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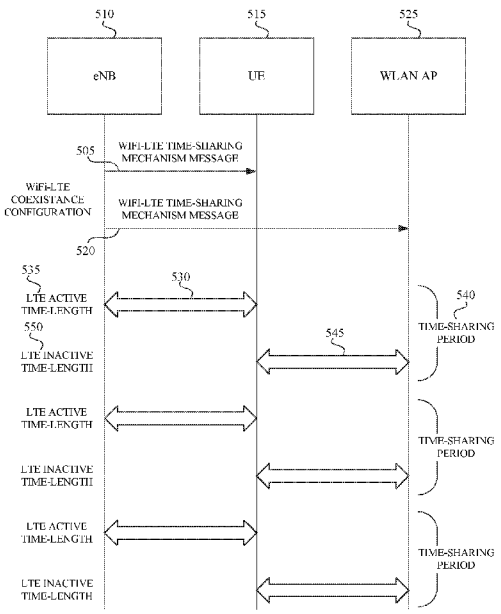


FIG. 5

(57) **Abstract**: Technology for a multi-connectivity system to provide for a time sharing mechanism is disclosed. The eNB can identify a WLAN-LTE concurrent use for a given UE, and transmit a message indicating activation of the WLAN-LTE time sharing mechanism. The message can include a time sharing period, an LTE active time length and an LTE inactive time length of the time sharing period, and a start time of the time sharing period. The eNB and UE can thereafter schedule LTE transmissions during the LTE active time-length of the time sharing period. The UE and WLAN AP can thereafter schedule WLAN transmissions during the LTE inactive time-length of the time sharing period.

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RADIO ACCESS TECHNOLOGY COEXISTENCE TECHNIQUES

BACKGROUND

[0001] In some wireless networks, user equipment (UE) may be capable of supporting multiple wireless technologies concurrently. UEs, for example, may include both Third Generation Partnership Project (3GPP) Long Term Evolved (LTE) and WiFi Radio Access Technologies (RAT) to allow communication over either LTE or WiFi, or both LTE and WiFi concurrently. UEs that support both LTE and WiFi communication may use the advantages of both RATs to increase the speed of communication while decreasing the cost and amount of power used to transfer data.

[0002] However, in-device coexistence issues may occur when UEs communicate over LTE and WiFi concurrently. The transmission on an LTE frequency band may cause interference with reception on a WiFi frequency band at the UE. Likewise, transmission on a WiFi frequency band may cause interference with reception on an LTE frequency band at the UE. Thus, a desire exists for a solution to provide functionality and protocols scalable and efficient to meet the constraints for communication using multiple wireless technologies concurrently.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] Features and advantages of the disclosure will be apparent from the detailed description which follows, taken in conjunction with the accompanying drawings, which together illustrate, by way of example, features of the disclosure; and, wherein:

FIG. 1 depicts a wireless multi-connectivity system in accordance with an example;
FIG. 2 depicts functionality of an Evolved NodeB (eNB) to facilitate wireless multi-connectivity in accordance with an example;
FIG. 3 depicts functionality of a User Equipment (UE) to facilitate wireless multi-connectivity in accordance with an example;
FIG. 4 depicts functionality of a Wireless Local Area Network (WLAN) Access Point (AP) to facilitate wireless multi-connectivity in accordance with an example;
FIG. 5 illustrates signaling in a wireless multi-connectivity system in accordance with an example;

FIG. 6 illustrates signaling in a wireless multi-connectivity system in accordance with an example;

FIG. 7 depicts functionality of an eNB to facilitate wireless multi-connectivity in accordance with an example;

FIG. 8 depicts functionality of a UE to facilitate wireless multi-connectivity in accordance with an example;

FIG. 9 depicts functionality of a WLAN AP to facilitate wireless multi-connectivity in accordance with an example;

FIG. 10 illustrates signaling in a wireless multi-connectivity system in accordance with an example;

FIG. 11 illustrates signaling in a wireless multi-connectivity system in accordance with an example;

FIG. 12 illustrates a diagram of example components of a UE in accordance with an example;

FIG. 13 illustrates a diagram of an eNB and UE in accordance with an example; and

FIG. 14 illustrates a diagram of example components of a UE in accordance with an example.

[0004] Reference will now be made to the exemplary embodiments illustrated, and specific language will be used herein to describe the same. It will nevertheless be understood that no limitation of the scope of the technology is thereby intended.

DETAILED DESCRIPTION

[0005] Before the present technology is disclosed and described, it is to be understood that this technology is not limited to the particular structures, process actions, or materials disclosed herein, but is extended to equivalents thereof as would be recognized by those ordinarily skilled in the relevant arts. It should also be understood that terminology employed herein is used for the purpose of describing particular examples only and is not intended to be limiting. The same reference numerals in different drawings represent the same element. Numbers provided in flow charts and processes are provided for clarity in illustrating actions and operations and do not necessarily indicate a particular order or sequence.

DEFINITIONS

[0006] As used herein, the term "User Equipment (UE)" refers to a computing device capable of wireless digital communication such as a smart phone, a tablet computing device, a laptop computer, a multimedia device such as a television or gaming device, or other type of computing device that provides text or voice communication. The term "User Equipment (UE)" may also be refer to as a "mobile device," "wireless device," of "wireless mobile device."

[0007] As used herein, the term "wireless access point" or "Wireless Local Area Network Access Point (WLAN-AP)" refers to a device or configured node on a network that allows wireless capable devices and wired networks to connect through a wireless standard, including WiFi, Bluetooth, or other wireless communication protocol.

[0008] As used herein, the term "Evolved NodeB," "eNodeB," or "eNB," refers to a device or configured node of a mobile phone network that communicates wirelessly with UEs.

[0009] As used herein, the term "cellular telephone network' or "Long Term Evolved (LTE)" refers to wireless broadband technology developed by the Third Generation Partnership Project (3GPP).

EXAMPLE EMBODIMENTS

[0010] An initial overview of technology embodiments is provided below and then specific technology embodiments are described in further detail later. This initial summary is intended to aid readers in understanding the technology more quickly but is not intended to identify key features or essential features of the technology nor is it intended to limit the scope of the claimed subject matter.

[0011] In one aspect, wireless multi-connectivity enables User Equipment (UE) to send and receive data on two or more wireless networks. For example, the UE may be used to provide voice communications over an LTE network, while also sending and receiving text, pictures, video or the like over a WLAN network using the same device. In addition, the bandwidth of two or more wireless networks may be aggregated to provide greater bandwidth. However, the simultaneous transmission and reception on two or more wireless networks may cause in-device co-existence issues. For example, the transmission of LTE data packets from a UE can cause interference with the reception

of WLAN data packets at the UE. Likewise, the transmission of WLAN data packets from the UE can cause interference with the reception of LTE data packets at the UE.

[0012] In one aspect, the present technology provides for a time sharing mechanism for two or more different Radio Access Networks (RAN). In one aspect, concurrent use of two different RANs is identified. The time sharing mechanism is activated in response to identification of the concurrent use. Once activated, the different RANs are operated in accordance with the time sharing mechanism

[0013] FIG. 1 depicts a wireless multi-connectivity system, in accordance with an example. In one aspect, the multi-connectivity system includes one or more Long Term Evolved (LTE) Evolved NodeBs (eNB) 110, one or more Wireless Local Area Network Access Point (WLAN-AP) 120, and one or more User Equipment (UE) devices 130. One or more LTE networks communicatively couple eNBs to UEs, and one or more WLAN networks communicatively couple WLAN-APs to UEs. eNBs may also be communicatively coupled to WLAN-APs by one or more additional network connections 140.

[0014] In one instance, the eNBs and UEs may include one or more antennas, one or more 3GPP LTE radios to modulate and/or demodulate signals transmitted or received on an air interface, and one or more 3GPP LTE digital processors to process signals transmitted and received on the air interface. In one instance, the UEs and WLAN-AP may include one or more antennas, one or more WLAN radios to modulate and/or demodulate signals transmitted or received on an air interface, and one or more WLAN digital processors to process signals transmitted and received on the air interface. In one instance the WLAN can be an Institute of Electronics and Electrical Engineers (IEEE) 802.11 network (WiFi). In one instance, the eNBs may be LTE Evolved NodeBs (eNB). In one instance, the WLAN-APs may each include one or more WiFi Access Points (AP). In one instance, the UEs may include one or more smart phones, tablet computing devices, laptop computers, internet of things (IOT) devices, and/or other types of computing devices that provide digital communication including data and/or voice communication.

[0015] An eNB may be a relatively high power node, referred to as a "macro node" or a relatively low power node (LPN). An LPN can include a micro node, pico node, home eNB (HeNB), remote radio head (RRH), remote radio entity (RRE), and the

like. The eNB can provide communication coverage for a particular geographic area. The term "cell" can refer to a coverage area of an eNB and/or an eNB subsystem serving this coverage area.

[0016] In one aspect, the LTE and WiFi radios of the UE can enable the UE to simultaneously transmit data over an LTE link while receiving other data over a WiFi link, or simultaneously receive data over the LTE link while transmitting other data over the WiFi link. In one aspect, the multi-connectivity system provides for LTE WLAN aggregation (LWA) (e.g., mobile data offload or "Wi-Fi Offloading"). In LWA, data packets (e.g., packet data units "PDUs") may be served on LTE and Wi-Fi radio links. An advantage of LWA is that it can provide increased control and utilization of resources on both links (e.g., LTE links and Wi-Fi radio links). LWA can be used to increase the aggregate throughput for all users and improve the total system capacity by better managing the radio resources among users. However, when an operating radio frequency (RF) band of the LTE link is relatively close to the operating RF band of the WiFi link, the simultaneous transmission on the LTE link and reception on the WiFi link, and/or simultaneous reception on the LTE link and transmission on the WiFi link may cause interference. The interference may cause in-device coexistence issues for LWA and other multi-mode operations.

[0017] FIG. 2 illustrates functionality of an eNB to facilitate wireless multi-connectivity, in accordance with an example. The functionality of the eNB includes a WLAN-LTE time sharing mechanism for concurrent use of an LTE service and a WLAN service. The WLAN-LTE time sharing mechanism of the eNB can be implemented by one or more processors and memory, wherein the memory stores one or more sets of instructions, that, when executed by the one or more processors, perform one or more functionalities including the WLAN-LTE time sharing mechanism. In one instance, the WLAN can be an Institute of Electronics and Electrical Engineers (IEEE) 802.11 network (WiFi), and the corresponding WLAN-LTE time sharing mechanism may be implemented by one or more processors and memory of an application circuitry, a baseband circuitry, and/or Radio Frequency (RF) circuitry of the eNB.

[0018] In one aspect, the functionality of the eNB can include identifying a WiFi-LTE concurrent use for one or more UEs 210. In one aspect, the WiFi-LTE concurrent use can be determined by the eNB based upon an operating state of the eNB.

In one instance, the eNB can determine that there is concurrent use when the eNB is communicating in an LTE-WLAN Aggregation (LWA) operating mode with a given UE. In one instance, the LWA may be performed using an Institute of Electronics and Electrical Engineers (IEEE) 802.11ax (WiFi) protocol.

[0019] In another aspect, the WiFi-LTE concurrent use can be identified based upon a message received from the UE that indicates the WiFi-LTE concurrent use. In one instance, the WiFi-LTE concurrent use can be indicated in an In-device Coexistence Indication (InDeviceCoexTimeSharing) message received by the eNB from a given UE. For example, Table 1 illustrates exemplary information conveyed as an InDeviceCoexTimeSharing message.

IE/Group Name	Presence	Range	IE type and reference	Semantics description	Criticality
Message Type	M		9.2.1		YES
WLAN Identifiers List		*0..1*		List of identifiers added by the WLAN-AP	GLOBAL
> WiFi-LTE-time-sharing period	M		INTEGER		
> LTE-active-period			INTEGER		
> LTE-not-active-period			INTEGER		

Table 1

The InDeviceCoexTimeSharing message can be used to inform the eNB about the in-device coexistence time sharing parameters. An exemplary implementation of the message may be as shown in Table 2.

```
-- ASN1START

InDeviceCoexTimeSharing-r14 ::=     SEQUENCE {
 criticalExtensions                 CHOICE {
    c1                                  CHOICE {
        inDeviceCoexTimeSharing-r14             InDeviceCoexTimeSharing-
r14-IEs,
        spare3 NULL, spare2 NULL, spare1 NULL
    },
    criticalExtensionsFuture            SEQUENCE {}
```

```
}
}

InDeviceCoexTimeSharing-r14-IEs ::= SEQUENCE {
  wlanLTETimeSharingPeriod-r14    INTEGER    OPTIONAL,
  lteActivePeriod                 INTEGER    OPTIONAL,
  lteNotActivePeriod              INTEGER    OPTIONAL
}
```

Table 2

[0020] In one aspect, the eNB can transmit to the UE a message that indicates the activation of a WiFi-LTE time sharing mechanism 220, in response to the identified WiFi-LTE concurrent use. The message can be transmitted from the eNB to the UE using a higher layer communication, such as a Radio Resource Control (RRC) communication, a Master Information Block (MIB), a Secondary Information Block (SIB), a Packet Data Convergence Protocol (PDCP), or another desired type of higher layer communication.

[0021] In one aspect, the indication of the activation of the WiFi-LTE time sharing mechanism can also include a time sharing period, an LTE active time-length of the time sharing period, an LTE inactive time-length of the time sharing period, and a start of the time sharing period. In one instance, the time sharing period may be 100 milliseconds (ms), and the LTE active and LTE inactive time-lengths may each be 50 ms, or any other appropriate periods and time-lengths, from several milliseconds to hundreds of milliseconds. In another instance, the time sharing period may be 100 ms, and the LTE active and LTE inactive time-lengths may each include five (5) 10 ms alternating time-lengths, or any other appropriate periods and time-lengths, from several milliseconds to hundreds of milliseconds.

[0022] In one aspect, the eNB can also transmit to the WLAN AP a message that indicates the activation of the WiFi-LTE time sharing mechanism 230, in response to the identified WiFi-LTE concurrent use. The message can be transmitted from the eNB to the WLAN AP across one or more wired communication links according to an Xw Rel-13 compliant protocol. The message may be transmitted from the eNB to the WLAN AP via one or more routers and or one or more GPT-U endpoints. In one aspect, the indication of the activation of the WiFi-LTE time sharing mechanism can also include the time sharing period, the LTE active time-length of the time sharing period, the LTE inactive time-length of the time sharing period, and the start of the time sharing period.

[0023] In one aspect, the LTE active time-length or one or more portions of the LTE active time-length of the time sharing period can be associated with a Discontinuous Reception (DRX) mechanism. In one aspect the UE and eNB can negotiate phases, in which data transfers occur, to correspond to the LTE active time-length of the time sharing period.

[0024] In one aspect, the eNB can transmit to the UE during the LTE active time-length or one or more portions of the LTE active-time length of the time sharing periods 240. Accordingly, communications from the eNB to the UE are timed to the LTE active time-length so that the wireless LTE transmission from the eNB to the UE during the active time-length does not interfere with communications between the WLAN-AP and the UE during the LTE inactive time length of the time sharing periods.

[0025] In one instance, the time sharing period may be 100 ms, and the LTE active and LTE inactive time-lengths may each be 50 ms. In such case, the eNB can transmit data on the LTE communication link to the UE during the 50 ms LTE active time-lengths, and does not transmit data on the LTE communication link during the 50 ms LTE inactive time-lengths. In another instance, the time sharing period may be 100 ms, and the LTE active and LTE inactive time-lengths may each include five (5) 10 ms alternating time-lengths, or other appropriate periods and time-lengths. In such case, the eNB can transmit data on the LTE communication link to the UE during each 10 ms LTE active time-lengths. In another case, the eNB can transmit data on the LTE communication link to the given UE during one or more of the five (5) 10 ms portions of the LTE active time-lengths, while data can be transmitted to other UEs on the other 10 ms portions of the LTE active time lengths.

[0026] In one aspect, transmission and reception during the LTE active time-length or one or more portions of the LTE active time-length, of the time sharing period, can be associated with a Discontinuous Reception (DRX) mechanism. During the LTE inactive time length of the time sharing period, the LTE transceiver of the UE can turn off or enter a lower power state.

[0027] FIG. 3 illustrates functionality of a UE to facilitate wireless multi-connectivity, in accordance with an example. The functionality of the UE can include a WLAN-LTE time sharing mechanism for concurrent use of an LTE service and a Wi-Fi service. The WLAN-LTE time sharing mechanism of the UE can be implemented by one

or more processors and memory, wherein the memory stores one or more sets of instructions, that, when executed by the one or more processors, perform one or more functionalities including the WLAN-LTE time sharing mechanism. In one instance, the WLAN can be an Institute of Electronics and Electrical Engineers (IEEE) 802.11 network (WiFi), and the corresponding WLAN-LTE time sharing mechanism may be implemented by one or more processors and memory of an application circuitry, a baseband circuitry, and/or Radio Frequency (RF) circuitry of the UE.

[0028] In some implementations of IEEE 802.11 (WiFi), the WLAN-AP provides an indication of when the UE can transmit. In one instance, the WLAN-AP provides a trigger frame, and the UE transmits immediately after the trigger frame. However, the WLAN-AP is not aware of LTE traffic between the eNB and UE and therefore may send trigger frames during LTE transmission between the eNB and UE. In other implementations of IEEE 802.11 (WiFi), the WLAN-AP may not provide an indication of when the UE can transmit. The UE implements a Listen-Before Transmit (LBT) procedure. If the UE detects traffic, the UE waits a random amount of time before transmitting. However, the predetermined wait or back-off may result in reduced bandwidth utilization, increased latency or similar deleterious effects. Furthermore, LTE transmissions between the eNB and UE occur in real time and change quickly. Therefore, it is difficult to adjust the WiFi transmissions between the WLAN-AP and UE.

[0029] In one aspect, the functionality of the UE can optionally include transmitting a message from the UE to the eNB indicating WiFi-LTE concurrent use 310. The WiFi-LTE concurrent use can be indicated in an In-device Coexistence Indication (InDeviceCoexIndication) message transmitted by the UE to the eNB. The message can be transmitted from the UE to the eNB using a higher layer communication, such as a Radio Resource Control (RRC) communication, a Master Information Block (MIB), a Secondary Information Block (SIB), a Packet Data Convergence Protocol (PDCP), or another desired type of higher layer communication.

[0030] In one aspect, the message that indicates the WiFi-LTE concurrent use can also suggest an LTE active time-length and an LTE inactive time-length of a time sharing period. In one instance, the suggested time sharing period may be 100 ms, and the LTE active and LTE inactive time-lengths may each be 50 ms, or any other appropriate periods and time-lengths. In another instance, the suggested time sharing

period may be 100 ms, and the LTE active and LTE inactive time-lengths may each include five (5) 10 ms alternating time-lengths, or any other appropriate periods and time-lengths, as previously described.

[0031] In one instance, the WiFi-LTE concurrent use can be indicated in an In-device Coexistence Indication (InDeviceCoexTimeSharing) message received by the eNB from a given UE. For example, Table 1 illustrates exemplary information conveyed as an InDeviceCoexTimeSharing message. The InDeviceCoexTimeSharing message can be used to inform the eNB about the in-device coexistence time sharing parameters. An exemplary implementation of the message can be as shown in Table 2.

[0032] In one aspect, the UE can decode a message from the eNB that indicates activation of a WiFi-LTE time sharing mechanism 320. The message can be received by the UE from the eNB across the wireless communication link according to the LTE compliant protocol. The message can be received by the UE from the eNB using a Radio Resource Control (RRC) layer communication, or another desired higher layer communication, as previously described. The indication of the activation of the WiFi-LTE time sharing mechanism can also include a time sharing period, an LTE active time-length of the time sharing period, an LTE inactive time-length of the time sharing period, and a start of the time sharing period. In one instance, the time sharing period may be 100 ms, and the LTE active and LTE inactive time-lengths may each be 50 ms, or any other appropriate periods and time-lengths, as previously described. In another instance, the time sharing period may be 100 ms, and the LTE active and LTE inactive time-lengths may each include five (5) 10 ms alternating time-lengths, or any other appropriate periods and time-lengths, as previously described.

[0033] In one aspect, the UE can transmit to the eNB during the LTE active time-length or one or more portions of the LTE active-time length of the time sharing periods 330. Accordingly, communications from the UE to the eNB are timed to the LTE active time-length so that the wireless LTE transmission from the UE to the eNB during the active time-length do not interfere with communications between the UE and the WLAN AP during the LTE inactive time length of the time sharing periods.

[0034] In one instance, the time sharing period may be 100 ms, and the LTE active and LTE inactive time-lengths may each be 50 ms. In such case, the UE can transmit data on the LTE communication link to the eNB during the 50 ms LTE active

time-lengths, and does not transmit data on the LTE communication link during the 50 ms LTE inactive time-lengths. In another instance, the time sharing period may be 100 ms, and the LTE active and LTE inactive time-lengths may each include five (5) 10 ms alternating time-lengths. In such case, the UE can transmit data on the LTE communication link to the eNB during each 10 ms LTE active time-lengths. In another case, the UE can transmit data on the LTE communication link to the eNB during one or more of the five (5) 10 ms portions of the LTE active time-lengths, while data is transmitted by other UEs on the other 10 ms portions of the LTE active time lengths.

[0035] In one aspect, transmission and reception during the LTE active time-length or one or more portions of the LTE active time-length, of the time sharing period, can be associated with a Discontinuous Reception (DRX) mechanism. During the LTE inactive time length of the time sharing period, the LTE transceiver of the UE can turn off or enter a lower power state.

[0036] In one aspect, the UE can transmit to the WLAN AP during the LTE inactive time-length or one or more portions of the LTE inactive time-length of the WiFi-LTE time sharing period 340. Accordingly, communications from the UE to the WLAN AP can be timed to the LTE inactive time-length so that the wireless WLAN transmission from the UE to the WLAN during the inactive time-length do not interfere with communications between the UE and the eNB during the LTE active time-length of the time sharing periods.

[0037] In one instance, the time sharing period may be 100 ms, and the LTE active and LTE inactive time-lengths may each be 50 ms. In such case, the UE can transmit data on the WiFi communication link to the WLAN AP during the 50 ms LTE inactive time-lengths, and does not transmit data on the WiFi communication link during the 50 ms LTE active time-lengths to the eNB. In another instance, the time sharing period may be 100 ms, and the LTE active and LTE inactive time-lengths may each include five (5) 10 ms alternating time-lengths. In such case, the UE can transmit data on the WiFi communication link to the WLAN AP during each 10 ms LTE inactive time-lengths. In another case, the UE can transmit data on the WiFi communication link to the WLAN AP during one or more of the five (5) 10 ms portions of the LTE active time-lengths, while data is transmitted from other UEs on the other 10 ms portions of the LTE active time lengths.

[0038] In one aspect, the communications between the UE and WLAN AP can be transmitted from the UE to the WLAN AP across one or more wireless communication links according to an IEEE 802.11 (WiFi) compliant protocol. WiFi compliant protocols include 802.11 (1997), 802.11a (199), 802.11b (1999), 802.11g (2003), 802.11n (2009), 802.11ac (2013) and 802.11ad (2012), or future compliant protocols such as 802.11ax and 802.11ay.

[0039] FIG. 4 illustrates functionality of a WLAN AP to facilitate wireless multi-connectivity, in accordance with an example. The functionality of the WLAN includes a WLAN-LTE time sharing mechanism for concurrent use of an LTE service and a WLAN service. The WLAN-LTE time sharing mechanism of the WLAN AP can be implemented by one or more processors and memory, wherein the memory stores one or more sets of instructions, that, when executed by the one or more processors, perform one or more functionalities including the WLAN-LTE time sharing mechanism. In one instance, the WLAN can be an Institute of Electronics and Electrical Engineers (IEEE) 802.11 network (WiFi), and the corresponding WLAN-LTE time sharing mechanism may be implemented by one or more processors and memory of an application circuitry, a baseband circuitry, and/or Radio Frequency (RF) circuitry of the WLAN AP.

[0040] In one aspect, the functionality of the WLAN AP can include decoding a message from the eNB that indicates activation of a WiFi-LTE time sharing mechanism 410. The message can be received by the WLAN AP from the eNB across one or more wired communication links according to an Xw compliant protocol. The message can be received by the WLAN AP from the eNB via one or more routers and or one or more GPT-U endpoints.

[0041] In one aspect, the indication of the activation of the WiFi-LTE time sharing mechanism can also include a time sharing period, an LTE active time-length of the time sharing period, an LTE inactive time-length of the time sharing period, and a start of the time sharing period. In one instance, the time sharing period may be 100 ms, and the LTE active and LTE inactive time-lengths may each be 50 ms, or any other appropriate periods and time-lengths, as previously described. In another instance, the time sharing period may be 100 ms, or other appropriate periods and time-lengths, and the LTE active and LTE inactive time-lengths may each include five (5) 10 ms alternating time-lengths, or other appropriate periods and time-lengths, as previously described. In

one instance, the time sharing period can be associated with the beacon interval of the IEEE 802.11 (WiFi) protocol. The beacon interval is included in a beacon frame transmitted periodically by the WLAN-AP. The beacon interval may be 102 ms. Therefore, the time sharing period, LTE active and LTE inactive time-lengths, and the start time of the time sharing period may be based upon the beacon interval.

[0042] In one aspect, the WLAN AP can transmit to the UE during the LTE inactive time-length or one or more portions of the LTE inactive time-length of the WiFi-LTE time sharing period 420. Accordingly, communications from the WLAN to the UE can be timed to the LTE inactive time-length so that the wireless WLAN transmission from the WLAN to the UE during the inactive time-length does not interfere with communications between the UE and the eNB during the LTE active time-length of the time sharing periods.

[0043] In one instance, the time sharing period may be 100 ms, and the LTE active and LTE inactive time-lengths may each be 50 ms. In such case, the WLAN AP can transmit data on the WiFi communication link to the UE during the 50 ms LTE inactive time-lengths, and does not transmit data on the WiFi communication link during the 50 ms LTE active time-lengths to the eNB. In another instance, the time sharing period may be 100 ms, and the LTE active and LTE inactive time-lengths may each include five (5) 10 ms alternating time-lengths. In such case, the WLAN AP can transmit data on the WiFi communication link to the UE during each 10 ms LTE inactive time-lengths. In another case, the WLAN AP can transmit data on the WiFi communication link to the UE during one or more of the five (5) 10 ms portions of the LTE active time-lengths, while data can be transmitted from to other UEs on the other 10 ms portions of the LTE active time lengths.

[0044] Accordingly, the WiFi-LTE time sharing mechanism advantageously allows both the WLAN AP and the eNB to share in-device air-time in a fair manner that will also provide good performance with external traffic controllers, such as the 802.11ax AP protocol, that otherwise may not synchronize with real-time in-device coexistence signals between the eNB, UE and WLAN.

[0045] FIG. 5 illustrates signaling in a wireless multi-connectivity system, in accordance with an example. In one aspect, a WiFi-LTE time sharing message can be transmitted 505 by a transceiver circuitry of an eNB 510 and received by a transceiver

circuitry of a UE 515. The message may be transmitted from the eNB to the UE using a higher layer communication, such as a Radio Resource Control (RRC) communication, a Master Information Block (MIB), a Secondary Information Block (SIB), a Packet Data Convergence Protocol (PDCP), or another desired type of higher layer communication.

[0046] In one aspect, the WiFi-LTE time sharing message may also be transmitted 520 by a transceiver circuitry of an eNB 510 and received by a transceiver circuitry of a WLAN AP 525. The message may be transmitted from the eNB to the WLAN AP across one or more wired communication links according to an Xw compliant protocol. The message may be transmitted from the eNB to the WLAN AP via one or more routers and or one or more GPT-U endpoints.

[0047] In one aspect, the WiFi-LTE time sharing messages can be sent from the eNB to the UE and WLAN AP in response to the eNB identifying a WiFi-LTE concurrent use at the given UE. In one aspect, the WiFi-LTE concurrent use may be determined by the eNB based upon an operating state of the eNB. In one instance, the eNB can determine that there is concurrent use when the eNB is communicating in an LTE-WLAN Aggregation (LWA) operating mode with a given UE. In one instance, the LWA may be performed using an IEEE 802.11ax protocol.

[0048] In one aspect, the WiFi-LTE time sharing messages sent from the eNB to the UE and WLAN AP can include an indication of activation of the WiFi-LTE time sharing mechanism, a time sharing period, an LTE active time-length of the time sharing period, an LTE inactive time-length of the time sharing period, and a start of the time sharing period. In one instance, the time sharing period may be 100 milliseconds (ms), and the LTE active and LTE inactive time-lengths may each be 50 ms, or any other appropriate periods and time-lengths, as previously described. In another instance, the time sharing period may be 100 ms, and the LTE active and LTE inactive time-lengths may each include five (5) 10 ms alternating time-lengths, or any other appropriate periods and time-lengths, as previously described.

[0049] After transmission of the WiFi-LTE time sharing messages, LTE data packets can be transmitted and received 530 between the eNB 510 and the UE 515 during the LTE active time-lengths 535 or one or more portions of the LTE active-time length of the time sharing periods 540. In addition, WiFi data packets can be transmitted and received 545 between the WLAN-AP 525 and the UE 515 during the LTE inactive time-

lengths 550 or one or more portions of the LTE active-time length of the time sharing periods 540. The time sharing mechanism including the time sharing period, the LTE active time-length of the time sharing period, the LTE inactive time-length of the time sharing period, and the start of the time sharing period may be applied to both LTE and WiFi transmissions in both the uplink (UL) and down link (DL) communication channels. Accordingly, communications between the eNB and the UE can be timed to the LTE active time-lengths so that the LTE transmissions between the eNB to the UE do not interfere with WiFi communications between the WLAN-AP and the UE. Similarly, communications between the WLAN AP and the UE can be timed to the LTE inactive time-lengths so that the WiFi transmissions between the WLAN AP and the UE do not interfere with LTE communications between the eNB and the UE.

[0050] FIG. 6 illustrates signaling in a wireless multi-connectivity system, in accordance with an example. In one aspect, a WiFi-LTE coexistence message can be transmitted 605 by a transceiver circuity of a UE 610 and received by the transceiver circuitry of an eNB 615. In one aspect, the WiFi-LTE coexistence message can be sent in response to the UE determining a WiFi-LTE concurrent use issue. The message can be transmitted from the UE to the eNB using a higher layer communication, such as a Radio Resource Control (RRC) communication, a Master Information Block (MIB), a Secondary Information Block (SIB), a Packet Data Convergence Protocol (PDCP), or another desired type of higher layer communication.

[0051] In one aspect, a WiFi-LTE time sharing message can be transmitted 620 by the transceiver circuitry of the eNB 615 and received by the transceiver circuitry of the UE 610 in response to the WiFi-LTE coexistence message. The message can be transmitted from the eNB to the UE using the higher layer communication, such as a Radio Resource Control (RRC) communication, a Master Information Block (MIB), a Secondary Information Block (SIB), a Packet Data Convergence Protocol (PDCP), or another desired type of higher layer communication.

[0052] In one aspect, a WiFi-LTE time sharing message 625 can also be transmitted by a transceiver circuitry of an eNB 615 and received by a transceiver circuitry of a WLAN AP 630. The message can be transmitted from the eNB to the WLAN AP across one or more wired communication links according to an Xw compliant

protocol. The message can be transmitted from the eNB to the WLAN AP via one or more routers and or one or more GPT-U endpoints.

[0053] In one aspect, the WiFi-LTE time sharing messages sent from the eNB to the UE and WLAN AP can include an indication of activation of the WiFi-LTE time sharing mechanism, a time sharing period, an LTE active time-length of the time sharing period, an LTE inactive time-length of the time sharing period and a start of the time sharing period.

[0054] After transmission of the WiFi-LTE time sharing messages, LTE data packets can be transmitted and received 635 between the transceiver circuitry of the eNB 615 and the transceiver circuitry of the UE 610 during the LTE active time-lengths 640 or one or more portions of the LTE active-time length of the time sharing periods 645. In addition, WiFi data packets may be transmitted and received 650 between the transceiver circuitry of the WLAN-AP 630 and the transceiver circuitry of the UE 610 during the LTE inactive time-lengths 655 or one or more portions of the LTE active-time length of the time sharing periods 645. The time sharing mechanism including the time sharing period, the LTE active time-length of the time sharing period, the LTE inactive time-length of the time sharing period, and the start of the time sharing period may be applied to both LTE and WiFi transmissions in both the uplink (UL) and down link (DL) communication channels. Accordingly, communications between the eNB and the UE can be timed to the LTE active time-lengths so that the LTE transmissions between the eNB to the UE do not interfere with WiFi communications between the WLAN-AP and the UE. Similarly, communications between the WLAN AP and the UE can be timed to the LTE inactive time-lengths so that the WiFi transmissions between the WLAN AP and the UE do not interfere with LTE communications between the eNB and the UE.

[0055] FIG. 7 illustrates functionality of an eNB to facilitate wireless multi-connectivity, in accordance with an example. The functionality of the eNB includes a WiFi-LTE time sharing mechanism for concurrent use of an LTE service and a Wi-Fi service. The WiFi-LTE time sharing mechanism of the eNB can be implemented by one or more processors and memory, wherein the memory stores one or more sets of instructions, that, when executed by the one or more processors, perform one or more functionalities performed by the eNB. In one instance, the WiFi-LTE time sharing mechanism of the eNB may be implemented in by one or more processors and memory of

an application circuitry, a baseband circuitry, and/or Radio Frequency (RF) circuitry of the eNB.

[0056] In one aspect, the functionality of the eNB can include identifying a WiFi-LTE concurrent use for one or more UEs 710. In one aspect, the WiFi-LTE concurrent use can be determined by the eNB based upon an operating state of the eNB. In one instance, the eNB can determine that there is concurrent use when the eNB is communicating in an LTE-WLAN Aggregation (LWA) operating mode with a given UE. In one instance, the LWA may be performed using an IEEE 802.11ax protocol.

[0057] In another aspect, the WiFi-LTE concurrent use can be identified based upon a message received from the UE that indicates the WiFi-LTE concurrent use. In one instance, the WiFi-LTE concurrent use can be indicated in an In-device Coexistence Indication (InDeviceCoexTimeSharing) message received by the eNB from a given UE. For example, Table 1 illustrates exemplary information conveyed as an InDeviceCoexTimeSharing message. The InDeviceCoexTimeSharing message can be used to inform the eNB about the in-device coexistence time sharing parameters. An exemplary implementation of the message can be as shown in Table 2.

[0058] In one aspect, the eNB can transmit to the UE a message that indicates the activation of a WiFi-LTE time sharing mechanism 720, in response to the identified WiFi-LTE concurrent use. The message can be transmitted from the eNB to the UE using a higher layer communication, such as a Radio Resource Control (RRC) communication, a Master Information Block (MIB), a Secondary Information Block (SIB), a Packet Data Convergence Protocol (PDCP), or another desired type of higher layer communication. In one aspect, the indication of the activation of the WiFi-LTE time sharing mechanism can also include a time sharing period, an LTE active time-length of the time sharing period, an LTE inactive time-length of the time sharing period and a start of the time sharing period. In one instance, the time sharing period may be 100 milliseconds (ms), and the LTE active and LTE inactive time-lengths may each be 50 ms, or any other appropriate periods and time-lengths, as previously described. In another instance, the time sharing period may be 100 ms, and the LTE active and LTE inactive time-lengths may each include five (5) 10 ms alternating time-lengths, or any other appropriate periods and time-lengths, as previously described.

[0059] In one aspect, the LTE active time-length or one or more portions of the LTE active time-length, of the time sharing period, can be associated with a Discontinuous Reception (DRX) mechanism. In one aspect the UE and eNB can negotiate phases, in which data transfers occur, to correspond to the LTE active time-length of the time sharing period.

[0060] In one aspect, the eNB can transmit to the UE during the LTE active time-length or one or more portions of the LTE active-time length of the time sharing periods 720. Accordingly, communications from the eNB to the UE can be timed to the LTE active time-length so that the wireless LTE transmission from the eNB to the UE during the active time-length does not interfere with WiFi communications between the WLAN-AP and the UE during the LTE inactive time length of the time sharing periods.

[0061] In one instance, the time sharing period may be 100 ms, and the LTE active and LTE inactive time-lengths may each be 50 ms. In such case, the eNB can transmit data on the LTE communication link to the UE during the 50 ms LTE active time-lengths, and does not transmit data on the LTE communication link during the 50 ms LTE inactive time-lengths. In another instance, the time sharing period may be 100 ms, and the LTE active and LTE inactive time-lengths may each include five (5) 10 ms alternating time-lengths. In such case, the eNB can transmit data on the LTE communication link to the UE during each 10 ms LTE active time-lengths. In another case, the eNB can transmit data on the LTE communication link to the given UE during one or more of the five (5) 10 ms portions of the LTE active time-lengths, while data is transmitted to other UEs on the other 10 ms portions of the LTE active time lengths.

[0062] In one aspect, transmission and reception during the LTE active time-length or one or more portions of the LTE active time-length, of the time sharing period, can be associated with a Discontinuous Reception (DRX) mechanism. During the LTE inactive time length of the time sharing period, the LTE transceiver of the UE can turn off or enter a lower power state.

[0063] FIG. 8 illustrates functionality of a UE to facilitate wireless multi-connectivity, in accordance with an example. The functionality of the UE includes a WiFi-LTE time sharing mechanism for concurrent use of an LTE service and a Wi-Fi service. The WiFi-LTE time sharing mechanism of the UE can be implemented by one or more processors and memory, wherein the memory stores one or more sets of

instructions, that, when executed by the one or more processors, perform one or more functionalities including the WiFi-LTE time sharing mechanism. In one instance, the WiFi-LTE time sharing mechanism may be implemented by one or more processors and memory of an application circuitry, a baseband circuitry, and/or Radio Frequency (RF) circuitry of the UE.

[0064] In one aspect, the functionality of the UE can optionally include transmitting a message from the UE to the eNB indicating WiFi-LTE concurrent use 810. The WiFi-LTE concurrent use can be indicated in an In-device Coexistence Indication (InDeviceCoexTimeSharing) message transmitted by the UE to the eNB. The message can be transmitted from the UE to the eNB using a higher layer communication, such as a Radio Resource Control (RRC) communication, a Master Information Block (MIB), a Secondary Information Block (SIB), a Packet Data Convergence Protocol (PDCP), or another desired type of higher layer communication. The message may be transmitted from the UE to the eNB across a wireless communication link according to an LTE compliant protocol.

[0065] In one aspect, the message that indicates the WiFi-LTE concurrent use can also suggest an LTE active time-length and an LTE inactive time-length of a time sharing period. In one instance, the suggested time sharing period may be 100 ms, and the LTE active and LTE inactive time-lengths may each be 50 ms, or any other appropriate periods and time-lengths, as previously described. In another instance, the suggested time sharing period may be 100 ms, and the LTE active and LTE inactive time-lengths may each include five (5) 10 ms alternating time-lengths, or any other appropriate periods and time-lengths, as previously described.

[0066] In one instance, the WiFi-LTE concurrent use can be indicated in an In-device Coexistence Indication (InDeviceCoexTimeSharing) message received by the eNB from a given UE. For example, Table 1 illustrates exemplary information conveyed as an InDeviceCoexTimeSharing message. The InDeviceCoexTimeSharing message can be used to inform the eNB about the in-device coexistence time sharing parameters. An exemplary implementation of the message can be as shown in Table 2.

[0067] In one aspect, the UE can decode a message from the eNB that indicates activation of a WiFi-LTE time sharing mechanism 820. The message can be received by the UE from the eNB using a higher layer communication, such as a Radio Resource

Control (RRC) communication, a Master Information Block (MIB), a Secondary Information Block (SIB), a Packet Data Convergence Protocol (PDCP), or another desired type of higher layer communication. The indication of the activation of the WiFi-LTE time sharing mechanism can also include a time sharing period, an LTE active time-length of the time sharing period, an LTE inactive time-length of the time sharing period and a start of the time sharing period. In one instance, the time sharing period may be 100 ms, and the LTE active and LTE inactive time-lengths may each be 50 ms, or any other appropriate periods and time-lengths, as previously described. In another instance, the time sharing period may be 100 ms, and the LTE active and LTE inactive time-lengths may each include five (5) 10 ms alternating time-lengths, or any other appropriate periods and time-lengths, as previously described.

[0068] In one aspect, the UE can transmit to the WLAN AP a message that indicates the activation of a WiFi-LTE time sharing mechanism 830. The message can be transmitted from the UE to the WLAN AP across a wireless communication link across one or more wireless communication links according to an 802.11 (WiFi) compliant protocol. WiFi compliant protocols include 802.11 (1997), 802.11a (199), 802.11b (1999), 802.11g (2003), 802.11n (2009), 802.11ac (2013) and 802.11ad (2012), or future compliant protocols such as 802.11ax and 802.11ay. In one aspect, the indication of the activation of the WiFi-LTE time sharing mechanism can also include a time sharing period, an LTE active time-length of the time sharing period, an LTE inactive time-length of the time sharing period and a start of the time sharing period. In one instance, the time sharing period may be 100 milliseconds (ms), and the LTE active and LTE inactive time-lengths may each be 50 ms, or any other appropriate periods and time-lengths, as previously described. In another instance, the time sharing period may be 100 ms, and the LTE active and LTE inactive time-lengths may each include five (5) 10 ms alternating time-lengths, or any other appropriate periods and time-lengths, as previously described.

[0069] In one aspect, the UE can transmit to the eNB during the LTE active time-length or one or more portions of the LTE active-time length of the time sharing periods 840. Accordingly, communications from the UE to the eNB can be timed to the LTE active time-length so that the wireless LTE transmission from the UE to the eNB during the active time-length do not interfere with WiFi communications between the UE and the WLAN AP during the LTE inactive time length of the time sharing periods.

[0070] In one instance, the time sharing period may be 100 ms, and the LTE active and LTE inactive time-lengths may each be 50 ms. In such case, the UE can transmit data on the LTE communication link to the UE during the 50 ms LTE active time-lengths, and does not transmit data on the LTE communication link during the 50 ms LTE inactive time-lengths. In another instance, the time sharing period may be 100 ms, and the LTE active and LTE inactive time-lengths may each include five (5) 10 ms alternating time-lengths. In such case, the UE can transmit data on the LTE communication link to the UE during each 10 ms LTE active time-lengths. In another case, the UE can transmit data on the LTE communication link to the eNB during one or more of the five (5) 10 ms portions of the LTE active time-lengths, while data is transmitted from other UEs on the other 10 ms portions of the LTE active time lengths.

[0071] In one aspect, transmission and reception during the LTE active time-length or one or more portions of the LTE active time-length, of the time sharing period, can be associated with a Discontinuous Reception (DRX) mechanism. During the LTE inactive time length of the time sharing period, the LTE transceiver of the UE can turn off or enter a lower power state.

[0072] In one aspect, the UE can transmit to the WLAN AP during the LTE inactive time-length or one or more portions of the LTE inactive time-length of the WiFi-LTE time sharing period 850. Accordingly, communications from the UE to the WLAN AP can be timed to the LTE inactive time-length so that the wireless WLAN transmission from the UE to the WLAN during the inactive time-length do not interfere with LTE communications between the UE and the eNB during the LTE active time-length of the time sharing periods.

[0073] In one instance, the time sharing period may be 100 ms, and the LTE active and LTE inactive time-lengths may each be 50 ms. In such case, the UE can transmit data on the WiFi communication link to the WLAN AP during the 50 ms LTE inactive time-lengths, and does not transmit data on the WiFi communication link during the 50 ms LTE active time-lengths to the eNB. In another instance, the time sharing period may be 100 ms, and the LTE active and LTE inactive time-lengths may each include five (5) 10 ms alternating time-lengths. In such case, the UE can transmit data on the WiFi communication link to the WLAN AP during each 10 ms LTE inactive time-lengths. In another case, the UE can transmit data on the WiFi communication link to the

WLAN AP during one or more of the five (5) 10 ms portions of the LTE active time-lengths, while data is transmitted from other UEs on the other 10 ms portions of the LTE active time lengths.

[0074] FIG. 9 illustrates functionality of a WLAN AP to facilitate wireless multi-connectivity, in accordance with an example. The functionality of the WLAN includes a WiFi-LTE time sharing mechanism for concurrent use of an LTE service and a Wi-Fi service. The WiFi-LTE time sharing mechanism of the WLAN AP can be implemented by one or more processors and memory, wherein the memory stores one or more sets of instructions, that, when executed by the one or more processors perform one or more functionalities including the WiFi-LTE time sharing mechanism. In one instance, the WiFi-LTE time sharing mechanism may be implemented by one or more processors and memory of an application circuitry, a baseband circuitry, and/or Radio Frequency (RF) circuitry of the WLAN AP.

[0075] In one aspect, the functionality of the WLAN AP can include decoding a message from the UE that indicates activation of a WiFi-LTE time sharing mechanism 910. The message can be received by the WLAN AP from the UE across one or more wireless communication links according to an 802.11 (WiFi) compliant protocol.

[0076] In one aspect, the indication of the activation of the WiFi-LTE time sharing mechanism can also include a time sharing period, an LTE active time-length of the time sharing period, an LTE inactive time-length of the time sharing period and a start of the time sharing period. In one instance, the time sharing period may be 100 ms, and the LTE active and LTE inactive time-lengths may each be 50 ms, or any other appropriate periods and time-lengths, as previously described. In another instance, the time sharing period may be 100 ms, and the LTE active and LTE inactive time-lengths may each include five (5) 10 ms alternating time-lengths, or any other appropriate periods and time-lengths, as previously described.

[0077] In one aspect, the WLAN AP can transmit to the UE during the LTE inactive time-length or one or more portions of the LTE inactive time-length of the WiFi-LTE time sharing period 920. Accordingly, communications from the WLAN to the UE are timed to the LTE inactive time-length so that the wireless WLAN transmission from the WLAN to the UE during the inactive time-length do not interfere with LTE

communications between the UE and the eNB during the LTE active time-length of the time sharing periods.

[0078] In one instance, the time sharing period may be 100 ms, and the LTE active and LTE inactive time-lengths may each be 50 ms. In such case, the UE can transmit data on the WiFi communication link to the WLAN AP during the 50 ms LTE inactive time-lengths, and does not transmit data on the WiFi communication link during the 50 ms LTE active time-lengths to the eNB. In another instance, the time sharing period may be 100 ms, and the LTE active and LTE inactive time-lengths may each include five (5) 10 ms alternating time-lengths. In such case, the UE can transmit data on the WiFi communication link to the WLAN AP during each 10 ms LTE inactive time-lengths. In another case, the UE can transmit data on the WiFi communication link to the WLAN AP during one or more of the five (5) 10 ms portions of the LTE active time-lengths, while data is transmitted from other UEs on the other 10 ms portions of the LTE active time lengths.

[0079] Accordingly, the WiFi-LTE time sharing mechanism advantageously allows both the WLAN AP and the eNB to share in-device air-time in a fair manner that will also provide good performance with external traffic controllers, such as according to the 802.11ax AP protocol, that otherwise may no synchronize with real-time in-device coexistence signals between the eNB, UE and WLAN.

[0080] FIG. 10 illustrates signaling in a wireless multi-connectivity system, in accordance with an example. In one aspect, a WiFi-LTE time sharing message can be transmitted 1005 by a transceiver circuitry of an eNB 1010 and received by a transceiver circuitry of a UE 1015. The message can be transmitted from the eNB to the UE across a Radio Resource Control (RRC) compliant protocol interface.

[0081] In one aspect, the WiFi-LTE time sharing message is sent from the eNB to the UE in response to the eNB identifying a WiFi-LTE concurrent use for the given UE. In one aspect, the WiFi-LTE concurrent use can be determined by the eNB based upon an operating state of the eNB. In one instance, the eNB can determine that there is concurrent use when the eNB is communicating in an LTE-WLAN Aggregation (LWA) operating mode with a given UE. In one instance, the LWA may be performed using an IEEE 802.11ax protocol.

[0082] In one aspect, the WiFi-LTE time sharing messages sent from the eNB to the UE can include an indication of activation of the WiFi-LTE time sharing mechanism, a time sharing period, an LTE active time-length of the time sharing period, an LTE inactive time-length of the time sharing period and a start of the time sharing period. In one instance, the time sharing period may be 100 milliseconds (ms), and the LTE active and LTE inactive time-lengths may each be 50 ms, or any other appropriate periods and time-lengths, as previously described. In another instance, the time sharing period may be 100 ms, and the LTE active and LTE inactive time-lengths may each include five (5) 10 ms alternating time-lengths, or any other appropriate periods and time-lengths, as previously described.

[0083] In one aspect, a WiFi-LTE time sharing message can also be transmitted 1020 by a transceiver circuitry of an UE 1015 and received by a transceiver circuitry of a WLAN AP 1025. Accordingly, the UE can forward the WiFi-LTE time sharing message to the WLAN AP in the event that there is no communication link between the eNB and the WLAN AP. The message can be transmitted from the UE to the WLAN AP across one or more wireless communication links according to an IEEE 802.11 (WiFi) compliant protocol.

[0084] In one aspect, the WiFi-LTE time sharing messages sent from the UE to the WLAN AP can include an indication of activation of the WiFi-LTE time sharing mechanism, a time sharing period, an LTE active time-length of the time sharing period, an LTE inactive time-length of the time sharing period and a start of the time sharing period. In one instance, the time sharing period may be 100 milliseconds (ms), and the LTE active and LTE inactive time-lengths may each be 50 ms, or any other appropriate periods and time-lengths. In another instance, the time sharing period may be 100 ms, and the LTE active and LTE inactive time-lengths may each include five (5) 10 ms alternating time-lengths, or any other appropriate periods and time-lengths.

[0085] After transmission of the WiFi-LTE time sharing messages by the eNB, LTE data packets can be transmitted and received 1030 between the eNB 1010 and the UE 1015 during the LTE active time-lengths 1035 or one or more portions of the LTE active-time length of the time sharing periods 1040. In addition, WiFi data packets can be transmitted and received 1045 between the WLAN AP 1025 and the UE 1015 during the LTE inactive time-lengths 1050 or one or more portions of the LTE active-time length

of the time sharing periods 1040. The time sharing mechanism including the time sharing period, the LTE active time-length of the time sharing period, the LTE inactive time-length of the time sharing period, and the start of the time sharing period may be applied to both LTE and WiFi transmissions in both the uplink (UL) and down link (DL) communication channels. Accordingly, communications between the eNB and the UE are timed to the LTE active time-lengths so that the LTE transmissions between the eNB and the UE do not interfere with WiFi communications between the WLAN-AP and the UE. Similarly, communications between the WLAN AP and the UE are timed to the LTE inactive time-lengths so that the WiFi transmissions between the WLAN AP and the UE do not interfere with LTE communications between the eNB and the UE.

[0086] FIG. 11 illustrates signaling in a wireless multi-connectivity system in accordance with an example. In one aspect, a WiFi-LTE coexistence message can be transmitted 1105 by a transceiver circuity of a UE 1110 and received by the transceiver circuitry of an eNB 1115. In one aspect, the WiFi-LTE coexistence message can be sent in response to UE determining a WiFi-LTE concurrent use issue. The message can be transmitted from the UE to the eNB using a higher layer communication, such as a Radio Resource Control (RRC) communication, a Master Information Block (MIB), a Secondary Information Block (SIB), a Packet Data Convergence Protocol (PDCP), or another desired type of higher layer communication.

[0087] In one aspect, a WiFi-LTE time sharing message can be transmitted 1120 by the transceiver circuitry of the eNB 1115 and received by the transceiver circuitry of the UE 1110 in response to the WiFi-LTE coexistence message. The message can be transmitted from the eNB to the UE using a higher layer communication, such as a Radio Resource Control (RRC) communication, a Master Information Block (MIB), a Secondary Information Block (SIB), a Packet Data Convergence Protocol (PDCP), or another desired type of higher layer communication.

[0088] In one aspect, the WiFi-LTE time sharing messages sent from the eNB to the UE can include an indication of activation of the WiFi-LTE time sharing mechanism, a time sharing period, an LTE active time-length of the time sharing period, an LTE inactive time-length of the time sharing period and a start of the time sharing period.

[0089] In one aspect, a WiFi-LTE time sharing message can also be transmitted 1125 by a transceiver circuitry of an UE 1110 and received by a transceiver circuitry of a WLAN AP 1130. Accordingly, the UE can forward the WiFi-LTE time sharing message to the WLAN AP in the event that there is no communication link between the eNB and the WLAN AP. The message can be transmitted from the UE to the WLAN AP across one or more wireless communication links according to an IEEE 802.11 (WiFi) compliant protocol.

[0090] In one aspect, the WiFi-LTE time sharing messages sent from the UE to the WLAN AP can include an indication of activation of the WiFi-LTE time sharing mechanism, a time sharing period, an LTE active time-length of the time sharing period, an LTE inactive time-length of the time sharing period and a start of the time sharing period.

[0091] After transmission of the WiFi-LTE time sharing messages by the eNB, LTE data packets can be transmitted and received 1135 between the transceiver circuitry of the eNB 1115 and the transceiver circuitry of the UE 1110 during the LTE active time-lengths 1140 or one or more portions of the LTE active-time length of the time sharing periods 1145. In addition, WiFi data packets can be transmitted and received 1150 between the transceiver circuitry of the WLAN-AP 1130 and the transceiver circuitry of the UE 1110 during the LTE inactive time-lengths 1155 or one or more portions of the LTE active-time length of the time sharing periods 1145. The time sharing mechanism including the time sharing period, the LTE active time-length of the time sharing period, the LTE inactive time-length of the time sharing period, and the start of the time sharing period may be applied to both LTE and WiFi transmissions in both the uplink (UL) and down link (DL) communication channels. Accordingly, communications between the eNB and the UE are timed to the LTE active time-lengths so that the LTE transmissions between the eNB to the UE do not interfere with WiFi communications between the WLAN-AP and the UE. Similarly, communications between the WLAN AP and the UE are timed to the LTE inactive time-lengths so that the WiFi transmission between the WLAN AP and the UE do not interfere with communications between the eNB and the UE.

[0092] FIG. 12 illustrates a diagram of example components of a User Equipment (UE) device in accordance with an example. In some aspects, the UE device 1200 can

include application circuitry 1202, baseband circuitry 1204, Radio Frequency (RF) circuitry 1206, front-end module (FEM) circuitry 1208 and one or more antennas 1210, coupled together at least as shown.

[0093] The application circuitry 1202 can include one or more application processors. For example, the application circuitry 1202 can include circuitry such as, but not limited to, one or more single-core or multi-core processors. The processor(s) can include any combination of general-purpose processors and dedicated processors (e.g., graphics processors, application processors, etc.). The processors can be coupled with and/or can include memory/storage and can be configured to execute instructions stored in the memory/storage to enable various applications and/or operating systems to run on the system.

[0094] The processor(s) can include any combination of general-purpose processors and dedicated processors (e.g., graphics processors, application processors, etc.). The processors can be coupled with and/or can include a storage medium 1212, and can be configured to execute instructions stored in the storage medium 1212 to enable various applications and/or operating systems to run on the system.

[0095] The baseband circuitry 1204 can include circuitry such as, but not limited to, one or more single-core or multi-core processors. The baseband circuitry 1204 can include one or more baseband processors and/or control logic to process baseband signals received from a receive signal path of the RF circuitry 1206 and to generate baseband signals for a transmit signal path of the RF circuitry 1206. Baseband processing circuitry 1204 can interface with the application circuitry 1202 for generation and processing of the baseband signals and for controlling operations of the RF circuitry 1206. For example, in some aspects, the baseband circuitry 1204 can include a second generation (2G) baseband processor 1204a, third generation (3G) baseband processor 1204b, fourth generation (4G) baseband processor 1204c, WiFi baseband processor 1204d and/or other baseband processor(s) 1204e for other existing generations, generations in development or to be developed in the future (e.g., fifth generation (5G), 6G, etc.). The baseband circuitry 1204 (e.g., one or more of baseband processors 1204a-d) can handle various radio control functions that enable communication with one or more radio networks via the RF circuitry 1206. The radio control functions can include, but are not limited to, signal modulation/demodulation, encoding/decoding, radio frequency shifting, etc. In

some aspects, modulation/demodulation circuitry of the baseband circuitry 1204 can include Fast-Fourier Transform (FFT), precoding, and/or constellation mapping/demapping functionality. In some aspects, encoding/decoding circuitry of the baseband circuitry 1204 can include convolution, tail-biting convolution, turbo, Viterbi, and/or Low Density Parity Check (LDPC) encoder/decoder functionality. Aspects of modulation/demodulation and encoder/decoder functionality are not limited to these examples and can include other suitable functionality in other aspects.

[0096] In some aspects, the baseband circuitry 1204 can include elements of a protocol stack such as, for example, elements of an evolved universal terrestrial radio access network (EUTRAN) protocol including, for example, physical (PHY), media access control (MAC), radio link control (RLC), packet data convergence protocol (PDCP), and/or radio resource control (RRC) elements. A central processing unit (CPU) 1204f of the baseband circuitry 1204 can be configured to run elements of the protocol stack for signaling of the PHY, MAC, RLC, PDCP and/or RRC layers. In some aspects, the baseband circuitry can include one or more audio digital signal processor(s) (DSP) 1204g. The audio DSP(s) 1204g can be include elements for compression/decompression and echo cancellation and can include other suitable processing elements in other aspects. Components of the baseband circuitry can be suitably combined in a single chip, a single chipset, or disposed on a same circuit board in some aspects. In some aspects, some or all of the constituent components of the baseband circuitry 1204 and the application circuitry 1202 can be implemented together such as, for example, on a system on a chip (SOC).

[0097] In some aspects, the baseband circuitry 1204 can provide for communication compatible with one or more radio technologies. For example, in some aspects, the baseband circuitry 1204 can support communication with an evolved universal terrestrial radio access network (EUTRAN) and/or other wireless metropolitan area networks (WMAN), a wireless local area network (WLAN), a wireless personal area network (WPAN). Aspects in which the baseband circuitry 1204 is configured to support radio communications of more than one wireless protocol can be referred to as multi-mode baseband circuitry.

[0098] RF circuitry 1206 can enable communication with wireless networks using modulated electromagnetic radiation through a non-solid medium. In various aspects, the RF circuitry 1206 can include switches, filters, amplifiers, etc. to facilitate the communication with the wireless network. RF circuitry 1206 can include a receive signal

path which can include circuitry to down-convert RF signals received from the FEM circuitry 1208 and provide baseband signals to the baseband circuitry 1204. RF circuitry 1206 can also include a transmit signal path which can include circuitry to up-convert baseband signals provided by the baseband circuitry 1204 and provide RF output signals to the FEM circuitry 1208 for transmission.

[0099] In some aspects, the RF circuitry 1206 can include a receive signal path and a transmit signal path. The receive signal path of the RF circuitry 1206 can include mixer circuitry 1206a, amplifier circuitry 1206b and filter circuitry 1206c. The transmit signal path of the RF circuitry 1206 can include filter circuitry 1206c and mixer circuitry 1206a. RF circuitry 1206 can also include synthesizer circuitry 1206d for synthesizing a frequency for use by the mixer circuitry 1206a of the receive signal path and the transmit signal path. In some aspects, the mixer circuitry 1206a of the receive signal path can be configured to down-convert RF signals received from the FEM circuitry 1208 based on the synthesized frequency provided by synthesizer circuitry 1206d. The amplifier circuitry 1206b can be configured to amplify the down-converted signals and the filter circuitry 1206c can be a low-pass filter (LPF) or band-pass filter (BPF) configured to remove unwanted signals from the down-converted signals to generate output baseband signals. Output baseband signals can be provided to the baseband circuitry 1204 for further processing. In some aspects, the output baseband signals can be zero-frequency baseband signals, although the output baseband signals do not have to be zero-frequency baseband signals. In some aspects, mixer circuitry 1206a of the receive signal path can comprise passive mixers, although the scope of the aspects is not limited in this respect.

[00100] In some aspects, the mixer circuitry 1206a of the transmit signal path can be configured to up-convert input baseband signals based on the synthesized frequency provided by the synthesizer circuitry 1206d to generate RF output signals for the FEM circuitry 1208. The baseband signals can be provided by the baseband circuitry 1204 and can be filtered by filter circuitry 1206c. The filter circuitry 1206c can include a low-pass filter (LPF), although the scope of the aspects is not limited in this respect.

[00101] In some aspects, the mixer circuitry 1206a of the receive signal path and the mixer circuitry 1206a of the transmit signal path can include two or more mixers and can be arranged for quadrature down conversion and/or up conversion respectively. In some aspects, the mixer circuitry 1206a of the receive signal path and the mixer circuitry 1206a of the transmit signal path can include two or more mixers and can

be arranged for image rejection (e.g., Hartley image rejection). In some aspects, the mixer circuitry 1206a of the receive signal path and the mixer circuitry 1206a can be arranged for direct down conversion and/or direct up conversion, respectively. In some aspects, the mixer circuitry 1206a of the receive signal path and the mixer circuitry 1206a of the transmit signal path can be configured for super-heterodyne operation.

[00102] In some aspects, the output baseband signals and the input baseband signals can be analog baseband signals, although the scope of the aspects is not limited in this respect. In some alternate aspects, the output baseband signals and the input baseband signals can be digital baseband signals. In these alternate aspects, the RF circuitry 1206 can include analog-to-digital converter (ADC) and digital-to-analog converter (DAC) circuitry and the baseband circuitry 1204 can include a digital baseband interface to communicate with the RF circuitry 1206.

[00103] In some dual-mode embodiments, a separate radio IC circuitry can be provided for processing signals for each spectrum, although the scope of the embodiments is not limited in this respect.

[00104] In some embodiments, the synthesizer circuitry 1206d can be a fractional-N synthesizer or a fractional N/N+1 synthesizer, although the scope of the embodiments is not limited in this respect as other types of frequency synthesizers can be suitable. For example, synthesizer circuitry 1206d can be a delta-sigma synthesizer, a frequency multiplier, or a synthesizer comprising a phase-locked loop with a frequency divider.

[00105] The synthesizer circuitry 1206d can be configured to synthesize an output frequency for use by the mixer circuitry 1206a of the RF circuitry 1206 based on a frequency input and a divider control input. In some embodiments, the synthesizer circuitry 1206d can be a fractional N/N+1 synthesizer.

[00106] In some embodiments, frequency input can be provided by a voltage controlled oscillator (VCO), although that is not a constraint. Divider control input can be provided by either the baseband circuitry 1204 or the applications processor 1202 depending on the desired output frequency. In some embodiments, a divider control input (e.g., N) can be determined from a look-up table based on a channel indicated by the applications processor 1202.

[00107] Synthesizer circuitry 1206d of the RF circuitry 1206 can include a divider, a delay-locked loop (DLL), a multiplexer and a phase accumulator. In some

embodiments, the divider can be a dual modulus divider (DMD) and the phase accumulator can be a digital phase accumulator (DPA). In some embodiments, the DMD can be configured to divide the input signal by either N or N+1 (e.g., based on a carry out) to provide a fractional division ratio. In some example embodiments, the DLL can include a set of cascaded, tunable, delay elements, a phase detector, a charge pump and a D-type flip-flop. In these embodiments, the delay elements can be configured to break a VCO period up into Nd equal packets of phase, where Nd is the number of delay elements in the delay line. In this way, the DLL provides negative feedback to help ensure that the total delay through the delay line is one VCO cycle.

[00108] In some embodiments, synthesizer circuitry 1206d can be configured to generate a carrier frequency as the output frequency, while in other embodiments, the output frequency can be a multiple of the carrier frequency (e.g., twice the carrier frequency, four times the carrier frequency) and used in conjunction with quadrature generator and divider circuitry to generate multiple signals at the carrier frequency with multiple different phases with respect to each other. In some embodiments, the output frequency can be a LO frequency (fLO). In some embodiments, the RF circuitry 1206 can include an IQ/polar converter.

[00109] FEM circuitry 1208 can include a receive signal path which can include circuitry configured to operate on RF signals received from one or more antennas 1210, amplify the received signals and provide the amplified versions of the received signals to the RF circuitry 1206 for further processing. FEM circuitry 1208 can also include a transmit signal path which can include circuitry configured to amplify signals for transmission provided by the RF circuitry 1206 for transmission by one or more of the one or more antennas 1210.

[00110] In some embodiments, the FEM circuitry 1208 can include a TX/RX switch to switch between transmit mode and receive mode operation. The FEM circuitry can include a receive signal path and a transmit signal path. The receive signal path of the FEM circuitry can include a low-noise amplifier (LNA) to amplify received RF signals and provide the amplified received RF signals as an output (e.g., to the RF circuitry 1206). The transmit signal path of the FEM circuitry 1208 can include a power amplifier (PA) to amplify input RF signals (e.g., provided by RF circuitry 1206), and one or more filters to generate RF signals for subsequent transmission (e.g., by one or more of the one or more antennas 1210.

[00111] In some embodiments, the UE device 1200 can include additional elements such as, for example, memory/storage, display, camera, sensor, and/or input/output (I/O) interface.

[00112] FIG. 13 illustrates a diagram 1300 of a node 1310 (e.g., eNB and/or a base station) and wireless device (e.g., UE) in accordance with an example. The node can include a base station (BS), a Node B (NB), an evolved Node B (eNB), a baseband unit (BBU), a remote radio head (RRH), a remote radio equipment (RRE), a remote radio unit (RRU), or a central processing module (CPM). In one aspect, the node can be a Serving GPRS Support Node. The node 1310 can include a node device 1312. The node device 1312 or the node 1310 can be configured to communicate with the wireless device 1320. The node device 1312 can be configured to implement the technology described. The node device 1312 can include a processing module 1314 and a transceiver module 1316. In one aspect, the node device 1312 can include the transceiver module 1316 and the processing module 1314 forming a circuitry 1318 for the node 1310. In one aspect, the transceiver module 1316 and the processing module 1314 can form a circuitry of the node device 1312. The processing module 1314 can include one or more processors and memory. In one embodiment, the processing module 1322 can include one or more application processors. The transceiver module 1316 can include a transceiver and one or more processors and memory. In one embodiment, the transceiver module 1316 can include a baseband processor.

[00113] The wireless device 1320 can include a transceiver module 1324 and a processing module 1322. The processing module 1322 can include one or more processors and memory. In one embodiment, the processing module 1322 can include one or more application processors. The transceiver module 1324 can include a transceiver and one or more processors and memory. In one embodiment, the transceiver module 1324 can include a baseband processor. The wireless device 1320 can be configured to implement the technology described. The node 1310 and the wireless devices 1320 can also include one or more storage mediums, such as the transceiver module 1316, 1324 and/or the processing module 1314, 1322. In one aspect, the components described herein of the transceiver module 1316 can be included in one or more separate devices that can be used in a cloud-RAN (C-RAN) environment.

[00114] FIG. 14 illustrates a diagram of a UE 1400, in accordance with an

example. The UE may be a mobile station (MS), a mobile wireless device, a mobile communication device, a tablet, a handset, or other type of wireless device. In one aspect, the UE 1400 can include at least one of an antenna 1405, a touch sensitive display screen 1410, a speaker 1415, a microphone 1420, a graphics processor 1425, a baseband processor 1430, an application processor 1435, internal memory 1440, a keyboard 1445, a non-volatile memory port 1450, and combinations thereof.

[00115] The UE can include one or more antennas configured to communicate with a node or transmission station, such as a base station (BS), an evolved Node B (eNB), a baseband unit (BBU), a remote radio head (RRH), a remote radio equipment (RRE), a relay station (RS), a radio equipment (RE), a remote radio unit (RRU), a central processing module (CPM), or other type of wireless wide area network (WWAN) access point. The wireless device can be configured to communicate using at least one wireless communication standard including 3GPP LTE, WiMAX, High Speed Packet Access (HSPA), Bluetooth, and WiFi. The wireless device can communicate using separate antennas for each wireless communication standard or shared antennas for multiple wireless communication standards. The wireless device can communicate in a wireless local area network (WLAN), a wireless personal area network (WPAN), and/or a WWAN. The mobile device can include a storage medium. In one aspect, the storage medium can be associated with and/or communicate with the application processor, the graphics processor, the display, the non-volatile memory port, and/or internal memory. In one aspect, the application processor and graphics processor are storage mediums.

EXAMPLES

[00116] The following examples pertain to specific technology embodiments and point out specific features, elements, or steps that may be used or otherwise combined in achieving such embodiments.

[00117] Example 1 includes an apparatus of an Evolved NodeB (eNB) comprising one or more processors and memory configured to: identify a concurrent use condition where a User Equipment is operable to communicate using a Wireless Local Area Network (WLAN) and a Long Term Evolution (LTE) network; and encode, in response to the identified concurrent use condition, a Radio Resource Control (RRC) message, for transmission to the UE, that indicates; an activation, by the eNB, of a

WLAN-LTE time sharing mechanism; a time sharing period; and a start of the time sharing period.

[00118] Example 2 includes the apparatus of Example 1, wherein a WLAN in the identified concurrent use condition is WiFi network compliant with an Institute of Electronics and Electrical Engineers (IEEE) 802.11 protocol to form a WiFi-LTE concurrent use and a WiFi-LTE time sharing mechanism.

[00119] Example 3 includes the apparatus of Examples 1 or 2, wherein the one or more processors and memory are further configured to encode the message, for transmission to the UE, that further indicates one or more of: an LTE active time-length of the time sharing period; or an LTE inactive time-length of the time sharing period.

[00120] Example 4 includes the apparatus of Examples 1 or 2, wherein identifying the concurrent use condition includes decode a message, received from the UE, that indicates the concurrent use condition.

[00121] Example 5 includes the apparatus of Example 4, wherein the message that indicates the concurrent use condition comprises an In-device Coexistence Indication (InDeviceCoexIndication) message.

[00122] Example 6 includes the apparatus of Examples 1 or 2, wherein identifying the concurrent use condition includes determine, by the eNB, the concurrent use condition based upon an LTE-WLAN Aggregation (LWA) operation.

[00123] Example 7 includes the apparatus of Example 2, wherein the one or more processors and memory are further configured to: encode, in response to the identified concurrent use condition, a message, for transmission to a WLAN Access Point (AP) via an Xw interface, that indicates: the activation, by the eNB, of the WiFi-LTE time sharing mechanism; the time sharing period; and the start of the time sharing period.

[00124] Example 8 includes the apparatus of Example 7, wherein the one or more processors and memory are further configured to encode the message, for transmission to the WLAN AP, that further indicates: an LTE active time-length of the time sharing period; and an LTE inactive time-length of the time sharing period.

[00125] Example 9 includes the apparatus of Example 7, wherein the eNB configured to communicate via the Xw interface, is further configured to transmit to the

WLAN AP via a router and General Packet Radio Service Tunneling Protocol (GTP-U) endpoint.

[00126] Example 10 includes the apparatus of Examples 1 or 2, wherein the one or more processors and memory are further configured to: schedule LTE communications to the UE during the LTE active time-length or one or more portions of the LTE active time-length of the time sharing period.

[00127] Example 11 includes the apparatus of Example 3, wherein the LTE active time-length or one or more portions of the LTE active time-length of the time sharing period is associated with a Discontinuous Reception (DRX) mechanism.

[00128] Example 12 includes an apparatus of a User Equipment (UE) comprising one or more processors and memory configured to: the UE to decode from an Evolved NodeB (eNB) a Radio Resource Control (RRC) message that indicates: an activation, by an eNB, of a Wireless Local Area Network-Long Term Evolution (WLAN-LTE) time sharing mechanism; a time sharing period; an LTE active time-length of the time sharing period; an LTE inactive time-length of the time sharing period; and a start of the time sharing period; schedule LTE communications to the eNB during the LTE active time-length or one or more portions of the LTE active time-length of the time sharing period; and schedule WLAN communications to a WLAN Access Point (AP) during the LTE inactive time-length or one or more portions of the LTE inactive time-length of the WLAN-LTE time sharing period.

[00129] Example 13 includes the apparatus of Example 12, wherein the one or more processors and memory are further configured to: encode a message, for transmission to the WLAN AP, that indicates; the activation, by the eNB, of the WLAN-LTE time sharing mechanism; the time sharing period; the LTE active time-length of the time sharing period; the LTE inactive time-length of the time sharing period; and the start of the time sharing period.

[00130] Example 14 includes the apparatus of Examples 12 or 13, wherein the LTE active time-length or one or more portions of the LTE active time-length of the time sharing period is associated with a Discontinuous Reception (DRX) mechanism.

[00131] Example 15 includes the apparatus of Examples 12 or 13, wherein the UE transmits to the WLAN Access Point using an Institute of Electronics and Electrical Engineers (IEEE) 802.11 (WiFi) compliant protocol interface.

[00132] Example 16 includes the apparatus of Examples 12 or 13, wherein the one or more processors and memory are further configured to: encode a message, for transmission to an eNB, that indicates a concurrent use condition.

[00133] Example 17 includes the apparatus of Example 16, wherein the message that indicates the concurrent use condition also suggests the LTE active time-length and the LTE inactive time-length of the time sharing period.

[00134] Example 18 includes the apparatus of Example 16, wherein the message that indicates the concurrent use condition comprises an In-device Coexistence Indication (InDeviceCoexIndication) message.

[00135] Example 19 includes the apparatus of Example 12, wherein the apparatus of the UE includes at least one of an antenna, a touch sensitive display screen, a speaker, a microphone, a graphics processor, a baseband processor, an application processor, internal memory, a non-volatile memory port, and combinations thereof.

[00136] Example 20 includes an apparatus of a Wireless Local Area Network Access Point (WLAN AP) comprising one or more processors and memory configured to: decode, from an Evolved NodeB (eNB) or a UE, a message that indicates; an activation, by the eNB, of a Wireless Local Area Network-Long Term Evolution (WLAN-LTE) time sharing mechanism; a time sharing period; an LTE active time-length of the time sharing period; an LTE inactive time-length of the time sharing period; and a start of the time sharing period; and schedule WLAN communications to a User Equipment (UE) during the LTE inactive time-length or one or more portions of the LTE inactive time-length of the WLAN-LTE time sharing period.

[00137] Example 21 includes the apparatus of Example 20, wherein the one or more processors and memory are further configured to, according to signal the WLAN transceiver of the WLAN AP to decode from the UE, the message that indicates: the activation, by the eNB, of the WLAN-LTE time sharing mechanism; the time sharing period; the LTE active time-length of the time sharing period; the LTE inactive time-

length of the time sharing period; and the start of the time sharing period based on a beacon interval of the WLAN AP.

[00138] Example 22 includes the apparatus of Examples 20 or 21, wherein the one or more processors and memory are further configured to, according to schedule transmissions to a User Equipment (UE) during the LTE inactive time-length or one or more portions of the LTE inactive time-length of the WLAN-LTE time sharing period: generate trigger frames by the WLAN AP during the LTE inactive time-length or one or more portions of the LTE inactive time-length of the time sharing period.

[00139] Example 23 includes the apparatus of Examples 20 or 21, wherein the WLAN AP receives from the eNB the message via a router and General Packet Radio Service (GPRS) Tunneling Protocol (GTP-U) endpoint.

[00140] Example 24 includes the apparatus of Examples 20 or 21, wherein the WLAN AP transmits to the UE using an Institute of Electronics and Electrical Engineers (IEEE) 802.11 (WiFi) compliant protocol interface.

[00141] Example 25 includes a method comprising: identifying, by an eNB, WiFi-LTE concurrent use for a user equipment (UE); encoding a message indicating initiation of a WiFi-LTE time sharing mechanism, including a time sharing period, an LTE active time-length, an LTE inactive time-length and a start of the time sharing period, for transmission to the UE; encoding a message indicating activation of the WiFi-LTE time sharing mechanism, including the time sharing period, the LTE active time-length, the LTE inactive time-length and the start of the time sharing period, for transmission to a WLAN access point (AP); and scheduling LTE communications during LTE active time-length or one or more portions of the LTE active time-length of time sharing periods.

[00142] Example 26 includes a method comprising decoding a message indicating activation of a WiFi-LTE time sharing mechanism, including a time sharing period, an LTE active time-length, an LTE inactive time-length and a start of the time sharing period, from an eNB; scheduling LTE communications during the LTE active time-length or one or more portions of the active time-length of time sharing periods; and scheduling WiFi communications during the LTE inactive time-length or one or more portions of the inactive time-length of time sharing periods.

[00143] Example 27 includes the method of Example, further comprising: encoding a message indicating the WiFi-LTE concurrent use for the UE, for transmission to the eNB.

[00144] Example 28 includes a method comprising: decoding a message indicating initiation of a WiFi-LTE time sharing mechanism, including a time sharing period, an LTE active time-length, an LTE inactive time-length and a start of the time sharing period, for an eNB; and scheduling WiFi communications during the LTE inactive time-length or one or more portions of the LTE inactive time-length of time sharing periods.

[00145] Example 29 includes a method comprising: identifying, by an eNB, WiFi concurrent use for a user equipment (UE); encoding a message indicating initiation of a WiFi-LTE time sharing mechanism, including a time sharing period, an LTE active time-length, an LTE inactive time-length and a start of the time period, for transmission to the UE; and scheduling LTE communications during LTE active time-length or one or more portions of the LTE active time-length of time sharing periods.

[00146] Example 30 includes a method comprising: decoding a message indicating activation of a WiFi-LTE time sharing mechanism, including a time sharing period, an LTE active time-length, an LTE inactive time-length and a start of the time sharing period, from the eNB; encoding a message indicating activation of the WiFi-LTE time sharing mechanism, including the time sharing period, the LTE active time-length, the LTE inactive time-length and the start of the time sharing period, for transmission to a WLAN access point (AP); scheduling LTE communications during the LTE active time-length or one or more portions of the active time-length of time sharing periods; and scheduling WiFi communications during the LTE inactive time-length or one or more portions of the inactive time-length of time sharing periods.

[00147] Example 31 includes the method of Example 30, further including encoding a message indicating WiFi-LTE concurrent use for the UE, for transmission to an eNB.

[00148] Example 32 includes a method comprising: decoding a message indicating initiation of a WiFi-LTE time sharing mechanism, including a time sharing period, an LTE active time-length, an LTE inactive time-length and a start of the time

sharing period, from a user equipment (UE); and scheduling WiFi communications during the LTE inactive time-length or one or more portions of the LTE inactive time-length of the time sharing period.

[00149] Example 33 includes an apparatus of an Evolved NodeB (eNB) comprising: a means for identifying a concurrent use condition where a User Equipment is operable to communicate using a Wireless Local Area Network (WLAN) and a Long Term Evolution (LTE) network; and a means for encoding, in response to the identified concurrent use condition, a Radio Resource Control (RRC) message, for transmission to the UE, that indicates; an activation, by the eNB, of a WLAN-LTE time sharing mechanism; a time sharing period; and a start of the time sharing period.

[00150] Example 34 includes the apparatus of Example 33, wherein a WLAN in the identified concurrent use condition is WiFi network compliant with an Institute of Electronics and Electrical Engineers (IEEE) 802.11 protocol to form a WiFi-LTE concurrent use and a WiFi-LTE time sharing mechanism.

[00151] Example 35 includes the apparatus of Examples 33 or 34, wherein the RRC message further indicates one or more of: an LTE active time-length of the time sharing period; or an LTE inactive time-length of the time sharing period.

[00152] Example 36 includes the apparatus of Examples 33 or 34, wherein identifying the concurrent use condition includes a means for decoding a message, received from the UE, that indicates the concurrent use condition.

[00153] Example 37 includes the apparatus of Example 36, wherein the message that indicates the concurrent use condition comprises an In-device Coexistence Indication (InDeviceCoexIndication) message.

[00154] Example 38 includes the apparatus of Examples 33 or 34, wherein the means for identifying the concurrent use condition includes a means for determine, by the eNB, the concurrent use condition based upon an LTE-WLAN Aggregation (LWA) operation.

[00155] Example 39 includes the apparatus of Example 34, further comprising: a means for encoding, in response to the identified concurrent use condition, a message, for transmission to a WLAN Access Point (AP) via an Xw interface, that indicates: the

activation, by the eNB, of the WiFi-LTE time sharing mechanism; the time sharing period; and the start of the time sharing period.

[00156] Example 40 includes the apparatus of Example 39, further comprising: a means for encoding the message, for transmission to the WLAN AP, that further indicates: an LTE active time-length of the time sharing period; and an LTE inactive time-length of the time sharing period.

[00157] Example 41 includes the apparatus of Example 49, wherein the eNB is further configured to transmit to the WLAN AP via a router and General Packet Radio Service Tunneling Protocol (GTP-U) endpoint.

[00158] Example 42 includes the apparatus of Examples 33 or 34, further comprising: a means for scheduling LTE communications to the UE during the LTE active time-length or one or more portions of the LTE active time-length of the time sharing period.

[00159] Example 43 includes the apparatus of Example 35, wherein the LTE active time-length or one or more portions of the LTE active time-length of the time sharing period is associated with a Discontinuous Reception (DRX) mechanism.

[00160] Example 44 includes an apparatus of a User Equipment (UE) comprising a means for decoding from an Evolved NodeB (eNB) a Radio Resource Control (RRC) message that indicates: an activation, by an eNB, of a Wireless Local Area Network-Long Term Evolution (WLAN-LTE) time sharing mechanism; a time sharing period; an LTE active time-length of the time sharing period; an LTE inactive time-length of the time sharing period; and a start of the time sharing period; schedule LTE communications to the eNB during the LTE active time-length or one or more portions of the LTE active time-length of the time sharing period; and a means for scheduling WLAN communications to a WLAN Access Point (AP) during the LTE inactive time-length or one or more portions of the LTE inactive time-length of the WLAN-LTE time sharing period.

[00161] Example 45 includes the apparatus of Example 44, further comprising: a means for encoding a message, for transmission to the WLAN AP, that indicates; the activation, by the eNB, of the WLAN-LTE time sharing mechanism; the time sharing

period; the LTE active time-length of the time sharing period; the LTE inactive time-length of the time sharing period; and the start of the time sharing period.

[00162] Example 46 includes the apparatus of Examples 44 or 45, wherein the LTE active time-length or one or more portions of the LTE active time-length of the time sharing period is associated with a Discontinuous Reception (DRX) mechanism.

[00163] Example 47 includes the apparatus of Examples 44 or 45, wherein the UE transmits to the WLAN Access Point using an Institute of Electronics and Electrical Engineers (IEEE) 802.11 (WiFi) compliant protocol interface.

[00164] Example 48 includes the apparatus of Examples 44 or 45, further comprising: a means for encoding a message, for transmission to an eNB, that indicates a concurrent use condition.

[00165] Example 49 includes the apparatus of Example 48, wherein the message that indicates the concurrent use condition also suggests the LTE active time-length and the LTE inactive time-length of the time sharing period.

[00166] Example 50 includes the apparatus of Example 48, wherein the message that indicates the concurrent use condition comprises an In-device Coexistence Indication (InDeviceCoexIndication) message.

[00167] Example 51 includes the apparatus of Example 44, wherein the apparatus of the UE includes at least one of an antenna, a touch sensitive display screen, a speaker, a microphone, a graphics processor, a baseband processor, an application processor, internal memory, a non-volatile memory port, and combinations thereof.

[00168] Example 52 includes an apparatus of a Wireless Local Area Network Access Point (WLAN AP) comprising: a means for decoding, from an Evolved NodeB (eNB) or a UE, a message that indicates; an activation, by the eNB, of a Wireless Local Area Network-Long Term Evolution (WLAN-LTE) time sharing mechanism; a time sharing period; an LTE active time-length of the time sharing period; an LTE inactive time-length of the time sharing period; and a start of the time sharing period; and a means for scheduling WLAN communications to a User Equipment (UE) during the LTE inactive time-length or one or more portions of the LTE inactive time-length of the WLAN-LTE time sharing period.

[00169] Example 53 includes the apparatus of Example 52, further comprising: a means for decoding from the UE, the message that indicates: the activation, by the eNB, of the WLAN-LTE time sharing mechanism; the time sharing period; the LTE active time-length of the time sharing period; the LTE inactive time-length of the time sharing period; and the start of the time sharing period based on a beacon interval of the WLAN AP.

[00170] Example 54 includes the apparatus of Examples 52 or 53, wherein, according to schedule transmissions to a User Equipment (UE) during the LTE inactive time-length or one or more portions of the LTE inactive time-length of the WLAN-LTE time sharing period includes: a means for generating trigger frames by the WLAN AP during the LTE inactive time-length or one or more portions of the LTE inactive time-length of the time sharing period.

[00171] Example 55 includes the apparatus of Examples 52 or 53, wherein the WLAN AP receives from the eNB the message via a router and General Packet Radio Service (GPRS) Tunneling Protocol (GTP-U) endpoint.

[00172] Example 56 includes the apparatus of Examples 52 or 53, wherein the WLAN AP transmits to the UE using an Institute of Electronics and Electrical Engineers (IEEE) 802.11 (WiFi) compliant protocol interface.

[00173] As used herein, the term "circuitry" may refer to, be part of, or include an Application Specific Integrated Circuit (ASIC), an electronic circuit, a processor (shared, dedicated, or group), and/or memory (shared, dedicated, or group) that execute one or more software or firmware programs, a combinational logic circuit, and/or other suitable hardware components that provide the described functionality. In some aspects, the circuitry may be implemented in, or functions associated with the circuitry may be implemented by, one or more software or firmware modules. In some aspects, circuitry may include logic, at least partially operable in hardware.

[00174] Various techniques, or certain aspects or portions thereof, may take the form of program code (i.e., instructions) embodied in tangible media, such as floppy diskettes, compact disc-read-only memory (CD-ROMs), hard drives, transitory or non-transitory computer readable storage medium, or any other machine-readable storage medium wherein, when the program code is loaded into and executed by a machine, such

as a computer, the machine becomes an apparatus for practicing the various techniques. Circuitry may include hardware, firmware, program code, executable code, computer instructions, and/or software. A non-transitory computer readable storage medium may be a computer readable storage medium that does not include signal. In the case of program code execution on programmable computers, the computing device may include a processor, a storage medium readable by the processor (including volatile and non-volatile memory and/or storage elements), at least one input device, and at least one output device. The volatile and non-volatile memory and/or storage elements may be a random-access memory (RAM), erasable programmable read only memory (EPROM), flash drive, optical drive, magnetic hard drive, solid state drive, or other medium for storing electronic data. The node and wireless device may also include a transceiver module (i.e., transceiver), a counter module (i.e., counter), a processing module (i.e., processor), and/or a clock module (i.e., clock) or timer module (i.e., timer). One or more programs that may implement or utilize the various techniques described herein may use an application programming interface (API), reusable controls, and the like. Such programs may be implemented in a high level procedural or object oriented programming language to communicate with a computer system. However, the program(s) may be implemented in assembly or machine language, if desired. In any case, the language may be a compiled or interpreted language, and combined with hardware implementations.

[00175] As used herein, the term processor may include general purpose processors, specialized processors such as VLSI, FPGAs, or other types of specialized processors, as well as base band processors used in transceivers to send, receive, and process wireless communications.

[00176] It should be understood that many of the functional units described in this specification have been labeled as modules, in order to more particularly emphasize their implementation independence. For example, a module may be implemented as a hardware circuit comprising custom very-large-scale integration (VLSI) circuits or gate arrays, off-the-shelf semiconductors such as logic chips, transistors, or other discrete components. A module may also be implemented in programmable hardware devices such as field programmable gate arrays, programmable array logic, programmable logic devices or the like.

[00177] Modules may also be implemented in software for execution by various types of processors. An identified module of executable code may, for instance, comprise one or more physical or logical blocks of computer instructions, which may, for instance, be organized as an object, procedure, or function. Nevertheless, the executables of an identified module cannot be physically located together, but may comprise disparate instructions stored in different locations which, when joined logically together, comprise the module and achieve the stated purpose for the module.

[00178] Indeed, a module of executable code may be a single instruction, or many instructions, and may even be distributed over several different code segments, among different programs, and across several memory devices. Similarly, operational data may be identified and illustrated herein within modules, and may be embodied in any suitable form and organized within any suitable type of data structure. The operational data may be collected as a single data set, or may be distributed over different locations including over different storage devices, and may exist, at least partially, merely as electronic signals on a system or network. The modules may be passive or active, including agents operable to perform desired functions.

[00179] Reference throughout this specification to "an example" or “exemplary” means that a particular feature, structure, or characteristic described in connection with the example is included in at least one embodiment of the present technology. Thus, appearances of the phrases "in an example" or the word “exemplary” in various places throughout this specification are not necessarily all referring to the same embodiment.

[00180] As used herein, a plurality of items, structural elements, compositional elements, and/or materials may be presented in a common list for convenience. However, these lists should be construed as though each member of the list is individually identified as a separate and unique member. Thus, no individual member of such list should be construed as a de facto equivalent of any other member of the same list solely based on their presentation in a common group without indications to the contrary. In addition, various embodiments and example of the present technology may be referred to herein along with alternatives for the various components thereof. It is understood that such embodiments, examples, and alternatives are not to be construed as de facto equivalents of one another, but are to be considered as separate and autonomous representations of the present technology.

[00181] Furthermore, the described features, structures, or characteristics may be combined in any suitable manner in one or more embodiments. In the following description, numerous specific details are provided, such as examples of layouts, distances, network examples, etc., to provide a thorough understanding of embodiments of the technology. One skilled in the relevant art will recognize, however, that the technology may be practiced without one or more of the specific details, or with other methods, components, layouts, etc. In other instances, well-known structures, materials, or operations are not shown or described in detail to avoid obscuring aspects of the technology.

[00182] While the forgoing examples are illustrative of the principles of the present technology in one or more particular applications, it will be apparent to those of ordinary skill in the art that numerous modifications in form, usage and details of implementation may be made without the exercise of inventive faculty, and without departing from the principles and concepts of the technology. Accordingly, it is not intended that the technology be limited, except as by the claims set forth below.

CLAIMS

What is claimed is:

1. An apparatus of an Evolved NodeB (eNB) comprising one or more processors and memory configured to:

identify a concurrent use condition where a User Equipment is operable to communicate using a Wireless Local Area Network (WLAN) and a Long Term Evolution (LTE) network; and

encode, in response to the identified concurrent use condition, a Radio Resource Control (RRC) message, for transmission to the UE, that indicates;

an activation, by the eNB, of a WLAN-LTE time sharing mechanism;

a time sharing period; and

a start of the time sharing period.

2. The apparatus of claim 1, wherein a WLAN in the identified concurrent use condition is WiFi network compliant with an Institute of Electronics and Electrical Engineers (IEEE) 802.11 protocol to form a WiFi-LTE concurrent use and a WiFi-LTE time sharing mechanism.

3. The apparatus of claims 1 or 2, wherein the one or more processors and memory are further configured to encode the message, for transmission to the UE, that further indicates one or more of:

an LTE active time-length of the time sharing period; or

an LTE inactive time-length of the time sharing period.

4. The apparatus of claims 1 or 2, wherein identifying the concurrent use condition includes decode a message, received from the UE, that indicates the concurrent use condition.

5. The apparatus of claim 4, wherein the message that indicates the concurrent use condition comprises an In-device Coexistence Indication (InDeviceCoexIndication) message.

6. The apparatus of claims 1 or 2, wherein identifying the concurrent use condition includes determine, by the eNB, the concurrent use condition based upon an LTE-WLAN Aggregation (LWA) operation.

7. The apparatus of claim 2, wherein the one or more processors and memory are further configured to:

encode, in response to the identified concurrent use condition, a message, for transmission to a WLAN Access Point (AP) via an Xw interface, that indicates:

the activation, by the eNB, of the WiFi-LTE time sharing mechanism;

the time sharing period; and

the start of the time sharing period.

8. The apparatus of claim 7, wherein the one or more processors and memory are further configured to encode the message, for transmission to the WLAN AP, that further indicates:

an LTE active time-length of the time sharing period; and

an LTE inactive time-length of the time sharing period.

9. The apparatus of claim 7, wherein the eNB configured to communicate via the Xw interface, is further configured to transmit to the WLAN AP via a router and General Packet Radio Service Tunneling Protocol (GTP-U) endpoint.

10. The apparatus of claims 1 or 2, wherein the one or more processors and memory are further configured to:

schedule LTE communications to the UE during the LTE active time-length or one or more portions of the LTE active time-length of the time sharing period.

11. The apparatus of claim 3, wherein the LTE active time-length or one or more portions of the LTE active time-length of the time sharing period is associated with a Discontinuous Reception (DRX) mechanism.

12. An apparatus of a User Equipment (UE) comprising one or more processors and memory configured to:

the UE to decode from an Evolved NodeB (eNB) a Radio Resource Control (RRC) message that indicates:

an activation, by an eNB, of a Wireless Local Area Network-Long Term Evolution (WLAN-LTE) time sharing mechanism;

a time sharing period;

an LTE active time-length of the time sharing period;

an LTE inactive time-length of the time sharing period; and

a start of the time sharing period;

schedule LTE communications to the eNB during the LTE active time-length or one or more portions of the LTE active time-length of the time sharing period; and

schedule WLAN communications to a WLAN Access Point (AP) during the LTE inactive time-length or one or more portions of the LTE inactive time-length of the WLAN-LTE time sharing period.

13. The apparatus of claim 12, wherein the one or more processors and memory are further configured to:

encode a message, for transmission to the WLAN AP, that indicates;

the activation, by the eNB, of the WLAN-LTE time sharing mechanism;

the time sharing period;

the LTE active time-length of the time sharing period;

the LTE inactive time-length of the time sharing period; and

the start of the time sharing period.

14. The apparatus of claims 12 or 13, wherein the LTE active time-length or one or more portions of the LTE active time-length of the time sharing period is associated with a Discontinuous Reception (DRX) mechanism.

15. The apparatus of claims 12 or 13, wherein the UE transmits to the WLAN Access Point using an Institute of Electronics and Electrical Engineers (IEEE) 802.11 (WiFi) compliant protocol interface.

16. The apparatus of claims 12 or 13, wherein the one or more processors and memory are further configured to:

encode a message, for transmission to an eNB, that indicates a concurrent use condition.

17. The apparatus of claim 16, wherein the message that indicates the concurrent use condition also suggests the LTE active time-length and the LTE inactive time-length of the time sharing period.

18. The apparatus of claim 16, wherein the message that indicates the concurrent use condition comprises an In-device Coexistence Indication (InDeviceCoexIndication) message.

19. The apparatus of claim 12, wherein the apparatus of the UE includes at least one of an antenna, a touch sensitive display screen, a speaker, a microphone, a graphics

processor, a baseband processor, an application processor, internal memory, a non-volatile memory port, and combinations thereof.

20. An apparatus of a Wireless Local Area Network Access Point (WLAN AP) comprising one or more processors and memory configured to:

decode, from an Evolved NodeB (eNB) or a UE, a message that indicates;

an activation, by the eNB, of a Wireless Local Area Network-Long Term Evolution (WLAN-LTE) time sharing mechanism;

a time sharing period;

an LTE active time-length of the time sharing period;

an LTE inactive time-length of the time sharing period; and

a start of the time sharing period; and

schedule WLAN communications to a User Equipment (UE) during the LTE inactive time-length or one or more portions of the LTE inactive time-length of the WLAN-LTE time sharing period.

21. The apparatus of claim 20, wherein the one or more processors and memory are further configured to, according to signal the WLAN transceiver of the WLAN AP, to decode from the UE, the message that indicates:

the activation, by the eNB, of the WLAN-LTE time sharing mechanism;

the time sharing period;

the LTE active time-length of the time sharing period;

the LTE inactive time-length of the time sharing period; and

the start of the time sharing period based on a beacon interval of the WLAN AP.

22. The apparatus of claims 20 or 21, wherein the one or more processors and memory are further configured to, according to schedule transmissions to a User Equipment (UE) during the LTE inactive time-length or one or more portions of the LTE

inactive time-length of the WLAN-LTE time sharing period: generate trigger frames by the WLAN AP during the LTE inactive time-length or one or more portions of the LTE inactive time-length of the time sharing period.

23. The apparatus of claims 20 or 21, wherein the WLAN AP receives from the eNB the message via a router and General Packet Radio Service (GPRS) Tunneling Protocol (GTP-U) endpoint.

24. The apparatus of claims 20 or 21, wherein the WLAN AP transmits to the UE using an Institute of Electronics and Electrical Engineers (IEEE) 802.11 (WiFi) compliant protocol interface.

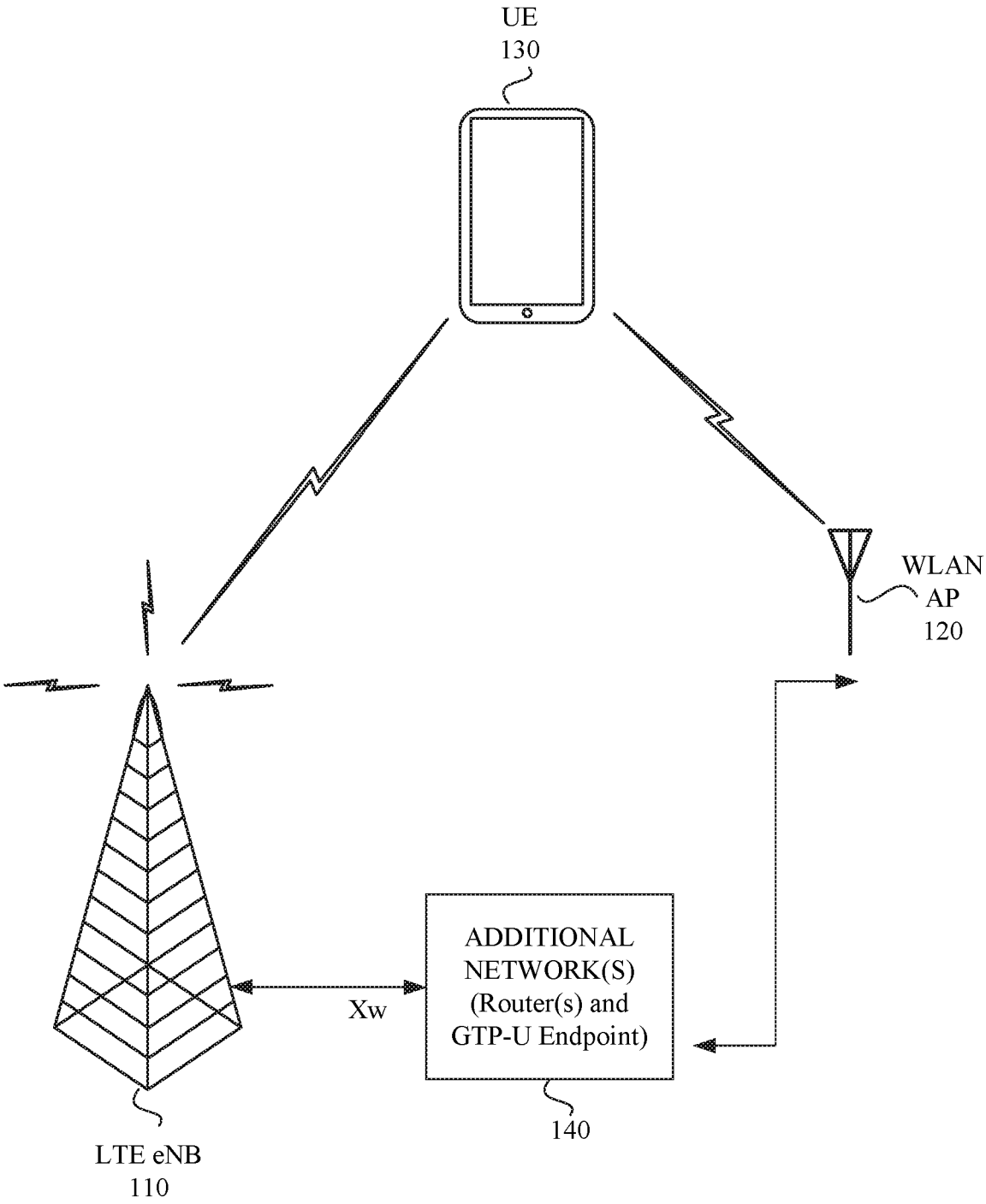

UE
130
WLAN
AP
120
ADDITIONAL
NETWORK(S)
(Router(s) and
GTP-U Endpoint)
140
Xw
LTE eNB
110

FIG. 1

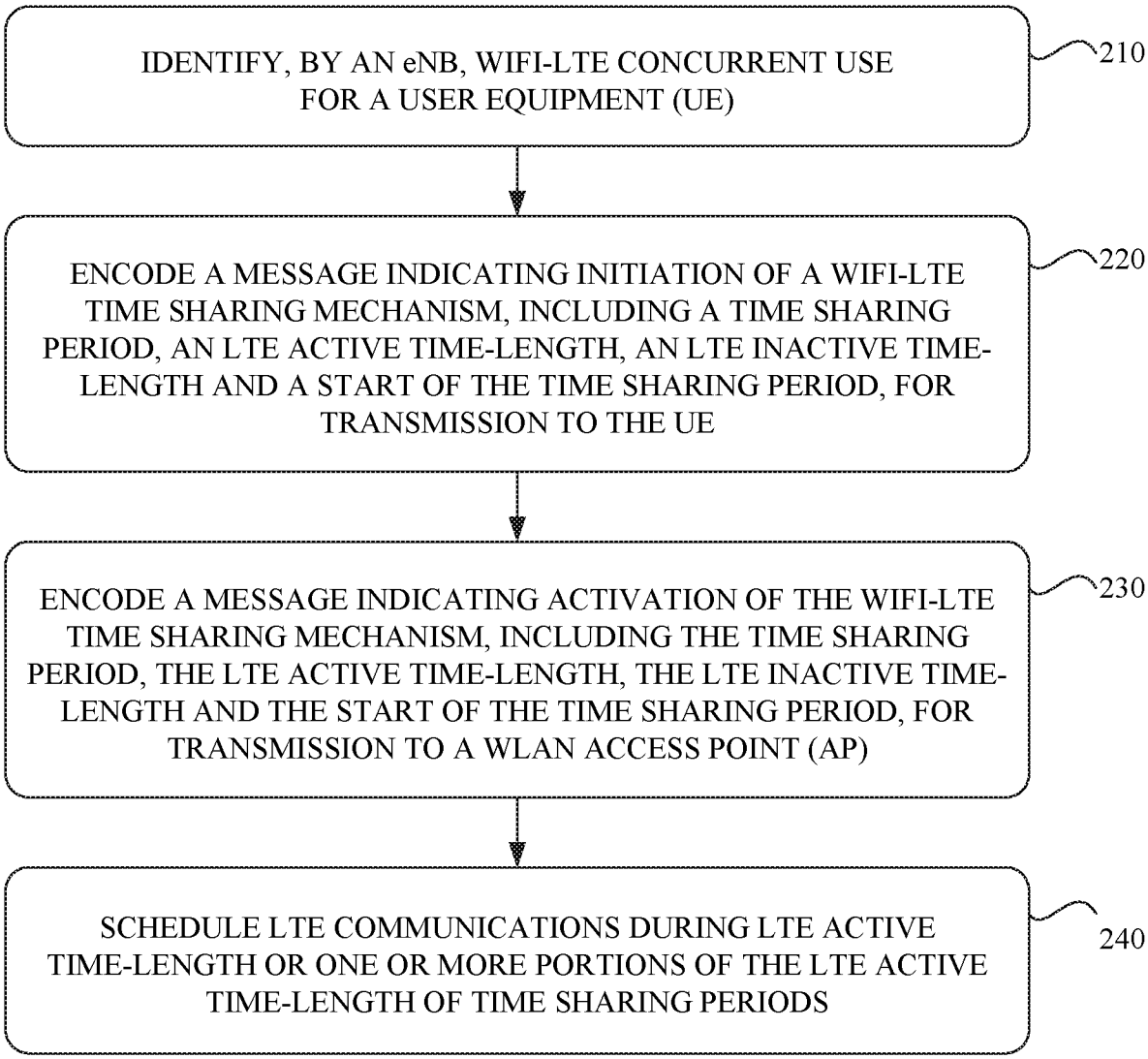

IDENTIFY, BY AN eNB, WIFI-LTE CONCURRENT USE FOR A USER EQUIPMENT (UE)
210
ENCODE A MESSAGE INDICATING INITIATION OF A WIFI-LTE TIME SHARING MECHANISM, INCLUDING A TIME SHARING PERIOD, AN LTE ACTIVE TIME-LENGTH, AN LTE INACTIVE TIME-LENGTH AND A START OF THE TIME SHARING PERIOD, FOR TRANSMISSION TO THE UE
220
ENCODE A MESSAGE INDICATING ACTIVATION OF THE WIFI-LTE TIME SHARING MECHANISM, INCLUDING THE TIME SHARING PERIOD, THE LTE ACTIVE TIME-LENGTH, THE LTE INACTIVE TIME-LENGTH AND THE START OF THE TIME SHARING PERIOD, FOR TRANSMISSION TO A WLAN ACCESS POINT (AP)
230
SCHEDULE LTE COMMUNICATIONS DURING LTE ACTIVE TIME-LENGTH OR ONE OR MORE PORTIONS OF THE LTE ACTIVE TIME-LENGTH OF TIME SHARING PERIODS
240

FIG. 2

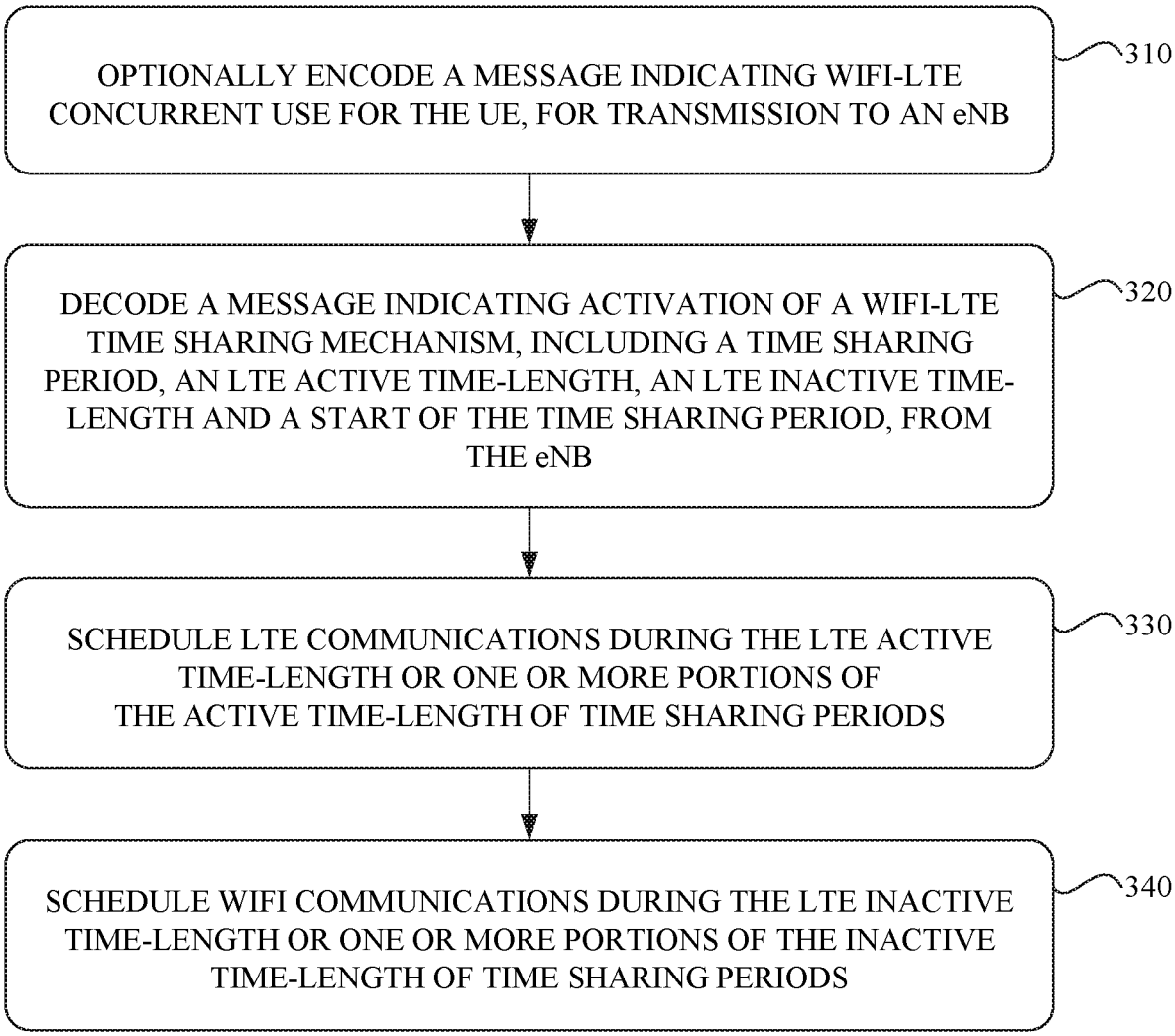

OPTIONALLY ENCODE A MESSAGE INDICATING WIFI-LTE CONCURRENT USE FOR THE UE, FOR TRANSMISSION TO AN eNB
310
DECODE A MESSAGE INDICATING ACTIVATION OF A WIFI-LTE TIME SHARING MECHANISM, INCLUDING A TIME SHARING PERIOD, AN LTE ACTIVE TIME-LENGTH, AN LTE INACTIVE TIME-LENGTH AND A START OF THE TIME SHARING PERIOD, FROM THE eNB
320
SCHEDULE LTE COMMUNICATIONS DURING THE LTE ACTIVE TIME-LENGTH OR ONE OR MORE PORTIONS OF THE ACTIVE TIME-LENGTH OF TIME SHARING PERIODS
330
SCHEDULE WIFI COMMUNICATIONS DURING THE LTE INACTIVE TIME-LENGTH OR ONE OR MORE PORTIONS OF THE INACTIVE TIME-LENGTH OF TIME SHARING PERIODS
340

FIG. 3

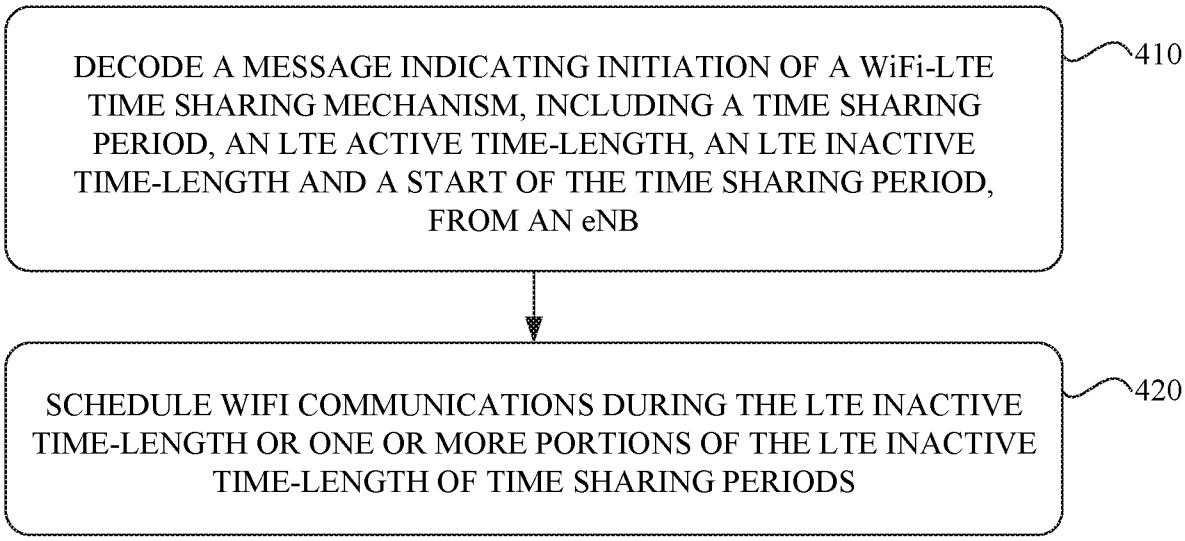

DECODE A MESSAGE INDICATING INITIATION OF A WiFi-LTE TIME SHARING MECHANISM, INCLUDING A TIME SHARING PERIOD, AN LTE ACTIVE TIME-LENGTH, AN LTE INACTIVE TIME-LENGTH AND A START OF THE TIME SHARING PERIOD, FROM AN eNB
410
SCHEDULE WIFI COMMUNICATIONS DURING THE LTE INACTIVE TIME-LENGTH OR ONE OR MORE PORTIONS OF THE LTE INACTIVE TIME-LENGTH OF TIME SHARING PERIODS
420

FIG. 4

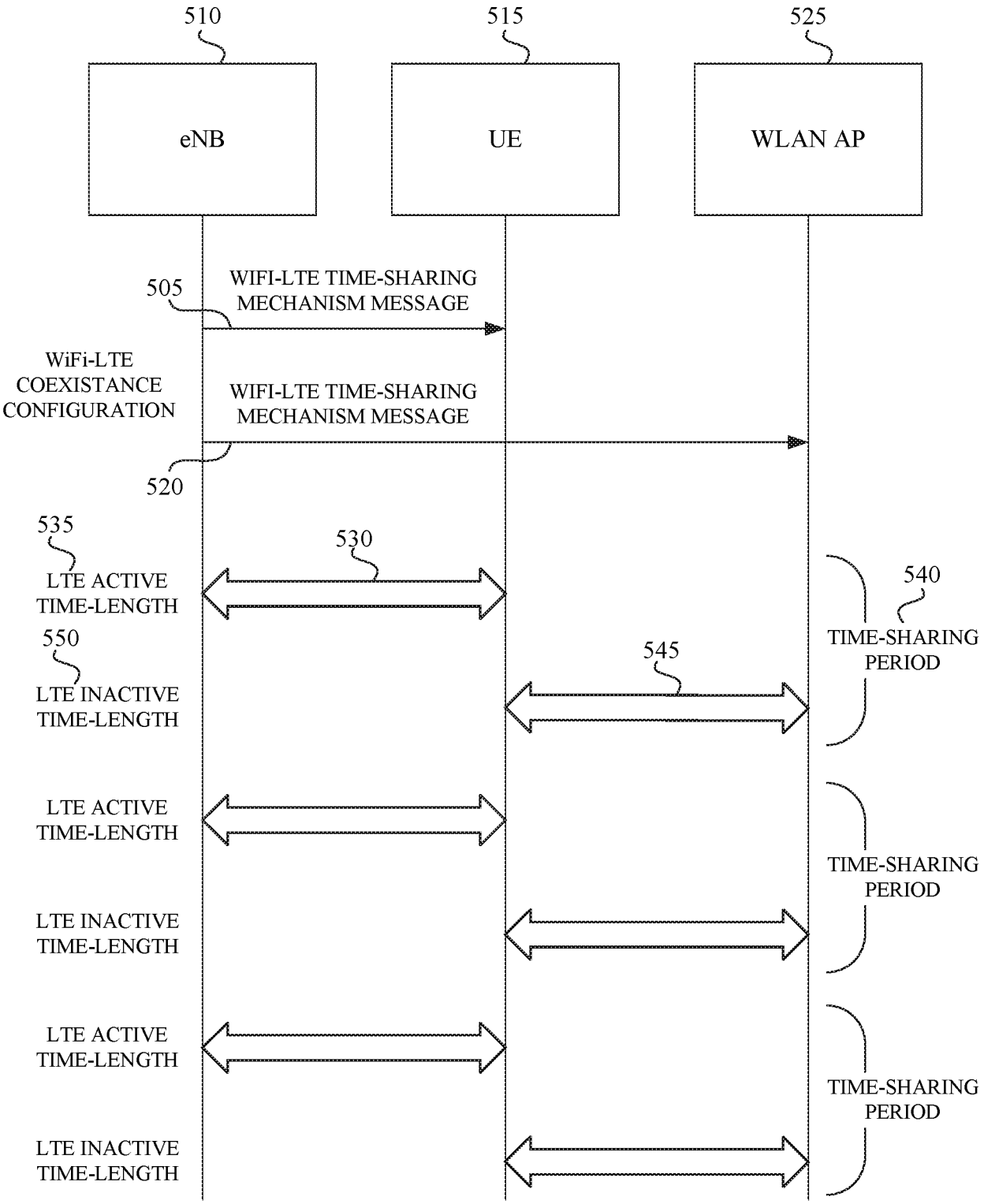

510
515
525
eNB
UE
WLAN AP
505
WIFI-LTE TIME-SHARING MECHANISM MESSAGE
WiFi-LTE COEXISTANCE CONFIGURATION
WIFI-LTE TIME-SHARING MECHANISM MESSAGE
520
535
530
LTE ACTIVE TIME-LENGTH
540
TIME-SHARING PERIOD
550
545
LTE INACTIVE TIME-LENGTH
LTE ACTIVE TIME-LENGTH
TIME-SHARING PERIOD
LTE INACTIVE TIME-LENGTH
LTE ACTIVE TIME-LENGTH
TIME-SHARING PERIOD
LTE INACTIVE TIME-LENGTH

FIG. 5

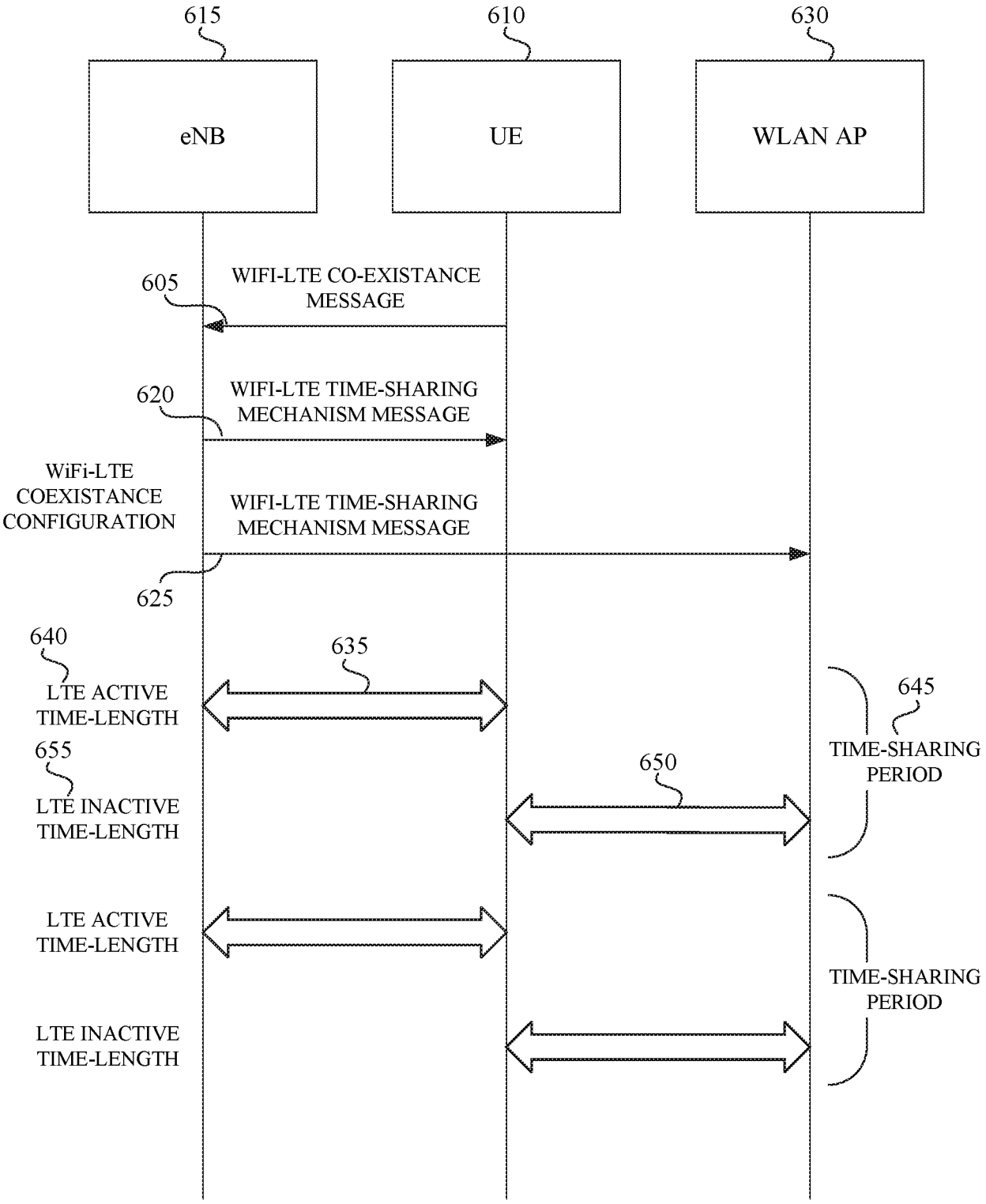

615
610
630
eNB
UE
WLAN AP
605
WIFI-LTE CO-EXISTANCE MESSAGE
620
WIFI-LTE TIME-SHARING MECHANISM MESSAGE
WiFi-LTE COEXISTANCE CONFIGURATION
WIFI-LTE TIME-SHARING MECHANISM MESSAGE
625
640
635
645
LTE ACTIVE TIME-LENGTH
655
650
TIME-SHARING PERIOD
LTE INACTIVE TIME-LENGTH
LTE ACTIVE TIME-LENGTH
TIME-SHARING PERIOD
LTE INACTIVE TIME-LENGTH

FIG. 6

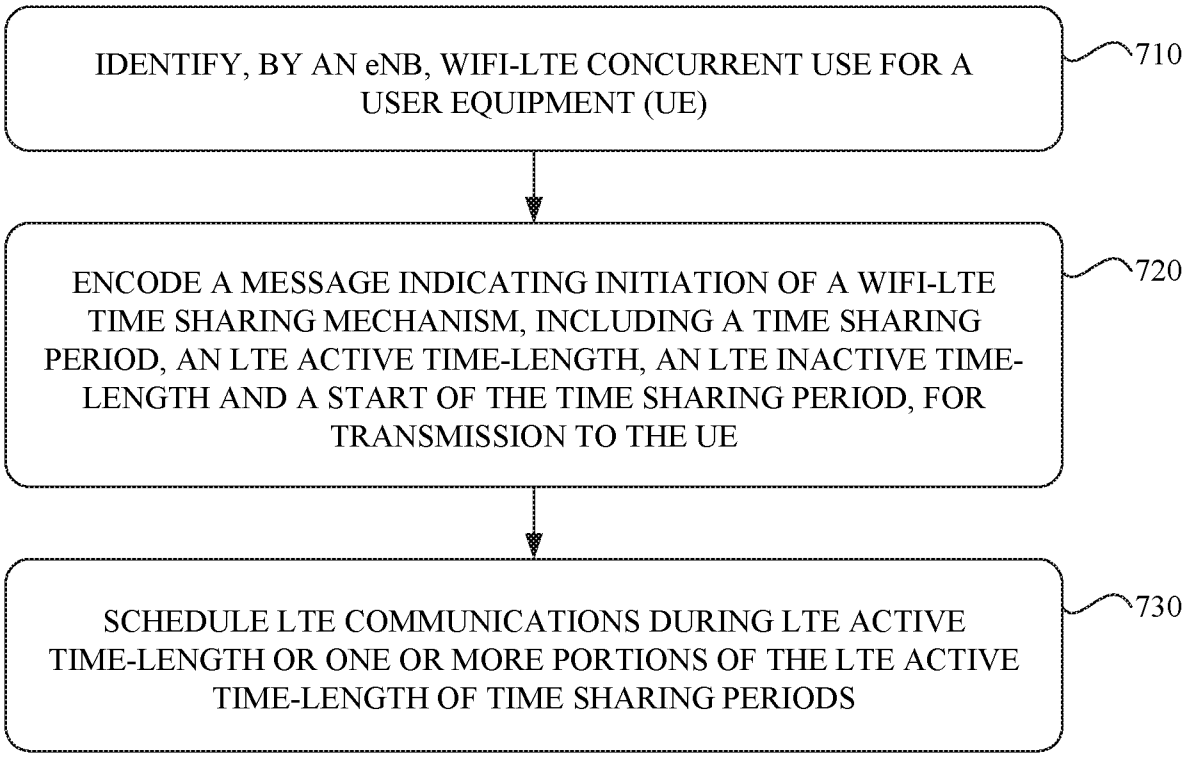

IDENTIFY, BY AN eNB, WIFI-LTE CONCURRENT USE FOR A USER EQUIPMENT (UE)
710
ENCODE A MESSAGE INDICATING INITIATION OF A WIFI-LTE TIME SHARING MECHANISM, INCLUDING A TIME SHARING PERIOD, AN LTE ACTIVE TIME-LENGTH, AN LTE INACTIVE TIME-LENGTH AND A START OF THE TIME SHARING PERIOD, FOR TRANSMISSION TO THE UE
720
SCHEDULE LTE COMMUNICATIONS DURING LTE ACTIVE TIME-LENGTH OR ONE OR MORE PORTIONS OF THE LTE ACTIVE TIME-LENGTH OF TIME SHARING PERIODS
730

FIG. 7

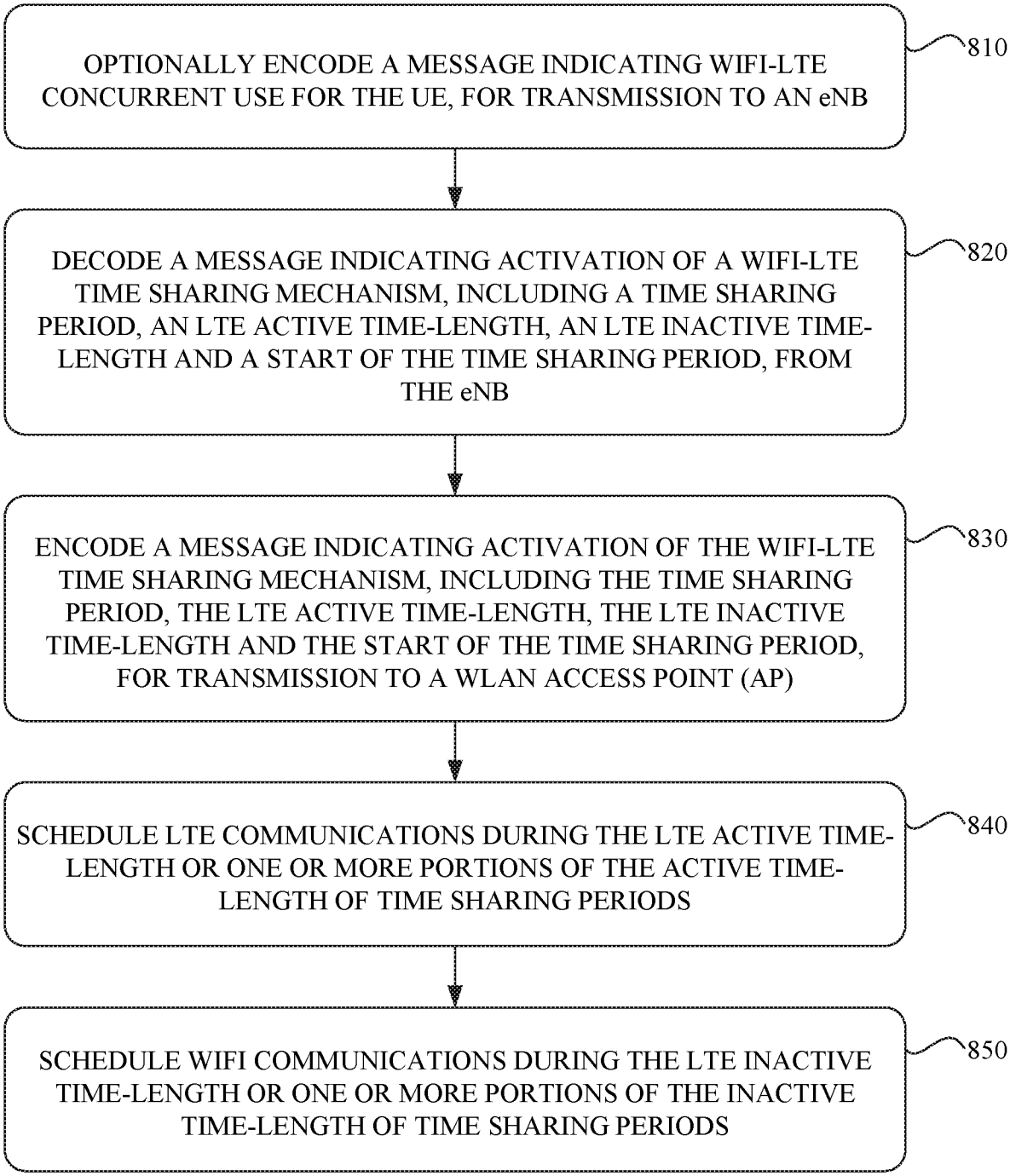

OPTIONALLY ENCODE A MESSAGE INDICATING WIFI-LTE CONCURRENT USE FOR THE UE, FOR TRANSMISSION TO AN eNB
810
DECODE A MESSAGE INDICATING ACTIVATION OF A WIFI-LTE TIME SHARING MECHANISM, INCLUDING A TIME SHARING PERIOD, AN LTE ACTIVE TIME-LENGTH, AN LTE INACTIVE TIME-LENGTH AND A START OF THE TIME SHARING PERIOD, FROM THE eNB
820
ENCODE A MESSAGE INDICATING ACTIVATION OF THE WIFI-LTE TIME SHARING MECHANISM, INCLUDING THE TIME SHARING PERIOD, THE LTE ACTIVE TIME-LENGTH, THE LTE INACTIVE TIME-LENGTH AND THE START OF THE TIME SHARING PERIOD, FOR TRANSMISSION TO A WLAN ACCESS POINT (AP)
830
SCHEDULE LTE COMMUNICATIONS DURING THE LTE ACTIVE TIME-LENGTH OR ONE OR MORE PORTIONS OF THE ACTIVE TIME-LENGTH OF TIME SHARING PERIODS
840
SCHEDULE WIFI COMMUNICATIONS DURING THE LTE INACTIVE TIME-LENGTH OR ONE OR MORE PORTIONS OF THE INACTIVE TIME-LENGTH OF TIME SHARING PERIODS
850

FIG. 8

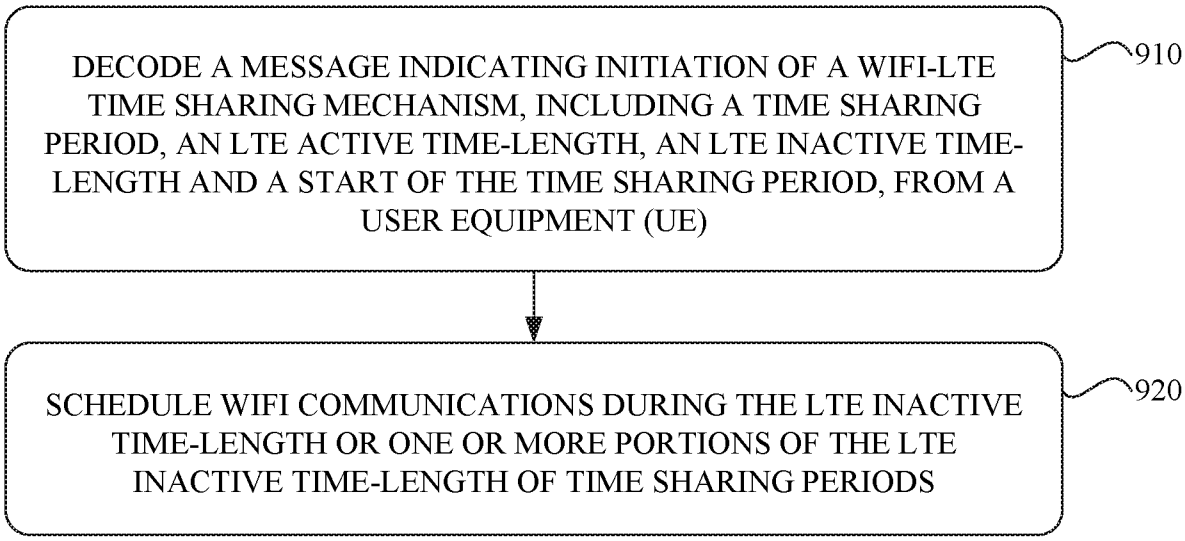

DECODE A MESSAGE INDICATING INITIATION OF A WIFI-LTE TIME SHARING MECHANISM, INCLUDING A TIME SHARING PERIOD, AN LTE ACTIVE TIME-LENGTH, AN LTE INACTIVE TIME-LENGTH AND A START OF THE TIME SHARING PERIOD, FROM A USER EQUIPMENT (UE)
910
SCHEDULE WIFI COMMUNICATIONS DURING THE LTE INACTIVE TIME-LENGTH OR ONE OR MORE PORTIONS OF THE LTE INACTIVE TIME-LENGTH OF TIME SHARING PERIODS
920

FIG. 9

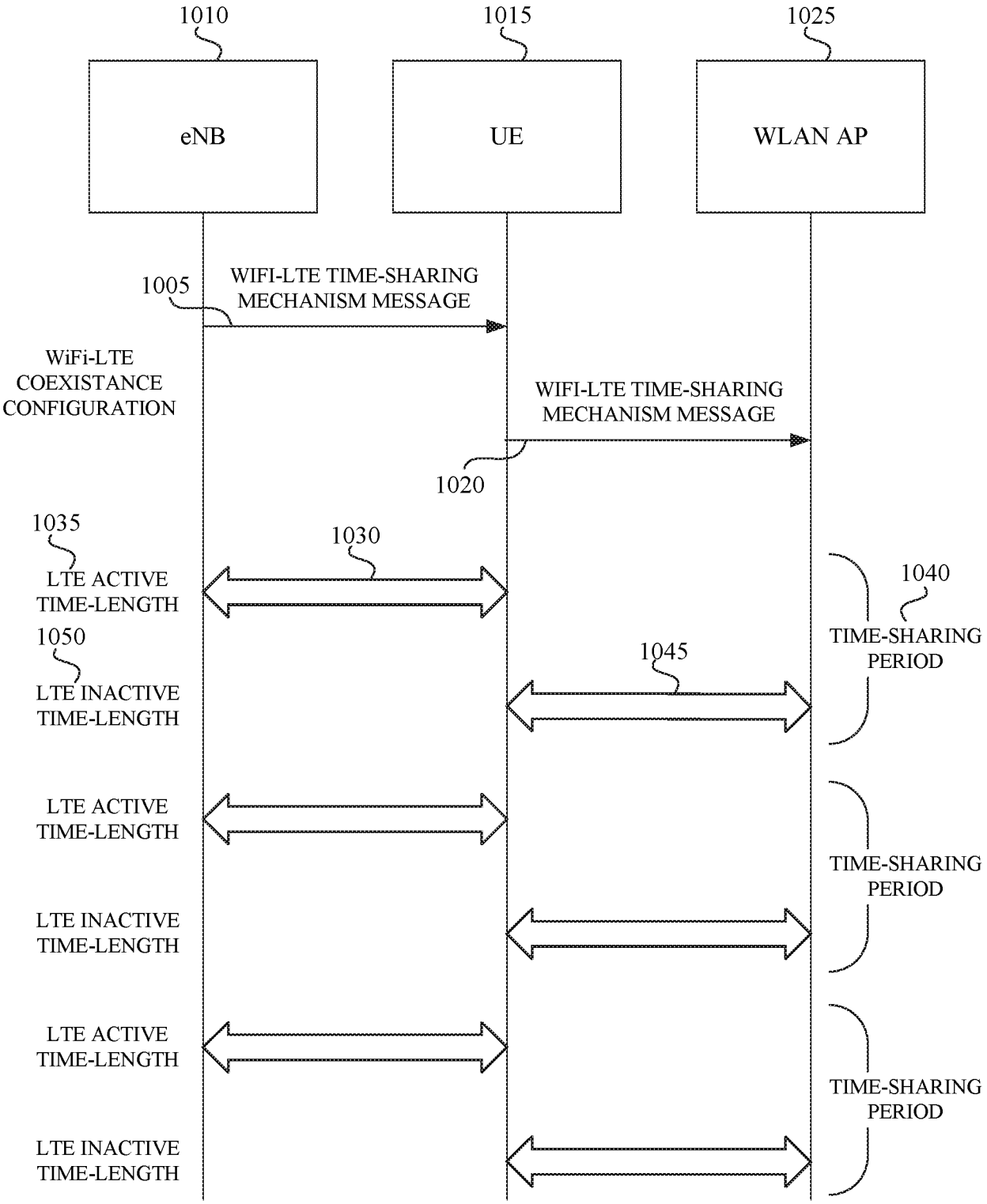

1010
1015
1025
eNB
UE
WLAN AP
1005
WIFI-LTE TIME-SHARING MECHANISM MESSAGE
WiFi-LTE COEXISTANCE CONFIGURATION
WIFI-LTE TIME-SHARING MECHANISM MESSAGE
1020
1035
1030
LTE ACTIVE TIME-LENGTH
1040
TIME-SHARING PERIOD
1050
1045
LTE INACTIVE TIME-LENGTH
LTE ACTIVE TIME-LENGTH
TIME-SHARING PERIOD
LTE INACTIVE TIME-LENGTH
LTE ACTIVE TIME-LENGTH
TIME-SHARING PERIOD
LTE INACTIVE TIME-LENGTH

FIG. 10

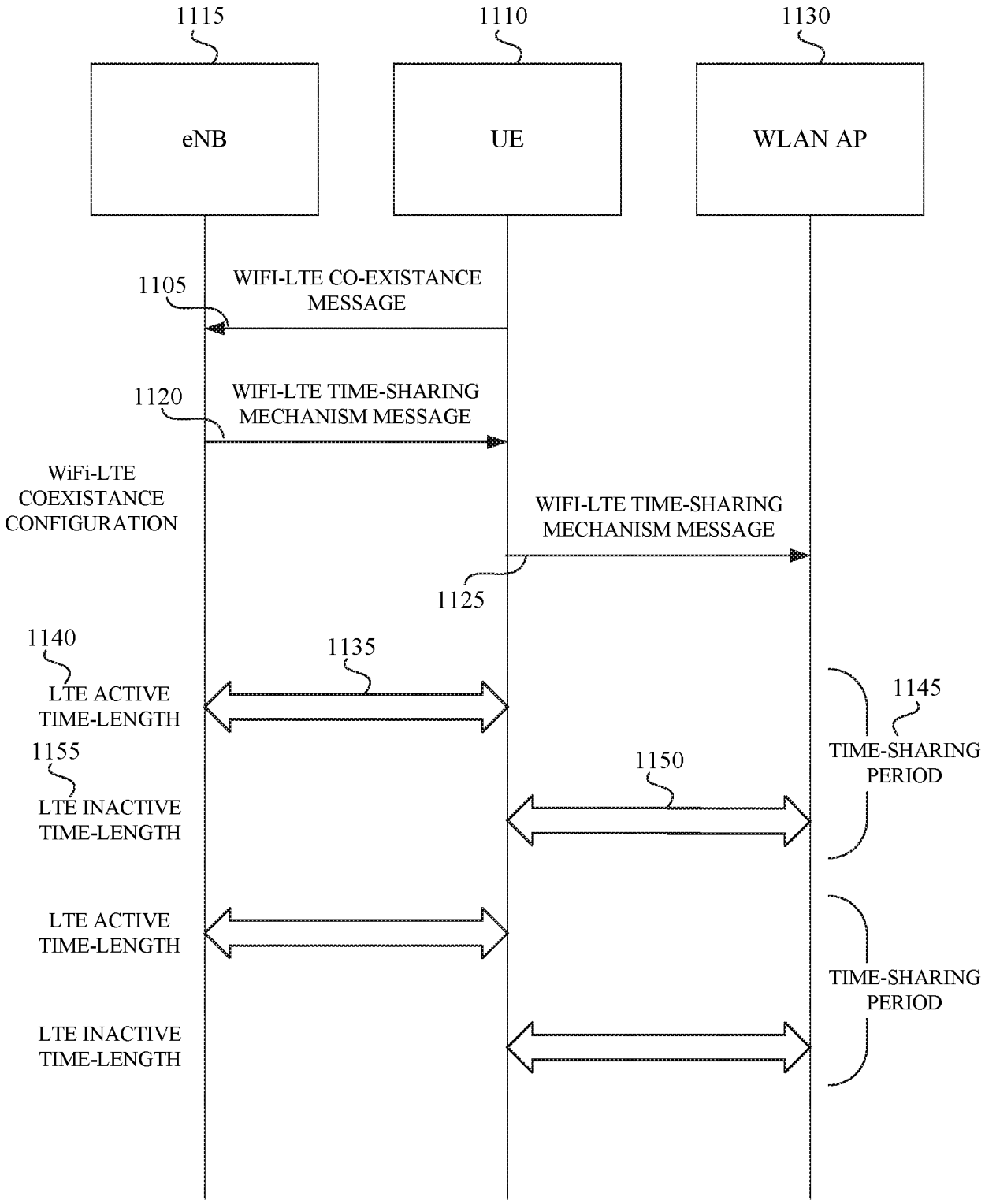

1115
1110
1130
eNB
UE
WLAN AP
1105
WIFI-LTE CO-EXISTANCE MESSAGE
1120
WIFI-LTE TIME-SHARING MECHANISM MESSAGE
WiFi-LTE COEXISTANCE CONFIGURATION
WIFI-LTE TIME-SHARING MECHANISM MESSAGE
1125
1140
1135
LTE ACTIVE TIME-LENGTH
1145
1155
1150
TIME-SHARING PERIOD
LTE INACTIVE TIME-LENGTH
LTE ACTIVE TIME-LENGTH
TIME-SHARING PERIOD
LTE INACTIVE TIME-LENGTH

FIG. 11

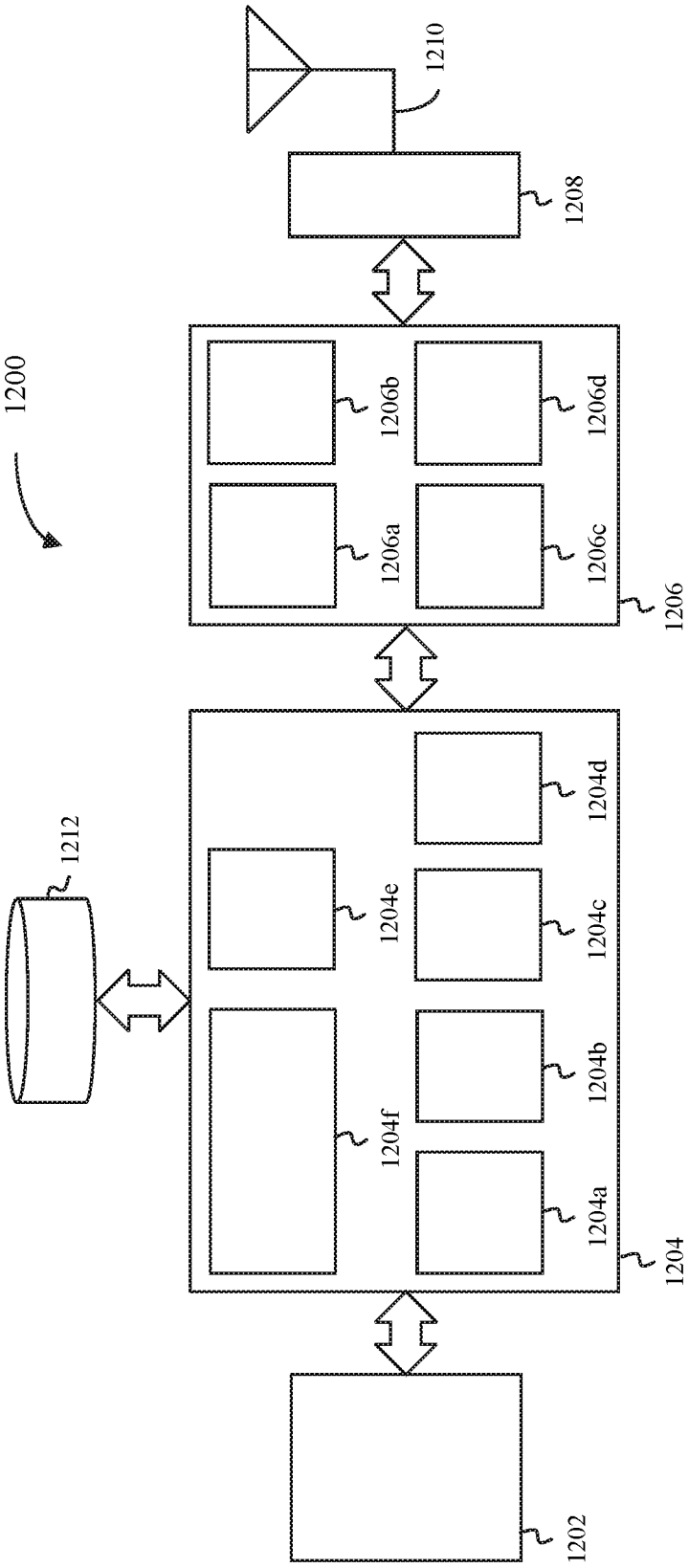

1200
1210
1208
1206b
1206d
1206a
1206c
1206
1212
1204e
1204d
1204c
1204f
1204b
1204a
1204
1202

FIG. 12

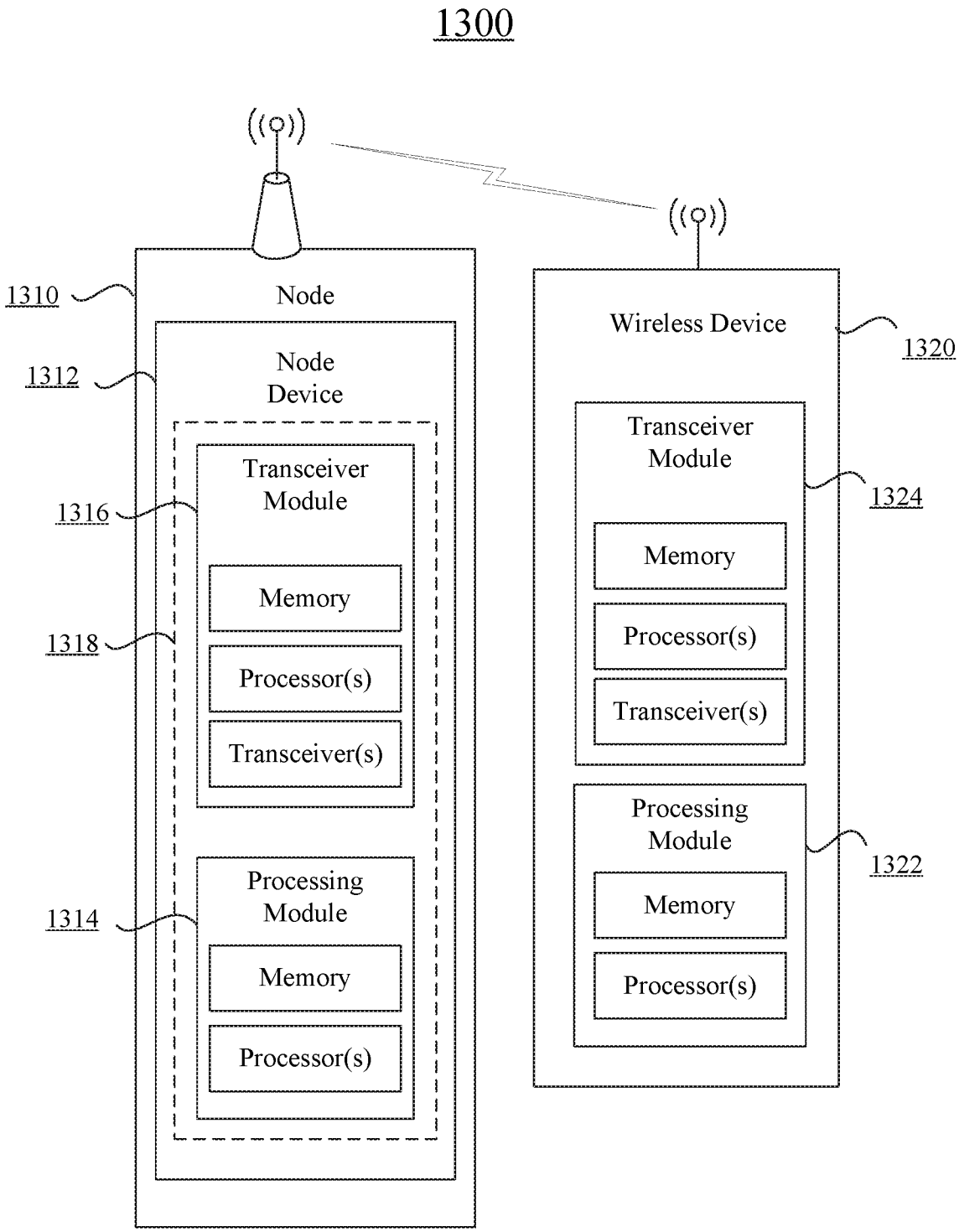

1300
1310
Node
1312
Node Device
Transceiver Module
1316
Memory
1318
Processor(s)
Transceiver(s)
Processing Module
1314
Memory
Processor(s)
Wireless Device
1320
Transceiver Module
1324
Memory
Processor(s)
Transceiver(s)
Processing Module
1322
Memory
Processor(s)

FIG. 13

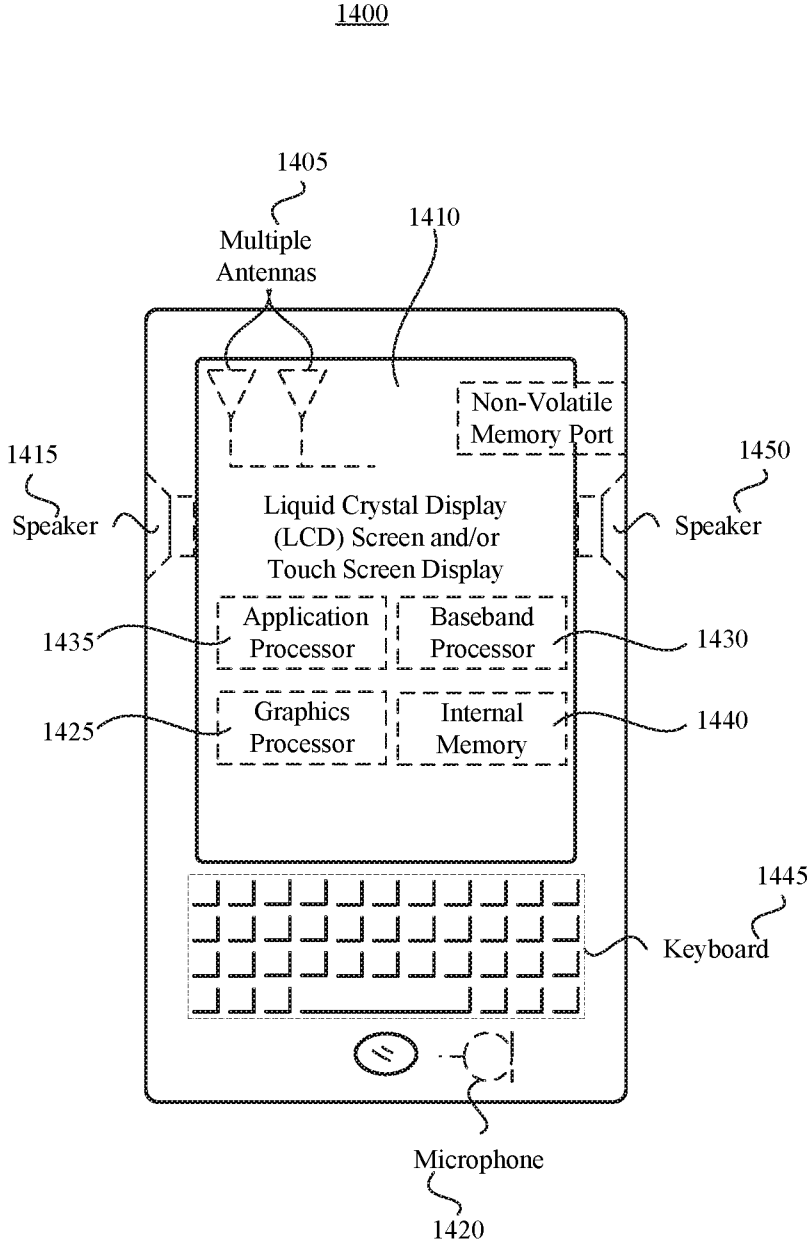

1400
1405
Multiple Antennas
1410
Non-Volatile Memory Port
1415
Speaker
1450
Speaker
Liquid Crystal Display (LCD) Screen and/or Touch Screen Display
1435
Application Processor
Baseband Processor
1430
1425
Graphics Processor
Internal Memory
1440
1445
Keyboard
Microphone
1420

FIG. 14

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2016/054998

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04W72/12
ADD. H04W88/06 H04W76/04

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

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)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2011/243047 A1 (DAYAL PRANAV [US] ET AL) 6 October 2011 (2011-10-06)	1-6, 10-12, 14-19
A	paragraphs [0100] - [0124]; figure 11	7-9,13, 20-24
X	EP 2 632 209 A2 (NOKIA CORP [FI]) 28 August 2013 (2013-08-28) paragraphs [0054], [0064], [0071], [0078], [0088]	1-24
X	US 2015/063182 A1 (WANG JIBING [US]) 5 March 2015 (2015-03-05) paragraphs [0050] - [0055], [0059], [0107]	1-24

-/--

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

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Date of the actual completion of the international search	Date of mailing of the international search report
5 December 2016	12/12/2016

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European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Schut, Gerhard

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