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(54) **NEIGHBOR LIST DISTRIBUTION FOR SMART MOBILITY**

(75) Inventors: **Keiichi Kubota**, Weybridge (GB); **Brian Alexander Martin**, Farnham (GB)

(73) Assignee: **Renesas Mobile Corporation**

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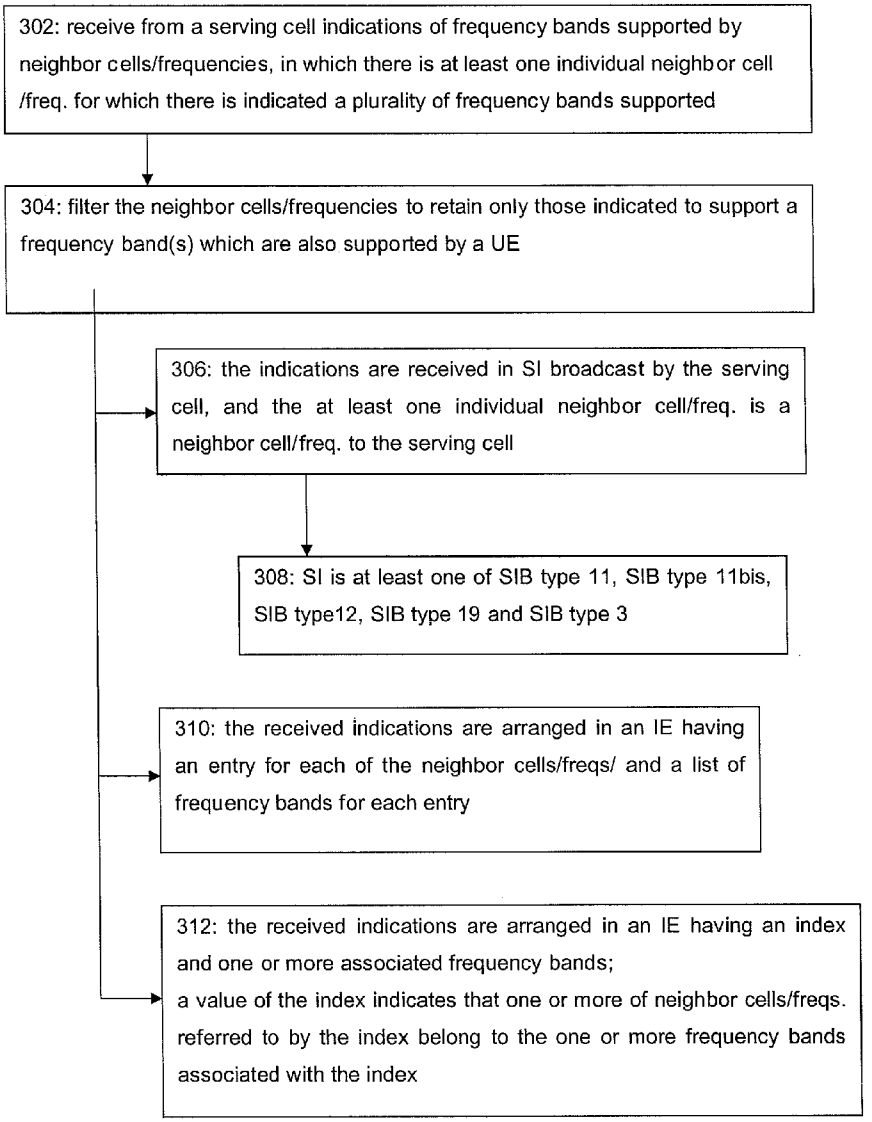
(57) **ABSTRACT**

A user equipment UE receives from a serving cell indications of frequency bands supported by neighbor cells/frequencies, and at least one individual neighbor cell/frequency supports a plurality of frequency bands. The neighbor cells/frequencies are filtered to retain only those which are indicated to support a frequency band or frequency bands which are also supported by the UE. Examples are given of various system information blocks for sending the frequency band indications to the UE. In one embodiment they are arranged in an information element IE having an entry for each of the neighbor cells/frequencies and a list of frequency bands for each entry. In another the IE has an index and an associated frequency band(s) where a value of the index indicates that one or more of the neighbor cells/frequencies referred to by the index belong to the associated frequency band(s).



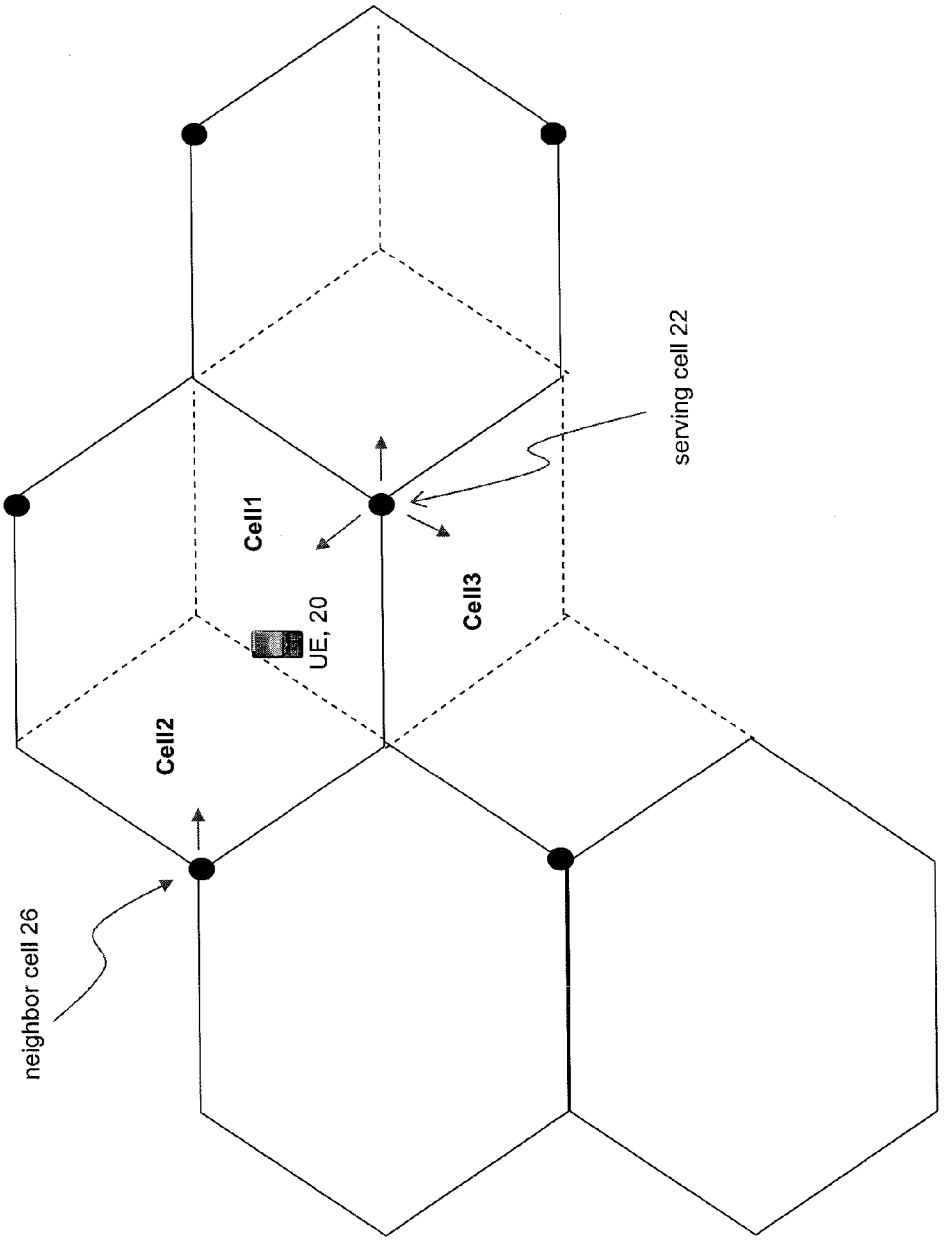


Figure 1

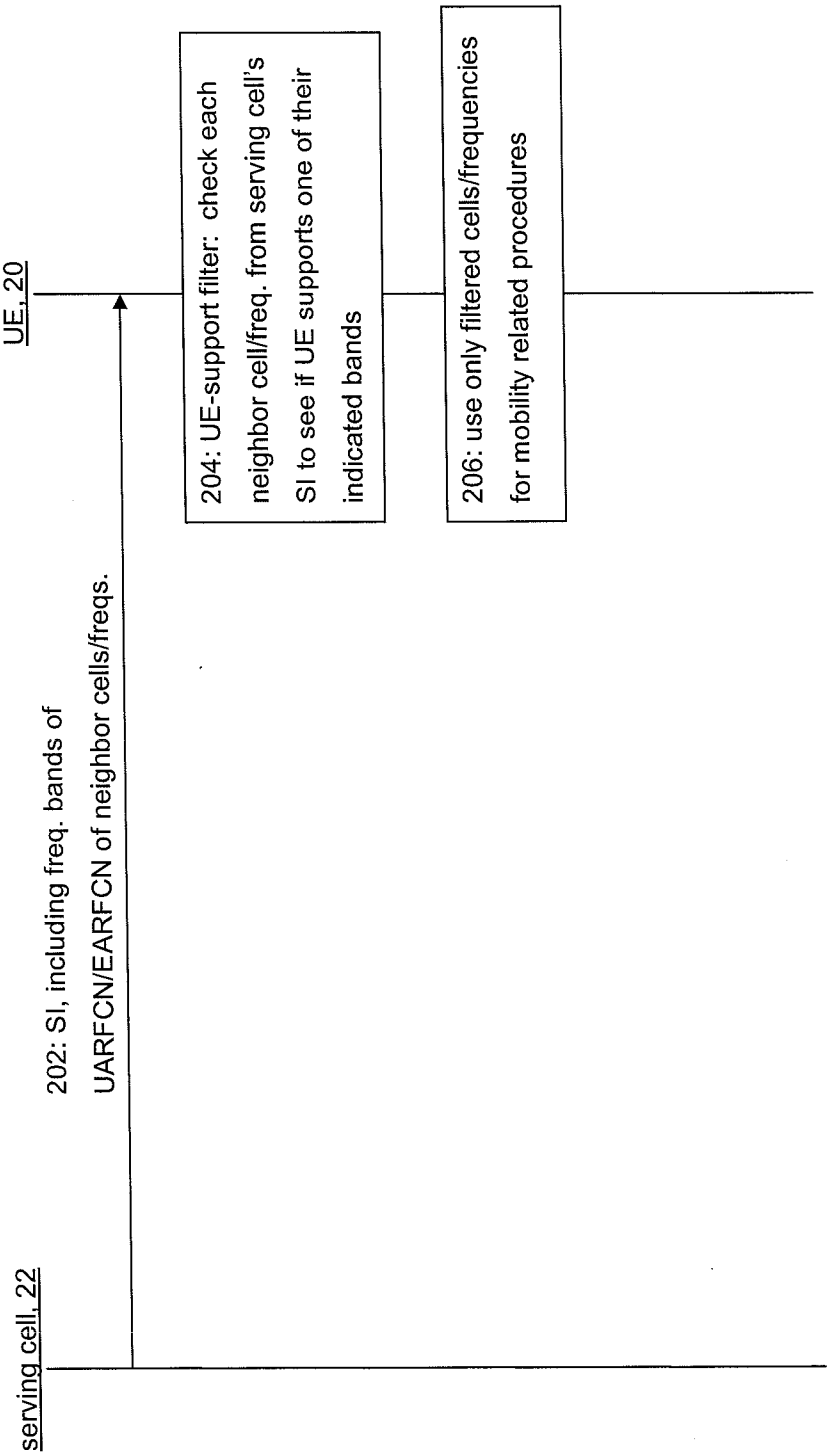

serving cell, 22
UE, 20
202: SI, including freq. bands of UARFCN/EARFCN of neighbor cells/freqs.
204: UE-support filter: check each neighbor cell/freq. from serving cell's SI to see if UE supports one of their indicated bands
206: use only filtered cells/frequencies for mobility related procedures

Figure 2

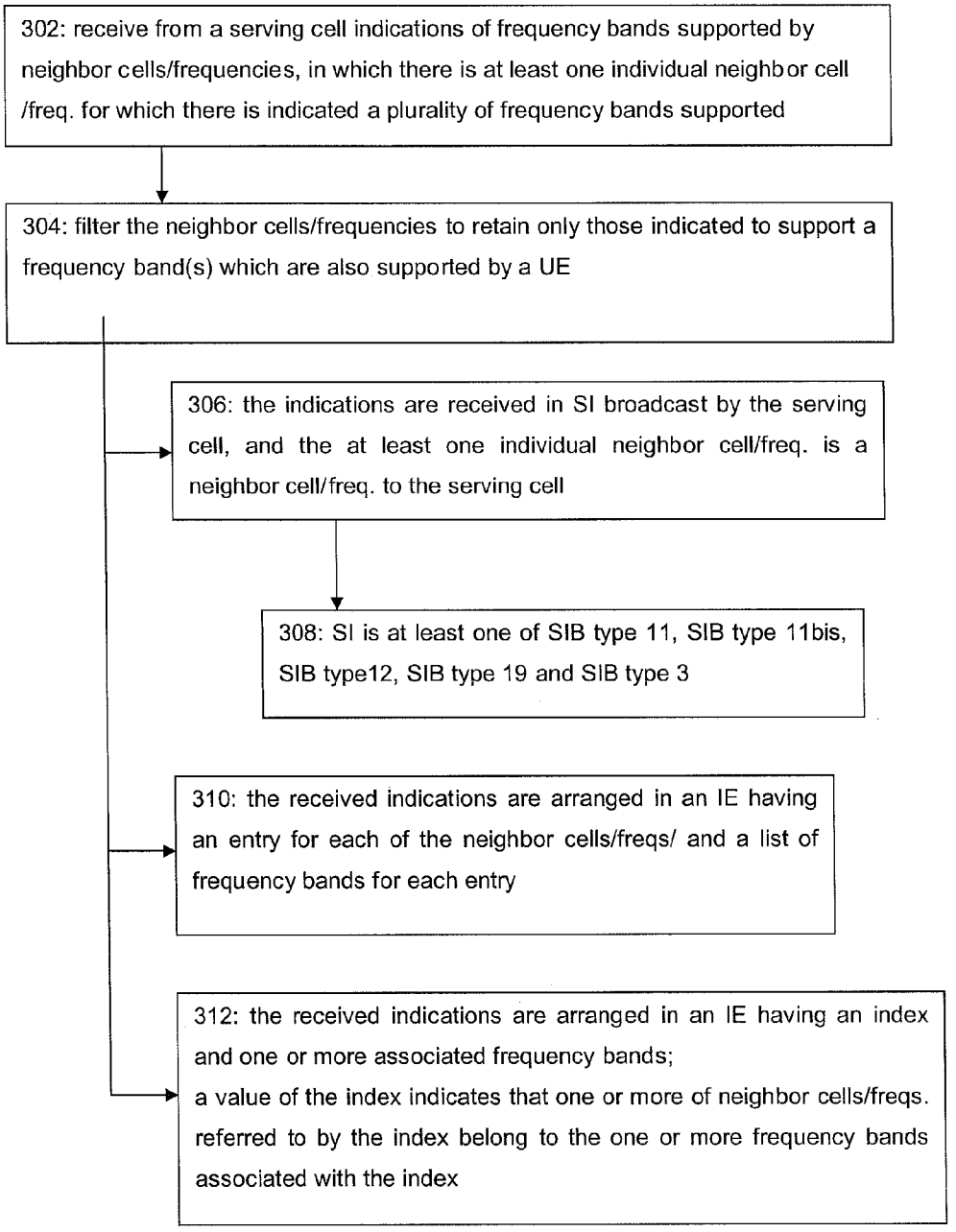

302: receive from a serving cell indications of frequency bands supported by neighbor cells/frequencies, in which there is at least one individual neighbor cell /freq. for which there is indicated a plurality of frequency bands supported
304: filter the neighbor cells/frequencies to retain only those indicated to support a frequency band(s) which are also supported by a UE
306: the indications are received in SI broadcast by the serving cell, and the at least one individual neighbor cell/freq. is a neighbor cell/freq. to the serving cell
308: SI is at least one of SIB type 11, SIB type 11bis, SIB type12, SIB type 19 and SIB type 3
310: the received indications are arranged in an IE having an entry for each of the neighbor cells/freqs/ and a list of frequency bands for each entry
312: the received indications are arranged in an IE having an index and one or more associated frequency bands;
a value of the index indicates that one or more of neighbor cells/freqs. referred to by the index belong to the one or more frequency bands associated with the index

Figure 3

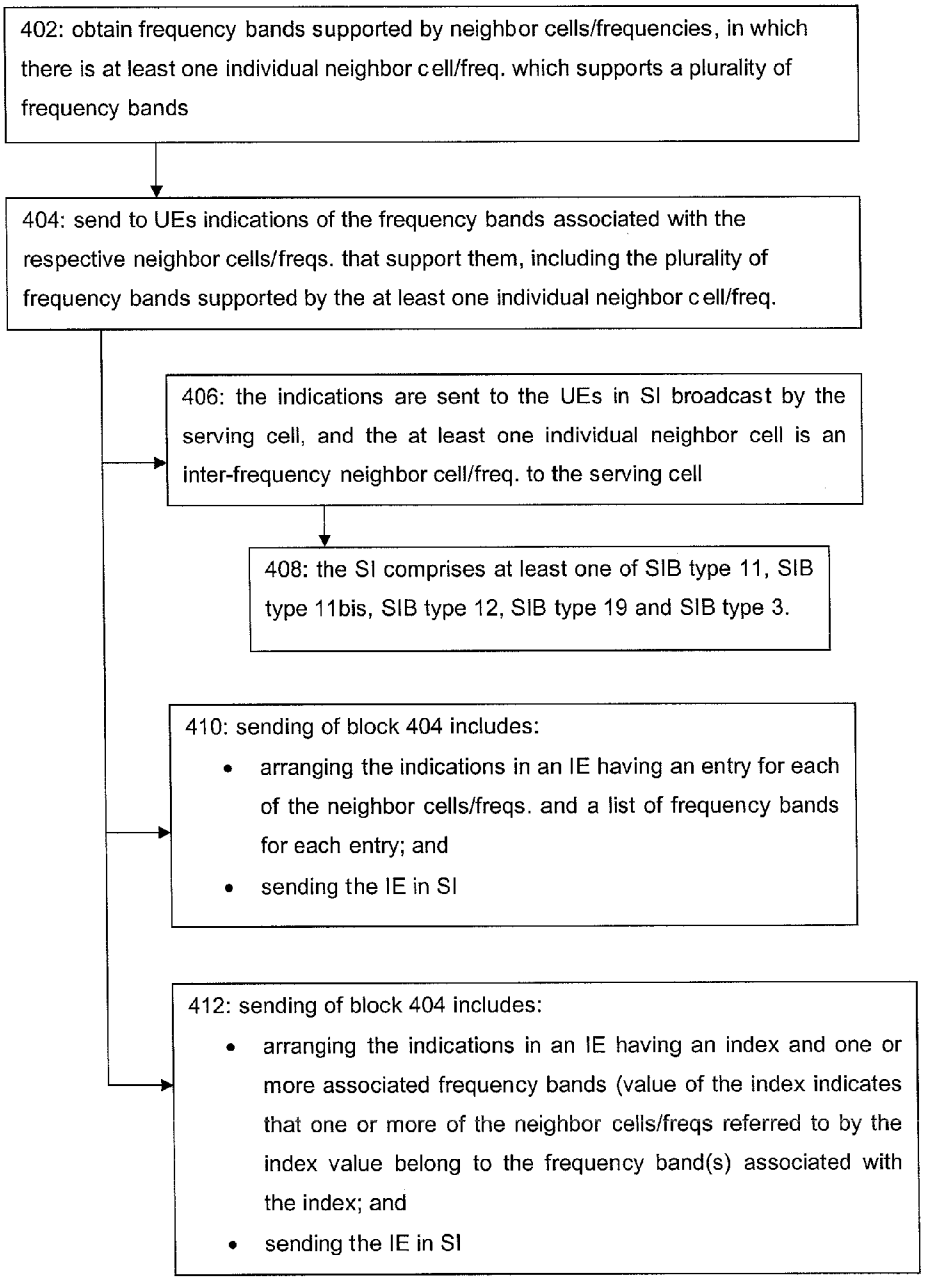

402: obtain frequency bands supported by neighbor cells/frequencies, in which there is at least one individual neighbor cell/freq. which supports a plurality of frequency bands
404: send to UEs indications of the frequency bands associated with the respective neighbor cells/freqs. that support them, including the plurality of frequency bands supported by the at least one individual neighbor cell/freq.
406: the indications are sent to the UEs in SI broadcast by the serving cell, and the at least one individual neighbor cell is an inter-frequency neighbor cell/freq. to the serving cell
408: the SI comprises at least one of SIB type 11, SIB type 11bis, SIB type 12, SIB type 19 and SIB type 3.
410: sending of block 404 includes:
• arranging the indications in an IE having an entry for each of the neighbor cells/freqs. and a list of frequency bands for each entry; and
• sending the IE in SI
412: sending of block 404 includes:
• arranging the indications in an IE having an index and one or more associated frequency bands (value of the index indicates that one or more of the neighbor cells/freqs referred to by the index value belong to the frequency band(s) associated with the index; and
• sending the IE in SI

Figure 4

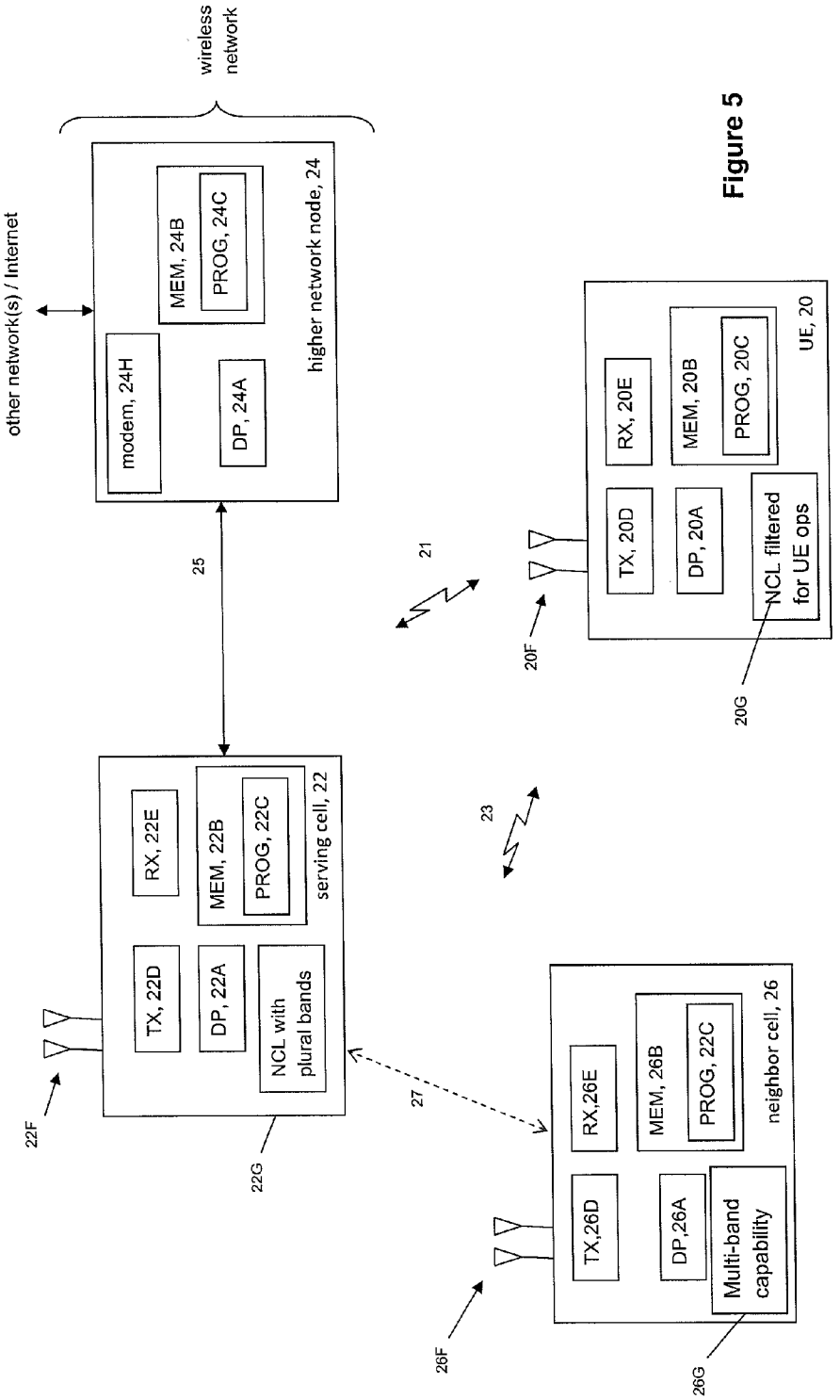

wireless network
other network(s) / Internet
modem, 24H
MEM, 24B
PROG, 24C
DP, 24A
higher network node, 24
25
21
23
27
TX, 22D
DP, 22A
NCL with plural bands
RX, 22E
MEM, 22B
PROG, 22C
serving cell, 22
22F
22G
TX, 20D
DP, 20A
NCL filtered for UE ops
RX, 20E
MEM, 20B
PROG, 20C
UE, 20
20F
20G
TX,26D
DP,26A
Multi-band capability
RX,26E
MEM, 26B
PROG, 22C
neighbor cell, 26
26F
26G

Figure 5

NEIGHBOR LIST DISTRIBUTION FOR SMART MOBILITY

TECHNICAL FIELD

[0001] The exemplary and non-limiting embodiments of this invention relate generally to wireless communication systems, methods, devices and computer programs and, more specifically, relate to neighbor cells which support multiple frequency bands.

BACKGROUND

[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
EARFCN	EUTRA absolute radio frequency channel number
EUTRA	evolved universal terrestrial radio access
IE	information element
LTE	long term evolution (EUTRA network)
LTE-A	LTE-advanced
RAN	radio access network
RF	radiofrequency
SI	system information
SIB	system information block
UARFCN	UTRA absolute radio frequency channel number
UMTS	universal mobile telecommunication system
UE	user equipment

[0003] Cellular radio communications now include individual cells operating on multiple radio frequency channels in order to better support a variety of different UEs, some of which may be capable of operating on only one of these frequency bands which is different than a band for which another UE in the cell is capable. Additionally, some bands in use by one cell may have some frequency portion overlapping with bands in an adjacent neighbor cell, particularly where such neighbor cells operate under different radio access technologies such as UMTS and LTE. For example, in the HSPA version of UMTS bands II and XXV have respective frequency bands 1930-1990 MHz and 1930-1995 MHz and thus are overlapping in frequency. There is a similar overlap among bands V (869-894 MHz), VI (875-885 MHz) and new band XXVI (814-849 and 859-894 MHz); bands IV (2110-2115 MHz) and X (2110-2170 MHz); and bands III (1805-1880 MHz) and IX (1844.9-1879.9 MHz).

[0004] Relevant to the above scenarios are certain proposals for LTE Release 10 set forth in document R2-114158 by Qualcomm entitled MULTIPLE HARMONISED BANDS PER CELL and in document R2-114299 by Ericsson and ST-Ericsson entitled MULTIPLE FREQUENCY BAND INDICATORS IN A CELL (both from 3GPP TSG-RAN WG2 meeting #75; Athens, Greece; 22-26 Aug. 2011). Specifically, these documents propose that some cells which belong to a frequency in an overlapping band will broadcast the multiple bands they support according to variously named extension fields for the SIB**1**. In the examples given there are in the context of a new band **26** which was recently introduced into Release 10 discussions. This broadcast that multiple bands are supported is to allow new UEs which support the new band **26** to relax their RF requirements as compared to the older defined bands so that when roaming onto an operators band they may then apply the new relaxed requirements, and thereby avoid the UE having to perform interoperability testing (IOT). These proposals are to additionally allow older UEs supporting the older bands to camp on the same cell as well as to allow legacy UEs to camp on the newer band. These proposals seek to adapt the requirement at section 5.4 of 3GPP TS 25.101 v10.2.0 (2011-06) that a cell is allowed to indicate in SI only one frequency band it supports.

[0005] A problem arises in the above solutions when considering UE mobility between cells. A UE performs mobility based on a neighbor list given to it by SI. The conventional practice is that for UMTS the individual cells on each frequency are listed, and for LTE only the frequency is listed. But if the above proposals of introducing multiple bands support in a cell were adopted, the UE would not know whether the neighbor cell (UMTS) or neighbor frequency (LTE) belongs to a frequency band which the UE supports until after that UE reads SI from the target cell (specifically, SIB**5** if the target cell is UMTS and SIB**1** if the target cell is LTE). So in some cases the UE will give up on re-selecting to the neighbor cell because of a non-supported frequency band only after the UE performed some mobility related processes (such as neighbor cell measurement, cell quality evaluation, cell reselection, target cell SI reading), which depletes the battery or other portable power source of the UE. Since the UARFCN or EARFCN indicated in the neighbor cell/frequency list may belong to multiple bands, the UE cannot determine which band to which it refers.

[0006] Further, the serving cell's broadcast of its own UARFCN/EARFCN referring to a specific frequency can be different for a different band; different UARFCN/EARFCN can refer to the same frequency but in a different band/channel. In this case the neighbor cell/frequency list which the UE uses for mobility purposes would need to be updated to broadcast the same frequency multiple times so that all UEs can reselect. But this then causes a problem in that there is a limited number of cells which can be broadcast in the UTRAN neighbor cell list. Even in some of today's networks, the size limitation imposed but the signalling restrictions of the UTRAN neighbor cell list can restrict the neighbor cell configuration therefore increasing the size further is not practical. This also causes a problem due to there being a maximum number of frequencies in UTRAN and/or EUTRAN which the UE which is required to measure. In UMTS the UE is required to be able to measure two frequencies in addition to the carrier (serving cell) frequency, and in LTE the UE is required to measure three frequencies in addition to the carrier frequency. If for example the serving cell supports three bands, the neighbor cell/frequency list size may increase by a factor of three. In principle the UE could measure three bands if the frequencies are all identical, but this is not required by current radio specifications because currently there is no possibility for a cell to belong to more than one band.

[0007] For that reason this issue was not a concern in the past. While there were some overlapping frequency bands (for example, Band V and Band VI overlap) there was no practical situation that the Band V cell could be signalled as a neighbor cell of a Band VI serving cell and additionally there was no possibility for either the serving or neighbor cell to support multiple bands. The detailed teachings below resolve the above problem which is wasteful of the UE's limited power source.

SUMMARY

[0008] The foregoing and other problems are overcome, and other advantages are realized, by the use of the exemplary embodiments of this invention.

[0009] In a first exemplary embodiment of the invention there is an apparatus comprising at least one processor; and at least one memory including computer program code. In this embodiment the at least one memory and the computer program code is configured, with the at least one processor, to cause the apparatus at least to: receive from a serving cell indications of frequency bands supported by neighbor cells or frequencies, in which there is at least one individual neighbor cell or frequency for which there is indicated a plurality of frequency bands supported; and filter the neighbor cells or frequencies to retain only those which are indicated to support a frequency band or bands which are also supported by a user equipment.

[0010] In a second exemplary embodiment of the invention there is a method comprising: receiving from a serving cell indications of frequency bands supported by neighbor cells or frequencies, in which there is at least one individual neighbor cell or frequency for which there is indicated a plurality of frequency bands supported; and filtering the neighbor cells or frequencies to retain only those which are indicated to support a frequency band or bands which are also supported by a user equipment.

[0011] In a third exemplary embodiment of the invention there is a computer readable memory tangibly storing a computer program that is executable by at least one processor. In this embodiment the computer program comprises code for receiving in system information broadcast by a serving cell indications of frequency bands supported by neighbor cells or frequencies, in which there is at least one individual neighbor cell or frequency for which there is indicated a plurality of frequency bands supported; and code for filtering the neighbor cells or frequencies to retain only those which are indicated to support a frequency band or bands which are also supported by a user equipment.

[0012] In a fourth exemplary embodiment of the invention there is an apparatus comprising at least one processor; and at least one memory including computer program code. In this embodiment the at least one memory and the computer program code is configured, with the at least one processor, to cause the apparatus at least to: obtain frequency bands supported by neighbor cells or frequencies, in which there is at least one individual neighbor cell or frequency which supports a plurality of frequency bands; and send to user equipments indications of the frequency bands associated with the respective neighbor cells or frequencies that support them, including the plurality of frequency bands supported by the at least one individual neighbor cell or frequency.

[0013] In a fifth exemplary embodiment of the invention there is a method comprising: obtaining frequency bands supported by neighbor cells or frequencies, in which there is at least one individual neighbor cell or frequency which supports a plurality of frequency bands; and sending to user equipments indications of the frequency bands associated with the respective neighbor cells or frequencies that support them, including the plurality of frequency bands supported by the at least one individual neighbor cell or frequency.

[0014] In a sixth exemplary embodiment of the invention there is a computer readable memory tangibly storing a computer program that is executable by at least one processor. In this embodiment the computer program comprises code for obtaining frequency bands supported by neighbor cells or frequencies, in which there is at least one individual neighbor cell or frequency which supports a plurality of frequency bands; and code for sending to user equipments indications of the frequency bands associated with the respective neighbor cells or frequencies that support them, including the plurality of frequency bands supported by the at least one individual neighbor cell or frequency.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] FIG. **1** is a plan view of a conceptual radio environment in which the various exemplary embodiments detailed herein may be practiced to advantage.

[0016] FIG. **2** is an exemplary signaling diagram showing signaling and internal processes according to exemplary embodiments detailed herein.

[0017] FIG. **3** is a logic flow diagram illustrating from the perspective of the UE the operation of a method, and a result of execution of computer program instructions embodied on a computer readable memory, for practicing exemplary embodiments of these teachings.

[0018] FIG. **4** is a logic flow diagram illustrating from the perspective of the serving cell/serving access node the operation of a method, and a result of execution of computer program instructions embodied on a computer readable memory, for practicing exemplary embodiments of these teachings.

[0019] FIG. **5** is a simplified block diagram of some of the devices shown at FIG. **1** which are exemplary electronic devices suitable for use in practicing the exemplary embodiments of this invention.

DETAILED DESCRIPTION

[0020] While the two documents noted in the background section above refer to the cell broadcasting in its own SI the additional bands which it supports, those proposals do not go far enough. To avoid the UE undertaking certain mobility procedures as noted above which will in the end prove fruitless due to the UE's incompatibility with a neighbor cell, in an embodiment of these teachings the serving cell will broadcast in its SI an indication of the multiple frequency bands that its individual neighbor cells or neighbor frequencies support. For example, a UTRAN serving cell will broadcast in its own SI indications of the frequency bands which its neighbor UTRAN cells support and which its neighbor LTE frequencies support. For the case of a LTE serving cell it will broadcast in its own SI indications of the frequency bands which its neighbor frequencies (UTRAN and LTE) support. In this manner the UE can see the entire list of bands which each neighbor cell or frequency supports, and construct its own locally stored neighbor cell list or neighbor frequency list (which it uses for its mobility choices) by filtering according to the UE's own capabilities on those channels/bands. Since the UE will have the relevant information before reading SI of the neighbor cell it can avoid performing mobility-related processes directed toward cell reselection to a neighbor cell to which it is incompatible. In case a network does not update the neighbor cell or frequency list the UE can still use the frequency band information in its previously-defined filtered list to avoid performing measurements in preparation for handover in a particular radio access technology. In these teachings a new cell which belongs to more than one frequency band can broadcast in the neighbor cell or frequency list that another cell or frequency also belongs to more than one frequency band, such as by indicating the frequency bands in the neighbors' UARFCN and/or EARFCN (depending on whether the neighbor cell is a UMTS or a LTE cell).

[0021] Before detailing further specific implementations, reference is made to FIG. **1** for illustrating an exemplary radio environment in which these teachings can be practiced to advantage. There is a UE **20** operating in the vicinity of a serving cell **22** and there are multiple neighbor cells operating on multiple neighbor frequencies, of which neighbor cell **26** is exemplary. The specifics vary depending on whether the serving cell **22** and the neighbor cell **26** are operating in the UMTS or the LTE systems, but in general the serving cell **22** will broadcast in its system information indications about all of the frequency bands which the neighbor cells and neighbor frequencies support. The UE **20** will of course get the SI broadcast from the serving cell **22** prior to performing any mobility-related procedures toward a given neighbor cell or neighbor frequency. From the list of frequency bands for the neighbor cells/frequencies the UE **20** will determine which if any of those bands it supports. The UE **20** will then construct the neighbor cell list using all the neighbor cells and neighbor frequencies it learned from the SI of its serving cell **22**, excluding those the UE **20** does not support. When the UE needs to perform some neighbor cell measurement, cell reselection, or other mobility-related process, it will use only those channels on the neighbor cell list that it constructed by filtering using the UE's own capabilities, and so all neighbor cells and frequencies on the UE's locally stored list will be viable to use for cell reselection (assuming sufficient signal strength and other dynamic parameters of the radio environment).

[0022] FIG. **2** is an exemplary signaling diagram illustrating signaling and internal processes in the serving cell **22** and the UE **20** according to the above overview. At **202** the serving cell **22** broadcasts its SI, which according to these teachings includes the frequency band information for the UARFCN and/or the EARFCN of each of its neighbor cells/frequencies. At **204** the UE **20**, having received the serving cell's broadcast SI **202**, then filters all of those neighbor cells/frequencies according to the UE's own frequency band capabilities. Each band the UE supports gets filtered in and each band it does not gets filtered out. In one embodiment the UE **20** constructs its neighbor cell list with this filtering and stores it in its local memory for use in the cell. That neighbor cell list will include every neighbor cell frequency band that the UE **20** learned from the serving cell's SI **202**, as filtered at **204** to exclude all bands which the UE **20** does not support. If for example a particular neighbor cell **26** is assigned to only one frequency band according to the serving cell's SI **202** and if the UE does not support the frequency band, then the UE **20** can exclude the cell from its neighbor cell list. If for example the neighbor cell **26** supports three frequency bands which the UE **20** learns at **202** from the serving cell's SI and the UE **20** supports two of them, then the UE **20** will include the cell into the neighbor cell list, and it keeps those two frequency bands in its memory. The UE **20** uses the neighbor cell list to select which cells/frequencies to measure and re-select on. The reader will recognize that typically there will be multiple neighbor cells and neighbor frequencies whose frequency band or bands (as the case may be) are indicated by the SI of the serving cell **22**.

[0023] In another embodiment the UE **20** stores the list it receives from the network, and filters at block **204** on a case by case basis anytime the UE **20** is about to start a mobility related procedure, and continues that procedure only if the band relevant to the procedure passes the UE-capability filtering. In this embodiment the UE does not store the filtered list but runs a stored algorithm that filters the network-supplied list each time it's needed and the same result is obtained. However the filtering of block **204** is implemented, at **206** the UE uses only the neighbor cells/frequencies which are indicated to support a frequency band which is also supported by the UE itself for any mobility related procedure.

[0024] From the network perspective, if the neighbor cell **26** is a UMTS cell the serving cell **22** signals the frequency band information for the UARFCN of that UMTS neighbor cell in the system information broadcasted on the serving cell's broadcast control channel. If the neighbor cell **26** is an LTE cell the serving cell **22** signals the frequency band information for the EARFCN of the neighbor frequencies in the serving cell's system information. In case the frequency is associated with different bands, the serving cell **22** will signal all of the potential bands that can be found on that frequency.

[0025] From the UE's perspective, the UE **20** will collect all of the neighbor cells' associated frequency bands signaled in the serving cell's SI. For those neighbor cells which are UMTS cells the UE **20** checks that neighbor cell's frequency band information before performing any mobility procedures to that neighbor cell. For a neighbor cell for which all of its assigned frequency bands are not supported by the UE **20**, the UE **20** simply discards the UTRAN neighbor cell from its locally stored list. That is, the UE **20** will not attempt any mobility procedure to move to that neighbor UMTS cell whose frequency band or frequency bands the UE **20** does not support. For a neighbor UMTS cell whose frequency band the UE does support, the UE **20** may perform the necessary mobility procedures for that neighbor UMTS cell (assuming it is a good cell reselection candidate in other respects such as signal strength).

[0026] Again from the UE's perspective, for those neighbor frequencies which are associated with LTE cells the UE **20** simply does not attempt to measure or perform any mobility procedures on that frequency if the UE **20** does not support the frequency bands indicated in the serving cell's SI. This is similar to the UMTS cell procedure except that the LTE cell frequency band information is always given per frequency instead of per cell. There may be cases where there is a mixture of different frequency band cells on one frequency. To address that case the serving cell **22** can signal in its SI the cell PCI range, a list of each frequency band on a cell or frequency, in order to optimize the UE mobility/reselection attempts. This case is expected to be atypical and likely not even needed due to the increased signalling overhead in SI it represents.

[0027] There are multiple ways to implement this increased signaling in the serving cell's SI. The following examples do so by adding an information element to the serving cell's system information which includes a list of frequency band information for all the neighbor cells and neighbor frequencies which support more than one frequency band. For example, if the serving cell **22** is UMTS it can add that new IE which carries the band information for its multi-band UMTS neighbor cell(s) in the serving cell's system information block type **11** (SIB**11**) or system information block type **11**bis (SIB**11**bis) or possibly its system information block type **12** (SIB**12**), and can also add that new IE which carries the band information for its multi-band LTE neighbor frequencies in its system information block type **19** (SIB**19**). If the serving cell **22** is LTE it can add the new IE which carries the band information for its multi-band LTE neighbor frequencies in the serving cell's system information block type **3** (SIB**3**).

The number of entries in this new IE is the same as the number of neighbor cells for UMTS and the number of neighbor frequencies for LTE. Each entry indicates the frequency band (s) associated with the corresponding neighbor cell or neighbor frequency in the neighbor cell list or neighbor frequency list. When the UE **20** filters the network supplied neighbor cell list or neighbor frequency list, the UE **20** excludes the cells/frequencies not belonging to the UE supported frequency bands. Then the UE **20** performs cell reselection only on the filtered neighbor cell list or the filtered neighbor frequency list.

[0028] In another embodiment the IE is added by the UMTS serving cell **22** to its SIB**11** or SIB**11**bis (and possibly also its SIB**12**) for the UMTS neighbor cells and in its SIB**19** for its LTE neighbor frequencies. Or if the serving cell **22** is an LTE cell it can add the new IE to its SIB**3** for all its neighbor frequencies. In these embodiments the IE can indicate an index and one or more frequency bands for each neighbor cell/frequency. The index, X for example, would indicate that the neighbor cells/frequencies from the 1^{st} neighbor cell/frequency to the X^{th} neighbor cell/frequency in the neighbor cell/frequency list belong to the frequency band(s) signalled in the same new IE. If more than one new IE is included in the SIB, then the subsequent IE's index, Y for example, would indicate that the neighbor cells/frequencies from (the previous IE's index +1)th neighbor cell/frequency to the Y^{th} neighbor cell/frequency in the neighbor cell/frequency list belong to the frequency band(s) signalled in the same IE. This can be repeated for additional indices. The UE **20** would then filter and exclude as in the above paragraph and perform cell reselection using its filtered neighbor cell/frequency list.

[0029] In another embodiment instead of a new IE in an existing SIB the information on the neighbor cell frequency bands is informed to the UE's via a new SIB, for example SIB**21** in the case of UMTS cells and SIB**14** in the case of LTE frequencies. Including the IE similar to that noted above in one or both of these new SIBs is a simple way to present the frequency band information to the UEs. In one implementation there is one entry in this new IE for each of the neighbor cells/frequencies, and each entry indicates the frequency band(s) associated with the corresponding neighbor cell/frequency in the neighbor cell/frequency list. In another implementation the IE indicates the index and the frequency band (s) for each neighbor cell/frequency as detailed above.

[0030] One technical effect of these teachings is that the UE **20** can identify from its serving cell SI which neighbor cells/frequencies, including all cells/frequencies on a frequency band, can be considered as a candidate suitable cell/frequency for cell reselection before performing any mobility procedures. This saves on UE battery consumption as noted in the background section above. Relatedly, implementing these teachings are seen to result in more effective cell reselection by the UE since there will be fewer failed/aborted cell reselections.

[0031] On the network side one technical effect is that the network operator can deploy multiple harmonized band cells without affecting UE battery life. The size of the neighbor cell/frequency list is unaffected, and so there is no need to utilize additional entries to refer to the same cell since the additional frequency band information can extend the applicability of a single UARFCN/EARFCN to refer to multiple bands. For this reason implementation of these teachings is not seen to affect the stipulated performance requirements.

[0032] FIGS. **3-4** are logic flow diagrams which may each be considered to illustrate the operation of a method, and a result of execution of a computer program stored in a computer readable memory, and a specific manner in which components of an electronic device are configured to cause that electronic device to operate. The various blocks shown in each of FIGS. **3-4** may also be considered as a plurality of coupled logic circuit elements constructed to carry out the associated function(s), or specific result of strings of computer program code stored in a memory.

[0033] Such blocks and the functions they represent are non-limiting examples, and may be practiced in various components such as integrated circuit chips and modules, and that the exemplary embodiments of this invention may be realized in an apparatus that is embodied as an integrated circuit. The integrated circuit, or circuits, may comprise circuitry (as well as possibly firmware) for embodying at least one or more of a data processor or data processors, a digital signal processor or processors, baseband circuitry and radio frequency circuitry that are configurable so as to operate in accordance with the exemplary embodiments of this invention.

[0034] FIG. **3** details particular exemplary embodiments of the invention from the perspective of the UE. FIG. **3** may be implemented by the entire UE or by one or more components thereof, more generally termed an apparatus. At block **302** of FIG. **3** the UE receives from its serving cell indications of frequency bands supported by neighbor cells or frequencies, in which there is at least one individual neighbor cell or frequency for which there is indicated a plurality of frequency bands supported. At block **304** the UE **20** filters the neighbor cells or frequencies to retain only those which are indicated to support a frequency band or bands which are also supported by the UE itself. As in the above examples the UE may filter to generate a new list which it stores in its local memory and checks each time it needs to run a mobility procedure on a new band, or it may store the network-provided neighbor cell/frequency list and filter out those which only support a band or bands for which the UE is not capable on an as needed basis when checking each new neighbor cell/frequency for a mobility related procedure.

[0035] Further portions of FIG. **3** are optional and may or may not be combined with one another in various embodiments. Block **306** details that the indications are received in system information broadcast by the serving cell and the at least one individual neighbor cell or neighbor frequency is a neighbor cell or frequency to the serving cell. Block **308** specifies that the system information comprises at least one of system information block types **11**, **11**bis, **12**, **19** and **3** as detailed in the examples above.

[0036] Block **310** specifies one embodiment of the IE above, that the received indications are arranged in an information element having an entry for each of the neighbor cells or neighbor frequencies and a list of frequency bands for each entry. Block **312** specifies another embodiment of the IE above, that the received indications are arranged in an information element having an index and one or more associated frequency bands, in which a value of the index (X) indicates that one or more of the neighbor cells/frequencies referred to by the index (1^{st} through the Xth) belong to the one or more frequency bands associated with the index. There can of course be more than one index in the IE of this embodiment with different indices referring to a different plurality of neighbor cells/frequencies and associated with a different band or bands.

[0037] From the above description and examples, the UE functioning according to the FIG. **3** embodiment is configured to utilize that filtered neighbor cell/neighbor frequency list for its own cell reselection processes.

[0038] FIG. **4** details particular exemplary embodiments of the invention from the perspective of the serving cell **22** which sends its SI with all of the neighbor cells' or neighbor frequencys' associated frequency bands. FIG. **4** may be implemented by the entire serving cell (more generally a wireless network access node) or by one or more components thereof, which is also more generally termed an apparatus. At block **402** of FIG. **4** the serving cell obtains frequency bands supported by neighbor cells or neighbor frequencies, in which there is at least one individual neighbor cell or neighbor frequency which supports a plurality of frequency bands. The serving cell may determine this band information itself such as by collecting that information from the neighbor cells directly via an X2 or similar interface, or the neighbor cells and associated frequency bands may be obtained from a higher network node such as a radio network controller or mobility management entity. At block **402** the 'individual neighbor cell or neighbor frequency' is used to better specify that from among the whole neighbor cell/frequency list the serving cell compiles, there is at least one of them which supports multiple frequency bands since not all of the neighbor cells/frequencies may be multi-band capable. However the serving cell obtains this frequency band data, it then at block **404** sends to UEs indications of the frequency bands associated with the respective neighbor cells/neighbor frequencies that support them, including the plurality of frequency bands supported by the at least one individual neighbor cell or neighbor frequency.

[0039] Further portions of FIG. **4** are optional and may or may not be combined with one another in various embodiments. Block **406** states as with the above exemplary examples that the indications are sent to the UEs in system information broadcast by the serving cell, and the at least one individual neighbor cell/neighbor frequency is a neighbor cell/frequency to the serving cell. Block **408** recites the SIBs from the above examples: the indications are added to at least one of system information block types **11**, **11**bis, **12**, **19** and **3**.

[0040] Blocks **410** and **412** give the different embodiments of the new IE that are detailed above. At block **410** the serving cell sends the indications of block **404** by first arranging the indications in an IE having an entry for each of the neighbor cells/neighbor frequencies and a list of frequency bands for each entry, and then sends the IE in SI. The other embodiment from the above examples is at block **412**, the sending of block **404** is implemented by the serving cell first arranging the indications in an information element having an index and one or more associated frequency bands, in which a value of the index indicates that one or more of the neighbor cells or frequencies that are referred to by the index belong to the one or more frequency bands associated with the index; and then the serving cell sends this IE in its SI.

[0041] Reference is now made to FIG. **5** for illustrating a simplified block diagram of various electronic devices and apparatus that are suitable for use in practicing the exemplary embodiments of this invention. In FIG. **5** there is a serving cell/serving network access node **22** and a neighbor cell/neighbor network access node **26**, which are adapted for communication over respective wireless links **21**, **23** with an apparatus **20** such as mobile terminals or termed more generally as a user equipment UE. In certain networks such as LTE there is also an interface **27** between the serving **22** and neighbor **26** cell. The illustrated neighbor cell **26** stands in the place of the 'at least one individual neighbor cell or neighbor frequency' noted above for FIGS. **3**-**4**, but there are typically other neighbor cells/frequencies to the serving cell **22** some or all of which may also support multiple frequency bands. The serving cell **22** may be further communicatively coupled via link **25** to a higher network node **24** such as a mobility management entity/serving gateway MME/S-GW **24** in the case of the LTE system or a radio network controller in the case of the UMTS system.

[0042] The UE **20** includes processing means such as at least one data processor (DP) **20**A, storing means such as at least one computer-readable memory (MEM) **20**B storing at least one computer program (PROG) **20**C, communicating means such as a transmitter TX **20**D and a receiver RX **20**E for bidirectional wireless communications with the serving cell **22** and with the neighbor cell **26** via one or more antennas **20**F. Within the memory **20**B of the UE **20** but shown separately as reference number **20**G is also a computer program for filtering, according to the UE capabilities, the list of neighbor cells/neighbor frequencies which the UE **20** receives from the serving cell's system information as is detailed above in various embodiments.

[0043] The serving cell **22** also includes processing means such as at least one data processor (DP) **22**A, storing means such as at least one computer-readable memory (MEM) **22**B storing at least one computer program (PROG) **22**C, and communicating means such as a transmitter TX **22**D and a receiver RX **22**E for bidirectional wireless communications with its associated user devices **20** via one or more antennas **22**F and a modem. The serving cell **22** also has stored in its memory at **22**G software to assemble in its system information broadcasts all of the neighbor cells/frequencies and all of their associated frequency bands as is detailed by example above. The serving cell **26** is similarly functional with blocks **26**A, **26**B, **26**C, **26**D, **26**E and **26**F, but its block **26**G simply has its own multi-channel capability which the serving cell **22** learns via the interface **27** (if the LTE system) or via the higher network node **24**/radio network controller (if a UMTS system). But note that the neighbor cell **26** has the same functionality according to these teachings as the serving cell **22** which it uses when sending its own SI to its UEs. By example, the serving cell **22** may be a node B (UMTS) or an e-NodeB (LTE), the neighbor cell **26** may be a node B (UMTS) or an e-NodeB (LTE), and in the case of the LTE system the interface **27** may be an X2 interface between them.

[0044] For completeness the higher network node **24** is also shown to include a DP **24**A, and a MEM **24**B storing a PROG **24**C, and additionally a modem **24**H for communicating with at least the serving cell **22** (to show embodiments in which the neighbor cell is not under the same higher network node). While not particularly illustrated for the UE **20** or cells **22**, **26**, those devices are also assumed to include as part of their wireless communicating means a modem which may in one exemplary but non limiting embodiment be inbuilt on an RF front end chip so as to carry the respective TX **20**D/**22**D/**26**D and RX **20**E/**22**E/**26**E.

[0045] At least one of the PROGs **20**C, **22**C, **26**C in the UE **20** and in the serving and neighbor cells **22**, **26** is assumed to include program instructions that, when executed by the associated DP **20**A, **22**A, **26**A, enable the device to operate in accordance with the exemplary embodiments of this invention as detailed more fully above. In this regard the exemplary

embodiments of this invention may be implemented at least in part by computer software stored on the MEM **20**B, **22**B, **26**B which is executable by the DP **20**A, **22**A, **26**A of the respective devices **20**, **22**, **26**; or by hardware; or by a combination of tangibly stored software and hardware (and tangibly stored firmware). Electronic devices implementing these aspects of the invention need not be the entire UE **20**, or serving cell **22**, or neighbor cell **26**, but exemplary embodiments may be implemented by one or more components of same such as the above described tangibly stored software, hardware, firmware and DP, or a system on a chip SOC or an application specific integrated circuit ASIC or a digital signal processor DSP or a modem or a subscriber identity module commonly referred to as a SIM card.

[0046] Various embodiments of the UE **20** can include, but are not limited to: cellular telephones; data cards, USB dongles, personal portable digital devices having wireless communication capabilities including but not limited to laptop/palmtop/tablet computers, digital cameras and music devices, and Internet appliances.

[0047] Various embodiments of the computer readable MEM **20**B, **22**B, **26**B include any data storage technology type which is suitable to the local technical environment, including but not limited to semiconductor based memory devices, magnetic memory devices and systems, optical memory devices and systems, fixed memory, removable memory, disc memory, flash memory, DRAM, SRAM, EEPROM and the like. Various embodiments of the DP **20**A, **22**A, **26**A include but are not limited to general purpose computers, special purpose computers, microprocessors, digital signal processors (DSPs) and multi-core processors.

[0048] Various modifications and adaptations to the foregoing exemplary embodiments of this invention may become apparent to those skilled in the relevant arts in view of the foregoing description. While the exemplary embodiments have been described above in the context of the UMTS and LTE/LTE-A systems, it should be appreciated that the exemplary embodiments of this invention are not limited for use with only this one particular type of wireless communication system, and that they may be used to advantage in other wireless communication systems such as for example WCDMA and others which may interface with a neighbor cell that supports multiple frequency bands.

[0049] Some of the various features of the above non-limiting embodiments may be used to advantage without the corresponding use of other described features. The foregoing description should therefore be considered as merely illustrative of the principles, teachings and exemplary embodiments of this invention, and not in limitation thereof.

1. An apparatus comprising at least one processor; and

at least one memory including computer program code;

in which the at least one memory and the computer program code is configured, with the at least one processor, to cause the apparatus at least to:

receive from a serving cell indications of frequency bands supported by neighbor cells or frequencies, in which there is at least one individual neighbor cell or frequency for which there is indicated a plurality of frequency bands supported; and

filter the neighbor cells or frequencies to retain only those which are indicated to support a frequency band or frequency bands which are also supported by a user equipment.

2. The apparatus according to claim **1**, in which the indications are received in system information broadcast by the serving cell and the at least one individual neighbor cell or frequency is a neighbor cell or frequency to the serving cell.

3. The apparatus according to claim **2**, in which the system information comprises at least one of system information block types **11**, **11**bis, **12**, **19** and **3**.

4. The apparatus according to claim **1**, in which the received indications are arranged in an information element having an entry for each of the neighbor cells or frequencies and a list of frequency bands for each entry.

5. The apparatus according to claim **1**, in which the received indications are arranged in an information element having an index and one or more associated frequency bands, in which a value of the index indicates that one or more of the neighbor cells or frequencies referred to by the index belong to the one or more frequency bands associated with the index.

6. The apparatus according to claim **1**, in which the apparatus comprises the user equipment which is configured to utilize only the filtered neighbor cells or frequencies for cell reselection.

7. A method, comprising:

receiving from a serving cell indications of frequency bands supported by neighbor cells or frequencies, in which there is at least one individual neighbor cell or frequency for which there is indicated a plurality of frequency bands supported; and

filtering the neighbor cells or frequencies to retain only those which are indicated to support a frequency band or bands which are also supported by a user equipment.

8. The method according to claim **7**, in which the indications are received in system information broadcast by the serving cell.

9. The method according to claim **7**, in which the received indications are arranged in an information element having an entry for each of the neighbor cells or frequencies and a list of frequency bands for each entry.

10. The method according to claim **7**, in which the received indications are arranged in an information element having an index and one or more associated frequency bands, in which a value of the index indicates that one or more of the neighbor cells or frequencies referred to by the index belong to the one or more frequency bands associated with the index.

11. A memory tangibly storing a computer program that is executable by at least one processor, in which the computer program comprises:

code for receiving in system information broadcast by a serving cell indications of frequency bands supported by neighbor cells, in which there is at least one individual neighbor cell for which there is indicated a plurality of frequency bands supported; and

code for filtering the frequency bands to retain only those indicated frequency bands which are also supported by a user equipment.

12. The memory according to claim **11**, in which the received indications are arranged in an information element having an entry for each of the neighbor cells and a list of frequency bands for each entry.

13. The memory according to claim **11**, in which the received indications are arranged in an information element having an index and one or more associated frequency bands, in which a value of the index indicates that one or more of the neighbor cells or frequencies referred to by the index belong to the one or more frequency bands associated with the index.

14. An apparatus comprising

at least one processor; and

at least one memory including computer program code;

in which the at least one memory and the computer program code is configured, with the at least one processor, to cause the apparatus at least to:

obtain frequency bands supported by neighbor cells or frequencies, in which there is at least one individual neighbor cell or frequency which supports a plurality of frequency bands; and

send to user equipments indications of the frequency bands associated with the respective neighbor cells or frequencies that support them, including the plurality of frequency bands supported by the at least one individual neighbor cell or frequency.

15. The apparatus according to claim **14**, in which the indications are sent to the user equipments in system information broadcast by the apparatus which comprises a serving cell, and the at least one individual neighbor cell or frequency is a neighbor cell or frequency to the serving cell.

16. The apparatus according to claim **15**, in which the system information comprises at least one of system information block types **11**, **11**bis, **12**, **19** and **3**.

17. The apparatus according to claim **14**, in which the at least one memory and the computer program code is configured with the at least one processor to cause the apparatus to send to the user equipments the indications by:

arranging the indications in an information element having an entry for each of the neighbor cells or frequencies and a list of frequency bands for each entry; and

sending the information element in system information.

18. The apparatus according to claim **14**, in which the at least one memory and the computer program code is configured with the at least one processor to cause the apparatus to send to the user equipments the indications by:

arranging the indications in an information element having an index and one or more associated frequency bands, in which a value of the index indicates that one or more of the neighbor cells or frequencies referred to by the index belong to the one or more frequency bands associated with the index; and

sending the information element in system information.

19. A method comprising:

obtaining frequency bands supported by neighbor cells or frequencies, in which there is at least one individual neighbor cell or frequency which supports a plurality of frequency bands; and

sending to user equipments indications of the frequency bands associated with the respective neighbor cells or frequencies that support them, including the plurality of frequency bands supported by the at least one individual neighbor cell or frequency.

20. The method according to claim **19**, in which the indications are sent to the user equipments in broadcast system information, and the at least one individual neighbor cell is an neighbor cell or frequency to a serving cell executing the method.

21. The method according to claim **19**, in which sending to the user equipments the indications comprises:

arranging the indications in an information element having an entry for each of the neighbor cells or frequencies and a list of frequency bands for each entry; and

sending the information element in system information.

22. The method according to claim **19** or **20**, in which sending to the user equipments the indications comprises:

arranging the indications in an information element having an index and one or more associated frequency bands, in which a value of the index indicates that one or more of the neighbor cells or frequencies referred to by the index belong to the one or more frequency bands associated with the index; and

sending the information element in system information.

23. A memory tangibly storing a computer program that is executable by at least one processor, in which the computer program comprises:

code for obtaining frequency bands supported by neighbor cells or frequencies, in which there is at least one individual neighbor cell or frequency which supports a plurality of frequency bands; and

code for sending to user equipments indications of the frequency bands associated with the respective neighbor cells or frequencies that support them, including the plurality of frequency bands supported by the at least one individual neighbor cell or frequency.

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