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(54) **MOBILE DEVICE WITH CELLULAR-WLAN OFFLAOD USING PASSIVE LOAD SENSING OF WLAN**

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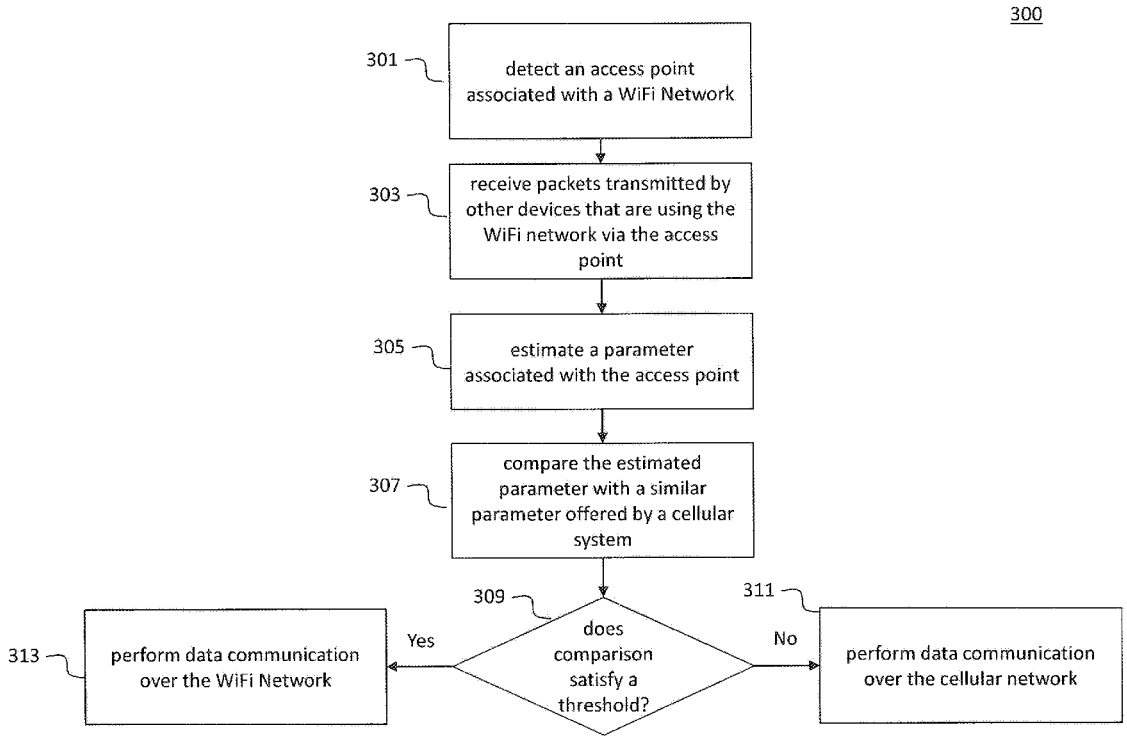
(57) **ABSTRACT**

Apparatus and methods are provided for switching between a wireless local area network (LAN) and a cellular network for a user equipment's (UE) data communication by passively sensing the load on the wireless LAN. A method is disclosed that includes detecting an access point associated with a wireless LAN and receiving packets that are transmitted by other devices that are using the wireless LAN. The method can further include examining the received packets to estimate a data load of the wireless LAN and selecting between the wireless LAN and a cellular network based on the estimated data load.



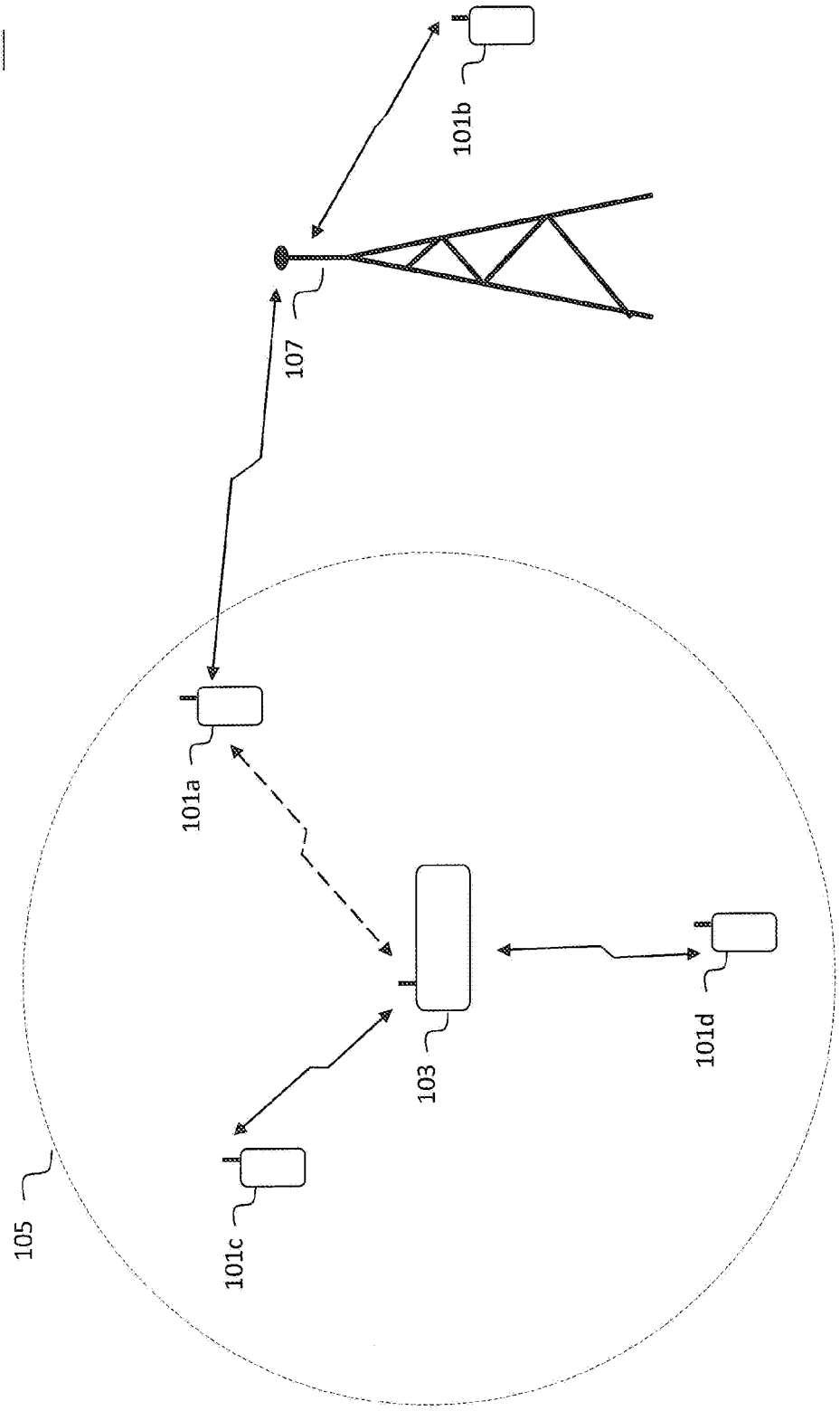


FIG. 1

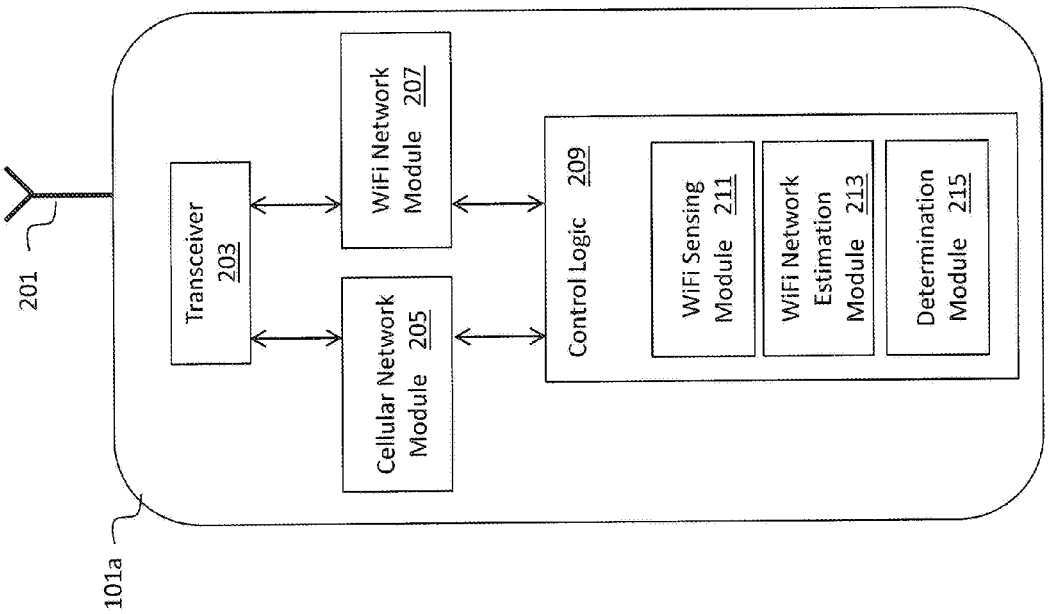

101a
201
Transceiver 203
WiFi Network Module 207
Cellular Network Module 205
Control Logic 209
WiFi Sensing Module 211
WiFi Network Estimation Module 213
Determination Module 215

FIG. 2

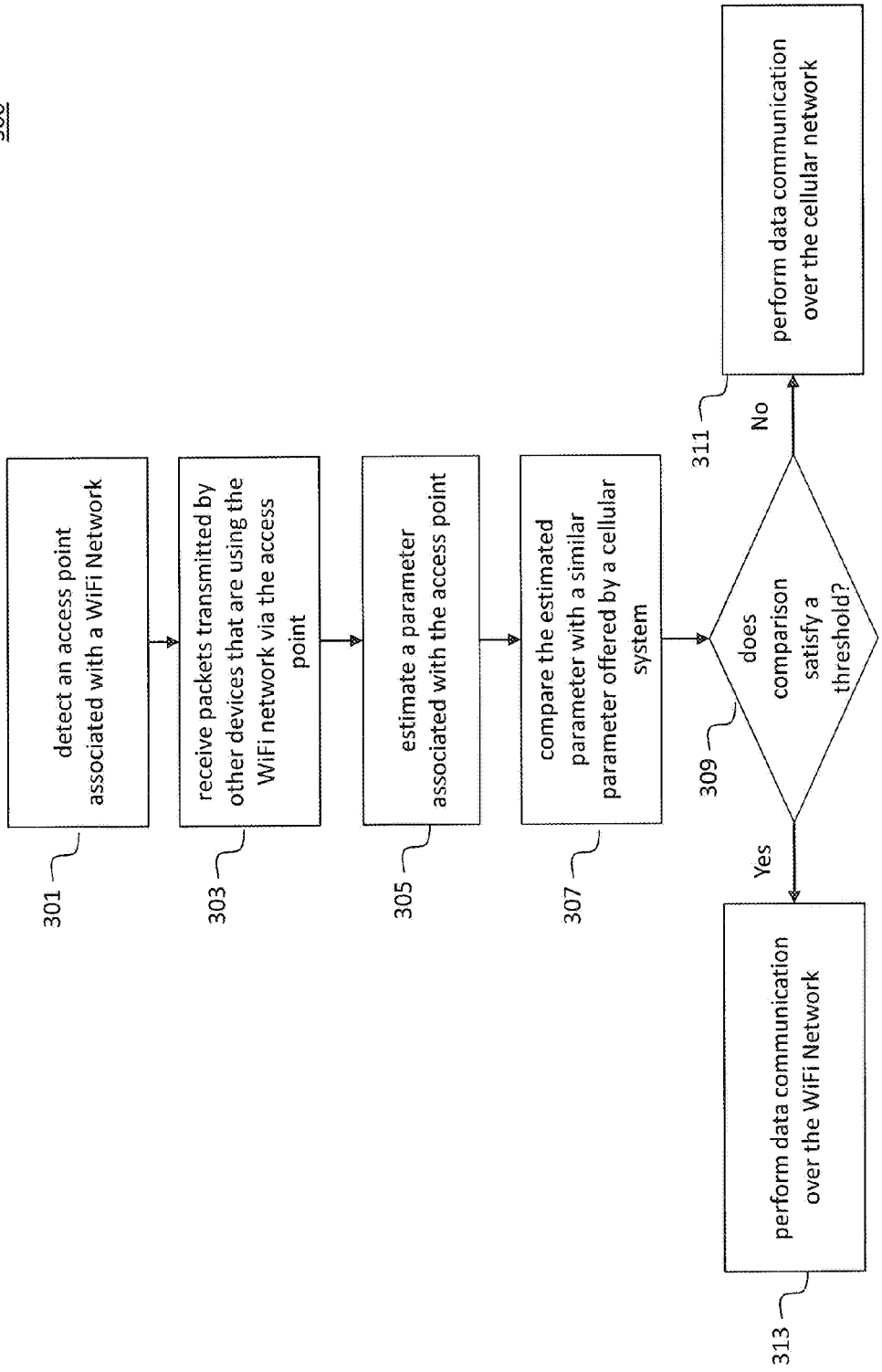

300
detect an access point associated with a WiFi Network
301
receive packets transmitted by other devices that are using the WiFi network via the access point
303
estimate a parameter associated with the access point
305
compare the estimated parameter with a similar parameter offered by a cellular system
307
does comparison satisfy a threshold?
309
Yes
No
311
perform data communication over the WiFi Network
313
perform data communication over the cellular network

FIG. 3

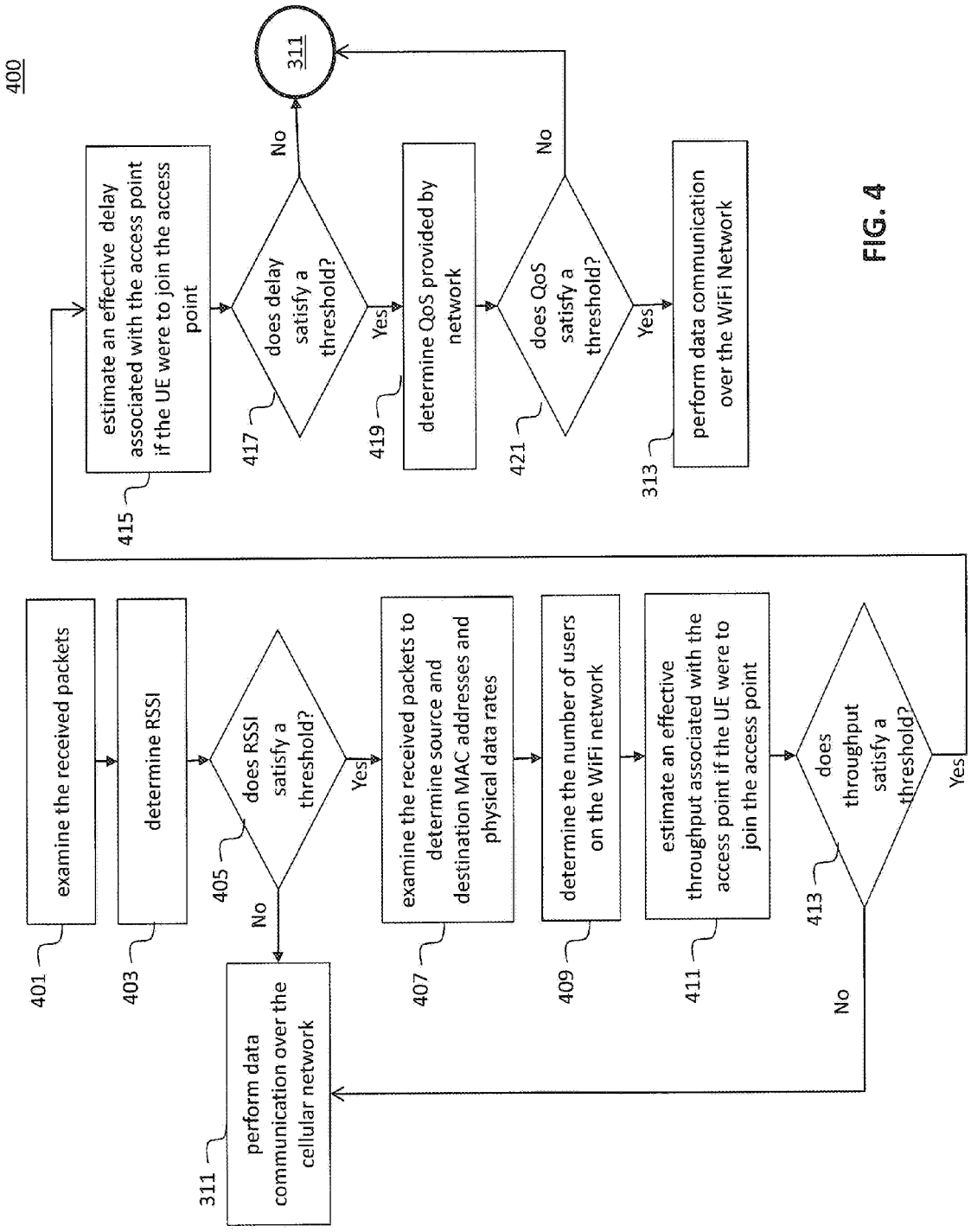

400
examine the received packets
401
determine RSSI
403
does RSSI satisfy a threshold?
405
No
Yes
perform data communication over the cellular network
311
examine the received packets to determine source and destination MAC addresses and physical data rates
407
determine the number of users on the WiFi network
409
estimate an effective throughput associated with the access point if the UE were to join the access point
411
does throughput satisfy a threshold?
413
No
Yes
estimate an effective delay associated with the access point if the UE were to join the access point
415
does delay satisfy a threshold?
417
No
Yes
311
determine QoS provided by network
419
does QoS satisfy a threshold?
421
No
Yes
perform data communication over the WiFi Network
313

FIG. 4

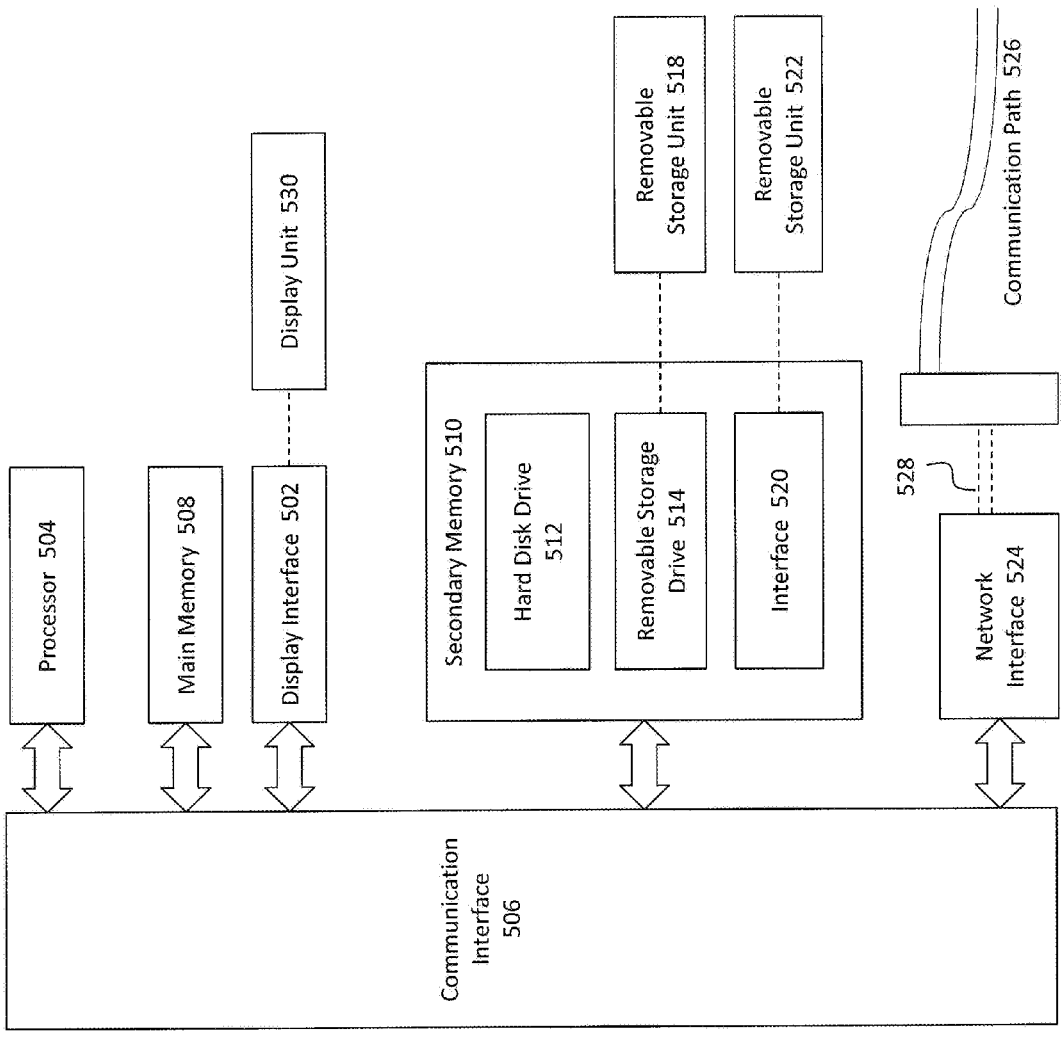

500
Processor 504
Main Memory 508
Display Interface 502
Display Unit 530
Secondary Memory 510
Hard Disk Drive 512
Removable Storage Drive 514
Interface 520
Removable Storage Unit 518
Removable Storage Unit 522
Communication Interface 506
528
Network Interface 524
Communication Path 526

FIG. 5

MOBILE DEVICE WITH CELLULAR-WLAN OFFLAOD USING PASSIVE LOAD SENSING OF WLAN

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims priority to U.S. Provisional Patent Application No. 61/750,283, filed on Jan. 8, 2013, which is hereby expressly incorporated by reference in its entirety.

BACKGROUND

[0002] 1. Field

[0003] The present disclosure relates generally to methods and systems for switching between a wireless local area network (LAN) and a cellular network for a user equipment's (UE) data communication by passively sensing the load on the wireless LAN.

[0004] 2. Background Art

[0005] Data communications of UEs are increasingly on rise. Video streaming, web browsing, text and multimedia messaging, etc. are examples of UE's data communications that are congesting the cellular air interface and its backhaul. Long Term Evolution (LTE) (which is based on Global System for Mobile communication (GSM)/GSM Evolution (EDGE) and Universal Mobile Telecommunications System (UMTS)/High Speed Packet Access (HSPA) network technologies) is a wireless communications standard that supports high-speed data for a UE. LTE has increased data capacity. However, cellular network operators are encouraging users of UEs to switch (offload) their bandwidth intensive applications to wireless LANs, such as WiFi networks, which can have a direct connection to a core backbone network such as a Public Data Network (PDN).

[0006] Cellular networks are evolving to Heterogeneous networks. A Heterogeneous network can include a macrocell (a cell in a cellular network that provides coverage using a cellular base station), a picocell (a small cellular base station covering a small area), a Femttocell (a small, low-power cellular base station, usually used in a home or small business), WiFi hotspots, relays, etc. Heterogeneous networks (HetNet), which connect different access technologies, can improve capacity and/or coverage. Many UEs automatically switch their data communications from a cellular network to a wireless LAN when they detect the wireless LAN. Although wireless LANs, such as WiFi networks, typically provide higher throughput than cellular networks, such as 3G (the 3rd Generation), however, user experience after switching to the wireless LAN can be unpredictable. A user's experience in the wireless LAN is a function of the "user load" on the network. The wireless LAN is a shared medium with limited effective resources per user. Therefore, UE can experience a better data communication on the cellular network, if the wireless LAN that UE has found is serving too many users, or pre-existing users with substantial bandwidth requirements. Conventionally, the switch between the cellular network and the wireless LAN occurs based on signal strength. Also, the user of the UE can manually disable or enable the wireless LAN option on the UE for a more predictable experience and battery life.

BRIEF DESCRIPTION OF THE DRAWINGS/FIGURES

[0007] The accompanying drawings, which are incorporated herein and form part of the specification, illustrate the present disclosure and, together with the description, further serve to explain the principles of the disclosure and to enable a person skilled in the relevant art(s) to make and use the disclosure.

[0008] FIG. **1** illustrates a system, in accordance with an embodiment of the present disclosure.

[0009] FIG. **2** illustrates a user equipment, in accordance with an embodiment of the present disclosure.

[0010] FIG. **3** is a flowchart illustrating a method, in accordance with an embodiment of the present disclosure.

[0011] FIG. **4** is another flowcharts illustrating a method, in accordance with an embodiment of the present disclosure.

[0012] FIG. **5** illustrates a computer system that can be utilized to implement one or more embodiments of the present disclosure.

[0013] The present disclosure will now be described with reference to the accompanying drawings. In the drawings, generally, like reference numbers indicate identical or functionally similar elements. Additionally, generally, the left-most digit(s) of a reference number identifies the drawing in which the reference number first appears.

DETAILED DESCRIPTION

Overview

[0014] Apparatus and methods are provided for switching between a wireless local area network (LAN) and a cellular network for a user equipment's (UE) data communication by passively sensing the load on the wireless LAN. According to a first embodiment, a method is disclosed that includes detecting an access point associated with a wireless LAN and receiving packets that are transmitted by other devices that are using the wireless LAN for communications. The method can further include examining the received packets to estimate a data load of the wireless LAN and selecting between the wireless LAN and a cellular network based on the estimated data load.

[0015] According to another embodiment, an apparatus is provided that includes a radio transceiver and a control logic. The radio transceiver is configured to transmit signals to a network device. The control logic is configured to detect an access point associated with a wireless LAN and receive packets that are transmitted by other devices that are using the wireless LAN for communications. The control logic is further configured to examine the received packets to estimate a data load of the wireless LAN and select between the wireless LAN and a cellular network based on the estimated data load.

DETAILED DISCUSSION

[0016] The following Detailed Description of the present disclosure refers to the accompanying drawings that illustrate exemplary embodiments consistent with this disclosure. The exemplary embodiments will so fully reveal the general nature of the disclosure that others can, by applying knowledge of those skilled in relevant art(s), readily modify and/or adapt for various applications such exemplary embodiments, without undue experimentation, without departing from the spirit and scope of the disclosure. Therefore, such adaptations and modifications are intended to be within the meaning and

plurality of equivalents of the exemplary embodiments based upon the teaching and guidance presented herein. It is to be understood that the phraseology or terminology herein is for the purpose of description and not of limitation, such that the terminology or phraseology of the present specification is to be interpreted by those skilled in relevant art(s) in light of the teachings herein. Therefore, the detailed description is not meant to limit the present disclosure.

[0017] The embodiment(s) described, and references in the specification to "one embodiment", "an embodiment", "an example embodiment", etc., indicate that the embodiment(s) described may include a particular feature, structure, or characteristic, but every embodiment may not necessarily include the particular feature, structure, or characteristic. Moreover, such phrases are not necessarily referring to the same embodiment. Further, when a particular feature, structure, or characteristic is described in connection with an embodiment, it is understood that it is within the knowledge of one skilled in the art to effect such feature, structure, or characteristic in connection with other embodiments whether or not explicitly described.

[0018] Embodiments of the disclosure may be implemented in hardware, firmware, software, or any combination thereof. Embodiments of the disclosure may also be implemented as instructions stored on a machine-readable medium, which may be read and executed by one or more processors. A machine-readable medium may include any mechanism for storing or transmitting information in a form readable by a machine (e.g., a computing device). For example, a machine-readable medium may include read only memory (ROM); random access memory (RAM); magnetic disk storage media; optical storage media; flash memory devices. Further, firmware, software, routines, instructions may be described herein as performing certain actions. However, it should be appreciated that such descriptions are merely for convenience and that such actions in fact result from computing devices, processors, controllers, or other devices executing the firmware, software, routines, instructions, etc.

[0019] For purposes of this discussion, the term "module" and the like, shall be understood to include at least one of software, firmware, and hardware (such as one or more circuits, microchips, processors, or devices, or any combination thereof), and any combination thereof. In addition, it will be understood that each module can include one, or more than one, component within an actual device, and each component that forms a part of the described module can function either cooperatively or independently of any other component forming a part of the module. Conversely, multiple modules described herein can represent a single component within an actual device. Further, components within a module can be in a single device or distributed among multiple devices in a wired or wireless manner.

[0020] Terms like "user equipment," "mobile station," "mobile," "mobile device," "subscriber station," "subscriber equipment," "access terminal," "terminal," "handset," and similar terminology, refer to a wireless device utilized by a subscriber or user of a wireless communication service to receive or convey data, control, voice, video, sound, gaming, or substantially any data-stream or signaling-stream. The foregoing terms may be utilized interchangeably in the subject specification and related drawings. Likewise, the terms "access point," "base station," "base transceiver station", "Node B." "evolved Node B (eNode B)," home Node B (HNB)," "home access point (HAP)," or the like, may be utilized interchangeably in the subject specification and drawings, and refer to a wireless network component or apparatus that serves and receives data, control, voice, video, sound, gaming, or substantially any data-stream or signaling-stream from a set of subscriber stations.

[0021] FIG. **1** illustrates a system **100**, according to an embodiment of the present disclosure. For example, system **100** illustrates user equipment (UE) **101***a* that communicates with a cellular network illustrated by wireless network device **107** such as a evolved Node B (enode B), a base station, or the like. According to one example, while UE **101***a* is in coverage area of wireless network device **107**, UE **101***a* can also be or can move to be in coverage area **105** of access point **103** that is associated with a wireless LAN that can be connected to a Public Data Network (PDN). When UE **101***a* is in coverage area **105** of access point **103**, UE **101***a* is configured to evaluate the wireless LAN provided by access point **103**. By evaluating the wireless LAN, UE **101***a* can determine whether it would be better for UE **101***a* to switch (offload) its data session from the cellular network (provided by wireless network device **107**) to the wireless LAN that is associated with the access point **103**.

[0022] According to one example, the switch between the cellular network and the wireless LAN occurs based on the UE passively sensing the wireless LAN, evaluating the "load" of the wireless LAN, and a comparison of the evaluated "load" of the wireless LAN with corresponding parameters of the cellular network. If UE **101***a* (which can be, but is not limited to, a mobile phone, smartphone, personal digital assistant (PDA), etc.) determines that data communication over the wireless LAN is more suitable, UE **101***a* can switch its data communication from the cellular network to the wireless LAN. While the data session of UE **101***a* is on the wireless LAN, TIE **101***a* can periodically monitor and evaluate one or more parameters of the wireless LAN, compare the one or more parameters of the wireless LAN to link conditions on the cellular network, and decide whether to continue its data session on the wireless LAN or switch back to the cellular network.

[0023] According to one example, access point **103** provides a wireless LAN (e.g., a WiFi network) with coverage **105**. Different parameters can affect the experience of a user, such as the user of UE **101***a*, when connected to access point **103**. For example, the specific communications protocol (e.g., which version of IEEE 802.11) used by access point **103** affects user's experience. The number of users that share the access point, in addition to their bandwidth or data rate requirements, can affect the user's experience. Further, throughput of the network, data rate of the links, delays, quality of service support, etc. can also affect user's experience. Further, the throughput and/or data rate of any backhaul or PDN connected to the wireless network can also affect the user's experience.

[0024] In one embodiment, UE **101***a* detects access point **103** by, for example, examining a Beacon frame that is broadcast by access point **103**. A Beacon frame is a management frame in IEEE 802.11 based wireless LANs that is transmitted periodically by access point **103** to broadcast the presence of the wireless LAN and includes information about the network. Alternatively or additionally, UE **101***a* detects access point **103** by, for example, detecting packets sent by access point **103** to UE **101***a* and/or other UEs, and/or by detecting packets transmitted by other UEs to access point **103**. Instead

of automatically switching its data communication from the cellular network to the wireless LAN supported by access point **103** (as in conventional methods), UE **101***a* passively senses the medium of the wireless LAN to intelligently decide whether or not to make the switch. By passively sensing the medium, UE **101***a* is not required to transmit any packets and is not required to connect to and stay on a network that provides a user experience worse than the cellular network, therefore, saving power. By passively sensing the medium, UE **101***a* can estimate one or more parameters ("load") associated with the wireless LAN, such as, but not limited to, a network type, received signal strength indicator (RSSI—that is a measurement of the power present in a received radio signal), number of users sharing the wireless medium, estimated throughput of the link if UE **101***a* was to connect to access point **103**, the delay of its link, quality of service (QoS) support provided by the network, etc. After UE **101***a* estimates one or more parameters, UE **101***a* can compare the estimates to link conditions on the cellular network. UE **101***a* can then determine whether or not to switch to access point **103** based on this comparison.

[0025] Additionally or alternatively, while UE **101***a* is connected to access point **103** for data communication, UE **101***a* can periodically estimate one or more parameters of the wireless LAN and compare the parameters with link conditions on the cellular network to determine whether it is more suitable for UE **101***a* to stay on the wireless LAN or would be better to switch back to the cellular network for its data sessions. Therefore, instead of staying on the wireless LAN that does not provide suitable user experience, UE **101***a* can intelligently switch back to cellular network when needed.

[0026] FIG. **2** illustrates a user equipment, in accordance with an embodiment of the present disclosure. In one example, UE **101***a* can include, but is not limited to, a transceiver **203** including a radio transmitter and receiver, a cellular network module **205**, a WiFi network module **207**, a control logic **209** (such as, but not limited to one or more WiFi sensing module **211**, WiFi network estimation module **213**, and determination module **215**), and an antenna **201**, all or some of which can be executed utilizing one or more processors. For example, the control logic **209** can be implemented using one or more processor(s) and/or state machine logic, or a combination thereof, programmed or implemented to have the functionality described herein. Although different modules are illustrated in FIG. **2**, the disclosure is not so limited, as will be understood by those skilled in the arts. The modules can be implemented as part of control logic **209**, can be combined in one or more modules, and can be implemented by software, hardware, or a combination thereof, etc.

[0027] According to one example, UE **101***a* is configured to use transceiver **203**, cellular network module **205**, and antenna **201** for communication with network device **107** of the a cellular network. For example, UE **101***a*, using cellular network module **205**, transmits control packets, signaling messages, and/or data and/or voice packets to network device **107** and receives acknowledgments, signaling messages, and/or data and/or voice packets from device **107** through antenna **201**, transceiver **203**, and cellular network module **205**. Cellular module **205** can provide an interface that properly formats (encodes/decodes) packets for communications with the associated cellular network.

[0028] Similarly, UE **101***a* is configured to use transceiver **203**, WiFi network module **207**, and antenna **201** for communication with access point **103** of a wireless LAN (such as a WiFi network). For example, UE **101***a*, using WiFi network module **205**, transmits control packets, signaling messages, and/or data packets to access point **103** and receives acknowledgments, signaling messages, and/or data packets from access point **103** through antenna **201**, transceiver **203**, and WiFi network module **207**. WiFi network module **207** can provide an interface that properly formats (encodes/decodes) packets for communications with the associated wireless LAN. Although separate modules for communications on cellular network and wireless LAN are illustrated, the disclosure is not so limited, as will be understood by those skilled in the arts and these modules can be combined in one or more modules.

[0029] Control logic **209**, which includes one or more sensing module **211**, network estimation module **213**, and determination module **215**, is configured to passively sense a wireless LAN, to evaluate the suitability of that network, to determine whether a switch between the cellular network and the wireless LAN is advisable, and to initiate the switch. According to one example, WiFi sensing module **211** is configured to detect a wireless LAN and collect information that is needed for estimating the "load" of the network and that is needed to make the switching determination. For example, sensing module **2011**, using WiFi network module **207**, can scan for presence of access point **103**. In one example, sensing module **211** can detect the wireless LAN by examining a Beacon frame that is sent by access point **103**; receiving and examining packets that are sent to UE **101***a* and/or other UEs by access point **103**; and/or by receiving signaling messages from access point **103** and/or receiving packets sent by other UEs in the wireless LAN. By passively sensing the packets, sensing module **211** can examine these packets by reading information includes in these packets.

[0030] In one example, sensing module **211** can determine the "load" of the wireless LAN using information that is provided by access point **103**. For example, in IEEE 802.11u (incorporated herein by reference in its entirety), which is a recent development on IEEE technical standards for wireless LANs, sensing module **211** can use Access Network Query Protocol (ANQP) to collect information regarding the wireless LAN. ANQP is a query and response protocol used by UE **101***a* to discover information, such as access point **103** operator's domain name; roaming partners; IP address type availability; and other metadata useful in UE's **101***a* network selection process. UE **101***a* can send a query message to access point **103** and receive information regarding the wireless LAN. The information received can be used by determination module **215** to determine whether or not to switch between the cellular network and the wireless LAN.

[0031] Additionally or alternatively, sensing module **211** can obtain RSSI of the wireless LAN, which is a measurement of the power present in a received radio signal, by passively monitoring and scanning the wireless LAN medium. Sensing module **211**, using WiFi network module **207**, can observe RSSI values associated with packets that sensing module **211** scans. The value(s) of RSSI can be sent to WiFi network estimation module **213**. Estimation module **213** can use this information to estimate one or more parameters associated with the wireless LAN. For example, estimation module **213** can use the value(s) RSSI sensed by sensing module **211**, to determine the signal strength of the wireless LAN.

[0032] Additionally or alternatively, sensing module **211** can examine the source and destination media access control

(MAC) addresses of packets it receives, The wireless LAN is a shared medium so that packets transmitted (by access point **103** and/or other UEs in the network) can be received ("heard") by UE **101***a* that is passively sensing the medium, even though the packets are not addressed to the UE **101***a*. Sensing module **211**, alone or in combination with estimation module **213**, can determine the number of "active" UEs (e.g., UEs which are actively communicating with access point **103** or each other) by examining and cataloging the source and destination MAC addresses that are provided in each packet (for example, in the header of the packets.) To determine the number of "active" UEs, sensing module **211**, alone or in combination with estimation module **213**, determines the number of distinctive and unicast (e.g., unique and not multicast) MAC addresses. Multicast MAC transmissions are available to all UEs and therefore distinguished when trying to determine active UEs.

[0033] The number of active UEs in the wireless LAN is another parameter that is estimated by estimation module **213**, which can be used to determine the "load" of the network. This estimation method is applicable both in a traditional AP-WLAN (where UEs communicate with each other through the access point (AP)) and in a WiFi Direct (where UEs can communicate with each other directly and not through the access point.) In each scenario, UEs are using a shared medium that can be heard by UE **101***a* and UEs are using source and destination MAC addresses in the packets they transmit and receive. UE **101***a* can monitor the medium for a given amount of time (a few seconds) to be able to effectively estimate the number of active users in the network. The given time can be a fixed amount or can be variable depending on the amount of traffic UE **101***a* senses on the medium.

[0034] According to one example, when UE **101***a* first determines the presence of access point **103**, UE **101***a* examines the RSSI of the medium. If the UE **101***a* determines that the RSSI does not meet a threshold, UE **101***a* can decide not to switch to the wireless LAN (or if UE **101***a* is on the wireless LAN, UE **101** can decide to switch back to the cellular network.) If the UE determines that the RSSI meets the threshold (meaning that the signal strength is acceptable on the wireless LAN), before deciding to switch to the wireless LAN, UE **101***a* can estimate the number of UEs on the wireless LAN for consideration in the switching decision.

[0035] Additionally or alternatively, sensing module **211** can examine the wireless LAN medium and the packets transmitted thereon and determine a physical layer (PHY) data rate associated with each UE on the network. For example, sensing module **211** can examine the PHY level headers (such as Preamble/PLCP header in IEEE 802.11 packets) and infer the PHY data rate associated with each UE. Data rate of each UE is an indication how that UE uses the shared medium, and therefore, can be used to calculate expected throughput for UE **101***a*. In other words, a UE with a high data rate transmits it packets faster than another UE with a low data rate with same amount of packets to transmit, and therefore utilizes the shared medium for shorter time periods when transmitting.

[0036] Network estimation module **213** can use the PHY data rates of UEs and the estimated number of UEs to determine the expected throughput (e.g., the average rate of successful message delivery over a communication channel) of UE **101***a* if it joined the wireless network. For example, estimation module **213** can estimate the throughput using an "average cycle time" approach discussed in "Throughput Analysis of IEEE 802.11 Wireless LANs using Average Cycle Time Approach," K. Medepalli and F. A. Tobagi, Proceedings of IEEE Globecom 2005, incorporated herein by reference in its entirety. However, the disclosure is not so limited, as will be understood by those skilled in the arts, The present disclosure can include other methods to estimate the throughput. According to one example, estimation module **213** estimates the throughput by assuming that UE **101***a* has joined the wireless LAN and UE's **101***a* data rate is estimated based on the link's RSSI. In this example, estimation module **213** estimates the throughput it can get if it were to "hypothetically" join the wireless LAN. The throughput of its link in the wireless LAN is another parameter that is estimated by estimation module **213**, which can be used to determine the "load" of the network.

[0037] Additionally or alternatively, estimation module **213** can estimate the delay of the UE's **101***a* link if UE **101***a* were to connect to the wireless LAN. In this example, estimation module **213** estimates the delay by dividing a packet size (which is a known value for the protocol used in the wireless LAN) by the estimated throughput. The estimated delay of its link in the wireless LAN is another parameter that can be used to determine the "load" of the network.

[0038] Additionally or alternatively, sensing module **211** can examine a Beacon frame that is sent by access point **103**. Sensing module **211** can examine the Beacon frame and, alone or in combination with estimation module **213**, can determine which communications protocol (e.g., media access control (MAC) and physical layer (PHY) specifications for implementing the wireless LAN) is used in the wireless LAN. For example, sensing module **211** and/or estimation module **213** can determine which of IEEE 802.11 standards are used in the network. For example, sensing module **211** and/or estimation module **213** can determine whether IEEE 802.11a, b, g, n, etc. is used in the wireless LAN. The communications protocol used in the network can limit the maximum throughput UE **101***a* can achieve if it were to switch to the wireless LAN. The network type is another parameter that can be used to determine the "load" of the network.

[0039] Additionally or alternatively, sensing module **211** and/or estimation module **213** can determine what level of quality of service (QoS) is provided by the wireless LAN. For example, per IEEE 802.11 standards, data and control frames can include a QoS control field that can indicate the QoS provided by the wireless LAN. The QoS in the wireless LAN is another parameter that can be used to determine the "load" of the network. The above-noted parameters that can be used to determine the "load" of the wireless LAN are provided as exemplary parameters and the disclosure is not so limited, as will be understood by those skilled in the arts. The present disclosure can include any other methods for UE **101***a* to passively sense the wireless LAN's medium and estimate other parameters that can be used by UE **101***a* to decide whether or not switch between the wireless LAN and the cellular network.

[0040] Determination module **215** can compare one or more of the parameters estimated by estimation module **213** with corresponding parameters/metrics of the cellular network and determine whether to switch between the networks. According to one example, the throughput of the cellular link provided by the cellular network is controlled mostly by the cellular network and therefore, the UE **101***a* can have a good estimate of the cellular link's throughput. Determination

module **215** can compare the estimated throughput (e.g., calculated by estimation module **213**) of the wireless LAN's link to the cellular link's throughput and make a decision accordingly. Additionally or alternatively, determination module **215** can compare the estimated delay and/or RSSI of the wireless LAN's link to cellular link's to make the switching decision.

[0041] Additionally or alternatively, determination module **215** can determine whether to switch between networks based on network type determination made by, for example, sensing module **211** and/or estimation module **213**. For example, if sensing module **211** and/or estimation module **213** determined that the wireless LAN implements IEEE 802.11b, determination module **215** can decide to stay on cellular network (or switch back to cellular network) since IEEE 802.11b has a low maximum achievable throughput.

[0042] Additionally or alternatively, determination module **215** can determine whether to switch between networks based on t eh QoS determined by sensing module **211** and/or estimation module **213**. For example, if UE **101***a* is used for a QoS sensitive application (e.g., voice over LTE), determination module **215** can compare the QoS of the wireless LAN with the required QoS for the application and determine whether to switch between the networks. For example, if determination module **215** determines that the wireless LAN does not support the needed QoS for a particular application, determination module **215** can decide that UE **101***a* will stay on the cellular network (or switch back to cellular network.)

[0043] According to one example, an operator of the cellular network can influence the determination of switching between the networks. According to this example, the operator can set one or more thresholds to be used for the comparison of the one or more parameters (metrics) of the wireless LAN and the cellular network. The operator can send the one or more thresholds to the UEs. In one example, open mobile alliance (OMA) device management (DM) protocol can be used for the management of UEs. OMA-DM can support configuration, enabling and disabling features of UEs; changes to setting and parameters of UEs; providing new software and/or fixes; error reports and UE's status query; etc. For example, a threshold can be set by the operator of the cellular network for the throughput of the link. When determination module **215** compares the estimated throughput of the wireless LAN's network to the throughput of the cellular network, determination module **215** makes the switch between the networks if the difference between the throughputs is greater than the set threshold. According to one example, the threshold can take into consideration various characteristics of the UE, for example, the mobility of UE **101***a*. Stated other way, UE **101***a* will switch from the cellular network to the wireless LAN if the expected throughput that UE **101***a* will get on the wireless LAN exceeds the expected throughput on the cellular network by a given threshold. The given threshold can used to account for the fact that UE **101***a* can move, which can affect UE's experience on the wireless LAN. One or more set thresholds can be used for one or more other parameters used by determination module **215**.

[0044] If determination module **215** determines that a switch between the networks is suitable, cellular network module **205** and/or WiFi network module **207** are informed to make the switch between networks and resume the data communication on the new network. When determination module **215** determines to switch to the wireless LAN and UE **101***a* switches to the wireless LAN, sensing module **211**, estimation module **213** and determination module **215** can continue to passively sense the wireless LAN and can trigger a switch back to the cellular network if/when the quality of data communications on the wireless LAN goes below a threshold.

[0045] FIG. **3** is a flowchart depicting a method **300**, according to an embodiment of the present disclosure. For example, method **300** can be performed by UE **101***a* (e.g., cellular network module **205**, WiFi network module **207**, and control logic **209**). It is to be appreciated not all steps may be needed to perform disclosure provided herein. Further, some of the steps may be performed simultaneously, or in a different order than that shown in FIG. **3**, as will be understood by those skilled in the art. Reference is made to UE **101***a* in FIGS. **1** and **2** merely for convenience of discussion. Other systems may be used to perform the method as will be understood by those skilled in the arts.

[0046] In step **301**, UE **101***a* can detect an access point (e.g., access point **103**) that is associated with a wireless LAN (e.g., a WiFi network.) In one example, UE **101***a* (using, for example, sensing module **211**) can examine a Beacon frame that is sent by access point **103**. In this example, Beacon frames are transmitted periodically by access point **103** to broadcast the presence of the wireless LAN and the access point and include information about the network.

[0047] In step **303**, UE **101***a* can receive one or more packets transmitted within the wireless LAN. For example, UE **101***a* can receive packets that are transmitted by access point **103** to UE **101***a* and/or other UEs connected to access point **103**. Additionally or alternatively, UE **101***a* can receive packets that are transmitted by other UEs destined to access point **103**, UE **101***a,* and/or other UEs. According to one example, detecting the presence of access point **103** can be based on receiving these packets and examining them.

[0048] In step **305**, UE **101***a* estimates one or more parameters associated with the wireless LAN and access point **103** based on the packets UE **101***a* has passively received. The one or more parameters estimated by UE **101***a* can include, but is not limited to, RSSI of the communication link on the wireless LAN, number of users in the network, the throughput of the link, the delay of the link, the QoS provided by the network, and/or the type of the wireless LAN. In step **307**, UE **101***a* compares the one or more estimated parameters with one or more corresponding metrics of the cellular link. The corresponding metrics of the cellular link can be provided to UE **101***a* by the operator of the cellular network and/or can be estimated by UE **101***a*.

[0049] In step **309**, a determination can be made whether the comparison in step **307** satisfies one or more thresholds. According to one example, the operator of the cellular network can provide one or more thresholds to UE **101***a* to influence the conditions at which the switch between networks occurs. For example, after UE **101***a* compares a first estimated parameter of the wireless LAN to a first corresponding metric of the cellular network, UE **101***a* further compares the difference between the first estimated parameter and the first metric to a first threshold, In this example, UE **101***a* will switch the networks if the difference between corresponding metric of the wireless LAN and the cellular network is greater than a threshold.

[0050] If the comparison between the estimated parameter of the wireless LAN and the corresponding metric of the cellular network does not meet the threshold, in step **311**, UE **101***a* will continue its data communication (or will switch back its data communication) on the cellular network. Oth-

erwise, in step **313**, UE **101***a* will switch its data communication (or will continue its data communication) on the wireless LAN.

[0051] FIG. **4** is a flowchart depicting method **400**, according to an embodiment of the present disclosure. In one example, these methods further define estimating one or more parameters **305** of method **300**. For example, method **400** can be performed by UE **101***a* (e.g., cellular network module **205**, WiFi network module **207**, and control logic **209**). It is to be appreciated not all steps may be needed to perform disclosure provided herein. Further, some of the steps may be performed simultaneously, or in a different order than that shown in FIG. **4**, as will be understood by those skilled in the art. Reference is made to UE **101***a* in FIGS. **1** and **2** merely for convenience of discussion. Other systems may be used to perform the method as will be understood by those skilled in the arts.

[0052] According to an embodiment, estimating one or more parameters associated with access point **103**, as discussed in step **305** of FIG. **3**, can include examining the received packets in step **401** and determining RSSI and/or the type of the wireless LAN, in step **403**. According to this example. UE **101***a* can observe RSSI values associated with packets that UE **101***a* scans. In one example, RSSI can indicate the maximum throughput UE **101***a* can achieve on the wireless LAN if it was the only UE in the network. UE **101***a* can use this information to estimate one or more parameters associated with the wireless LAN. For example, UE **101***a* can use the value(s) RSSI sensed to determine the signal strength of the wireless LAN. In step **405**, UE **101** can compare the determined RSSI value with a threshold. If the determined RSSI does not meet the threshold, which can be set by the operator of the cellular network, in step **311**. UE **101***a* can perform its data communication on the cellular network. If the requirement of step **405** is satisfied, UE **101***a* can decided to perform its data communication of the wireless LAN or can continue with further examining the wireless LAN to determine if data communications should be performed on the wireless LAN.

[0053] In step **407**, the received packets are examined to determine source and destination MAC addresses included in the received packets. Each packet and/or frame transmitted on the wireless LAN (e.g., a wireless LAN that support an IEEE 802.11 standard) can be divided into specific sections, such as, a MAC header, a payload, and a frame check sequence (FCS). Each section includes one or more bytes that include information regarding that section or other sections of the frame. For example, an 802.11 frame can have up to four address fields, which can include a MAC address of the source, a MAC address of the destination. Additionally, in step **407**, UE **101***a* can determine PHY data rates of corresponding UEs. For example, the PHY level headers (such as Preamble/PLCP header in IEEE 802.11 packets) of the received packets can be examined and the PHY data rates can be determined from these PHY level headers.

[0054] Based on the number of distinctive and unicast MAC addresses, in step **409**, UE **101***a* can determine how many users are using the wireless LAN. In one embodiment, broadcast addresses are excluded from being counted as an active user. The estimated number of active users in the network can be used as one estimated parameter for comparison decisions **307** and **309** of FIG. **3**. Additionally or alternatively, in step **411**, UE **101***a* can use the PHY data rates and the estimated number of UEs to determine the throughput of UE's **101***a* in the network. In one embodiment, the throughput estimation can be based on "average cycle time" approach discuss in "Throughput Analysis of IEEE 802.11 Wireless LANs using Average Cycle Time Approach," K. Medepalli and F. A. Tobagi, Proceedings of IEEE Globecom 2005, incorporated herein by reference in its entirety. However, the disclosure is not so limited, as will be understood by those skilled in the arts and can include any other methods to estimate the throughput. According to one example, UE **101***a* estimates the throughput by assuming that UE **101***a* has joined the wireless LAN and UE's **101***a* data rate is estimated based on the link's RSSI.

[0055] According to one example, when "average cycle time" approach is used, the effective throughput of the system, assuming UE **101***a* is connected to the wireless LAN, is calculated as following:

$$S = \frac{P}{H + (P+O)\frac{1}{N}\sum_{j=1}^{N}\frac{1}{R_j} + \frac{E[B]}{N} + \frac{E[C]}{N_C}}$$

[0056] According to this example, P illustrates average packet size (e.g., 1500 bytes internet frame). The packet size distribution is known based on the protocol used in the wireless LAN and UEs in the wireless network use the same average packet size. Parameter H illustrates the size of the MAC header used in each packet, that can also be standard. Parameter O illustrates other higher layer overhead size. For example, the size of headers used by other layers, such as TCP (transmission control protocol) layer, RTP (real-time transport protocol) layer, etc. are accounted for in H.

[0057] Parameter R_j represents the physical data rate of user j. N represents the total number of users in the network, including UE **101***a*, that, for example, has been estimated by UE **101***a*. E[B] is the expected time spent in back-off by different users. E[B] is a function of total number of users in the network (N, including UE **101***a*) and therefore, can be determined by UE **101***a* based on the number of users estimated in step **409**. E[C] is an average channel time wasted because of collision on the channel, which can be calculated by UE **101***a* based on estimated number of users and other parameters that UE **101***a* can determine from the received packets, such as PHY data rates, packet size, the expected back-off time, etc. Finally, N_c represents number of users involved in a collision.

[0058] The estimated throughput of UE's **101***a* link in the wireless LAN can be used as one estimated parameter for comparison decisions **307** and **309** of FIG. **3**. For example, in step **413**, UE **101***a* can compare the estimated effective throughput with a threshold and perform the data communication over the cellular network if the threshold is not satisfied. If the threshold is satisfied, UE **101***a* can perform its data communication on the wireless LAN in step **313**, or decide to further examine the wireless LAN.

[0059] If the threshold is satisfied, and UE **101***a* continues with examining the wireless LAN, in step **415**, UE **101***a* can use the estimated throughput and a packet size (which is a known value for the protocol used in the wireless LAN) to determine an estimated delay for its link if UE **101***a* were to connect to the wireless LAN. According to this example, the delay is estimated by dividing the known packet size by the estimated throughput. The estimated delay of UE's **101***a* link in the wireless LAN can be used as one estimated parameter

for comparison decisions **307** and **309** of FIG. **3**. For example, in step **417**, UE **101***a* can compare the estimated delay with a threshold and perform the data communication over the cellular network if the threshold is not satisfied. If the threshold is satisfied, UE **101***a* can perform its data communication on the wireless LAN in step **313**, or decide to further examine the wireless LAN.

[0060] If the threshold is satisfied, and UE **101***a* continues with examining the wireless LAN, in step **419**, UE **101***a* can determine QoS provided by network. UE **101***a* can use the received packets to determine the QoS supported by the wireless LAN. According to one example, the packets/frames received by UE **101***a* can include a QoS control field that provides the QoS supported by the network. This QoS information can include quantitative measures of some aspects of the network such as error rates, bandwidth, throughput, transmission delay, availability, jitter, etc. The estimated QoS of the network can be used as one estimated parameter for comparison decisions **307** and **309** of FIG. **3**. For example, in step **421**, UE **101***a* can compare the determined QoS of the wireless LAN with one or more thresholds for one or more applications supported by UE **101***a*. If the one or more thresholds are not satisfied, UE **101***a* can perform the data communication over the cellular network. If the threshold is satisfied, UE **101***a* can perform its data communication on the wireless LAN in step **313**, or decide to further examine the wireless LAN.

[0061] Various aspects of the present disclosure can be implemented by software, firmware, hardware, or a combination thereof. FIG. **5** illustrates an example computer system **500** in which the present disclosure, or portions thereof, can be implemented as computer-readable code. For example, all or portions of methods **300** and **400** and control logic **209** can be implemented by computer system **500**. Various embodiments of the disclosure are described in terms of this example computer system **500**. After reading this description, it will become apparent to a person skilled in the relevant art how to implement the disclosure using other computer systems and/or computer architectures.

[0062] Computer system **500** includes one or more processors, such as processor **504**. Processor **504** can be a special purpose or a general purpose processor. Processor **504** is connected to a communication infrastructure **506** (for example, a bus or network).

[0063] Computer system **500** also includes a main memory **508**, preferably random access memory (RAM), and may also include a secondary memory **510**. Secondary memory **510** may include, for example, a hard disk drive **512**, a removable storage drive **514**, and/or a memory stick. Removable storage drive **514** may comprise a floppy disk drive, a magnetic tape drive, an optical disk drive, a flash memory, or the like. The removable storage drive **514** reads from and/or writes to a removable storage unit **518** in a well-known manner. Removable storage unit **518** may comprise a floppy disk, magnetic tape, optical disk, etc. that is read by and written to by removable storage drive **514**. As will be appreciated by persons skilled in the relevant art(s), removable storage unit **518** includes a computer usable storage medium having stored therein computer software and/or data.

[0064] In alternative implementations, secondary memory **510** may include other similar means for allowing computer programs or other instructions to be loaded into computer system **500**. Such means may include, for example, a removable storage unit **522** and an interface **520**. Examples of such means may include a program cartridge and cartridge interface (such as that found in video game devices), a removable memory chip (such as an EPROM, or PROM) and associated socket, and other removable storage units **522** and interfaces **520** that allow software and data to be transferred from the removable storage unit **522** to computer system **500**.

[0065] Computer system **500** may also include a communications interface **524**. Communications interface **524** allows software and data to be transferred between computer system **500** and external devices. Communications interface **524** may include a modem, a network interface (such as an Ethernet card), a communications port, a PCMCIA slot and card, or the like. Software and data transferred via communications interface **524** are in the form of signals that may be electronic, electromagnetic, optical, or other signals capable of being received by communications interface **524**. These signals are provided to communications interface **524** via a communications path **526**. Communications path **526** carries signals and may be implemented using wire or cable, fiber optics, a phone line, a cellular phone link, an RF link or other communications channels.

[0066] In this document, the terms "computer program medium" and "computer usable medium" are used to generally refer to media such as removable storage unit **518**, removable storage unit **522**, and a hard disk installed in hard disk drive **512**. Signals carried over communications path **526** can also embody the logic described herein. Computer program medium and computer usable medium can also refer to memories, such as main memory **508** and secondary memory **510**, which can be memory semiconductors (e.g. DRAMs, etc.). These computer program products are means for providing software to computer system **500**.

[0067] Computer programs (also called computer control logic) are stored in main memory **508** and/or secondary memory **510**. Computer programs may also be received via communications interface **524**. Such computer programs, when executed, enable computer system **500** to implement the present disclosure as discussed herein. In particular, the computer programs, when executed, enable processor **504** to implement the processes of the present disclosure. Accordingly, such computer programs represent controllers of the computer system **500**. Where the disclosure is implemented using software, the software may be stored in a computer program product and loaded into computer system **500** using removable storage drive **514**, interface **520**, hard drive **512** or communications interface **524**.

[0068] The disclosure is also directed to computer program products comprising software stored on any computer useable medium. Such software, when executed in one or more data processing device, causes a data processing device(s) to operate as described herein. Embodiments of the disclosure employ any computer useable or readable medium, known now or in the future. Examples of computer useable mediums include, but are not limited to, primary storage devices (e.g., any type of random access memory), secondary storage devices (e.g., hard drives, floppy disks, CD ROMS, ZIP disks, tapes, magnetic storage devices, optical storage devices, MEMS, nanotechnological storage device, etc.), and communication mediums (e.g., wired and wireless communications networks, local area networks, wide area networks, intranets, etc.).

[0069] The exemplary embodiments described herein are provided for illustrative purposes, and are not limiting. Other

exemplary embodiments are possible, and modifications may be made to the exemplary embodiments within the spirit and scope of the disclosure.

[0070] It is to be appreciated that the Detailed Description section, and not the Abstract section, is intended to be used to interpret the claims. The Abstract section may set forth one or more, but not all exemplary embodiments, of the disclosure, and thus, are not intended to limit the disclosure and the appended claims in any way.

[0071] The disclosure has been described above with the aid of functional building blocks illustrating the implementation of specified functions and relationships thereof. The boundaries of these functional building blocks have been arbitrarily defined herein for the convenience of the description. Alternate boundaries may be defined so long as the specified functions and relationships thereof are appropriately performed.

[0072] It will be apparent to those skilled in the relevant art(s) that various changes in form and detail can be made therein without departing from the spirit and scope of the disclosure. Thus the disclosure should not be limited by any of the above-described exemplary embodiments. Further, the claims should be defined only in accordance with the following claims and their equivalents.

What is claimed is:

1. A method of signal processing in a user equipment (UE) to select between a wireless local area network (LAN) and a cellular network for data transmission, comprising:
- detecting, by the UE, an access point associated with the wireless LAN;
- receiving, by the UE, packets that are transmitted by other devices that are using the wireless LAN;
- examining, by the UE, the received packets to estimate a data load of the wireless LAN; and
- selecting between the wireless LAN and the cellular network based on the estimated data load.

2. The method of claim **1**, further comprising:
- comparing the estimated data load of the wireless LAN with a corresponding parameter of the cellular network; and
- selecting one of the wireless LAN or the cellular network for the data transmission based on the comparison.

3. The method of claim **2**, further comprising:
- determining a difference between the estimated data load of the wireless LAN and the corresponding parameter of the cellular network;
- comparing the difference with a threshold; and
- selecting one of the wireless LAN or the cellular network for the data transmission based on the comparison of the difference and the threshold.

4. The method of claim **1**, wherein the estimating a data load comprises:
- determining a number of active users on the wireless LAN based on a number of different media access control (MAC) addresses identified for the received packets; and
- determining data rates of the active users based on packet headers of the received packets associated with the active users.

5. The method of claim **4**, wherein the estimating a data load further comprises:
- determining a prospective data rate of the UE if the UE were to access the wireless LAN; and
- estimating an expected throughput for the UE if the UE were to access the wireless LAN, based on the determined prospective data rate of the UE and the data rates of the active users.

6. The method of claim **5**, wherein the estimating a data load further comprises:
- determining an expected delay of the UE if the UE were to access the wireless LAN based on the estimated expected throughput for the UE.

7. The method of claim **4**, wherein the determining data rates of the active users comprises determining data rates of the active users by examining preamble/PLOP headers of 802.11 packets associated with the active users.

8. The method of claim **5**, wherein the determining a prospective data rate of the UE is based on a detected RSSI associated with the access point.

9. The method of claim **1**, further comprising:
- determining a quality of service provided the by wireless LAN;
- comparing the determined quality of service with a quality of service required by an application supported by the UE; and
- selecting one of the wireless LAN or the cellular network for the data transmission based on the comparison.

10. The method of claim **1**, further comprising:
- transmitting data, by the UE, on the selected network; and
- periodically updating the estimated data load, and changing networks if warranted.

11. A user equipment (UE), comprising:
- a radio transceiver configured to transmit signals to a wireless local area network (LAN); and
- a control logic configured to:
  - detect an access point associated with the wireless LAN;
  - receive packets that are transmitted by other devices that are using the wireless LAN;
  - examine the received packets to estimate a data load of the wireless LAN; and
  - select between the wireless LAN and a cellular network based on the estimated data load.

12. The UE of claim **11**, wherein the control logic is further configured to;
- compare the estimated data load of the wireless LAN with a corresponding parameter of the cellular network; and
- select one of the wireless LAN or the cellular network for the data transmission based on the comparison.

13. The UE of claim **12**, wherein the control logic is further configured to:
- determine a difference between the estimated data load of the wireless LAN and the corresponding parameter of the cellular network;
- compare the difference with a threshold; and
- select one of the wireless LAN or the cellular network for the data transmission based on the comparison of the difference.

14. The UE of claim **11**, wherein the estimating a data load comprises:
- determining a number of active users on the wireless LAN based on a number of different media access control (MAC) addresses identified for the received packets; and
- determining data rates of the active users based on packet headers of the received packets associated with the active users.

15. The UE of claim **14**, wherein the estimating a data load further comprises:

determining a prospective data rate for prospective data transmissions of the UE over the wireless LAN; and

estimating an expected throughput for the prospective data transmissions, based on the determined prospective data rate and the data rates of the active users.

16. The UE of claim **15**, wherein the estimating a data load further comprises:

determining an expected delay for the data transmissions if the UE were to access the wireless LAN based on the estimated expected throughput for the data transmissions.

17. The UE of claim **14**, wherein the determining data rates of the active users comprises determining data rates of the active users by examining preamble/PLCP headers of 802.11 packets associated with the active users.

18. The UE of claim **15**, wherein the determining a prospective data rate of the UE is based on a detected RSSI associated with the access point.

19. The UE of claim **11**, wherein the control logic is further configured to:

determine a quality of service provided the by wireless LAN;

compare the determined quality of service with a quality of service required by an application supported by the UE; and

select one of the wireless LAN or the cellular network for the data transmission based on the comparison.

20. The UE of claim **11**, wherein the control logic is further configured to:

initiate transmission of data on the selected network; and

periodically update the estimated data load, and change networks if warranted.

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