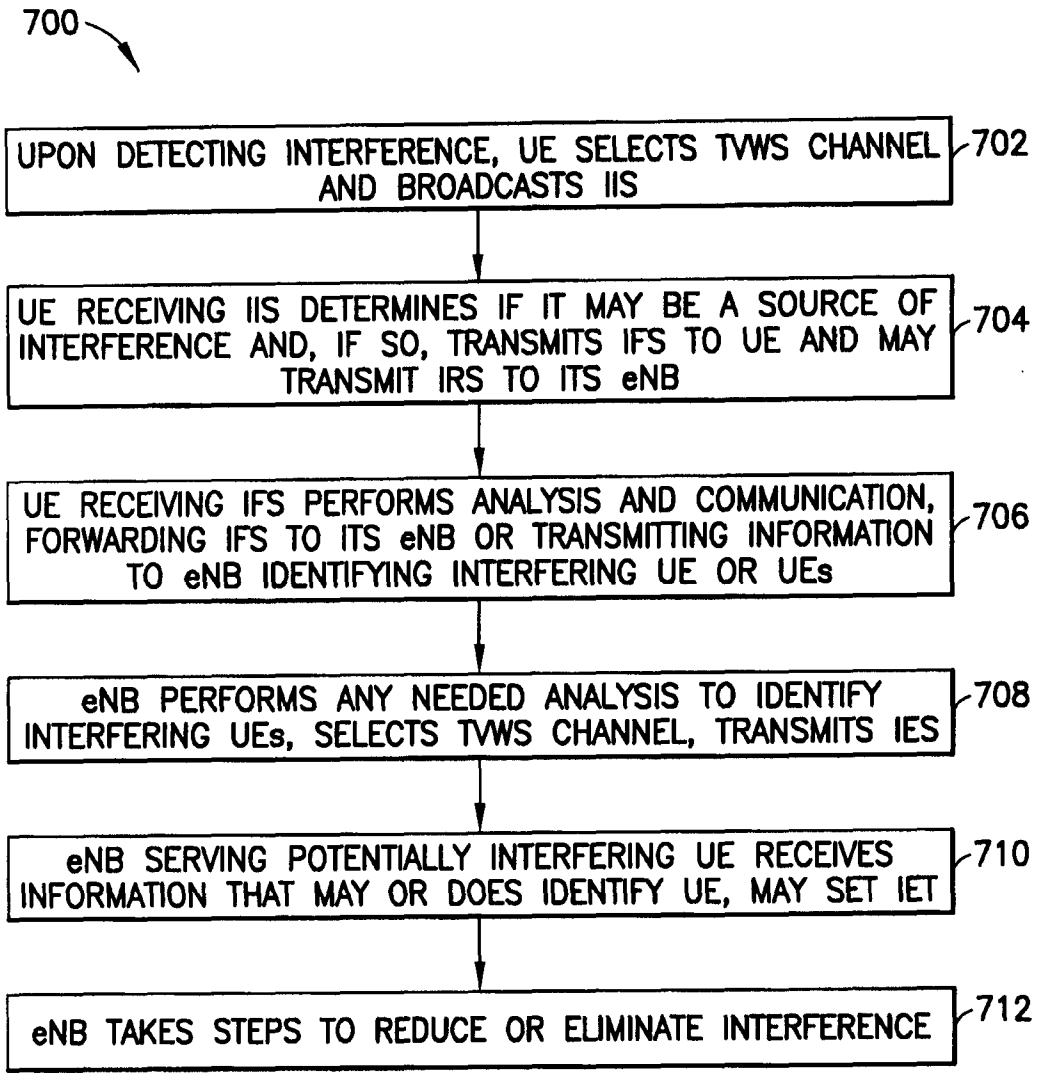
700
UPON DETECTING INTERFERENCE, UE SELECTS TVWS CHANNEL AND BROADCASTS IIS
702
UE RECEIVING IIS DETERMINES IF IT MAY BE A SOURCE OF INTERFERENCE AND, IF SO, TRANSMITS IFS TO UE AND MAY TRANSMIT IRS TO ITS eNB
704
UE RECEIVING IFS PERFORMS ANALYSIS AND COMMUNICATION, FORWARDING IFS TO ITS eNB OR TRANSMITTING INFORMATION TO eNB IDENTIFYING INTERFERING UE OR UEs
706
eNB PERFORMS ANY NEEDED ANALYSIS TO IDENTIFY INTERFERING UEs, SELECTS TVWS CHANNEL, TRANSMITS IES
708
eNB SERVING POTENTIALLY INTERFERING UE RECEIVES INFORMATION THAT MAY OR DOES IDENTIFY UE, MAY SET IET
710
eNB TAKES STEPS TO REDUCE OR ELIMINATE INTERFERENCE
712

FIG.7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2011/079494

A. CLASSIFICATION OF SUBJECT MATTER

H04W24/08 (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)

IPC: H04W; H04L; H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CNABS, CNTXT, CNKI, VEN: interfer+, disturb+, mess, licence, license, permit+, permission, allow+, consent+, authoriz+, un-, no, not, frequency, band, link, channel, ID, identify???, identification, identified, identifies, broadcast+, inquir+, query???, queries, queried

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN102131223A (CHINA MOBILE COMMUNICATION CORP) 20 July 2011(20.07.2011) Description paragraphs [0046]-[0058], figures 1-3	1-20
A	CN1790970A (MICROSOFT CORP) 21 June 2006 (21.06.2006) The whole document	1-20
A	CN101651700A (SPREADTRUM COMMUNICATIONS SHANGHAI CO LTD) 17 Feb. 2010 (17.02.2010) The whole document	1-20
A	CN101790231A (HUAWEI TECHNOLOGIES CO LTD) 28 July 2010 (28.07.2010) The whole document	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
23 May 2012 (23.05.2012)	**14 Jun. 2012 (14.06.2012)**
Name and mailing address of the ISA/CN The State Intellectual Property Office, the P.R.China 6 Xitucheng Rd., Jimen Bridge, Haidian District, Beijing, China 100088 Facsimile No. 86-10-62019451	Authorized officer LIU, Yunan Telephone No. (86-10)62411377

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

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2011/079494

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
CN102131223A	20.07.2011	None	
CN1790970A	21.06.2006	US2006121854A1	08.06.2006
		JP2006186992A	13.07.2006
		IN200503189I1	02.10.2009
		EP1667372A1	07.06.2006
		KR20060063704A	12.06.2006
		JP4845496B2	28.12.2011
		US7440728B2	21.10.2008
		EP1667372B1	24.08.2011
CN101651700A	17.02.2010	None	
CN101790231A	28.07.2010	None	