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(54) **SEAMLESS MOBILITY FOR WIRELESS DEVICES**

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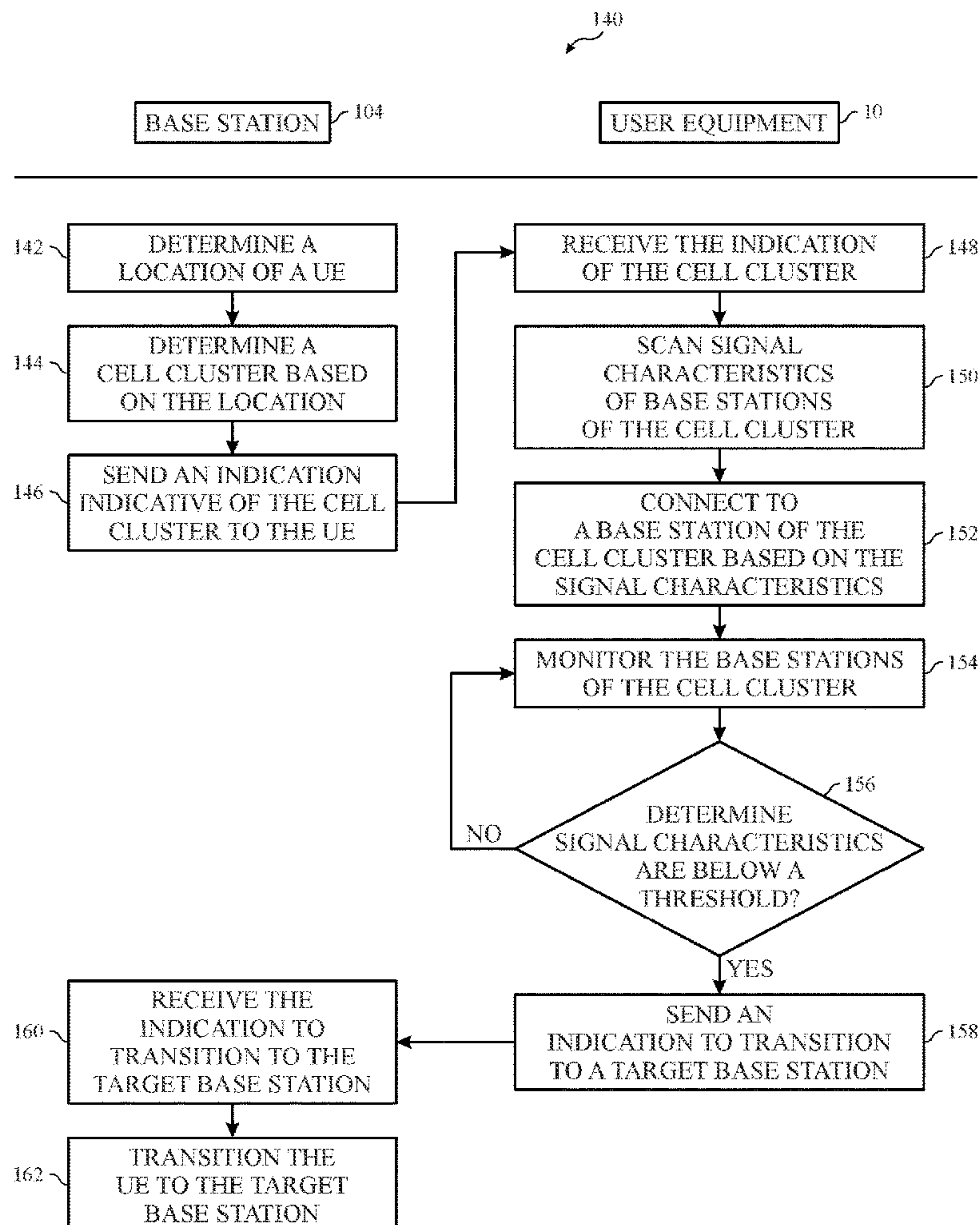
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ABSTRACT

User equipment may include a transmitter and a receiver coupled to an antenna to enable the user equipment to transmit and receive user data with a base station of the wireless network. However, the user equipment may perform power-consuming searches to determine a base station for connection. Furthermore, the connection may be affected by blockages and transitions during mobility scenarios. As such, it may be beneficial for the user equipment to implement mobility procedures. For example, the user equipment may form links with multiple base stations of a cell cluster for transitioning. In another example, the wireless network may generate a map with locations of base stations and beam characteristics for the user equipment to determine coverage areas and decrease a number of transitions. Still in another example, the user equipment may receive blockage information to predict a blockage and implement mobility procedures to maintain wireless service during a blockage.



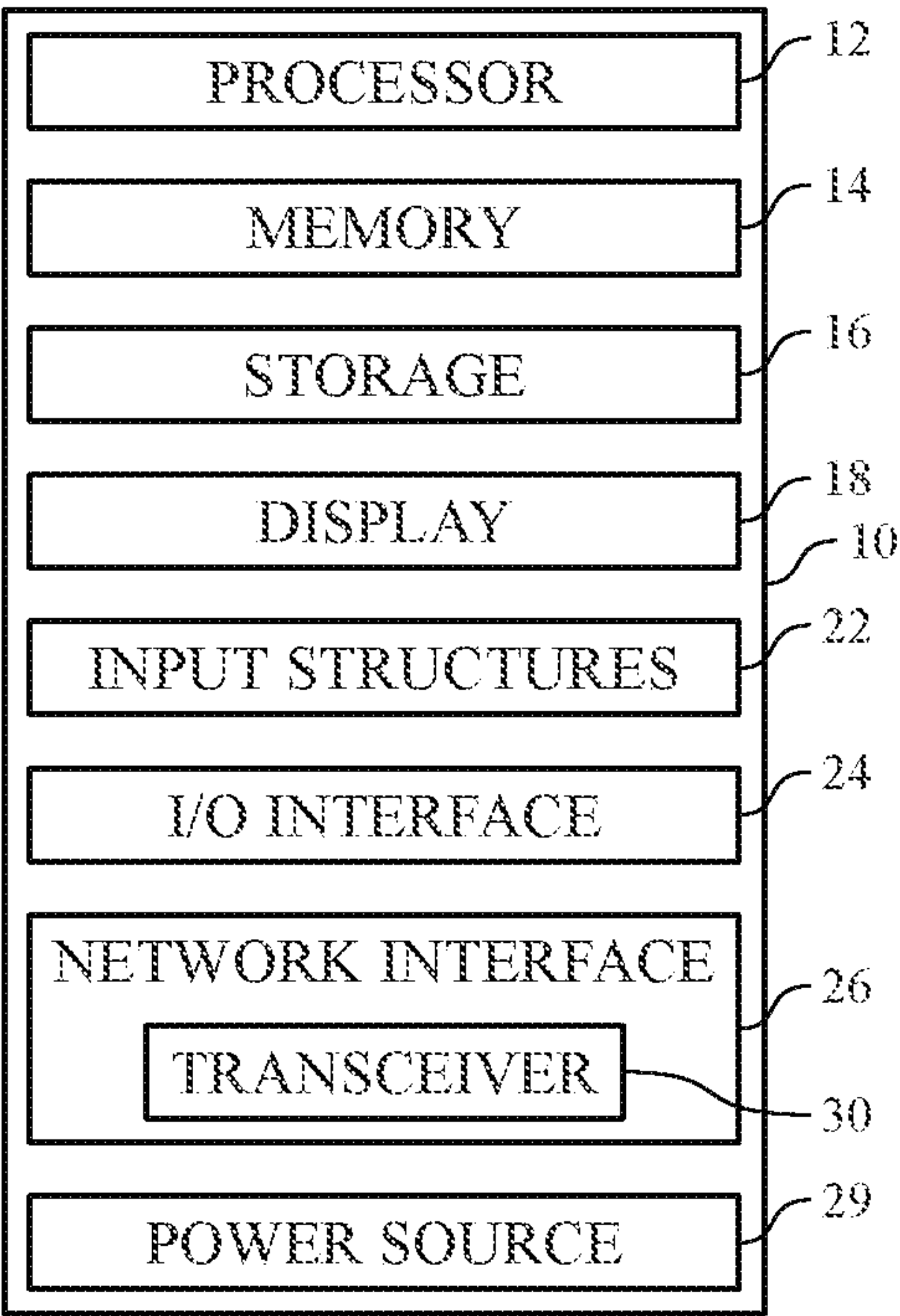


FIG. 1

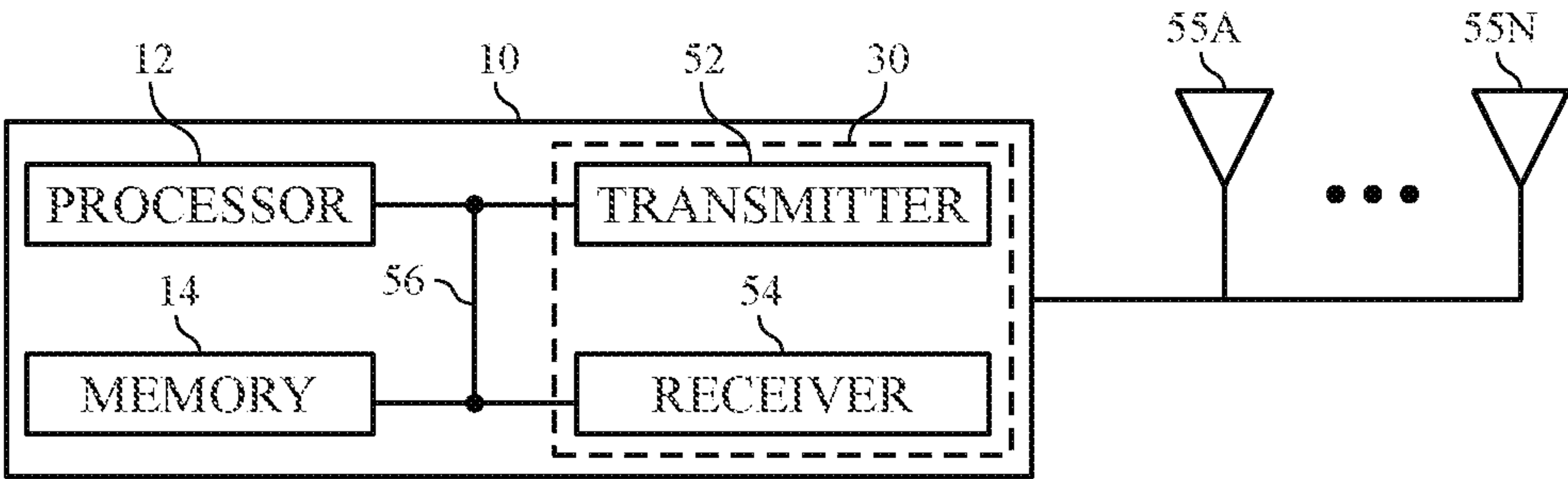


FIG. 2

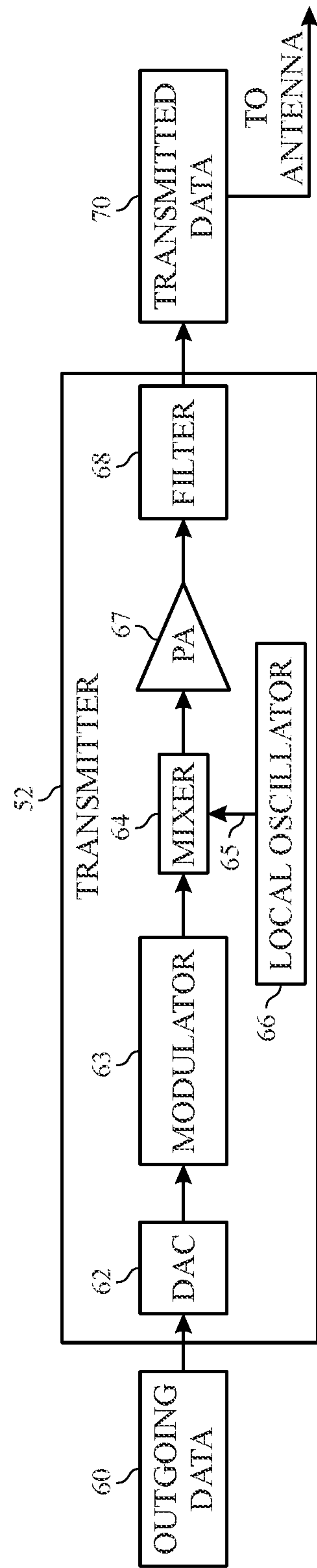


FIG. 3

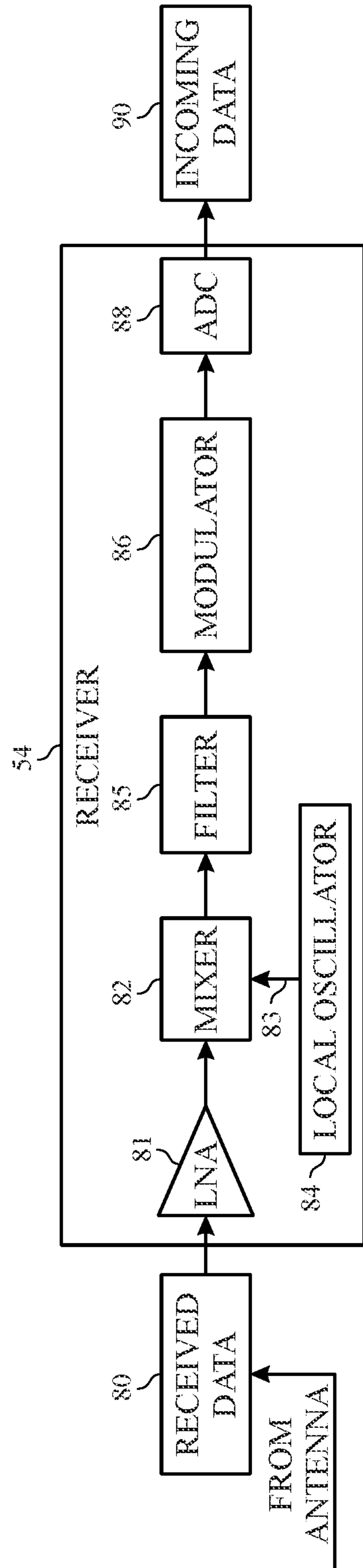


FIG. 4

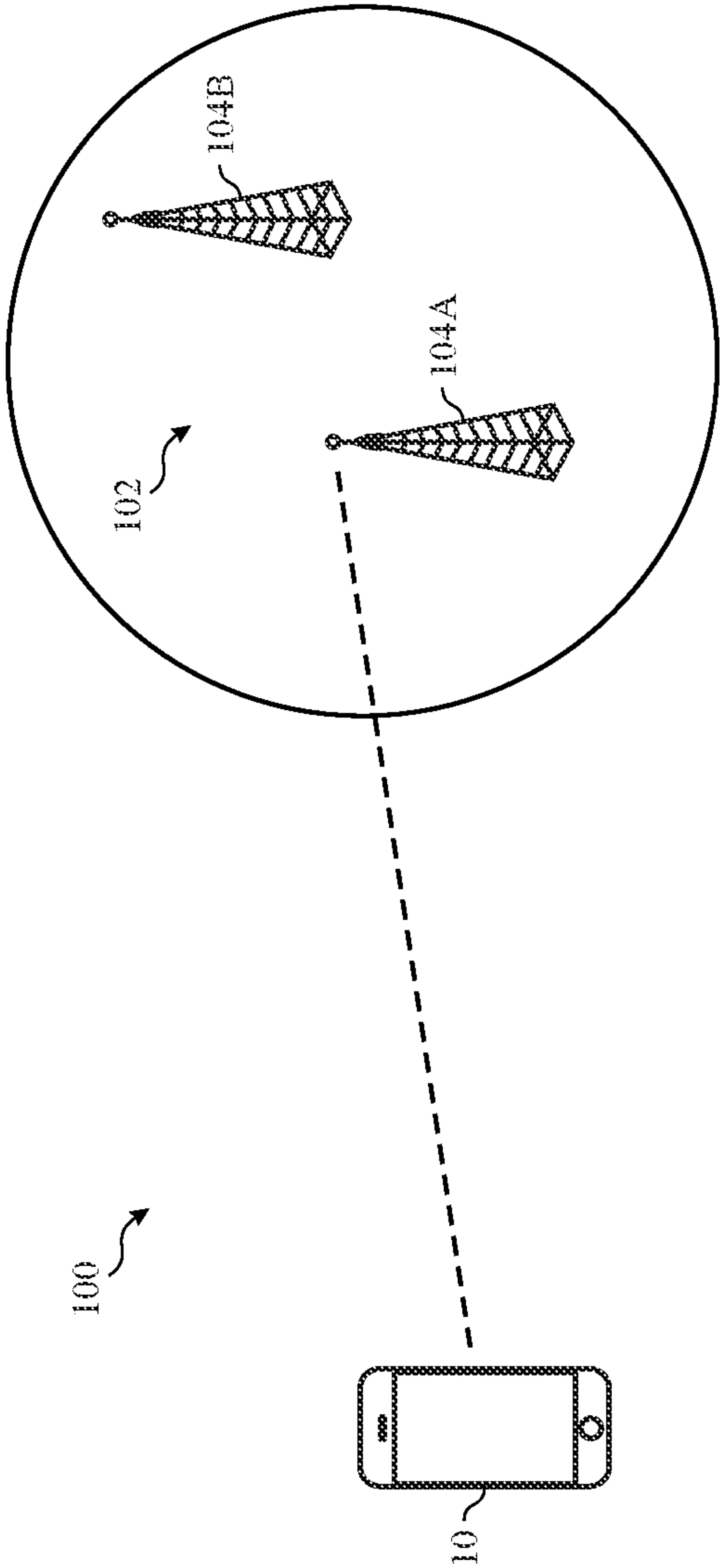


FIG. 5

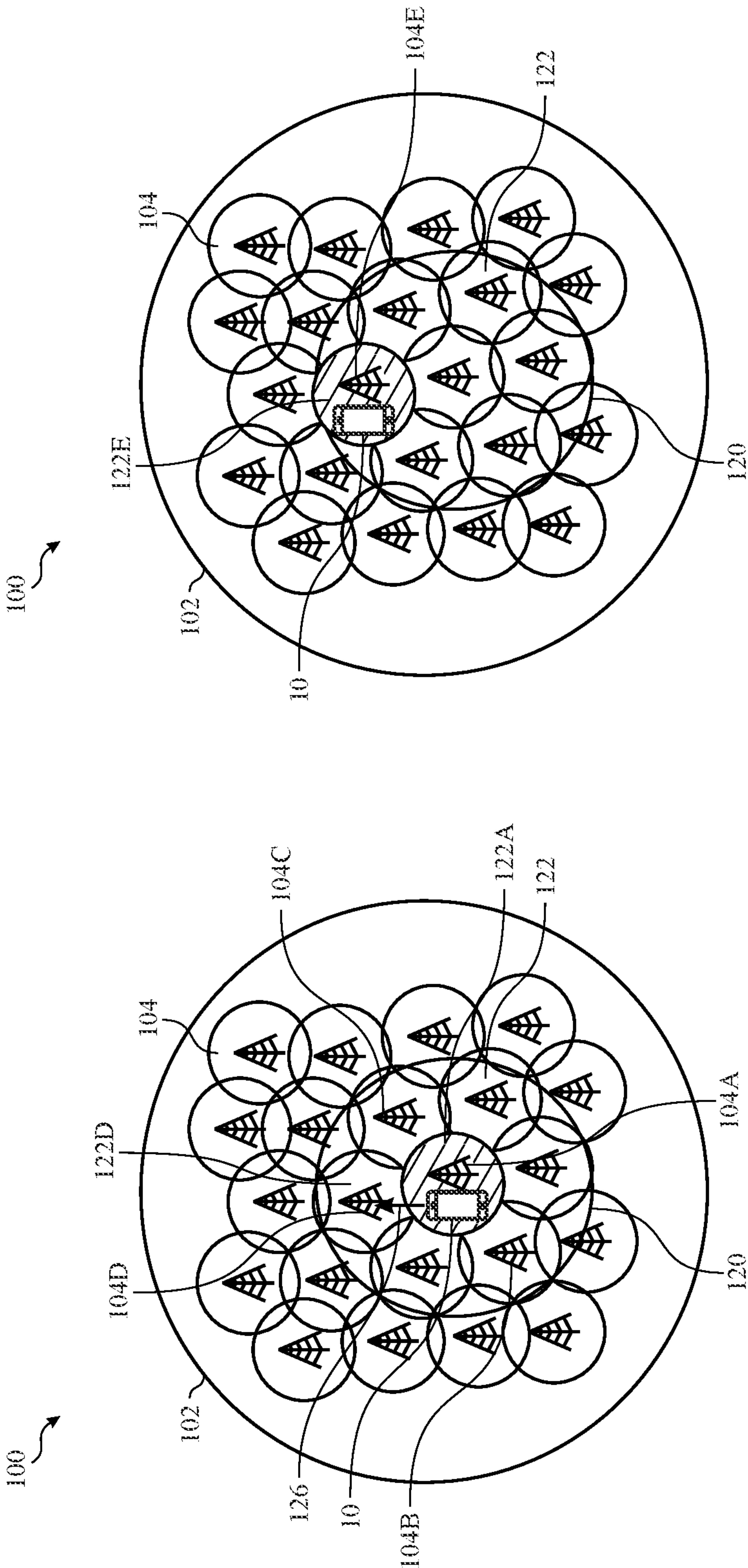


FIG. 6A

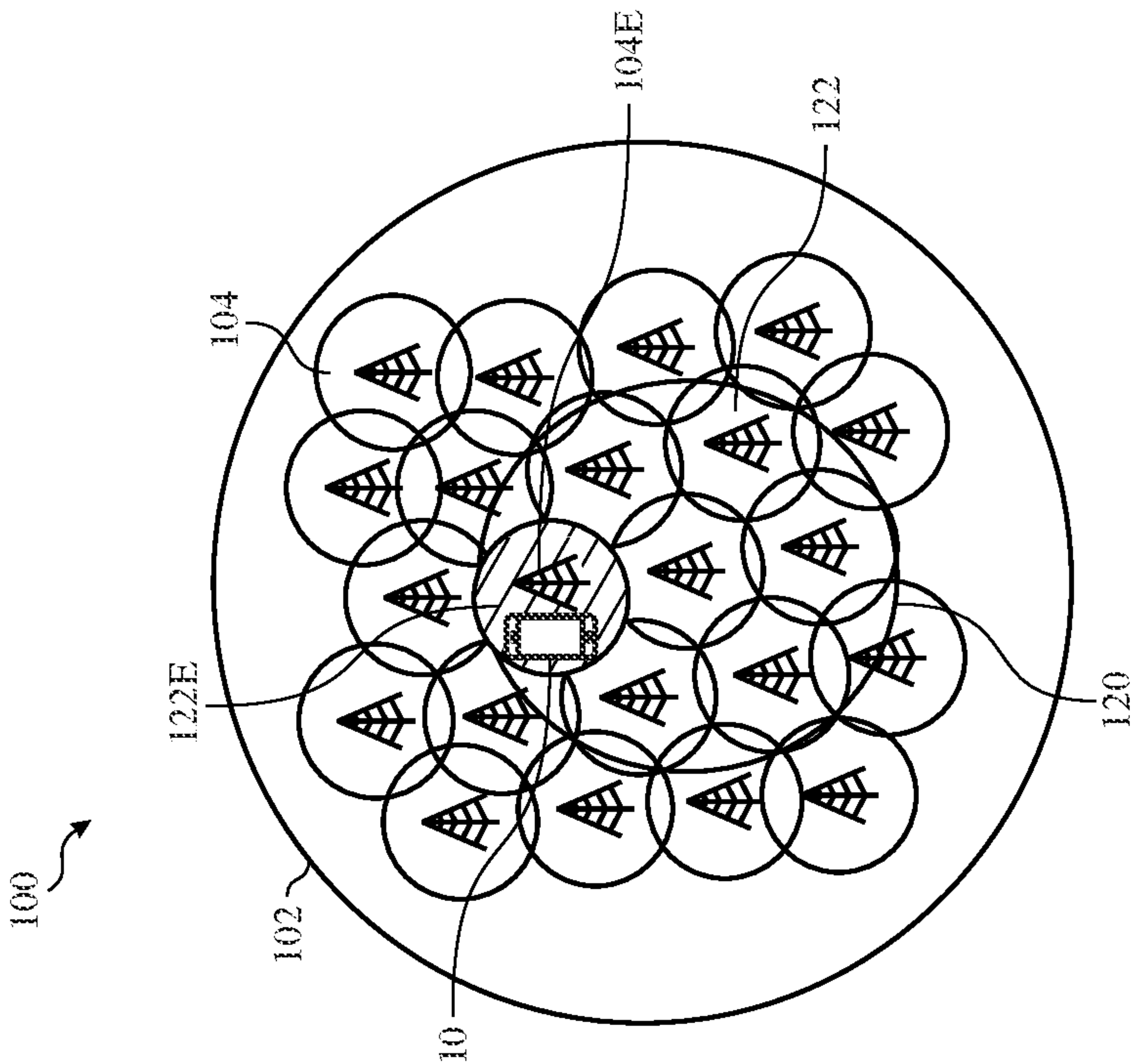


FIG. 6B

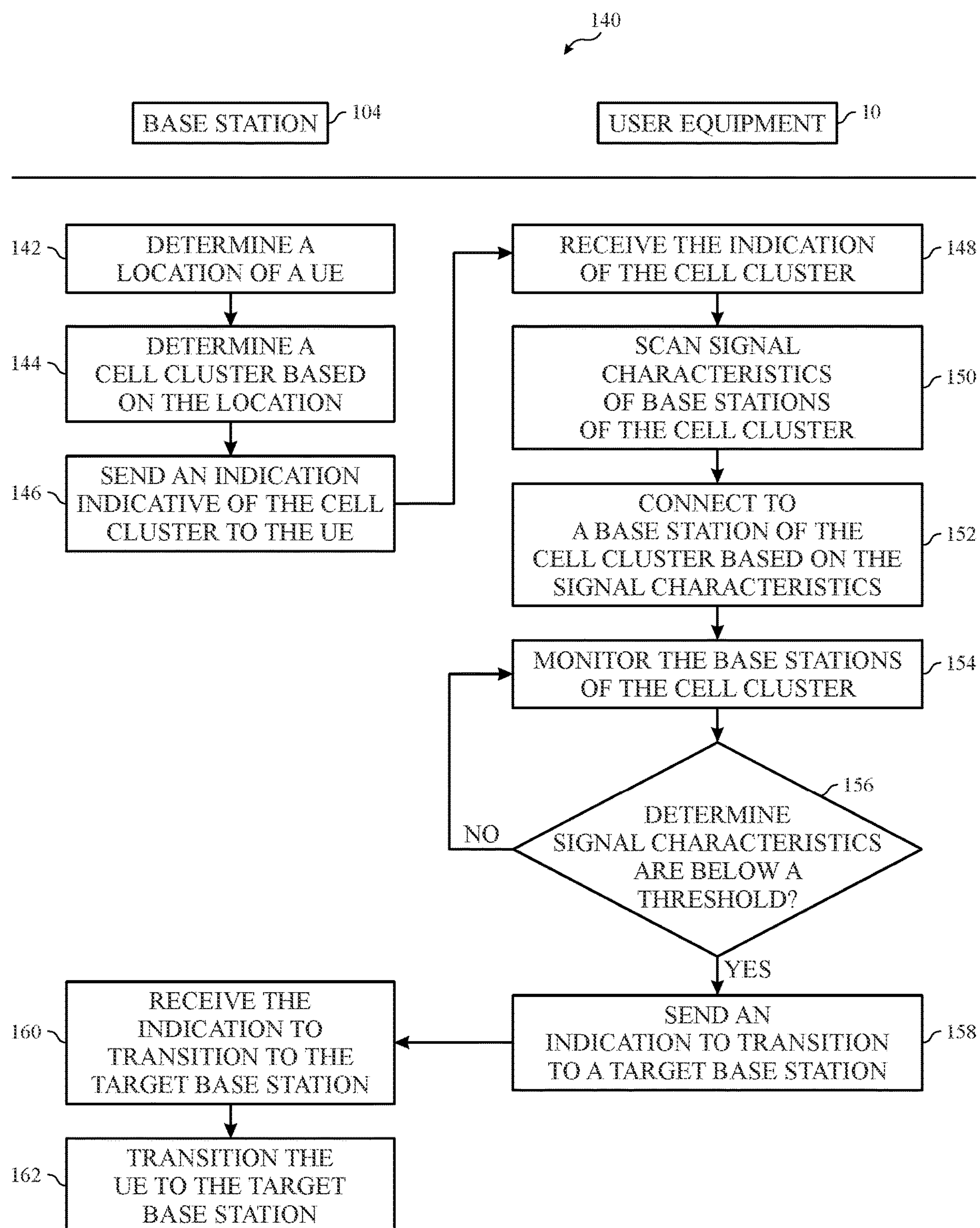


FIG. 7

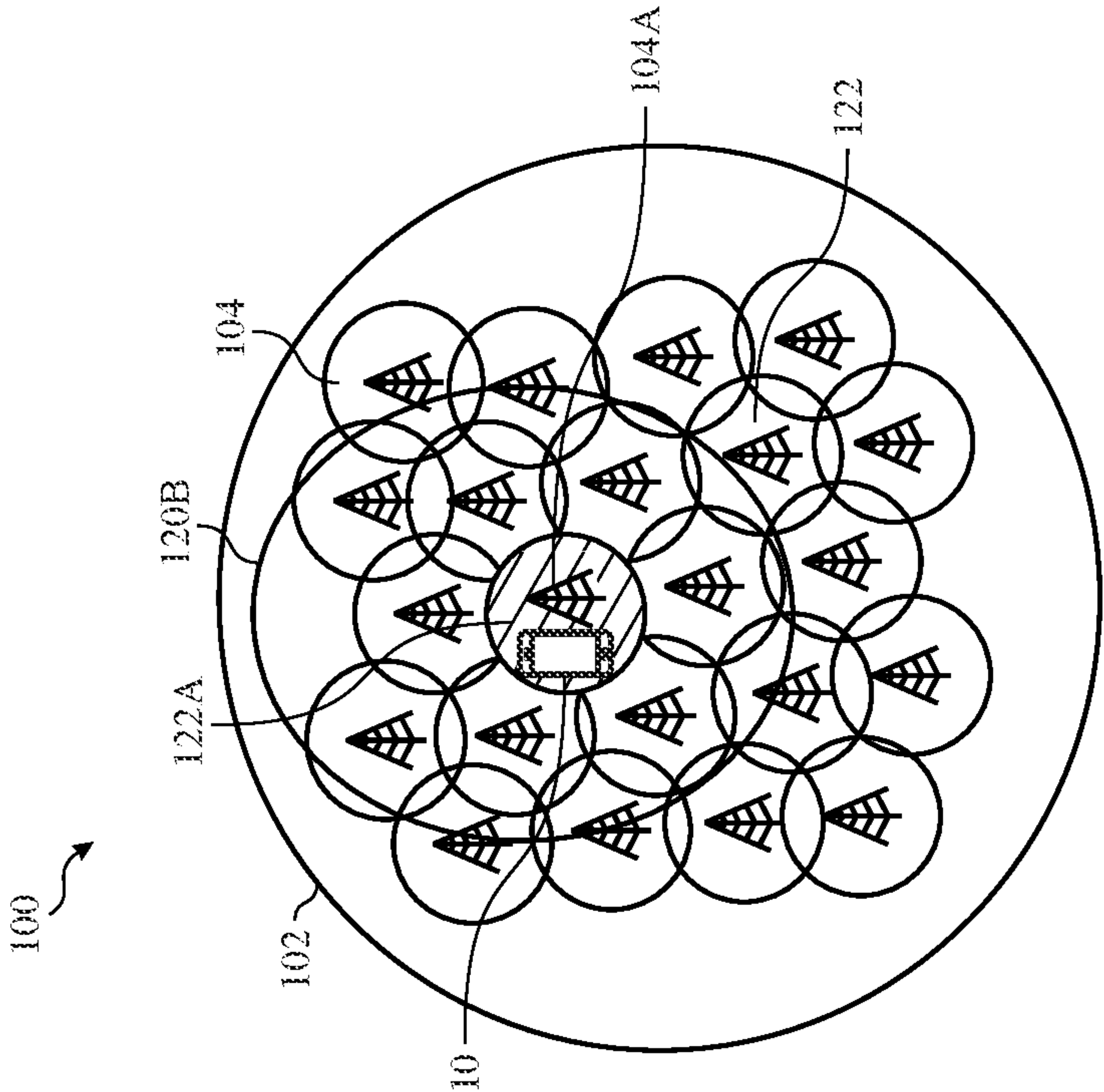


FIG. 8A

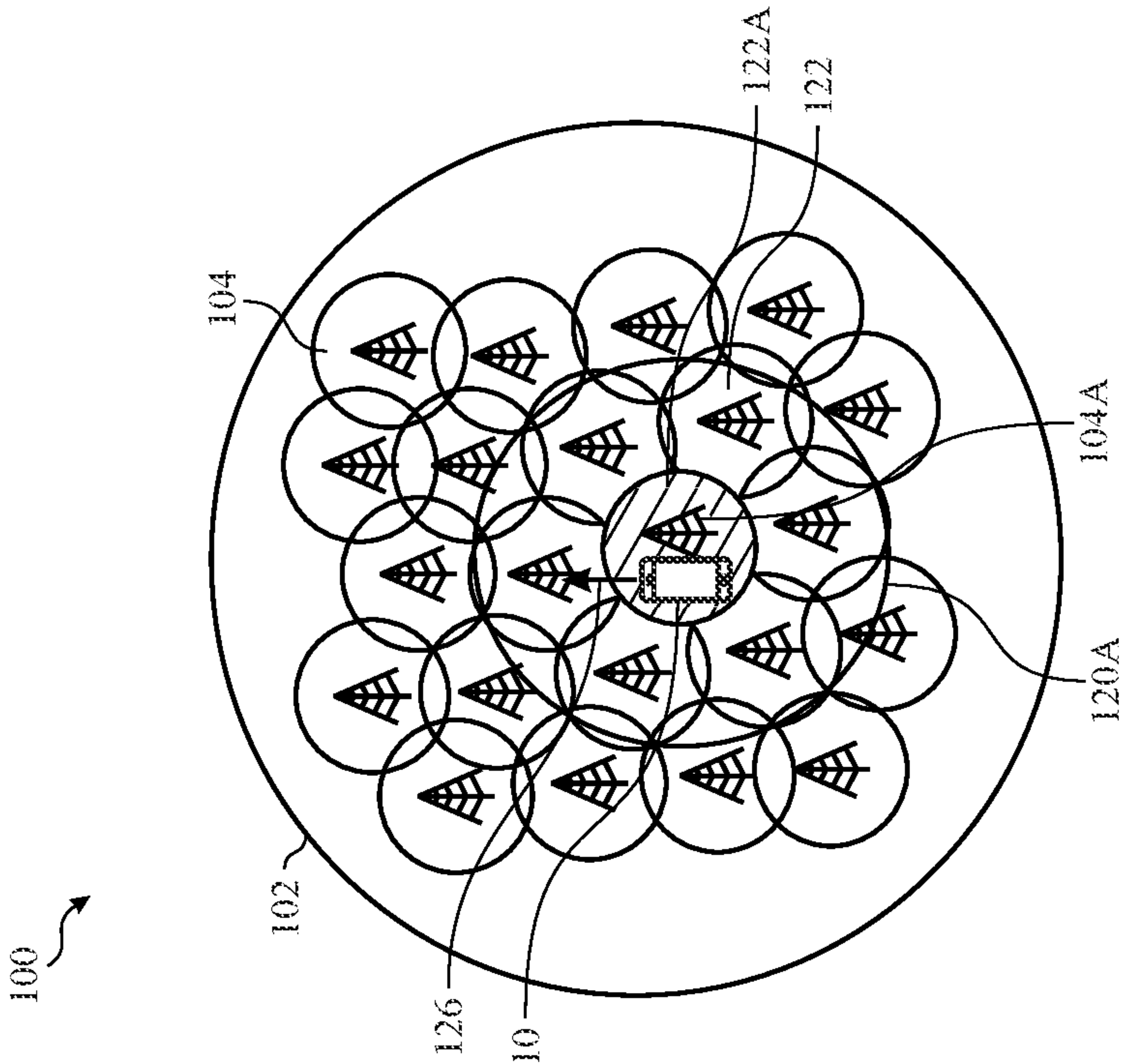


FIG. 8B

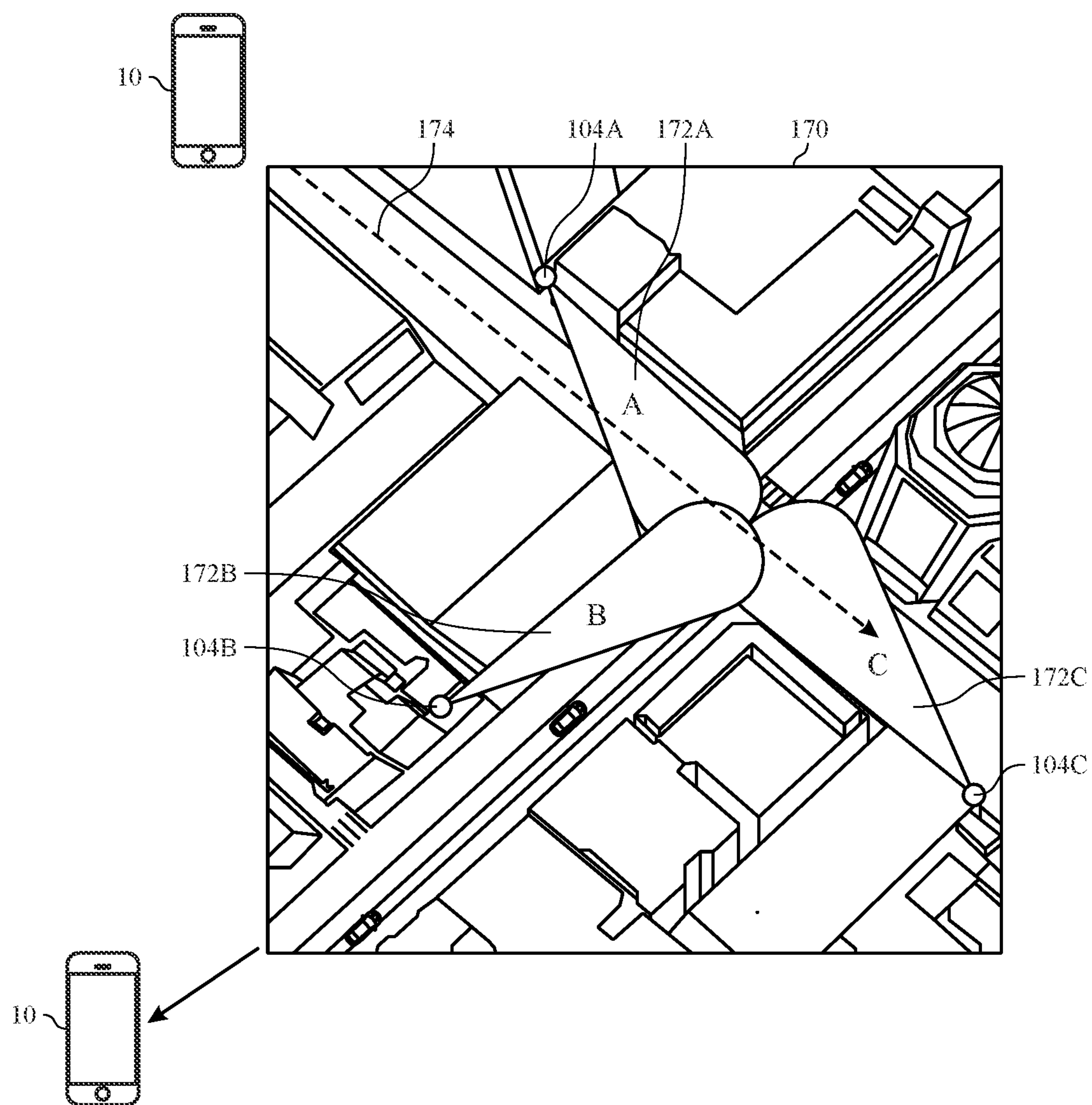


FIG. 9

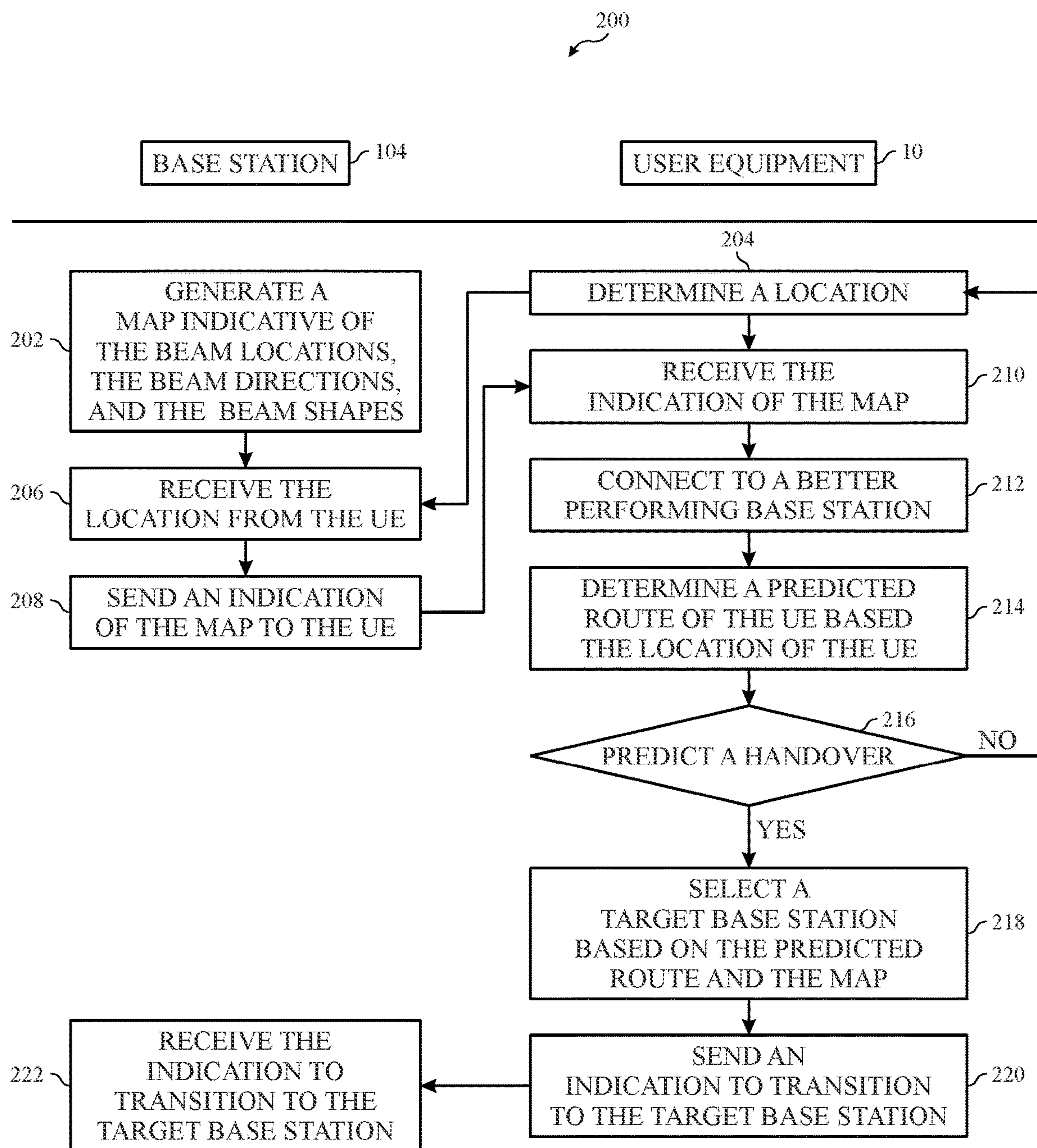


FIG. 10

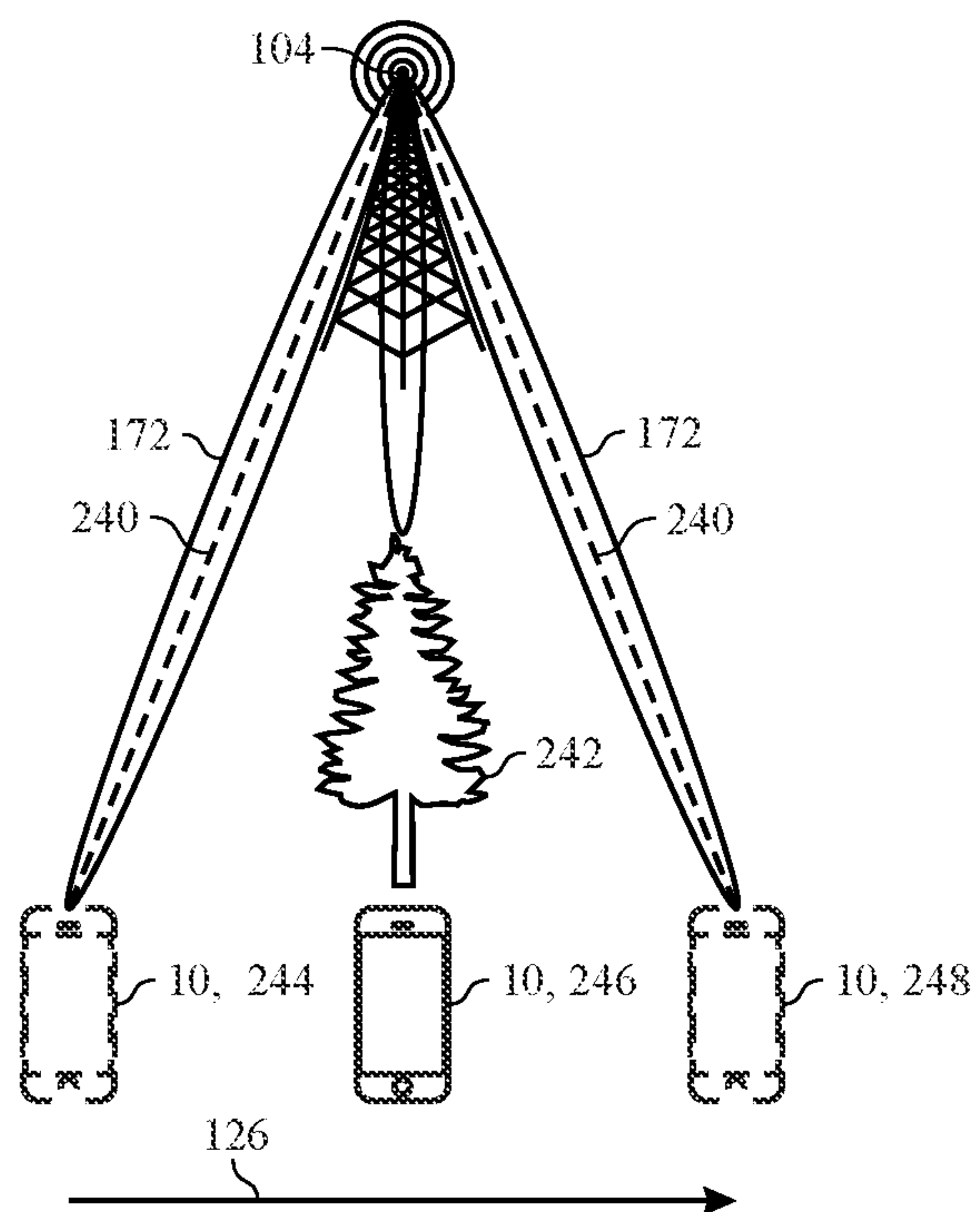


FIG. 11

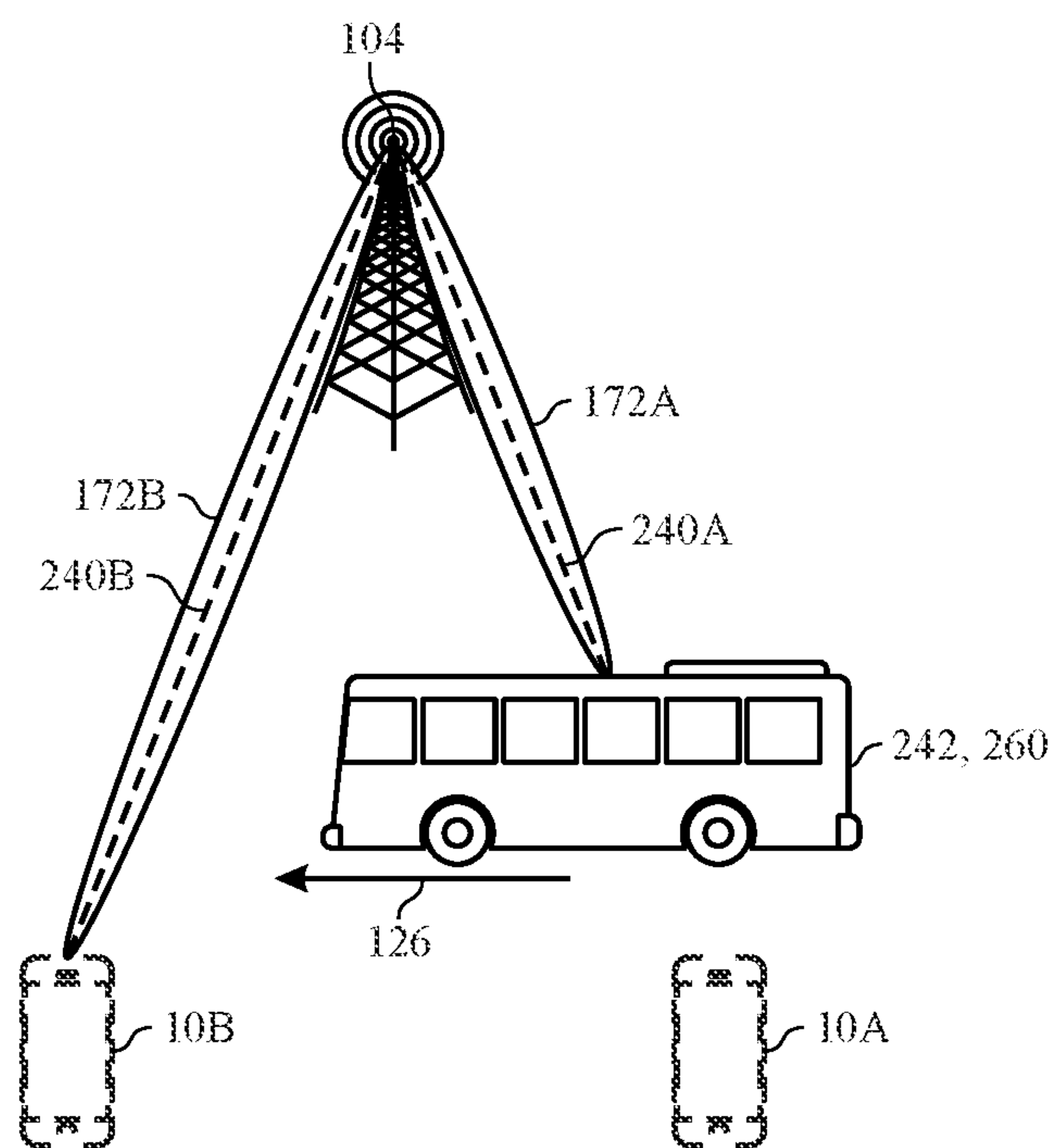
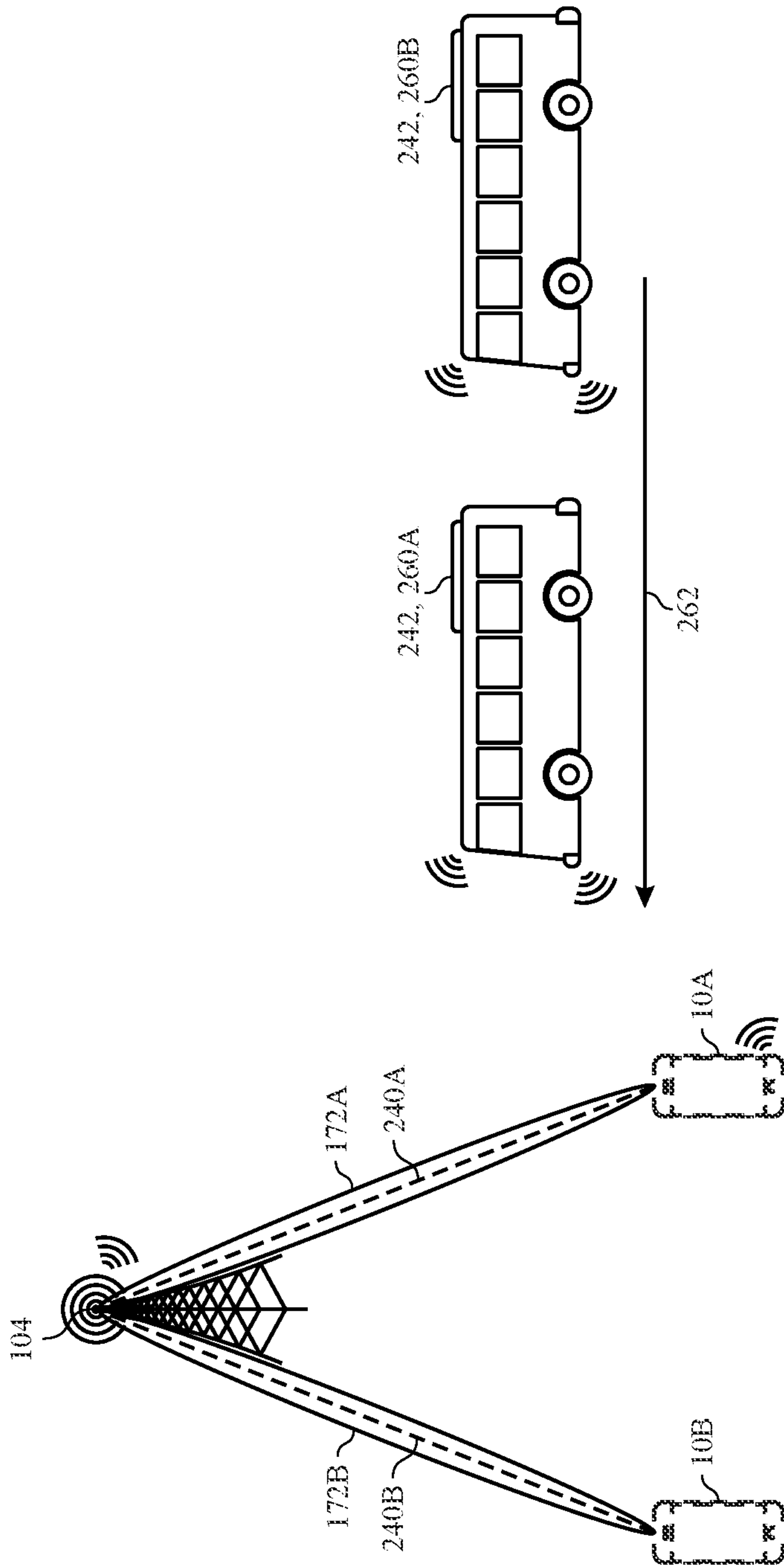


FIG. 12



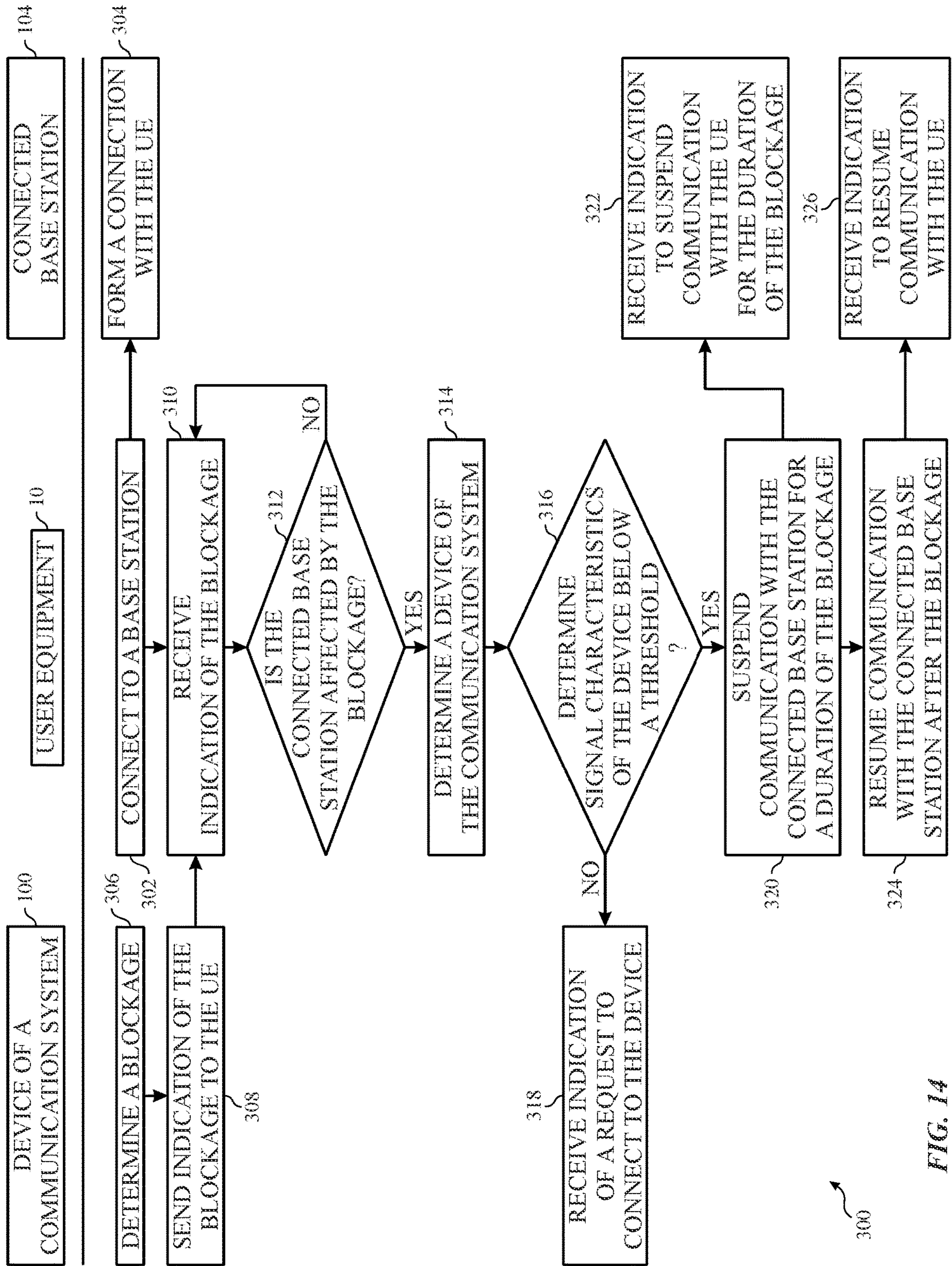


FIG. 14

SEAMLESS MOBILITY FOR WIRELESS DEVICES

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of U.S. Provisional Application No. 63/336,467, entitled “Seamless Mobility Solutions,” filed on Apr. 29, 2022, which is incorporated herein by reference in its entirety for all purposes.

BACKGROUND

[0002] The present disclosure relates generally to wireless communication, and more specifically to maintaining wireless communication service to user equipment (e.g., mobile wireless communication devices).

[0003] User equipment may include a transmitter and a receiver coupled to one or more antennas wirelessly couple (e.g., enable wireless signal transmission and/or reception) with a wireless network (e.g., including one or more base stations supporting one or more cells). To detect a base station, the user equipment may perform power-consuming search procedures, such as scanning over a frequency range to detect the base station. Then, the user equipment may join the wireless network by communicatively coupling to the base station. However, performance on the network, as measured by a signal characteristic (e.g., strength or quality), may be affected by any number of factors, such as movement of the user equipment, obstructions or blockages between the user equipment and the base station, or the like.

[0004] For example, in high frequency networks (e.g., having millimeter wave (mmWave) or sub-terahertz (sub-THz) frequencies), coverage may be limited to certain areas. As the user equipment moves, the user equipment may enter or leave multiple coverage areas supported by multiple base stations, resulting in transitions (e.g., handovers) of service from a currently coupled base station to a target base station. Such frequent handovers may cause signal delays and/or service interruptions. Further, the signal characteristic may depend on a path (e.g., a line of sight) between the user equipment and the connected base station. When the line of sight is blocked, the signal characteristic may decrease, or in some instances, the connection between the user equipment and the base station may be interrupted. Accordingly, mobility procedures that maintain wireless communication service to user equipment may be desired.

SUMMARY

[0005] A summary of certain embodiments disclosed herein is set forth below. It should be understood that these aspects are presented merely to provide the reader with a brief summary of these certain embodiments and that these aspects are not intended to limit the scope of this disclosure. Indeed, this disclosure may encompass a variety of aspects that may not be set forth below.

[0006] In one embodiment, user equipment may include one or more antennas, a transceiver coupled to the one or more antennas, and processing circuitry coupled to the transceiver. The processing circuitry may be configured to detect a first base station using the transceiver, synchronize to the first base station, and receive a first indication of a cell cluster comprising the first base station and a plurality of additional base stations using the transceiver. The processing circuitry may also be configured to send or receive user

data via the one or more antennas using the transceiver to or from the first base station and receive signal characteristics of the first base station and the plurality of additional base stations. The processing circuitry may be configured to request transitioning to send or receive the user data to or from a second base station of the plurality of additional base stations based on the signal characteristics and send or receive the user data via the one or more antennas using the transceiver to or from the second base station based on a response to the request.

[0007] In another embodiment, a base station may include a transmitter, a receiver, and processing circuitry coupled to the transmitter and the receiver. The processing circuitry may be configured to receive a first indication of a location of a user equipment using the receiver, generate a cell cluster including the base station and a plurality of additional base stations within a range of the location, and transmit a second indication of the cell cluster using the transmitter. The processing circuitry may also be configured to receive a request to transition to a better performing base station of the cell cluster with respect to the user equipment, the plurality of additional base stations may include the better performing base station and schedule the user equipment to send or receive user data on the better performing base station.

[0008] In yet another embodiment, a method for wireless communications may include receiving, at a user equipment, an indication of a cell cluster comprising a plurality of base stations from a base station and receiving signal characteristics from each base station of the cell cluster. The method may transmit, by the user equipment, a request to transition to a better performing base station of the cell cluster based on the signal characteristics and communicate with the better performing base station based on a response to the request.

[0009] Various refinements of the features noted above may exist in relation to various aspects of the present disclosure. Further features may also be incorporated in these various aspects as well. These refinements and additional features may exist individually or in any combination. For instance, various features discussed below in relation to one or more of the illustrated embodiments may be incorporated into any of the above-described aspects of the present disclosure alone or in any combination. The brief summary presented above is intended only to familiarize the reader with certain aspects and contexts of embodiments of the present disclosure without limitation to the claimed subject matter.

BRIEF DESCRIPTION OF DRAWINGS

[0010] Various aspects of this disclosure may be better understood upon reading the following detailed description and upon reference to the drawings described below in which like numerals refer to like parts.

[0011] FIG. 1 is a block diagram of user equipment, according to embodiments of the present disclosure;

[0012] FIG. 2 is a functional diagram of the user equipment of FIG. 1, according to embodiments of the present disclosure;

[0013] FIG. 3 is a schematic diagram of a transmitter of the user equipment of FIG. 1, according to embodiments of the present disclosure;

[0014] FIG. 4 is a schematic diagram of a receiver of the user equipment of FIG. 1, according to embodiments of the present disclosure;

[0015] FIG. 5 is a schematic diagram of a communication system including the user equipment of FIG. 1 communicatively coupled to a wireless communication network supported by base stations, according to embodiments of the present disclosure;

[0016] FIG. 6A is a schematic diagram of the communication system including the user equipment of FIG. 1 communicatively coupled to the wireless communication network supported by a cell cluster, according to embodiments of the present disclosure;

[0017] FIG. 6B is a schematic diagram of the communication system including the user equipment of FIG. 1 communicatively coupled to the wireless communication network supported by the cell cluster 120, according to embodiments of the present disclosure.

[0018] FIG. 7 is a flowchart of a method for enabling the user equipment of FIG. 1 to transition between base stations of the cell cluster of FIG. 6, according to embodiments of the present disclosure;

[0019] FIG. 8A is a schematic diagram of the user equipment of FIG. 1 communicatively coupled to the wireless communication network supported by a first cell cluster, according to embodiments of the present disclosure;

[0020] FIG. 8B is a schematic diagram of the user equipment of FIG. 1 communicatively coupled to the wireless communication network supported by a second cell cluster, according to embodiments of the present disclosure;

[0021] FIG. 9 is a perspective diagram of the user equipment of FIG. 1 utilizing a map indicative of coverage of different base stations, according to embodiments of the present disclosure;

[0022] FIG. 10 is a flowchart of a method enabling the user equipment of FIG. 1 to transition between base stations based on the map of FIG. 9 and a predicted route, according to embodiments of the present disclosure;

[0023] FIG. 11 is a schematic diagram of the user equipment of FIG. 1 being blocked from a base station by a stationary object, according to embodiments of the present disclosure;

[0024] FIG. 12 is a schematic diagram of the user equipment of FIG. 1 blocked from a base station by a moving object, according to embodiments of the present disclosure;

[0025] FIG. 13 is a schematic diagram of the user equipment of FIG. 1 predicting a blockage based on blockage information, according to embodiments of the present disclosure; and

[0026] FIG. 14 is a flowchart of a method enabling the user equipment of FIG. 1 to receive indication of a blockage and implement mobility procedures, according to embodiments of the present disclosure.

DETAILED DESCRIPTION OF SPECIFIC EMBODIMENTS

[0027] One or more specific embodiments will be described below. In an effort to provide a concise description of these embodiments, not all features of an actual implementation are described in the specification. It should be appreciated that in the development of any such actual implementation, as in any engineering or design project, numerous implementation-specific decisions must be made to achieve the developers' specific goals, such as compliance with system-related and business-related constraints, which may vary from one implementation to another. Moreover, it should be appreciated that such a development effort

might be complex and time consuming, but would nevertheless be a routine undertaking of design, fabrication, and manufacture for those of ordinary skill having the benefit of this disclosure.

[0028] When introducing elements of various embodiments of the present disclosure, the articles “a,” “an,” and “the” are intended to mean that there are one or more of the elements. The terms “comprising,” “including,” and “having” are intended to be inclusive and mean that there may be additional elements other than the listed elements. Additionally, it should be understood that references to “one embodiment” or “an embodiment” of the present disclosure are not intended to be interpreted as excluding the existence of additional embodiments that also incorporate the recited features. Furthermore, the particular features, structures, or characteristics may be combined in any suitable manner in one or more embodiments. Use of the terms “approximately,” “near,” “about,” “close to,” and/or “substantially” should be understood to mean including close to a target (e.g., design, value, amount), such as within a margin of any suitable or contemplable error (e.g., within 0.1% of a target, within 1% of a target, within 5% of a target, within 10% of a target, within 25% of a target, and so on). Moreover, it should be understood that any exact values, numbers, measurements, and so on, provided herein, are contemplated to include approximations (e.g., within a margin of suitable or contemplable error) of the exact values, numbers, measurements, and so on.

[0029] This disclosure is directed to maintaining wireless communication service to user equipment by implementing mobility procedures. As discussed above, the user equipment (e.g., a mobile communication device) may join a wireless communication network by communicatively coupling or connecting to a base station. In high frequency (e.g., mmWave, sub-THz) networks, coverage may be limited to certain areas. During mobility scenarios, the user equipment may enter or leave coverage supported by different base stations resulting in transitioning (e.g., handover) from a currently connected base station to a target base station. In an embodiment, the user equipment may connect to a cell cluster made up of multiple cells supported by multiple base stations. For example, the cell cluster may include a primary cell supported by a primary base station and additional (e.g., secondary) cells supported by additional (e.g., secondary) base stations. The user equipment may maintain (e.g., monitor) a link with each base station of the cell cluster, while transmitting or receiving user data to or from the primary base station. However, as the user equipment moves within the cell cluster, a signal characteristic (e.g., at the receiver) of the user equipment may fall below a threshold value. The user equipment may request a handover from the primary base station to another (e.g., better performing, target) base station within the cell cluster. Additionally or alternatively, base stations may be added or removed from the cell cluster (e.g., by a cloud server, a primary base station) as the user equipment moves. In this way, the user equipment may transition (e.g., seamlessly transition) between base stations of the cell cluster, thereby maintaining wireless network service, while reducing or eliminating interruptions to the wireless network service.

[0030] In an embodiment, the user equipment may implement mobility procedures to save power and trigger transitions (e.g., seamless transitions). In particular, the wireless network may generate a map indicative of locations of the

base stations, beam directions of the base stations, and coverage areas of the beams for the user equipment. As the user equipment moves (e.g., along a busy street), it may determine a predicted route. The user equipment may also determine or receive indication of one or more obstructions or blockages (e.g., moving objects, static objects) along the predicted route. Based on the predicted route and the map, the user equipment may determine base stations along its route and predict handovers, thereby implementing mobility procedures. Furthermore, the user equipment may save power by reducing search procedures by utilizing the locations of the base stations within the map (e.g., as opposed to dynamically determining the base stations in real-time).

[0031] In additional or alternative embodiments, the user equipment may utilize mobility procedures to mitigate line of sight blockages. That is, a signal (e.g., downlink) from the base station may travel in a direct path (e.g., line of sight) to the user equipment, and vice versa (e.g., in the case of an uplink signal). As such, a signal characteristic (e.g., strength or quality) may depend on the line of sight between the user equipment and the base station. When the line of sight is blocked, the signal characteristic may decrease (e.g., to a point where data of a received signal may not be of a sufficient level to be processed). For example, the blockage may include a moving object (e.g., a moving vehicle) or a static object (e.g., a tree) interfering with the connection. In the case of moving objects, the blockage duration may be dependent on a velocity and a size of the object; while in the case of static objects, the blockage duration may be dependent on the velocity of the user equipment and the size of the object. In certain instances, the user equipment may receive indication of blockage information from other user equipment, the wireless network, or the moving object itself. Then, the user equipment may perform mobility procedures before the connection suffers from the blockage.

[0032] For example, the user equipment may receive indication of the blockage and request a handover to another base station (e.g., a better performing base station, a target base station) not affected or affected less by the blockage. In another example, the user equipment may utilize reflective intelligent surfaces (RIS's) to relay network connection elements and maintain connection during the blockage. Still in another example, it may be beneficial to briefly suspend connection for a predetermined duration of time (e.g., that may be based on the blockage) and resume operation afterwards. Performing mitigation procedures before the blockage occurs may help to maintain wireless service and reduce or eliminate signal degradation and/or wireless service interruptions (e.g., due to a broken connection).

[0033] With the foregoing in mind, FIG. 1 is a block diagram of user equipment 10 (e.g., an electronic device, a wireless communication device, a mobile communication device, and so on), according to embodiments of the present disclosure. The user equipment 10 may include, among other things, one or more processors 12 (collectively referred to herein as a single processor for convenience, which may be implemented in any suitable form of processing circuitry), memory 14, nonvolatile storage 16, a display 18, input structures 22, an input/output (I/O) interface 24, a network interface 26, and a power source 29. The various functional blocks shown in FIG. 1 may include hardware elements (including circuitry), software elements (including machine-executable instructions) or a combination of both hardware and software elements (which may be referred to

as logic). The processor 12, memory 14, the nonvolatile storage 16, the display 18, the input structures 22, the input/output (I/O) interface 24, the network interface 26, and/or the power source 29 may each be communicatively coupled directly or indirectly (e.g., through or via another component, a communication bus, a network) to one another to transmit and/or receive data between one another. It should be noted that FIG. 1 is merely one example of a particular implementation and is intended to illustrate the types of components that may be present in the user equipment 10.

[0034] By way of example, the user equipment 10 may include any suitable computing device, including a desktop or notebook computer (e.g., in the form of a MacBook®, MacBook® Pro, MacBook Air®, iMac®, Mac® mini, or Mac Pro® available from Apple Inc. of Cupertino, California), a portable electronic or handheld electronic device such as a wireless electronic device or smartphone (e.g., in the form of a model of an iPhone® available from Apple Inc. of Cupertino, California), a tablet (e.g., in the form of a model of an iPad® available from Apple Inc. of Cupertino, California), a wearable electronic device (e.g., in the form of an Apple Watch® by Apple Inc. of Cupertino, California), and other similar devices. It should be noted that the processor 12 and other related items in FIG. 1 may be embodied wholly or in part as software, hardware, or both. Furthermore, the processor 12 and other related items in FIG. 1 may be a single contained processing module or may be incorporated wholly or partially within any of the other elements within the user equipment 10. The processor 12 may be implemented with any combination of general-purpose microprocessors, microcontrollers, digital signal processors (DSPs), field programmable gate array (FPGAs), programmable logic devices (PLDs), controllers, state machines, gated logic, discrete hardware components, dedicated hardware finite state machines, or any other suitable entities that may perform calculations or other manipulations of information. The processors 12 may include one or more application processors, one or more baseband processors, or both, and perform the various functions described herein.

[0035] In the user equipment 10 of FIG. 1, the processor 12 may be operably coupled with a memory 14 and a nonvolatile storage 16 to perform various algorithms. Such programs or instructions executed by the processor 12 may be stored in any suitable article of manufacture that includes one or more tangible, computer-readable media. The tangible, computer-readable media may include the memory 14 and/or the nonvolatile storage 16, individually or collectively, to store the instructions or routines. The memory 14 and the nonvolatile storage 16 may include any suitable articles of manufacture for storing data and executable instructions, such as random-access memory, read-only memory, rewritable flash memory, hard drives, and optical discs. In addition, programs (e.g., an operating system) encoded on such a computer program product may also include instructions that may be executed by the processor 12 to enable the user equipment 10 to provide various functionalities.

[0036] In certain embodiments, the display 18 may facilitate users to view images generated on the user equipment 10. In some embodiments, the display 18 may include a touch screen, which may facilitate user interaction with a user interface of the user equipment 10. Furthermore, it should be appreciated that, in some embodiments, the dis-

play **18** may include one or more liquid crystal displays (LCDs), light-emitting diode (LED) displays, organic light-emitting diode (OLED) displays, active-matrix organic light-emitting diode (AMOLED) displays, or some combination of these and/or other display technologies.

[0037] The input structures **22** of the user equipment **10** may enable a user to interact with the user equipment **10** (e.g., pressing a button to increase or decrease a volume level). The I/O interface **24** may enable user equipment **10** to interface with various other electronic devices, as may the network interface **26**. In some embodiments, the I/O interface **24** may include an I/O port for a hardwired connection for charging and/or content manipulation using a standard connector and protocol, such as the Lightning connector provided by Apple Inc. of Cupertino, California, a universal serial bus (USB), or other similar connector and protocol. The network interface **26** may include, for example, one or more interfaces for a personal area network (PAN), such as an ultra-wideband (UWB) or a BLUETOOTH® network, a local area network (LAN) or wireless local area network (WLAN), such as a network employing one of the IEEE 802.11x family of protocols (e.g., WI-FI®), and/or a wide area network (WAN), such as any standards related to the Third Generation Partnership Project (3GPP), including, for example, a 3rd generation (3G) cellular network, universal mobile telecommunication system (UMTS), 4th generation (4G) cellular network, long term evolution (LTE®) cellular network, long term evolution license assisted access (LTE-LAA) cellular network, 5th generation (5G) cellular network, and/or New Radio (NR) cellular network, a 6th generation (6G) or greater than 6G cellular network, a satellite network, a non-terrestrial network, and so on. In particular, the network interface **26** may include, for example, one or more interfaces for using a cellular communication standard of the 5G specifications that include the mmWave frequency range (e.g., 24.25-300 gigahertz (GHz) or sub-THz) that defines and/or enables frequency ranges used for wireless communication. The network interface **26** of the user equipment **10** may allow communication over the aforementioned networks (e.g., 5G, Wi-Fi, LTE-LAA, and so forth).

[0038] The network interface **26** may also include one or more interfaces for, for example, broadband fixed wireless access networks (e.g., WIMAX®), mobile broadband Wireless networks (mobile WIMAX®), asynchronous digital subscriber lines (e.g., ADSL, VDSL), digital video broadcasting-terrestrial (DVB-T®) network and its extension DVB Handheld (DVB-H®) network, ultra-wideband (UWB) network, alternating current (AC) power lines, and so forth.

[0039] As illustrated, the network interface **26** may include a transceiver **30**. In some embodiments, all or portions of the transceiver **30** may be disposed within the processor **12**. The transceiver **30** may support transmission and receipt of various wireless signals (e.g., user data) via one or more antennas, and thus may include a transmitter and a receiver. The power source **29** of the user equipment **10** may include any suitable source of power, such as a rechargeable lithium polymer (Li-poly) battery and/or an alternating current (AC) power converter.

[0040] FIG. 2 is a functional diagram of the user equipment **10** of FIG. 1, according to embodiments of the present disclosure. As illustrated, the processor **12**, the memory **14**, the transceiver **30**, a transmitter **52**, a receiver **54**, and/or antennas **55** (illustrated as **55A-55N**, collectively referred to

as an antenna **55**) may be communicatively coupled directly or indirectly (e.g., through or via another component, a communication bus, a network) to one another to transmit and/or receive data between one another.

[0041] The user equipment **10** may include the transmitter **52** and/or the receiver **54** that respectively enable transmission and reception of data between the user equipment **10** and an external device via, for example, a network (e.g., including base stations or access points) or a direct connection. As illustrated, the transmitter **52** and the receiver **54** may be combined into the transceiver **30**. The user equipment **10** may also have one or more antennas **55A-55N** electrically coupled to the transceiver **30**. The antennas **55A-55N** may be configured in an omnidirectional or directional configuration, in a single-beam, dual-beam, or multi-beam arrangement, and so on. Each antenna **55** may be associated with a one or more beams and various configurations. In some embodiments, multiple antennas of the antennas **55A-55N** of an antenna group or module may be communicatively coupled a respective transceiver **30** and each emit radio frequency signals that may constructively and/or destructively combine to form a beam. The user equipment **10** may include multiple transmitters, multiple receivers, multiple transceivers, and/or multiple antennas as suitable for various communication standards. In some embodiments, the transmitter **52** and the receiver **54** may transmit and receive information via other wired or wireline systems or means.

[0042] As illustrated, the various components of the user equipment **10** may be coupled together by a bus system **56**. The bus system **56** may include a data bus, for example, as well as a power bus, a control signal bus, and a status signal bus, in addition to the data bus. The components of the user equipment **10** may be coupled together or accept or provide inputs to each other using some other mechanism.

[0043] As mentioned above, the transceiver **30** of the user equipment **10** may include a transmitter and a receiver that are coupled to at least one antenna to enable the user equipment **10** to transmit and receive wireless signals (e.g., user data). FIG. 3 is a block diagram of a transmitter **52** (e.g., transmit circuitry) that may be part of the transceiver **30**, according to embodiments of the present disclosure. As illustrated, the transmitter **52** may receive outgoing data **60** in the form of a digital signal to be transmitted via the one or more antennas **55**. A digital-to-analog converter (DAC) **62** of the transmitter **52** may convert the digital signal to an analog signal, and a modulator **63** may combine the converted analog signal with a carrier signal. A mixer **64** may combine the carrier signal with a local oscillator signal **65** (which may include quadrature component signals) from a local oscillator **66** to generate a radio frequency signal. A power amplifier (PA) **67** receives the radio frequency signal from the mixer **64**, and may amplify the modulated signal to a suitable level to drive transmission of the signal via the one or more antennas **55**. A filter **68** (e.g., filter circuitry and/or software) of the transmitter **52** may then remove undesirable noise from the amplified signal to generate transmitted data **70** to be transmitted via the one or more antennas **55**. The filter **68** may include any suitable filter or filters to remove the undesirable noise from the amplified signal, such as a bandpass filter, a bandstop filter, a low pass filter, a high pass filter, and/or a decimation filter. Additionally, the transmitter **52** may include any suitable additional components not shown, or may not include certain of the illustrated compo-

nents, such that the transmitter **52** may transmit the outgoing data **60** via the one or more antennas **55**. For example, the transmitter **52** may include an additional mixer and/or a digital up converter (e.g., for converting an input signal from a baseband frequency to an intermediate frequency). As another example, the transmitter **52** may not include the filter **68** if the power amplifier **67** outputs the amplified signal in or approximately in a desired frequency range (such that filtering of the amplified signal may be unnecessary).

[0044] FIG. 4 is a schematic diagram of a receiver **54** (e.g., receive circuitry) that may be part of the transceiver **30**, according to embodiments of the present disclosure. As illustrated, the receiver **54** may receive received data **80** from the one or more antennas **55** in the form of an analog signal. A low noise amplifier (LNA) **81** may amplify the received analog signal to a suitable level for the receiver **54** to process. A mixer **82** may combine the amplified signal with a local oscillator signal **83** (which may include quadrature component signals) from a local oscillator **84** to generate an intermediate or baseband frequency signal. A filter **85** (e.g., filter circuitry and/or software) may remove undesired noise from the signal, such as cross-channel interference. The filter **85** may also remove additional signals received by the one or more antennas **55** that are at frequencies other than the desired signal. The filter **85** may include any suitable filter or filters to remove the undesired noise or signals from the received signal, such as a bandpass filter, a bandstop filter, a low pass filter, a high pass filter, and/or a decimation filter. A demodulator **86** may remove a radio frequency envelope and/or extract a demodulated signal from the filtered signal for processing. An analog-to-digital converter (ADC) **88** may receive the demodulated analog signal and convert the signal to a digital signal of incoming data **90** to be further processed by the user equipment **10**. Additionally, the receiver **54** may include any suitable additional components not shown, or may not include certain of the illustrated components, such that the receiver **54** may receive the received data **80** via the one or more antennas **55**. For example, the receiver **54** may include an additional mixer and/or a digital down converter (e.g., for converting an input signal from an intermediate frequency to a baseband frequency).

[0045] FIG. 5 is a schematic diagram of a communication system **100** including the user equipment **10** of FIG. 1 communicatively coupled to a wireless communication network **102** supported by base stations **104A**, **104B** (collectively **104**), according to embodiments of the present disclosure. In particular, the base stations **104** may include Next Generation NodeB (gNodeB or gNB) base stations and may provide 5G/NR coverage via the wireless communication network **102** to the user equipment **10**. The base stations **104** may include any suitable electronic device, such as a communication hub or node that facilitates, supports, and/or implements the network **102**. In some embodiments, the base stations **104** may include Evolved NodeB (eNodeB) base stations and may provide 4G/LTE coverage via the wireless communication network **102** to the user equipment **10**. Each of the base stations **104** may include at least some of the components of the user equipment **10** shown in FIGS. 1 and 2, including one or more processors **12**, the memory **14**, the storage **16**, the transceiver **30**, the transmitter **52**, the receiver **54**, and the associated circuitry shown in FIG. 4. It should be understood that while the present disclosure may

use 5G/NR as an example specification or standard, the embodiments disclosed herein may apply to other suitable specifications or standards (e.g., such as the 4G/LTE specification, sixth generation (6G), beyond 6G, and so on). Moreover, the network **102** may include any suitable number of user equipment(s) **10** (e.g., one or more user equipment **10**, four or more user equipment **10**, ten or more user equipment **10**, and so on) and/or base stations **104** (e.g., one or more base stations **104**, four or more base stations **104**, ten or more base stations **104**, and so on).

[0046] To connect to a first base station **104A**, the user equipment **10** may scan to detect base stations **104** of the wireless network **102**. In particular, the user equipment **10** may detect the first base station **104A** by receiving a radio frequency (RF) signal when the user equipment **10** enters a coverage area of the base station **104A** (e.g., a geographical region for which the base station **104** provides network coverage). The user equipment **10** may synchronize to the first base station **104A** by aligning its signal with the RF signal of the first base station **104A**. Further, the first base station **104A** may broadcast or transmit system information (e.g., downlink data) indicative of frequency bands supported by the base station **104A**. The system information may also include timing specification, power specifications, Global Positioning System (GPS) or Global Navigation Satellite System (GNSS) coordinates, and/or other suitable information to enable the user equipment to establish the connection with the base station **104A**. The user equipment **10** may receive the system information and to establish a communication link (e.g., connection) with the base station **104A** and the wireless network **102**. For example, user data may be sent over a channel of the communication link that is allocated to the user equipment **10** by the base station **104** and/or the wireless network **102**. Moreover, the user equipment **10** may monitor to the communication link for signal characteristics, such as a signal strength, a signal quality, or the like. In other words, the base station **104** may transmit or receive user data to or from the user equipment **10** over the channel allocated to the user equipment **10** or the established communication link. Additionally or alternatively, the user equipment **10** may transmit indication of its capabilities (e.g., uplink data) to the base station **104**.

[0047] However, in certain instances, the user equipment **10** may move locations (e.g., relative to the base station **104**) or an object may interfere with the connection, referred to herein as a “mobility scenario.” For example, movement of the user equipment **10** may cause the user equipment to leave the coverage area of the first base station **104A**, thereby degrading the connection. The user equipment **10** may perform power-consuming search procedures to determine a target base station (e.g., second base station **104B**) for connection and send an indication of a request to transition (e.g., handover) to the second base station **104B**. The wireless communication network **102** may schedule a transition from the first base station **104A** to the second base station **104B**. However, control signaling for handovers may cause service interruptions (e.g., signal delays) and user equipment **10** throughput may suffer due to continued and impaired connection to the first base station **104A**. Additionally or alternatively, a moving object may block the connection between the user equipment **10** and the first base station **104A**, thereby causing service interruptions. As such, it may be beneficial for the user equipment **10** to implement

one or more mobility procedure(s) to reduce or eliminate interruptions to wireless network service.

[0048] The devices and/or user equipment disclosed herein may include the user equipment **10** as described above. Additionally, the cells and/or network nodes disclosed herein may include the base stations **104** as described above. Further, the network disclosed herein may include the wireless communication network **102**.

[0049] With the foregoing in mind, FIG. 6A is a schematic diagram of the communication system **100** including the user equipment **10** of FIG. 1 communicatively coupled to the wireless communication network **102** supported by a cell cluster **120**, according to embodiments of the present disclosure. In particular, the cell cluster **120** may include one or more cells **122** (e.g., supported by base stations **104**), including a primary cell **122a** (e.g., supported by base station **104a**). Each cell **122** is supported by a respective base station **104**. For example, the base station **104** may have antennas **55** configured in an omnidirectional configuration and provide coverage to an area for wireless service. In other words, the cell **122** may be the coverage area provided by the base station **104**. For example, the user equipment **10** may enter the cell **122** of the base station **104**, communicatively couple to the base station **104**, and receive wireless service. In mobility scenarios, the user equipment **10** may also leave the cell **122** and a signal characteristic may fall below a threshold value causing wireless service to degrade. As such, the user equipment **10** may request a handover.

[0050] In the illustrated example, the cell cluster **120** includes seven cells **122** (e.g., supported by seven respective base stations **104**); one cell **122** of the cell cluster **120** may act as the primary cell **122a** (e.g., supported by a primary base station **104a**) and provide coverage to the user equipment **10**. However, the cell cluster **120** may include any suitable number of cells **122** (e.g., two cells **122**, four cells **122**, ten cells **122**, and so on) that are supported by any suitable number of base stations **104**.

[0051] The user equipment **10** may communicatively couple or connect to each base station **104** of the cell cluster **120**, but only transmit or receive user data using the primary base station **104a**. For example, user equipment **10** may establish a link (e.g., open a channel) with each base station **104** of the cell cluster **120**. The user equipment **10** may monitor link conditions to determine a signal characteristic of each base station **104**. The signal characteristic may include a signal quality (e.g., Reference Signal Received Quality (RSRQ), signal-to-noise ratio (SNR), signal-to-interference & noise ratio (SINR)), a signal strength (e.g., Reference Signal Received Power (RSRP)), a power signal, a signal delivery, or the like. For example, a link of a first base station **104b** may have an acceptable signal quality (e.g., above a threshold) due to close proximity between the first base station **104b** and the user equipment **10**. In another example, a blockage between a second base station **104c** and the user equipment **10** may result in poor signal strength (e.g., below the threshold). By monitoring the link of each base station **104**, the user equipment **10** may determine a better performing base station **104** based on the signal characteristic(s).

[0052] The primary base station **104a** may be a better performing base station **104** of the cell cluster **120**. For example, the primary base station **104a** may be in a center of the cell cluster **120** with the strongest signal strength (relative to the base stations **104** of the cell cluster **120**).

Further, the signal quality of the primary base station **104a** may be greater than the signal quality of the first cell **122b**, which may cause the user equipment **10** to connect to the primary base station **104a** over the first base station **104b**.

[0053] In another example, the user equipment **10** may enter the primary cell **122a** and connect to the primary base station **104a** to transmit or receive user data. The user data may include data specific to operations requested or initiated by a user executing software applications on the user equipment **10**, such as for transmitting or receiving messages (e.g., electronic mail, Short Message Service (SMS) text message, streaming, gaming, chatting, video conferencing, or the like). For example, downlink and uplink user data may be transferred using the primary base station **104a**. However, in certain instances, the signal characteristics of the primary base station **104a** may decrease below a threshold value. For example, during mobility scenarios, the user equipment **10** may move in a direction of travel **126** and out of the primary cell **122a**, thereby causing the signal characteristic to decrease below the threshold value. In another example, connection with the primary base station **104a** may fail (e.g., due to a lack of signal strength, connection failure, power failure) causing the signal characteristic (e.g., at the receiver **54**) of the user equipment **10** to fall below the threshold value. Still in another example, an object may block a line of sight, and thus the connection, between the user equipment **10** and the primary base station **104a**. As such, the user equipment **10** may utilize mobility procedures to switch between base stations **104** of the cell cluster **120** to maintain wireless service.

[0054] In certain instances, the user equipment **10** may request to switch beams (e.g., generated by multiple antennas) of the primary base station **104a** supporting the primary cell **122a** to maintain connection. In other instances, the user equipment **10** may request a transition from the primary base station **104a** to a target base station **104d**. The target base station **104d** may be a better performing base station **104** with better signal characteristics compared to the current primary base station **104a** or an additional base station **104** of the cell cluster **120** that may start providing coverage to the user equipment **10**. In the illustrated example, the user equipment **10** may travel in the direction of travel **126** and leave the primary cell **122a**, thereby causing signal characteristics to decrease. The user equipment **10** may enter an adjacent cell **122d** supported by the target base station **104d**, which is an adjacent base station **104** in the direction of travel **126**. As such, the user equipment **10** may request to transition from the primary base station **104a** to the target base station **104d**.

[0055] To transition (e.g., seamlessly transition) between the primary base station **104a** to the target base station **104d**, the user equipment **10** may use lower layer (e.g., Layer 2, physical layer, Media Access Control (MAC) layer, and so on) signaling to avoid slower higher layer (e.g., Radio Resource Control (RRC) layer) signaling procedures. In some embodiments, while the user equipment **10** monitors the primary base station **104a** to receive downlink scheduling information, an uplink channel may allow the user equipment **10** to start monitoring the downlink control channel of the target base station **104d**. The wireless network **102** may schedule a transition for the user equipment **10** connect to the target base station **104d**, enabling a seamless transition from the primary base station **104a** to the target base station **104d**. Since the user equipment **10** maintains

links with each base station **104** of the cell cluster **120**, the wireless network **102** may transition the data link to the target base station **104d** by scheduling the user equipment **10** to use the target base station **104d**. Once the user equipment **10** detects scheduling on the target base station **104d**, the transition (e.g., handover) is completed and the user equipment **10** may stop monitoring the downlink control channel of the primary base station **104a**. In other words, the user equipment **10** may transmit and receive user data using the target base station **104d**.

[0056] FIG. 6B is a schematic diagram of the communication system **100** including the user equipment **10** of FIG. 1 communicatively coupled to the wireless communication network **102** supported by the cell cluster **120**, according to embodiments of the present disclosure. During mobility scenarios, the user equipment **10** may enter and leave cells **122** of the cell cluster **120**. In certain instances, the cell **122** in which the user equipment **10** is located may be the primary cell **122a** providing coverage to the user equipment **10**.

[0057] As described with respect to FIG. 6A, the user equipment **10** may be located in the primary cell **122a**, move in the direction of travel **126**, and enter the target cell **122d**. The user equipment **10** may request transition from the primary base station **104a** (supporting the primary cell **122a**) to the target base station **104d** (supporting the target cell **122d**). Following the transition, the target cell **122d** may become the new primary cell **122e** (supported by the new primary base station **104e**) and the old primary base station **104a** may act as a base station **104** of the cell cluster **120**, as illustrated in FIG. 6B. That is, the user equipment **10** may transmit and receive user data using the new primary base station **104e** and monitor the link of the old primary base station **104a**.

[0058] FIG. 7 is a flowchart of a method **140** for enabling the user equipment **10** of FIG. 1 to transition between base stations **104** of the cell cluster **120**, according to embodiments of the present disclosure. Any suitable device (e.g., a controller) that may control components of the user equipment **10**, the network **102**, and/or the base station **104**, such as the processor **12**, may perform the method **140**. In some embodiments, the method **140** may be implemented by executing instructions stored in a tangible, non-transitory, computer-readable medium, such as the memory **14** or storage **16**, using the processor **12**. For example, the method **140** may be performed at least in part by one or more software components, such as an operating system of the user equipment **10**, the network **74**, and/or the base station **104**, one or more software applications of the user equipment **10**, the network **102**, and/or the base station **104**, and the like. While the method **140** is described using steps in a specific sequence, it should be understood that the present disclosure contemplates that the described steps may be performed in different sequences than the sequence illustrated, and certain described steps may be skipped or not performed altogether.

[0059] In process block **142**, the base station **104** determines a location of the user equipment **10**. For example, the base station **104** may receive an indication of the location of the user equipment **10** from uplink user data sent by the user equipment **10**. In another example, the wireless network **102** may determine the location of the user equipment **10** based on the location of the connected base station **104**. Additionally or alternatively, the user equipment **10** may determine

its location and send an indication of the location (e.g., GPS coordinates or GNSS coordinates) to the base station **104**.

[0060] In process block **144**, the base station **104** determines a cell cluster **120** based on the location of the user equipment **10**. The cell cluster **120** may be maintained by a central unit, a primary cell **122a**, a cloud server, or the like. The wireless network **102** may have network information indicative of one or more base stations **104**, a location of the base stations **104**, a beam characteristic of the base stations **104**, or other information for determining the cell cluster **120**. For example, the wireless network **102** may determine one or more base stations **104** within a threshold area of the user equipment **10** to form the cell cluster **120**. In a region with fewer base stations **104**, the size (e.g., area covered) by the cell cluster **120** may be greater than the size of the cell cluster **120** formed in a region densely populated by base stations **104**. In another example, the wireless network **102** may determine a threshold number of base stations **104** for the cell cluster **120**.

[0061] In process block **146**, the base station **104** sends an indication indicative of the cell cluster **120** to the user equipment **10**. The base station **104** may transmit an indication of the cell cluster **120** as downlink data. The indication may include a number of base stations **104**, the locations of the base stations **104** (e.g., GPS coordinates or GNSS coordinates), downlink data of each base station **104**, or the like. Further, as described with respect to FIGS. 8A and 8B, the base stations **104** may be added or removed from the cell cluster **120** during mobility scenarios. As such, the base station **104** may periodically send the indication of the cell cluster **120** to the user equipment **10**.

[0062] In process block **148**, the user equipment **10** receives the indication of the cell cluster **120**. Upon receiving the indication, the user equipment **10** may scan the cell cluster **120** in process block **150** to prepare for future transitions. That is, the user equipment **10** may establish a link with each base station **104** of the cell cluster **120** to determine signal characteristics of each base station **104**. For example, the user equipment **10** may monitor the links to the cells **122** to determine a signal strength, a signal quality, a power signal, and/or a signal delivery. Based on the signal characteristics of each cell **122**, the cell cluster **120** may determine a better performing base station **104** of the cell cluster **120**. The user equipment **10** may select one or more signal characteristics for determining the better performing base station **104**. For example, the user equipment **10** may monitor signal strength and signal quality to determine the better performing base station **104**. In an embodiment, the user equipment **10** may apply a weighting system by assigning weights to each signal characteristic and determine the better performing base station **104** based on the weights applied to the corresponding signal characteristic.

[0063] In process block **152**, the user equipment **10** connects to a base station **104** of the cell cluster **120** based on the signal characteristics. In some embodiments, the user equipment **10** may connect to a better performing base station **104** based on the signal characteristics. The connected cell may be used as the primary cell **122a**. The user equipment **10** may transmit or receive user data using the primary base station **104a**, while monitoring the links with the base stations **104** of the cell cluster **120**. In certain embodiments, the user equipment **10** may center a cell **122** of the cell cluster **120** and connect to the base station **104** supporting the cell **122**.

[0064] In process block 154, the user equipment 10 monitors the base stations 104 of the cell cluster 120. For example, the user equipment 10 may determine or receive the signal strength, the signal quality, the power signal, and/or the signal delivery of each link to each base station 104 in preparation for a possible transition. In another example, the user equipment 10 may monitor the channel conditions of each base station 104 of the cell cluster.

[0065] In decision block 156, the user equipment 10 may determine if signal characteristics of the primary base station 104a are below a threshold. For example, the user equipment 10 may periodically determine if the signal characteristics (e.g., strength or quality) of the primary base station 104a decrease below the threshold. In certain instances, the user equipment 10 may move out of the primary cell 122a causing signal characteristics to decrease. In other instances, a blockage may occur causing signal characteristics from the primary base station 104a to decrease.

[0066] However, in certain instances, the signal characteristics may not decrease below the threshold. If the signal characteristics are not below the threshold, then the method may return to process block 154 and the user equipment 10 continues to monitor the cells 122 of the cell cluster 120.

[0067] If signal characteristics are below the threshold, then in process block 158, the user equipment 10 sends an indication to transition to a target base station 104d. Since the user equipment 10 maintains links with each base station 104 of the cell cluster 120, the user equipment 10 may immediately determine a better performing base station 104d based on the signal characteristics. That is, the user equipment 10 may determine the better performing base station 104 to be the target base station 104d. For example, the better performing base station 104d may have a stronger or strongest signal quality compared to other base stations 104 within the cell cluster 120. As such, the user equipment 10 may determine the target base station 104d for transitioning. The user equipment 10 may request scheduling to the target base station 104d in response to determining the target base station 104d. In certain instances, the user equipment 10 may start transmitting or receiving user data to or from the target base station 104d instead of waiting for a command signal from the base station 104 for the transition.

[0068] At process block 160, the base station 104 receives the indication to transition to the target base station 104d. The user equipment 10 may request scheduling through a lower layer to avoid signal delays in the upper layers and the base station 104 may receive the request through the lower layer. In process block 162, the base station 104 transitions the user equipment 10 to the target base station 104d. That is, the wireless communication network 102 may start transmitting or receiving data to or from the user equipment 10 through the target base station 104d. Once the user equipment 10 detects transitioning on the target base station 104d, the transition (e.g., handover) is completed and the user equipment 10 may stop monitoring the downlink control channel of the primary base station 104a. In other words, the user equipment 10 may immediately transmit and receive user data using the target base station 104d. In this way, the user equipment 10 may not wait for command signaling from the wireless communication network 102, and, instead, the user equipment 10 may start using the target base station 104d in response to determining signal characteristics decreasing below the threshold (e.g., from decision

block 156). As such, the method 140 may enable the user equipment 10 to maintain wireless communication service while decreasing or eliminating interruptions to the wireless communication service during handovers.

[0069] FIG. 8A is a schematic diagram of the user equipment 10 of FIG. 1 communicatively coupled to the wireless communication network 102 supported by a first cell cluster 120A, according to embodiments of the present disclosure. The cell cluster 120 may be maintained (cloud server, primary cell, central unit of the wireless network 102) based on the location of the user equipment 10. Maintaining the cell cluster 120 may require the user equipment 10 to exchange information (e.g., downlink or uplink data) with the wireless network 102. For example, the wireless network 102 may receive an indication of the location of the user equipment 10 and create the cell cluster 120 based on a number of base stations 104 surrounding the location of the user equipment 10. That is, the wireless network 102 and/or the base station 104 may determine a number of base stations 104 surrounding the location of the user equipment 10. A smaller cell cluster 120 may be formed by combining base stations 104 within a smaller (e.g., 50 meter, 100 meter, and so on) radius from the location of the user equipment 10, while a larger cell cluster 120 may include base stations 104 within a larger (e.g., 1 kilometer, multiple kilometers, and so on) radius from the location of the user equipment 10. In another example, the smaller cell cluster 120 may be formed in an area with high base station density, such as a city, a downtown area. A larger cell cluster 120 may be formed in an area with low base station density, such as a rural region. In certain instances, the wireless network 102 may determine a number of base stations 104 within a pre-determined radius of where the user equipment 10 is located. If the number of base stations 104 is greater than a threshold value, then the wireless network 102 may generate the smaller cell cluster 120 (e.g., of an area having a radius smaller than the pre-determined radius). If the number of base stations 104 is smaller than the threshold value, then the wireless network 102 may generate the larger cell cluster 120 (e.g., of an area having a radius larger than the pre-determined radius). Additionally or alternatively, the wireless network 102 may form the cell cluster 120 based on a frequency (e.g., mmWave, GHz, sub-THz) used for connection. Additionally or alternatively, the wireless network 102 may determine a mobility type (e.g., driving, walking) of the user equipment 10 to determine the cell cluster size. For example, for a first mobility type (e.g., walking), the smaller cell cluster 120 may be formed since a period of time to travel a certain distance (e.g., 50 meters) may be greater than for a second mobility type (e.g., driving). In such an example, the larger cell cluster 120 may be formed for the second mobility type, since frequent transitions (e.g., handovers) may be needed to maintain wireless service. To facilitate such transitions, each base station 104 of the cell cluster 120 may apply a standardized configuration with minimal base station specific parameters (e.g., same DCI).

[0070] In the illustrated example, the first cell cluster 120A may include seven cells 122 (supported by seven base stations 104). The user equipment 10 may be located in a primary cell 122a (supported by a primary base station 104a). However, the user equipment 10 may move in the direction of travel 126, causing the user equipment 10 to leave the primary cell 122a and enter an adjacent cell 122d (supported by the target base station 104d). As described

with respect to FIGS. 6A, 6B, and 7, the user equipment 10 may send an indication of a request to transition to the target base station 104d and the base station 104 may receive the indication of the request and schedule the user equipment 10 to the target base station 104d. As the user equipment 10 moves within the first cell cluster 120A, base stations 104 may be added to or removed to form a second cell cluster 120B, further described with respect to FIG. 8B. For example, the wireless network 102 may add in the direction of travel 126 or remove base stations 104 from the cell cluster 120, such that the cell cluster 120 moves with the user equipment 10 during mobility scenarios. With the foregoing in mind, FIG. 8B is a schematic diagram of the user equipment 10 of FIG. 1 communicatively coupled to the wireless communication network 102 supported by a second cell cluster 120B, according to embodiments of the present disclosure. In certain embodiments, following the transition from the primary base station 104a to the target base station 104d, the wireless network 102 may add or remove base stations 104 from the cell cluster 120 such that the user equipment 10 remains within the cell cluster 120 during mobility scenarios. The second cell cluster 120B may include nine cells 122. The location of the second cell cluster 120B may be shifted in the direction of travel 126 (e.g., direction of movement of the user equipment 10) relative to the first cell cluster 120A described with respect to FIG. 8A. For example, the wireless network 102 may expand the first cell cluster 120A by adding neighboring (e.g., surrounding) base stations 104 adjacent the new primary cell 122a (previously the target cell 122d) in the direction of travel 126. In this way, the user equipment 10 may remain within the cell cluster 120 when moving in the direction of travel 126. In the illustrated example, the second cell cluster 120B includes five new cells 122 (supported by five new base stations 104) in the direction of travel 126. The wireless network 102 may send an indication of the new base stations 104 and the user equipment 10 may begin monitoring a link in preparation of potential transitions.

[0071] Additionally or alternatively, the wireless network 102 may remove one or more base stations 104 in response to the transition. For example, three cells 122 opposite the direction of travel 126 may be removed from the second cell cluster. To remove base stations 104 from the cell cluster 120 (e.g., first cell cluster 120A or second cell cluster 120B), the wireless network 102 may send indication of to stop monitoring the links of the removed base stations 104 to the user equipment 10 and the user equipment 10 may stop monitoring the link of the removed cells 122. While the illustrated example adds more base stations 104 to the cell cluster 120, in certain instances, the wireless network 102 may remove one or more current base stations 104 from the cell cluster 120 in response to adding one or more new base stations 104 to the cell cluster 120. As such, in some embodiments, a number of base stations 104 of the cell cluster 120 may remain constant. In this manner, overall signal characteristics for the user equipment 10 may improve, signal delay may be decreased, and service interruption when transitioning may be decreased.

[0072] In high frequency networks, coverage may be limited to certain areas, as such the user equipment 10 may perform power-consuming search operations to identify such coverage. Furthermore, during mobility scenarios, frequent transitions may be required to maintain wireless service. As such, the user equipment 10 may frequently

perform the power-consuming search operations. For example, the user equipment 10 may move along a busy street with multiple objects (e.g., obstacles). The user equipment 10 may connect to a first base station 104a along a route, but quickly leave the coverage area of the first base station 104a. As such, the user equipment 10 may search for a second base station 104b for coverage and transition. However, the second base station 104b may provide poor signal characteristics or coverage for a limited time, thereby requiring the user equipment 10 to perform another search for a better performing base station 104. In certain instances, the search procedures may be reduced or eliminated by providing the user equipment 10 a map indicating the locations of base stations 104 and coverage information.

[0073] With the foregoing in mind, FIG. 9 is a perspective diagram of the user equipment of FIG. 1 utilizing a map 170 indicative of coverage of different base stations 104, according to embodiments of the present disclosure. In some cases, to determine the base stations 104 of the wireless network 102, the user equipment 10 may perform power-consuming searches. To avoid or decrease the searches, the wireless network 102 may generate a map 170 with locations of base stations 104 and a coverage area (e.g., of a beam 172) of each base station 104. In this way, the user equipment 10 may proactively connect to base stations 104 along a predicted route instead of reactively searching for base stations 104 each time it leaves a coverage area. For example, the user equipment 10 may determine travel in a straight line (e.g., down a street) and predict the route to continue down the line. In another example, the route may be a historical route periodically traveled by the user equipment 10. The user equipment 10 may utilize a time (e.g., day, week, time) and the location (e.g., school, work, home) to predict the route. Still in another example, the user equipment 10 may receive directions on a map software application that generates a route; and, as the user equipment 10 travels along the route, the user equipment 10 may predict the route according to the route generated by the map software application.

[0074] In the illustrated example, each base station 104 may emit a beam 172 with multiple antennas that provides network coverage to the user equipment 10. For example, the beam 172 may have a frequency (e.g., radio frequency), be directed in a direction, have a shape, have a size (e.g., width, length, angle), have an elevation, and so on. For example, the beams 172 may include short range beams, long range beams, wide beams, narrow beams, or the like. Further, a beam width may include a horizontal direction and/or a vertical direction and a shape may include cone-shaped, pencil-shaped, triangular, and so on. The beam characteristics may be received, determined, and/or saved by the wireless network 102 during a network planning or implementation stage by operators and vendors. Additionally or alternatively, the wireless network 102 may use sensing operations to detect a location of static obstacles, such as buildings located in the beam direction. In certain embodiments, the wireless network 102 may determine coordinates of coverage provided by a beam 172 based on the network deployment. For example, the wireless network 102 may determine coordinates indicative of a location of a base station 104, a shape of the beam 172, a border of the beam 172, coordinates of borders of the beam 172, and so on. The wireless network 102 may share location coordi-

nates of the coverage (e.g., longitude and latitude coordinates of the coverage of the beam 172).

[0075] After the user equipment 10 connects to a first base station 104A, the user equipment 10 may receive the map 170 including a location of base stations 104 and coverage information (e.g., beam characteristics). The user equipment 10 may utilize the map 170 to implement mobility procedures based on its position, a predicted route, and/or movement relative to the base stations 104. For example, if the user equipment 10 leaves a coverage area of a beam, the user equipment 10 may utilize the map 170 and its location to determine subsequent coverage areas of other beams. In another example, the user equipment 10 may determine an order and periodicity of search procedures by prioritizing subsequent beams along its route (e.g., able to provide network coverage along the route) over base stations 104 that are not along the route (e.g., unable to provide network coverage along the route, only able to provide brief or limited network coverage along the route). The user equipment 10 may determine signal characteristics of base stations 104 along the route for future use to ensure updated radio resource management (RRM) (e.g., power delivery, handover criteria) and/or channel state information (CSI) measurements (e.g., downlink control channel) for mobility decisions (e.g., handovers) and reduce or eliminate measurements for base stations 104 that may not provide coverage along the route. As such knowing the locations of the base stations 104 may not only allow the user equipment 10 to save power by reducing or eliminating search procedures (e.g., RRM measurements, CSI measurements), but also improve performance due to prioritizing procedures for base stations 104 along the route of the user equipment 10.

[0076] For example, the map 170 may include a first base station 104A emitting a first beam 172A, a second base station 104B emitting a second beam 172B, and a third base station 104C emitting a third beam 172C. By way of example, the user equipment 10 may travel along a route 176, which enters and leaves multiple coverage areas. With the map 170, the user equipment 10 may improve mobility procedures by decreasing a number of handovers needed. For example, without usage of the map 170, the user equipment 10 may connect to the first base station 104A, transition to the second base station 104B, and then transition to the third base station 104C to maintain cell coverage. The user equipment 10 may leave the coverage area of the first base station 104A and search for an adjacent base station 104 for coverage. In this way, the user equipment 10 may be reacting to leaving the coverage areas, which may cause service interruptions.

[0077] With the map 170, the user equipment 10 may proactively determine base stations 104 along the route 174 for wireless service. In certain embodiments, the user equipment 10 may compare the coverage area of each base station 104 with respect to (e.g., along) the predicted route 174 to a threshold. If the coverage area of the base station 104 is less than the threshold, then the user equipment 10 may not connect and determine different base station 104 along the route 174 for connection. Returning to the map 170, the user equipment 10 may determine that coverage provided by the first base station 104A and the third base station 104C is greater than the threshold, while coverage provided by the second base station 104B is less than the threshold. Indeed, the second base station 104B may provide coverage to a limited area with respect to the predicted route 174 of the

user equipment. As such, the user equipment 10 may connect to the first base station 104A and transition to the third base station 104C. In this way, the user equipment 10 may reduce the number of handovers along the predicted route 174.

[0078] Furthermore, by providing the user equipment 10 with coverage information, the user equipment 10 may save power by not performing or reducing the number of search procedures, therefore optimizing mobility procedures. Accordingly, the user equipment 10 may proactively determine base stations 104 along the route 174. In other words, instead of dynamically performing handovers and beam switches as the user equipment 10 leaves coverage areas, the user equipment 10 may consider its location and the map 170 to improve mobility procedures.

[0079] FIG. 10 is a flowchart of a method 200 enabling the user equipment 10 of FIG. 1 to transition between base stations 104 of the wireless communication network 102 based on the map 170, according to embodiments of the present disclosure. Any suitable device (e.g., a controller) that may control components of the user equipment 10, the network 102, and/or the base station 104, such as the processor 12, may perform the method 200. In some embodiments, the method 200 may be implemented by executing instructions stored in a tangible, non-transitory, computer-readable medium, such as the memory 14 or storage 16, using the processor 12. For example, the method 200 may be performed at least in part by one or more software components, such as an operating system of the user equipment 10, the network 74, and/or the base station 104, one or more software applications of the user equipment 10, the network 102, and/or the base station 104, and the like. While the method 200 is described using steps in a specific sequence, it should be understood that the present disclosure contemplates that the described steps may be performed in different sequences than the sequence illustrated, and certain described steps may be skipped or not performed altogether.

[0080] In process block 202, the base station 104 (and/or the network 102) generates a map 170 indicative of one or more base stations 104, beam locations, beam directions, and/or beam shapes of the base station 104 (and/or other base stations 104 of the network 102). For example, the base station 104 (and/or the network 102) may determine coordinates indicate of a location of a base station 104, a shape of the beam 172, a border of the beam 172, coordinates of borders of the beam 172, and so on. For example, during the network planning or implementation stage, one or more operators and/or vendors may determine locations of the base stations 104 and coverage areas. The operators and/or vendors may also determine beam characteristics (e.g., directions, shapes) of each base station 104. Furthermore, the operators and vendors may specify a frequency of the base station 104, a type of the base station 104, or the like. Such network information may be used by the wireless network 102 to generate the map 170. Additionally or alternatively, base stations 104 may be added or removed over time. As such, the map 170 may be periodically updated to include changes in base stations 104.

[0081] In process block 204, the user equipment 10 determines a location. For example, the user equipment 10 may determine the location based on GPS coordinates or GNSS coordinates. The user equipment 10 may transmit an indication of the location to the base station 104. In process

block 206, the base station 104 receives an indication of the location from the user equipment 10. Additionally or alternatively, the base station 104 may determine the location of the user equipment 10, similar to process block 144 described above with respect to FIG. 7.

[0082] In process block 208, the base station 104 sends an indication of the map 170 to the user equipment 10. The base station 104 may send the map 170 as part of the downlink data to the user equipment 10 and the user equipment 10 may utilize the map 170 to determine surrounding base stations 104. In certain instances, the map 170 may cover a large region and certain areas of the map 170 may not be useful to the user equipment 10. For example, the map 170 may include base stations 104 across multiple countries, states, provinces, cities, towns, and so on. To reduce an amount of data transferred, the base station 104 may determine a portion of the map 170 useful to the user equipment 10 based on the location of the user equipment 10. For example, the base station 104 may determine a threshold radius around the user equipment 10 and send a portion of the map 170 that corresponds to the threshold radius around the user equipment 10.

[0083] In process block 210, the user equipment 10 receives the indication of the map 170. For example, the user equipment 10 may download the map 170 and determine the base stations 104 surrounding the user equipment 10. Further, the user equipment 10 may use the map 170 to determine beam characteristics of each base station 104 and determine a better performing base station 104 (e.g., relative to the connected base station 104). As such, in process block 212, the user equipment 10 connects to the better performing base station 104, similar to process block 152 described above with respect to FIG. 7.

[0084] In some cases, the user equipment 10 may move in a direction causing the user equipment 10 to leave a coverage area of the connected base station 104 (e.g., the better performing base station 104 described in process block 212). In process block 214, the user equipment 10 determines a predicted route 174 of the user equipment 10 based on a location of the user equipment 10. The predicted route 174 user equipment 10 may be a historical route the user equipment 10 travels along at a same time, same day, from a same location. For example, the user equipment 10 may travel from home to work, or vice versa, at the same time during the weekdays. Based on the location (e.g., home, work) the user equipment 10 may predict travel along the route. In another example, the predicted route 174 may be determined from a map software application. Still in another example, the user equipment 10 may predict multiple routes using GNSS data and the location. The user equipment 10 may be traveling on a road (e.g., highway) and predict multiple routes based on possible switches.

[0085] With the map 170, the user equipment 10 determines one or more base stations 104 with coverage along the predicted route 174. For example, the user equipment 10 may determine one or more beams 172 that provides coverage along the predicted route and an area of coverage provided. Further, the user equipment 10 may determine if the coverage is greater than a threshold to minimize handovers during travel. If the coverage is less than the threshold, then the user equipment 10 may not scan the base station 104 to prepare for handovers. Additionally or alternatively,

the user equipment 10 may determine one or more base stations 104 with overlapping coverage areas, which may be useful for handovers.

[0086] In determination block 216, the user equipment 10 predicts a handover. During mobility scenarios, the user equipment 10 may enter or leave coverage of the base stations 104; as such the user equipment 10 may need to transition between different base stations 104 along the predicted route 174. Based on the predicted route 176 and the map 170, the user equipment 10 may predict leaving or entering coverage, thereby predicting handovers before the handover occurs.

[0087] In certain instances, the user equipment 10 determines the handover is not occurring. For example, the user equipment 10 may remain within the coverage of the connected base station 104 while traveling along the predicted route 174. As such, a handover may not be necessary. Then, the method 200 may return to process block 204 to determine the location of the user equipment 10 and process block 214 to determine the predicted route of the user equipment 10 based on the location.

[0088] In some instances, the user equipment 10 determines the handover may be needed to maintain wireless service. For example, the user equipment 10 may determine one or more points along the predicted route 174 that leaves the coverage of the connected base station 104, therefore requiring a handover. In process block 218, the user equipment 10 determines a target base station 104 for the handover based on the predicted route and the map 170. For example, the user equipment 10 may determine a target base station 104 providing coverage along the predicted route 174 above the threshold, thereby reducing a number of required handovers during the mobility scenarios. As discussed with respect to FIG. 9, the user equipment 10 may determine that coverage of the first base station 104A and the third base station 104C may be above the threshold, while coverage of the second base station 104B may be below the threshold. As such, the user equipment 10 may skip connecting to the second base station 104 and only predict the handover from the first base station 104A to the third base station 104C. In other words, the user equipment 10 may connect to the first beam 172A, then connect to the third beam 172C, and skip connecting to the second beam 172B. In another example, the user equipment 10 may prioritize scanning a subset of base stations 104 and/or beams 172 closest to the predicted route to determine a target base station 104. In certain instances, the user equipment 10 scans for the subset of target base stations 104 for signal characteristics of for each base station of the subset similar to process block 150 described with respect to FIG. 7. In this way, the user equipment 10 may save power by limiting scanning to the subset of base stations 104 closest to the predicted route rather than multiple base stations 104 within a region of the user equipment 10.

[0089] In process block 220, the user equipment 10 sends an indication to transition to the target base station 104. For example, uplink data from the user equipment 10 to the base station 104 may include a request to transition to the better performing base station 104 determined by the user equipment 10. At process block 222, the base station 104 receives the indication to transition to the target base station 104. The base station 104 may start scheduling the user equipment 10 to the target base station 104 and the user equipment 10 may form a link. As such, the user equipment 10 may transition

(e.g., seamlessly transition) to the target base station **104**, thereby reducing or eliminating wireless service interruptions. Furthermore, the user equipment **10** may save power by reducing searching operations and the base stations **104** may also save power by reducing advertising schemes.

[0090] In certain instances, the user equipment **10** may connect to beams **172** of the base station **104** for wireless transfer. However, the connection may be interrupted by obstructions or blockages, such as objects interfering with line of sight between the user equipment **10** and the base station **104**. Temporary blockages (e.g., line of sight blockage) may easily and frequently occur in densely populated regions or during mobility scenarios. With the foregoing in mind, FIG. **11** is a schematic diagram of the user equipment **10** of FIG. **1** being blocked from communication with the base station **104** by a stationary object **242**, according to embodiments of the present disclosure. The base stations **104** (via the one or more antennas **55**) may be configured to emit one or more beams **172** in a directional configuration. The user equipment **10** may connect to the beam **172** and/or the base station **104** for wireless service. The connection may travel in a direct path (e.g., line of sight **240**) from the base station **104** to the user equipment **10** or vice versa. The signal characteristics (e.g., strength or quality) may depend on the line of sight **240**. For example, blocking all or a portion of the line of sight **240** may lead to a decrease in signal characteristics (e.g., to a point where data of the received user data may not be of sufficient level to be processed), a drop in user equipment **10** throughput, or in extreme circumstances, beam or connection failure. In the illustrated example, the line of sight **240** between the user equipment **10** and the base station **104** may be temporarily blocked by a stationary object **242** (e.g., tree).

[0091] For example, during mobility scenarios, the user equipment **10** may move behind stationary objects **242**, which may result in blockages of the line of sight **240**. At point **244**, the user equipment **10** may begin traveling and the line of sight **240** may be clear. As such, the user equipment **10** may form a beam **172** with the base station **104** and signal characteristics of the beam **172** may be above the threshold. However, at point **246**, the object **242** may interfere with the line of sight **240**; as such, no beam **172** may be formed. That is, the user equipment may not form the connection with the base station **104** and the connection may fail. As the user equipment **10** continues to move, at point **246**, the user equipment **10** may move past the blockage and form the beam **172** with the base station **104**. In other words, the blockage from the object **242** may be gone and the line of sight **240** between the user equipment **10** and the base station **104** may be clear. As such, the beam **172** may be formed.

[0092] A duration of the blockage may be determined be dependent on a velocity of the user equipment **10** and a size of the object **242** causing the blockage. The blockage duration may be shorter if the blockage size is small or if the user equipment **10** is travelling quickly, while the blockage duration may be longer if the blockage size is large or if the user equipment **10** is travelling slowly. As further described herein, predicting the blockage duration may enable the user equipment **10** to implement more effective mobility procedures, thereby maintaining wireless service and reducing or eliminating interruptions to wireless service.

[0093] FIG. **12** is a schematic diagram of the user equipment **10** of FIG. **1** blocked from communicating with the

base station **104** by a moving object **242**, according to embodiments of the present disclosure. As described herein, the connection may be formed when the line of sight **240** between the user equipment **10** and the base station **104** is clear or sufficiently clear (e.g., such that there is no obstruction blocking the line of sight **240** to affect transmitted user data from being received and data from being extracted from the user data with a bit error rate greater than a threshold bit error rate). For example, the second user equipment **10B** may connect to a second beam **172B** (supported by the base station **104**) based on a second line of sight **240B** being clear. However, in certain instances, the line of sight **240** may be blocked by the moving object **242**. For example, the moving object **242** may move in a direction of travel **126** in between the first user equipment **10A** and the base station **104**. As such, a first line of sight **240A** between the first user equipment **10A** and the base station **104** may be blocked by a moving object **242** (e.g., bus **260**).

[0094] The first user equipment **10A** and/or the wireless network **102** may use sensing to determine blockage information. The blockage information may include a relative distance between the moving object **242** and the first user equipment **10A**, a direction of travel of the moving object **242**, a speed of the moving object **242**, a size of the moving object **242**, or the like. For example, the first user equipment **10A** and/or the wireless network **102** may include and/or utilize proximity sensors, cameras, radio frequency sensors, infrared sensors, radar sensors, and so on, to determine a presence of the moving object **242** and/or the blockage information. Then, the first user equipment **10A** may use the blockage information to determine a blockage duration using the speed and the size of the moving object **242**. In certain instances, the first user equipment **10A** may transmit a signal indicative of the blockage information to nearby user equipment **10** (e.g., the second user equipment **10B**), the base station **104**, and/or the wireless network **102**. As such, the second user equipment **10B** may receive indication of a potential blockage and implement a mobility procedure to maintain wireless service during the blockage.

[0095] Further, device-to-device communication may be utilized for blockage detection and predictions. For example, the second user equipment **10B** may crowdsource information from user equipment **10** within an area surrounding the location of the user equipment **10B** to predict the blockage. In another example, the first user equipment **10A** may share the blockage information with the second user equipment **10B**. For example, the first user equipment **10A** may share a speed of the moving object **242** or the direction of travel **126** of the moving object **242**. The second user equipment **10B** may use the blockage information to predict a start time and a duration of the blockage (e.g., based on the blockage information received from the first user equipment **10A** and/or the base station **104**). If the second user equipment **10B** predicts a blockage (e.g., potential blockage), then the second user equipment **10B** may implement mobility procedures for the duration of the blockage to reduce or eliminate service interruptions.

[0096] Additionally or alternatively, the moving object **242** may provide the blockage information to the user equipment **10**. In the illustrated example, the blockage is caused by the bus **260** interfering with the line of sight **240**. An RF transceiver of the bus **260** may scan for RF signals from the base station **104** and synchronize to the base station **104**. Further, the RF transceiver of the bus **260** may provide

blockage information, such as a speed, a size, a location, a route of travel, a direction of travel, or the like to the base station **104**. In another example, the user equipment **10** may connect to the RF transceiver of the bus **260** (e.g., via a WiFi signal) and the bus **260** may transmit a signal indicative of blockage information. In this way, the wireless network **102** and/or the user equipment **10** may predict blockages before service interruptions and implement mobility procedures to maintain network coverage and/or reduce or eliminate service interruptions.

[0097] In certain instances, the moving object **242** may include multiple objects, thereby increasing the blockage duration. FIG. **13** is a schematic diagram of the user equipment **10** of FIG. **1** predicting a blockage (e.g., potential blockage) based on blockage information, according to embodiments of the present disclosure. For example, the moving object **242** may include multiple vehicles (e.g., first vehicle **260A**, second vehicle **260B**, collectively **260**) traveling in the same direction **262**. The vehicles **260** may exchange blockage information between the group and/or share the blockage information with the wireless network **102** and/or the user equipment **10** by platooning. As described herein, the blockage information may include a location, the direction of travel, the velocity, the size, and a number of vehicles to the first user equipment **10A**. For example, the first vehicle **260A** may receive blockage information from the second vehicle **260B** and add its blockage information for the user equipment **10** to predict the blockage duration. The first vehicle **260A** may be a master vehicle and communicate blockage information with the wireless network **102** and/or the user equipment **10**. While the illustrated example includes two vehicles (e.g., one master vehicle, one additional vehicle), any suitable number of vehicles of any suitable size may cause the blockage. For example, two or more additional vehicles **260**, four or more additional vehicles **260**, ten or more additional vehicles **260**, and so on may transmit blockage information to the master vehicle (e.g., the first vehicle **260A**) while the second vehicle **242B** may communicate blockage information with the first vehicle **242A**.

[0098] In certain instances, the first vehicle **260A** may be located closer (relative to the second vehicle **260B**) to the base station **104** and/or the user equipment **10** and may send an indication of the blockage information. Based on the indication, the first user equipment **10A** may determine a relative distance to the vehicles **260** and implement mobility procedures before blockage occurs. Further, the first user equipment **10A** may share blockage information with other user equipment **10**. For example, the first user equipment **10A** may share blockage information with the second user equipment **10B** (via device-to-device communication), similar to the user equipment **10** described with respect to FIG. **12**. In this way, the second user equipment **10B** may prepare for and mitigate signal interruptions for the duration of the blockage.

[0099] In certain instances, the second user equipment **10B** may predict a blockage based on the blockage information. The second user equipment **10B** may scan the base stations **104** and determine a target base station **104** that may not be blocked by the vehicles **260**. The second user equipment **10B** may request transition before the blockage occurs, thereby maintaining wireless service as the moving vehicles **260** pass by (e.g., interfere with the line of sight **240**). Additionally or alternatively, the second user equip-

ment **10B** may request transition to a different beam **172** of the base station **104** that may not be affected by the blockage. In certain instances, the user equipment **10** may not be able to form a connection with the base station **104**. The wireless network **102** may relay the connection using intelligent reflective surfaces (RIS) or a stationary relay mesh. For example, the wireless network **102** may include reflective surfaces (e.g., glass mirror, polished metal) that may reflect wireless signals (e.g., user data) from the base station **104** to a region (which may be dependent on the surface). In another example, the moving vehicles **260** may be utilized as a moving relay interconnecting the wireless network **102** and the user equipment **10** during the blockage. In other instances, the user equipment **10** may utilize cooperative communication between other user equipment **10** to relay the connection via a device-to-device connection. However, in certain instances, it may be beneficial to suspend the connection for the blockage duration and immediately resume connection after, thereby minimizing service interruptions. Predicting the blockage and the blockage duration allows for coordination between the user equipment **10** and the wireless communication network **102** to prevent unintended interruptions to wireless service and/or beam failures during the temporary blockage.

[0100] FIG. **14** is a flowchart of a method **300** for enabling the user equipment **10** of FIG. **1** to receive indication of a blockage (e.g., potential blockage of the line of sight **240**) and implement mobility procedures, according to embodiments of the present disclosure. Any suitable device (e.g., a controller) that may control components of the user equipment **10**, the network **102**, and/or the base station **104**, such as the processor **12**, may perform the method **300**. In some embodiments, the method **300** may be implemented by executing instructions stored in a tangible, non-transitory, computer-readable medium, such as the memory **14** or storage **16**, using the processor **12**. For example, the method **300** may be performed at least in part by one or more software components, such as an operating system of the user equipment **10**, the network **74**, and/or the base station **104**, one or more software applications of the user equipment **10**, the network **102**, and/or the base station **104**, and the like. While the method **300** is described using steps in a specific sequence, it should be understood that the present disclosure contemplates that the described steps may be performed in different sequences than the sequence illustrated, and certain described steps may be skipped or not performed altogether.

[0101] In process block **302**, the user equipment **10** connects to a base station **104**. The base station **104** may advertise radio frequency (RF) signals and the user equipment **10** may detect the base station **104** by receiving the RF signals when the user equipment **10** enters the coverage area of the base station **104** (e.g., a geographical region for which the base station provides network coverage).

[0102] In process block **304**, the base station **104** forms a connection with the user equipment **10**. The user equipment **10** may synchronize to the base station **104** and the base station **104** may broadcast or transmit system information indicative of frequency bands supported by the base station **104**. The system information may also include timing specification, power specification, GPS or GNSS coordinates, and/or any other suitable information to enable the user equipment **10** to establish communication with the base station **104**. Further, the user equipment **10** may transmit an

indication of its capabilities and the base station **104** may send a configuration of uplink resources (e.g., modulation order, signal power, resource blocks, timing, and so on) and the user equipment **10** may apply the configuration for communication with the base station **104**. Additionally or alternatively, the user equipment **10** may connect to a beam **172** of the base station **104**.

[0103] In process block **306**, a device of the communication system **100** (e.g., base station **104**, user equipment **10**) determines a blockage. For example, the user equipment **10**, the wireless network **102**, and/or the objects **242** may use sensing to standalone or jointly detect potential blockages and share the blockage information before the blockage occurs. For example, the user equipment and/or the wireless network **102** may include or utilize proximity sensors, cameras, radio frequency sensors, infrared sensors, and so on to determine the blockage information. The blockage information may include presence of a moving object, a relative distance of the moving object **242**, a direction of movement, a speed of movement, or a size of the moving object **242**. The blockage information may be used to determine a duration of the blockage. Additionally or alternatively, the location of the blockage may be used to determine a distance between the blockage and the user equipment **10** and/or a start time of the blockage.

[0104] In process block **308**, the device of the communication network **100** sends an indication of the blockage to the user equipment **10**. For example, the object **242** (e.g., vehicles **260**) may transmit blockage information to the user equipment **10** and/or the base station **104**. In another example, the user equipment **10** may utilize device-to-device communication to relay blockage information to other user equipment **10** within an area (e.g., within range of the utilize device-to-device communication) around the user equipment **10**. Additionally or alternatively, the user equipment **10** may crowdsource information (e.g., sensing information, blockage information) from other user equipment **10** to predict a blockage. Still in another example, the wireless network **102** may receive the indication of blockage information from one or more connected user equipment(s) **10** and/or the object **242** and send the indication of the blockage information to the user equipment **10**.

[0105] In process block **310**, the user equipment **10** receives the indication of the blockage. For example, the user equipment **10** may receive the blockage information from other user equipment **10**, the wireless network **102**, the connected base station **104**, or the like. Then, in decision block **312**, the user equipment **10** may determine if the connected base station **104** is affected by the blockage. As described herein, the base station **104** and the user equipment **10** may transmit signals (e.g., user data) in a direct path (e.g., line of sight **240**). If the line of sight **240** is blocked or partially blocked, signal characteristics may decrease. As such, it may be beneficial for the user equipment **10** to determine if the object **242** interferes with the line of sight **240** and implement mobility procedures. The user equipment **10** may predict the blockage based on the predicted location of the blockage and the location of the line of sight **240**.

[0106] If the user equipment **10** determines that the connected base station **104** is not affected by the blockage, then the method **300** may return to process block **306** to determine a blockage, send an indication of the blockage to the

user equipment **10**, and the user equipment **10** may return to process block **310** to receive the indication of the blockage.

[0107] If the user equipment **10** determines that the connected base station **104** is affected by the blockage, then at process block **314**, the user equipment **10** determines a device (e.g., base station **104**, user equipment **10**) of the communication system **100** for a handover. For example, the user equipment **10** may scan base stations **104**, similar to process **150** described above with respect to FIG. 7. The user equipment **10** may determine a better performing base station **104** (e.g., based on signal characteristics) for connection. Additionally or alternatively, the user equipment **10** may determine a different base station **104** (e.g., a base station **104** not affected by the blockage) for temporary connection. In another example, the user equipment **10** may use device-to-device communication to determine one or more user equipment **10** within an area (e.g., a geographical region for which the user equipment **10** may transmit user data) to relay network elements for connection. Still in another example, the user equipment **10** may determine RIS surfaces within the wireless network **102** for connection.

[0108] In decision block **316**, the user equipment **10** determines if signal characteristics of the device are below a threshold, similar to decision block **156** described above with respect to FIG. 7. If the signal characteristics of the device are not below the threshold, then the user equipment **10** may send an indication to transition to the device of the communication system **100**. In process block **318**, the device of the communication system **100** receives the indication of a request to connect. For example, the user equipment **10** may determine a target base station **104** that may not be affected by the blockage and send a request to transition. The wireless network **102** may receive the request to transition and start scheduling the user equipment **10** to the target base station **104**. As such, the user equipment **10** may connect to the target base station before the blockage occurs, thereby maintaining wireless service. In another example, the user equipment **10** may determine another user equipment **10** with signal characteristics above the threshold. The user equipment **10** may utilize device-to-device communications to relay network services and maintain wireless service. Still in another example, the user equipment **10** and/or the object **242** may relay network elements using a stationary relay mesh or RIS. As such, interruptions to wireless services may be reduced or eliminated.

[0109] However, if the user equipment **10** determines that signal characteristics of the device are below the threshold, then it may be beneficial to suspend the connection for a predicted duration of the blockage. In process block **320**, the user equipment **10** suspends communication with the connected base station **104** for the duration of the blockage. For example, the user equipment **10** may stop transmitting or receiving user data with the connected base station **104** during the blockage. However, the user equipment **10** may still maintain the link with the connected base station **104**. In this way, the user equipment **10** may immediately resume communication after the blockage. In process block **322**, the connected base station **104** receives the indication to suspend communication with the connected base station **104** for the duration of the blockage.

[0110] However, after (e.g., immediately after) the blockage, the user equipment **10** and the base station **104** may resume the connection. In process block **324**, the user equipment **10** resumes communication with the connected

base station **104** after the blockage. For example, the user equipment **10** may send an indication to the connected base station **104** indicative of expiration of the blockage duration. At process block **326**, the connected base station **104** receives the indication to resume communication with the user equipment **10**. For example, the user equipment **10** and/or the connected base station **104** may start transmitting or receiving user data from the connected base station. Coordination between the user equipment **10** and the wireless network **102** may prevent unintended wireless network interruptions due to failure due to a temporary blockage or unintended beam failure. As such, performing a mitigation procedure before the blockage may maintain network coverage by reducing signal degradation and/or service interruptions (e.g., due to a broken connection).

[0111] In one embodiment, user equipment may include one or more antennas, a transceiver coupled to the one or more antennas, and processing circuitry coupled to the transceiver. The processing circuitry may be configured to detect a first base station using the transceiver, synchronize to the first base station, and send or receive user data via the one or more antennas using the transceiver to or from the first base station. The processing circuitry may also be configured to receive a map using the transceiver, the map indicating a location of each base station of a plurality of base stations and a beam coverage area of each base station of the plurality of base stations, request transitioning to send or receive the user data to or from a second base station using the transceiver based on a predicted route of the user equipment and the map, and send or receive the user data via the one or more antennas using the transceiver to or from the second base station based on a response to the request.

[0112] The processing circuitry may be configured to determine a location of the user equipment, determine the predicted route of the user equipment based on the location, and determine the second base station of the plurality of base stations based on the predicted route and the map.

[0113] The processing circuitry may be configured to determine a beam coverage area of the second base station is above a threshold coverage area based on the map and the predicted route, and request a transition to the second base station prior to the user equipment leaving a beam coverage area of the first base station using the transceiver.

[0114] The processing circuitry may be configured to determine a beam coverage area of the second base station is below a threshold coverage area based on the map and the predicted route, and determine a third base station of the plurality of base stations based on the predicted route and the map.

[0115] The processing circuitry may be configured to determine the predicted route based on a historical route of the user equipment, instructions from a map software application, Global Navigation Satellite System data, or any combination thereof.

[0116] The beam coverage area may be indicated by a beam shape and a beam direction, where the beam shape is indicated by global navigation satellite system data.

[0117] The processing circuitry may be configured to receive a portion of the map using the transceiver, where the portion comprising a threshold radius surrounding the location of the user equipment.

[0118] The processing circuitry may be configured to determine a subset of base stations of the plurality of base stations along the predicted route of the user equipment,

receive the user data using the transceiver from each of the subset of base stations to determine a signal characteristic, and determine the second base station based on the signal characteristic.

[0119] A wireless network may be configured to determine the location of each base station of the plurality of base stations and the beam coverage area of each base station of the plurality of base stations to generate the map.

[0120] In another embodiment, a base station may include a transmitter, a receiver, and processing circuitry coupled to the transmitter and receiver. The processing circuitry may be configured to generate a map indicating a location of each base station of a plurality of base stations and a beam coverage area of each base station of the plurality of base stations, determine or receive a first indication of a location of an user equipment using the receiver, and transmit a portion of the map to the user equipment based on the location of the user equipment using the transmitter. The processing circuitry may also be configured to receive a second indication of a request from the user equipment to transition to a second base station using the receiver, and transition the user equipment to the second base station.

[0121] The processing circuitry may be configured to update the map with one or more added or removed base stations indicated by a wireless network.

[0122] The processing circuitry may be configured to determine a threshold radius surrounding the location of the user equipment, and generate the portion of the map based on the threshold radius.

[0123] The coverage area comprises a beam shape or a beam direction.

[0124] The map comprises Global Navigation Satellite System coordinates indicative of the beam coverage area of each base station of the plurality of base stations.

[0125] The base station comprises a Next Generation NodeB base station.

[0126] The processing circuitry may be configured to determine a range of a beam of each base station of the plurality of base stations by performing a sensing operation, and update the map with the range of the beam based on the sensing operation.

[0127] In yet another embodiment, a method for wireless communications may include receiving, at a user equipment, a map from a first base station indicating a location of each base station of a plurality of base stations and a beam coverage area of each base station of the plurality of base stations, and predicting, by the user equipment, a route of the user equipment based on a location of the user equipment. The method may also determine, by the user equipment, a second base station of the plurality of base stations for transitioning based on the map and the route, transmit a request to transition to the second base station, and communicate with the second base station based on a response to the request.

[0128] The method may include determining, by the user equipment, a subset of base stations of the plurality of base stations along the route based on the map, receiving, a signal characteristic from each base station of the subset of base stations, and determining the second base station based on the signal characteristic.

[0129] The method may include determining, by the user equipment, the beam coverage area of the second base station is above a threshold based on the route and the map.

[0130] The method may include transmitting, by the user equipment, an indication of the location of the user equipment to the second base station, and receiving, by the user equipment, the map from the second base station comprising a region surrounding the location of the user equipment.

[0131] In one embodiment, user equipment may include one or more antennas, a transceiver coupled to the one or more antennas, and processing circuitry coupled to the transceiver. The processing circuitry may be configured to detect a first base station using the transceiver, synchronize to the first base station, and send or receive user data via the one or more antennas using the transceiver to or from the first base station. The processing circuitry may also be configured to determine or receive an indication of blockage information using the transceiver, request a transition to send or receive the user data to or from a second base station based on the blockage information, and send or receive the user data via the one or more antennas using the transceiver to or from the second base station based on a response to the request.

[0132] The processing circuitry may be configured to determine a signal characteristic of the second base station is above a threshold value.

[0133] The blockage information comprises a speed of an object, a size of the object, a relative distance of the object, a speed of the user equipment, or any combination thereof.

[0134] The processing circuitry may be configured to determine the speed of the user equipment, determine the size of the object, the object comprises a stationary object, and predict a blockage based on the speed of the user equipment and the size of the object.

[0135] The processing circuitry may be configured to predict a blockage based on the blockage information, the prediction is indicative of a start time and a duration of the blockage, and at the start time, suspend sending or receiving the user data via the one or more antennas using the transceiver to or from the first base station for the duration of the blockage.

[0136] The processing circuitry may be configured to send or receive the user data via the one or more antennas using the transceiver to or from the second base station via an intelligent reflective surface or a stationary relay mesh.

[0137] The processing circuitry may be configured to send or receive the user data via the one or more antennas using the transceiver to or from one or more neighboring user equipment via device-to-device communication.

[0138] The user equipment may include one or more sensors and the processing circuitry may be configured to perform sensing operations via the one or more sensors to determine the blockage information, and send the indication the blockage information using the transceiver to the first base station, one or more neighboring user equipment, or both.

[0139] The indication of the blockage information may be transmitted by one or more neighboring user equipment, a base station, a wireless network, an object, or any combination thereof.

[0140] In another embodiment, a base station may include a transmitter, a receiver, and processing circuitry coupled to the transmitter and the receiver. The processing circuitry may receive an indication of a potential blockage of a line of sight using the receiver, the indication comprising a start time of the potential blockage and a duration of the potential blockage and transmit the start time of the potential block-

age and the duration of the potential blockage to an user equipment using the transmitter. The processing circuitry may also receive a request from the user equipment to connect to a second base station based on the start time of the potential blockage and the duration of the potential blockage and transition the user equipment to the second base station.

[0141] The processing circuitry may be configured to connect to a vehicle using a Wi-Fi signal, a radio frequency (RF) signal, or any combination thereof to receive the indication of the potential blockage using the receiver.

[0142] The vehicle may include multiple vehicles, and the processing circuitry may be configured to connect to a master vehicle of the multiple vehicles to receive the indication of the potential blockage using the receiver.

[0143] The processing circuitry may be configured to suspend transmitting user data to the user equipment using the transmitter for the duration of the potential blockage, and after the duration of the potential blockage, resume transmitting the user data to the user equipment using the transmitter.

[0144] The processing circuitry may be configured to transmit the user data to the user equipment via an intelligent reflective surface or a stationary relay mesh using the transmitter.

[0145] The processing circuitry may be configured to transition the user equipment to a different beam of the base station for the duration of the potential blockage.

[0146] The processing circuitry may be configured to receive blockage information from one or more user equipment, a wireless network, an object, or any combination thereof, and transmit the blockage information to the user equipment.

[0147] In yet another embodiment, a method may include receiving, at a user equipment, blockage information from a first base station, the blockage information comprising a speed of an object, a size of the object, a relative distance of the object, or any combination thereof and predicting a line of sight blockage between the user equipment and the first base station based on the blockage information, the line of sight blockage comprising a start time and a blockage duration. The method may also transmit, by the user equipment, a request to transition to a second base station based on the prediction of the line of sight blockage.

[0148] The method may include receiving, by the user equipment, system information from the second base station based on the prediction of the line of sight blockage from the second base station, the system information comprising a signal characteristic, determining, by the user equipment, that the signal characteristic is below a threshold value, and transmitting, by the user equipment, a request to transition to a third base station.

[0149] The method may include communicatively coupling, by the user equipment, to one or more other user equipment via device-to-device communication for the blockage duration.

[0150] The method may include receiving, by the user equipment, system information from the second base station, determining a signal characteristic is above a threshold value, and communicating with to the second base station based on the signal characteristic being above the threshold value.

[0151] The specific embodiments described above have been shown by way of example, and it should be understood

that these embodiments may be susceptible to various modifications and alternative forms. It should be further understood that the claims are not intended to be limited to the particular forms disclosed, but rather to cover all modifications, equivalents, and alternatives falling within the spirit and scope of this disclosure.

[0152] The techniques presented and claimed herein are referenced and applied to material objects and concrete examples of a practical nature that demonstrably improve the present technical field and, as such, are not abstract, intangible or purely theoretical. Further, if any claims appended to the end of this specification contain one or more elements designated as “means for [perform]ing [a function] . . . ” or “step for [perform]ing [a function] . . . ,” it is intended that such elements are to be interpreted under 35 U.S.C. 112(f). However, for any claims containing elements designated in any other manner, it is intended that such elements are not to be interpreted under 35 U.S.C. 112(f).

[0153] It is well understood that the use of personally identifiable information should follow privacy policies and practices that are generally recognized as meeting or exceeding industry or governmental requirements for maintaining the privacy of users. In particular, personally identifiable information data should be managed and handled so as to minimize risks of unintentional or unauthorized access or use, and the nature of authorized use should be clearly indicated to users.

1. User equipment, comprising:
one or more antennas;
a transceiver coupled to the one or more antennas; and
processing circuitry coupled to the transceiver and configured to
detect a first base station using the transceiver,
synchronize to the first base station,
receive a first indication of a cell cluster comprising the first base station and a plurality of additional base stations using the transceiver,
send or receive user data via the one or more antennas using the transceiver to or from the first base station,
receive signal characteristics of the first base station and the plurality of additional base stations,
request transitioning to sending or receiving the user data to or from a second base station of the plurality of additional base stations based on the signal characteristics, and
send or receive the user data via the one or more antennas using the transceiver to or from the second base station based on a response to the request.
2. The user equipment of claim 1, wherein the processing circuitry is configured to determine a better performing base station of the plurality of additional base stations based on the signal characteristics.
3. The user equipment of claim 2, wherein the processing circuitry is configured to receive a second indication of an additional cell cluster using the transceiver, the additional cell cluster comprising the better performing base station and a second plurality of base stations based on moving out of a coverage area of the first base station.
4. The user equipment of claim 3, wherein the processing circuitry is configured to receive signal characteristics of the better performing base station and the second plurality of base stations based on the second indication.
5. The user equipment of claim 2, wherein the processing circuitry is configured to send or receive the user data via the

one or more antennas using the transceiver while receiving the signal characteristics of the first base station and the plurality of additional base stations.

6. The user equipment of claim 1, wherein a computing device associated with the cell cluster or a primary base station of the cell cluster is configured to maintain the cell cluster.

7. The user equipment of claim 1, wherein the signal characteristics comprise a signal strength, a signal quality, a power delivery, a signal delivery, or any combination thereof.

8. The user equipment of claim 1, wherein the processing circuitry is configured to determine a location of the user equipment and send a second indication of the location to the first base station using the transceiver.

9. The user equipment of claim 1, wherein the response comprises a second indication of scheduling the user equipment on the second base station and a third indication to stop sending or receiving the user data to or from the first base station.

10. A base station, comprising:
a transmitter;
a receiver; and
processing circuitry coupled to the transmitter and the receiver, the processing circuitry configured to
receive a first indication of a location of a user equipment using the receiver,
generate a cell cluster comprising the base station and a plurality of additional base stations within a range of the location,
transmit a second indication of the cell cluster using the transmitter,
receive a request to transition to a better performing base station of the cell cluster based on signal characteristics of the base station and the better performing base station with respect to the user equipment, the plurality of additional base stations comprising the better performing base station, and
schedule the user equipment to send or receive user data on the better performing base station.

11. The base station of claim 10, wherein the processing circuitry is configured to generate a second cell cluster comprising the better performing base station and a second plurality of additional base stations.

12. The base station of claim 10, wherein the processing circuitry is configured to generate the cell cluster based on a density of base stations within the range of the location of the user equipment.

13. The base station of claim 12, wherein the processing circuitry is configured to generate the cell cluster based on a mobility type of the user equipment.

14. The base station of claim 10, wherein the processing circuitry is configured to add one or more additional base stations and remove one or more base stations from the cell cluster based on the second indication.

15. The base station of claim 14, wherein the processing circuitry is configured to stop transmitting or receiving the user data to or from the user equipment based on scheduling the user equipment on the better performing base station.

16. A method for wireless communications comprising:
receiving, at a user equipment, an indication of a cell cluster comprising a plurality of base stations from a base station;

receiving, at the user equipment, signal characteristics from each base station of the cell cluster;
transmitting, by the user equipment, a request to transition to a better performing base station of the cell cluster based on the signal characteristics; and
communicating with the better performing base station based on a response to the request.

17. The method of claim **16**, comprising, receiving, at the user equipment, an indication of a second cell cluster based on the response to the request, the second cell cluster comprising the better performing base station and a second plurality of base stations.

18. The method of claim **17**, comprising, receiving, at the user equipment, signal characteristics from each base station of the second cell cluster.

19. The method of claim **17**, comprising, receiving, at the user equipment, an indication of scheduling the user equipment on the better performing base station.

20. The method of claim **16**, wherein the cell cluster comprises the better performing base station.

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