(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
18 December 2014 (18.12.2014)

(10) International Publication Number
WO 2014/201191 A1

(51) International Patent Classification:
H04B 1/38 (2006.01) *H04W 52/04* (2009.01)

(21) International Application Number:
PCT/US2014/042023

(22) International Filing Date:
12 June 2014 (12.06.2014)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
13/918,846 14 June 2013 (14.06.2013) US

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(81) **Designated States** *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) **Designated States** *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

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(54) Title: RADIO FREQUENCY (RF) POWER BACK-OFF OPTIMIZATION FOR SPECIFIC ABSORPTION RATE (SAR) COMPLIANCE

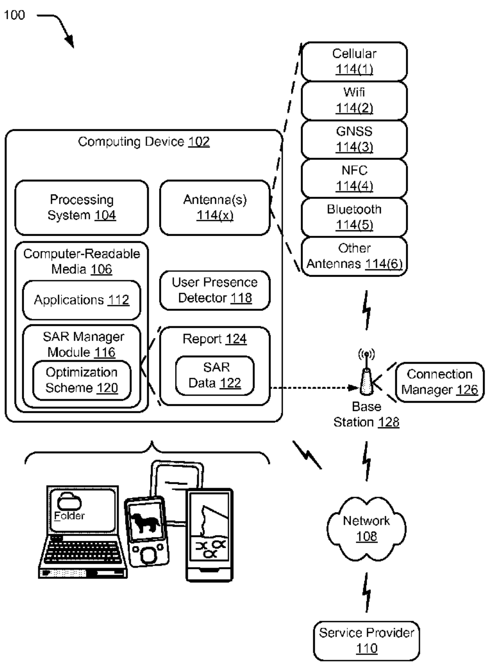

Fig. 1

(57) Abstract: Radio Frequency (RF) power back-off optimization techniques are described for specific absorption rate (SAR) compliance. A mobile device may be configured to intelligently modify antennas and radio device transmission levels to maintain compliance with SAR limits while minimally perturbing radio operations. The mobile device may implement a SAR optimization scheme that accounts for user presence and signal conditions to maintain compliance. Rather than setting a fixed back-off, user presence detectors may be employed along with information on current signal conditions to determine potential for excessive SAR exposure and selectively apply variable adjustments to RF transmission power (e.g., "back-offs"), accordingly. The mobile device may also be configured to report SAR conditions and/or mitigation actions to a base station to enable the base station to manage a connection to services based at least in part upon knowledge of SAR actions taken by the mobile computing device.

WO 2014/201191 A1

Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

Published:

— *with international search report (Art. 21(3))*

RADIO FREQUENCY (RF) POWER BACK-OFF OPTIMIZATION FOR SPECIFIC ABSORPTION RATE (SAR) COMPLIANCE

BACKGROUND

[0001] Mobile computing devices have been developed to increase the functionality that is made available to users in a mobile setting. For example, a user may interact with a mobile phone, tablet computer, or other mobile computing device to check email, surf the web, compose texts, interact with applications, and so on. Modern mobile computing devices may incorporate multiple antennas to support various wireless subsystems and communications. The multiple antennas may include for example one or more cellular, Wi-Fi, Bluetooth, global navigation satellite system (GNSS), and/or near field communication (NFC) antennas.

[0002] One challenge faced by mobile computing device designers is adherence to regulatory requirements that are imposed by entities such as the Federal Communication Commission (FCC), the European Union (EU), and so forth. An example of such regulatory requirements is legal limits on Specific Absorption Rate (SAR) that are established in relation to radio frequency (RF) energy associated with the various wireless and communications subsystems of a mobile computing device. A traditional solution for achieving compliance with SAR limits involves setting a fixed maximum RF transmit power for communication hardware (e.g., radios) to a power level that maintains legal compliance in the presence of a user. However, placing such a fixed maximum on the transmit power underutilizes the capabilities of communication hardware and may adversely affect communication connections and/or quality. Thus, traditional techniques for SAR compliance may be inadequate for some device configurations and use scenarios.

SUMMARY

[0003] Radio Frequency (RF) power back-off optimization techniques are described for intelligently modifying the performance of radio devices to maintain specific absorption rate (SAR) compliance with regulatory requirements while minimally perturbing antennas/radio operations. In one or more implementations, a mobile computing device is configured to implement a SAR optimization scheme to maintain compliance. Rather than setting a fixed back-off for power reductions, one or more user presence detectors may be employed along with information obtained regarding signal conditions to determine when humans are potentially at risk from SAR exposure and selectively apply variable adjustments to RF power (e.g., “back-offs”) that vary based on user presence and signal conditions. The mobile

computing device may also be configured to report SAR conditions and/or mitigation actions to a base station to enable the base station to manage a connection to services based at least in part upon knowledge of SAR actions taken by the mobile computing device.

[0004] This Summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used as an aid in determining the scope of the claimed subject matter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] The detailed description is described with reference to the accompanying figures. In the figures, the left-most digit(s) of a reference number identifies the figure in which the reference number first appears. The use of the same reference numbers in different instances in the description and the figures may indicate similar or identical items. Entities represented in the figures may be indicative of one or more entities and thus reference may be made interchangeably to single or plural forms of the entities in the discussion.

[0006] Fig. 1 is an illustration of an environment in an example implementation that is operable to employ the techniques described herein.

[0007] Fig. 2 is a flow diagram that describes an example procedure in which antennas are controlled in dependence upon SAR conditions and a current transmission power level.

[0008] Fig. 3 is a flow diagram that describes an example procedure in which a base station manages connections to service based in part upon reported SAR conditions.

[0009] Fig. 4 is a flow diagram that describes an example procedure in which a prediction model is established and applied to SAR mitigation based on expected signal conditions predicted via the model.

[0010] Fig. 5 illustrates an example system including various components of an example device that can be implemented as any type of computing device as described with reference to Figs. 1-4 to implement techniques described herein.

DETAILED DESCRIPTION

Overview

[0011] One challenge faced by mobile computing device designers is adherence to Specific Absorption Rate (SAR) limits that are established in relation to radio frequency (RF) emissions by mobile devices. A traditional solution involves setting a fixed maximum RF transmit power across all communication hardware, however, this approach generally sets a cautiously low maximum to maintain compliance at the expense of communication connection performance and/or quality.

[0012] Radio Frequency (RF) power back-off optimization techniques are described for specific absorption rate (SAR) compliance. In one or more implementations, a mobile computing device is configured to implement a SAR optimization scheme to maintain SAR compliance. Rather than setting a fixed back-off that is merely turned on and off in response to a triggering event, one or more user presence detectors may be employed along with information obtained regarding current signal conditions to determine when humans are potentially at risk from SAR exposure and selectively apply variable adjustments to RF power (e.g., "back-offs") that may vary based on user presence and signal conditions. The mobile computing device may also be configured to report SAR conditions and/or mitigation actions to a base station to enable the base station to manage a connection to services based at least in part upon knowledge of SAR actions taken by the mobile computing device.

[0013] In the following discussion, an example environment and devices are first described that may employ the techniques described herein. Example details and procedures are then described which may occur in the example environment and by the devices as well as in other environments and by other devices. Consequently, the example details and procedures are not limited to the example environment/devices and the example environment/devices are not limited to performance of the example details and procedures.

Example Operating Environment

[0014] Fig. 1 is an illustration of an environment 100 in an example implementation that is operable to employ the techniques described herein. The illustrated environment 100 includes an example of a computing device 102 that includes a processing system 104 and computer-readable media 106 that are representative of various different types and combinations of processing components, media, memory, and storage components and/or devices that may be associated with a computing device and employed to provide a wide range of device functionality. In at least some embodiments, the processing system 104 and computer-readable media 106 represent processing power and memory/storage that may be employed for general purpose computing operations. More generally, the computing device 102 may be configured as any suitable computing system and/or device that employ various processing systems and computer-readable media to implement functionality described herein, additional details and examples of which are discussed in relation to the example computing system of Fig. 5.

[0015] The computing device 102 may be configured in a variety of ways. For example, the computing device 102 may be configured as a mobile computing device for mobile use as illustrated, such as a mobile phone, a tablet computer, a laptop, a portable media device, and so on. The computing device 102 may range from full resource devices with substantial memory and processor resources to a low-resource device with limited memory and/or processing resources. The computing device 102 may also relate to software that causes the computing device 102 to perform one or more operations.

[0016] The computing device 102 may further be communicatively coupled over a network 108 to a service provider 110. The service provider 110 may be configured to make various resources (e.g. content and services) available over the network 108 to the computing device 102 and other clients. Generally, resources made accessible by a service provider 110 may include any suitable combination of services and/or content typically made available over a network by one or more providers. Some examples of services include, but are not limited to, cellular communication service, Internet data service, navigation service, a search service, an email service, an instant messaging service, an online productivity suite, and an authentication service to control access of clients to the resources, to name a few examples. Content may include various combinations of text, multi-media streams, documents, application files, photos, audio/video files animations, images, web pages, web applications, device applications, content for display by a browser or other client application, and the like.

[0017] As further illustrated in Fig. 1 the computing device 102 may include various applications 112, one or more antennas 114(x) to provide various wireless communication functionality, a SAR manager module 116 operable to control the antennas for SAR compliance, and one or more user presence detectors 118 to supply user presence indications with respect to the antennas. A variety of applications 112 that provide different functionality to the device may be provided on some form of computer-readable media and may be executed via the processing system. Some examples of applications 112 typically associated with computing devices include, but are not limited to, an operating system, a productivity suite that integrates multiple office productivity modules, a web browser, games, a multi-media player, a word processor, a spreadsheet program, a photo manager, and so forth.

[0018] The one or more antennas 114(x) are representative of various antennas employed by the computing device to implement wireless functionality, subsystems, and communications. In accordance with techniques described herein, the antennas may include multiple different kinds of antennas (e.g., radios) that are arranged together within one or more antennas zones established for the computing device. In general, the antennas may be placed to minimize interference between antennas and/or achieve performance objectives for the suite of antennas as a whole. A variety of different types of antennas, combinations of different types of antennas, and arrangements of antennas are contemplated. For example, the antennas 114(x) may include one or more cellular 114(1) antennas, Wi-Fi 114(2) antennas, global navigation satellite system (GNSS) 114(3) antennas, Near Field Communication (NFC) 114(4) antennas, Bluetooth 114(5) antennas, and/or other 114(6) antennas. In accordance with techniques described herein, the antennas 114 may include multiple antennas that may be interdependent upon one another and/or are arranged/designed in combination. In some scenarios, some wireless technologies may be implemented using two or more individual radios/antennas.

[0019] For instance, the Wi-Fi 114(2) antennas may employ a two-by-two multiple input/multiple output configuration (e.g., 2x2 MIMO). The Wi-Fi antennas may include at least a main and a MIMO antenna in some configurations. In addition, a Bluetooth 114(5) antenna may optionally be combined with the Wi-Fi 114(2) antennas. Further, modern cellular technologies such as Long Term Evolution (LTE), WiMax, and/or 4G may employ two or more cellular 114(1) antennas, such as a main cellular antenna and a MIMO cellular antenna and cover various frequencies, geographic areas, and so forth. The GNSS 114(3) antennas may be configured for use with various types of navigation standards, technologies, and systems including but not limited to GPS, GLONASS, Galileo, and/or BeiDou navigation systems, to name some examples.

[0020] The SAR manager module 116 represents functionality operable to implement an optimization scheme 120 to control antennas 114(x) to maintain SAR compliance in various scenarios. The SAR manager module 116 may be implemented as a standalone module, as firmware of one or more antennas/communication subsystems, as a component of an operating system or other application 112 (e.g., an antenna performance and communication manager application), and so forth. In accordance with techniques described herein, the optimization scheme 120 is configured to select and apply variable back-offs that may be determined based upon a plurality of considerations. For example, a variable amount of RF transmission power reduction may be selected in response to a trigger based upon a user presence indication in combination with signal conditions that are determined for a device. The amount of power reduction applied may be selected from a range of multiple options that are dependent at least partially upon ascertained signal conditions, rather than merely user presence alone. As discussed in more detail in relation to the following figures, signal conditions may include but are not limited to current RF transmission power levels measured via suitable hardware (e.g., sensors, circuitry, etc.) and/or predicted future conditions determined using a prediction model established for a device. The multiple options for may include options to apply a reduction at different levels, maintain a current level, and/or delay a reduction in different scenarios in accordance with signal conditions. Under some detected conditions indicative of low or non-existent potential for SAR exposure, RF transmission power may even be boosted to a higher levels to improve performance/quality. This is in contrast to traditional techniques that employ fixed back-offs at pre-set levels that are either turned on or off in a binary manner when triggered by user presence or otherwise.

[0021] To control antenna operations, the SAR manager module 116 may be configured to obtain user presence indications from user presence detectors 118. The user presence detectors 118 are representative of suitable hardware, software, firmware, logic and combinations thereof to obtain user presence indications and to supply such information for use by the SAR manager module 116. A variety of different physical sensors, sensor arrangements, and techniques for the user presence detectors 118 may be employed.

[0022] For example, a user presence detector 118 may be configured as a hardware sensor capable of detecting and indicating presence of a user relative to the computing device and/or relative to particular regions of the device for which SAR mitigation is relevant. Generally, a user presence detector 118 may be located proximate to antennas 114(x) to indicate when a user is positioned in a manner relative to the antennas that would increase or decrease the likelihood of exceeding SAR limits. For instance, placing a hand over a region having one or more of the antennas to hold a device may increase the amount of RF energy that the user is exposed to. On the other hand, some device hand positions for holding a device may be at a sufficient distance from the antennas to reduce exposure and permit higher RF energy outputs without causing SAR violations. Further, SAR compliance may depend in general upon whether or not a user is physically interacting with the device and the context of interaction.

[0023] Thus, if the device is set down to watch a media presentation or placed on a table after use, the level of potential exposure decreases. User actions with a device such as typing, gestures, selecting buttons, and other types of input may be indicative of user presence. These and other contextual factors regarding usage of the device may be considered along with information obtained directly from user presence detectors 118 to determine when and how to trigger and adjust antenna output. By way of example, user presence detectors 118 employed by a device may include but are not limited to capacitive sensors, infrared radiation (IR) sensors, pressure sensors, optical detectors, a camera, sensors for measuring reflected RF radiation from the antennas 114(x), and/or other type of sensors capable of determining a relationship of a user relative to the device and supplying such information as user presence indications.

[0024] In addition to implementing the optimization scheme 120 to control antennas and mitigate SAR exposure, the SAR manager module 116 may be further configured to initiate reporting of data describing SAR related conditions and actions to other entities to facilitate management of connections of the device to access services associated with one or more service providers 110. To do so, the SAR manager module 116 may generate SAR data 122 in a suitable format for inclusion in a report 124 for communication to a connection manager 126.

[0025] The connection manager 126 represents functionality operable to facilitate management of connections of the computing device 102 via the antennas 114(x) to corresponding services and service providers. This may include but is not limited to opening/closing connections, client authentication, providing access to data and resources, setting data rates, controlling communication quality, handling hand-offs between access points, routing operations, and so forth. In at least some implementations, the connection manager 126 is configured to utilize SAR data 122 supplied in reports 124 from devices to manage connections of the devices in a manner that takes SAR related conditions and activities of the devices into account. In other words, connection management operations performed by the connection manager 126 may be informed by and/or selected in dependence upon SAR data 122 supplied by devices. The connection manager 126 may be implemented a component of a base station 128 associated with a cellular network, Wi-Fi network, a satellite network, or other network as represented in Fig. 1. The base station 128 is therefore representative of any suitable wireless network access point through which antennas 114(x) may gain access to corresponding services, such as a cellular tower/cellular base station, a Wi-Fi access point, a wireless router, a satellite network satellite, or other base station device.

[0026] Having discussed an example environment and devices, consider now some example details regarding RF power back-off optimization for SAR compliance in accordance with various implementations.

__**RF Power Back-Off Optimization Details**__

[0027] The following discussion presents some details regarding RF power back-off optimization for SAR compliance in relation to some illustrative procedures. Aspects of each of the procedures may be implemented in hardware, firmware, software, or a combination thereof. The procedures are shown as a set of blocks that specify operations performed by one or more devices and are not necessarily limited to the orders shown for performing the operations by the respective blocks. Aspects of the described procedures may be implemented by one or more suitably configured computing devices individually or in combination, such as a computing device 102 of Fig. 1 that includes a SAR manager module 116 and/or a base station 128 device that implements a connection manager 126.

[0028] Fig. 2 depicts an example procedure 200 procedure in which antennas are controlled in dependence upon SAR conditions and a current transmission power level. Conditions are detected at a mobile computing device that are indicative of potential for non-compliance with specific absorption rate (SAR) legal limits (block 202). The detected conditions may include indications of user presence with respect to one or more antennas 114(x). The indications of user presence may be determined using information from one or more user presence detectors 118. Generally, user presence detectors 118 may be placed within or proximate to a portion of a device that houses antennas and/or in relation to individual antennas to detect when a user is “present”. The presence of a user in the context of SAR mitigation refers to whether the relationship of the user to a device encroaches upon the antennas to an extent that potential for the user to be exposed to RF emissions above SAR limits is increased to an unacceptable level. A user may be considered present under conditions that increase potential exposure to unacceptable levels and considered not present when the user is sufficiently removed from the antennas. Presence may be indicated for different antennas or groups of antennas of a device on an individual basis. Thus, a user may be considered present with respect to some antennas and at the same time considered not present with respect to other antennas of a particular device.

[0029] In addition or alternatively, other conditions may also be detected that provide contextual clues regarding whether or not a user is at risk for excessive SAR exposure. Presence with respect to SAR compliance may depend in general upon whether or not a user is physically interacting with the device and the context of interaction. Thus, if the device is set down to watch a media presentation or placed on a table after use, the level of potential exposure decreases. User actions with a device such as typing, gestures, selecting buttons, and other types of input may also be indicative of user presence. Additionally, future conditions and user activities that are predicted using a prediction model as described below may also be considered. These and other contextual factors regarding usage of the device may be detected as conditions used along with information obtained directly from user presence detectors 118 to determine when and how to adjust antenna output.

[0030] In accordance with techniques discussed herein the user presence indications and other conditions indicative of potential for non-compliance with specific absorption rate (SAR) legal limits may operate as triggering events that initiate a SAR analysis by the SAR manager module 116. Rather than using such triggers as a singular basis for initiating SAR mitigation, the triggers may be used as one of multiple factors considered in making decisions regarding actions for SAR mitigation. Further, variable rather the pre-determined fixed back-off may be applied. For example, various signal and communication connection conditions associated with a device may be taken into account for RF transmission power control. By so doing, the SAR manager module 116 may be configured to selectively apply variable adjustments to RF power (e.g., “back-offs”) that may vary based on user presence and signal conditions.

[0031] In particular, a current radio frequency transmission power level is ascertained for one or more antennas of the mobile computing device (block 204). Then, an optimization scheme is applied based on the detected conditions and the current RF transmission power to select an amount of RF transmission power reduction to implement to maintain SAR compliance in response to the detected conditions (block 206). For instance, the current radio frequency transmission power may be monitored in various ways and employed to inform an optimization scheme 120 implemented by the SAR manager module 116. In one approach, transmission power may be measured via power monitoring circuitry incorporated with hardware of particular radios/antennas. In addition or alternatively, a computing device 102 may be configured to include a monitoring device having a power detector circuit designed to monitor RF levels of one or more corresponding antennas. Measurement of actual, current transmission conditions enables the system to determine with precision the potential that exists for non-compliance with SAR limits. For instance, when a device is relatively close to base station, transmission power may be low and the risk for SAR exposure may be correspondingly low as well. In this case, there may be no cause for applying a RF back-off even though a user is present. Thus, the current power level may be maintained. On the other hand, transmission power and SAR exposure may increase in other scenarios, in which case an appropriate RF back-off may be selected and applied based on the current power level.

[0032] Thus, the optimization scheme 120 may operate to selectively apply variable RF transmission power reductions based on the detected conditions and the current RF transmission power. Such RF “back-offs” that are applied may vary based upon the ascertained power level and/or other signal conditions. The decision regarding whether or not to apply a back-off is also based upon indications of user presence and other conditions that may trigger SAR analysis. Detection of certain conditions and/or combinations of conditions may trigger control actions to adapt antenna operations for compliance. This may occur when detected conditions are indicative of potential to exceed SAR legal limits. On the other hand, some conditions have no substantial impact on SAR compliance in which case antennas may be controlled to optimize performance. For instance, a current transmission power level may be maintained when the power level is sufficiently low to avoid exceeding SAR legal limits. Further, a back-off may be delayed in circumstances in which detected conditions indicate an expected change in signal strength that will avoid exceeding SAR legal limits is already forthcoming.

[0033] Accordingly, the optimization scheme 120 implemented by the SAR manager module 116 may operate to modify transmission power levels and/or other operational parameters for one or more antennas device in dependence upon detected SAR conditions and signal conditions. This may include reducing transmission power levels for SAR compliance in response to detection of some conditions and boosting transmission power levels for performance in response to detection of some other conditions. Moreover, different antennas may be controlled individually based on the accessory arrangement such that for a given arrangement one or more selected antennas having the potential to cause excessive SAR conditions may be controlled for compliance (e.g., reduce energy output/power level) while in the same arrangement other antennas (e.g., antennas that do not contribute to excess SAR conditions) may continue to operate “normally” and/or may be boosted for performance.

[0034] In an implementation, back-offs are implemented in a gradual manner, such as by using multiple steps or stages to ramp down the transmission power a selected amount over a period of time. Power may also be ramped back up in similar manner in appropriate circumstances. By ramping down and up in this manner, as opposed to taking large singular jumps, the system has additional time to prepare for changes that are applied. This may assist in avoiding both sudden SAR spikes and overly aggressive handoffs or dropped connections due to SAR mitigation actions. The approach also gives additional time to a connection manager 126 and/or base station 128 to determine how to respond to SAR mitigation actions that are taken by clients.

[0035] Data indicative of the amount of RF transmission power reduction selected is reported to a base station through which the mobile computing device is connected to service (block 208). As mentioned, the SAR manager module 116 may be configured to initiate reporting of data describing SAR related conditions and actions to other entities in addition to implementing the optimization scheme 120. For instance, the SAR manager module 116 may be configured to include SAR data 122 in a report 124 to a base station 128. The SAR data 122 is effective to enable the base station to distinguish between power reductions due to SAR mitigation and power reductions that may be due to other causes, which may include but are not limited device location, base station coverage and layout, network conditions, and/or signal obstruction zones, to name a few examples. The base station may employ information regarding SAR mitigations and/or back-off actions taken by a device to manage one or more connections for the device accordingly, additional details of which may be found in relation the following example procedure.

[0036] Fig. 3 is a flow diagram that describes an example procedure 300 in which a base station manages connections to services based in part upon reported SAR conditions. A report from a mobile computing device is obtained at a base station that includes data indicative of an amount of RF transmission power reduction applied at the mobile computing device in relation to SAR compliance (block 302). For instance, a report 124 having SAR data 122 may be obtained at a base station 128 from a computing device 102. The report may be received and processed by way of a connection manager 126 or comparable functionality. The report may be also configured in various ways. In one approach, the SAR data 122 is included in an existing measurement report exchanged between a device and base station, such as a measurement report typically sent by a mobile phone to a cellular tower in a cellular communication network. The report may also be a dedicated report, message, or other suitable notification generated by a SAR manager module 116 to provide the SAR data 122. The SAR data 122 may include information regarding SAR conditions and/or signal conditions observed by the device and actions taken with respect to SAR mitigation. In instances in which a back-off is applied at the device, the SAR data 122 may indicate the amount of back-off. The report may further include indications regarding signal coverage and strength that may be used by the base station for processing of hand-offs between base stations/access points.

[0037] A connection of the mobile computing device to service through the base station is managed based at least in part upon the data included in the report (block 304). For instance, a connection manager 126 associated with services from a service provider 110 and/or a corresponding base station 128 may operate to manage connections of mobile computing devices to access services. The connection manager 126 may further be configured to receive and process reports 124 from the mobile devices that contain SAR data 122 as described herein.

[0038] The connection manager 126 may perform various operations to manage connections in dependence upon the SAR data 122 contained in the reports. This may include operations to distinguish between back-offs due to SAR compliance and power reductions caused by other channel conditions (block 306) and operations to selectively manage base station handoffs in accordance with the data regarding RF transmission power reduction indicated in the report (block 308). Thus, the SAR data 122 assists the connection manager 126 of a base station 128 in understanding the cause of observed channel conditions and determining how to react to manage connections accordingly. In one example, the connection manager may determine how to handle hand-offs between base stations based upon the understanding of SAR conditions and signal conditions at a device. For instance, the connection manager may determine based on provided SAR data that a transmission drop off is due to SAR mitigation rather that other channel conditions, such as movement of the device between locations, obstructions, and so forth. In this case, a hand-off to another base station may be prevented or delayed until the SAR concern is resolved. In another scenario, the connection manager may proceed with a hand-off in response to determining that the cause of poor signal and channel conditions is due to movement/relocation of a mobile device and that another base station is available that may improve the connection and/or service quality. In a further example, the connection manager may force a hand-off to occur to assist in mitigating SAR. This may occur for example in a situation in which base station coverage overlaps and the forced switch enables the device to drop down to a lower transmission power level based on proximity of the device to the target base station.

[0039] Additionally, the connection manager 126 may identify situations in which a channel drop is imminent based on the SAR data. Anticipation of channel drops in this manner may enable the base station and device to handle the drop gracefully. For example, the connection manager 126 may attempt to hand-off to another base station with potentially better signal conditions, cause an alert regarding the drop to be communicated, or otherwise take action to minimize the impact of the channel drop. Various other examples are also contemplated. Thus, a base station may utilize knowledge of SAR actions and conditions obtained from devices to manage connections of the devices in various ways including but not limited to the example management scenarios just described.

[0040] Fig. 4 is a flow diagram that describes an example procedure 400 in which a prediction model is established and applied for SAR mitigation based on expected signal conditions predicted via the model. A model is established to predict signal conditions for a mobile computing device including at least an expected transmission power level for one or more antennas of the mobile computing device (block 402) and signal conditions are predicted using the model (block 404). For example, the SAR manager module 116 may be configured to include and make use of a prediction model that may be used along with measured and detected conditions to drive SAR mitigation analysis and actions. The prediction model may be configured in various ways to provide predictions of expected signal conditions. The predictions of expected signal conditions may be employed in connection with other techniques described herein, such as in conjunction with the power back-off optimization techniques discussed in relation to the example procedures of Figs. 2 and 3. For instance, signal conditions used to drive an optimization scheme 120 may include an expected transmission power level predicted for one or more antennas using a prediction model established for the mobile computing device.

[0041] In one approach, the prediction model is configured to derive prediction for a signal strength measurement such as a received signal strength indicator (RSSI). The model may designed to account for a plurality of factors to generate predictions for an expected transmission power level of a particular antenna at a given time. For instance, the model may account for one or more of historical analysis of connection traffic, usage and travel patterns for individual devices, network topology, base station arrangement and coverage grids, information regarding coverage overlaps, historic bandwidth metrics, device and base station capabilities, and/or other factors that facilitate predictions of expected changes in transmission power based on signal conditions within the network. Statistical analysis and/or weighted combinations of these and other factors may be used to create a model that indicates when changes to transmission power are likely to occur and the amount of drop or increase expected. Predictions derived via the model may then be used to inform decisions regarding whether to take action in response to a SAR triggering event and what action to take.

[0042] In particular, a SAR trigger is detected at the mobile computing device that is indicative of potential for non-compliance with SAR legal limits (block 406) and actions taken to maintain SAR compliance are adjusted in response to the detected SAR trigger to account for the predicted signal conditions (block 408). The SAR manager module 116 may be configured to utilize predicted signal conditions in various ways. For example, the SAR manager module 116 may operate to effectuate techniques for SAR mitigation with RF back-off optimization described herein in response to a trigger, such as detection of user presence. Generally speaking, control actions to take with respect to one or more antennas may be specified or computed in relation to different conditions. By way of example and not limitation, antenna control actions may include but are not limited to setting transmission power limits, throttling of one or more antennas or types of antennas, prioritization of antenna communications, and power back-off adjustments, as well as intentional radio degradation and/or radiation pattern modifications achieved through programmable elements (e.g., counter-measure devices), to name a few examples. One or more control actions to mitigate potential for exceeding legal SAR limits may be potentially applied for antennas that contribute to SAR emissions.

[0043] Such potential actions to take may be derived based upon actual, current SAR conditions. However, in at least some cases identified actions may be adjusted based upon predicted conditions ascertained via the prediction model. For instance, the prediction model may indicate an expected reduction in transmission power for a mobile device as the mobile device is transported/relocated closer to a base station, such as when a user of the device travels along a route to work on a daily basis. In this example, historic usage data for the device/user along the route may be employed to predict a future reduction in transmission power. In this case, a back-off triggered based on SAR concerns may be delayed or foregone since a reduction is already expected. On the other hand, a predicted increase in transmission power may be used as a basis to effectuate a SAR back-off or take other mitigation action, such as forcing a hand-off, outputting a notice of the expected change, or otherwise adjusting the SAR related activities based on the predictions. In this manner, a prediction model may be employed to produce predictions of expected signal conditions that may be used as at least one consideration for optimization of RF power back-offs using an optimization scheme as detailed herein.

[0044] Having considered the foregoing example procedures, consider now a discussion of example systems and devices that may be employed to implement aspects of techniques in one or more embodiments.

Example System and Device

[0045] Fig. 5 illustrates an example system generally at 500 that includes an example computing device 502 that is representative of one or more computing systems and/or devices that may implement the various techniques described herein. The computing device 502 may, for example, be configured to assume a mobile configuration through use of a housing formed and size to be grasped and carried by one or more hands of a user, illustrated examples of which include a mobile phone, mobile game and music device, and tablet computer although other examples are also contemplated.

[0046] The example computing device 502 as illustrated includes a processing system 504, one or more computer-readable media 506, and one or more I/O interface 508 that are communicatively coupled, one to another. Although not shown, the computing device 502 may further include a system bus or other data and command transfer system that couples the various components, one to another. A system bus can include any one or combination of different bus structures, such as a memory bus or memory controller, a peripheral bus, a universal serial bus, and/or a processor or local bus that utilizes any of a variety of bus architectures. A variety of other examples are also contemplated, such as control and data lines.

[0047] The processing system 504 is representative of functionality to perform one or more operations using hardware. Accordingly, the processing system 504 is illustrated as including hardware elements 510 that may be configured as processors, functional blocks, and so forth. This may include implementation in hardware as an application specific integrated circuit or other logic device formed using one or more semiconductors. The hardware elements 510 are not limited by the materials from which they are formed or the processing mechanisms employed therein. For example, processors may be comprised of semiconductor(s) and/or transistors (e.g., electronic integrated circuits (ICs)). In such a context, processor-executable instructions may be electronically-executable instructions.

[0048] The computer-readable media 506 is illustrated as including memory/storage 512. The memory/storage 512 represents memory/storage capacity associated with one or more computer-readable media. The memory/storage component 512 may include volatile media (such as random access memory (RAM)) and/or nonvolatile media (such as read only memory (ROM), Flash memory, optical disks, magnetic disks, and so forth). The memory/storage component 512 may include fixed media (e.g., RAM, ROM, a fixed hard drive, and so on) as well as removable media (e.g., Flash memory, a removable hard drive, an optical disc, and so forth). The computer-readable media 506 may be configured in a variety of other ways as further described below.

[0049] Input/output interface(s) 508 are representative of functionality to allow a user to enter commands and information to computing device 502, and also allow information to be presented to the user and/or other components or devices using various input/output devices. Examples of input devices include a keyboard, a cursor control device (e.g., a mouse), a microphone, a scanner, touch functionality (e.g., capacitive or other sensors that are configured to detect physical touch), a camera (e.g., which may employ visible or non-visible wavelengths such as infrared frequencies to recognize movement as gestures that do not involve touch), and so forth. Examples of output devices include a display device (e.g., a monitor or projector), speakers, a printer, a network card, tactile-response device, and so forth. Thus, the computing device 502 may be configured in a variety of ways to support user interaction.

[0050] Various techniques may be described herein in the general context of software, hardware elements, or program modules. Generally, such modules include routines, programs, objects, elements, components, data structures, and so forth that perform particular tasks or implement particular abstract data types. The terms “module”, “functionality”, and “component” as used herein generally represent software, firmware, hardware, or a combination thereof. The features of the techniques described herein are platform-independent, meaning that the techniques may be implemented on a variety of commercial computing platforms having a variety of processors.

[0051] An implementation of the modules and techniques described herein, including but not limited to the SAR manager module 116 (as shown) and connection manager 126, may be stored on or transmitted across some form of computer-readable media. The computer-readable media may include a variety of media that may be accessed by the computing device 502. By way of example, and not limitation, computer-readable media may include “computer-readable storage media” and “computer-readable signal media”.

[0052] “Computer-readable storage media” may refer to media and/or devices that enable storage of information in contrast to mere signal transmission, carrier waves, or signals per se. Thus, computer-readable storage media does not include signal bearing media or signals per se. The computer-readable storage media includes hardware such as volatile and non-volatile, removable and non-removable media and/or storage devices implemented in a method or technology suitable for storage of information such as computer readable instructions, data structures, program modules, logic elements/circuits, or other data. Examples of computer-readable storage media may include, but are not limited to, RAM, ROM, EEPROM, flash memory or other memory technology, CD-ROM, digital versatile disks (DVD) or other optical storage, hard disks, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices, or other storage device, tangible media, or article of manufacture suitable to store the desired information and which may be accessed by a computer.

[0053] "Computer-readable signal media" may refer to a signal-bearing medium that is configured to transmit instructions to the hardware of the computing device 502, such as via a network. Signal media typically may embody computer readable instructions, data structures, program modules, or other data in a modulated data signal, such as carrier waves, data signals, or other transport mechanism. Signal media also include any information delivery media. The term "modulated data signal" means a signal that has one or more of its characteristics set or changed in such a manner as to encode information in the signal. By way of example, and not limitation, communication media include wired media such as a wired network or direct-wired connection, and wireless media such as acoustic, RF, infrared, and other wireless media.

[0054] As previously described, hardware elements 510 and computer-readable media 506 are representative of modules, programmable device logic and/or fixed device logic implemented in a hardware form that may be employed in some embodiments to implement at least some aspects of the techniques described herein, such as to perform one or more instructions. Hardware may include components of an integrated circuit or on-chip system, microcontroller devices, an application-specific integrated circuit (ASIC), a field-programmable gate array (FPGA), a complex programmable logic device (CPLD), and other implementations in silicon or other hardware. In this context, hardware may operate as a processing device that performs program tasks defined by instructions and/or logic embodied by the hardware as well as a hardware utilized to store instructions for execution, e.g., the computer-readable media described previously.

[0055] Combinations of the foregoing may also be employed to implement various techniques described herein. Accordingly, software, hardware, or executable modules may be implemented as one or more instructions and/or logic embodied on some form of computer-readable media and/or by one or more hardware elements 510. The computing device 502 may be configured to implement particular instructions and/or functions corresponding to the software and/or hardware modules. Accordingly, implementation of a module that is executable by the computing device 502 as software may be achieved at least partially in hardware, e.g., through use of computer-readable media and/or hardware elements 510 of the processing system 504. The instructions and/or functions may be executable/operable by one or more articles of manufacture (for example, one or more computing devices 502 and/or processing systems 504) to implement techniques, modules, and examples described herein.

Conclusion

[0056] Although the example implementations have been described in language specific to structural features and/or methodological acts, it is to be understood that the implementations defined in the appended claims are not necessarily limited to the specific features or acts described. Rather, the specific features and acts are disclosed as example forms of implementing the claimed features.

CLAIMS

1. A method comprising:

detecting conditions at a mobile computing device indicative of potential for non-compliance with specific absorption rate (SAR) legal limits; and

ascertaining a current radio frequency (RF) transmission power for one or more antennas of the mobile computing device; and

applying an optimization scheme based on the detected conditions and the current RF transmission power to select an amount of power reduction to implement for the mobile computing device to maintain SAR compliance in response to the detected conditions.

2. A method as described in claim 1, further comprising reporting data indicative of the amount of RF transmission power selected to a base station through which the mobile computing device is connected to service.

3. A method as described in claim 2, wherein the data indicative of the amount of RF transmission power selected is included in a measurement report sent to the base station and effective to enable the base station to distinguish between power reductions due to SAR mitigation and power reductions due to other causes.

4. A method as described in claim 1, wherein the amount of RF transmission power reduction selected varies based upon the current RF transmission power that is ascertained.

5. A method as described in claim 1, applying the optimization scheme comprises reducing the RF transmission power a variable amount when the detected conditions and current RF transmission power are indicative of a potential to exceed the SAR legal limits.

6. A method as described in claim 1, wherein applying the optimization scheme comprises maintaining the current RF transmission power when the current RF transmission power is sufficiently low to avoid exceeding the SAR legal limits.

7. A method as described in claim 1, wherein applying the optimization scheme comprises delaying a reduction of the RF transmission power when the detected conditions indicate that a change in signal strength is expected that will avoid exceeding the SAR legal limits.

8. A method as described in claim 1, wherein detecting the conditions comprises recognizing whether or not a user is present with respect to the one or more antennas via one or more user presence detectors provided with the mobile computing device.

9. A method as described in claim 8, wherein the user presence detectors comprise one or more of a capacitive sensor, a pressure sensor, a camera, an optical sensor, or an infrared radiation (IR) sensor.

10. A method as described in claim 1, wherein the one or more antennas include at least a pair of cellular antennas for cellular communications.

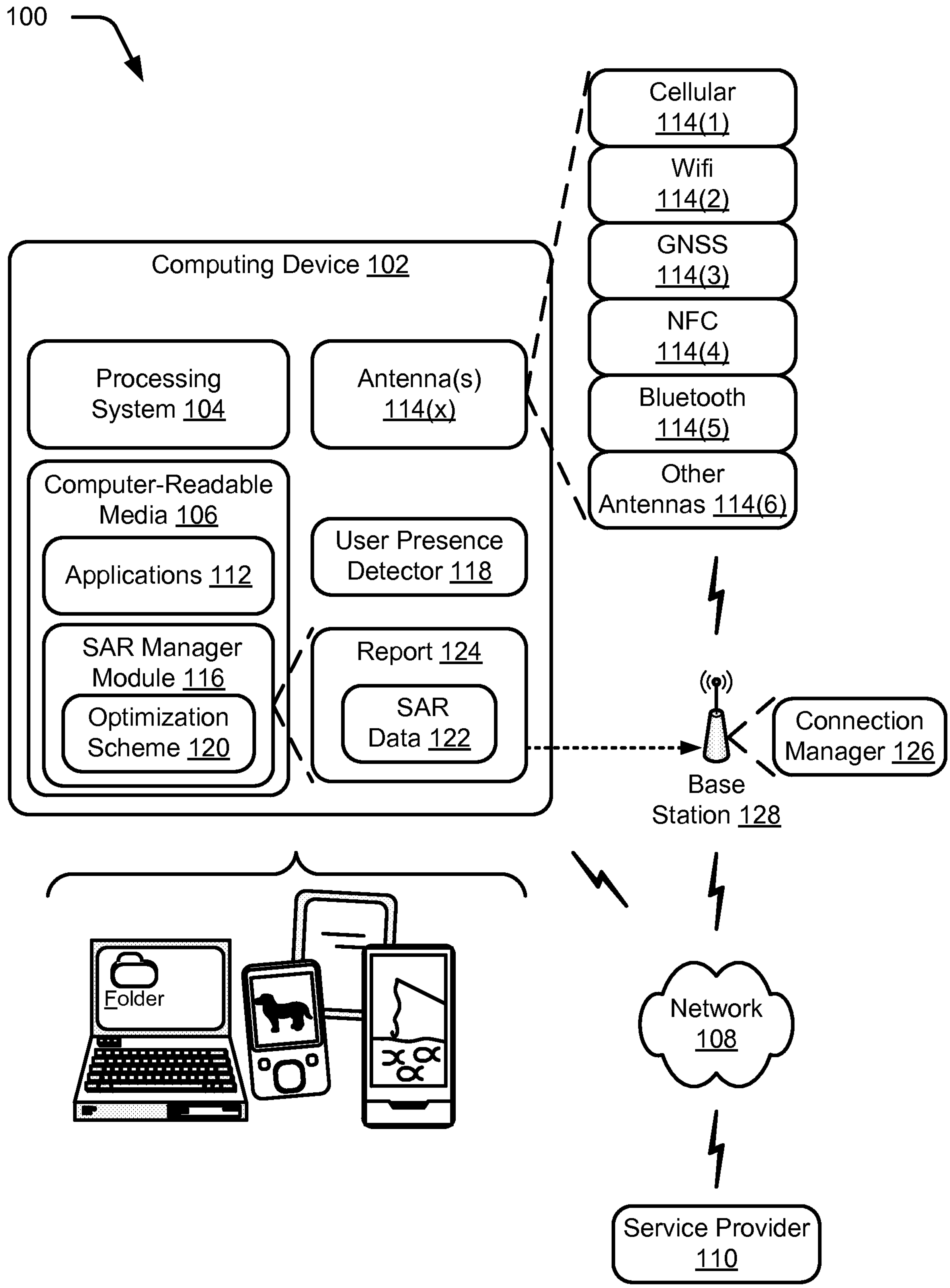
100
Computing Device 102
Processing System 104
Antenna(s) 114(x)
Computer-Readable Media 106
Applications 112
User Presence Detector 118
SAR Manager Module 116
Optimization Scheme 120
Report 124
SAR Data 122
Cellular 114(1)
Wifi 114(2)
GNSS 114(3)
NFC 114(4)
Bluetooth 114(5)
Other Antennas 114(6)
Connection Manager 126
Base Station 128
Folder
Network 108
Service Provider 110

Fig. 1

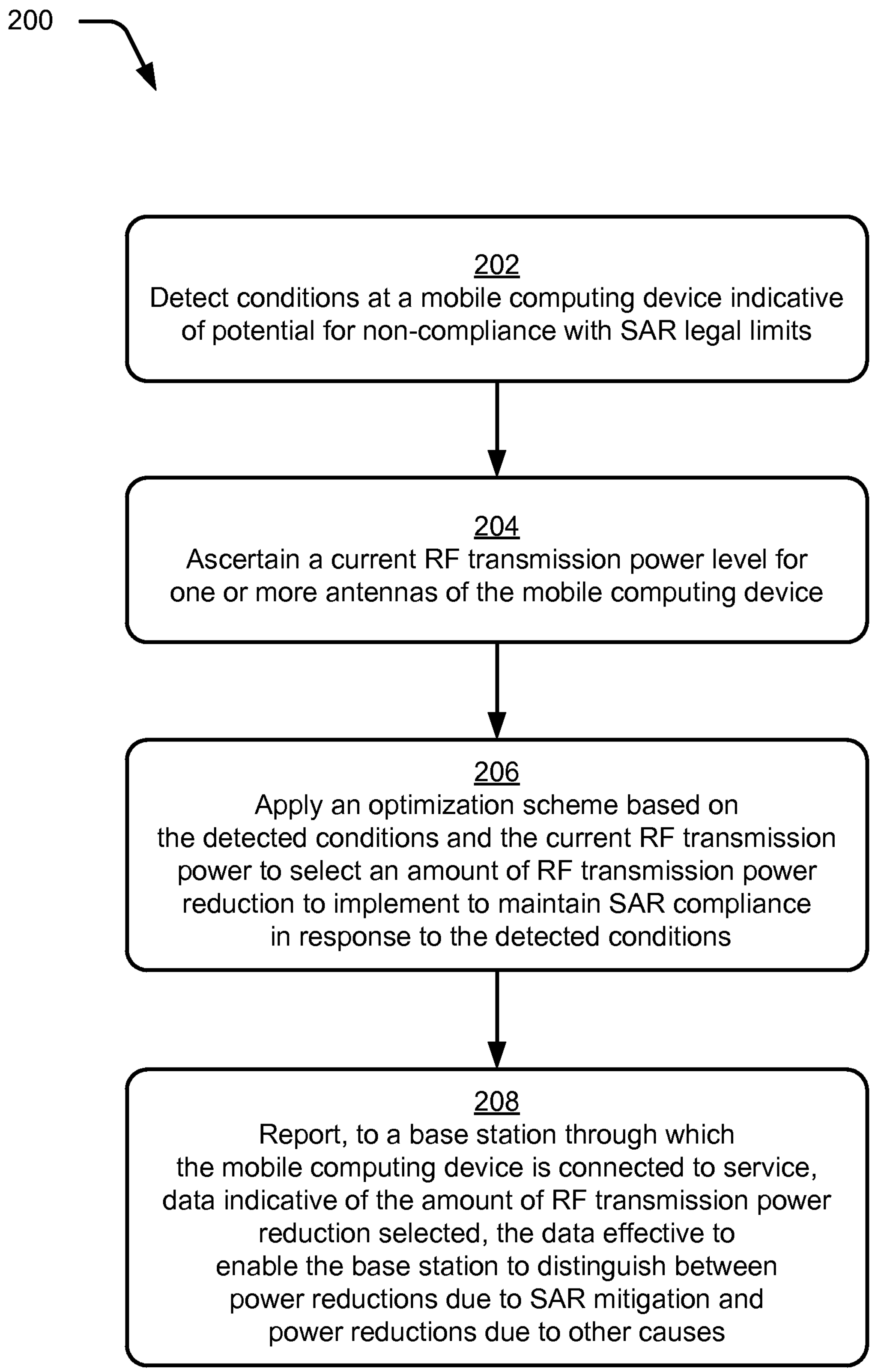
200
202
Detect conditions at a mobile computing device indicative of potential for non-compliance with SAR legal limits
204
Ascertain a current RF transmission power level for one or more antennas of the mobile computing device
206
Apply an optimization scheme based on the detected conditions and the current RF transmission power to select an amount of RF transmission power reduction to implement to maintain SAR compliance in response to the detected conditions
208
Report, to a base station through which the mobile computing device is connected to service, data indicative of the amount of RF transmission power reduction selected, the data effective to enable the base station to distinguish between power reductions due to SAR mitigation and power reductions due to other causes

Fig. 2

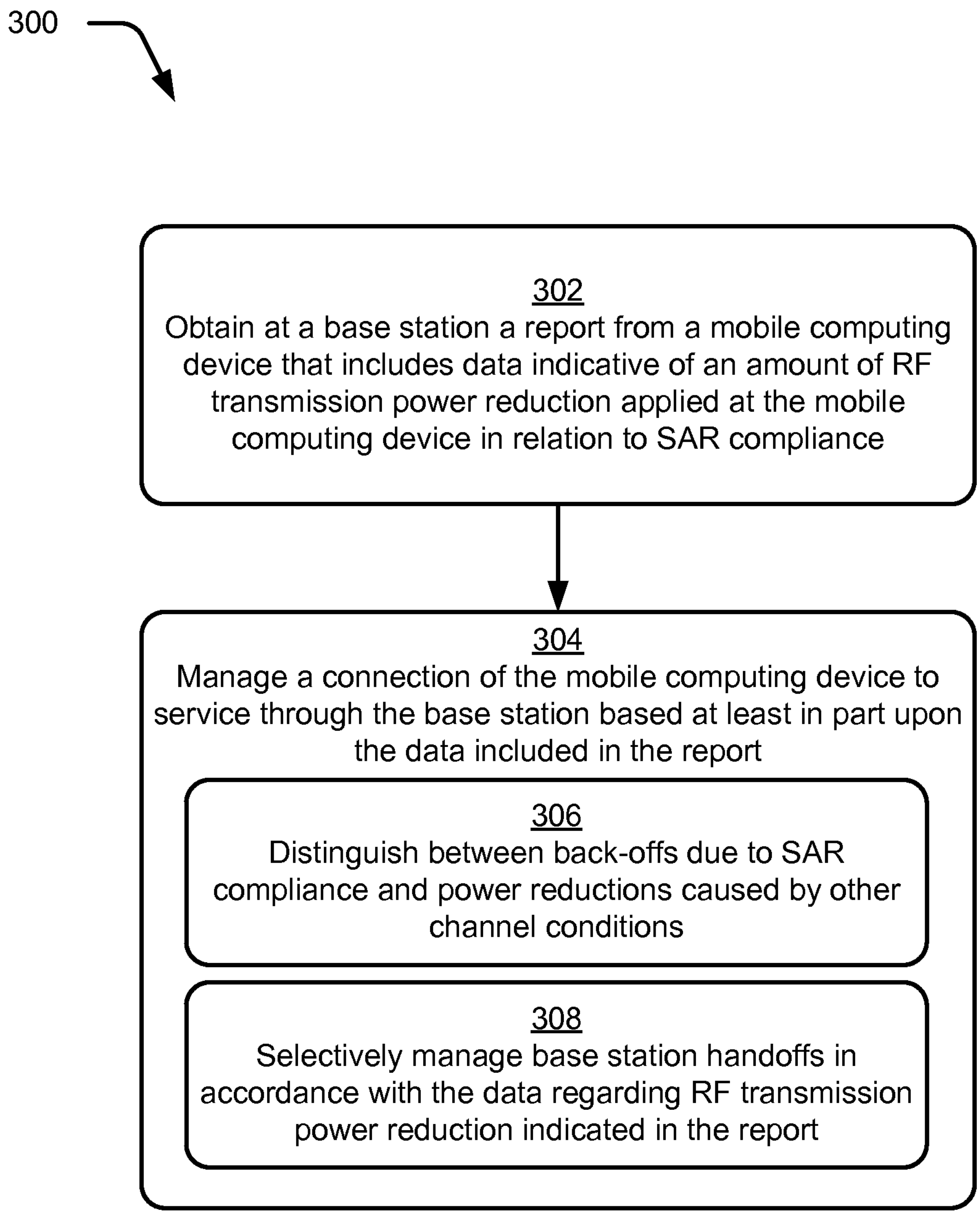
300
302
Obtain at a base station a report from a mobile computing device that includes data indicative of an amount of RF transmission power reduction applied at the mobile computing device in relation to SAR compliance
304
Manage a connection of the mobile computing device to service through the base station based at least in part upon the data included in the report
306
Distinguish between back-offs due to SAR compliance and power reductions caused by other channel conditions
308
Selectively manage base station handoffs in accordance with the data regarding RF transmission power reduction indicated in the report

Fig. 3

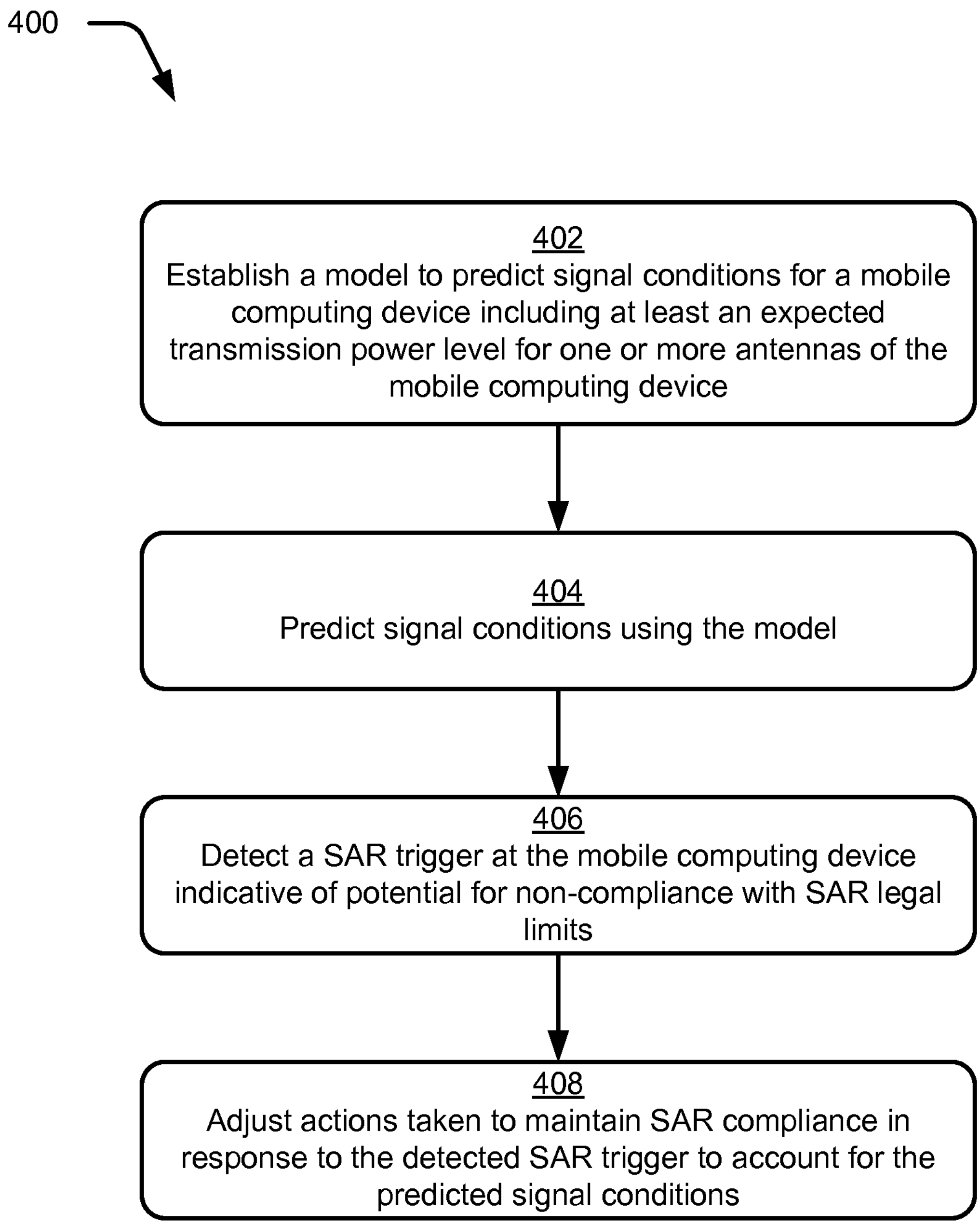
400
402
Establish a model to predict signal conditions for a mobile computing device including at least an expected transmission power level for one or more antennas of the mobile computing device
404
Predict signal conditions using the model
406
Detect a SAR trigger at the mobile computing device indicative of potential for non-compliance with SAR legal limits
408
Adjust actions taken to maintain SAR compliance in response to the detected SAR trigger to account for the predicted signal conditions

Fig. 4

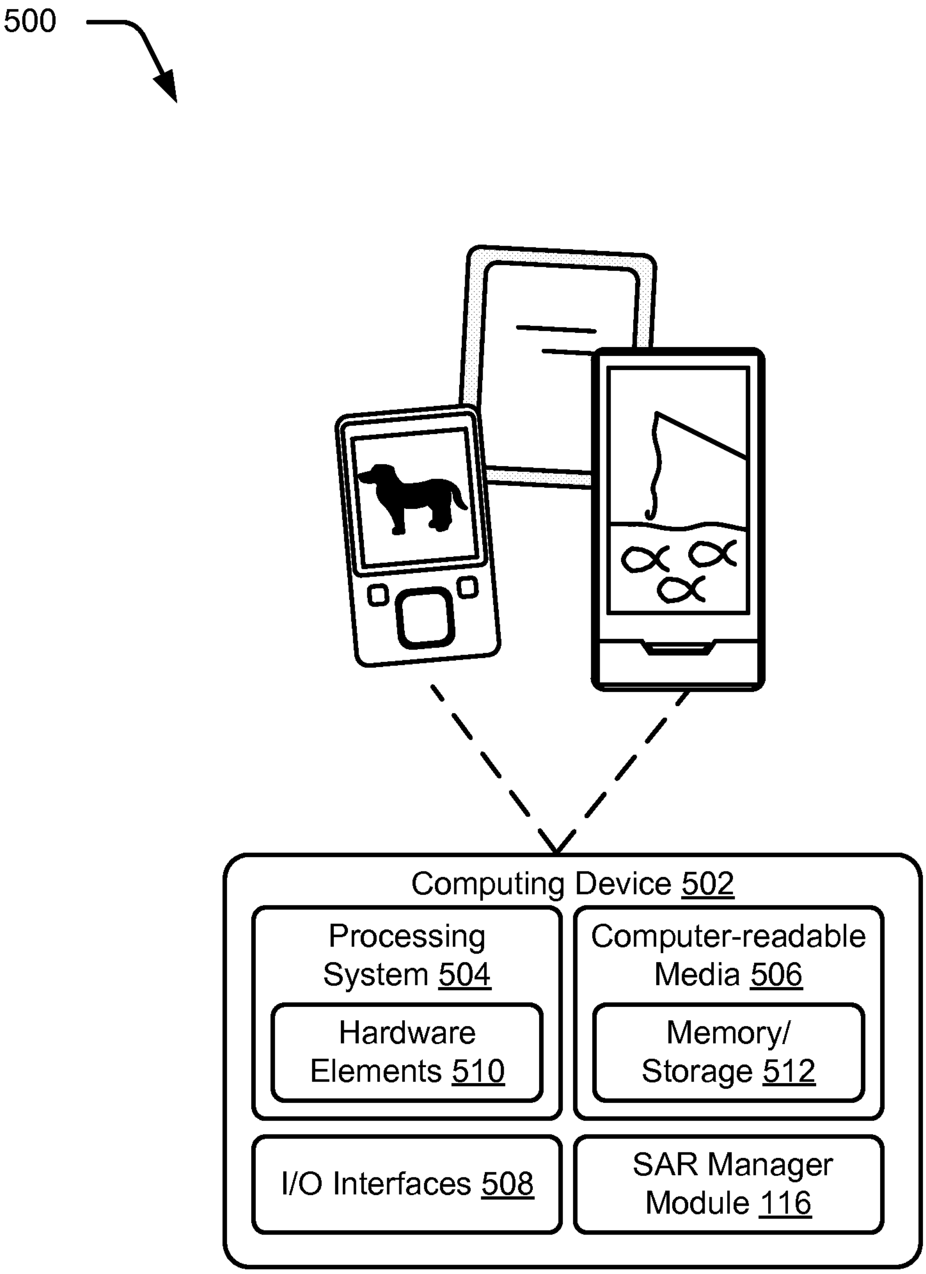
500
Computing Device 502
Processing System 504
Hardware Elements 510
Computer-readable Media 506
Memory/ Storage 512
I/O Interfaces 508
SAR Manager Module 116

Fig. 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2014/042023

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04B1/38 H04W52/04
ADD.

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)
H04B H04W

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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X Y	EP 1 298 809 A2 (SIEMENS INF & COMM MOBILE LLC [US] SIEMENS COMM INC [US]) 2 April 2003 (2003-04-02) abstract; figures 2,6 paragraph [0020] -----	1,4-10 2,3
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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

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

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"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
22 August 2014	29/08/2014

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Almenar Muñoz, M

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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A	abstract; figures 7,8,10 paragraphs [0063], [0067] -----	8-10

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2014/042023

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