Methods, systems, and devices are described for adjusting the number of base stations of a paging group based on the mobility state of a mobile device. The mobile device may autonomously determine its mobility state based on a sequence of repeated historical events associated with mobility patterns of the mobile device. The mobile device may communicate the mobility state to a base stations and receive a page from at least one of a subset of base stations of a paging group. The subset of base stations may be selected based on the mobility state of the mobile device. The number of base stations selected to be included in the subset of base stations may be reduces when the mobile device is in a stationary state or increased when the mobile device is in a mobile state. The mobile device may explicitly or implicitly convey the mobility state.
FIG. 10

1010 Processor
1017 Applications
1019 Historical Information
1015 Memory

1020 Mobility State Module

1025 Paging Group Selection Module

1030 Paging Module

1035 Transceiver Module
1040 Backhaul/Core Network Interface

To/From UE(s)
To/From Assisting eNodeB and Core Network
Determine, autonomously by a mobile device, a mobility state of the mobile device based on a sequence of repeated historical events associated with mobility patterns of the mobile device.

Communicate the mobility state of the mobile device to a base station.

Receive a page from at least one of a subset of base stations of a paging group, wherein the subset of base stations of the paging group is selected based on the mobility state of the mobile device.

FIG. 13
Determine, autonomously by a mobile device, a mobility state of the mobile device based on a sequence of repeated historical events associated with mobility patterns of the mobile device

Stationary State?

No

Yes

Transmit a location area update to the base station, wherein the base station is different from a recipient of a previous location area update

Transmit two location area updates when the mobility state of the mobile device has changed to a stationary state, each of the location area updates indicating that the mobile device is within a same location area

Receive a page from at least one of a subset of base stations of a paging group, wherein the subset of base stations of the paging group is selected based on the mobility state of the mobile device

FIG. 14
Determine that a mobile device has transmitted a plurality of location area updates to one or more base stations within a same location area

Determine a mobility state of the mobile device based on the plurality of location area updates

Determine, based on the mobility state of the mobile device, a subset of base stations of a paging group to send a page to the mobile device

Transmit the page to the subset of base stations of the paging group

FIG. 15
Determine that a mobile device has transmitted a plurality of location area updates to one or more base stations within a same location area

Determine a mobility state of the mobile device based on the plurality of location area updates

No

Yes

Stationary State?

Increase a number of base stations in the subset of base stations of the paging group in response to a determination that the mobile device is in the mobile state

Reduce a number of base stations in the paging group in response to a determination that the mobile device is in the stationary state

Transmit the page to the subset of base stations of the paging group

FIG. 16
PAGING AREA REDUCTION BASED PREDICTIVE MOBILITY

CROSS-REFERENCE


BACKGROUND

[0002] The present description relates generally to wireless communication, and more specifically to adjusting the number of base stations of a paging group for a mobile device based on observed mobility trends. Wireless communications systems are widely deployed to provide various types of communication content such as voice, video, packet data, messaging, broadcast, and so on. These systems may be multiple-access systems capable of supporting communication with multiple users sharing the available system resources (e.g., time, frequency, space, and power). Examples of such multiple-access systems include code-division multiple access (CDMA) systems, time-division multiple access (TDMA) systems, frequency-division multiple access (FDMA) systems, and orthogonal frequency-division multiple access (OFDMA) systems.

[0003] Generally, a wireless multiple-access communications system may include a number of base stations, each simultaneously supporting communication for multiple mobile devices. Base stations may communicate with mobile devices on downstream and upstream links. Each base station has a coverage range, which may be referred to as the coverage area of the cell. A cellular network may define one or more geographical areas as paging areas and assign some or all of the cells within the paging area to a paging group. The network may attempt to page a mobile device by sending a page to the mobile device on at least one cell assigned to the paging group. The network typically assigns the cells to the paging group to provide a level of abstraction regarding the location of the mobile device. For instance, the network may create and assign mobile devices to the paging group in order to reduce the granularity with which the network tracks the location of the mobile devices. Thus, the network may avoid the processing and storage load required to monitor which cell the mobile device is attached to at any given instant.

[0004] The paging messages are typically sent over a paging channel of the cellular network. As more and more mobile devices enter the paging area and camp on the cells of the paging group, the number of pages being sent within the paging group increases substantially. As can be appreciated, each page consumes backhaul resources between the cells as well between the cells and network entities. Moreover, each page consumes over-the-air resources of the cellular network. As the number of mobile devices within the paging area increases, the likelihood of paging collisions increases. Paging collisions can delay page receipt and consume battery life of the mobile devices.

SUMMARY

[0005] The described features generally relate to one or more improved systems, methods, and/or apparatuses for a mobile device to autonomously determine its mobility state based on a sequence of repeated historical events associated with mobility patterns of the mobile device and, based on the mobility state, being assigned to a paging group. Generally, the mobile device may analyze its historical information to determine whether the mobile device is likely to be in a stationary state or a mobile state for a predetermined period of time, for example. Once the mobile device determines its mobility state, the mobile device may communicate information indicative of the mobility state to a cell or base station, e.g., the serving cell of the mobile device. Accordingly, a network entity (e.g., a mobility management entity (MME)) may assign cells to a paging group for the mobile device based on the mobility state. For example, the network entity may reduce the cells assigned to the paging group if the mobile device is in a stationary state or assign more cells to the paging group if the mobile device is in a mobile state.

[0006] In a first illustrative set of embodiments, a method for managing wireless communications is described. The method may include: determining, autonomously by a mobile device, a mobility state of the mobile device based on a sequence of repeated historical events associated with mobility patterns of the mobile device; communicating the mobility state of the mobile device to a base station; and receiving a page from at least one of a subset of base stations of a paging group, wherein the subset of base stations of the paging group is selected based on the mobility state of the mobile device.

[0007] In some aspects, the mobility state may be one or more of a stationary state or a mobile state. The number of base stations in the paging group may be reduced when the mobile device is in the stationary state and increased when the mobile device is in the mobile state. Communicating the mobility state may include transmitting a location area update.

[0008] In some aspects, communicating the mobility state may include transmitting two location area updates when the mobility state of the mobile device has changed to a stationary state, each of the location area updates indicating that the mobile device is located within a cell. Communicating the mobility state may include transmitting a location area update to the base station at a time when the base station is different from a recipient of a previous location area update.

[0009] In some aspects, communicating the mobility state of the mobile device may include transmitting a location area update, the location area update indicating that the mobile device is located in a cell or within a cell. Communicating the mobility state may include transmitting a location area update to the base station at a time when the base station is different from a recipient of a previous location area update.

[0010] In some aspects, the method may include: predicting a future mobility of the mobile device based on a correlation among the sequence of historical events; wherein the mobility state of the mobile device is based on the predicted future mobility of the mobile device.

[0011] In a second set of illustrative embodiments, an apparatus for managing wireless communications is described. The apparatus may include a processor and memory in electronic communication with the processor. The memory may embody instructions. The instructions may be executable by the processor to: determine, autonomously by a mobile device, a mobility state of the mobile device based on a sequence of repeated historical events associated with mobil-
ity patterns of the mobile device; communicate the mobility state of the mobile device to a base station; and receive a page from at least one of a subset of base stations of a paging group, wherein the subset of base stations of the paging group is selected based on the mobility state of the mobile device.

[0012] In some aspects, the mobility state may include one or more of a mobile state or a stationary state. A number of base stations in the paging group may be reduced when the mobile device is in the stationary state and increased when the mobile device is in the mobile state. The instructions executable by the processor to communicate the mobility state may be further executable to transmit a location area update.

[0013] In some aspects, the instructions executable by the processor to communicate the mobility state may be further executable to transmit two location area updates when the mobility state of the mobile device has changed to a stationary state, each of the location area updates indicating that the mobile device is within a same location area. The instructions executable by the processor to communicate the mobility state may be further executable to: transmit a location area update to the base station, wherein the base station is different from a recipient of a previous location area update.

[0014] In some aspects, the instructions executable by the processor to communicate the mobility state may be further executable to transmit a location area update, the location area update including at least one of a mobility state change information element or a cause information element indicative of the mobility state. The sequence of historical events indicated by mobility patterns of the mobile device may include at least two previous instances of a same historical event within a predetermined time period. The sequence of historical events may include one or more of: a channel environment event, a user event, a location event, or a time event.

[0015] In some aspects, the apparatus may include instructions executable by the processor to: predict a future mobility of the mobile device based on a correlation among the sequence of historical events; wherein the mobility state of the mobile device is based on the predicted future mobility of the mobile device.

[0016] In a third illustrative set of embodiments, a method for managing wireless communications is described. The method may include: determining that a mobile device has transmitted a plurality of location area updates to one or more base stations within a same location area; determining a mobility state of the mobile device based on the plurality of location area updates; determining, based on the mobility state of the mobile device, a subset of base stations of a paging group to send a page to the mobile device; and transmitting the page to the subset of base stations of the paging group.

[0017] In some aspects, the mobility state may include at least one of: a mobile state or a stationary state. The method may also include reducing a number of base stations in the paging group in response to a determination that the mobile device is in the stationary state. The method may also include increasing a number of base stations in the subset of base stations of the paging group in response to a determination that the mobile device is in the mobile state. The method may also include: determining that the mobile device has transmitted a location area update to a base station other than a recipient of a previous location area update from the mobile device; and updating the mobility state of the mobile device based on the location area update.

[0018] In some aspects, transmission of a second one of the location area updates by the mobile device indicates that the mobile device has transitioned to a mobile state.

[0019] In a fourth illustrative set of embodiments, an apparatus for managing wireless communications is described. The apparatus may include a processor and a memory in electronic communication with the processor. The memory may embody instructions. The instructions may be executable by the processor to: determine that a mobile device has transmitted a plurality of location area updates to one or more base stations within a same location area; determine a mobility state of the mobile device based on the plurality of location area updates; determine, based on the mobility state of the mobile device, a subset of base stations of a paging group to send a page to the mobile device; and transmit the page to the subset of base stations of the paging group.

[0020] In some aspects, the mobility state may include at least one of: a mobile state or a stationary state. The apparatus may include instructions executable by the processor to reduce a number of base stations in the paging group in response to a determination that the mobile device is in the stationary state. The apparatus may include instructions executable by the processor to increase a number of base stations in the subset of base stations of the paging group in response to a determination that the mobile device is in the mobile state.

[0021] Further scope of the applicability of the described methods and apparatuses will become apparent from the following detailed description, claims, and drawings. The detailed description and specific examples are given by way of illustration only, since various changes and modifications within the spirit and scope of the description will become apparent to those skilled in the art.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] A further understanding of the nature and advantages of the present invention may be realized by reference to the following drawings. In the appended figures, similar components or features may have the same reference label. Further, various components of the same type may be distinguished by following the reference label by a dash and a second label that distinguishes among the similar components. If only the first reference label is used in the specification, the description is applicable to any one of the similar components having the same first reference label irrespective of the second reference label.

[0023] FIG. 1 shows a block diagram of a wireless communications system, according to one aspect of the principles described herein;

[0024] FIG. 2 shows a diagram of an example of device mobility in a wireless communications system, according to one aspect of the principles described herein;

[0025] FIG. 3 shows a diagram of another example of device mobility in a wireless communications system, according to one aspect of the principles described herein;

[0026] FIG. 4 shows a diagram of an example of communications between devices in a wireless communications system, according to one aspect of the principles described herein;

[0027] FIG. 5 shows a diagram of an example of communications between devices in a wireless communications system, according to one aspect of the principles described herein;
FIG. 6 shows a diagram of an example of communications between devices in a wireless communications system, according to one aspect of the principles described herein;

FIG. 7 shows a diagram of an example of communications between devices in a wireless communications system, according to one aspect so the principles described herein;

FIG. 8 shows a block diagram of a wireless communications system, according to one aspect of the principles described herein;

FIG. 9 shows a block diagram of one example of a mobile device, according to one aspect of the principles described herein;

FIG. 10 shows a block diagram of one example of a base station, according to one aspect of the principles described herein;

FIG. 11 shows a block diagram of one example of a mobile, according to one aspect of the principles described herein;

FIG. 12 shows a block diagram of one example of a base station, according to one aspect of the principles described herein;

FIG. 13 shows a flowchart diagram of a method for managing wireless communications, according to one aspect of the principles described herein;

FIG. 14 shows a flowchart diagram of a method for managing wireless communications, according to one aspect of the principles described herein;

FIG. 15 shows a flowchart diagram of a method for managing wireless communications, according to one aspect of the principles described herein;

FIG. 16 shows a flowchart diagram of a method for managing wireless communications, according to one aspect of the principles described herein.

DETAILED DESCRIPTION

[0028] Methods, systems, and devices are provided that may be used to improve network and/or mobile device performance based on learning and predicting the behavior of a mobile device (e.g., mobile phone, laptop, tablet, etc.) user. For a mobile device user, for example, using predictive behavior may involve a mobile device autonomously determining its mobility state based on a sequence of repeated historical events associated with mobility patterns of the mobile device. The mobile device may communicate the mobility state to a base station, e.g., its serving base station, and receive a page from one of a subset of base stations of a paging group. The subset of base stations may be selected based on the mobility state, e.g., a reduced subset of base stations may be selected when the mobile device is in a stationary state.

[0039] On the network side, the described techniques provide for a network entity, e.g., a mobility management entity (MME), to determine a mobility state of a mobile device based on the mobile device sending more than one location area update to base station(s) within the same location area. The plurality of location area updates sent within the same location area may indicate that the mobile device is in a stationary state, for example. The network entity may identify and assign a subset of base stations of a paging group to send pages to the mobile device and, when a page for the mobile device arrives, send the page to the subset of base stations. The network entity may update the mobility state when it determines the mobile device has sent a location area update to a base station other than the base stations the previous location area updates were transmitted to.

[0040] Thus, the following description provides examples, and is not limited to the scope, applicability, or configuration set forth in the claims. Changes may be made in the function and arrangement of elements discussed without departing from the spirit and scope of the disclosure. Various embodiments may omit, substitute, or add various procedures or components as appropriate. For instance, the methods described may be performed in an order different from that described, and various steps may be added, omitted, or combined. Also, features described with respect to certain embodiments may be combined in other embodiments.

[0041] Techniques described herein may be used for various wireless communications systems such as CDMA, TDMA, FDMA, OFDMA, SC-FDMA, and other systems. The terms “system” and “network” are often used interchangeably. A CDMA system may implement a radio technology such as CDMA2000, Universal Terrestrial Radio Access (UTRA), etc. CDMA2000 covers IS-2000, IS-95, and IS-856 standards. IS-2000 Releases 0 and A are commonly referred to as CDMA2000 1X, 1X, etc. IS-856 (TIA-856) is commonly referred to as CDMA2000 1xEV-DO, High Rate Packet Data (HRPD), etc. UTRA includes Wideband CDMA (WCDMA) and other variants of CDMA. A TDMA system may implement a radio technology such as Global System for Mobile Communications (GSM). An OFDMA system may implement a radio technology such as Ultra Mobile Broadband (UMB), Evolved UTRA (E-UTRA), IEEE 802.11 (WiFi), IEEE 802.16 (WiMAX), IEEE 802.20 (Flash-OFDMA). UTRA and E-UTRA are part of Universal Mobile Telecommunication System (UMTS). 3GPP Long Term Evolution (LTE) and LTE-Advanced (LTE-Advanced) are new releases of UMTS that use E-UTRA. UTRA, E-UTRA, UMTS, LTE, LTE-A, and GSM are described in documents from an organization named “3rd Generation Partnership Project” (3GPP). CDMA2000 and UMB are described in documents from an organization named “3rd Generation Partnership Project 2” (3GPP2). The techniques described herein may be used for the systems and radio technologies mentioned above as well as other systems and radio technologies. The description below, however, describes an LTE system for purposes of example, and LTE terminology is used in much of the description below, although the techniques are applicable beyond LTE applications.

[0042] FIG. 1 is a block diagram conceptually illustrating an example of a wireless communications system 100, in accordance with an aspect of the present disclosure. The wireless communications system 100 includes base stations (or cells) 105, mobile devices 115, and a core network 130. The base stations 105 may communicate with the mobile devices 115 under the control of a base station controller (not shown), which may be part of the core network 130 or the base stations 105 in various embodiments. Base stations 105 may communicate control information and/or user data with the core network 130 through backhaul links 132. In certain embodiments, the base stations 105 may communicate, either directly or indirectly, with each other over backhaul links 134, which may be wired or wireless communication links. The wireless communications system 100 may support operation on multiple carriers (waveform signals of different frequencies). Multi-carrier transmitters can transmit modulated signals simultaneously on the multiple carriers. For example,
each communication link 125 may be a multi-carrier signal modulated according to the various radio technologies described above. Each modulated signal may be sent on a different carrier and may carry control information (e.g., reference signals, control channels, etc.), overhead information, data, etc.

[0044] The base stations 105 may wirelessly communicate with the mobile devices 115 via one or more base station antennas. Each of the base stations 105 sites may provide communication coverage for a respective coverage area 110. In some embodiments, base stations 105 may be referred to as a base transceiver station, a radio base station, an access point, a radio transceiver, a basic service set (BSS), an extended service set (ESS), a NodeB, eNodeB, Home NodeB, a Home eNodeB, or some other suitable terminology. The coverage area 110 for a base station may be divided into sectors making up only a portion of the coverage area (not shown). The wireless communications system 100 may include base stations 105 of different types (e.g., macro, micro, and/or pico base stations). There may be overlapping coverage areas for different technologies.

[0045] In certain embodiments, the wireless communications system 100 is an LTE/LTE-A network communication system. In LTE/LTE-A network communication systems, the terms evolved Node B (eNodeB) may be generally used to describe the base stations 105. The wireless communications system 100 may be a Heterogeneous LTE/LTE-A network in which different types of eNodeBs provide coverage for various geographical regions. For example, each eNodeB may provide communication coverage for a macro cell, a pico cell, a femto cell, and/or other types of cell. A macro cell generally covers a relatively large coverage area (e.g., several kilometers in radius) and may allow unrestricted access by mobile devices 115 with service subscriptions with the network provider. A pico cell would generally cover a relatively smaller coverage area (e.g., buildings) and may allow unrestricted access by mobile devices 115 with service subscriptions with the network provider. A femto cell would also generally cover a relatively small coverage area (e.g., a home) and, in addition to unrestricted access, may also provide restricted access by mobile devices 115 having an association with the femto cell (e.g., mobile devices 115 in a closed subscriber group (CSG), mobile devices 115 for users in the home, and the like). In such examples, a base station 105 for a macro cell may be referred to as a macro eNodeB, a base station 105 for a pico cell may be referred to as a pico eNodeB, and a base station 105 for a femto cell may be referred to as a femto eNodeB or a home eNodeB. A base station 105 may support one or multiple (e.g., two, three, four, and the like) cells.

[0046] The core network 130 may communicate with the base stations 105 via a backhaul link 132 (e.g., S1 interface, etc.). The base stations 105 may also communicate with one another, e.g., directly or indirectly via backhaul links 134 (e.g., X2 interface, etc.) and/or via backhaul links 132 (e.g., through core network 130). The wireless communications system 100 may support synchronous or asynchronous operation. For synchronous operation, the base stations 105 may have similar frame timing, and transmissions from different base stations 105 may be approximately aligned in time. For asynchronous operation, the base stations 105 may have different frame timing, and transmissions from different base stations 105 may not be aligned in time. The techniques described herein may be used for either synchronous or asynchronous operations.

[0047] The mobile devices 115 may be dispersed throughout the wireless communications system 100, and each mobile device 115 may be stationary or mobile. A mobile device 115 may also be referred to as a mobile terminal (MT), mobile station, a subscriber station, a mobile unit, a subscriber unit, a wireless unit, a remote terminal, a wireless communications device, a remote device, a mobile subscriber station, an access terminal, a mobile terminal, a wireless terminal, a remote terminal, a handset, a user agent, a mobile client, a client, or some other suitable terminology. A mobile device 115 may be a cellular phone, a personal digital assistant (PDA), a wireless modem, a wireless communication device, a handheld device, a tablet computer, a laptop computer, a cordless phone, a wireless local loop (WLL) station, or the like.

[0048] The communication links 125 shown in the wireless communications system 100 may include uplink (UL) transmissions from a mobile device 115 to a base station 105, and/or downlink (DL) transmissions, from a base station 105 to a mobile device 115. The downlink transmissions may also be called forward link transmissions while the uplink transmissions may also be called reverse link transmissions.

[0049] Mobile device 115 users typically have predictable behavior, often doing the same things or going to the same places at about the same time each day. One example is the travel pattern and schedule of a mobile device 115 user going to and from work. The user may typically leave home at a certain time, travel certain roads to get to work, stay at work until it is time to go back home using the same roads as before, and then repeat more or less the same routine the next day. Because the locations of mobile devices 115 user in such a scenario can be forecasted, it may be possible to predict with a high degree of confidence which cells are used by the mobile device 115 at particular times when going to work, returning home at the end of the day, or even when taking a lunch break. This prediction may be based on previous measurements, cell reselections (e.g., when the mobile device 115 is in idle mode), and handovers, which were performed by the mobile device 115 during the user’s commute. Moreover, the use of predictive behavior may also apply to other devices such as laptops, tablets, pads, machine-to-machine (M2M) devices, and the like.

[0050] The historical information defining predictable behavior may refer to data taken over a long enough time to show at least two instances of a repeated sequence of mobile device environmental events. Example environmental events may include one or more radio frequency (RF) events, such as channel measurements of particular cells, connection to a specific wireless fidelity (Wi-Fi) access point, and the like. Another example environmental event may include one or more user events. Example user events may include, but are not limited to, initiation or acceptance of calls, sending or receiving data, usage of a particular application, and the like. Yet another example environmental event may include one or more location events. Example location events may include, but are not limited to, arriving at a location, leaving a location, a speed of movement, and the like. A further example of an environment event may include one or more time events. Example time events may include, but are not limited to, start or end of work hours, etc. Repeated sequences of environmental events may be taken as sequences with enough commonality and regularity to ensure the mobile device is following a similar path with the same use requirements. The sequences may not necessarily be identical, but may occur
frequently enough and with sufficient similarity to provide confidence of the predictive mobility of the mobile device.

The ability to learn and predict the behavior of the mobile device 115 user may be used to reduce the (usually large) number of base stations assigned to the paging group for the mobile device 115. For example, when the historical behavior of the mobile device 115 indicates that the mobile device 115 is currently in a stationary or less-mobile state, the number of base stations in the paging group for the mobile device 115 may be reduced. Alternatively, if the historical behavior of the mobile device 115 indicates that the mobile device 115 is currently in a mobile state, the number of base stations in the paging group for the mobile device 115 may remain the same or be increased. Dynamically adjusting the number of base stations assigned to the subset of base stations of the paging group (and related reporting/control messaging) may have the benefit of reducing overhead signaling requirements as well as conserving time frequency resources at each base station. In dense urban areas, for example, where large numbers of small cells and/or Wi-Fi hot spots are deployed, predicting the mobile device 115 mobility (e.g., pattern and schedule) may have an impact on the performance of both the network and the mobile device 115.

Although the described techniques refer to a paging group, it is to be understood that the described techniques may be equally applied to dynamically adjusting a base stations of a tracking group based on the mobility state of a mobile device 115. Moreover, it is also to be understood that, in some aspects, the location area described in the present disclosure may be coextensive with one or more of the paging groups/tracking groups.

In addition to the commuting example described above, there may be other instances in which the behavior of the mobile device 115 user may be leveraged to predict cells to adjust the subset of base stations of a paging group. One example is when “airplane mode” is turned off after the user arrives at her destination. When such a trip is routine and the behavior predictable, the mobile device 115 may start by sending an unsolicited signal indicating its arrival and associated mobility state to the network.

In yet another example of predictive behavior, when a cell that is typically used by a mobile device during the user’s commute to work is congested, the network may look at other cells and may use predictive techniques and the loading levels on the other cells to identify and assign base stations to the subset of base stations of the paging group. Moreover, when the network knows that the mobile device 115 is going to use a particular cell at a certain time it may reduce the subset of base stations assigned to the mobile device 115 during that time.

Generally, predictive mobility in wireless networks may be used to alleviate network signaling demands, to control the subset of base stations that are assigned to the paging group for the mobile device 115 and/or to allocate networking resources more effectively, for example.

FIG. 2 shows a diagram of a simplified example of device mobility in a wireless communications system 200, according to one aspect of the principles described herein. In the wireless communications system 200 of FIG. 2, a mobile device 115—a travels along a path 205 through the coverage areas 110—a, 110—b, 110—c, 110—d of a first base station 105—a, a second base station 105—b, a third base station 105—c, and a fourth base station 105—d, respectively. The mobile device 115—a may be an example of one or more of the mobile devices 115 of FIG. 1. Similarly, the base stations 105 of FIG. 2 may be examples of one or more of the base stations 105 of FIG. 1.

Each base station 105 may represent an actual or potential serving cell for the mobile device 115—a. In the present example, the mobile device 115—a may begin at position 1 with the first base station 105—a as the serving cell, then move through the coverage area 110—a of the first base station 105—a to position 2. At position 2, the mobile device 115—a may be located at the outer reaches of the coverage area 110—a of the first base station 105—a and enter an intersection of the coverage areas 110—a, 110—b, 110—c of the first, second, and third base stations 105—a, 105—b, 105—c. At position 2, the mobile device 115—a may report a signal strength measurement of the first base station 105—a, the current serving cell, to the first base station 105—a.

In conventional systems, if the mobile device 115—a is in a connected mode with the first base station 105—a, the signal strength measurement of the first base station 105—a may indicate that the mobile device 115—a is exiting the coverage area 110—a of the first base station 105—a and trigger preparations for a handover of the mobile device 115—a from the first base station 105—a to a new serving cell base station. Accordingly, the first base station 105—a may instruct the mobile device 115—a to measure the signal strengths of neighboring base stations to identify a handover candidate for the mobile device 115—a. The mobile device 115—a may identify the neighboring base stations 105—b, 105—c using a stored neighboring cell list (NCL) and/or by scanning for the neighboring base stations 105—b, 105—c. If the mobile device 115—a is in idle mode, the mobile device 115—a may measure neighboring cells to identify a reselection target based on a predefined threshold for the serving cell signal strength, as configured by the carrier.

The mobile device 115—a may transmit signal strength measurements to the serving base station 105—a, and the serving base station 105—a may select either the second base station 105—b or the third base station 105—c as the handover target base station for the mobile device 115—a based on the signal strength measurements. If the second base station 105—b is selected as the handover target, the mobile device 115—a might briefly handover to the second base station 105—b, and then perform an additional handover to the third base station 105—c as the mobile device 115—a moves out of the coverage area 110—b of the second base station 105—b. In certain examples, upon arriving at position 3, the mobile device 115—a may be handed over to the fourth base station 105—d (e.g., a femtocell or picocell) before returning to the third base station 105—c.

In such systems, it may be difficult for the current serving cell and the mobile device 115—a to determine the optimal time to perform a handover, and the most appropriate handover target. For example, at position 2, a more efficient transition may be for the mobile device 115—a to bypass the second base station 105—b and move directly from the first base station 105—a to the third base station 105—c. Similarly, when the mobile device 115—a is at position 3, the signal strength of the fourth base station 105—d may be stronger than that of the third base station 105—c for a short amount of time, but as the mobile device 115—a is moving along the path 205 (e.g., in a train or automobile), the mobile device 115—a may spend a small amount of time in the coverage area 110—d of the fourth base station 105—d, thereby triggering another handover in short order. In certain examples, the mobile device
115-a may exit the coverage area 110-d of the fourth base station 105-d before there is an opportunity to complete a handover to the next serving cell, which may result in a dropped call or interrupted data connectivity. Thus, it may be more efficient to refrain from handing the mobile device 115-a over to the fourth base station 105-d when it can be determined that the mobile device 115-a is traveling along the path 205.

[0061] The above described handover scenarios may provide an example of environmental events that may be recorded and tracked as historical information of mobility patterns of the mobile device 115-a. Over a period of time, the mobility pattern of the mobile device 115-a along the path 205 may be repeated a predetermined number of times to provide a high degree of confidence of which of the base stations 105 may be suitable candidates to be selected as part of a subset of base stations of a paging group. The present description provides methods, systems, and devices that may be used to improve network and/or mobile device 115-a performance based on learning such example environmental events and predicting the behavior of the mobile device 115-a. Using predictive behavior may involve the mobile device 115-a determining its mobility state based on the historical information associated with mobility patterns of the mobile device 115-a. The historical information may indicate that a sequence of repeated historical events associated with mobility patterns of the mobile device 115-a, in combination with the current state of the mobile device 115-a, is being repeated with a degree of confidence that suggests the future mobility of the mobile device 115-a may be predicted. The predicted behavior of the mobile device 115-a may be used to modify mobility parameters (e.g., the mobile device 115-a may autonomously or without direction from its serving base station and/or any other network entity determine its mobility state and report same) to improve performance. The self-reported mobility state may then be used to select a subset of base stations 105 of a paging group to assign to the mobile device 115-a.

[0062] In the example of FIG. 2, for example, the mobile device 115-a may regularly travel along path 205 at regular intervals, times of day, and at consistent speeds. This behavior may be tracked and stored at the mobile device 115-a, a network server, and/or one or more of the base stations 105. Based on the historical information, the mobile device 115-a can predict a next location of the mobile device 115-a, using the predicted next location to inform the base station of its mobility state (e.g., a mobile state), and receive a page from one of the subset of base stations of the paging group selected based on the mobility state. For example, as the mobile device 115-a approaches position 2, a network entity may assign the first base station 105-a and the third base station 105-c to the subset of base stations of the paging group to send a page to the mobile device 115-a.

[0063] FIG. 3 show a diagram of an example of device mobility in a wireless communications system 300, according to aspects of the principles described herein. Specifically, FIG. 3 illustrates an illustrative path 205-a of a mobile device 115-b between a home location 305 and a work location 310. The path 205-a may traverse the coverage areas 110 of a number of large cells and small cells.

[0064] When behavioral information is not considered, the user may travel from the home location 305 to the work location 310 along the depicted path 205-a in a normal manner. For example, cells along the path 205-a may be assigned to paging groups based on known network management protocols and without consideration of the mobility state of the mobile device 115-b, e.g., without considering the repeated historical events associated with the mobility patterns of the mobile device 115-b along the path 205-a and/or the home or work locations 305 and 310, respectively.

[0065] In one example of a repeated historical event, after the signal strength drops in cell 1, the mobile device 115-b may find cell 2 the strongest and the network may ask the mobile device 115-b to hand-off to cell 2. Thesame process may take place with cells 3, 4, 5, 6, 7, 8, 9, and 10 until the user reaches the work location 310. Moreover, the mobile device 115-b may traverse clusters of femtocells or other small cells (e.g., cells 5, 6, and 10) having small cell radiiuses along the path 205-a, which may result in various other handover events in which the mobile device 115-b is handed over to or from one or more cells. Each handover event may be an example of an environmental event for the mobile device 115-b that may repeated with sufficient regularity and consistency that the mobility patterns of the mobile device 115-b may be predicted to within a high degree of confidence (e.g., >75%, >85%, >95%). In addition to the handover events, the mobile device 115-b may record and store other environmental events, e.g., how long the mobile device 115-b remains at a given location, what time the mobile device arrives or departs from a location, etc. In conventional systems, the mobile device 115-b may be assigned to a paging group having base stations that does not consider the mobility state of the mobile device 115-b. To overcome these inefficiencies, predictive behavior of the mobile device 115-b may be leveraged in a number of ways.

[0066] According to a first approach, a predictive algorithmic application may reside on the mobile device 115-b. Mobile device profile information (i.e., based on collected historical information associated with mobility patterns of the mobile device) may be stored by the mobile device 115-b for use by the predictive algorithmic application. Over a certain learning period (e.g., twenty days), enough environmental event information (e.g., location, time, speed, cell measurements, etc.) may be collected by the mobile device 115-b to predict with a high degree of confidence where the mobile device 115-b will be on a certain day and time, and where and when the mobile device 115-b will stationary for a period of time, and the like. Alternatively, a network entity (e.g., measurement server) may collect and store the profile information of the mobile device 115-b, and the predictive algorithmic application of the mobile device 115-b may communicate with the network entity to access the mobile device profile information.

[0067] The predictive algorithmic application may identify with a high degree of confidence (e.g., >90%) that the mobile device 115-b is moving along a known path 205-a and that the next cell along the path 205-a to the work location 310 is cell 2. The predictive algorithmic application may determine that the mobile device 115-b is in a mobile state based on the sequence of repeated historical events associated with moving along the path 205-a. The mobile device 115-b may communicate the mobility state to a base station, e.g., the serving base station. The mobile device 115-b may receive page(s) from a subset of base stations of a paging group that are selected based on the communicated mobility state. Based on the communicated mobile state, the number of base stations of the paging group may be increased to, for example, ensure paging coverage for the mobile device 115-b along the path 205-a.
Once the mobile device 115-b arrives at the work location 310, the predictive algorithm application may identify with a high degree of confidence (e.g., >90%) that the mobile device 115-b will remain at the work location 310 for a known period of time. The predictive algorithm application may determine that the mobile device 115-b is in a stationary state based on the sequence of repeated historical events associated with being located at the work location 310. The mobile device 115-b may communicate the stationary mobility state to a base station, e.g., the serving base station. The mobile device 115-b may receive page(s) from a subset of base stations of a paging group that are selected based on the communicated mobility state. Based on the communicated stationary state, the number of base stations in the subset of base stations of the paging group may be reduced to, for example, conserve paging resources while the mobile device 115-b is located at or near the work location 310.

In some aspects, the mobile device 115-b may determine and report its mobility state autonomously. For example, the predictive algorithm application may monitor the current status of the mobile device 115-b (e.g., location, speed, serving base station, etc.) and compare the current status to the recorded historical information to determine if a sequence of repeated historical events are consistent with the current status. The predictive algorithm application may predict a future mobility of the mobile device 115-b based on a correlation among the sequence of historical events. The mobility state of the mobile device 115-b may be based on the predicted future mobility of the mobile device. If the comparison indicates to within a degree of accuracy or confidence that the mobility state of the mobile device 115-b may be known for a predetermined period of time, the mobile device 115-b may communicate the mobility state to its serving base station. For example, the mobile device 115-b may send one or more location area update messages to the serving base station that include a mobility state information element, a cause information element indicative of the mobility state, and the like, to communicate its mobility state. The mobile device 115-b autonomously monitoring and reporting its mobility state may conserve resources of the serving base station, network entities, etc.

In other aspects, the mobile device 115-b may communicate its mobility state using existing signaling schemes. As one example, the mobile device 115-b may send more than one location area updates within the same location area to communicate its mobility state. As previously discussed, a mobile device 115-b may generally send location area update messages when it moves into a new location area. Transmitting two or more location area updates when the mobility state of the mobile device has changed to a stationary state may, implicitly signal the mobility state to the base station. In each of the location area updates may include information indicating that the mobile device is within a same location area. The mobile device 115-b may transmit a third location area to indicate that its mobility state has changed to a mobile state. The transmission of location area updates may allow for the transitions from a stationary state to a mobile state, and vice versa, to be signaled according to the described techniques.

On the network side, a network entity (e.g., a MME) may determine that the mobile device 115-b has sent multiple location area updates to base station(s) within the same location area. The network entity may determine the mobility state based on the multiple location area updates and select a subset of base stations of a paging group based on the mobility state. The network entity may then transmit page(s) to the subset of base stations of the paging group to page the mobile device 115-b. The network entity may reduce the number of base stations selected for the subset of base stations of the paging group when the mobile device 115-b is in a stationary state. The network entity may increase the number of base stations selected for the subset of base stations of the paging group when the mobile device 115-b is in a mobile state. The network entity may update or change the mobility state of the mobile device 115-b based on the mobile device 115-b transmitting another location area update to a different base station, e.g., a base station other than the base station(s) the previous location area updates were transmitted to. The subsequent location area update, e.g., a third location area update message, may signal that the mobile device 115-b is mobile again and the network entity may reselect the subset of base stations of the paging group accordingly.

When the network entity has reduced the number of base stations selected for the subset of base stations of the paging group and a page to the mobile device fails, the network may conduct fallback operations where additional base stations are added to the subset of base stations of the paging group to increase the paging coverage area. In some aspects, the network entity may assume a default mobility state for the mobile device 115-b when the mobile device 115-b initially connects (e.g., wakes up and connects to a base station). The default mobility state may be a mobile state to ensure the broadest paging coverage area.

FIG. 4 shows a diagram 400 of an example of communications between devices in a wireless communications system, according to one aspect of the principles described herein. The diagram 400 of the present example includes a mobile device 115-c, a first base station 105-e, and a second base station 105-f. In certain embodiments, the mobility profile of the mobile device may be stored entirely on the mobile device 115-c. The diagram 400 may be an example of one or more of the wireless communications systems described above with respect to the previous figures. The mobile device 115-c may be an example of a mobile device described above with respect to the previous figures. The first base station 105-e and/or the second base station 105-f may be examples of the base stations described above with respect to the previous figures.

The mobile device 115-c may determine its mobility state at 405. Generally, the mobility state may be determined autonomously and be based on historical information associated with a sequence of repeated historical events associated with the mobility patterns of the mobile device 115-c. In one example, a predictive algorithm application may be executed by the mobile device 115-c to determine the mobility state. The predictive algorithm application of the mobile device 115-c may store and/or retrieve historical information associated with mobility patterns of the mobile device 115-c. As described above, the historical information may be entirely collected by, and stored on the mobile device 115-c.

At block 410, the mobile device 115-c may communicate its mobility state to the base station 105-e. The mobile device 115-c may communicate the mobility state via one or more location area update messages that include one or more information elements indicative of the mobility state. The mobile device 115-c may communicate the mobility state without direction from, or control of the first base station 105-e. The first base station 105-e and/or the second base
station 105-f may be selected to be included in the subset of base stations of a paging group based on the mobility state. At least at the time the mobile device 115-c communicates its mobility state, the first base station 105-e might be considered the serving base station of the mobile device. At block 415, the second base station 105-f may send a page to the mobile device 115-c. Although the page is shown as being transmitted from the second base station 105-f, it can be appreciated that the page may likely be sent to the mobile device 115-c from the first base station 105-e, so long as the first base station 105-e has been selected to be included in the subset of base stations of the paging group. As discussed above, the first base station 105-e may be the serving base station for the mobile device 115-c (at least when the mobility status indicator is transmitted) and, therefore, will likely be selected to be included in the subset of base stations of the paging group. In the scenario illustrated in FIG. 4, the first and second base station may be neighbor base stations. The mobile device 115-c may have moved away from the first base station 105-e and closer to the second base station 105-f since the mobility information was communicated to the first base station 105-e. In this scenario, the second base station 105-f may then be the serving base station of the mobile device 115-c and, accordingly, may be assigned to the subset of base stations of the paging group and send the page to the mobile device 115-c.

FIG. 5 shows a diagram 500 of an example of communications between devices in a wireless communications system, according to one aspect of the principles described herein. The diagram 500 of the present example includes a mobile device 115-d, a first base station 105-g, a second base station 105-h, and a network entity 505. The diagram 500 may be an example of communications in one or more of the wireless communications systems 100, 200, 300 described above with respect to the previous figures. The mobile device 115-d may be an example of a mobile device 115 described above with respect to the previous figures. The first base station 105-g and/or the second base station 105-h may be examples of the base stations 105 described above with respect to the previous figures. The network entity 505 may be an example of the core network 130 described above with respect to the previous figures.

The mobile device 115-d may determine its mobility state at 405-a. Generally, the mobility state may be determined autonomously and be based on historical information associated with a sequence of repeated historical events associated with the mobility patterns of the mobile device 115-d. In one example, a predictive algorithm application may be executed by the mobile device 115-d to determine the mobility state. The predictive algorithm application of the mobile device 115-d may store and/or retrieve historical information associated with mobility patterns of the mobile device 115-d. The mobility state may be a mobile state where the mobile device 115-d is moving along a path, for example, or a stationary state where the mobile device 115-d is expected to be stationary (e.g., within a coverage of the first base station 105-g and/or an adjacent base station) for a predetermined amount of time.

At block 410-a, the mobile device 115-d may communicate its mobility state to the first base station 105-g. The mobile device 115-d may communicate the mobility state via one or more location area update messages that include one or more information elements indicative of the mobility state. The first base station 105-g might be considered the serving base station of the mobile device based on the mobile device 115-d transmitting the mobility state information. The first base station 105-g may forward the mobility state information of the mobile device 115-d to the network entity 505 at 510. The network entity 505 may determine or otherwise select a subset of base stations of a paging group based on the mobility state at 515. The network entity 505 may assign the subset of base stations to the paging group at 520 and send signals to the second base station 105-h at 525 and to the first base station 105-g at 530. In some aspects, the first base station 105-g and the second base station 105-h may be selected to be included in the subset of base stations of the paging group based on their proximity to each other with respect to the mobile device 115-d. The network entity 505 may subsequently receive a page for the mobile device 115-d and send the page to the first base station 105-g at 540, for example, which sends the page to the mobile device 115-d at 545. Although the page is shown as being transmitted from the first base station 105-g, it can be appreciated that the page may additionally or alternatively be sent to the mobile device 115-d from the second base station 105-h, since the second base station 105-h was assigned to the subset of base stations of the paging group at 525.

FIG. 6 shows a diagram 600 of an example of communications between devices in a wireless communications system, according to one aspect of the principles described herein. The diagram 600 of the present example includes a mobile device 115-e, a first base station 105-i, a second base station 105-j, and a network entity 505. The diagram 600 may be an example of communications in one or more of the wireless communications systems 100, 200, 300 described above with respect to the previous figures. The mobile device 115-e may be an example of a mobile device 115 described above with respect to the previous figures. The first base station 105-i and/or the second base station 105-j may be examples of the base stations 105 described above with respect to the previous figures. The network entity 505 may be an example of the core network 130 described above with respect to the previous figures.

The mobile device 115-e may determine its mobility state at 405-h. Generally, the mobility state may be determined autonomously and be based on historical information associated with a sequence of repeated historical events associated with the mobility patterns of the mobile device 115-e. In one example, a predictive algorithm application may be executed by the mobile device 115-e to determine the mobility state. The predictive algorithm application of the mobile device 115-e may store and/or retrieve historical information associated with mobility patterns of the mobile device 115-e. The mobility state may be a mobile state where the mobile device 115-e is moving along a path, for example, or a stationary state where the mobile device 115-e is expected to be stationary (e.g., within a coverage of its first base station 105-i and/or an adjacent base station) for a predetermined amount of time.

At block 610, the mobile device 115-e may communicate its mobility state to the first base station 105-i by sending two location area updates. Although the two location area updates are shown as being sent to the first base station 105-i, the two location area updates may be sent to two base stations within the same location area to indicate the mobility state of the mobile device 115-e. The first base station 105-i might be considered the serving base station of the mobile device based on the mobile device 115-e transmitting the mobility state information. The first base station 105-i may
forward information indicative of the mobility state of the mobile device 115-e, or information indicating that the mobile device 115-e has sent the two location area updates within the same location area, to the network entity 505-a at 615. The network entity 505-a may reduce the number of base stations selected to be included in a subset of base stations of a paging group based on the mobility state at 620. That is, the two location area updates may indicate that the mobile device 115-e is in a stationary state and, therefore a smaller number of base stations may be assigned to the paging group. The network entity 505-a may assign the subset of base stations to the paging group at 520-a and send signals to the second base station 105-j at 525-a and to the first base station 105-i at 530-a assigning them to the paging group. Although the example illustrated in FIG. 6 depicts the network entity 505-a assigning, and signaling the assignment of, the second base station 105-j to the subset of base stations of the paging group, it is to be understood that the second base station 105-j may not be selected based on the network entity 505-a reducing the subset of base stations. In this scenario, the network entity 505-a may not send the signal at 525-a assigning the second base station 105-j to the subset of base stations. The network entity 505-a may subsequently receive a page for the mobile device 115-e and send the page to the first base station 105-i at 540-a, for example, which sends the page to the mobile device 115-e at 545-a. Although the page is shown as being transmitted from the first base station 105-i, it can be appreciated that the page may additionally or alternatively be sent to the mobile device 115-e from the second base station 105-j, in the scenario where the second base station 105-j was assigned to the subset of base stations of the paging group at 525-a.

[0084] At block 610-a, the mobile device 115-f may communicate its mobility state to the first base station 105-k by sending two location area updates. Although the two location area updates are shown as being sent to the first base station 105-k, the two location area updates may be sent to two base stations within the same location area to indicate the mobility state of the mobile device 115-f, e.g., a first location area update sent to the first base station 105-k and a second location area update sent to the second base station 105-l, assuming these base stations are within the same location area. The first base station 105-k (and the second base stations 105-l, if appropriate) may forward information indicative of the mobility state of the mobile device 115-f, or information indicating that the mobile device 115-f has sent the two location area updates within the same location area, to the network entity 505-b at 615-a. The network entity 505-b may reduce the number of base stations selected to be included in a subset of base stations of a paging group based on the mobility state at 620-a. That is, the two location area updates may indicate that the mobile device 115-f is in a stationary state and, therefore a smaller number of base stations may be assigned to the paging group. The network entity 505-b may assign the subset of base stations to the paging group at 520-b and send a signal to the first base station 105-k at 530-b assigning it to the paging group. In the example illustrated in FIG. 7 and as discussed above, the second base station 105-l may not be selected to be included in the subset of base stations of the paging group based on the network entity 505-b reducing the subset of base stations and, therefore, no signal is sent assigning the second base station 105-l to the paging group. The network entity 505-b may subsequently receive a page for the mobile device 115-f and send the page to the first base station 105-k at 540-b which sends the page to the mobile device 115-f at 545-b.

[0085] At block 705, the mobile device 115-f may again determine its mobility state. The mobile device 115-f may determine that its mobility state has changed at 705 based on the mobile device 115-f user leaving work location 310 and beginning to travel along path 205-a towards the home location 305, for example and referring again to FIG. 3. The mobile device 115-f may send another location area update at 710 to signal its mobility state. The location area update sent at 710 may be sent to the second base station 105-l, i.e., to a base station other than the base station(s) the two location area updates were sent to at 610-a. The second base station 105-l that the third location area update is sent to may be in the same location area or in a different location area with respect to the first base station 105-k.

[0086] The second base station 105-l may forward information indicative of the mobility state of the mobile device 115-f, or information indicating that the mobile device 115-f has sent a third location area update to the network entity 505-b at 715. The network entity 505-b may increase the number of base stations selected to be included in a subset of base stations of a paging group based on the mobility state at 720. That is, the third location area update may indicate that the mobile device 115-f has transitioned to a mobile state and, therefore a larger number of base stations may be assigned to the paging group. The network entity 505-b may assign the subset of base stations to the paging group at 725 and send signals to the second base station 105-l at 730 and to the first base station 105-k at 735 assigning them to the paging group. In this instance, the second base station 105-l has been added to the subset of base stations of the paging group. It is to be
understood, again, that it is likely that a base station the mobile device sends its mobility state to may, for at least a period of time, be the serving base station and, therefore, likely included in the paging group. The network entity 505-b may assign additional base stations (not shown) to the subset of base stations of the paging group. The network entity 505-b may subsequently receive a page at 740 for the mobile device 115-f and send the page to the second base station 105-f at 745, for example, which sends the page to the mobile device 115-f at 750.

[0087] FIG. 8 shows a block diagram of a wireless communications system 800, according to one aspect of the principles described herein. Specifically, FIG. 8 illustrates a design of a base station 105-m and a mobile device 115-g, in accordance with an aspect of the present disclosure. The wireless communications system 800 may illustrate aspects of one or more of the wireless communications systems 100, 200, or 300 described above with reference to previous figures. For example, the base station 105-m may be an example of one or more of the base stations 105 described above with respect to FIGS. 1-7, and the mobile device 115-g may be an example of one or more of the mobile devices 115 described above with respect to FIGS. 1-7.

[0088] The base station 105-m may be equipped with base station antennas 834-a through 834-x, where x is a positive integer, and the mobile device 115-g may be equipped with mobile device antennas 852-a through 852-n, where n is a positive integer. In the wireless communications system 800, the base station 105-m may be able to send data over multiple communication links at the same time. Each communication link may be called a “layer” and the “rank” of the communication link may indicate the number of layers used for communication. For example, in a 2x2 MIMO system where base station 105-m transmits two “layers,” the rank of the communication link between the base station 105-m and the mobile device 115-g is two.

[0089] At the base station 105-m, a base station transmit processor 820 may receive data from a base station data source and control information from a base station processor 840 or other controller. The control information may be for the PSCCH, PCFICH, PHICH, PDOCH, etc. The data may be for the PDSCH, etc. The base station transmit processor 820 may process (e.g., encode and symbol map) the data and control information to obtain data symbols and control symbols, respectively. The base station transmit processor 820 may also generate reference symbols, e.g., for the PSS, SSS, and cell-specific reference signal. An base station transmit (TX) MIMO processor 830 may perform spatial processing (e.g., precoding) on data symbols, control symbols, and/or reference symbols, if applicable, and may provide output symbol streams to the base station modulator/demodulators 832-a through 832-x. Each base station modulator/demodulator 832 may process a respective output symbol stream (e.g., for OFDM, etc.) to obtain an output sample stream. Each base station modulator/demodulator 832 may further process (e.g., convert to analog, amplify, filter, and upconvert) the output sample stream to obtain a downlink (DL) signal. In one example, DL signals from base station modulator/demodulators 832-a through 832-x may be transmitted via the base station antennas 834-a through 834-x, respectively.

[0090] At the mobile device 115-g, the mobile device antennas 852-a through 852-n may receive the DL signals from the base station 105-m and may provide the received signals to the mobile device modulator/demodulators 854-a through 854-n, respectively. Each mobile device modulator/demodulator 854 may condition (e.g., filter, amplify, downconvert, and digitize) a respective received signal to obtain input samples. Each mobile device modulator/demodulator 854 may further process the input samples (e.g., for OFDM, etc.) to obtain received symbols. A mobile device MIMO detector 856 may obtain received symbols from all the mobile device modulator/demodulators 854-a through 854-n, perform MIMO detection on the received symbols if applicable, and provide detected symbols. A mobile device receiver processor 858 may process (e.g., demodulate, deinterleave, and decode) the detected symbols, providing decoded data for the mobile device 115-g to a data output, and provide decoded control information to a mobile device processor 880 or controller, or mobile device memory 882.

[0091] On the uplink (UL), at the mobile device 115-g, a mobile device transmit processor 864 may receive and process data from a mobile device data source. The mobile device transmit processor 864 may also generate reference symbols for a reference signal. The symbols from the mobile device transmit processor 864 may be precoded by a mobile device transmit MIMO processor 866 if applicable, further processed by the mobile device modulator/demodulators 854-a through 854-n (e.g., for SC-FDMA, etc.), and be transmitted to the base station 105-m in accordance with the transmission parameters received from the base station 105-m. At the base station 105-m, the UL signals from the mobile device 115-g may be received by the base station antennas 834, processed by the base station modulator/demodulators 832, detected by a base station MIMO detector 836 if applicable, and further processed by a base station receiver processor 838. The base station receiver processor 838 may provide decoded data to a base station data output and to the base station processor 840.

[0092] The components of the mobile device 115-g may, individually or collectively, be implemented with one or more Application Specific Integrated Circuits (ASICs) adapted to perform some or all of the applicable functions in hardware. Each of the noted modules may be a means for performing one or more functions related to operation of the wireless communications system 800. Similarly, the components of the base station 105-m may, individually or collectively, be implemented with one or more Application Specific Integrated Circuits (ASICs) adapted to perform some or all of the applicable functions in hardware. Each of the noted components may be a means for performing one or more functions related to operation of the wireless communications system 800.

[0093] The communication networks that may accommodate some of the various disclosed embodiments may be packet-based networks that operate according to a layered protocol stack. For example, communications at the bearer or Packet Data Convergence Protocol (PDCP) layer may be IP-based. A Radio Link Control (RLC) layer may perform packet segmentation and reassembly to communicate over logical channels. A Medium Access Control (MAC) layer may perform priority handling and multiplexing of logical channels into transport channels. The MAC layer may also use Hybrid ARQ (HARQ) to provide retransmission at the MAC layer to improve link efficiency. At the Physical layer, the transport channels may be mapped to Physical channels.

[0094] In one configuration, the base station 105-m may operate as a first base station 105-m for the mobile device 115-g, and may include means for determining that the
mobile device 115-g has transmitted a plurality of location area updates to base station(s) with a same location area, determining a mobility state of the mobile device 115-g based on the location area updates, selecting a subset of base stations of a paging group based on the mobility state, and/or transmitting a page to the subset of base stations of the paging group. In one aspect, the aforementioned means may be the base station processor 840, the base station memory 842, the base station transmit processor 820, base station receiver processor 838, the base station modulator/demodulators 832, and the base station antennas 834 of the base station 105-m configured to perform the functions recited by the aforementioned means.

[0095] In an additional or alternative configuration, the mobile device 115-g may include means for determining, autonomously, a mobility state of the mobile device 115-g based on a sequence of repeated historical events associated with mobility patterns of the mobile device, communicating the mobility state of the mobile device 115-g to the base station 105-m, and receiving a page from at least one of a subset of base stations of a paging group, wherein the subset of base stations of the paging group is selected based on the mobility state of the mobile device 115-g. In one aspect, the aforementioned means may be the mobile device processor 880, the mobile device memory 882, the mobile device transmit processor 864, mobile device receiver processor 858, the mobile device modulator/demodulators 854, and the mobile device antennas 852 configured to perform the functions recited by the aforementioned means.

[0096] FIG. 9 shows a block diagram of one example of a mobile device 115-h, according to one aspect of the principles described herein. The mobile device 115-h may be an example of one or more of the mobile devices 115 described above with reference to the previous figures.

[0097] The mobile device 115-h may include a processor 910, a memory 915, a historical information module 920, a mobility state module 925, a paging module 930, and a transceiver 935. Each of these components may be in communication, directly or indirectly.

[0098] The processor 910 may be configured to execute computer-readable program code stored by the memory 915 to implement one or more aspects of the historical information module 920, the mobility state module 925, the paging module 930, and/or the transceiver 935. The processor 910 may also execute computer-readable program code stored by the memory 915 to implement other applications 917.

[0099] The historical information module 920 may be configured to implement aspects of the functionality of one or more of the predictive algorithm applications described above with respect to the previous figures. In certain examples, the historical information module 920 may identify and store (e.g., in historical information 919 of memory 915) historical information associated with mobility patterns of the mobile device 115-h. The historical information may further be identified based on a current location or state of the mobile device 115-h in relation to the historical information 919.

[0100] In certain examples, a serving cell of the mobile device 115-h (e.g., a cell associated with one or more of the base stations 105 described in other figures) and/or other network entity may identify and store the historical information. In this case, the historical information module 920 may determine this information based on signaling from the serving cell and/or other network entity. The mobile device 115-h may communicate with the serving cell using the transceiver 935 to retrieve the historical information. In certain examples, the historical information module 920 may communicate with a server (e.g., over transceiver 935) to receive the historical information. Additionally or alternatively, the mobile device 115-h may collect and store the historical information 919 locally in the memory 915 of the mobile device 115-h, as shown in FIG. 9.

[0101] The historical information may include information about the mobility patterns of the mobile device 115-h. The mobility patterns may include, for example, a route and a schedule of the mobile device 115-h between a first location and a second location. Additionally or alternatively, the mobility patterns may include a location and a period of time during which the mobile device 115-h remains at the location. Thus, in certain examples, the historical information may include a serving cell history of the mobile device 115-h over a predetermined period of time, as observed and stored by the server, the serving cell, and/or the mobile device 115-h. In some cases, the historical information may defining predictable behavior may refer to data taken over a long enough time to show at least two instances of a repeated sequence of a mobile device environmental event. Example environmental events may include one or more radio frequency (RF) events, one or more user events, one or more location events, and/or one or more time events. Repeated sequences of environmental events may be taken as sequences with enough commonality and regularity to ensure the mobile device is following a similar path with the same use requirements. The sequences may not necessarily be identical, but may occur frequently enough with sufficient similarity to provide confidence of the predictive mobility of the mobile device.

[0102] The mobility state module 925 may be configured to determine a mobility state of the mobile device 115-h based on the historical information determined by the historical information module 920. For example, the mobility state module 925 may compare the current status of the mobile device 115-h with previously recorded sequences of events to determine a future mobility state of the mobile device 115-h. As one example, the mobility state module 925 may determine that the mobile device is traveling along the known path 205-a based on the historical information and, therefore, is in a mobile state and will remain in the mobile state until arrival at the work location 310. As another example, the mobility state module 925 may determine that the mobile device 115-h has arrived at the work location 310, based on the comparison, and will remain there and in a stationary state until the end of the work day (i.e., for a predetermined time). The mobility state module 925 may, in conjunction with the transceiver 935, send a signal to communicate the mobility state to a serving base station, e.g., send one or more location area updates.

[0103] In certain examples, the paging module 930 may be configured to receive a page from at least one base station of a subset of base stations of a paging group. The subset of base station of the paging group may be selected based on the mobility state information communicated by the mobility state module 925. In some cases, the number of base stations selected to be included in the subset of base stations of the paging group may be reduced when the mobile device 115-h is in a stationary state and may be increased when the mobile device 115-h is in a mobile state.

[0104] FIG. 10 shows a block diagram of one example of a base station 105-a, according to one aspect of the principles
described herein. The base station 105-n may be an example of one or more of the base stations 105 described above with reference to the previous figures. The base station 105-n may be associated with a serving cell of one or more of the mobile devices 115 described above with reference to the previous figures.

[0105] The base station 105-n of FIG. 10 may include a processor 1010, a memory 1015, a mobility state module 1020, a paging group selection module 1025, a paging module 1030, a transceiver module 1035, and a backhaul/core network interface 1040. Each of these components may be in communication, directly or indirectly.

[0106] The processor 1010 may be configured to execute computer-readable program code stored by the memory 1015 to implement one or more aspects of the mobility state module 1020, the paging group selection module 1025, the paging module 1030, the transceiver module 1035, and/or the backhaul/core network interface 1040. The processor 1010 may also execute computer-readable program code stored by the memory 1015 to implement other applications 1017.

[0107] The mobility state module 1020 may be configured to identify a mobility state of a mobile device (e.g., one or more of the mobile devices 115 described above with respect to the previous figures). The mobility state may be determined based on receiving one or more signals transmitted from the mobile device, e.g., a signal forwarded from a serving base station of the mobile device. The signal may be a location area update having one or more information elements. An example information element may include a mobility state information element as a component of the location area update. Another example information element may include a cause information element repurposed to indicate the mobility state. The mobility state may be a mobile state or a stationary state. A mobile state may indicate that the mobile device is moving (along a path 205-a, for example). A stationary state may indicate that the mobile device is not moving (e.g., stationary at a work location 310). The mobile device may determine its communicated mobility state based on historical information, as discussed above.

[0108] In some examples, the mobility state module 1020 may determine the mobility state based on a determination that the mobile device has transmitted a plurality of location area updates to base station(s) with a same location area. The location area update messages within the same location area may implicitly convey to the mobility state module 1020 that the mobile device is in a stationary state, for example. The mobility state module 1020 may also determine that the mobility state of the mobile device has changed to a mobile state based on a determination that the mobile device has sent another location area update to a base station other than the base station(s) the plurality of location area updates were sent to. The third, for example, location area update message may be within the same or a different location area.

[0109] In some examples, the paging group selection module 1025 may be configured to identify and select base stations to be included in a subset of base stations of a paging group. The paging group selection module 1025 may select base stations to be included in the subset to ensure paging coverage is provided to the mobile device, i.e., based on the mobility state of the mobile device. The paging group selection module 1025 may reduce the number of base stations included in the subset of base stations of the paging group when the mobile device is in a stationary state. The paging group selection module 1025 may increase the number of base stations included in the subset of base stations of the paging group when the mobile device is in a mobile state. The paging group selection module 1025 may, in cooperation with the transceiver module 1035 and/or the backhaul/core network interface 1040, send one or more signals to the selected base stations indicating their assignment to the subset of base stations of the paging group.

[0110] In certain examples, the paging module 1030 may determine that the mobile device is an intended recipient of a page and output one or more signals, through the transceiver module 1035, to at least one base station of the subset of base stations of the paging groups to send the page to the mobile device. The paging module 1030, in cooperation with the paging group selection module 1025 may identify the selected subset of base stations to send the page to. At least one of the base stations of the subset of base stations of the paging group may send the page to the mobile device via the transceiver module 1035 and/or the backhaul/core network interface 1040.

[0111] FIG. 11 shows a block diagram of one example of a mobile device 115-i, according to one aspect of the principles described herein. The mobile device 115-i may be an example of one or more of the mobile devices 115 described above with reference to the previous figures.

[0112] The mobile device 115-i may include a processor 910-a, a memory 915-a, a historical information module 920-a, a mobility state module 925-a, a paging module 930-a, a mobility state signaling module 1105, and a transceiver 935-a. Each of these components may be in communication, directly or indirectly.

[0113] The processor 910-a may be configured to execute computer-readable program code stored by the memory 915-a to implement one or more aspects of the historical information module 920-a, the mobility state module 925-a, the paging module 930-a, the mobility state signaling module 1105, and/or the transceiver 935-a. The processor 910-a may also execute computer-readable program code stored by the memory 915-a to implement other applications 917-a.

[0114] The historical information module 920-a may be configured to implement aspects of the functionality of one or more of the predictive algorithm applications described above with respect to the previous figures. In certain examples, the historical information module 920-a may identify and store (e.g., in historical information 919-a of memory 915-a) historical information associated with mobility patterns of the mobile device 115-i. The historical information may further be identified based on a current location or state of the mobile device 115-i in relation to the historical information 919-a.

[0115] In certain examples, a serving cell of the mobile device 115-i (e.g., a cell associated with one or more of the base stations 105 described in other figures) and/or other network entity may identify and store the historical information. In this case, the historical information module 920-a may determine this information based on signaling from the serving cell and/or other network entity. The mobile device 115-i may communicate with the serving cell using the transceiver 935-a to retrieve the historical information. In certain examples, the historical information module 920-a may communicate with a server (e.g., over transceiver 935-a) to receive the historical information. Additionally or alternatively, the mobile device 115-i may collect and store the historical information 919-a locally in the memory 915-a of the mobile device 115-i, as shown in FIG. 11.
The historical information may include information about the mobility patterns of the mobile device 115-i. The mobility patterns may include, for example, a route and a schedule of the mobile device 115-i between a first location and a second location. Additionally or alternatively, the mobility patterns may include a location and a period of time during which the mobile device 115-i remains at the location. Thus, in certain examples, the historical information may include a serving cell history of the mobile device 115-i over a predetermined period of time, as observed and stored by the server, the serving cell, and/or the mobile device 115-i. In some cases, the historical information may define predictable behavior that refers to data taken over a long enough time to show at least two instances of a repeated sequence of a mobile device environmental event. Example environmental events may include one or more radio frequency (RF) events, one or more user events, one or more location events, and/or one or more time events. Repeated sequences of environmental events may be taken as sequences with enough commonality and regularity to ensure the mobile device is following a similar path with the same use requirements. The sequences may not necessarily be identical, but may occur frequently enough with sufficient similarity to provide confidence of the predictive mobility of the mobile device.

The mobility state module 925-a may be configured to determine a mobility state of the mobile device 115-i based on the historical information determined by the historical information module 920-a. For example, the mobility state module 925-a may compare the current status of the mobile device 115-i with previously recorded sequences of events to determine a future mobility state of the mobile device 115-i.

In some examples, the mobility state signaling module 1105 may be configured to determine a signaling scheme to communicate the mobility state of the mobile device 115-i. Exemplary signaling schemes may include explicitly signaling the mobility state or implicitly signaling the mobility state. The mobility state may be signaled explicitly in a mobility state message having one or more information fields indicative of the mobility state, the length of predetermined future time the mobile device will be in the current mobility state, a confidence level indicator field indicative of the degree of confidence the mobile device will be in the current mobility state for the predetermined future time, and the like. The mobility state may also be explicitly signaled via one or more location area updates messages. The location area update messages may include a mobility state indicator field, for example. In another example, one or more information elements in the location area update message may be repurposed to convey the mobility state, e.g., the cause information element.

The mobility state may be implicitly signaled by sending a plurality of location area update messages to base station(s) within the same location area. For instance, two location area update messages within the same location area may indicate that the mobile device is in a stationary state. Two location area update messages may also be sent within a predefined time period to indicate that the mobile device is in a stationary state. A third location area update message may indicate that the mobile device has transitioned to a mobile state.

The mobility state signaling module, in cooperation with the mobility state module 925-a and/or the transceiver 935-a, may send a signal to communicate the mobility state to a serving base station.

In certain examples, the paging module 930-a may be configured to receive a page from at least one base station of a subset of base stations of a paging group. The subset of base stations of the paging group may be selected based on the mobility state information communicated by the mobility state module 925-a. In some cases, the number of base stations selected to be included in the subset of base stations of the paging group may be reduced when the mobile device 115-i is in a stationary state and may be increased when the mobile device 115-i is in a mobile state.

FIG. 12 shows a block diagram of one example of a base station 105-a, according to one aspect of the principles described herein. The base station 105-a may be an example of one or more of the base stations 115 described above with reference to the previous figures. The base station 105-a may be associated with a serving cell of one or more of the mobile devices 115 described above with reference to the previous figures.

The base station 105-a of FIG. 12 may include a processor 1010-a, a memory 1015-a, a mobility state module 1020-a, a paging group selection module 1025-a, a paging module 1030-a, a location area update monitor module 1205, a transceiver module 1035-a, and a backhaul/core network interface 1040-a. Each of these components may be in communication, directly or indirectly.

The processor 1010-a may be configured to execute computer-readable program code stored by the memory 1015-a to implement one or more aspects of the mobility state module 1020-a, the paging group selection module 1025-a, the paging module 1030-a, the location area update monitor module 1205, the transceiver module 1035-a, and/or the backhaul/core network interface 1040-a. The processor 1010-a may also execute computer-readable program code stored by the memory 1015-a to implement other applications 1017-a.

The mobility state module 1020-a may be configured to identify a mobility state of a mobile device (e.g., one or more of the mobile devices 115 described above with respect to the previous figures). The mobility state may be determined based on receiving one or more signal transmitted from the mobile device, e.g., a signal forwarded from a serving base station of the mobile device. The signal may be a location area update having one or more information elements. An example information element may include a mobility state information element as a component of the location area update. Another example information element may include a cause information element repurposed to indicate the mobility state. The mobility state may be a mobile state or a stationary state. A mobile state may indicate that the mobile device is moving (along a path 205-a, for example). A stationary state may indicate that the mobile device is not moving (e.g., stationary at a work location 310). The mobile device may determine its communicated mobility state based on historical information, as discussed above.

In one example, the location area update monitor module 1205 may be configured to monitor for location area update messages transmitted from a mobile device. Upon determining that a mobile device has sent a plurality of location area update messages to base station(s) within the same location area, the location area update monitor module 1205 may output information indicative of the location area updates (e.g., as the location area updates relate to mobility state). The location area update monitor module 1205 may continue to monitor for and output information indicative of
location area update messages transmitted from the mobile device to, for example, indicate a change in mobility state.

[0127] The location area update messages transmitted within the same location area may implicitly convey to the mobility state module 1020-a that the mobile device is in a stationary state, for example. The mobility state module 1020-a, in cooperation with the location area update monitor module 1205, may also determine that the mobility state of the mobile device has changed to a mobile state based on a determination that the mobile device has sent another location area update to a base station other than the base station(s) the plurality of location area updates were sent to. The third, for example, location area update message may be within the same or a different location area.

[0128] In some examples, the paging group selection module 1025-a may be configured to identify and select base stations to be included in a subset of base stations of a paging group. The paging group selection module 1025-a may select base stations to be included in the subset to ensure paging coverage is provided to the mobile device, i.e., based on the mobility state of the mobile device. The paging group selection module 1025-a may reduce the number of base stations included in the subset of base stations of the paging group when the mobile device is in a stationary state. The paging group selection module 1025-a may increase the number of base stations included in the subset of base stations of the paging group when the mobile device is in a mobile state. The paging group selection module 1025-a may, in cooperation with the transceiver module 1035-a and/or the backhaul/core network interface 1040-a, send one or more signals to the selected base stations indicating their assignment to the subset of base stations of the paging group.

[0129] In certain examples, the paging module 1030-a may determine that the mobile device is an intended recipient of a page and output one or more signals, through the transceiver module 1035-a, to at least one base station of the subset of base stations of the paging group to send the page to the mobile device. The paging module 1030-a, in cooperation with the paging group selection module 1025-a may identify the selected subset of base stations to send the page to. At least one of the base stations of the subset of base stations of the paging group may send the page to the mobile device via the transceiver module 1035-a and/or the backhaul/core network interface 1040-a.

[0130] FIG. 13 shows a flowchart diagram of a method 1300 for managing wireless communications, in accordance with an aspect of the present disclosure. Specifically, FIG. 13 illustrates a method 1300 of improving network and/or mobile device utilization and performance based on learning and predicting the behavior of a mobile device. The method 1300 may be implemented in one or more of the wireless communications systems 100, 200, 300, 400, 500, 600, 700, 800 described above with respect to the previous figures. In particular, the method 1300 may be performed by one or more of the mobile devices 115 described above with reference to the previous figures.

[0131] At block 1305, a mobile device may autonomously determine its mobility state based on a sequence of repeated historical events associated with mobility patterns of the mobile device. The historical information may be accessed by collecting and storing the historical information and/or receiving the historical information from another device. At block 1310, the mobility state of the mobile device may be communicated to a base station, e.g., a serving base station of the mobile device. The mobility state may be transmitted in one or more messages, e.g., location area update messages. At block 1305, a page may be received from one of a subset of base stations of a paging group, the subset of base stations of the paging group being selected based on the mobility state of the mobile device.

[0132] FIG. 14 shows a flowchart diagram of a method 1400 for managing wireless communications, in accordance with an aspect of the present disclosure. Specifically, FIG. 14 illustrates a method 1400 of improving network and/or mobile device utilization and performance based on learning and predicting the behavior of a mobile device. The method 1400 may be implemented in one or more of the wireless communications systems 100, 200, 300, 400, 500, 600, 700, 800 described above with respect to the previous figures. In particular, the method 1400 may be performed by one or more of the mobile devices 115 described above with reference to the previous figures.

[0133] At block 1405, a mobile device may autonomously determine its mobility state based on a sequence of repeated historical events associated with mobility patterns of the mobile device. The historical information may be accessed by collecting and storing the historical information and/or receiving the historical information from another device. At block 1410, it may be determined whether the mobile device is in a mobile state or a stationary state. If the mobile device is in a stationary state, at block 1415, two location area updates may be transmitted, each location area update indicating that the mobile device is in the same location area. The mobility state of the mobile device may be communicated via the two location area updates to base station(s) with the same location area. If the mobile device is in a mobile state, at block 1420 a location area update may be transmitted to a base station, e.g., the serving base station. The base station may be different from recipient base station(s) of previous location area updates. The location area update to the different base station may indicate that the mobile device is in the mobile state. At block 1425, a page may be received from one of a subset of base stations of a paging group, the subset of base stations of the paging group being selected based on the mobility state of the mobile device.

[0134] FIG. 15 shows a flowchart diagram of a method 1500 for managing wireless communications, in accordance with an aspect of the present disclosure. Specifically, FIG. 15 illustrates a method 1500 of improving network and/or mobile device utilization and performance based on learning and predicting the behavior of a mobile device. The method 1500 may be implemented in one or more of the wireless communications systems 100, 200, 300, 400, 500, 600, 700, 800 described above with respect to the previous figures. In particular, the method 1500 may be performed by one or more of the base stations 105 and/or a network entity 505 described above with reference to the previous figures.

[0135] At block 1505, a determination is made that a mobile device has transmitted a plurality of location area updates to base station(s) within a same location area. The multiple location area updates within the same location area may implicitly indicate that the mobile device is in a stationary state, for example. At block 1510, the mobility state of the mobile device may be determined based on the plurality of location area updates. The mobility state may be a mobile state or a stationary state.

[0136] At block 1515, a subset of base stations of a paging group may be determined for sending a page to the mobile
device, the determination based on the mobility state. The number of base stations selected to be included in the subset may be increased when the mobile device is in a mobile state or reduced when the mobile device is in a stationary state. At block 1520, a page may be transmitted to the subset of base stations of the paging group. The page may be further communicated to the mobile device from one or more of the base stations of the subset of base stations.

[0137] FIG. 16 shows a flowchart diagram of a method 1600 for managing wireless communications, in accordance with an aspect of the present disclosure. Specifically, FIG. 16 illustrates a method 1600 of improving network and/or mobile device utilization and performance based on learning and predicting the behavior of a mobile device. The method 1600 may be implemented in one or more of the wireless communications systems 100, 200, 300, 400, 500, 600, 700, 800 described above with respect to the previous figures. In particular, the method 1600 may be performed by one or more of the base stations 105 and/or the network entity 505 described above with reference to the previous figures.

[0138] At block 1605, a determination is made that a mobile device has transmitted a plurality of location area updates to base station(s) within a same location area. The multiple location area updates within the same location area may implicitly indicate that the mobile device is in a stationary state, for example. At block 1610, the mobility state of the mobile device may be determined based on the plurality of location area updates. The mobility state may be a mobile state or a stationary state. As one example, if the mobile device is in a stationary state, two location area updates may be transmitted, each location area update indicating that the mobile device is in the same location area. The mobility state of the mobile device may be communicated via the two location area updates to base station(s) with the same location area. As another example, if the mobile device transitions to a mobile state, a third location area update may be sent to a base station other than the base station(s) that were the recipient(s) of the first two location area updates.

[0139] At block 1615, a determination may be made whether the mobile device is in a stationary state or a mobile state. If the mobile device is in a stationary state, at block 1620 the number of base stations in a paging group may be reduced based on the mobile device being in the stationary state. If the mobile device is in a mobile state, at block 1625 the number of base stations in a paging group may be increased based on the mobile device being in the mobile state. Adjusting the number of the base stations in the paging group may ensure adequate paging coverage area for the mobile device while conserving resources of the base station(s) and/or other network entities.

[0140] At block 1630, a page may be transmitted to the subset of base stations of the paging group. The page may be further communicated to the mobile device from one or more of the base stations of the subset of base stations.

[0141] The detailed description set forth above in connection with the appended drawings describes exemplary embodiments and does not represent the only embodiments that may be implemented or that are within the scope of the claims. The term “exemplary” used throughout this description means “serving as an example, instance, or illustration,” and not “preferred” or “advantageous over other embodiments.” The detailed description includes specific details for the purpose of providing an understanding of the described techniques. These techniques, however, may be practiced without these specific details. In some instances, well-known structures and devices are shown in block diagram form in order to avoid obscuring the concepts of the described embodiments.

[0142] Information and signals may be represented using any of a variety of different technologies and techniques. For example, data, instructions, commands, information, signals, bits, symbols, and chips that may be referenced throughout the above description may be represented by voltages, currents, electromagnetic waves, magnetic fields or particles, optical fields or particles, or any combination thereof.

[0143] The various illustrative blocks and modules described in connection with the disclosure herein may be implemented or performed with a general-purpose processor; a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general-purpose processor may be a microprocessor, but in the alternative, the processor may be any conventional processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of computing devices, e.g., a combination of a DSP and a microprocessor, multiple microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration.

[0144] The functions described herein may be implemented in hardware, software executed by a processor, firmware, or any combination thereof. If implemented in software executed by a processor, the functions may be stored on or transmitted over as one or more instructions or code on a computer-readable medium. Other examples and implementations are within the scope and spirit of the disclosure and appended claims. For example, due to the nature of software, functions described above can be implemented using software executed by a processor, hardware, firmware, hardwiring, or combinations of any of these. Features implementing functions may also be physically located at various positions, including being distributed such that portions of functions are implemented at different physical locations. Also, as used herein, including in the claims, “or” as used in a list of items prefixed by “at least one of” indicates a disjunctive list such that, for example, a list of “at least one of A, B, or C” means A or B or C or AB or AC or BC or ABC (i.e., A and B and C).

[0145] Computer-readable media includes both computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. A storage medium may be any available medium that can be accessed by a general purpose or special purpose computer. By way of example, and not limitation, computer-readable media can comprise RAM, ROM, EEPROM, CD-ROM or other optical disk storage, magnetic disk storage or any other magnetic storage devices, or any other medium that can be used to carry or store desired program code means in the form of instructions or data structures and that can be accessed by a general-purpose or special-purpose computer, or a general-purpose or special-purpose processor. Also, any connection is properly termed a computer-readable medium. For example, if the software is transmitted from a website, server, or other remote source using a coaxial cable, fiber optic cable, twisted pair, digital subscriber line (DSL), wireless technologies such as infrared, radio, and microwave, then the coaxial cable, fiber optic cable, twisted pair, DSL, or
wireless technologies such as infrared, radio, and microwave are included in the definition of medium. Disk and disc, as used herein, include compact disc (CD), laser disc, optical disc, digital versatile disk (DVD), floppy disk and Blu-Ray disc where disks usually reproduce data magnetically, while discs reproduce data optically with lasers. Combinations of the above are also included within the scope of computer-readable media.

[0146] The previous description of the disclosure is provided to enable a person skilled in the art to make or use the disclosure. Various modifications to the disclosure will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other variations without departing from the spirit or scope of the disclosure. Throughout this disclosure the term “example” or “exemplary” indicates an example or instance and does not imply or require any preference for the noted example. Thus, the disclosure is not to be limited to the examples and designs described herein but is to be accorded the widest scope consistent with the principles and novel features disclosed herein.

What is claimed is:

1. A method for managing wireless communications, comprising:
   determining, autonomously by a mobile device, a mobility state of the mobile device based on a sequence of repeated historical events associated with mobility patterns of the mobile device; 
   communicating the mobility state of the mobile device to a base station; and 
   receiving a page from at least one of a subset of base stations of a paging group, wherein the subset of base stations of the paging group is selected based on the mobility state of the mobile device.

2. The method of claim 1, wherein the mobility state comprises one or more of a mobile state or a stationary state.

3. The method of claim 2, wherein a number of base stations in the paging group is reduced when the mobile device is in the stationary state and increased when the mobile device is in the mobile state.

4. The method of claim 1, wherein communicating the mobility state comprises transmitting a location area update.

5. The method of claim 4, wherein communicating the mobility state comprises:
   transmitting two location area updates when the mobility state of the mobile device has changed to a stationary state, each of the location area updates indicating that the mobile device is within a same location area.

6. The method of claim 4, wherein communicating the mobility state comprises:
   transmitting a location area update to the base station, wherein the base station is different from a recipient of a previous location area update.

7. The method of claim 1, wherein communicating the mobility state of the mobile device comprises:
   transmitting a location area update, the location area update comprising at least one of: a mobility state information element or a cause information element indicative of the mobility state.

8. The method of claim 1, wherein the sequence of historical events associated with the mobility patterns of the mobile device comprises at least two previous instances of a same historical event within a predetermined time period.

9. The method of claim 8, wherein the sequence of historical events comprises one or more of: a channel environment event, a user event, a location event, or a time event.

10. The method of claim 8, further comprises:
   predicting a future mobility of the mobile device based on a correlation among the sequence of historical events; wherein the mobility state of the mobile device is based on the predicted future mobility of the mobile device.

11. An apparatus for managing wireless communications, comprising:
   a processor; and
   memory in electronic communication with the processor, the memory embodying instructions, the instructions being executable by the processor to:
   determine, autonomously by a mobile device, a mobility state of the mobile device based on a sequence of repeated historical events associated with mobility patterns of the mobile device; 
   communicate the mobility state of the mobile device to a base station; and 
   receive a page from at least one of a subset of base stations of a paging group, wherein the subset of base stations of the paging group is selected based on the mobility state of the mobile device.

12. The apparatus of claim 11, wherein the mobility state comprises one or more of a mobile state or a stationary state.

13. The apparatus of claim 12, wherein a number of base stations in the paging group is reduced when the mobile device is in the stationary state and increased when the mobile device is in the mobile state.

14. The apparatus of claim 11, wherein the instructions executable by the processor to communicate the mobility state are further executable to transmit a location area update.

15. The apparatus of claim 14, wherein the instructions executable by the processor to communicate the mobility state are further executable to:
   transmit two location area updates when the mobility state of the mobile device has changed to a stationary state, each of the location area updates indicating that the mobile device is within a same location area.

16. The apparatus of claim 14, wherein the instructions executable by the processor to communicate the mobility state are further executable to:
   transmit a location area update to the base station, wherein the base station is different from a recipient of a previous location area update.

17. The apparatus of claim 11, wherein the instructions executable by the processor to communicate the mobility state are further executable to:
   transmit a location area update, the location area update comprising at least one of: a mobility state information element or a cause information element indicative of the mobility state.

18. The apparatus of claim 11, wherein the sequence of historical events associated with the mobility patterns of the mobile device comprises at least two previous instances of a same historical event within a predetermined time period.

19. The apparatus of claim 18, wherein the sequence of historical events comprises one or more of: a channel environment event, a user event, a location event, or a time event.

20. The apparatus of claim 18, further comprising instructions executable by the processor to:
   predict a future mobility of the mobile device based on a correlation among the sequence of historical events;
wherein the mobility state of the mobile device is based on the predicted future mobility of the mobile device.

21. A method for managing wireless communications, comprising:
   determining that a mobile device has transmitted a plurality of location area updates to one or more base stations within a same location area;
   determining a mobility state of the mobile device based on the plurality of location area updates;
   determining, based on the mobility state of the mobile device, a subset of base stations of a paging group to send a page to the mobile device; and
   transmitting the page to the subset of base stations of the paging group.

22. The method of claim 21, wherein the mobility state comprises at least one of: a mobile state or a stationary state.

23. The method of claim 22, further comprising:
   reducing a number of base stations in the paging group in response to a determination that the mobile device is in the stationary state.

24. The method of claim 22, further comprising:
   increasing a number of base stations in the subset of base stations of the paging group in response to a determination that the mobile device is in the mobile state.

25. The method of claim 21, further comprising:
   determining that the mobile device has transmitted a location area update to a base station other than a recipient of a previous location area update from the mobile device; and
   updating the mobility state of the mobile device based on the location area update.

26. The method of claim 25, wherein the transmission of a second one of the location area updates by the mobile device indicates that the mobile device has transitioned to a mobile state.

27. An apparatus for managing wireless communications, comprising:
   a processor; and
   a memory in electronic communication with the processor, the memory embodying instructions, the instructions executable by the processor to:
   determine that a mobile device has transmitted a plurality of location area updates to one or more base stations within a same location area;
   determine a mobility state of the mobile device based on the plurality of location area updates;
   determine, based on the mobility state of the mobile device, a subset of base stations of a paging group to send a page to the mobile device; and
   transmit the page to the subset of base stations of the paging group.

28. The apparatus of claim 27, wherein the mobility state comprises at least one of: a mobile state or a stationary state.

29. The apparatus of claim 28, further comprising instructions executable by the processor to:
   reduce a number of base stations in the paging group in response to a determination that the mobile device is in the stationary state.

30. The apparatus of claim 28, further comprising instructions executable by the processor to:
   increase a number of base stations in the subset of base stations of the paging group in response to a determination that the mobile device is in the mobile state.

* * * * *