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(54) **Title:** METHODS AND APPARATUS FOR MULTIPLE CARRIER WIRELESS COMMUNICATION

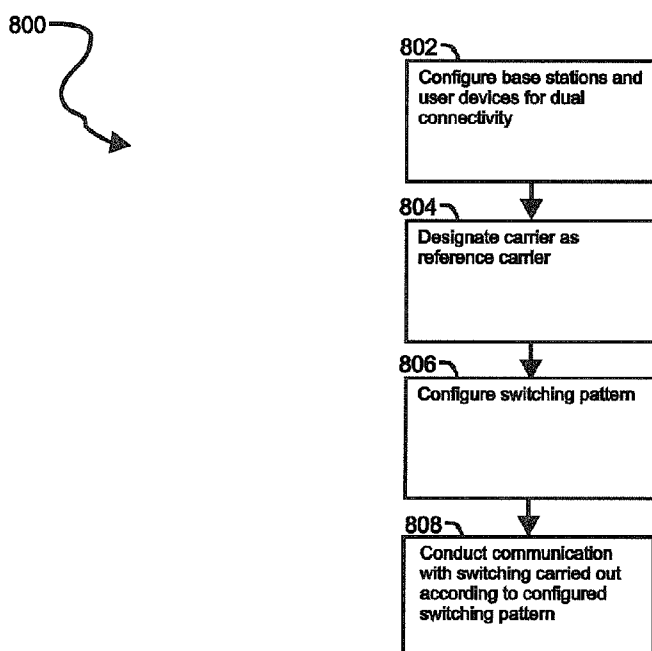


Fig. 8

(57) **Abstract:** Systems and techniques for managing switching between carriers in a multiple carrier cellular communication. A switching pattern is configured for switching a user device between carriers, such as may be used in dual connection. A reference carrier, which may be a specific carrier or may be derived from multiple carriers being used, is designated and a switching pattern is configured based on the reference pattern. Dual connection communication is performed, with the user device switching between carriers as specified by the switching pattern.





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METHODS AND APPARATUS FOR MULTIPLE CARRIER WIRELESS COMMUNICATION

TECHNICAL FIELD:

The present invention relates generally to wireless communication. More
5 particularly, the invention relates to improved systems and techniques for multiple
carrier aggregation in wireless communications.

BACKGROUND:

In order to increase the efficiency of their use of infrastructure and, in
particular, of the available frequency bands, wireless cellular network operators are
10 giving more and more attention to the use of small cells using lower power base
stations. Such base stations have a lesser range and therefore allow for re-use of
overlapping or partially overlapping frequency resources than would be the case with
higher power and longer range base stations. Larger cells may be referred to as
macro cells. More attention is being turned to the use of dual connectivity to macro
15 and small cell layers, in which a user device may be simultaneously connected to a
macro cell and to a small cell, with each connection serving a different purpose. In
systems operated according to standards developed by the Third Generation
Partnership Project (3GPP) and various evolutions of such standards, such as 3GPP
long term evolution (LTE) and LTE-advanced (LTE-A), base stations may be
20 eNodeBs (eNBs) and user devices may be referred to as user equipments (UEs). In
some scenarios of interest, macro and small cell layers are implemented on different
carriers, and a UE supports downlink carrier aggregation, but is not capable of
transmitting simultaneously on multiple uplink carriers.

SUMMARY:

25 In one embodiment of the invention, an apparatus comprises at least one
processor and memory storing a program of instructions. The memory storing the
program of instructions is configured to, with the at least one processor, cause the

apparatus to at least designate one of multiple carriers of cells used by a cellular wireless network carrier as a reference carrier on which to base switching patterns, configure a switching pattern for switching a user device between the reference carrier and at least one carrier other than the reference carrier based on a configuration of the reference carrier, wherein the configuration of the reference carrier designates at least one transmission opportunity, at least one reception opportunity, or at least one transmission and at least one reception opportunity among multiple carriers of the user device, and specify scheduling for the user device based on the switching pattern.

In another embodiment of the invention, a method comprises designating one of multiple carriers of cells used by a cellular wireless network carrier as a reference carrier on which to base switching patterns configuring a switching pattern for switching a user device between the reference carrier and at least one carrier other than the reference carrier based on a configuration of the reference carrier, wherein the configuration of the reference carrier designates at least one transmission opportunity, at least one reception opportunity, or at least one transmission and at least one reception opportunity among multiple carriers of the user device and specifying scheduling for the user device based on the switching pattern.

In another embodiment of the invention, a computer readable medium stores a program of instructions, execution of which by a processor configures an apparatus to at least designating one of multiple carriers of cells used by a cellular wireless network carrier as a reference carrier on which to base switching patterns configuring a switching pattern for switching a user device between the reference carrier and at least one carrier other than the reference carrier based on a configuration of the reference carrier, wherein the configuration of the reference carrier designates at least one transmission opportunity, at least one reception opportunity, or at least one transmission and at least one reception opportunity among multiple carriers of the

user device and specifying scheduling for the user device based on the switching pattern.

In another embodiment of the invention, an apparatus comprises means for designating one of multiple carriers of cells used by a cellular wireless network carrier as a reference carrier on which to base switching patterns, means for
5 configuring a switching pattern for switching a user device between the reference carrier and at least one carrier other than the reference carrier based on a configuration of the reference carrier, wherein the configuration of the reference carrier designates at least one transmission opportunity, at least one reception opportunity, or at least
10 one transmission and at least one reception opportunity among multiple carriers of the user device, and means for specifying scheduling for the user device based on the switching pattern.

BRIEF DESCRIPTION OF THE DRAWINGS:

Fig. 1 illustrates a network that may use one or more embodiments of the
15 present invention;

Fig. 2 illustrates a reference carrier pattern according to an embodiment of the present invention;

Fig. 3 illustrates a HARQ pattern according to an embodiment of the present invention;

20 Figs. 4-7 illustrate switching patterns according to embodiments of the present invention;

Figs. 8-10 illustrate processes according to embodiments of the present invention;

Fig. 11 illustrates a scheduling bitmap according to an embodiment of the
25 present invention; and

Fig. 12 illustrates elements that can be used in carrying out embodiments of

the present invention.

DETAILED DESCRIPTION:

Fig. 1 illustrates an exemplary network 100 that may use embodiments of the present invention. The network 100 may be a third generation partnership project long term evolution (3GPP-LTE) network, and may be a heterogeneous network using two carriers. One carrier, F1, is allocated for the Macro layer and the other carrier, F2, is allocated for the small cell layer. For example, the first carrier may be based on LTE frequency division duplex (LTE-FDD) and the second carrier may be based on LTE time division duplex (LTE-TDD). A signaling entity, providing for X2 signaling, may be implemented between the macro and small cells, allowing for control signaling between the Macro and the small cell layer. In such implementations, latency requirements for control signaling are generally relatively relaxed - on the order of tens of milliseconds - so that signaling delays prevent the use of conventional carrier aggregation because signaling delays between the macro and the small cell nodes render it impossible to exchange certain L1/L2 information such as hybrid automatic repeat request acknowledgements (HARQ-ACKs) fast enough.

It can be anticipated that the rate of acceptance of uplink versus downlink carrier aggregation will be different, with downlink carrier aggregation spreading significantly faster. If this is true with TDD-FDD carrier aggregation, a user equipment (UE) supporting TDD-FDD carrier aggregation on downlink but not on uplink will be a typical device category at the time when small cell features appear in LTE networks. Embodiments of the present invention, therefore, present mechanisms for supporting dual connectivity for small cell devices in such a way as to take advantage of downlink carrier aggregation capability. Specific goals achieved by such mechanisms include minimization of overhead resulting from uplink switching, minimization of changes to standards, maintaining a significant degree of

independence between carriers, and minimizing degradation of performance by legacy UEs, that is, UEs that are not capable of or configured for FDD/TDD dual connectivity. Another goal that is achieved is the maximization of commonality between FDD/TDD and TDD/TDD scenarios.

5 One or more embodiments therefore provide for dual connectivity between carriers, such as FDD/TDD carriers or TDD/TDD carriers, in cases in which a UE supports simultaneous downlink reception through multiple (typically two) carriers but supports transmission via only one carrier at a time. From the point of view of the UE, such mechanisms might be considered as falling between half duplex and full
10 duplex.

According to one or more embodiments of the invention, switching and scheduling patterns between carriers may be determined based on a TDD configuration. The UE switches its uplink periodically between carriers or alternatively is presented with a switching opportunity, although switching need not
15 take place at every opportunity. The switching pattern is determined based on the uplink-downlink configuration used in the predetermined TDD carrier, which may be viewed as a reference carrier. In one or more embodiments of the invention, the reference carrier may be a small cell carrier, but this is not limiting, and a different carrier, such as a macro cell carrier, may be used as the non-reference carrier.

20 Fig. 2 presents a carrier pattern 200 according to an embodiment of the present invention, illustrating dynamic flow switching between TDD and FDD carriers for a UE with carrier aggregation capability on two DL but only one UL carrier. Lack of shading in subframes indicates that those subframes may not be available for the UE.

A predefined TDD carrier is used as the reference carrier. The reference
25 carrier is available for bidirectional communication without interruption. This need not be the case for other carriers, such as FDD or TDD carriers. At least one of the

scheduling pattern, switching pattern, HARQ timing, and UL/DL configuration for other (non-reference) carriers is determined based on the UL/DL configuration used in the reference carrier.

The UL/DL configuration (which may, for example, be implemented as a UL/DL switching pattern) of the reference carrier determines the time instances when an UL transmitter can be used to serve non-reference carriers.

UL switching to the reference carrier takes place after DwPTS and before UpPTS of the reference carrier - that is, during its guard period. UL switching from the reference carrier takes place immediately after the last UL subframe (with respect to the next special subframe on the reference carrier).

In the case of FDD/TDD this scenario leads to the TDD carrier (reference carrier) being available all the time, while UL transmissions on the FDD carrier are forbidden (or otherwise not supported) in the subframes overlapping with TDD UL subframes, as illustrated in Fig. 2. Furthermore, due to synchronous HARQ operation (for example, fixed HARQ-ACK feedback), some of the DL subframes in the FDD carrier may not be utilized (depending on whether inter-site carrier aggregation (CA) or flow switching is applied).

Thus, the switching pattern may define, for example:

Available DL subframes in FDD carrier, based on the signaling latency involved in HARQ-ACK feedback (e.g. 4 subframes as in existing LTE) and available UL subframes in the FDD carrier.

The switching patterns are to be known for all cells (or carriers) and UEs involved in the dual connectivity operation, and X2 signaling can be used to exchange the information necessary for pattern determination between eNodeBs. Such determination may include, for example, indication of reference carriers. In the case in which a UE is configured to a "flow switching mode" it performs continuous

bi-directional communications in only one cell (serving cell) at a time. However the UE may continuously monitor enhanced physical downlink control channel (EPDCCH) on both cells.

In one or more embodiments of the invention, HARQ optimization is performed. In an intelligent flow switching-type operation, due to the structure of LTE-TDD (where UL-DL switching periodicity equals to 5 or 10 ms), difficulties may arise in arranging efficient re-transmissions for physical uplink shared channel (PUSCH) HARQ processes sent via the FDD carrier due to the fact that the number of HARQ processes equals to 8. In one embodiment, HARQ processes are arranged in such a way that re-transmissions take place on the UL subframes according to the switching pattern. HARQ timing can be kept unchanged.

In an inter-site carrier aggregation type of operation, the UE can additionally receive data on both carrier in all DL subframes. This, approach, however, requires some changes to HARQ timing of the FDD carrier.

Embodiments of the invention provide for specific time synchronization between TDD and FDD carriers. There is a predefined timing offset between TDD DL and FDD DL carriers. The size of the offset equals to a timing advance (TA) value to be applied in the FDD carrier. Timing advances such as the timing advance 208 are illustrated in Fig. 2. The synchronization provided by the timing advance value in the FDD carrier helps to insure that the uplink (that is, subframe) timing of the FDD carrier is equal or nearly equal to that of downlink timing in the TDD carrier.

Embodiments of the present invention employ a special subframe of a TDD carrier dimensioned in such a way that a guard period is long enough to support both $Tx_{TDD} \leftrightarrow Rx_{TDD}$ switching within TDD carrier and $Tx_{TDD} \leftrightarrow Tx_{FDD}$ between TDD and FDD carriers. In addition to special subframe configuration, additional time may be defined for UEs performing UL carrier switching. For example, a

cell-specific sounding reference signal (SRS) subframe may be configured in an FDD carrier for switching subframes, that is, subframes preceding actual carrier switching. This subframe may be configured for aperiodic SRS usage for UEs configured to use dual connectivity between FDD and TDD. When the switching is performed, the
5 opportunity for aperiodic SRS is not used. Instead, the time is used for UL carrier switching (this can be taken into account when dimensioning a special subframe). Similar configuration can be applied in TDD carrier as well.

It will be noted that additional overhead due to switching between UL carriers imposed by embodiments of the present invention is almost zero when compared to
10 the TDD case, providing switching between Tx and Rx.

As noted above, at least one of scheduling pattern, switching pattern, HARQ-timing and UL-DL configuration for other (FDD/TDD) carriers may be determined based on UL-DL configuration used in the reference carrier. Each cell participating in carrier aggregation may suitably be configured with appropriate
15 scheduling pattern, switching pattern, HARQ-timing and UL-DL configuration, through communication between cells using, suitably, X2 can be used for this purpose. In the preferred embodiment, macro cell is in charge of coordinating the dual cell operation.

A UE may have two parallel sets of RRC configured resources for each
20 (FDD/TDD) cell. Available RRC resources may be, for example, physical random access channel (PRACH), scheduling request (SR), SRS, periodic channel state information (CSI) reporting, other semi-persistent physical uplink control channel (PUCCH) resource allocations. However, only the resource set on the serving cell is active (that is, used) at any particular time. Separate discontinuous transmission
25 (DTX) patterns can be configured for each cell involved.

One or more embodiments of the invention provide for HARQ optimization

for flow switching. The structure of time division LTE specifies that switching periodicity is equal to 5 or 10 ms, and the number of HARQ processes is 8. According to one or more embodiments of the invention, HARQ processes are arranged in such a way that re-transmissions take place in uplink subframes according to a defined switching pattern. In one or more embodiments, the number of HARQ processes is not increased from 8 compared to existing LTE. In addition, processing timing requirements continue to adhere to existing standards, and are compatible, for example, with 3GPP LTE release 8.

Fig. 3 illustrates a HARQ optimization pattern 300 that may follow the reference carrier, including downlink subframes 302A-302C, 304A-304C, and 306A-306C. Retransmission opportunities come in the uplink subframes - that is, subframes 308A, 308B and 308C, 308D and 308E, and 308F. In one or more embodiments of the invention, the HARQ processes per cell (carrier) are numbered according to available UL subframes instead of according to total number of UL subframes.

Further embodiments of the invention address inter-site carrier aggregation and dynamic flow switching between TDD carriers. In exemplary approach, one of the TDD carriers is to be selected as the reference carrier. Following are specific noteworthy aspects of this approach. Specific synchronization between two carriers is accomplished.

Specific synchronization between two carriers

In this case, UpPTS timing of one of the TDD carriers (the reference carrier) is aligned with downlink timing of another carrier. Pre-defined switching and scheduling patterns between two carriers are based on the TDD configuration or TDD configurations used. In one exemplary embodiment, the TDD UL-DL configuration of the reference carrier is kept unchanged while TDD UL-DL configuration of the

other carriers (which may be a single carrier or may be more than one carrier) is selected based on the TDD configuration used on the reference carrier. The selection is made such that the UL phase does not appear at the same time in two carriers.

In another embodiment, TDD configuration of two carriers is selected jointly, that is, without a need to specify a reference carrier. There might be no need for specific scheduling restrictions in the case of two TDD carriers, as opposed to the case when TDD/FDD is used. In addition, HARQ optimization may not be needed at all in the case of two TDD carriers. Both carriers can have their HARQ operation running as normal.

Fig. 4 illustrates an exemplary dual carrier pattern, 400, comprising first and second TDD carriers 402 and 404, respectively. The pattern 400 exhibits dynamic switching between the two TDD carriers for a user device with carrier aggregation capability on two downlink carriers but only one uplink carrier. It can be seen that the downlink and uplink subframes of the carriers 402 and 404 are phased apart between the two carriers.

Figs. 5-7 illustrate further configuration example patterns 500, 600, and 700, for TDD/TDD carrier aggregation, showing carriers 502 and 504, 602 and 604, and 702, and 704, respectively. These examples show that various embodiments can be implemented without downlink carrier aggregation capability. However, in the typical example, a reasonable approach is to assume that downlink CA capability is present. In addition, assuming that DL carrier aggregation is available provides much more freedom to select various TDD combinations for two involved carriers.

Fig. 8 illustrates a process of dual carrier aggregation according to an embodiment of the present invention. At block 802, one or more base stations and user devices, such as eNBs and UEs, are configured for dual connectivity between carriers. Depending on the specific configuration chosen, the carriers may be

frequency division duplex/time division duplex or time division duplex/time division duplex. At block 804, one of the carriers is designated as a reference carrier. At block 806, a switching pattern between carriers is configured, defining switching between carriers for uplink and/or for downlink operations. At block 808, communication is carried out (for example, between a UE and two eNBs serving the UE) on the different carriers, with switching between carriers being carried out according to the configured switching pattern.

As noted above, switching between carriers can frequently be expected to be carried out when a UE has only one transmitter, and therefore should avoid simultaneous uplink transmission to both a macro cell and a small cell. Small cells generally use dynamic TDD for traffic adaptation in uplink and downlink, and as noted above uplink and downlink configuration in embodiments of the present invention may change rapidly - on the order of every 10ms, so that embodiments of the invention address managing such configuration changes in the face of problems, such as delays, presented by non-ideal backhaul.

Fig. 9 therefore illustrates a process 900 according to an embodiment of the present invention. At block 902, a small cell eNB communicates with a Macro eNB to identify a starting point for a reconfiguration signaling exchange. This starting point may be, for example, based on timing of sub-frame 0 at a small cell eNB. In an exemplary embodiment, signaling may be carried out using X2 signaling, in a one-time signaling exchange.

At block 904, the small cell base station, such as an eNB, operating in TDD mode sends TDD UL/DL configuration information to be used in a subsequent reconfiguration period (such as the next reconfiguration period) together with pre-scheduling information to a UE. The configuration may be sent, for example, 10ms in advance of the next reconfiguration period. Taking a reconfiguration period

of 10 ms as one example, the TDD UL/DL configuration indicates the subframe (SF) direction in the next frame, and the pre-scheduling information indicates the scheduling information in UL and DL for the small cell, where "1" might mean that the small cell will schedule this specific UE in a specified downlink SF or UL subframe, and a "0" indicates that the UE will not be scheduled in that subframe. The TDD UL/DL configuration and pre-scheduling information are transmitted in PDCCH in current frame at SF0 from small cell to UE.

At block 906, the UE receiving the UL/DL configuration information and pre-scheduling information derives UL subframes for UL transmission in the next radio frame (such as an UL subframe for A/N feedback or PUSCH transmission) and composes a bitmap corresponding to an UL SF set to indicate which UL subframe is to be used in a small cell. The UE then sends the bitmap to the macro eNB, suitably over the PUCCH.

At block 908, based on the UL usage bitmap, the macro eNB restricts DL scheduling or UL scheduling in specified subframes, in order to avoid simultaneous uplink transmissions in both Macro and small cells. The restriction is informed by the information provided by the bitmap as to which subframe is to be used by the UE for UL transmission to a small cell eNB.

Fig 10 illustrates a process 1000 according to an alternative embodiment of the present invention. At block 1002, a small cell eNB derives a UL usage bitmap according to UL/DL configuration and pre-scheduling information and transmits the bitmap to the UE. At block 1004, upon receiving the bitmap, the UE transmits the bitmap to the macro eNB in the PUCCH. The information provided by the bitmap furnishes the Macro eNB with the UE's UL subframe usage in a small cell (for example, the UL subframe for PDSCH A/N feedback or PUSCH transmission for the next frame). Thus, at block 1006 the Macro eNB uses the information provided by

the bitmap to schedule the UE so as to avoid simultaneous UL transmission between a small cell and the Marco cell by restricting DL scheduling or UL scheduling in appropriate subframes.

Fig. 11 illustrates an exemplary bitmap 1100 according to an embodiment of the present invention. Assuming that the small cell activates dynamic TDD UL/DL reconfiguration and TDD UL/DL configuration 1 with {D, S, U, U, D, D, S, U, U, D} as frame structure will be used in the next frame, and the pre-scheduling information {1, 1, 1, 1, 1, 1, 1, 0, 1, 1} indicates that subframe 0, 1, 4, 5, 6 and 9 are to be used for DL transmission and subframe 2 and 3, 8 are to be used for UL transmission. In that sense, UE needs to transmit UL ACK/NACK in UL subframe 8 according to DL HARQ timing and transmit PUSCH in UL 2 and 3 in small cell. In Fig. 11, “1” in the DL subframes indicates DL scheduling and “1” in UL subframes indicates uplink scheduling. Considering the dynamic TDD UL/DL configuration is selected from all seven existing TDD UL/DL configurations, then SF3, 4, 7, 8 and 9 are flexible subframes which may be used for DL transmission in some configurations or for UL transmission in other configurations. So the possible UL subframes include SF3, 4, 7, 8 and 9 besides fixed UL subframe 2. Then the length of the UL usage bitmap corresponding to SF2, 3, 4, 7, 8 and 9 is equal to 6. Therefore, the UE derived UL usage bitmap will be {1,1,0,0,1,0} for the UL subframe set consisting of SF2,SF3, SF4,SF7,SF8, SF9. Using the information provided by the bitmap, at the next frame the Marco cell will restrict scheduling of the UE for UL PUSCH transmission at SF2, SF3, and SF8 or restrict DL PDSCH scheduling at SF8, SF9 and SF4 because A/N corresponding to DL PDSCH transmission at SF8, SF9 and SF4 are transmitted at UL SF2, SF3, and SF8 in case a Macro cell is being operated in FDD mode. In this way, the simultaneous UL transmission at both the Macro cell and the small cell can be avoided. . On the other hand, if small cell use fixed TDD UL/DL configuration, then

the bitmap length is equal to the number of practical UL subframes in this fixed TDD UL/DL configuration. For example, if TDD UL/DL configuration 1 is used in fixed TDD mode, then the length of UL usage bitmap corresponding to UL subframe 2, 3, 7 and 8 is equal to 4. In addition to Macro cell operated in TDD mode, if the Macro
5 and the small cell are both operated on TDD mode, the Macro eNB restricts UL scheduling and DL scheduling according to the Macro cell-small cell TDD UL/DL configuration and small cell pre-scheduling information to avoid simultaneous UL transmission with a small cell.

In the case of a non-scheduled UL transmission, the related Macro
10 transmission timing of the UE is informed by the following considerations:

The PDSCH A/N for the scheduled DL subframe corresponding to the non-scheduled UL SF such as SF8 (for example, PDSCH at SF4) will change its timing to nearest available UL SF9. Other PDSCH A/N for the scheduled DL SF follows normal FDD timing.

15 Fig. 12 illustrates details of a base station, implemented as an eNB 1200, and a mobile communications device, implemented as a UE 1250. The eNB 1200 may suitably comprise a transmitter 1202, receiver 1204, and antenna 1206. The eNB 1200 may also include a processor 1208 and memory 1210. The eNB 1200 may employ data 1212 and programs (PROGS) 1214, residing in memory 1210.

20 The UE 1250 may suitably comprise a transmitter 1252, receiver 1254, and antenna 1256. The UE 1250 may also include a processor 1258 and memory 1260. The UE 1250 may employ data 1262 and programs (PROGS) 1264, residing in memory 1260.

At least one of the PROGS 1214 in the eNB 1200 is assumed to include a set of
25 program instructions that, when executed by the associated DP 1208, enable the device to operate in accordance with the exemplary embodiments of this invention, as detailed

above. In these regards the exemplary embodiments of this invention may be implemented at least in part by computer software stored on the MEM 1210, which is executable by the DP 1208 of the eNB 1200, or by hardware, or by a combination of tangibly stored software and hardware (and tangibly stored firmware). Similarly,

5 at least one of the PROGs 1264 in the UE 1250 is assumed to include a set of program instructions that, when executed by the associated DP 1258, enable the device to operate in accordance with the exemplary embodiments of this invention, as detailed above. In these regards the exemplary embodiments of this invention may be implemented at least in part by computer software stored on the MEM 1260, which is

10 executable by the DP 1258 of the UE 1250, 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 devices as depicted at Figure 1 or Fig. 6 or may be one or more components of same such as the above described tangibly stored software, hardware, firmware and DP, or a system on a

15 chip SOC or an application specific integrated circuit ASIC.

In general, the various embodiments of the UE 1250 can include, but are not limited to personal portable digital devices having wireless communication capabilities, including but not limited to cellular telephones, navigation devices, laptop/palmtop/tablet computers, digital cameras and music devices, and Internet

20 appliances.

Various embodiments of the computer readable MEM 1210 and 1260 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

25 memory, disc memory, flash memory, DRAM, SRAM, EEPROM and the like. Various embodiments of the DP 1208 and 1258 include but are not limited to general

purpose computers, special purpose computers, microprocessors, digital signal processors (DSPs) and multi-core processors.

Electronic devices implementing these aspects of the invention need not be the entire devices as depicted at Figure 1 or Fig. 12 or may be one or more components of
5 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.

While various exemplary embodiments have been described above it should be appreciated that the practice of the invention is not limited to the exemplary embodiments shown and discussed here. Various modifications and adaptations to
10 the foregoing exemplary embodiments of this invention may become apparent to those skilled in the relevant arts in view of the foregoing description. It will be further recognized that various blocks discussed above may be performed as steps, but the order in which they are presented is not limiting and they may be performed in any appropriate order with or without additional intervening blocks or steps.

15 Further, 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.

WHAT IS CLAIMED IS:

1. An apparatus comprising:
at least one processor;
memory storing a program of instructions;
5 wherein the memory storing the program of instructions is configured to, with
the at least one processor, cause the apparatus to at least:
designate one of multiple carriers of cells used by a cellular wireless network
carrier as a reference carrier on which to base switching patterns;
configure a switching pattern for switching a user device between the
10 reference carrier and at least one carrier other than the reference carrier based on a
configuration of the reference carrier, wherein the configuration of the reference
carrier designates at least one transmission opportunity, at least one reception
opportunity, or at least one transmission and at least one reception opportunity among
multiple carriers of the user device; and
15 specify scheduling for the user device based on the switching pattern.
2. The apparatus of claim 1, wherein the reference carrier is a time
division duplex carrier and wherein the each of the other carriers is either a time
division duplex or a frequency division duplex carrier.
3. The apparatus of claim 1 or 2, wherein the reference carrier operates
20 according to a predefined uplink and downlink configuration.
4. The apparatus of any preceding claim, where at least one carrier other
than the reference carrier is configured such that at least one uplink subframe of the
radio frame is unavailable for uplink transmission.
5. The apparatus of any preceding claim, wherein the carriers are a
25 frequency division duplex carrier and a time division duplex carrier, and wherein the
reference carrier specifies a predetermined time offset to be applied to the frequency

division duplex carrier to achieve synchronization between the time division duplex and the frequency division duplex carriers.

6. The apparatus of claim 5, wherein the downlink timing and predetermined time offset in the frequency division duplex carrier provide an uplink subframe timing of the frequency division duplex carrier substantially equal to that of the time division duplex carrier.

7. The apparatus of any of claims 1-4, wherein both carriers are time division duplex carriers.

8. The apparatus of claim 7, wherein the switching pattern is configured such that an uplink phase does not appear at the same time in both carriers.

9. The apparatus of claim 7, wherein the reference carrier is derived through analysis of the time division duplex carriers.

10. The apparatus of any preceding claim, wherein the switching pattern is based on a precomputed bitmap derived through information exchange between a small cell base station and a Macro cell base station.

11. The apparatus of any of claims 1-9, wherein the switching pattern is based on a precomputed bitmap derived by user device based on information received by the user device from a small cell base station, and wherein the precomputed bitmap is received by a Macro cell base station from the user device.

12. The apparatus of any of claims 1-9, wherein the switching pattern is based on a precomputed bitmap sent from a small cell base station to the user device, and wherein the precomputed bitmap is received by a Macro cell base station from the user device.

13. The apparatus of claim 11, wherein the precomputed bitmap is derived by the user device based on configuration information and a pre-scheduling pattern provided by the small cell base station.

14. A method comprising:
- designating one of multiple carriers of cells used by a cellular wireless network carrier as a reference carrier on which to base switching patterns;
- configuring a switching pattern for switching a user device between the
- 5 reference carrier and at least one carrier other than the reference carrier based on a configuration of the reference carrier, wherein the configuration of the reference carrier designates at least one transmission opportunity, at least one reception opportunity, or at least one transmission and at least one reception opportunity among multiple carriers of the user device; and
- 10 specifying scheduling for the user device based on the switching pattern.
15. The method of claim 14, wherein the reference carrier is a time division duplex carrier and wherein the each of the other carriers is either a time division duplex or a frequency division duplex carrier.
16. The method of claim 14 or 15, wherein the reference carrier operates
- 15 according to a predefined uplink and downlink configuration.
17. The method of any of claims 14-16, where at least one carrier other than the reference carrier is configured such that at least one uplink subframe of the radio frame is unavailable for uplink transmission.
18. The method of any of claims 14-17, wherein the carriers are a
- 20 frequency division duplex carrier and a time division duplex carrier, and wherein the reference carrier specifies a predetermined time offset to be applied to the frequency division duplex carrier to achieve synchronization between the time division duplex and the frequency division duplex carriers.
19. The method of claim 18, wherein the downlink timing and
- 25 predetermined time offset in the frequency division duplex carrier provide an uplink subframe timing of the frequency division duplex carrier substantially equal to that of

the time division duplex carrier.

20. The method of any of claims 12-16, wherein both carriers are time division duplex carriers.

21. The method of claim 20, wherein the switching pattern is configured
5 such that an uplink phase does not appear at the same time in both carriers.

22. The method of claim 20, wherein the reference carrier is derived through analysis of the time division duplex carriers.

23. The method of any of claims 12-22, wherein the switching pattern is based on a precomputed bitmap derived through information exchange between a
10 small cell base station and a Macro cell base station.

24. The method of any of claims 12-22, wherein the switching pattern is based on a precomputed bitmap derived by user device based on information received by the user device from a small cell base station, and wherein the precomputed bitmap is received by a Macro cell base station from the user device.

25. The method of any of claims 12-22, wherein the switching pattern is
15 based on a precomputed bitmap sent from a small cell base station to the user device, and wherein the precomputed bitmap is received by a Macro cell base station from the user device.

26. The method of claim 25, wherein the precomputed bitmap is derived
20 by the user device based on configuration information and a pre-scheduling pattern provided by the small cell base station.

27. A computer readable medium storing a program of instructions, execution of which by a processor configures an apparatus to at least:

designate one of multiple carriers of cells used by a cellular wireless network
25 carrier as a reference carrier on which to base switching patterns;

configure a switching pattern for switching a user device between the

reference carrier and at least one carrier other than the reference carrier based on a configuration of the reference carrier, wherein the configuration of the reference carrier designates at least one transmission opportunity, at least one reception opportunity, or at least one transmission and at least one reception opportunity among
5 multiple carriers of the user device; and

specify scheduling for the user device based on the switching pattern.

28. The computer readable medium of claim 27, wherein the reference carrier is a time division duplex carrier and wherein the each of the other carriers is either a time division duplex or a frequency division duplex carrier.

10 29. The computer readable medium of claim 27 or 28, wherein the reference carrier operates according to a predefined uplink and downlink configuration.

30. The computer readable medium of any of claims 27-29, where at least one carrier other than the reference carrier is configured such that at least one uplink
15 subframe of the radio frame is unavailable for uplink transmission.

31. The computer readable medium of The computer readable medium of any of claims 27-30, wherein the carriers are a frequency division duplex carrier and a time division duplex carrier, and wherein the reference carrier specifies a predetermined time offset to be applied to the frequency division duplex carrier to
20 achieve synchronization between the time division duplex and the frequency division duplex carriers.

32. The computer readable medium of claim 31, wherein the downlink timing and predetermined time offset in the frequency division duplex carrier provide an uplink subframe timing of the frequency division duplex carrier substantially equal
25 to that of the time division duplex carrier.

33. The computer readable medium of any of claims 27-30, wherein both

carriers are time division duplex carriers.

34. The computer readable medium of claim 33, wherein the switching pattern is configured such that an uplink phase does not appear at the same time in both carriers.

5 35. The computer readable medium of claim 33, wherein the reference carrier is derived through analysis of the time division duplex carriers.

36. The computer readable medium of any of claims 27-35, wherein the switching pattern is based on a precomputed bitmap derived through information exchange between a small cell base station and a Macro cell base station.

10 37. The computer readable medium of any of claims 27-35, wherein the switching pattern is based on a precomputed bitmap derived by user device based on information received by the user device from a small cell base station, and wherein the precomputed bitmap is received by a Macro cell base station from the user device.

38. The computer readable medium of any of claims 27-35, wherein the
15 switching pattern is based on a precomputed bitmap sent from a small cell base station to the user device, and wherein the precomputed bitmap is received by a Macro cell base station from the user device.

39. The computer readable medium of claim 37, wherein the
precomputed bitmap is derived by the user device based on configuration information
20 and a pre-scheduling pattern provided by the small cell base station.

40. An apparatus comprising:

means for designating one of multiple carriers of cells used by a cellular wireless network carrier as a reference carrier on which to base switching patterns;

means for configuring a switching pattern for switching a user device between
25 the reference carrier and at least one carrier other than the reference carrier based on a configuration of the reference carrier, wherein the configuration of the reference

carrier designates at least one transmission opportunity, at least one reception opportunity, or at least one transmission and at least one reception opportunity among multiple carriers of the user device; and

5 means for specifying scheduling for the user device based on the switching pattern.

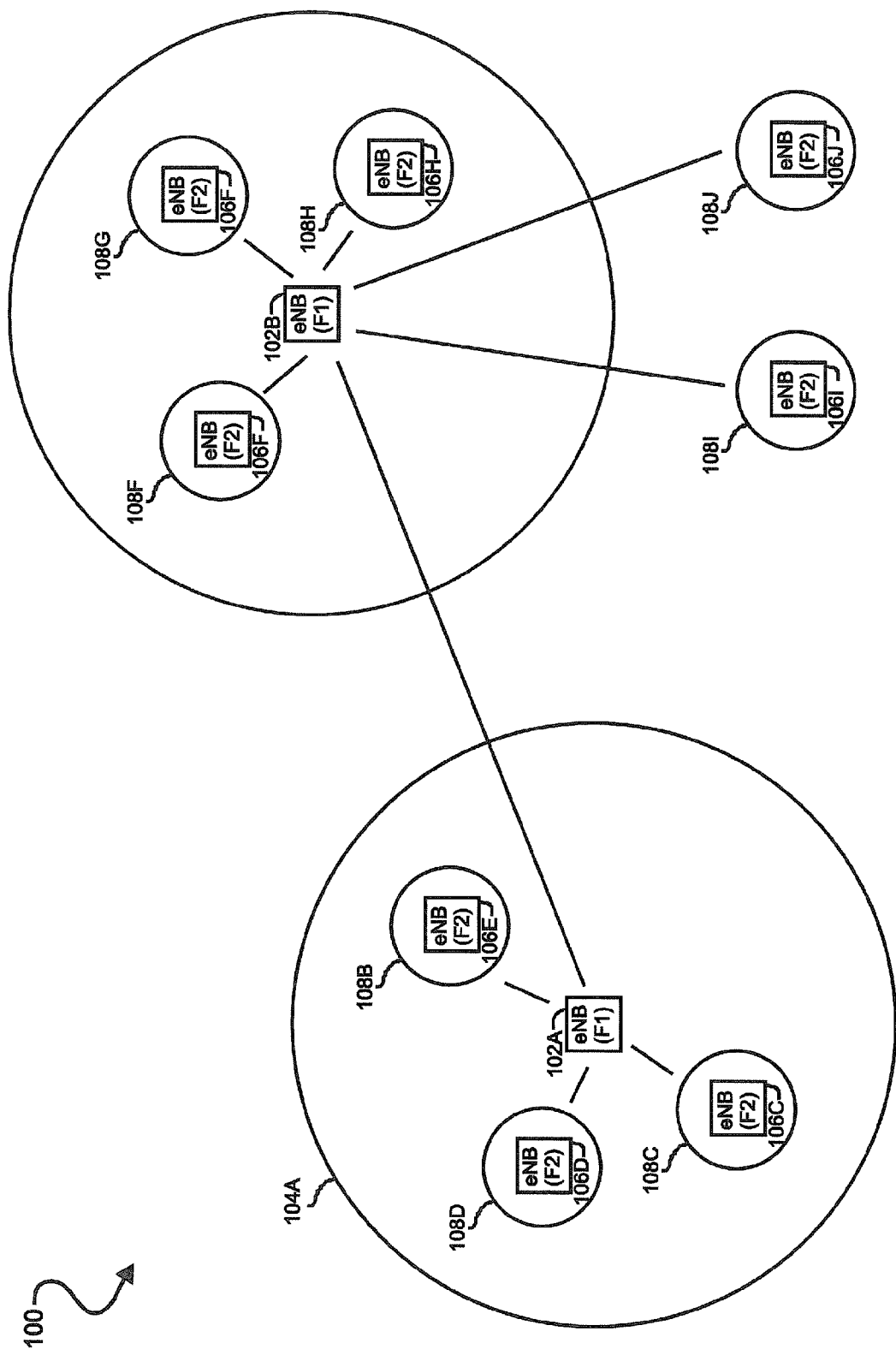


Fig. 1

200

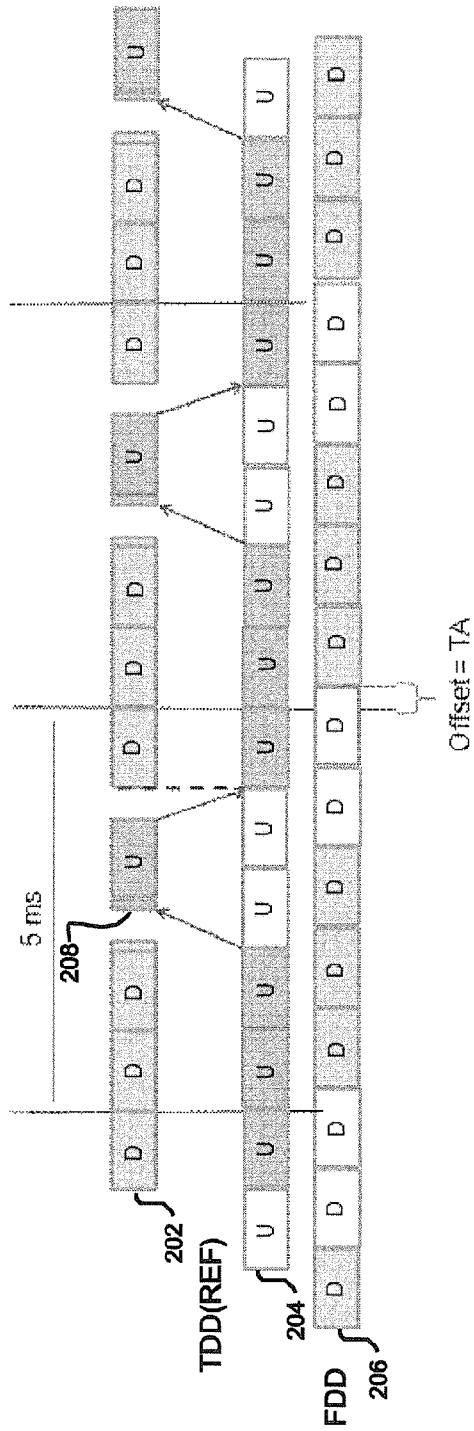


Fig. 2

300



Fig. 3

400

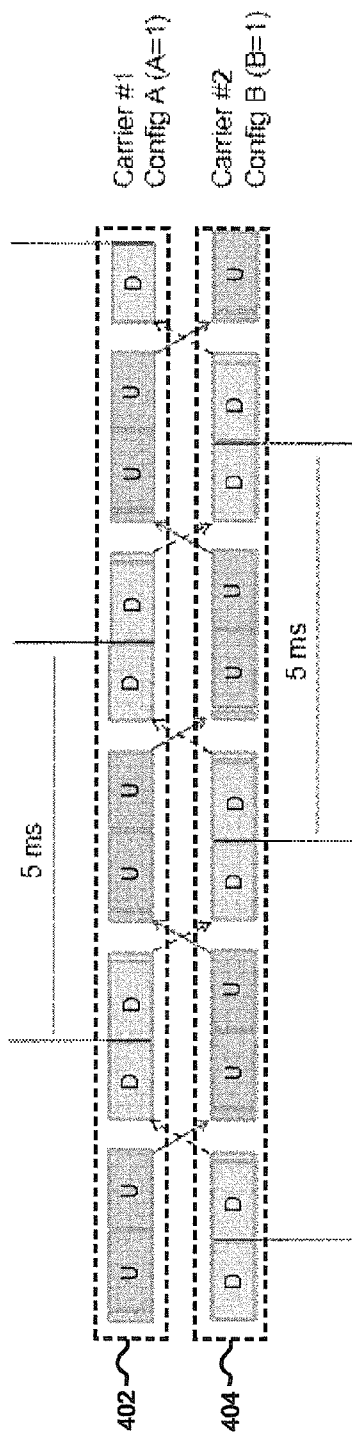


Fig. 4

500

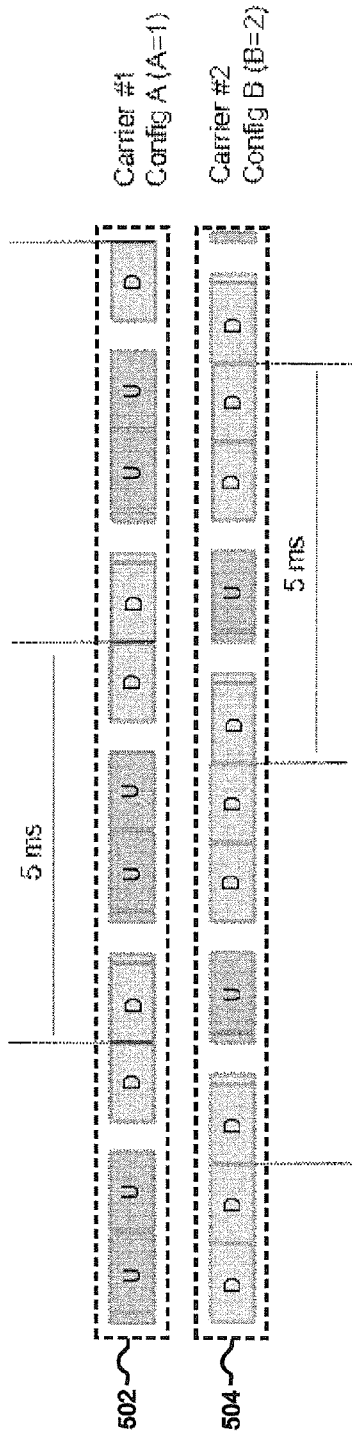


Fig. 5

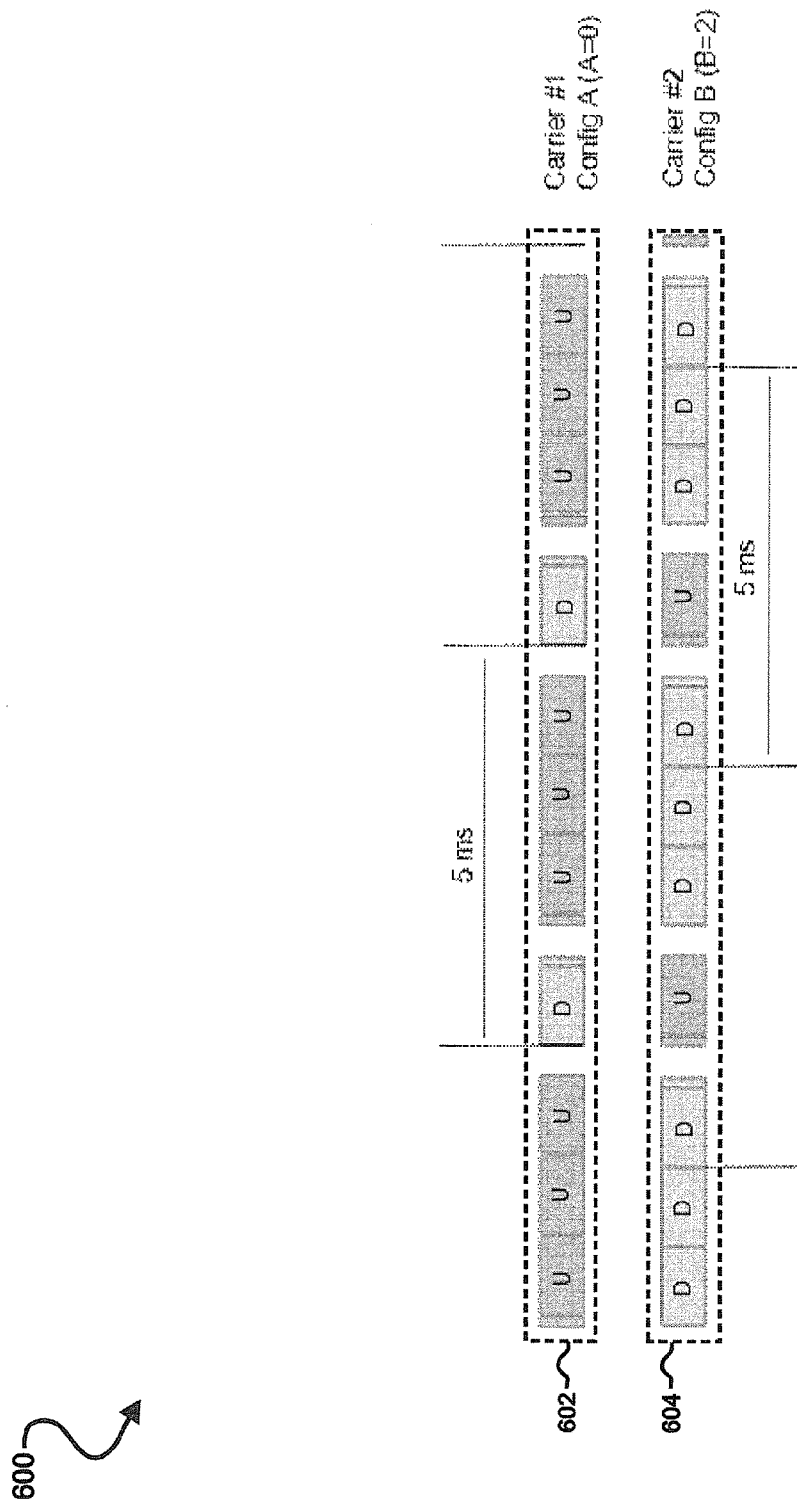


Fig. 6

700

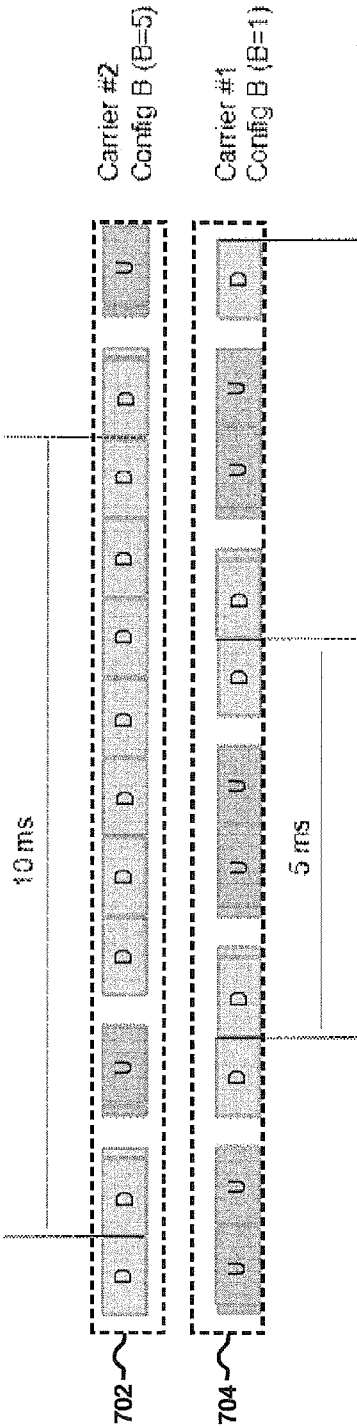


Fig. 7

800

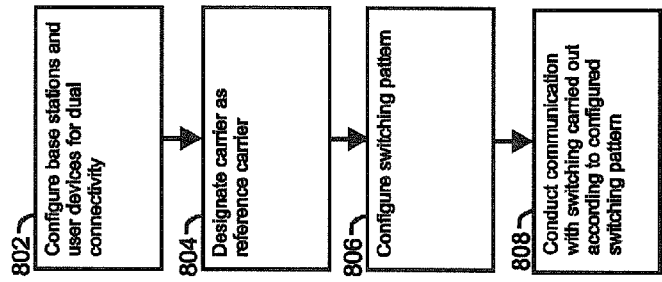
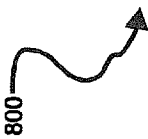


Fig. 8

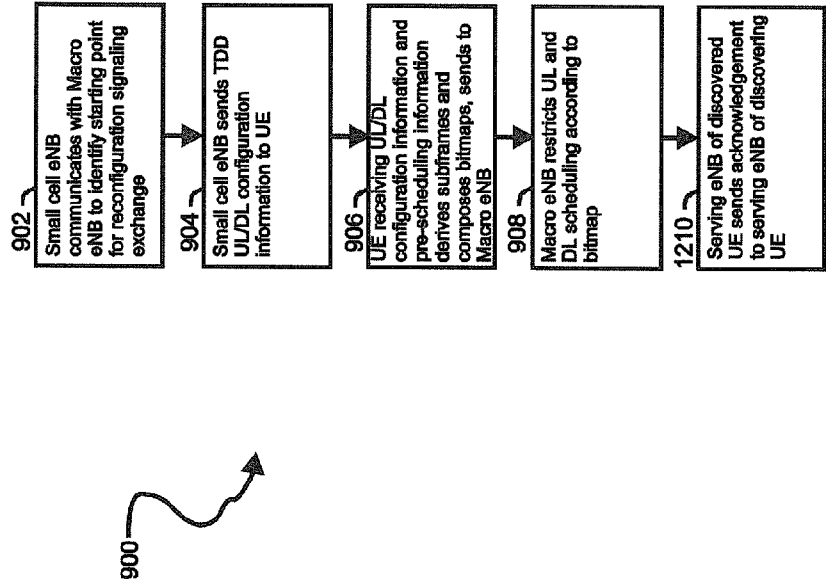


Fig. 9

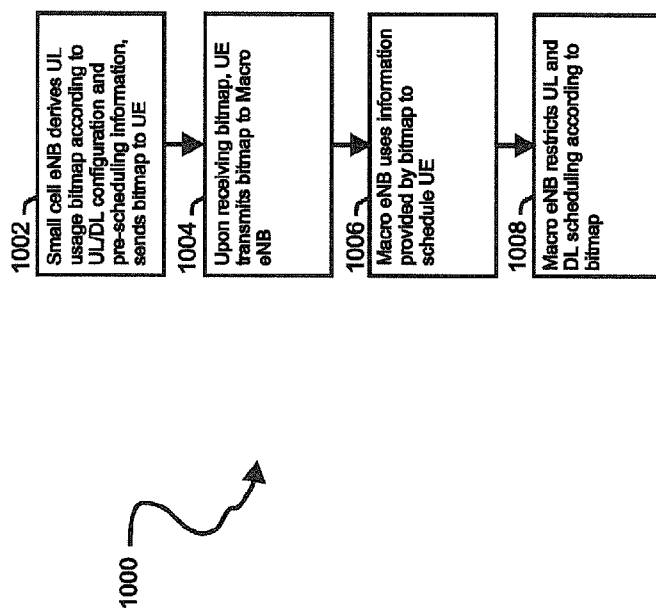


Fig. 10

1100

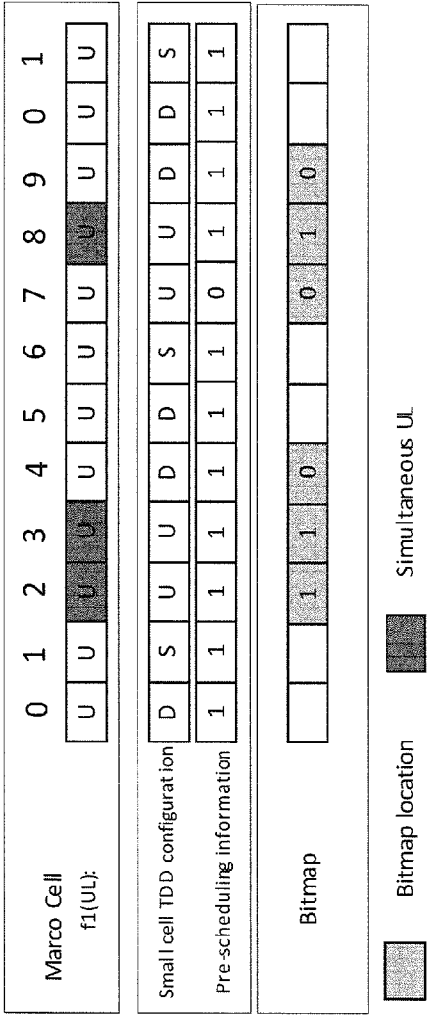


Fig. 11

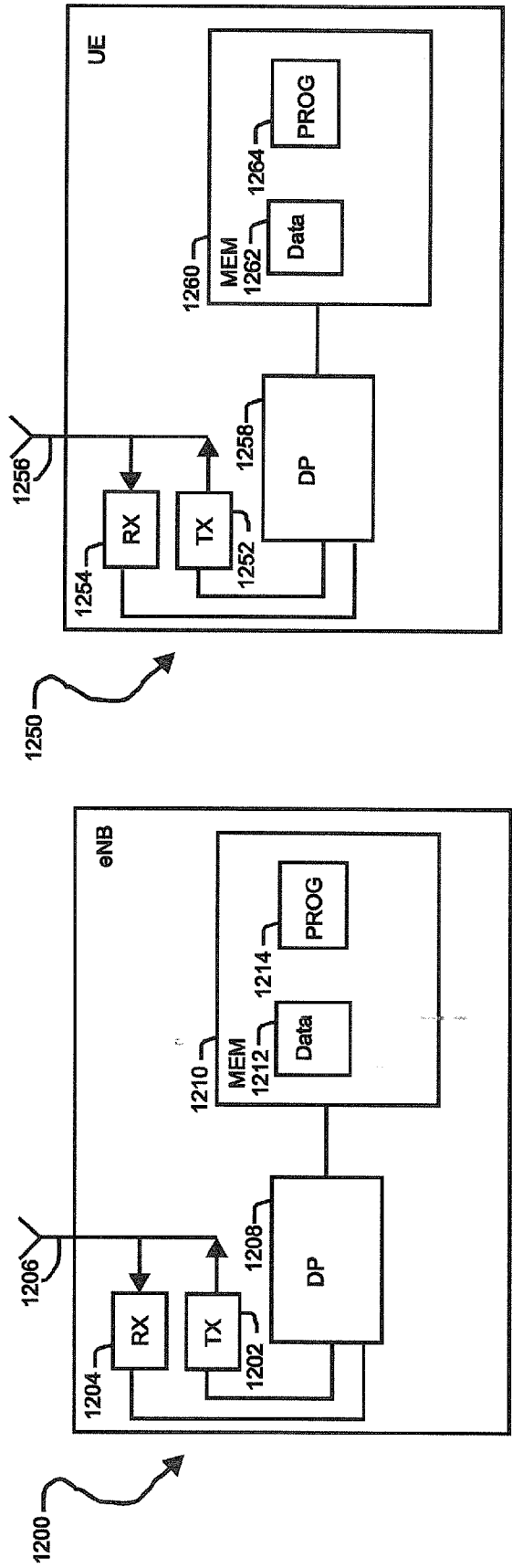


Fig. 12

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2013/081215

A. CLASSIFICATION OF SUBJECT MATTER

H04W 36/04(2009.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04W; H04L; H04Q; H04M

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)

CNPAT,CNKI,WPI,EPODOC:multiple,carrier?,multi?carrier,aggregation,switch
+,handover,handoff,reference,anchor,primary,pattern,TDD,FDD**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	EP 2405599A2 (LG ELECTRONICS INC.) 11 January 2012 (2012-01-11) description, paragraphs [0059] to [0065], figure 6	1-40
Y	WO 2012163423A1 (NOKIA SIEMENS NETWORKS OY) 06 December 2012 (2012-12-06) description, page 11 line 15 to page15 line 22, figures 7-9	1-40
Y	WO 2012061410A2 (QUALCOMM INCORPORATED) 10 May 2012 (2012-05-10) description, paragraphs [0081] to [0084], figures 6-7	2, 4, 7-9, 15, 17, 20-22, 28, 30, 33-35
A	CN 101686534A (HUAWEI TECHNOLOGIES CO., LTD.) 31 March 2010 (2010-03-31) the whole document	1-40
A	CN 102264093A (NTT DOCOMO INC.) 30 November 2011 (2011-11-30) the whole document	1-40

☐ 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	“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
“E”	earlier application or patent but published on or after the international filing date	“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
“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)	“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
“O”	document referring to an oral disclosure, use, exhibition or other means	“&”	document member of the same patent family
“P”	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search

21 April 2014

Date of mailing of the international search report

14 May 2014

Name and mailing address of the ISA/

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/CN2013/081215

Patent document cited in search report		Publication date (day/month/year)	Patent family member(s)		Publication date (day/month/year)
EP	2405599A2	11 January 2012	WO	2010101409A2	10 September 2010
			JP	2012519410A	23 August 2012
			US	2011317652A1	29 December 2011
			CN	102342054A	01 February 2012
			KR	20100100644A	15 September 2010
			JP	2013243784A	05 December 2013
WO	2012163423A1	06 December 2012	EP	2715966A1	09 April 2014
			CN	103597772A	19 February 2014
WO	2012061410A2	10 May 2012	US	2012106404A1	03 May 2012
CN	101686534A	31 March 2010	WO	2010037325A1	08 April 2010
			US	2011170508A1	14 July 2011
CN	102264093A	30 November 2011	JP	2011254466A	15 December 2011