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(54) **Title:** AVOIDING IDLE-STATE TRANSITION FOR WLAN-CONNECTED MOBILE TERMINAL

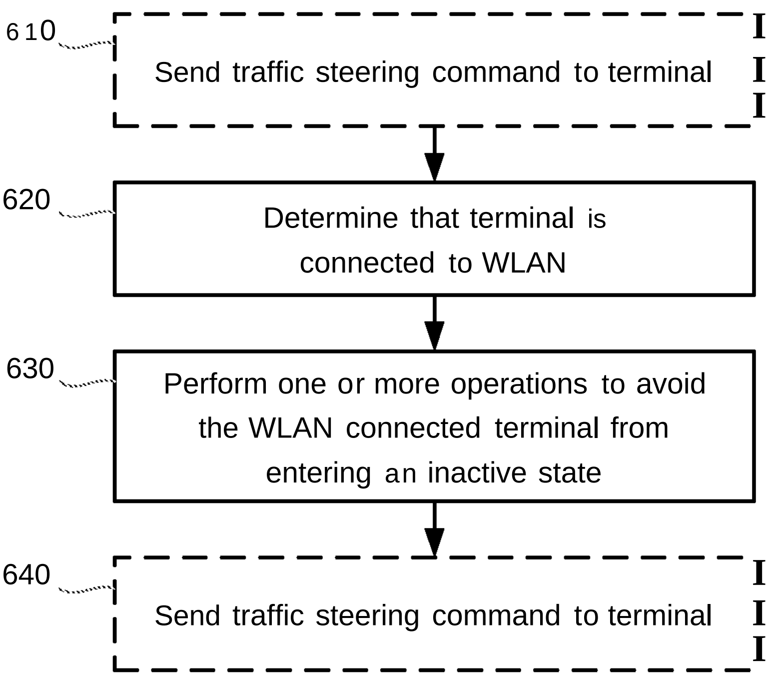

Figure 8

(57) **Abstract:** There is provided a method in a network node (320) of a first wireless telecommunications network (304), the method comprising determining (620) whether a terminal (300) served by the first network (320) is connected to a wireless local area network, WLAN (302); and if the terminal (300) is connected to a WLAN (302), performing (630) one or more operations to avoid the terminal (300) entering an inactive state with respect to the first network (320).

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AVOIDING IDLE-STATE TRANSITION FOR WLAN-CONNECTED MOBILE TERMINAL

TECHNICAL FIELD

The present disclosure is generally related to wireless communications systems, and is more particularly related to techniques for controlling the operation of mobile terminals with respect to the use of multiple radio access technologies, such as a wide area wireless communication technology and a wireless local area network (WLAN) technology.

BACKGROUND

The wireless local-area network (WLAN) technology known as "Wi-Fi" has been standardized by IEEE in the 802.1 1 series of specifications (i.e., as "IEEE Standard for Information technology—Telecommunications and information exchange between systems. Local and metropolitan area networks—Specific requirements. Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications"). As currently specified, W-Fi systems are primarily operated in the 2.4 GHz or 5 GHz bands.

The IEEE 802.1 1 specifications regulate the functions and operations of the W-Fi access points or wireless terminals, collectively known as "stations" or "STA," in the IEEE 802.1 1, including the physical layer protocols, Medium Access Control (MAC) layer protocols, and other aspects needed to secure compatibility and inter-operability between access points and portable terminals. Because W-Fi is generally operated in unlicensed bands, communication over W-Fi may be subject to interference sources from any number of both known and unknown devices. W-Fi is commonly used as wireless extensions to fixed broadband access, e.g., in domestic environments and in so-called hotspots, like airports, train stations and restaurants.

Recently, W-Fi has been subject to increased interest from cellular network operators, who are studying the possibility of using W-Fi for purposes beyond its conventional role as an extension to fixed broadband access. These operators are responding to the ever-increasing market demands for wireless bandwidth, and are interested in using W-Fi technology as an extension of, or alternative to, cellular radio access network technologies. Cellular operators that are currently serving mobile users with, for example, any of the technologies standardized by the 3rd-Generation Partnership

Project (3GPP), including the radio-access technologies known as Long-Term Evolution (LTE), Universal Mobile Telecommunications System (UMTS)/Wideband Code-Division Multiple Access (WCDMA), High Speed Packet Access (HSPA) and Global System for Mobile Communications (GSM), see Wi-Fi as a wireless technology that can provide good additional support for users in their regular cellular networks.

As used herein, the term "operator-controlled W-Fi" indicates a Wi-Fi deployment that on some level is integrated with a cellular network operator's existing network, where the operator's radio access network(s) and one or more W-Fi wireless access points may even be connected to the same core network and provide the same or overlapping services. Currently, several standardization organizations are intensely active in the area of operator-controlled W-Fi. In 3GPP, for example, activities to connect W-Fi access points to the 3GPP-specified core network are being pursued. In the W-Fi alliance (WFA), activities related to certification of W-Fi products are undertaken, which to some extent is also driven from the need to make W-Fi a viable wireless technology for cellular operators to support high bandwidth offerings in their networks. In these standardization efforts, the term "Wi-Fi offload" is commonly used and indicates that cellular network operators seek means to offload traffic from their cellular networks to W-Fi, e.g., during peak-traffic-hours and in situations when the cellular network needs to be off-loaded for one reason or another, e.g., to provide a requested quality-of-service, to maximize bandwidth, or simply for improved coverage.

Using W-Fi/WLAN (the two terms are used interchangeably throughout this document) to offload traffic from the mobile networks is becoming more and more interesting from both the operator's and end user's points of view. Some of the reasons for this tendency are:

- **Additional frequency:** by using W-Fi, operators can access an additional 85MHz of radio bandwidth in the 2.4GHz band and another (close to) 500MHz in the 5GHz band.
- **Cost:** From the operator's point of view, W-Fi uses unlicensed frequency that is free of charge. On top of that, the cost of Wi-Fi Access Points (APs), both from capital expense (CAPEX) and operational expenses (OPEX) aspects, is considerably lower than that of a 3GPP base station (BS) (i.e. NodeB (NB) in case of UMTS or enhanced NodeB (eNB) in case of LTE). Operators can also take advantage of already deployed APs that are already deployed in hotspots such as train stations, airports, stadiums,

shopping malls, etc. Most end users are also currently used to having Wi-Fi for free at home (as home broadband subscriptions are usually flat rate) and public places.

- **Terminal support:** Many User Equipments (UEs), including virtually all smartphones, and other portable devices currently available in the market, support Wi-Fi. In the W-Fi world, the term Station (STA) is used instead of UE, and as such the terms UE, STA and terminal are used interchangeably in this document.
- **High data rate:** Under low interference conditions and assuming the user device is close to the Wi-Fi AP, Wi-Fi can provide high peak data rates (for example, theoretically up to 600Mbps for IEEE 802.1 1η deployments with MIMO (Multiple Input Multiple Output)).

For a wireless operator, offering a mix of two technologies that have been standardized in isolation from each other raises the challenge of providing intelligent mechanisms for co-existence. One area that needs these intelligent mechanisms is connection management.

Many of today's portable wireless devices (referred to hereinafter as "user equipments" or "UEs") support W-Fi in addition to one or several 3GPP cellular technologies. In many cases, however, these terminals essentially behave as two separate devices, from a radio access perspective. The 3GPP radio access network and the UE-based modems and protocols that are operating pursuant to the 3GPP specifications are generally unaware of the wireless access W-Fi protocols and modems that may be simultaneously operating pursuant to the 802.1 1 specifications. Techniques for coordinated control of these multiple radio-access technologies are needed.

One example of a procedure for mobility between 3GPP networks and WLAN is described below. In short, this procedure is based on three messages and some associated procedures that allow the 3GPP network to determine when a terminal should associate with a WLAN or, more generally, to a network operating according to a second (different) radio access technology (RAT). The procedure is illustrated in Figure 1. The first message, a reporting configuration message (message 1), is sent from the 3GPP radio access network (RAN) 10 to the terminal 12 and configures the terminal 12 with a set of criteria for enabling, detecting, and/or performing measurements over the second RAT (WLAN 14). The terminal 12 subsequently sends a terminal report, message 2, to the 3GPP network 10, when the criteria given in the first message (message 1) have been fulfilled. The third message (message 3), a traffic steering message, is an indicator sent from the 3GPP network 10 to the terminal 12 that the terminal 12 should steer all or a subset of its traffic to the second RAT (WLAN 14).

Message 1 - Reporting configuration message: The content of this message is a set of criteria. The criteria could be that certain parameters should exceed or fall below a given threshold. Parameters which could be considered include 3GPP received signal strength, WLAN received signal strength, 3GPP received signal quality, WLAN received signal quality, 3GPP related load, WLAN related load, etc.

One possible set of criteria contained in one possible reporting configuration message is as follows:

- Received signal strength larger than threshold x
- Received signal quality larger than threshold y
- WLAN load less than threshold z

When the terminal 12 has received reporting configuration message it should monitor the parameters associated with the criteria indicated in reporting configuration message. In case the criteria are fulfilled the terminal 12 should send a terminal report (message 2) to the 3GPP network 10.

Message 2 - Terminal report: The terminal report is a message sent from the terminal 12 to the 3GPP network 10 reporting the fulfilment of the conditions given in reporting configuration message (message 1). The content of the report may include more information, such as all or part of the measurements done in the terminal 12 of the WLAN APs 14, and/or other information available in the terminal 12 from the WLAN 14, such as the WLAN load, etc. The arrow in Figure 1 from the WLAN 14 to the UE 12 indicates the transmission of BSS/WAN metrics, such as WLAN load, from the WLAN 14 to the UE 12. In addition to metrics such as the WLAN load, the UE 12 can include additional information about the WLAN 14 in the terminal report that has not been signalled by the WLAN 14 to the UE 12. For example, the UE 12 may also include measurements of WLAN signals in the terminal report.

A time-to-trigger value can be specified to indicate to the UE (terminal 12) for how long the criteria should be fulfilled before the UE (terminal 12) reports back with the terminal report (message 2). In addition to that, the UE (terminal 12) can be configured with some filtering/smoothing parameters that it can use when collecting measurements to ensure that decisions will not be made based on instantaneous values. For example, the UE (terminal 12) can be configured with a moving average filter over a given duration, and the filtered value will be the one that will be compared with the threshold specified in the reporting configuration message (message 1). The parameters for filtering could be included in the reporting configuration message (message 1) and applicable only to the associated criteria, or they can be generic and communicated to the UEs (terminal 12) beforehand (either in a dedicated or broadcasted manner) and applicable to all reporting configuration messages thereafter.

In the event that there is a need for the 3GPP network 10 to identify a specific WLAN 14 network and associated measurements, WLAN identifiers (such as service set identification (SSID), basic SSID (BSSID)) may be included in the terminal report along with the relevant measurements (e.g. for SSID X the signal strength is A, for SSID Y the signal strength is B). This information may be necessary if the 3GPP network 10 wants to move a terminal 12 to a specific WLAN network 14/AP/etc.

An exemplary terminal report (message 2) is shown below:

SSID = operatorX-WLAN7 Received signal strength = - 73 dBm Received signal quality = 4.2 dB WLAN load = 47%
SSID = operatorX-WLAN2 Received signal strength = - 82 dBm Received signal quality = 2.5 dB WLAN load = 47%
SSID = operatorX-WLAN5 Received signal strength = - 96 dBm Received signal quality = 1.4 dB WLAN load = 49%

Message 3 - Traffic steering message: The traffic steering message (message 3) is sent from the 3GPP network 10 to the terminal 12 and is used by the 3GPP network 10 to indicate to the terminal 12 that some, or all, of the terminal's traffic should be steered to WLAN 14. The 3GPP network 10 will decide whether all or some of the terminal's bearers will be moved to one of the WLAN access points 14. In addition to the received information from the terminal 12, the 3GPP network 10 will also take into account other information available in the whole network (also from other network nodes), such as information determining radio interface load, load in backhaul, which radio capabilities are used, which radio capabilities could be used to enhance quality of service (QoS), etc. The 3GPP network 10 may also collect relevant information from other WLAN access points 14. All relevant information can be used to determine whether a move (of the traffic/bearers) should take place. The 3GPP network 10 may also request information from the possible target WLAN AP 14 over an interface between the 3GPP network 10 and WLAN nodes 14 (not shown in Figure 1) about its possibilities to serve the potential traffic.

Other procedures for mobility between 3GPP networks and WLAN that do not require the three message procedure above are also contemplated, for example procedures in which the 3GPP network sends one or more messages to the terminal to configure the terminal to switch its traffic from the 3GPP network to the WLAN if certain criteria are met and/or in which the 3GPP network otherwise configures the terminal to take measurements of the available WLANs using criteria specified by the 3GPP network.

SUMMARY

As seen above, dedicated traffic steering commands or policies (i.e. some form of rule for controlling traffic steering (e.g. an Access Network Discovery and Selection Function (ANDSF) policy)) can be sent from the 3GPP RAN to the terminal. For example, the 3GPP RAN can send a message (with a traffic steering command or policy) to the terminal, ordering it to route (i.e. switch) its traffic from the 3GPP RAN to a WLAN network, or ordering it to route the traffic from WLAN to the 3GPP network. However, for this (or similar) procedures to be used, it is required that a dedicated connection between the 3GPP RAN 10 and the terminal 12 is established.

It is common that in 3GPP networks, a terminal that does not have any ongoing data traffic for a certain period of time will be moved to an inactive state by the 3GPP network. This means that the 3GPP RAN generally cannot reach the terminal for control purposes. More particularly, in the event that the terminal is not transmitting/receiving any data in the 3GPP RAN for a certain period of time, the 3GPP network moves this terminal to a state (e.g., IDLE state) in which dedicated signalling between the UE and the 3GPP RAN is not possible, and hence the command-based procedure for traffic steering described above can no longer be used. So, if the 3GPP RAN has ordered the terminal to route all its traffic over WLAN and no traffic is transmitted or received over the 3GPP RAN, then the described mechanism in the 3GPP specifications will trigger the terminal to enter the state in which dedicated signalling between the UE and the 3GPP RAN is not possible. As a result, the traffic steering command procedure described above (and other procedures in which the 3GPP network needs to signal information to the terminal to enable the selection of an appropriate RAN) cannot be used.

Described herein are several techniques that allow the terminal to remain in a state where dedicated traffic steering commands can be used, even when the terminal has no transmissions or receptions of data over 3GPP RAN, such as in the case when the terminal has routed (or is routing) its traffic over WLAN. Some of the described techniques also allow the terminal to enter an inactive state when the terminal is disconnected from the WLAN or no user plane traffic detected in both 3GPP RAN and WLAN.

In a first embodiment of the disclosed techniques, keeping the terminal in a state where dedicated traffic steering commands can be used is realized by having the 3GPP network (e.g. the RAN) adjust timers in such a way that triggering of the process of moving a terminal to a state without possibility of transmission of dedicated traffic steering commands to the terminal is impossible or very unlikely.

In a related approach, the actions associated with timer expiry are changed such that triggering of the process of moving a terminal to a state in which dedicated signalling between the UE and the 3GPP RAN is not possible is prevented.

In a second embodiment of the techniques, the terminal is adapted to refrain from entering a state in which dedicated signalling between the UE and the 3GPP RAN is not possible.

According to another technique, the terminal enters an inactive state when it is disconnected from the WLAN or is inactive in both 3GPP RAN and WLAN for a predetermined period.

Example aspects and embodiments of some of the techniques disclosed herein are described below. However, it should be understood that the list of example aspects and embodiments is not intended to be an exhaustive representation of the aspects and embodiments disclosed herein.

According to a first aspect there is provided a method in a radio access network, RAN, node of a wireless telecommunications system, the method comprising determining whether a terminal served by the RAN is connected to a wireless local area network, WLAN and if the terminal is connected to a WLAN, performing one or more operations to avoid the terminal entering an inactive state with respect to the RAN.

In some embodiments the RAN is a 3GPP RAN, such as Long Term Evolution, LTE, Wdeband Code Division Multiple Access (WCDMA), High Speed Packet Access, HSPA or Global System for Mobile, GSM.

In some embodiments determining whether a terminal served by the RAN is connected to a WLAN is based on a WLAN status report received from the terminal. In other embodiments determining whether a terminal served by the RAN is connected to a WLAN is based on the sending of a traffic steering message to the terminal by the RAN. In other embodiments determining whether a terminal served by the RAN is connected to a WLAN is based on the reception from the terminal of an indication that a traffic steering message, sent to the terminal by the RAN, has been applied by the terminal. In other embodiments determining whether a terminal served by the RAN is connected to a WLAN is based on information received from a core network associated with the RAN.

In some embodiments the step of performing one or more operations to avoid the terminal entering an inactive state with respect to the RAN comprises adjusting operation of an inactivity timer associated with the terminal so that triggering of an operation to move the terminal to an inactive state, with respect to the RAN, is unlikely or impossible.

In some embodiments adjusting operation of an inactivity timer associated with the terminal comprises setting the value of an inactivity timer to a value that will be interpreted to prevent the timer from ever expiring. In other embodiments adjusting operation of an inactivity timer associated with the terminal comprises setting the value of an inactivity timer to a value such that expiration of the inactivity is unlikely in view of other activities of the RAN node. In other embodiments adjusting operation of an inactivity timer associated with the terminal comprises disabling the inactivity timer. In other embodiments adjusting operation of an inactivity timer associated with the terminal comprises responding to the expiration of the inactivity timer by refraining from triggering an operation to move the terminal to an inactive state. In other embodiments adjusting operation of an inactivity timer associated with the terminal comprises resetting the timer when the connection between the terminal and WLAN is active.

In some embodiments the method further comprises the steps of determining whether the terminal has disconnected from the WLAN; and performing one or more operations to allow or cause the terminal to enter an inactive state if the terminal has disconnected from the WLAN. In other embodiments the method further comprises the steps of determining whether the terminal is inactive in both the WLAN and RAN; and performing one or more operations to allow or cause the terminal to enter an inactive state if the terminal is inactive in both the WLAN and RAN.

In some embodiments, after the step of performing one or more operations, the method further comprises the step of configuring the terminal with a discontinuous reception configuration.

In some embodiments the inactive state with respect to the RAN is a state of the terminal in which dedicated signalling between the terminal and the RAN is not possible.

In some embodiments the step of determining whether a terminal served by the RAN is connected to a WLAN comprises receiving an indication from the terminal indicating that the terminal does not wish to be moved to an inactive state with respect to the RAN, and the step of performing one or more operations to avoid the terminal entering an inactive state with respect to the RAN comprises refraining from moving the terminal to an inactive state.

In some embodiments the method further comprises the steps of receiving an indication from the terminal that the terminal can be moved to an inactive state with respect to the RAN; and performing one or more operations to allow or cause the terminal to enter an inactive state.

According to a second aspect, there is provided a radio access network, RAN, node in a wireless telecommunication system, the RAN node comprising means for determining whether a terminal served by the RAN is connected to a wireless local area network (WLAN); and means for adjusting operation of an inactivity timer associated with the terminal so that triggering of an operation to move the terminal to an inactive state, with respect to the first network, is unlikely or impossible.

Various embodiments of the above RAN node are also contemplated in which the RAN node is further configured or adapted, or further means are provided, to perform the method steps according to any of the above method embodiments.

According to a third aspect, there is provided a radio access network, RAN, node in a wireless telecommunication system, the RAN node comprising a processing circuit adapted to determine whether a terminal served by the RAN node is connected to a wireless local area network, WLAN; and perform one or more operations to avoid the terminal entering an inactive state with respect to the RAN if the terminal is connected to a WLAN.

In some embodiments the RAN is a 3GPP RAN, such as Long Term Evolution, LTE, Wdeband Code Division Multiple Access, WCDMA, High Speed Packet Access, HSPA or Global System for Mobile, GSM).

In some embodiments the processing circuit is adapted to determine whether a terminal served by the RAN is connected to a WLAN based on a WLAN status report received from the terminal. In other embodiments the processing circuit is adapted to determine whether a terminal served by the RAN is connected to a WLAN based on the sending of a traffic steering message sent to the terminal by the RAN. In other embodiments the processing circuit is adapted to determine whether a terminal served by the RAN is connected to a WLAN is based on the reception from the terminal of an indication that a traffic steering message, sent to the terminal by the RAN, has been applied by the terminal. In other embodiments the processing circuit is adapted to determine whether a terminal served by the RAN is connected to a WLAN based on information received from a core network associated with the RAN.

In some embodiments the one or more operations the processing circuit is adapted to perform comprises adjusting operation of an inactivity timer associated with the terminal so that triggering of an operation to move the terminal to an inactive state, with respect to the RAN, is unlikely or impossible.

In some embodiments the processing circuit is adapted to adjust operation of an inactivity timer associated with the terminal by setting the value of an inactivity timer to a value that will be interpreted to prevent the timer from ever expiring. In other embodiments the processing circuit is adapted to adjust operation of an inactivity timer associated with the terminal by setting the value of an inactivity timer to a value such that expiration of the inactivity is unlikely in view of other activities of the RAN node. In other embodiments the processing circuit is adapted to adjust operation of an inactivity timer associated with the terminal by disabling the inactivity timer. In other embodiments the processing circuit is adapted to adjust operation of an inactivity timer associated with the terminal by responding to the inactivity timer by refraining from triggering an operation to move the terminal to an inactive state. In other embodiments the processing circuit is adapted to adjust operation of an inactivity timer associated with the terminal by resetting the timer when the connection between the terminal and WLAN is active.

In some embodiments the processing circuit is further adapted to determine whether the terminal has disconnected from the WLAN; and perform one or more operations to allow or cause the terminal to enter an inactive state if the terminal has disconnected from the WLAN. In other embodiments the processing circuit is further adapted to determine whether the terminal is inactive in both the WLAN and RAN; and perform one or more operations to allow or cause the terminal to enter an inactive state if the terminal is inactive in both the WLAN and RAN.

In some embodiments the processing circuit is further adapted to configure the terminal with a discontinuous reception configuration after performing the one or more operations.

In some embodiments the inactive state with respect to the RAN is a state of the terminal in which dedicated signalling between the terminal and the RAN is not possible.

In some embodiments the processing circuit is adapted to determine whether a terminal served by the RAN is connected to a WLAN by receiving an indication from the terminal indicating that the terminal does not wish to be moved to an inactive state with respect to the RAN; and wherein the one or more operations the processing circuit is adapted to perform comprises refraining from moving the terminal to an inactive state.

In some embodiments the processing circuit is further adapted to receive an indication from the terminal that the terminal can be moved to an inactive state with respect to the RAN; and to perform one or more operations to allow or cause the terminal to enter an inactive state.

According to a fourth aspect there is provided a computer readable medium having a set of computer instructions stored therein, the computer instructions being configured such that, on execution by a processor or computer, the processor or computer performs any of the methods defined above.

According to a fifth aspect there is provided a method in a terminal that is being served by a radio access network, RAN, of a wireless telecommunications system, the method comprising determining whether the terminal is connected to a wireless local area network, WLAN; and if the terminal is connected to a WLAN, refraining from entering an inactive state with respect to the RAN.

In some embodiments the RAN is a 3GPP RAN, such as Long Term Evolution, LTE, Wdeband Code Division Multiple Access (WCDMA), High Speed Packet Access, HSPA or Global System for Mobile, GSM.

In some embodiments the step of refraining from entering an inactive state with respect to the RAN comprises refraining from entering an inactive state with respect to the RAN even if the RAN indicates that the terminal should enter an inactive state. In other embodiments the step of refraining from entering an inactive state with respect to the

RAN comprises indicating to the RAN that the terminal is refraining from entering an inactive state or that the terminal does not wish to be moved to an inactive state.

In some embodiments the method further comprising the step of entering an inactive state if indicated to do so by the RAN if it is determined that the terminal is not connected to a WLAN.

In some embodiments, after the step of refraining, the method further comprises the steps of determining whether the terminal has disconnected from the WLAN; and if the terminal has disconnected from the WLAN, enabling the terminal to enter an inactive state if indicated to do so by the RAN. In other embodiments, after the step of refraining, the method further comprises the steps of determining whether the terminal is inactive in both the WLAN and RAN; and if the terminal is inactive in both the WLAN and RAN, enabling the terminal to enter an inactive state if indicated to do so by the RAN.

In some embodiments the inactive state with respect to the RAN is a state of the terminal in which dedicated signalling between the terminal and the RAN is not possible.

According to a sixth aspect, there is provided a terminal for use in a wireless telecommunication system, the terminal comprising a processing circuit adapted to determine whether the terminal is connected to a wireless local area network, WLAN, while being served by a radio access network, RAN, of the wireless telecommunications system; and refrain from entering an inactive state with respect to the RAN if the terminal is connected to a WLAN.

In some embodiments the RAN is a 3GPP RAN, such as Long Term Evolution, LTE, Wdeband Code Division Multiple Access (WCDMA), High Speed Packet Access, HSPA or Global System for Mobile, GSM.

In some embodiments the processing circuit is adapted to refrain from entering an inactive state with respect to the RAN by refraining from entering an inactive state with respect to the RAN even if the RAN indicates that the terminal should enter an inactive state. In other embodiments the processing circuit is adapted to refrain from entering an inactive state with respect to the RAN by indicating to the RAN that the terminal is refraining from entering an inactive state or that the terminal does not wish to be moved to an inactive state.

In some embodiments the processing circuit is further adapted to control the terminal to enter an inactive state if indicated to do so by the RAN if it is determined that the terminal is not connected to a WLAN.

In some embodiments the processing circuit is further adapted to determine whether the terminal has disconnected from the WLAN; and enable the terminal to enter an inactive state if indicated to do so by the RAN if the terminal has disconnected from the WLAN. In other embodiments the processing circuit is further adapted to determine whether the terminal is inactive in both the WLAN and RAN; and enable the terminal to enter an inactive state if indicated to do so by the RAN if the terminal is inactive in both the WLAN and RAN.

In some embodiments the inactive state with respect to the RAN is a state of the terminal in which dedicated signalling between the terminal and the RAN is not possible.

According to a seventh aspect, there is provided a computer readable medium having a set of computer instructions stored therein, the computer instructions being configured such that, on execution by a processor or computer, the processor or computer performs any of the methods defined above.

According to an eighth aspect, there is provided a method of operating a radio access network, RAN, node in a RAN of a wireless telecommunication system, the method comprising receiving an indication from a terminal served by the RAN node indicating that the terminal does not wish to be moved to an inactive state with respect to the RAN; and refraining from moving the terminal to an inactive state.

In some embodiments, the method further comprises the steps of receiving an indication from the terminal that the terminal can be moved to an inactive state with respect to the RAN; and performing one or more operations to allow or cause the terminal to enter an inactive state.

According to a ninth aspect, there is provided a radio access network, RAN, node for use in a RAN of a wireless telecommunication system, the RAN node comprising a processing circuit adapted to receive an indication from a terminal served by the RAN node indicating that the terminal does not wish to be moved to an inactive state with respect to the RAN; and refrain from moving the terminal to an inactive state.

In some embodiments, the processing circuit is further adapted to receive an indication from the terminal that the terminal can be moved to an inactive state with respect to the RAN; and to perform one or more operations to allow or cause the terminal to enter an inactive state.

BRIEF DESCRIPTION OF THE DRAWINGS

Exemplary embodiments of the techniques introduced in this document are described below with reference to the following figures, in which:

Figure 1 is a signalling diagram illustrating a technique for network controlled access selection and traffic steering;

Figure 2 illustrates an exemplary wireless terminal that is able to communicate with a Wi-Fi access point;

Figure 3 illustrates a portion of a radio access network and controller nodes;

Figure 4 illustrates a network where LTE radio access parts and a Wi-Fi wireless access point are both connected to the same P-GW;

Figure 5 illustrates a UE capable of communicating both over a 3GPP-specified access technology and also over an 802.1 1 W-Fi specified access technology;

Figure 6 illustrates an exemplary control state as a sub-state of an active state;

Figure 7 illustrates an exemplary control state 540 as a new state in addition to an active state and an inactive state;

Figure 8 is a process flow diagram illustrating an exemplary network-based process according to various embodiments;

Figure 9 is a process flow diagram illustrating a further network-based process according to various embodiments;

Figure 10 is a process flow diagram illustrating an exemplary terminal-based process according to various alternative embodiments;

Figure 11 is a block diagram of an exemplary network node according to various embodiments;

Figure 12 is a block diagram of an alternative network node according to various embodiments; and

Figure 13 is a block diagram of a terminal according to various embodiments.

DETAILED DESCRIPTION

In the discussion that follows, specific details of particular embodiments of the present invention are set forth for purposes of explanation and not limitation. It will be appreciated by those skilled in the art that other embodiments may be employed apart from these specific details. Furthermore, in some instances detailed descriptions of well-known methods, nodes, interfaces, circuits, and devices are omitted so as not obscure the description with unnecessary detail. Those skilled in the art will appreciate that the functions described may be implemented in one or in several nodes. Some or all of the functions described may be implemented using hardware circuitry, such as analog and/or discrete logic gates interconnected to perform a specialized function, application specific integrated circuits (ASICs), programmable logic arrays (PLAs), etc. Likewise, some or all of the functions may be implemented using software programs and data in conjunction with one or more digital microprocessors or general purpose computers. Where nodes that communicate using the air interface are described, it will be appreciated that those nodes also have suitable radio communications circuitry. Moreover, the technology can additionally be considered to be embodied entirely within any form of computer-readable memory, including non-transitory embodiments such as solid-state memory, magnetic disk, or optical disk containing an appropriate set of computer instructions that would cause a processor to carry out the techniques described herein.

Hardware implementations of the present invention may include or encompass, without limitation, digital signal processor (DSP) hardware, a reduced instruction set processor, hardware (e.g., digital or analog) circuitry including but not limited to application specific integrated circuit(s) (ASIC) and/or field programmable gate array(s) (FPGA(s)), and (where appropriate) state machines capable of performing such functions.

In terms of computer implementation, a computer is generally understood to comprise one or more processors or one or more controllers, and the terms computer, processor, and controller may be employed interchangeably. When provided by a computer, processor, or controller, the functions may be provided by a single dedicated computer or processor or controller, by a single shared computer or processor or controller, or by a plurality of individual computers or processors or controllers, some of which may be shared or distributed. Moreover, the term "processor" or "controller" also refers to other hardware capable of performing such functions and/or executing software, such as the example hardware recited above.

The discussion that follows frequently refers to "UEs", which is the 3GPP term for end user wireless devices. It should be appreciated, however, that the techniques and apparatus described herein are not limited to 3GPP UEs, but are more generally applicable to end user wireless devices (e.g., portable cellular telephones, smartphones, wireless-enabled tablet computers, etc.) that are useable in cellular systems (also referred to as "terminals" herein). It should also be noted that the current disclosure relates to end user wireless devices that support, for example, both a wireless local area network (WLAN) technology, such as one or more of the IEEE 802.1 1 standards, and one or more wide-area cellular technologies, such as any of the wide-area radio access standards maintained by 3GPP and/or for example more than one radio access technology (RAT), for example two or more wide-area cellular technologies, such as any of the wide-area radio access standards maintained by 3GPP. End user devices are referred to in W-Fi document as "stations," or "STA" - it should be appreciated that the term "UE" or "terminal" as used herein should be understood to refer to a STA, and vice-versa, unless the context clearly indicates otherwise.

Figure 2 illustrates a wireless terminal UE 100 able to communicate, using 802.1 1-specified protocols, with a W-Fi access point 110. Downlink communication 120 is directed from the W-Fi access point 110 to the UE 100, while uplink communication

130 is directed from the UE 100 to the Wi-Fi access point 110. Note that while the detailed embodiments discussed herein are described in reference to the IEEE 802.1 1 standards commonly referred to as "Wi-Fi," the techniques and apparatus described are not necessarily limited to those standards, but may be applied more generally to other wireless local area network (WLAN) technologies.

For the UE to find an access point to connect to, a beacon signal is transmitted from the Wi-Fi access point. This beacon signal indicates details about the access point and provides the UE with enough information to be able to send a request for access. Accessing a W-Fi access point includes an information exchange between UE 100 and W-Fi Access point 110, including, for example, probe requests and responses, and authentication requests and response. The exact content of these sequences are omitted for clarity.

Figure 3 illustrates a portion of the LTE radio access network and controller nodes. The LTE network 200 is more formally known as the Evolved UMTS Terrestrial Radio Access Network (E-UTRAN) 210, and includes base stations 220, 230, 240, called enhanced NodeBs (eNBs or eNodeBs), which provide the E-UTRA (Evolved UMTS Terrestrial Radio Access) user plane and control plane protocol terminations towards the User Equipment (UE). It should be noted that even though LTE is used as an example of a radio access technology (RAT) herein, the procedures described herein can be applied to other wide-area RATs, including (but not limited to) other 3GPP RATs.

Referring again to Figure 3, the eNBs 220, 230, 240 are interconnected with each other by means of the X2 interface 250, 252, 254. The eNBs are also connected by means of the S1 interface 260, 262, 264, 266 to the Evolved Packet Core (EPC) 270, and more specifically to Mobility Management Entities (MMEs) 280, 290, by means of the SI-MME interface, and to the Serving Gateway (S-GW) 280, 290 by means of the S1-U interface. The S1 interface supports many-to-many relation between MMEs / S-GWs and eNBs.

The eNB hosts functionalities such as Radio Resource Management (RRM), radio bearer control, admission control, header compression of user plane data towards serving gateway, and routing of user plane data towards the serving gateway. The MME 280, 290 is the control node that processes the signalling between the UE and the core network EPC 270. The main functions of the MME 280, 290 are related to connection management and bearer management, which are handled via Non Access Stratum (NAS) protocols. The S-GW 280, 290 is the anchor point for UE mobility, and also includes other functionalities such as temporary downlink (DL) data buffering while the UE is being paged, packet routing and forwarding the right eNB, gathering of information for charging and lawful interception. A packet data network (PDN) Gateway (P-GW), not shown in Figure 3, is the node responsible for UE Internet Protocol (IP) address allocation, as well as for Quality-of-Service (QoS) enforcement.

Figure 4 illustrates a network where the LTE radio access parts (eNBs) 320, 322 and a Wi-Fi wireless access point 310 are both connected to the same P-GW 340. In the case of the LTE radio access parts, the eNBs 320, 322 are connected to the P-GW 340 via an S-GW 330, A UE 300 is shown that is capable of being served both from the Wi-Fi Access Point 310 and the LTE eNBs 320, 322. Arrows 350 and 352 illustrate the uplink (UL) and downlink (DL) transmissions between the UE 300 and the W-Fi AP 310 respectively and arrows 360 and 362 illustrate the uplink (UL) and downlink (DL) transmissions between the UE 300 and the eNBs respectively. Figure 4 illustrates one possible way of connecting a W-Fi access network 302 to the same core network as the 3GPP-specified access network 304. It should be noted that the presently disclosed techniques are not restricted to scenarios where the W-Fi access network 302 is connected in this way; scenarios where the networks are more separate, e.g., as illustrated in Figure 2 and 3, are also possible scenarios.

There can be an interface 370 between the Wi-Fi and 3GPP domains, whereby the two networks can exchange information that can be used to facilitate on steering traffic over the right network. One example of such information exchanged via the interface 370 is load conditions in the two networks. The two networks can also exchange information with regard to the context of the UE 300, so that each can be aware of whether the UE is being served by the other network, as well as some details of the connection over the other network (e.g. traffic volume, throughput, etc..)

It should be noted that an access-point controller (AC) functionality may also exist in the W-Fi domain 302 that controls the W-Fi AP 310. This functionality, though not depicted in the figure for the sake of clarity, can be physically located in 310, 340 or another separate physical entity.

Figure 5 illustrates a UE 400 capable of communicating both over a 3GPP-specified access technology and also over an 802.1 1 Wi-Fi specified access technology. For illustrative purposes, the processing and modem related to the W-Fi parts 410 are separated from the processing and modem related to the 3GPP parts 420. It will be appreciated that the implementation of these portions could be integrated on the same hardware unit, or can be carried out using physically distinct hardware and/or hardware-software combinations.

As noted above, many smartphones on the market today support W-Fi connectivity in addition to supporting one or more cellular radio-access technologies (RATs), such as the several RATs standardized by 3GPP. With many of these smartphones, the W-Fi connection manager, which handles communications to and from W-Fi access points, immediately tries to attach to a W-Fi access point (AP) as soon as the device is within the coverage area of the AP, provided that the SSID of the W-Fi AP is identified/pre-defined and credentials are provided (usually manually). To be able to do this, the device performs W-Fi scanning, i.e., searching for W-Fi access points to connect to, on a more-or-less continuous basis. This continuous scanning drains battery power from the UE, shortening the time between re-charges.

In an operator controlled W-Fi scenario, a UE may usually be served with communication through the cellular 3GPP network. Occasionally, e.g., when moving indoors, or when cellular performance deteriorates and there is good Wi-Fi coverage, it would be advantageous, from a network-performance perspective or a user-experience perspective, or both, for the UE to receive services through W-Fi instead of through the 3GPP radio access network. In scenarios where a UE is currently being served by a 3GPP network, it is not necessary for a UE to continuously scan for W-Fi access points whenever W-Fi operation is enabled. Likewise, when the UE is connected to a W-Fi access point, it need not necessarily search out other connection means on a continuous basis.

To address these problems, mechanisms have been provided for overcoming the shortcoming of having UEs that are capable of providing service through both a 3GPP-specified radio access and a W-Fi wireless access technology, in situations when the UE is connected to one, from continuously scanning for access opportunities of the other.

One such mechanism is the mobility procedure described above and illustrated in Figure 1. In this mechanism, to enable a 3GPP Radio Access Network (RAN) 10 to be in control of a terminal's WLAN connection, dedicated traffic steering commands (message 3) or policies can be sent from the 3GPP RAN 10 to the terminal 12. For example, the 3GPP RAN 10 can send a message 3 (with a traffic steering command or policy) to the terminal 12, ordering it to route (switch) its traffic from the 3GPP RAN 10 to a WLAN network 14, or ordering it to route (switch) the traffic from WLAN 14 to the 3GPP network 10. However, for this procedure to be used, it is required that a dedicated connection between the 3GPP RAN 10 and the terminal 12 is established.

In the event that the terminal 12 is not transmitting/receiving any data in the 3GPP RAN 10 for a certain period of time, the 3GPP network moves this terminal 12 to a state (e.g., IDLE state) in which dedicated signalling between the UE 12 and the 3GPP RAN 10 is not possible, and hence the procedure described above can no longer be used.

So, if the 3GPP RAN 10 has ordered the terminal 12 to route all its traffic over WLAN 14 and no traffic is transmitted or received over the 3GPP RAN 10, then the described mechanism in the 3GPP specifications will trigger the terminal 12 to enter the state in which dedicated signalling between the UE 12 and the 3GPP RAN 10 is not possible. As a result, the traffic steering command procedure described above cannot be used.

Similar problems occur in other procedures for managing the mobility between 3GPP networks and WLAN in which the 3GPP network needs to use dedicated signalling to communicate with the terminal, for example procedures in which the 3GPP network sends one or more messages to the terminal to configure the terminal to switch its traffic from the 3GPP network to the WLAN if certain criteria are met and/or in which the 3GPP network otherwise configures the terminal to take measurements of the available WLANs using criteria specified by the 3GPP network.

Described below are several techniques that allow the terminal to remain in a state where dedicated signalling (e.g. dedicated traffic steering commands) can be used, even when the terminal has no transmissions or receptions of data over 3GPP RAN, such as in the case when the terminal has routed (or is routing) its traffic over WLAN.

As noted above in the Summary section, in a first embodiment of these techniques, this is realized by having the 3GPP RAN adjust timers in a way such that triggering of the process of moving a terminal to a state without possibility of transmission of dedicated traffic steering commands to the terminal is impossible or very unlikely. In a related approach, the actions associated with timer expiry are changed such that triggering of the process of moving a terminal to a state in which dedicated signalling between the UE and the 3GPP RAN is not possible is prevented.

In a second embodiment of the techniques, the terminal is adapted to refrain from entering a state in which dedicated signalling between the UE and the 3GPP RAN is not possible when it is necessary for the 3GPP RAN to retain control over the UE.

For the sake of simplicity, the list below introduces some terms which will be used throughout this document:

- Active state - A state of the terminal in which dedicated signalling between the terminal and the wide-area RAN (e.g., the 3GPP RAN) is possible. Examples of such states are: CELL_FACH and CELL_DCH in UMTS, and RRC_CONNECTED in LTE (with RRC representing Radio Resource Control).
- Inactive state - A state of the terminal in which dedicated signalling between the terminal and the wide-area RAN (e.g., the 3GPP RAN) is not possible. Examples of such states are: URA_PCH, CELL_PCH and Idle Mode in UMTS, and RRC IDLE in LTE.

At various points in this document it may be mentioned that a terminal is "connected" to WLAN. It should be appreciated that being connected to WLAN can mean any of several different things, as exemplified by the existence of one or more of the below conditions:

- 802.1 1 authentication (Authentication to the WLAN AP) has been completed or is underway;
- 802.1x extensible authentication protocol for subscriber identity module (EAP-SIM) authentication (Authentication to the authentication, authorization and accounting (AAA)-servers) has been completed or is underway;
- Four way hand-shake between the terminal and the WLAN network has been completed;
- An IP address has been assigned to the terminal in WLAN;

- a packet data network (PDN) connection has been established through the WLAN network, i.e., a connection between the terminal and the PDN gateway;
- Data traffic has been started through the WLAN network.

Examples of messages indicating to the UE that it should be moved to an inactive state are:

- RRCConnectionRelease. As specified in section 5.3.8 of 3GPP TS 36.331 **v11.1.10;**
- Radio Bearer Reconfiguration. As specified in section 8.2 in 3GPP TS 25.331, v. 11.5.0.

A control state in 3GPP

In the 3GPP states described above, the terminal has both user plane and control plane connections to the RAN when in an active state, and has neither when in an inactive state. The user plane carries the data traffic and the control plane is used to configure the terminal. In certain circumstances, e.g., in the embodiments above when 3GPP RAN is used for control purposes only (e.g. control of a terminal's WLAN connection (through signalling from the 3GPP RAN to the terminal) after the terminal has moved its traffic to the WLAN), it is desirable for the terminal to be in a state in which it has a control plane connection, but not necessarily a user plane connection. Such a state is referred to as a *control state* in this document. The control state may be either a sub-state of the active state in which there is no user plane traffic or a new state with no user plane connectivity.

In the example shown in Figure 6, the control state 500 is a sub-state of the active state 510, where the terminal has both user plane (UP) and control plane (CP) connections to the 3GPP RAN, but no user plane traffic. In the inactive state 520, the terminal has neither UP nor CP connections to the 3GPP RAN. In this case, existing 3GPP procedures, i.e. as specified in 3GPP TS 25.304 v11.4.0 (2013-09) and 3GPP TS 36.304 v11.5.0 (2013-09), may be followed to maintain UE contexts, handling mobility, etc. However, a new mechanism is required to keep the terminal in the active state 510. It is also possible to reduce the terminal contexts in 3GPP when no data traffic exists.

In the example illustrated in Figure 7, the control state 540 is a new state in addition to the active state 550 and inactive state 560, where the terminal has only a control plane connection and no user plane connection. For user plane data transmission, the user plane connection has to be established for the terminal. When only a control plane connection is maintained, UE contexts in the 3GPP network (RAN and/or core network) may be minimized. For example, there may be no default bearer in LTE and no primary packet data protocol (PDP) context in UMTS. It is also possible that the default bearer is kept, but UE contexts in (e)NB and/or radio network controller (RNC) is minimized.

In either case, with a user plane connection but no user plane traffic, the control state 500, 540 is a special case of the active state 510, 550, but with no active data traffic. Current 3GPP procedures will change the terminal to the inactive state 520, 560 when no data activity is detected for a while. Methods are described below to avoid the terminal entering the inactive state 520, 560. Once the control plane connection is not needed anymore, the methods allow the terminal to transit to the inactive state 520, 560.

In the following description of the various solutions provided by the present disclosure, the arrangement shown in Figure 4 is used as a basis for the explanation, and references in the description below to a terminal/UE, eNB, 3GPP network, Wi-Fi AP and WLAN are to the UE 300, eNB 320, 3GPP network 304, Wi-Fi AP 310 and WLAN 302 shown in Figure 4. However, it will be appreciated that the various solutions provided by the present disclosure are not limited to implementation in the arrangement shown in Figure 4.

<u>Network based solution for avoiding terminal to enter inactive state</u>

According to several network-based solutions contemplated by the present disclosure, a RAN network node 320, e.g., an eNB, a base station or Radio Network Controller (RNC), will perform one or more operations to avoid that a WLAN connected terminal 300 enters an inactive state.

Figure 8 is a process flow diagram illustrating an example process according to the network-based techniques described above, as implemented in a RAN node 320. As shown at block 610, the illustrated method begins with the sending of a traffic steering command to the terminal 300, indicating that the terminal 300 should steer its traffic towards a WLAN 302. It will be appreciated that the terminal's behaviour may be commanded by a node other than the node carrying out the other operations of Figure 8, or that the terminal 300 may connect to the WLAN 302 for other reasons, in some embodiments - for that reason, block 610 is outlined with a dashed line to indicate that this operation is "optional."

The method continues, as shown at block 620, with determining whether the terminal 300 is connected to a WLAN 302. Various ways of implementing block 620 are described in more detail below.

If the terminal 300 is connected to a WLAN 302, then, as shown at block 630, the network node 320 performs one or more operations to avoid that the WLAN connected terminal enters an inactive state, with respect to the first network 304. Various ways of implementing block 630 are described in more detail below.

Some particular ways of implementing block 630 provide that operation of an inactivity timer is adjusted, so that a trigger operation to move the terminal 300 to an inactive state, with respect to the first network 304, is unlikely or impossible. Several variations of adjusting operation of an inactivity timer are described below.

Finally, as shown at block 640, another traffic steering command is sent to the terminal 300, indicating that the terminal 300 should steer its traffic toward the RAN node 320. It will be appreciated that this command would not be possible if the terminal 300 had been permitted to enter an inactive state with respect to the RAN 304. It will also be appreciated that this command may be sent by a node other than the node performing the operations at block 620 and 630; accordingly, block 640 is also outlined with a dashed line, indicating that this step is "optional."

As noted above, in some embodiments block 630 can be implemented by having a network node 320 configure an inactivity timer, which is used for triggering the process of moving the terminal 300 from an active state to an inactive state, in a certain way. The timer could, for example, be configured in one or more of the following ways:

- Set the timer value to infinity (or to a value that is interpreted by the timer so that the timer never expires);
- Set the timer value such that it is unlikely that it will expire before it is restarted. For example, there may be signalling of messages between the terminal 300 and the 3GPP network 304 also when the terminal 300 is

connected to WLAN 302, so if the timer is set to a value larger than the expected inter-arrival time of the messages between the terminal 300 and the 3GPP network 304 then the timer will generally be restarted before expiring.

- Disable the timer.
- Reset the timer when ongoing communication is indicative of an active connection between the terminal 300 and WLAN 302 (e.g. data is being transmitted between the terminal 300 and WLAN 302). There are many different ways that the 3GPP network 304 can be aware of the ongoing communication, e.g., explicit signalling between the WLAN AP 310 and eNB 320, or between the UE 300 and eNB 320.

It should be appreciated that there may be multiple inactivity timers that the procedures described herein can be applied to. For example, one timer may be used for moving a terminal 300 from the state CELL_DCH to the state URA_PCH and another timer may be used to move the terminal 300 to the state IDLE from any other state. The techniques described herein may be applied to all or a subset of these timers.

Another way to realize block 630 in the network-based approach is to adapt the network node 320 so that it refrains from sending a command ordering the terminal 300 to go to an inactive state when the associated timer expires, for example, if the timer that controls when a terminal 300 is moving from CELL_DCH to Idle Mode expires, a network node 320 adapted according to this approach will refrain from sending a command ordering the terminal 300 to go to IDLE.

Different possibilities exist for the 3GPP network 304 to determine whether the terminal 300 is connected to WLAN 302 in block 620. Below are listed a few examples that may or may not be used in combination:

- Based on a WLAN status report from the terminal 300. For example, the UE 300 may signal, to the 3GPP network 304, information regarding its connection to WLAN 302. For instance, the terminal 300 may signal a WLAN status report upon connection to WLAN 302.
- If the 3GPP network 304 is in control of when the terminal 300 should connect to and in control of when the terminal 300 should disconnect from WLAN 302, the 3GPP network 304 will then know, e.g., based on (e.g. traffic steering) commands sent to the UE 300 and/or on receipt of an

indication from the UE 300 that the commands have been applied, whether the UE 300 is connected to WLAN 302 or not.

- Based on information received from the core network.

Enabling a terminal to enter an inactive state

Following the process above in which the WLAN connected terminal is prevented from entering an inactive state, if the terminal 300 is disconnected to WLAN 302 or is inactive in both 3GPP 304 and WLAN 302 for some time (i.e. there has been no data transmission for a predetermined period), it may be desired to enter an inactive state to save network resources and reduce battery consumption.

Figure 9 shows an exemplary process flow diagram in a network node 320 that implements this functionality. Following a block 650 in which the network node 320 performs one or more operations to avoid the WLAN connected terminal from entering an inactive state (as described above with reference to block 630 of Figure 8), the network node 320 determines, in one embodiment, whether the terminal 300 has disconnected from the WLAN 302, and in another embodiment, whether the terminal 300 is inactive in both the WLAN 302 and 3GPP network 304 (block 660). If the terminal 300 has disconnected from the WLAN 302, or the terminal 300 is inactive in both the WLAN 302 and 3GPP network 304 (as appropriate), the network node 320 performs one or more operations to allow or cause the terminal 300 to enter an inactive state (block 670).

As noted above, in some embodiments, the one or more operations in block 670 are performed upon disconnection from the WLAN 302, for example. Upon knowing that the terminal 300 is not connected to WLAN 302 (anymore), the network node 320 can (again) allow the terminal 300 to be moved to an inactive state (if, for example, no user traffic occurs between the 3GPP network 304 and the terminal 300) by, for example, using one or more of the following alternatives:

- Set the timer value to a finite value that is suitable for a UE 300 not connected to WLAN 302. For example, if the 3GPP network 304 used timer value T1 prior to the UE 300 being connected to WLAN 302, and when the UE 300 connected to WLAN 302 it was set to T2, then according to this alternative the timer value can be set to T1 again upon the 3GPP network 304 knowing that the terminal 300 is no longer connected to WLAN 302. Note that the 3GPP network 304 may set the timer to another value than T1 upon knowing that the terminal 300 is no longer connected to WLAN 302, if deemed suitable.

- Enable the timer.

Also as noted above, in some embodiments, the one or more operations in block 670 to move the terminal 300 into an inactive state are performed when the terminal 300 has become inactive in both the 3GPP RAN 304 and WLAN 302. Upon knowing that the terminal 300 is not active in WLAN 302 for a long period, the network node 320 may allow the terminal 300 to enter the inactive state. The mechanism to allow the state change can be the same as described above for the case when the terminal 300 disconnects from the WLAN 302.

Terminal activity information may be communicated from WLAN 302 to 3GPP RAN 304 in a couple of ways, e.g.:

- Based on a WLAN traffic activity report from the terminal 300;
- Via an X2 type link between (e)NB/RNC 320 and WLAN AP/gateway 310; and/or
- Based on information from a core network in which the WLAN 302 is integrated.

In one embodiment, the terminal activity information may be an inactivity indicator. In this case, the terminal inactivity in WLAN 302 is determined by the WLAN 302, e.g., using an inactivity timer located in WLAN 302, WLAN 302 will inform 3GPP RAN 304 that the terminal 300 is inactive in WLAN 302, e.g., upon expiry of the timer. In another embodiment, the exchanged information is an indicator that the terminal 300 is still active in WLAN 302. Then 3GPP RAN 304 uses the signalled WLAN activity to determine when the terminal 300 should enter the inactive state.

One advantage of the techniques in this section is that in some situations 3GPP 304 has only control over which RAT the terminal 300 should use for communication but no control right to disconnect the terminal 300 from WLAN 302. The techniques avoid a situation where the terminal 300 is connected to 3GPP 304 but has no active traffic at all in both RATs.

Another advantage is that in some situations the 3GPP network 304 may not need to control how the terminal 300 is handling WLAN 302, in which case it could allow the UE

300 to enter an inactive state, e.g., to save power and to decrease load in the RAN 304 (both signalling and processing load). Instead the 3GPP network 304 may only require keeping control over the terminal 300 when the terminal 300 has ongoing traffic in WLAN 302. In other words, if the 3GPP network 304 has indicated that the terminal 300 should connect to WLAN 302 but the terminal 300 has no ongoing traffic in WLAN 302, then the 3GPP network 304 may leave it up to terminal 300 implementation (or other procedures) how the terminal's WLAN connection should be handled. The techniques are also useful when the 3GPP RAN 304 has only control over which RAT the UE 300 should use for communication but no control right to disconnect the UE 300 from WLAN 302.

<u>Terminal based solution for avoiding terminal to enter inactive state</u>

In an alternative to the above approaches, a terminal 300 is adapted or configured so that it will, when connected to WLAN 302, refrain from entering an inactive state even if indicated so by the network 304. In a variant of this approach, the terminal 300 indicates to the 3GPP RAN 304 that it is refraining from entering an inactive state. For example, this indication could be sent to the 3GPP RAN 304 when the UE 300 receives, from the 3GPP RAN 304, a command indicating that the terminal 300 should enter an inactive state.

Figure 10 shows an exemplary process flow diagram in a terminal 300 that implements this functionality. In a block 700, it is determined if the terminal 300 is connected to a WLAN 302. If the terminal 300 is connected to a WLAN 302, the terminal 300 refrains from entering an inactive state with respect to the 3GPP network 304 (block 710), for example by refraining from entering an inactive state even if indicated so by the 3GPP network 304, or by the terminal 300 indicating to the 3GPP RAN 304 that it is refraining from entering an inactive state.

If at block 700 it is determined that the terminal 300 is not connected to a WLAN 302, the terminal 300 is configured to operate normally and enter an inactive state if indicated to do so by the 3GPP network 304 (block 720).

If, following block 710 in which the terminal 300 refrains from entering an inactive state, the terminal 300 subsequently disconnects from the WLAN 302 or the terminal 300 is inactive in both the WLAN 302 and 3GPP network 304 (as determined by repeating block 700), the terminal 300 can return to operating normally and enter an inactive state if indicated by the 3GPP network 304 (block 720).

Thus, in some embodiments, upon disconnection from a WLAN network 302, a terminal 300 adapted or configured according to this approach (i.e. configured according to block 710) will enable itself to enter an inactive state (block 720). The terminal 300 will subsequently follow the 3GPP network's indications to do so.

In another alternative implementation of block 710, the terminal 300 can indicate to the 3GPP RAN 304 that terminal 300 does not wish to be moved to an inactive state with respect to the 3GPP RAN 304 and, if so, the 3GPP RAN 304 refrains from moving the terminal 300 to an inactive state. The terminal 300 could indicate so, e.g., upon connection to WLAN 302.

If the terminal 300 is configured to refrain from entering an inactive state, the terminal 300 could, upon disconnection from a WLAN 302, indicate to the 3GPP RAN 304 at block 720 that the 3GPP RAN 304 can move the terminal 300 to inactive state and if so, 3GPP RAN 304 may subsequently move the terminal 300 to the inactive state (if deemed suitable by the 3GPP RAN 304).

Methods for power savings for UE in active state

As discussed above, keeping the UE 300 always connected to 3GPP RAN 304 (i.e. by preventing the UE 300 from entering an inactive state) will make it possible for the 3GPP RAN 304 to have dedicated control in steering traffic sent by the UE 300 from WLAN 302 back to 3GPP RAN 304. However, keeping both 3GPP radio and WLAN radio active can drain the UE battery. Accordingly, in another embodiment of this invention, in addition to setting the inactivity timer for the UE 300 that is connected to WLAN 302 to a different value (or performing one or more other operations to avoid the UE 300 from entering an inactive state), the 3GPP RAN 304 also configures the UE 300 with a discontinuous reception (DRX) configuration in order to reduce the UE battery consumption. This can be achieved by setting the DRX cycle value to a longer value, i.e. 2560 ms as the largest value specified in 3GPP TS 36.321 v11.3.0 (2013-06) or/and setting a shorter "on duration" timer, i.e. less than 10 ms in the range specified in 3GPP TS 36.321, so that the UE 300 will be mostly in a sleeping state. During the on duration, the UE 300 will be able to perform measurements and if the conditions for sending measurement reports (e.g. terminal reports as described above) are fulfilled it can request uplink resources for sending the measurement to 3GPP RAN 304.

Alternatively, the UE 300 might be configured to send all traffic to 3GPP RAN 304 (i.e., move traffic from WLAN 302 to the 3GPP RAN) immediately upon fulfilment of the previously specified (or predetermined) conditions, rather than sending measurement reports to 3GPP RAN 304. The conditions for triggering measurements or immediate sending of all traffic from WLAN 302 to 3GPP RAN 304 can be either broadcast or communicated to the UE 300 in a dedicated fashion by the 3GPP RAN 304. Once the UE 300 start sending all traffic to the 3GPP RAN 304, the DRX settings can be modified to reflect this (e.g., turn DRX off, decrease the DRX cycle length, etc.).

Note that sending of traffic to WLAN 302 doesn't necessarily have to be complete. For example, it might be decided to run some background traffic over WLAN 302 while routing the traffic with the most stringent quality requirements over 3GPP. When the decision is made to do such partial sending of traffic to WLAN 302, the 3GPP RAN 304 will configure the UE 300 with DRX settings that are appropriate for the traffic that is being handled via 3GPP RAN 304, as already indicated above, rather than setting them to longer values as proposed above.

Advantages of various embodiments of the presently disclosed techniques (including the network-based and terminal-based techniques described above) include that these techniques can be used to allow a terminal supporting 3GPP to remain in connected mode even when the terminal's traffic has been steered to WLAN and no traffic is carried over 3GPP. This allows the 3GPP network to maintain the control over the terminal with dedicated commands, for example to carry out mobility procedures.

Apparatus

Although the described solutions may be implemented in any appropriate type of telecommunication system supporting any suitable communication standards and using any suitable components, network-based embodiments of the described solutions may be implemented in one or more nodes of a radio access network (RAN), such as a node in a 3GPP RAN network, such as LTE. These nodes include, but are not limited to, an eNodeB in an LTE network, or a base station or RNC in a UMTS network.

The network in which these techniques are implemented may further include any additional elements suitable to support communication between wireless devices or between a wireless device and another communication device (such as a landline telephone). Although the illustrated network nodes may represent a network communication device that includes any suitable combination of hardware and/or software, these network nodes may, in particular embodiments, represent a device such as the example network node 900 illustrated in greater detail by Figure 11. Similarly, although the illustrated base station nodes (e.g., an eNB) may represent network nodes that include any suitable combination of hardware and/or software, these network nodes may, in particular embodiments, represent devices such as the example network node 1000 illustrated in greater detail by Figure 12.

As shown in Figure 11, the example network node 900 includes processing circuitry 920, a memory 930, and network interface circuitry 910. In particular embodiments, some or all of the functionality described above as being provided by a core network node or a node in a RAN may be provided by the processing circuitry 920 executing instructions stored on a computer-readable medium, such as the memory 930 shown in Figure 11. Alternative embodiments of the network node 900 may include additional components beyond those shown in Figure 11 that may be responsible for providing certain aspects of the node's functionality, including any of the functionality described above and/or any functionality necessary to support the solutions described above.

As shown in Figure 12, an example base station 1000 includes processing circuitry 1020, a memory 1030, radio circuitry 1010, and at least one antenna. The processing circuitry 1020 may comprise RF circuitry and baseband processing circuitry (not shown). In particular embodiments, some or all of the functionality described above as being provided by a mobile base station, a radio network controller, a base station controller, a relay node, a NodeB, an enhanced NodeB, and/or any other type of mobile communications node may be provided by the processing circuitry 1020 executing instructions stored on a computer-readable medium, such as the memory 1030 shown in Figure 12. Alternative embodiments of the network node 1000 may include additional components responsible for providing additional functionality, including any of the functionality identified above and/or any functionality necessary to support the solution described above.

Several of the terminal-based techniques and methods described above may be implemented using radio circuitry and electronic data processing circuitry provided in a terminal. Figure 13 illustrates features of an example terminal 1500 according to several embodiments of the present invention. Terminal 1500, which may be a UE configured for operation with an LTE network (E-UTRAN) and that also supports Wi-Fi, for example, comprises a transceiver unit 1520 for communicating with one or more base stations as well as a processing circuit 1510 for processing the signals transmitted and received by the transceiver unit 1520. Transceiver unit 1520 includes a transmitter 1525 coupled to one or more transmit antennas 1528 and receiver 1530 coupled to one or more receiver antennas 1533. The same antenna(s) 1528 and 1533 may be used for both transmission and reception. Receiver 1530 and transmitter 1525 use known radio processing and signal processing components and techniques, typically according to a particular telecommunications standard such as the 3GPP standards for LTE. Note also that transmitter unit 1520 may comprise separate radio and/or baseband circuitry for each of two or more different types of radio access network, such as radio/baseband circuitry adapted for E-UTRAN access and separate radio/baseband circuitry adapted for Wi-Fi access. The same applies to the antennas -while in some cases one or more antennas may be used for accessing multiple types of networks, in other cases one or more antennas may be specifically adapted to a particular radio access network or networks. Because the various details and engineering tradeoffs associated with the design and implementation of such circuitry are well known and are unnecessary to a full understanding of the invention, additional details are not shown here.

Processing circuit 1510 comprises one or more processors 1540 coupled to one or more memory devices 1550 that make up a data storage memory 1555 and a program storage memory 1560. Processor 1540, identified as CPU 1540 in Figure 13, may be a microprocessor, microcontroller, or digital signal processor, in some embodiments. More generally, processing circuit 1510 may comprise a processor/firmware combination, or specialized digital hardware, or a combination thereof. Memory 1550 may comprise one or several types of memory such as read-only memory (ROM), random-access memory, cache memory, flash memory devices, optical storage devices, etc. Because terminal 1500 supports multiple radio access networks, processing circuit 1510 may include separate processing resources dedicated to one or several radio access technologies, in some embodiments. Again, because the various details and engineering tradeoffs associated with the design of baseband processing circuitry for mobile devices are well known and are unnecessary to a full understanding of the invention, additional details are not shown here.

Typical functions of the processing circuit 1510 include modulation and coding of transmitted signals and the demodulation and decoding of received signals. In several embodiments of the disclosed techniques, processing circuit 1510 is adapted, using suitable program code stored in program storage memory 1560, for example, to carry out one of the techniques described above for access network selection. Of course, it will be appreciated that not all of the steps of these techniques are necessarily performed in a single microprocessor or even in a single module.

A draft discussion document to be released for standardization purposes is attached to the present document as Appendix A. This Appendix A forms an integral part of the present disclosure.

It will be appreciated by the person of skill in the art that various modifications may be made to the above described embodiments without departing from the scope of the presently disclosed techniques. For example, it will be readily appreciated that although the above embodiments are described with reference to parts of a 3GPP network, embodiments will also be applicable to like networks, such as a successor of the 3GPP network, having like functional components. Therefore, in particular, the terms 3GPP and associated or related terms used in the above description and in the enclosed drawings and any appended claims now or in the future are to be interpreted accordingly.

Examples of several embodiments have been described in detail above and are summarized below, with reference to the attached illustrations of specific embodiments. Because it is not possible, of course, to describe every conceivable combination of components or techniques, those skilled in the art will appreciate that the presently disclosed techniques can be implemented in other ways than those specifically set forth herein. The present embodiments are thus to be considered in all respects as illustrative and not restrictive.

Appendix A

3GPP TSG-RAN WG2 #82 **Tdoc R2-1 3xxxx**

Fukuoka, Japan, 20th - 24th May 2013

DRAFT

Agenda Item: **x.x.x.x**

Source: **Ericsson, ST-Ericsson**

Title: **WLAN/3GPP Radio Interworking - More on IDLE and CONNECTED mode solution**

Document for: **Discussion, Decision**

1 Introduction

Improved integration of WLAN access points into 3GPP radio access networks is intended to enhance radio resource utilization, network capacity and user perceived performance. At the same time, it should not significantly increase, and preferably decrease, the battery consumption of terminals.

As of today, WLAN access points are mostly deployed independently of the LTE or UMTS access. Only recently somewhat tighter integration on core network level for the purpose of authentication has been observed. But it is still mainly left to UE implementation to discover WLAN APs and to decide proprietarily whether to use it or not. This does not only result in undesirable load distribution and non-ideal performance. It also requires the UE to unnecessary scan for WLAN access which increases the battery consumption. Frequent transitions between WLAN and UMTS/LTE would cause additional control signalling traffic and therefore also increase the battery consumption as well as the load in RAN and CN and should thus be avoided, and unnecessary service interruptions may further be created.

In this paper we will expand on the solution description 3 as defined in the TR [1] introducing a solution working in both idle and connected mode, see Section 3 for an extended description while section 2 contains the reasoning. Conformance to the set of requirements identified in the TR is provided in Section 4. A text proposal updating the solution description 3 can be found in Annex A. Based on the description and comparison, the conclusion is that the WLAN integration would from a RAN performance and complexity point of view be well served by either a connected mode only or a connected and idle mode combined solution. Both possibilities are having same overall procedural signalling that matches current RRC signalling enabling flexibility in control.

2 Discussion

In the following sub-sections we briefly discuss the anticipated benefits due to traffic steering, describe briefly the existing mobility mechanisms in idle and connected mode and discuss how they could be extended for WLAN integration.

2.1 Anticipated benefits due to traffic steering

As expressed in the study item and during initial discussions in RAN2, the intention of most operator deployed WLAN APs is to extend the capacity and the experienced performance for users in areas with high load. To achieve that, it is of course necessary that the load is distributed across the access technologies in accordance with their capacity. Furthermore, it is vital that the radio conditions are taken into account so that

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UEs in good WLAN radio conditions are connected to WLAN whereas UEs in poor WLAN radio conditions stay in LTE or UTRAN.

Observation 1 A traffic steering algorithm needs to take capacity and load of WLAN APs and (e)NBs as well as radio conditions of UEs into account.

As was observed in recent study items (e.g. eDDA) a large fraction of the UE population run so called back-ground- or inter-active services which create small amounts of data with inter-arrival times of several seconds or tens of seconds. Offloading a UE sending only a couple of bytes every few (tens of) seconds does not help to reduce the load in a cell. In fact, it may even increase the load due to additional control signalling. On the other hand, if it is possible to steer the traffic of a UE performing a file download or a video streaming session to a less loaded node, this has considerable offloading potential. Naturally, the amount of control signalling is negligible compared to the large amount of data being transferred.

Furthermore, the generated load by a UE depends also on the channel conditions in which the UE is while transmitting or receiving a large amount of data. In particular the UEs sending or receiving significant amounts of data while being in poor radio conditions contribute a lot to the load of their serving cell.

Observation 2 Traffic steering should focus on UEs contributing most to the overload in their serving cell.

As RAN2 observed, for background- and inter-active services the signalling overhead compared to the transmitted user data is pretty high. This effect is particularly pronounced when cells are small and UEs are moving. Additional control signalling caused by traffic steering to and from WLAN would emphasize this effect. As has also been observed in the heterogeneous network study, it is preferable to serve moving UEs by macro cells. In particular if pico cells are deployed on a separate carrier, detecting and measuring those would increase the terminal's battery consumption without giving a significant benefit in terms of offloading potential. The same reasoning should of course be applied to WLAN APs which typically have a relatively small coverage area and are, of course, operating on a different carrier frequency than the 3GPP RAT. On the other hand, a UE that has to transfer a significant amount of data may benefit from steering traffic to WLAN if it is in close proximity to a WLAN AP. This is since in good radio conditions the data transfer will take less time so that the UE can enter DRX quickly.

Observation 3 Traffic steering to WLAN should be battery efficient and create low (relative) control signalling overhead.

2.2 Existing mobility mechanisms within 3GPP RATs

In LTE RRC CONNECTED and UMTS CELL_DCH/CELL_FACH the network (RNC or eNB) has tight control of the UE's mobility. This applies both for inter- and intra- frequency use cases. The serving RNC or eNB may for example decide not to handover a UE to a pico cell (see the heterogeneous network discussions) if it discovers that a UE is moving quickly. Or it decides, not to request inter-frequency measurements from a UE that is moving or has only negligible amounts of data to transfer. As indicated above, this helps to reduce UE's battery consumption as well as signalling load.

Observation 4 Network based mobility as in RRC CONNECTED/CELL_DCH/CELL_FACH allows to steer those UEs that contribute most to the (over-)load.

If a UE does not transfer any data it usually enters DRX and thereby reduces battery consumption. With an appropriate configuration, a UE in RRC CONNECTED with DRX does not transmit any UL data except for mobility related signalling. Therefore, signalling overhead and battery consumption are very low in this state provided that the UE is not moving too much.

Observation 5 RRC CONNECTED with DRX is efficient in terms of UE power consumption and control signalling provided that a UE is not moving too much.

Mobility in LTE RRC IDLE mode and UMTS URA_PCH/CELL_PCH/IDLE modes has been optimized to reduce UEs' battery consumption as well as the signalling load. The network releases the RRC connection of a UE that is not transferring any data for a longer period of time. The UE may then sleep most of the time and only wake up to receive paging and to perform measurements for the purpose of cell re-selection. As long as it stays within the tracking area or URA, CELL (if in such UMTS states) no control signalling is needed.

Load balancing mechanisms have also been introduced for IDLE mode. The UE applies cell re-selection thresholds or priorities that are either broadcast or provided to the UE when the RRC connection is being released. While this is a decent tool for coarse inter-frequency or inter-RAT load control, it cannot take aspects such as the UE's contribution to the overall load cell into account. That is, of course, due to the fact that a UE in IDLE mode has by definition no ongoing data transfer. Therefore, IDLE mode load balancing primarily controls the number of UEs camping on a certain frequency or RAT. As a consequence, it can also help to level out the number of UEs that perform accesses on those frequencies or RATs as soon as a data transfer starts. However, as soon as the UE enters RRC CONNECTED, the network has full control and can decide, e.g. based on the amount of data being transferred or based on serving cell measurements, whether or not to trigger inter-frequency or inter-RAT measurements and whether or not to handover the UE. As explained in section 2.1 (Observation 2) it is essential to offload those UEs that contribute most to the current overload condition.

Observation 6 **Inter-frequency and inter-RAT load balancing in IDLE mode controls the number of UEs camping on a carrier but cannot focus on those UEs that contribute most to the overload in the current frequency or RAT.**

2.3 Applying idle and connected mode mobility to WLAN

The above observations indicate that network interaction is necessary and UE cannot perform the traffic steering decisions between 3GPP and WLAN on its own.

Observation 7 **Access network selection based on traffic steering to and from WLAN allows offloading main load contributors while minimizing battery consumption for the others.**

If the traffic steering can be decided by the network in both idle and connected modes an efficient steering of UEs can be made. The most important steering is when there is traffic ongoing in either WLAN and/or 3GPP RAT so this would need to be considered as first priority.

Proposal 1 **Adopt network controlled traffic steering in RRC CONNECTED to WLAN.**

As explained above, the main intention is to steer traffic of those UEs to WLAN that contribute most to the load in the serving LTE or UTRAN cell. For such UEs, the relative overhead in terms of control signalling is negligible. Therefore, it is possible to maintain the RRC connection for those UEs even if they offload all their data to WLAN. The same reasoning applies to the UE's battery consumption: Transferring a significant amount of data in WLAN consumes considerably more battery power than maintaining an RRC connection (with DRX) in LTE or UMTS.

If the RRC connection is maintained while the UE transfers (some or all) user plane data to WLAN, the RAN can also easily decide when to steer traffic back from WLAN to 3GPP. This will also apply to the UMTS states CELL_PCH and URA_PCH states in addition to CELL_FACH and CELL_DCH states as the UE is known in RAN and can thus be paged in order to be steered back if RAN sees a potential need (e.g. load became low in RAN).

Proposal 2 **Adopt network controlled traffic steering in RRC CONNECTED to 3GPP.**

This leaves the question whether there is any need for traffic steering to and from WLAN for UEs that are idle in 3GPP. However, idle mode is an important legacy state and there is no intention to change this so it would need to be supported. As explained above, the 3GPP RAN may maintain an RRC connection for UEs actively involved in a data transfer on WLAN, however if such a UE is idle mode (here meaning that the UE has no an RRC signalling connection), the UE will on the basis of thresholds and/or policies trigger establishment of a connection to 3GPP RAN and from that point eNB/RNC can further process relevant information and, if needed, steer the UE's traffic to 3GPP or say it should remain in WLAN in case the UE are connected to WLAN. This would include the general case to which RAT the UE will send the next UL packet.

Proposal 3 **For backwards traffic steering of a UE in idle mode the UE should establish an RRC connection on the basis of thresholds and/or policies.**

Proposal 4 **Upon RRC connection establishment RAN performs access network selection and traffic steering.**

3 Detailed Solution

A mobility procedure similar to the intra-3GPP mobility procedure can be extended and adopted to work also for WLAN, see Figure 1, [2].

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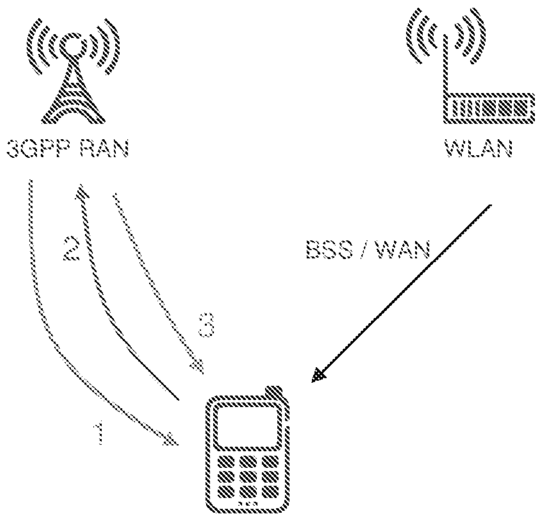

Figure 1: 3GPP - WLAN mobility procedure.

The 3GPP RAN would configure a UE with events for triggering the UE to send WLAN measurement reports to the 3GPP network. One event for finding out when the serving 3GPP cell becomes bad and/or WLAN AP gets good, which can be used for steering traffic from 3GPP to WLAN. Another event for finding out when the serving 3GPP cell becomes good and/or the WLAN AP gets bad which can be used for steering traffic back to 3GPP, naturally this event would only be configured for UEs which has traffic in WLAN.

The event configurations could either be broadcast or dedicated, see examples in Table 1.

Table 1: Example of conditions for event reporting

Event configuration for 3GPP bad and WLAN good	Event configuration for 3GPP good and WLAN bad
LTE RSRP[1] < Threshold1 WLAN RSSI > Threshold2	LTE RSRP[1] > Threshold1 WLAN RSSI < Threshold2

When the event conditions are met the UE will send a WLAN measurement report to the 3GPP RAN. The WLAN measurement report contains relevant information such as WLAN channel quality and WLAN load (obtained through HotSpot 2.0). An identifier for the WLAN should also be reported to support per WLAN system distinction.

The 3GPP RAN will, based on the measurement report from the UE and the state of the 3GPP RAN, decide if the UE's traffic should be steered to or from WLAN. The 3GPP RAN sends a traffic steering command which tells the UE to steer traffic to or from WLAN. It is FFS whether the traffic steering command should indicate which radio bearers should be handed over, or if it is sufficient to move all traffic (possibly keeping traffic of a certain QCI in 3GPP).

Naturally this mobility procedure allows for per-UE control. For example, the 3GPP network can configure the measurement triggering event for only the UEs which contribute to significant 3GPP load and the rest of the UEs can save power as they do not need to scan for WLAN unnecessary. The 3GPP network could also make sure to configure the event only when there is a need to perform offloading to WLAN, i.e. in case the 3GPP network can fulfill the QoS requirements for all the UEs it would not configure this event and instead keep the UEs in 3GPP.

Proposal 5 **The network may configure UEs with WLAN <u>radio signal</u> measurements. Similar principles as for inter-frequency/RAT measurements should apply.**

Proposal 6 **The RAN may instruct a UE to offload data to a particular WLAN access (e.g. SSID). It is up to the UE to execute setup of the WLAN connection and to direct traffic onto WLAN.**

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[1] In UMTS RSCP can be used.

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Proposal 7 **It is FFS whether the RAN may indicate per radio bearer traffic steering.**

Proposal 8 **The traffic steering to WLAN does not imply an RRC connection release, i.e., the RRC connection may be maintained but the RAN may notice that radio bearers do not carry any data.**

Sections 3.1 and 3.2 show some example drawings of mobility to and from WLAN.

3.1 Example 1: Moving to WLAN

A possible signalling sequence for the case when there is an RRC signalling connection established is shown in Figure 2.

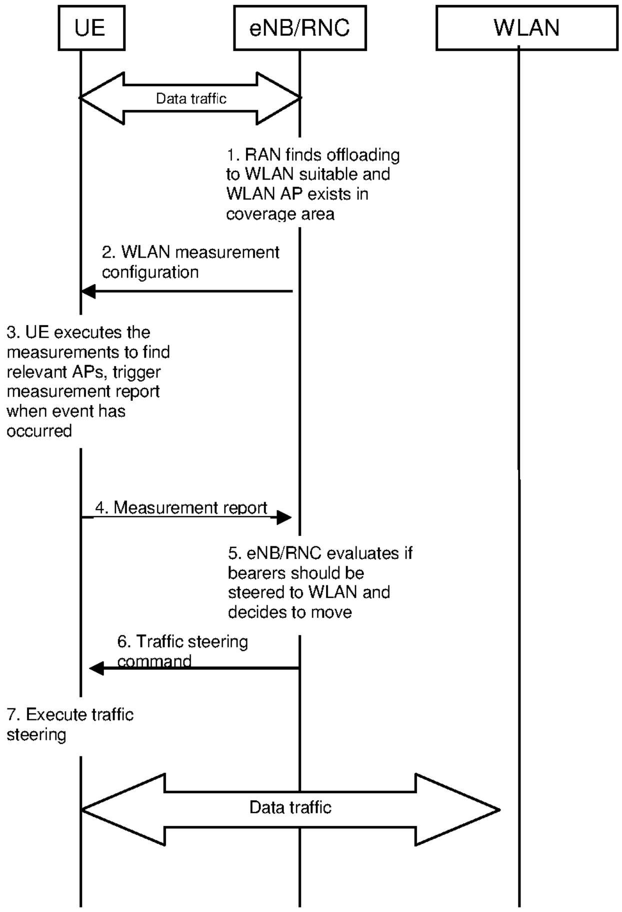

Figure 2: Going to WLAN from 3GPP when there is an RRC connection established.

3.2 Example 2: Moving to 3GPP

A possible signalling sequence for the case when there is no RRC signalling connection established is shown in Figure 3. Note that if the UE still maintain an RRC signalling connection to eNB or RNC step 3 in Figure 3 is not needed and signalling procedure reduces to a similar signalling procedure as in Figure 2 in section 3.1.

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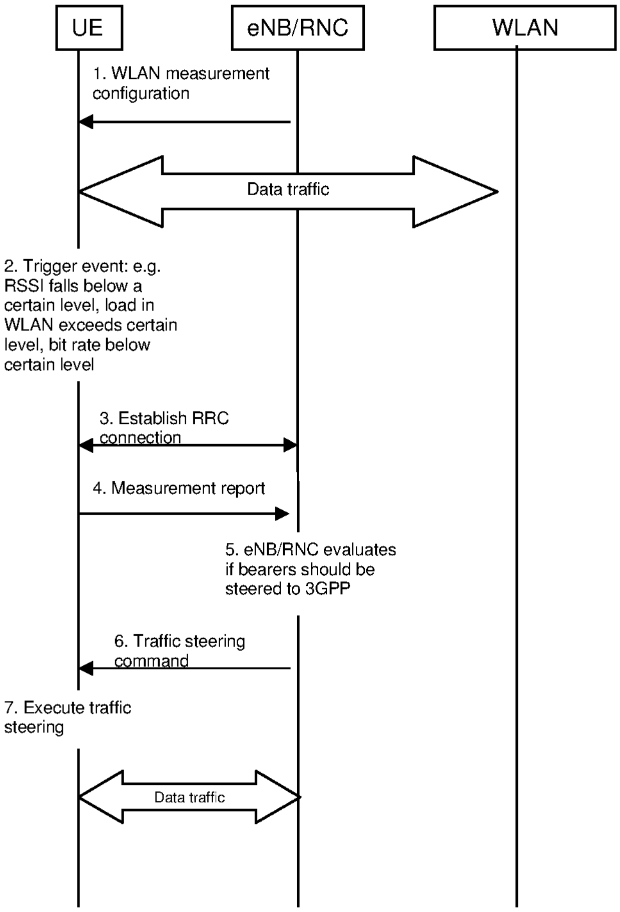

Figure 3: Going to 3GPP in 3GPP RRC idle mode/URA_PCH/CELL_PCH

The WLAN measurement configuration defines the event trigger thresholds and policies used to trigger a possible change/modify use of access technology/technologies. It can be broadcast or sent by dedicated signalling.

3.3 Summary

The common part of the examples in 3.1 and 3.2 is the three-step procedure of:

1. WLAN measurement configuration (including possible event triggers)
2. Measurement reporting
3. Traffic steering command

The above framework can be used for all use cases and provides for a simple per-UE traffic steering that would avoid any ping-ponging, mass-toggling and possibilities to improve overall system performance and enhanced user experience. It also provides for a variety of implementation possibilities and possible future standardisation enhancements as it is building on existing 3GPP mobility principles.

A text proposal capturing the above solution is provided in Annex A.

Proposal 9 It is proposed to capture the text proposal in Annex A in the TR.

4 Fulfilment of requirements

Table 2 shows how the requirements defined in TR 37.834 are fulfilled by the solution described in Section 3.

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Table 2: The requirements in TR 37.834 [1]

Requirement	Solution 3 (including idle mode)
Solutions should provide improved bi-directional load balancing between WLAN and 3GPP radio access networks in order to provide improved system capacity	Yes, by utilising real-time measurements from both network(s) and UE when determining if offloading should be performed, and selecting the UEs that provides best offloading performance (taking into account both system and user point of view).
Solutions should improve performance (WLAN interworking should not result in decreased but preferable in better user experience)	Yes, by utilising real-time measurements from both network(s) and UE when determining if off-load should be performed, selecting the UEs that provides best off-loading performance (taking into account both system and user point of view).
Solutions should improve the utilization of WLAN when it is available and not congested.	Yes, by utilising real-time measurements from both network(s) and UE when determining if off-load should be performed.
Solutions should reduce or maintain battery consumption (e.g. due to WLAN scanning/discovery).	Yes, by initiating measurements in WLAN only when necessary.
Solutions should be compatible with all existing CN WLAN related functionality, e.g. seamless and non-seamless offload, trusted and non-trusted access, MAPCON and IFOM	No issues foreseen (FFS)
Solutions should be backward compatible with existing 3GPP and WLAN specifications, i.e. work with legacy UEs even though legacy UEs may not benefit from the improvements provided by these solutions	Yes.
Solutions should rely on existing WLAN functionality and should avoid changes to IEEE and WFA specifications	Yes
Per target WLAN system distinction (e.g. based on SSID) should be possible	Yes
Per-UE control for traffic steering should be possible	Yes, by individual UE-control.
Solutions should ensure that access selection decisions should not lead to ping-ponging between UTRAN/E-UTRAN and WLAN	Yes, by individual UE-control.

Proposal 10 **It is proposed to include Table 2 in the TR.**

Proposal 11 **It is suggested that the other solutions are also included in the table.**

Appendix A

5 Conclusion

A text proposal to TR is shown in Annex A.

Observation 1	**A traffic steering algorithm needs to take capacity and load of WLAN APs and (e)NBs as well as radio conditions of UEs into account.**
Observation 2	**Traffic steering should focus on UEs contributing most to the overload in their serving cell.**
Observation 3	**Traffic steering to WLAN should be battery efficient and create low (relative) control signalling overhead.**
Observation 4	**Network based mobility as in RRC CONNECTED/CELL _DCH/CELL_FACH allows to steer those UEs that contribute most to the (over-)load.**
Observation 5	**RRC CONNECTED with DRX is efficient in terms of UE power consumption and control signalling provided that a UE is not moving too much.**
Observation 6	**Inter-frequency and inter-RAT load balancing in IDLE mode controls the number of UEs camping on a carrier but cannot focus on those UEs that contribute most to the overload in the current frequency or RAT.**
Observation 7	**Access network selection based on traffic steering to and from WLAN allows offloading main load contributors while minimizing battery consumption for the others.**
Proposal 1	**Adopt network controlled traffic steering in RRC CONNECTED to WLAN.**
Proposal 2	**Adopt network controlled traffic steering in RRC CONNECTED to 3GPP.**
Proposal 3	**For backwards traffic steering of a UE in idle mode the UE should establish an RRC connection on the basis of thresholds and/or policies.**
Proposal 4	**Upon RRC connection establishment RAN performs access network selection and traffic steering.**
Proposal 5	**The network may configure UEs with WLAN radio signal measurements. Similar principles as for inter-frequency/RAT measurements should apply.**
Proposal 6	**The RAN may instruct a UE to offload data to a particular WLAN access (e.g. SSID). It is up to the UE to execute setup of the WLAN connection and to direct traffic onto WLAN.**
Proposal 7	**It is FFS whether the RAN may indicate per radio bearer traffic steering.**
Proposal 8	**The traffic steering to WLAN does not imply an RRC connection release, i.e., the RRC connection may be maintained but the RAN may notice that radio bearers do not carry any data.**
Proposal 9	**It is proposed to capture the text proposal in Annex A in the TR.**
Proposal 10	**It is proposed to include Table 2 in the TR.**
Proposal 11	**It is suggested that the other solutions are also included in the table.**

6 References

[1] TR 37.834, Study on WLAN/3GPP Radio Interworking, vO.2.0.

[2] R2-1 3 1389, Connection mdoe access selection solution for WLAN/3GPP radio interworking, Ericsson, ST-Ericsson, Deutsche Telkom, RAN2#81 bis.

Appendix A

Annex A

Text proposal to TR 37.834v0.2.0 (R2-131545).

6.1 .3 Solution 3

In this solution the traffic steering for UEs in RRC CONNECTED/CELL _DCH/CELL _FACH state is controlled by the network using dedicated traffic steering commands, potentially based also on WLAN measurements and other reports from UE.

For UEs in IDLE mode and CELL_PCH and URA_PCH states the solution is similar to solution 2 but in this solution the network can control the steering by using dedicated traffic steering commands. This is performed after the UE has established a RRC connection to RAN based e.g. a certain measurement event has occurred in the UE. The measurements have been configured by RAN (e.g. events, thresholds^: etc.) by broadcast or dedicated signalling.

Figure x and y are two examples how the basic signalling framework for traffic steering between 3GPP RATs and WLAN can be used.

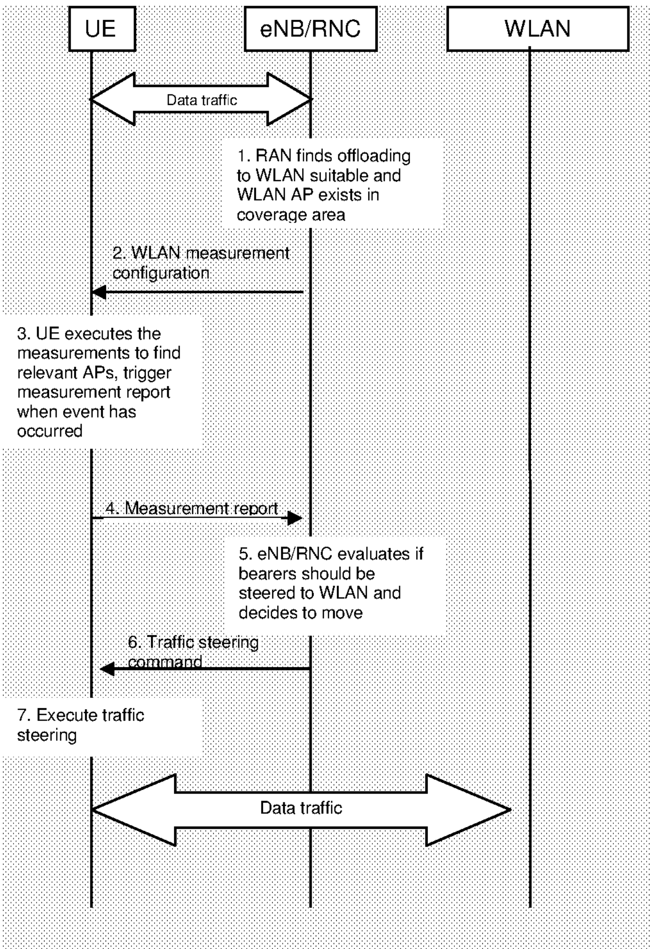


Figure x: Going to WLAN from 3GPP when there is an RRC connection established

Appendix A

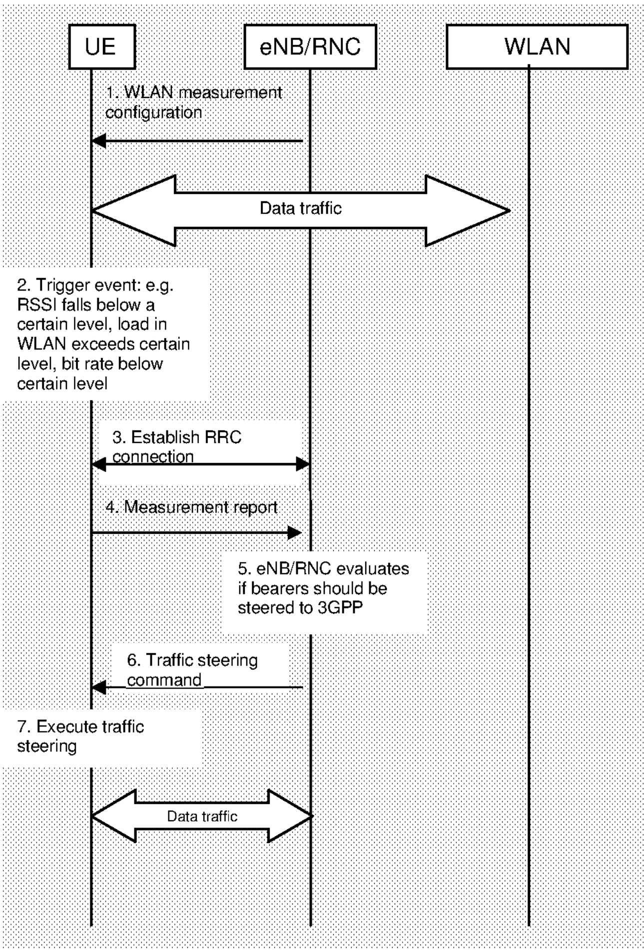


Figure y: Going to 3GPP in 3GPP RRC idle mode/URA_PCH/CELL_PCH

Solution details are FFS.

Relation to ANDSF is FFS.

CLAIMS

1. A method in a network node of a first wireless telecommunications network, the method comprising:

determining whether a terminal served by the first network is connected to a wireless local area network, WLAN (620); and

if the terminal is connected to a WLAN, performing one or more operations to avoid the terminal entering an inactive state with respect to the first network (630).

2. The method of claim 1, wherein determining whether a terminal served by the first network is connected to a WLAN (620) is based on a WLAN status report received from the terminal.

3. The method of claim 1, wherein determining whether a terminal served by the first network is connected to a WLAN (620) is based on the sending of a traffic steering message to the terminal by the first network.

4. The method of claim 1, wherein determining whether a terminal served by the first network is connected to a WLAN (620) is based on the reception from the terminal of an indication that a traffic steering message, sent to the terminal by the first network, has been applied by the terminal.

5. The method of claim 1, wherein determining whether a terminal served by the first network is connected to a WLAN (620) is based on information received from a core network associated with the first network.

6. The method of any of claims 1-5, wherein the step of performing one or more operations to avoid the terminal entering an inactive state with respect to the first network (630) comprises adjusting operation of an inactivity timer associated with the terminal so that triggering of an operation to move the terminal to an inactive state, with respect to the first network, is unlikely or impossible.

7. The method of any of claims 1 to 6, further comprising the steps of:

determining whether the terminal has disconnected from the WLAN (660); and

performing one or more operations to allow or cause the terminal to enter an inactive state if the terminal has disconnected from the WLAN (670).

8. The method of any of claims 1 to 6, further comprising the steps of:

determining whether the terminal is inactive in both the WLAN and first network (660); and

performing one or more operations to allow or cause the terminal to enter an inactive state if the terminal is inactive in both the WLAN and first network (670).

9. The method of any of claims 1 to 8, wherein after the step of performing one or more operations, the method further comprises the step of:

configuring the terminal with a discontinuous reception configuration.

10. The method as in claim 1, wherein the step of determining whether a terminal served by the first network is connected to a WLAN (620) comprises receiving an indication from the terminal indicating that the terminal does not wish to be moved to an inactive state with respect to the first network, and the step of performing one or more operations to avoid the terminal entering an inactive state with respect to the first network (630) comprises refraining from moving the terminal to an inactive state.

11. The method as in claim 10, further comprising the steps of:

receiving an indication from the terminal that the terminal can be moved to an inactive state with respect to the first network; and

performing one or more operations to allow or cause the terminal to enter an inactive state (670).

12. A network node (900) for use in a first wireless telecommunication network, the network node (900) comprising a processing circuit (920) adapted to:

determine whether a terminal (300) served by the first network (304) is connected to a wireless local area network, WLAN (302); and

perform one or more operations to avoid the terminal (300) entering an inactive state with respect to the first network (304) if the terminal (300) is connected to a WLAN (302).

13. The network node (900) of claim 12, wherein the one or more operations the processing circuit (920) is adapted to perform comprises adjusting operation of an inactivity timer associated with the terminal (300) so that triggering of an operation to

move the terminal (300) to an inactive state, with respect to the first network (304), is unlikely or impossible.

14. The network node (900) of claim 13, wherein the processing circuit (920) is adapted to adjust operation of an inactivity timer associated with the terminal (300) by setting the value of an inactivity timer to a value that will be interpreted to prevent the timer from ever expiring.

15. The network node (900) of claim 13, wherein the processing circuit (920) is adapted to adjust operation of an inactivity timer associated with the terminal (300) by setting the value of an inactivity timer to a value such that expiration of the inactivity is unlikely in view of other activities of the first network (900).

16. The network node (900) of claim 13, wherein the processing circuit (920) is adapted to adjust operation of an inactivity timer associated with the terminal (300) by disabling the inactivity timer.

17. The network node (900) of claim 13, wherein the processing circuit (920) is adapted to adjust operation of an inactivity timer associated with the terminal (300) by responding to the inactivity timer by refraining from triggering an operation to move the terminal (300) to an inactive state.

18. The network node (900) of claim 13, wherein the processing circuit (920) is adapted to adjust operation of an inactivity timer associated with the terminal (300) by resetting the timer when the connection between the terminal (300) and WLAN (302) is active.

19. A method in a terminal that is being served by a first wireless telecommunications network, the method comprising:

determining whether the terminal is connected to a wireless local area network, WLAN (700); and

if the terminal is connected to a WLAN, refraining from entering an inactive state with respect to the first network (710).

20. The method of claim 19, wherein the step of refraining from entering an inactive state with respect to the first network (710) comprises refraining from entering an

inactive state with respect to the first network even if the first network indicates that the terminal should enter an inactive state.

21. The method of claim 19, wherein the step of refraining from entering an inactive state with respect to the first network (710) comprises indicating to the first network that the terminal is refraining from entering an inactive state or that the terminal does not wish to be moved to an inactive state.

22. The method of any of claims 19 to 21, the method further comprising the step of:

entering an inactive state if indicated to do so by the first network if it is determined that the terminal is not connected to a WLAN (720).

23. The method of any of claims 19 to 22, wherein after the step of refraining (710), the method further comprises the steps of:

determining whether the terminal has disconnected from the WLAN (700); and

if the terminal has disconnected from the WLAN, enabling the terminal to enter an inactive state if indicated to do so by the first network (720).

24. The method of any of claims 19 to 22, wherein after the step of refraining (710), the method further comprises the steps of:

determining whether the terminal is inactive in both the WLAN and the first network (700); and

if the terminal is inactive in both the WLAN and the first network, enabling the terminal to enter an inactive state if indicated to do so by the first network (720).

25. A terminal (300) for use in a first wireless telecommunication network, the terminal (300) comprising a processing circuit (1510) adapted to:

determine whether the terminal (300) is connected to a wireless local area network, WLAN (302), while being served by the first network (304); and

refrain from entering an inactive state with respect to the first network (304) if the terminal (300) is connected to a WLAN (302).

26. The terminal (300) of claim 25, wherein the processing circuit (1510) is adapted to refrain from entering an inactive state with respect to the first network by refraining from entering an inactive state with respect to the first network even if the first network indicates that the terminal should enter an inactive state.

27. The terminal (300) of claim 25, wherein the processing circuit (1510) is adapted to refrain from entering an inactive state with respect to the first network by indicating to the first network that the terminal is refraining from entering an inactive state or that the terminal does not wish to be moved to an inactive state.

28. The terminal (300) of any of claims 25 to 27, wherein the processing circuit (1510) is further adapted to:

control the terminal to enter an inactive state if indicated to do so by the first network if it is determined that the terminal is not connected to a WLAN.

29. The terminal (300) of any of claims 25 to 28, wherein the processing circuit (1510) is further adapted to:

determine whether the terminal (300) has disconnected from the WLAN (302); and

enable the terminal (300) to enter an inactive state if indicated to do so by the first network (304) if the terminal (300) has disconnected from the WLAN (302).

30. The terminal (300) of any of claims 25 to 29, wherein the processing circuit (1510) is further adapted to:

determine whether the terminal (300) is inactive in both the WLAN (302) and first network (304); and

enable the terminal (300) to enter an inactive state if indicated to do so by the first network (302) if the terminal (300) is inactive in both the WLAN (302) and the first network (304).

31. A computer readable medium having a set of computer instructions stored therein, the computer instructions being configured such that, on execution by a processor or computer, the processor or computer performs the method of any of claims 1 to 11 or 19 to 24.

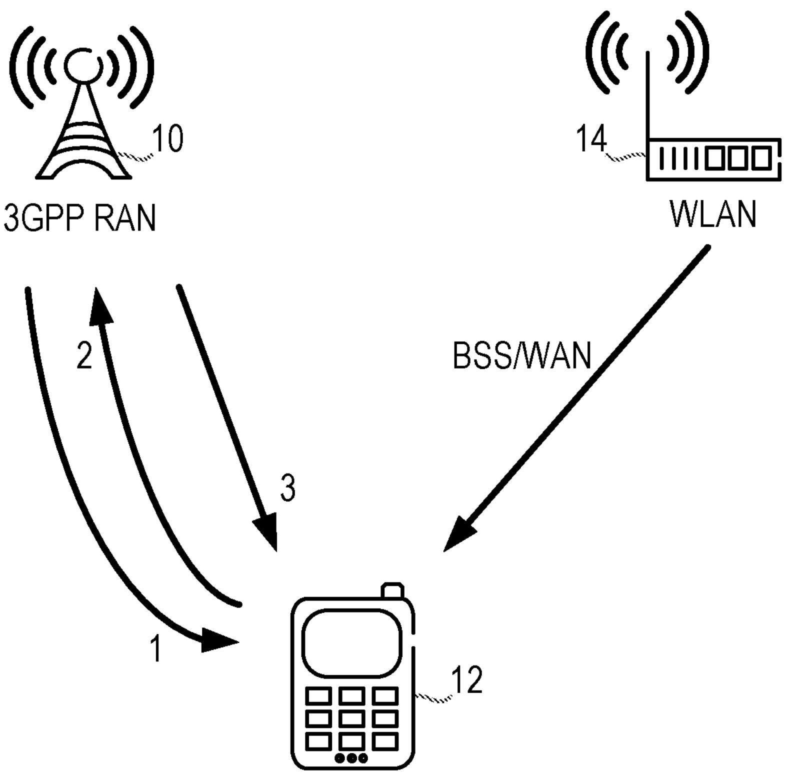


Figure 1

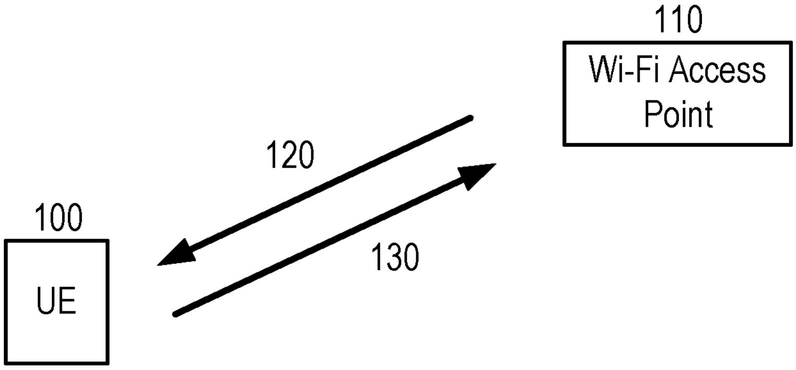
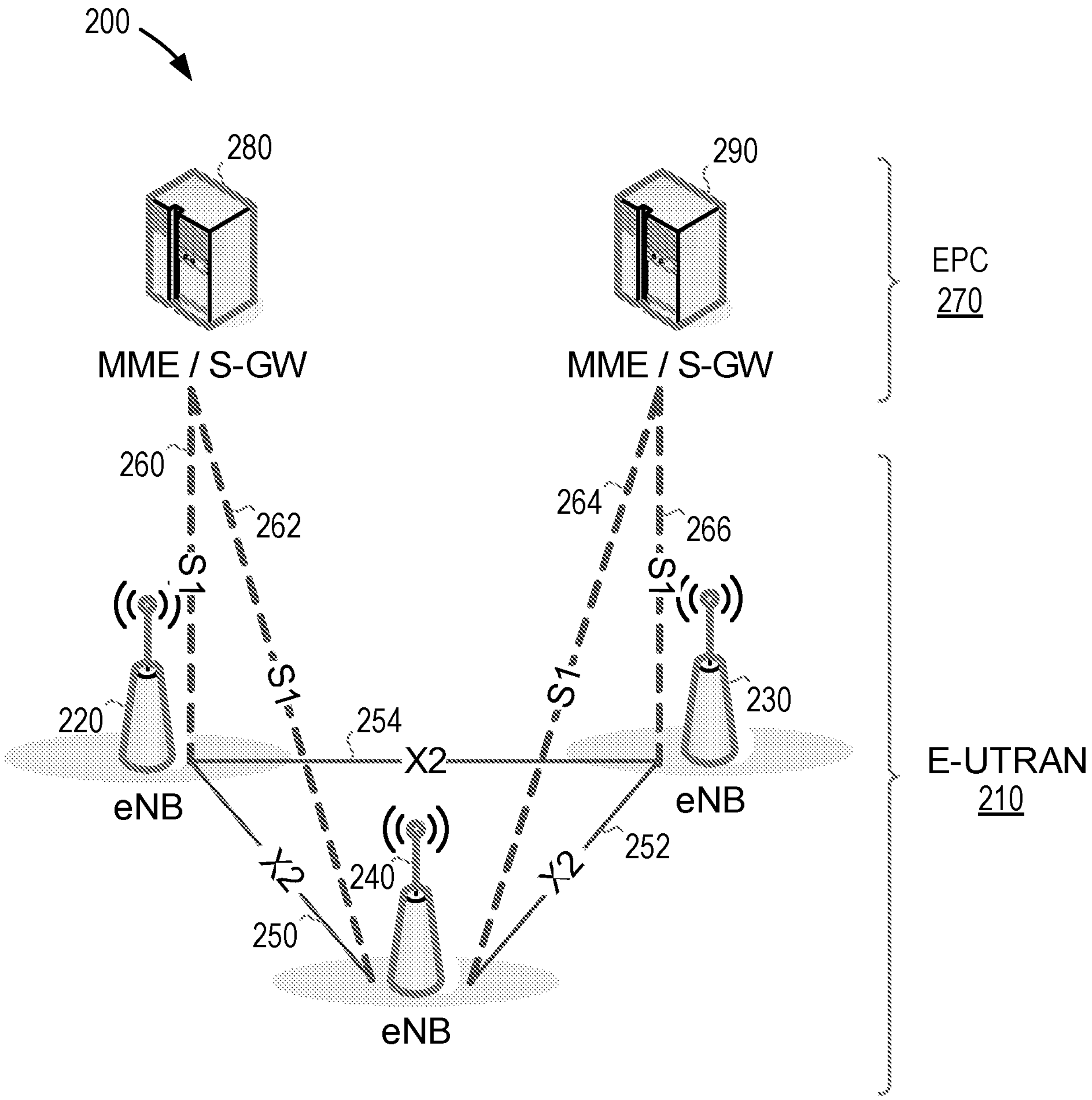


Figure 2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280
290
MME / S-GW
MME / S-GW
EPC
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262
264
266
S1
S1
S1
S1
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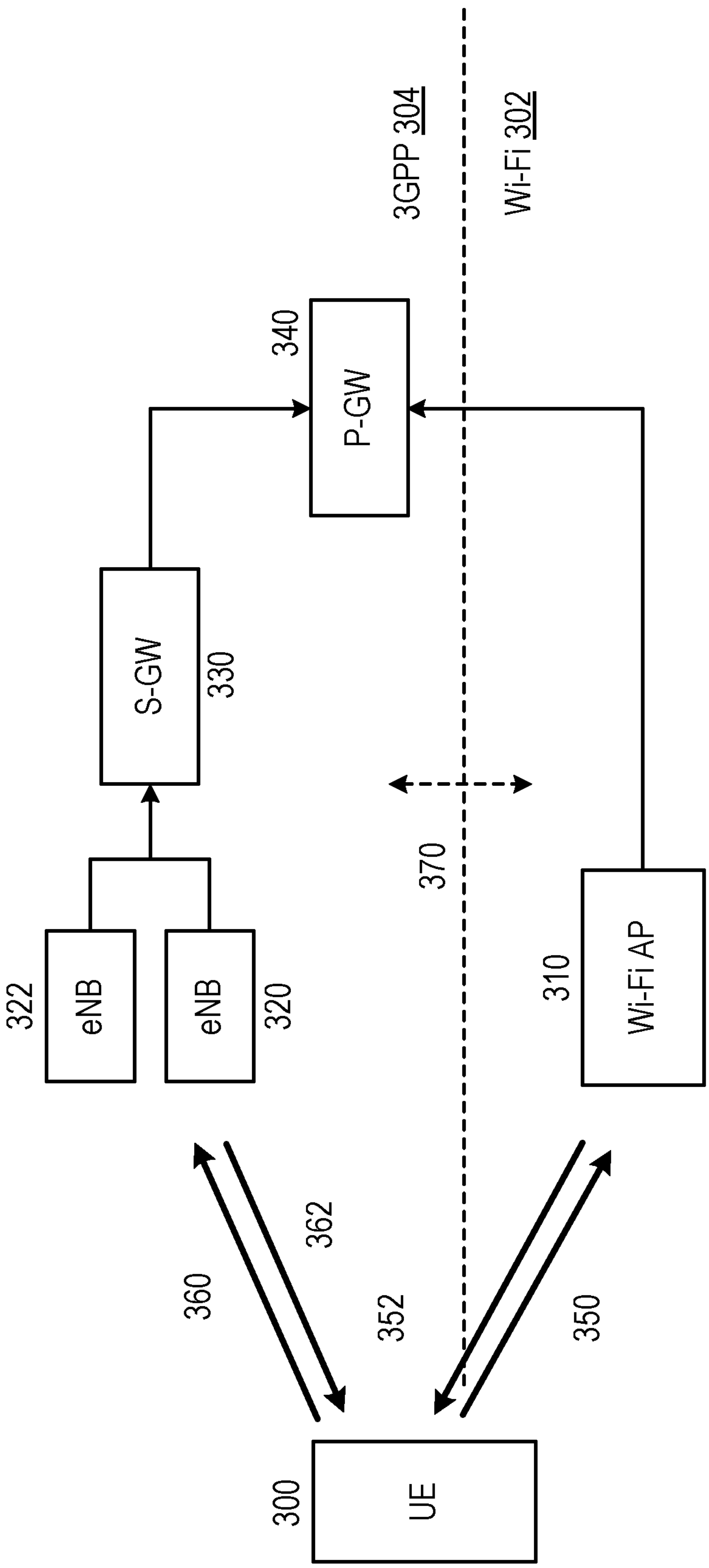
230
254
X2
eNB
eNB
E-UTRAN
210
X2
X2
240
252
250
eNB

Figure 3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P-GW
S-GW
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eNB
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Wi-Fi AP
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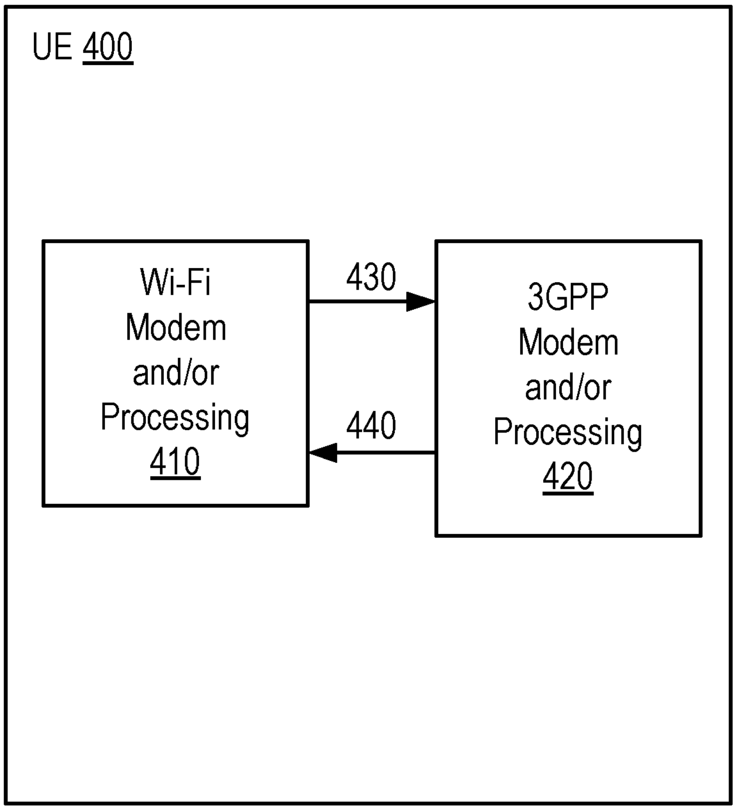
362
352
350
300
UE

Figure 4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Wi-Fi Modem and/or Processing 410
430
440
3GPP Modem and/or Processing 420

Figure 5

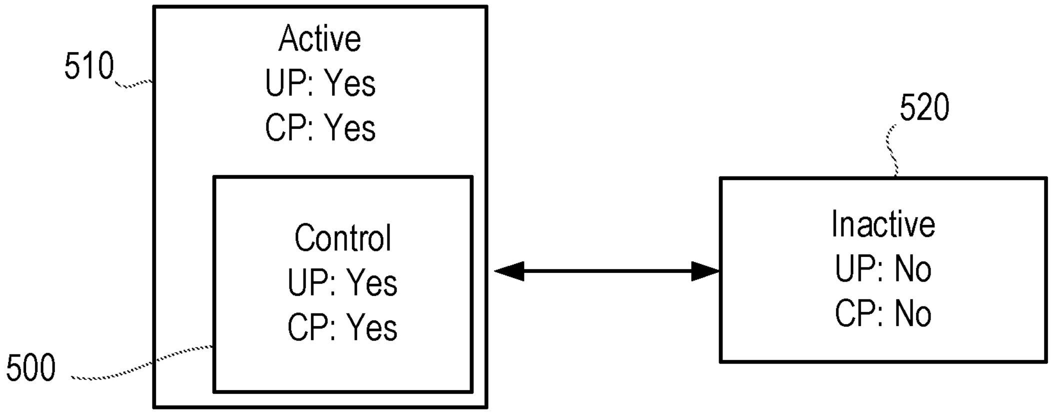


Figure 6

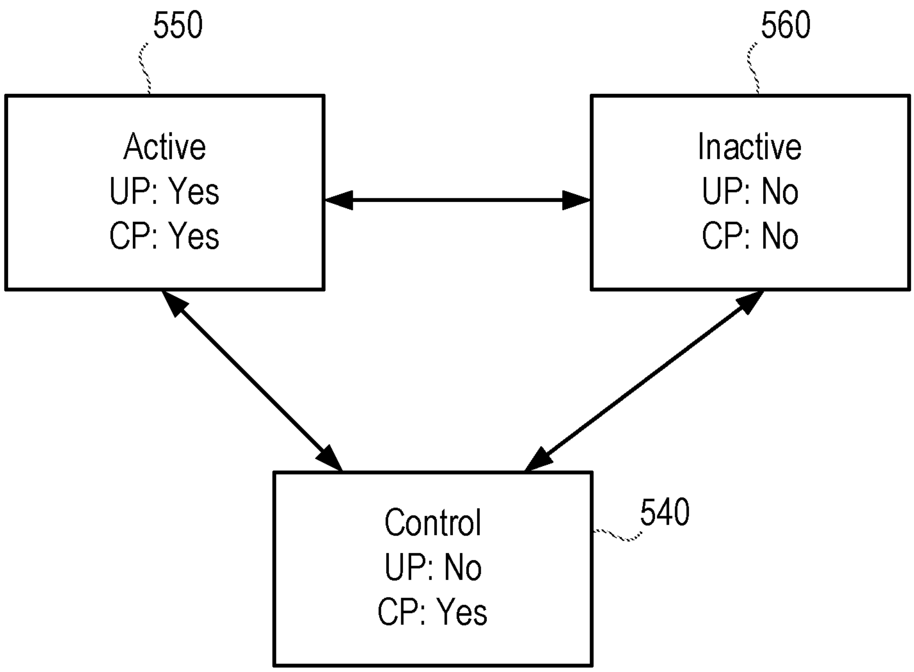


Figure 7

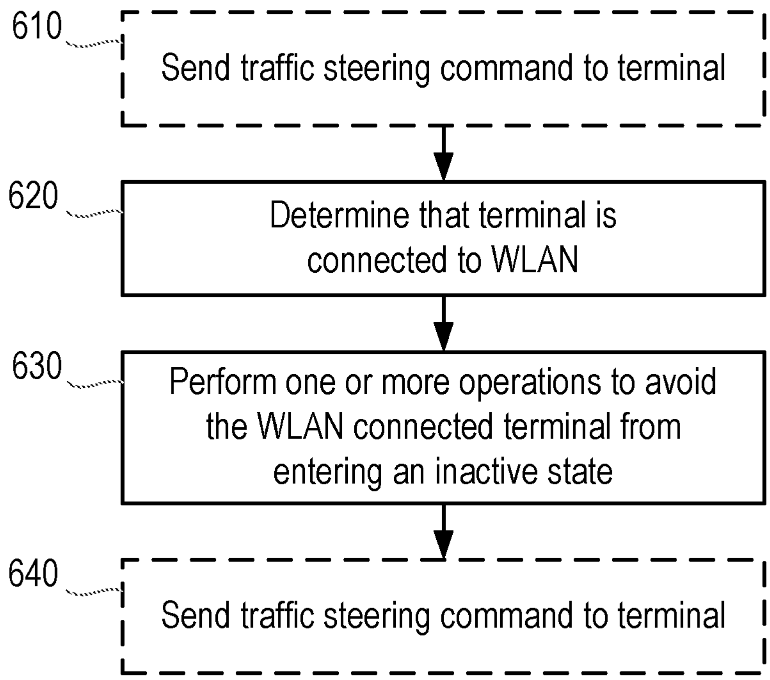


Figure 8

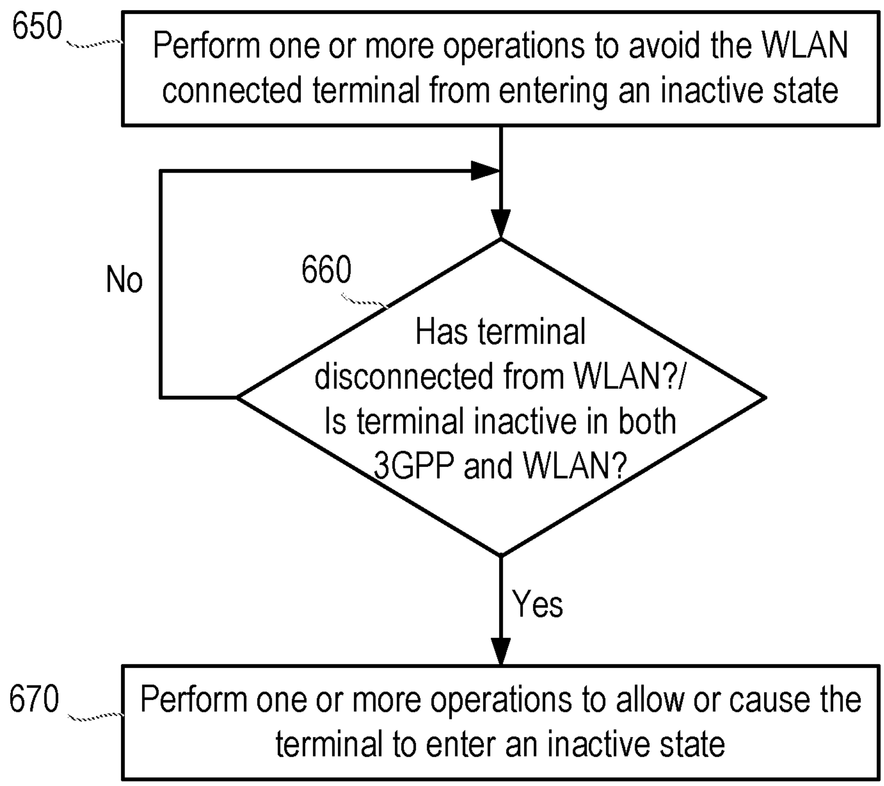


Figure 9

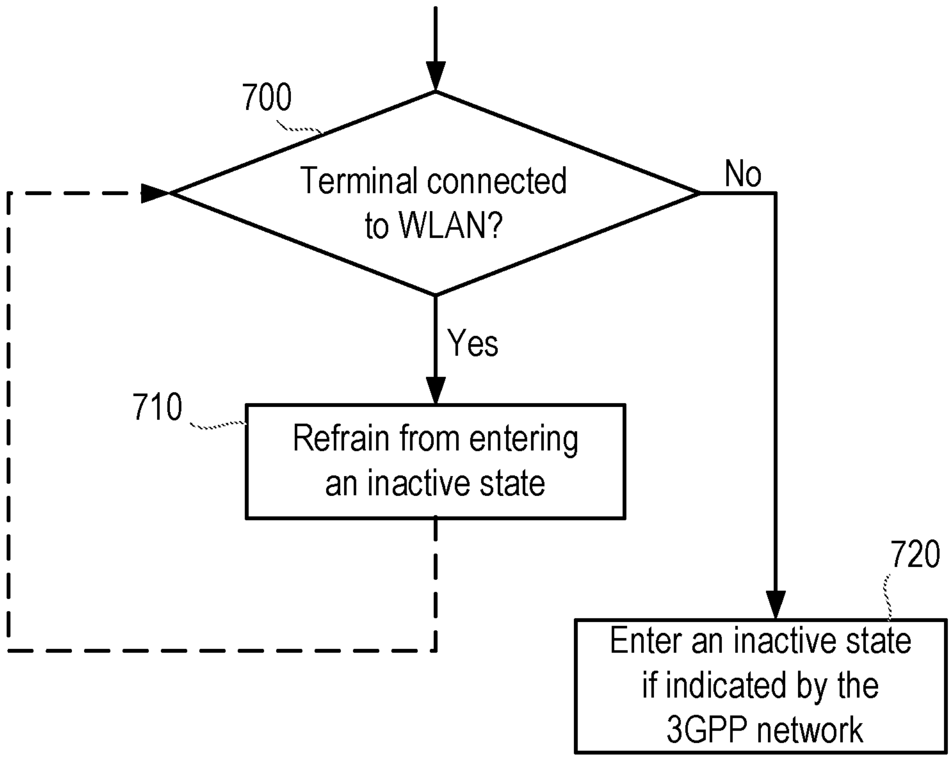

700
Terminal connected to WLAN?
No
Yes
710
Refrain from entering an inactive state
720
Enter an inactive state if indicated by the 3GPP network

Figure 10

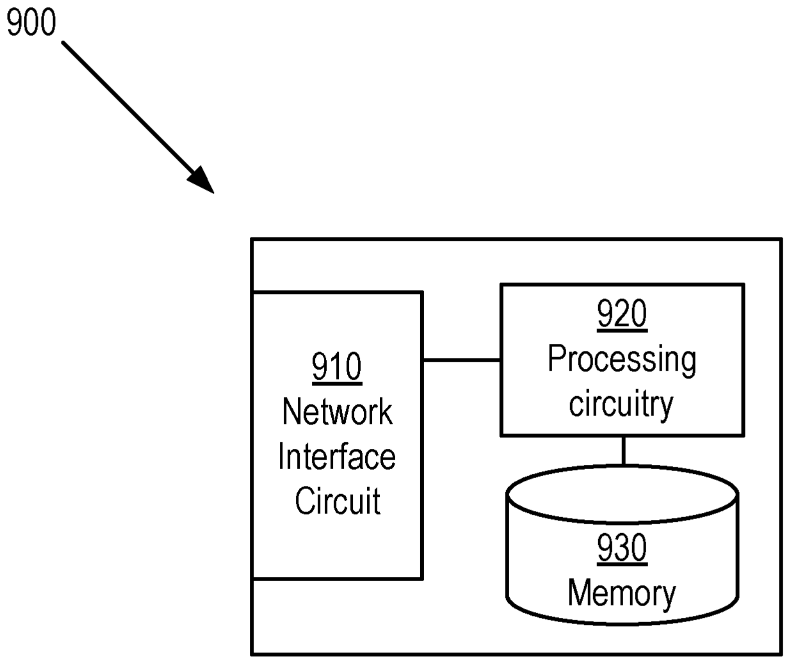


Figure 11

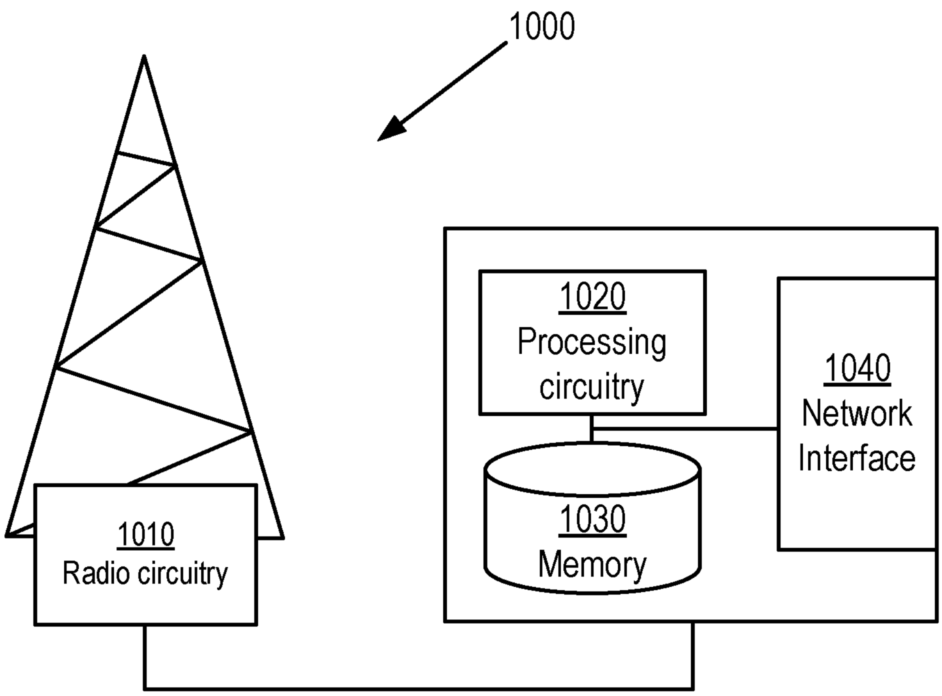
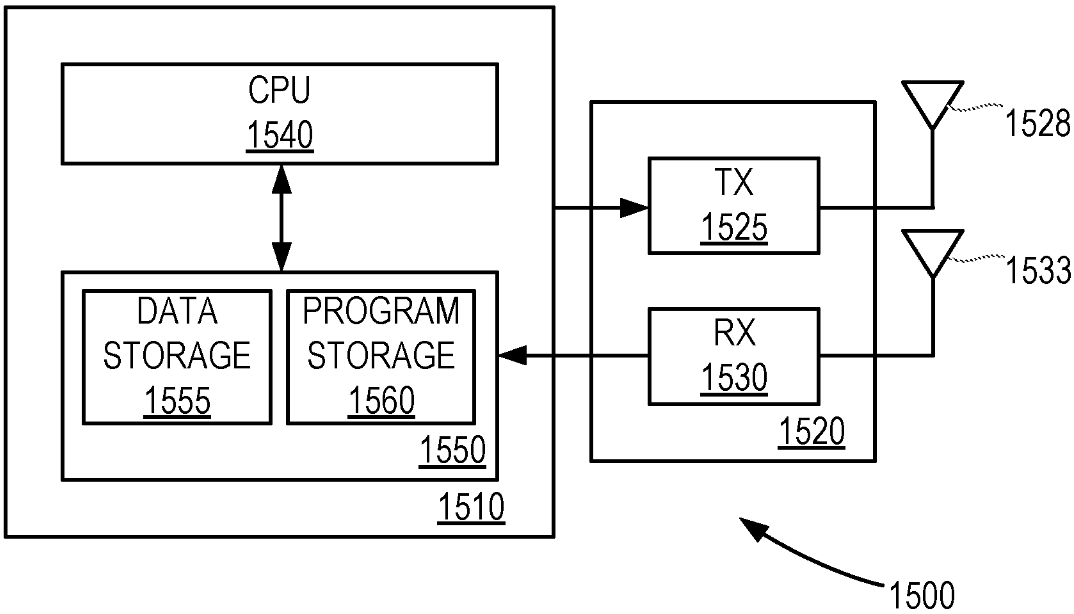


Figure 12


CPU
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STORAGE
1555
PROGRAM
STORAGE
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1510
TX
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RX
1530
1520
1528
1533
1500

Figure 13

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2014/050042

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: H04W

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

SE, DK, FI, NO classes as above

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

EPO-Internal, PAJ, WPI data, COMPENDEX, EMBASE, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	R2-131389; Connected mode access selection solution for WLAN/3GPP radio interworking; Ericsson, ST-Ericsson, Deutsche Telekom; 3GPP TSG-RAN WG2 #81 bis; Chicago, IL, USA, 15 - 19 April 2013; whole document; abstract; section 3	1-9, 12-19, 22-25, 28-31
A		10-11, 20-21, 26-27
	--	
Y	US 20130064107 A1 (SRIDHAR KAMAKSHI), 14 March 2013 (2013-03-14); abstract; paragraph [0025]; figure 3	1-9, 12-19, 22-25, 28-31
A		10-11, 20-21, 26-27
	--	

☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10-10-2014	13-10-2014
Name and mailing address of the ISA/SE Patent- och registreringsverket Box 5055 S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Per Karlsson Telephone No. +46 8 782 25 00

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2004002051 A2 (THOMSON LICENSING SA ET AL), 31 December 2003 (2003-12-31); abstract; page 2, line 5 - page 2, line 22; page 8, line 23 - page 9, line 5 --	1-31
A	WO 2004008787 A1 (ASUSTEK COMP INC), 22 January 2004 (2004-01-22); abstract; page 9, line 15 - page 11, line 30; claim 1 --	1-31
A	3GPP TR 37.834 VO.2.0 (2013-04) 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Study on WLAN/3GPP Radio Interworking (Release 12); whole document; abstract -- --------	1-31

Continuation of: second sheet

International Patent Classification (IPC)

H04W 40/00 (2009.01)
H04W 76/04 *(2009.01)*

US	20130064107 A1	14/03/2013	US	8792355	B2	29/07/2014
WO	2004002051 A2	31/12/2003	AU	2003245633	A1	06/01/2004
			CN	1663166	B	01/12/2010
			EP	1523821	A4	20/01/2010
			JP	4684649	B2	18/05/2011
			JP	2005531223	A	13/10/2005
			KR	101010806	B1	25/01/2011
			KR	20050012821	A	02/02/2005
			MX	PA04012665	A	23/03/2005
			US	7764660	B2	27/07/2010
			US	20050239461	A1	27/10/2005
WO	2004008787 A1	22/01/2004	CN	1557104	A	22/12/2004
			CN	100490585	C	20/05/2009
			EP	1383348	A1	21/01/2004
			JP	2004159297	A	03/06/2004
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			KR	20040008100	A	28/01/2004
			KR	100556589	B1	06/03/2006
			TW	I223966	B	11/11/2004
			US	6961570	B2	01/11/2005
			US	20040203778	A1	14/10/2004