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Talley et al.

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(54) **SYSTEMS AND METHODS FOR DYNAMICALLY CONFIGURING FEMTOCELL PILOT BEACON BASED ON MACRO-NETWORK LOADING**

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H04W 84/04	(2009.01)
H04W 48/00	(2009.01)
H04W 72/02	(2009.01)
H04B 1/713	(2011.01)
H04B 7/00	(2006.01)

(52) **U.S. Cl.**
CPC ***H04W 72/0486*** (2013.01); ***H04B 1/713*** (2013.01); ***H04W 72/02*** (2013.01); ***H04W 84/045*** (2013.01); *H04B 7/00* (2013.01); *H04W 48/00* (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

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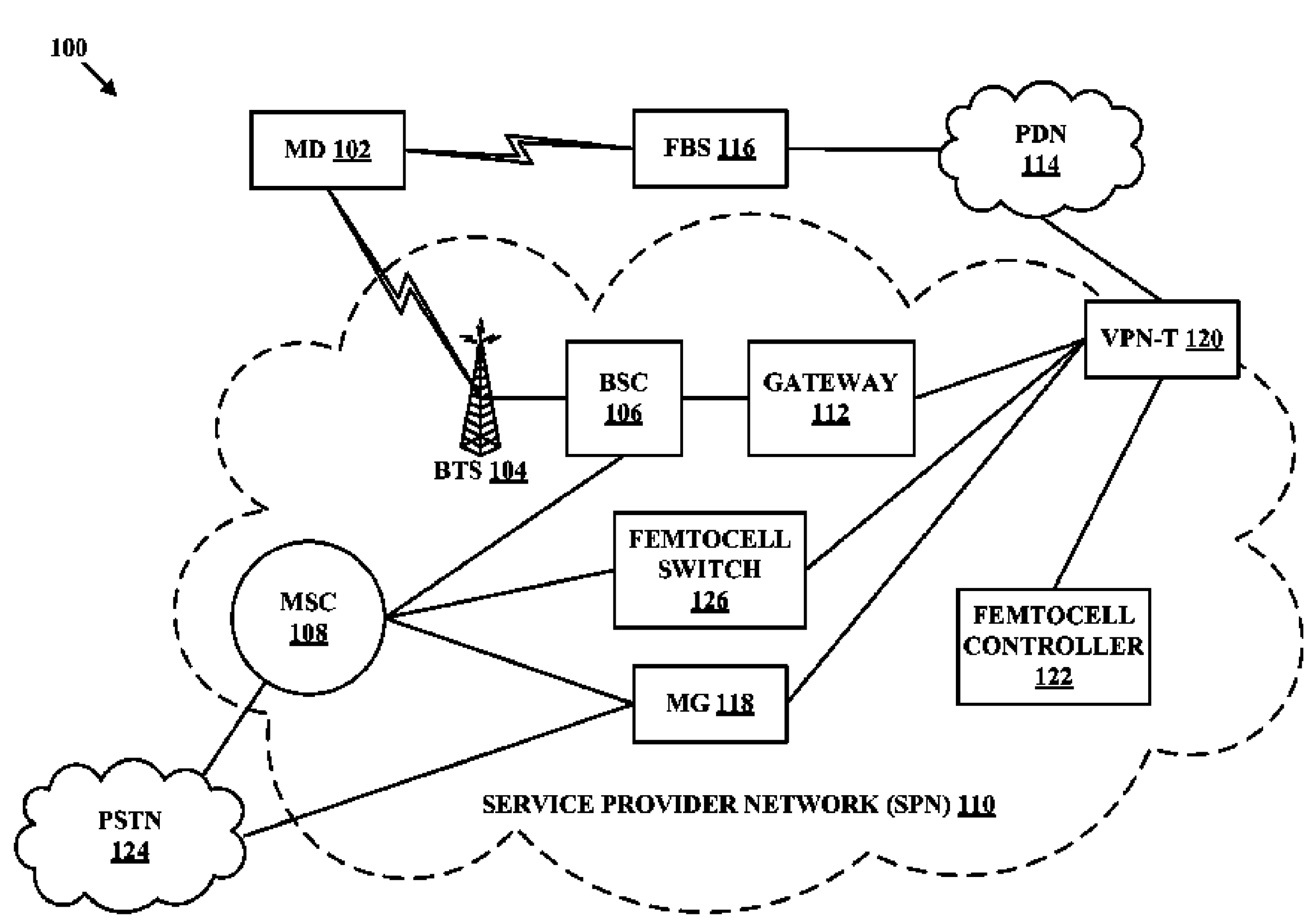
Primary Examiner — Michael Thier
Assistant Examiner — Yaotang Wang

(57) **ABSTRACT**

Disclosed herein are systems and methods for dynamically configuring femtocell pilot beacon based on macro-network load. An embodiment takes the form of a method of operating a wireless network system that includes a first base station operating on a first frequency and one or more second base stations operating on a plurality of second frequencies. The method includes transmitting a frequency-hopping pilot beacon among the plurality of second frequencies. The method further includes determining loading on each of the second frequencies and in particular that a given one of the second frequencies is more heavily loaded than at least one other, and responsively prioritizing transmission of the frequency-hopping pilot beacon on the given frequency as compared to the at least one other frequency.

15 Claims, 6 Drawing Sheets



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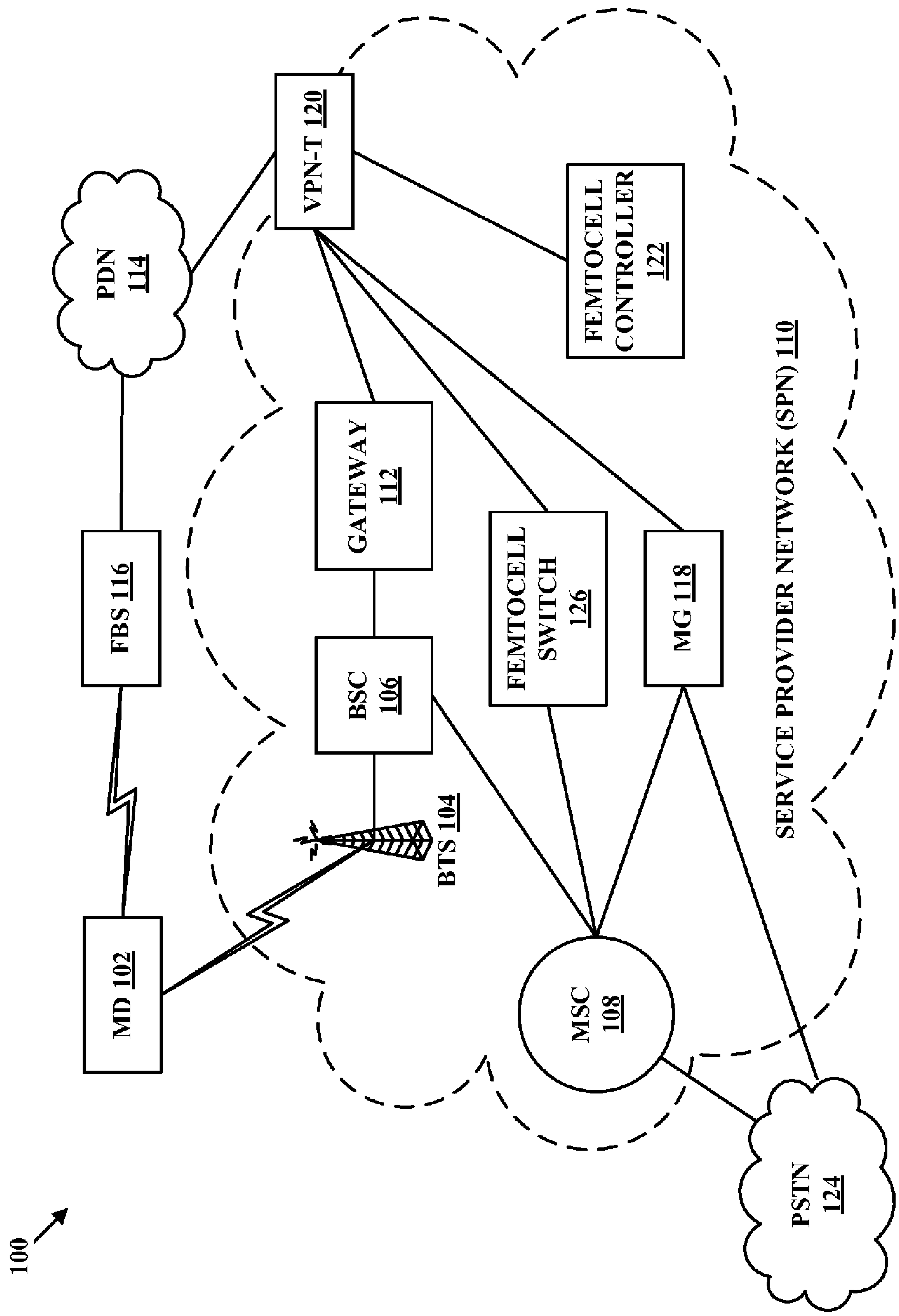
100
PDN 114
VPN-T 120
FEMTOCELL CONTROLLER 122
GATEWAY 112
FBS 116
BSC 106
FEMTOCELL SWITCH 126
MG 118
SERVICE PROVIDER NETWORK (SPN) 110
BTS 104
MD 102
MSC 108
PSTN 124

FIG. 1

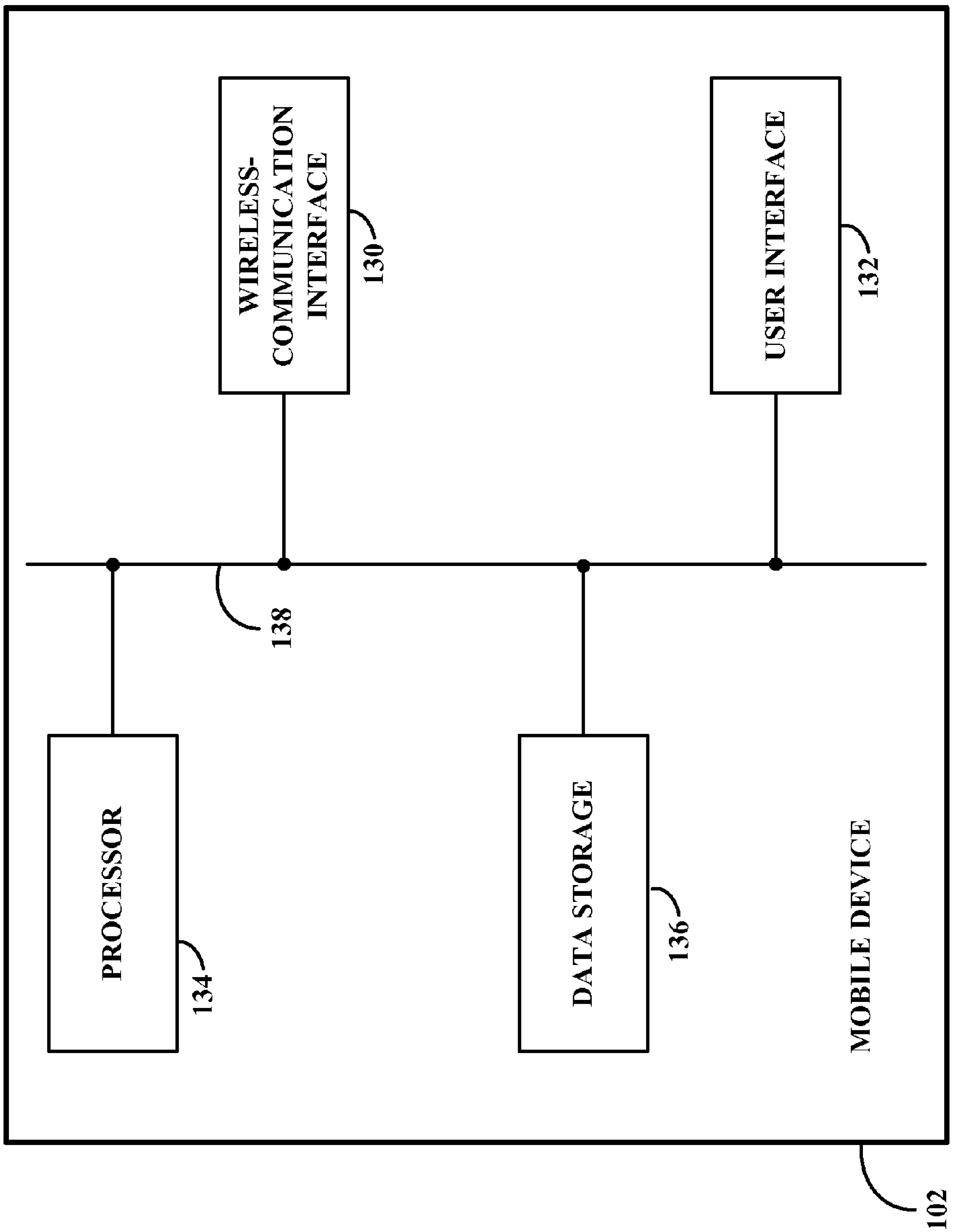
WIRELESS-COMMUNICATION INTERFACE
130
USER INTERFACE
132
138
PROCESSOR
134
DATA STORAGE
136
MOBILE DEVICE
102

FIG. 2

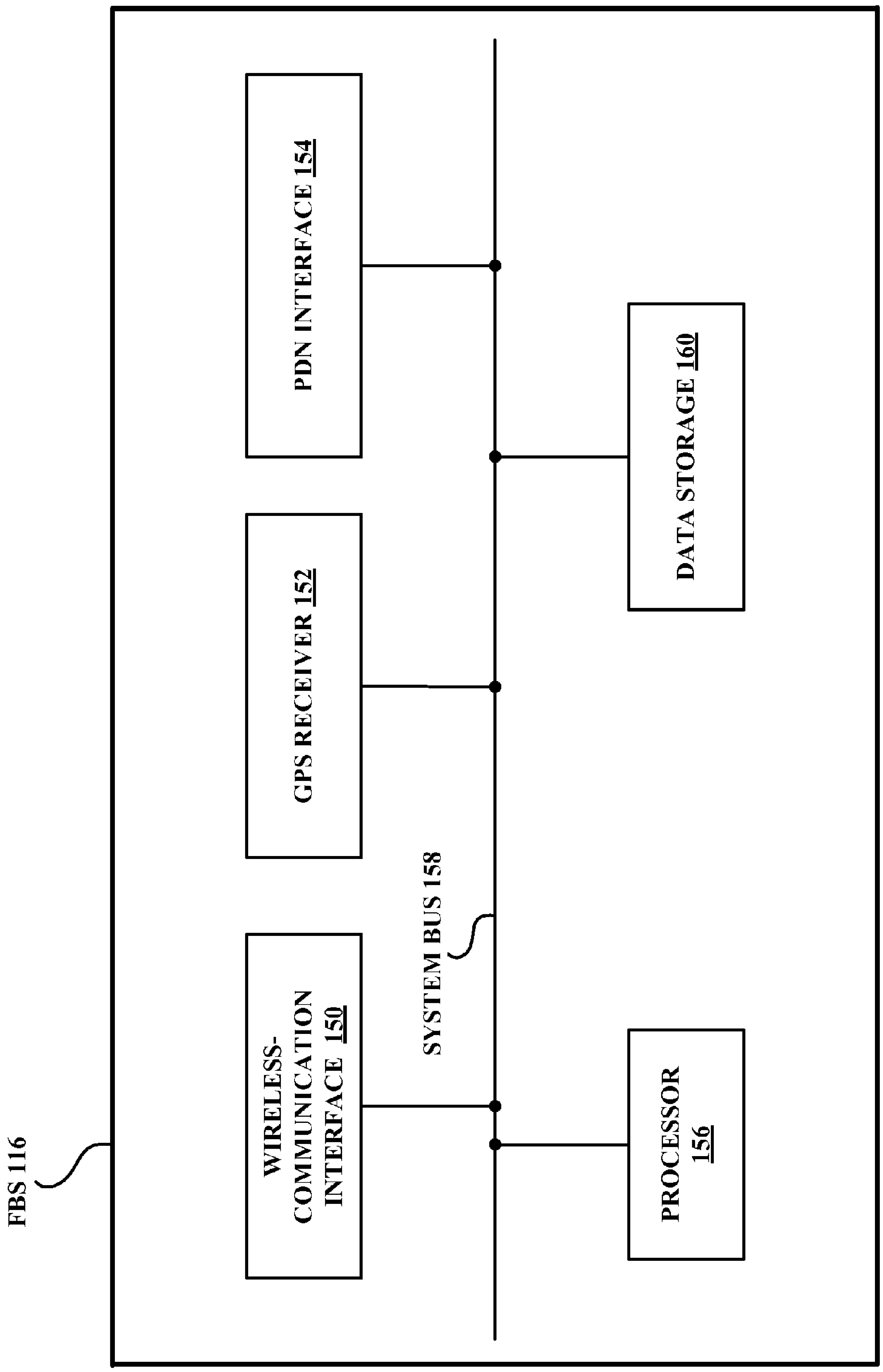
FBS 116
WIRELESS-COMMUNICATION INTERFACE 150
GPS RECEIVER 152
PDN INTERFACE 154
SYSTEM BUS 158
PROCESSOR 156
DATA STORAGE 160

FIG. 3

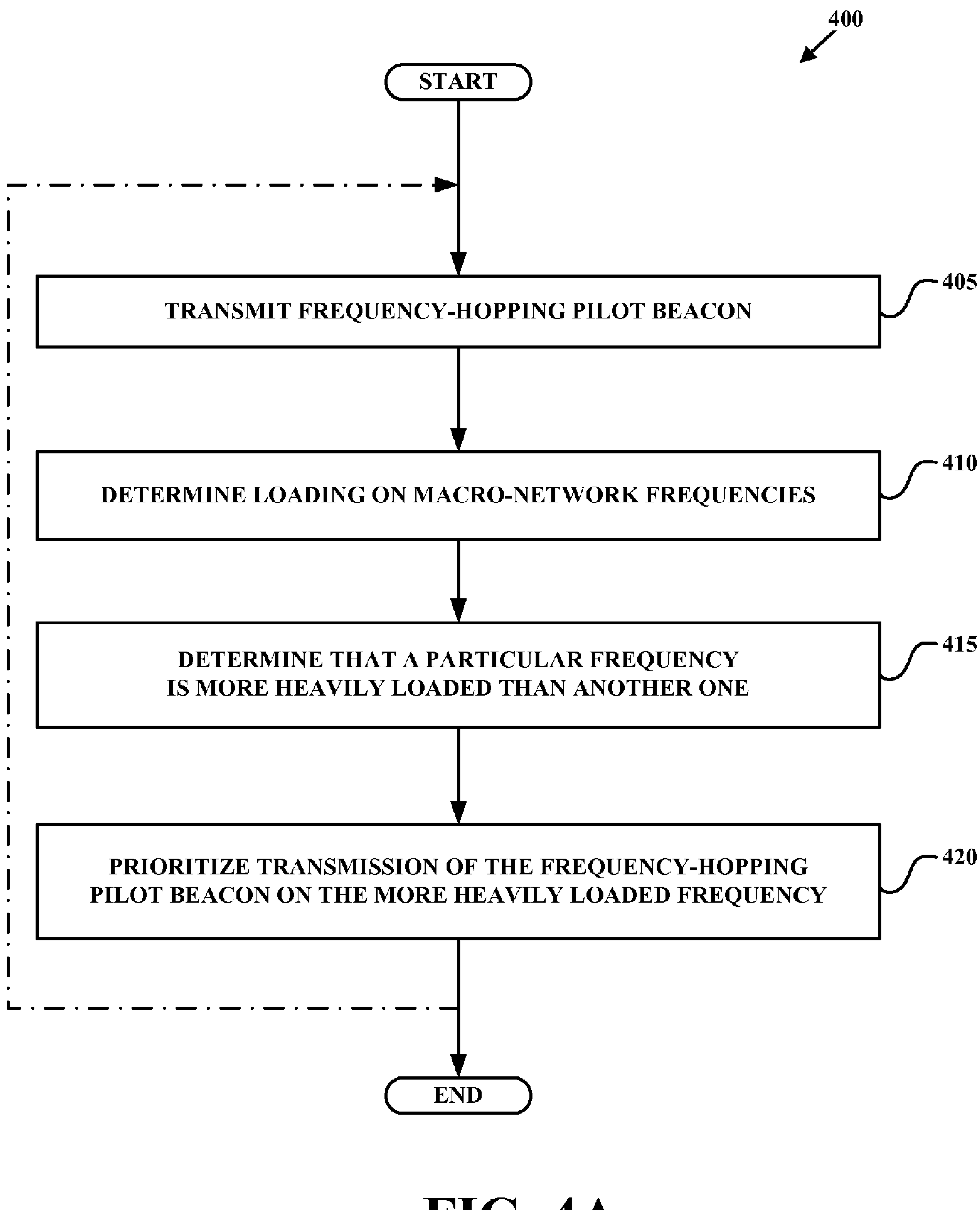
400
START
TRANSMIT FREQUENCY-HOPPING PILOT BEACON
405
DETERMINE LOADING ON MACRO-NETWORK FREQUENCIES
410
DETERMINE THAT A PARTICULAR FREQUENCY IS MORE HEAVILY LOADED THAN ANOTHER ONE
415
PRIORITIZE TRANSMISSION OF THE FREQUENCY-HOPPING PILOT BEACON ON THE MORE HEAVILY LOADED FREQUENCY
420
END

FIG. 4A

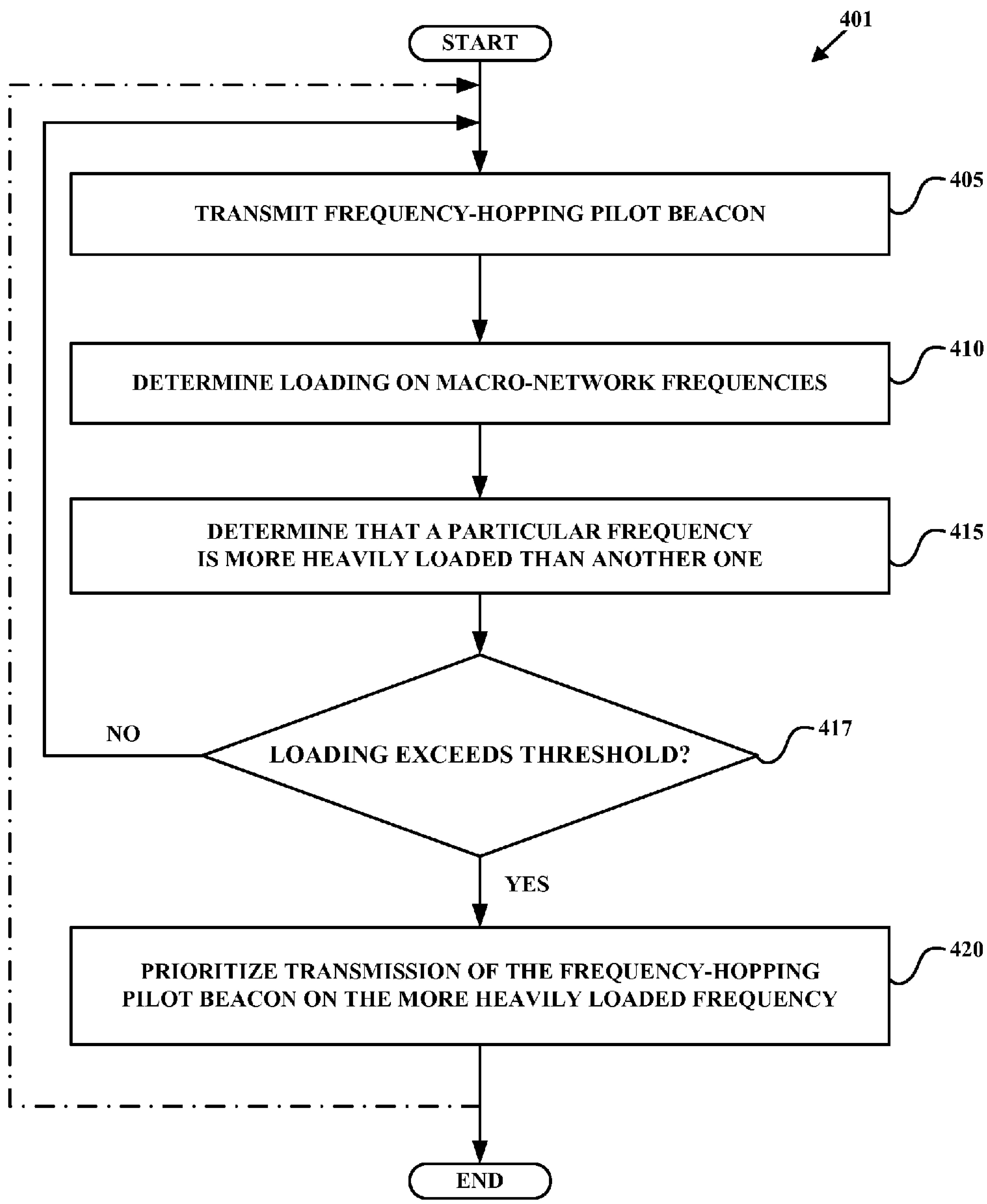
401
START
TRANSMIT FREQUENCY-HOPPING PILOT BEACON
405
DETERMINE LOADING ON MACRO-NETWORK FREQUENCIES
410
DETERMINE THAT A PARTICULAR FREQUENCY IS MORE HEAVILY LOADED THAN ANOTHER ONE
415
NO
LOADING EXCEEDS THRESHOLD?
417
YES
PRIORITIZE TRANSMISSION OF THE FREQUENCY-HOPPING PILOT BEACON ON THE MORE HEAVILY LOADED FREQUENCY
420
END

FIG. 4B

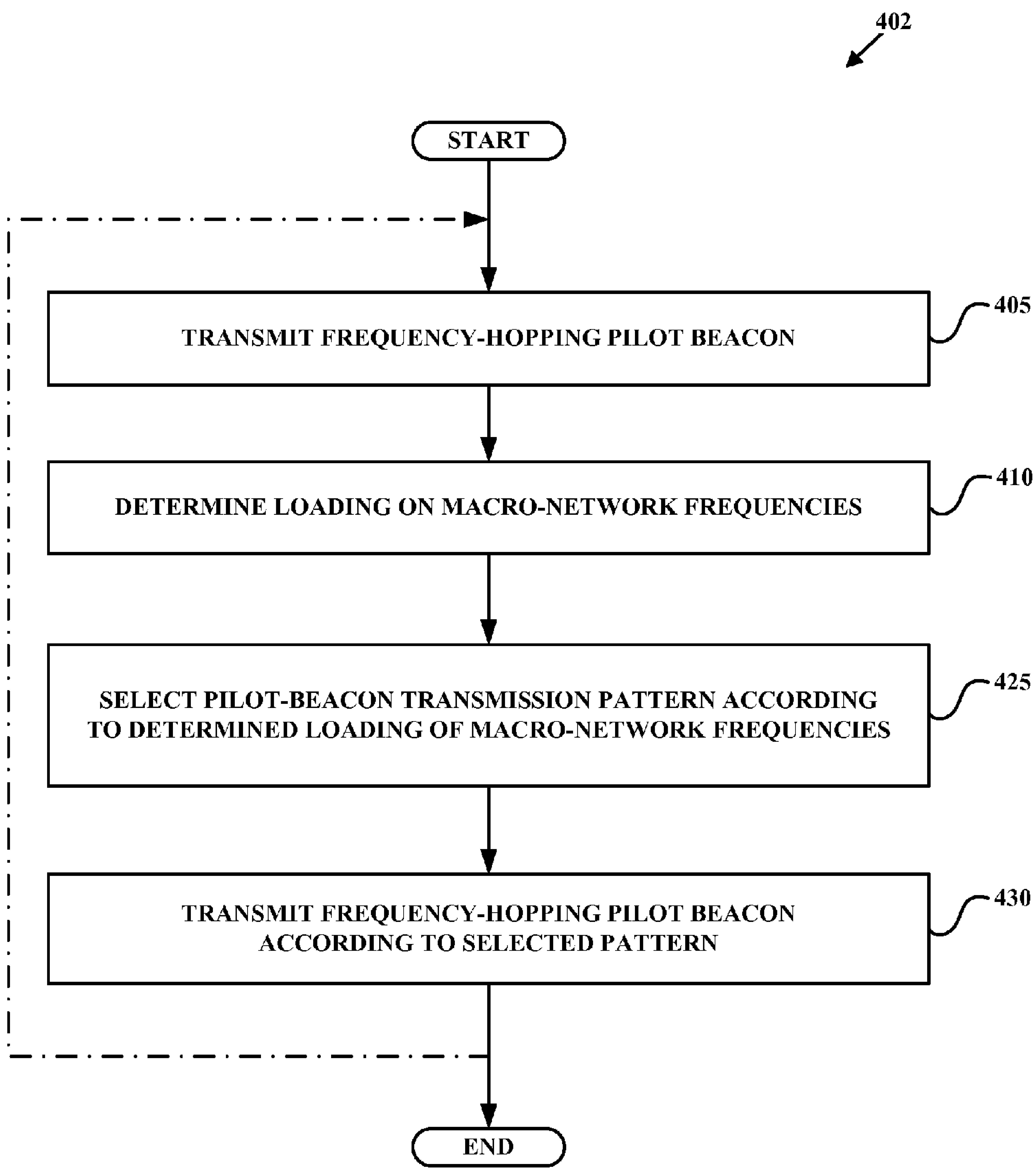
402
START
TRANSMIT FREQUENCY-HOPPING PILOT BEACON
405
DETERMINE LOADING ON MACRO-NETWORK FREQUENCIES
410
SELECT PILOT-BEACON TRANSMISSION PATTERN ACCORDING TO DETERMINED LOADING OF MACRO-NETWORK FREQUENCIES
425
TRANSMIT FREQUENCY-HOPPING PILOT BEACON ACCORDING TO SELECTED PATTERN
430
END

FIG. 4C

SYSTEMS AND METHODS FOR DYNAMICALLY CONFIGURING FEMTOCELL PILOT BEACON BASED ON MACRO-NETWORK LOADING

BACKGROUND

1. Service Provider Networks (SPNs)

It is increasingly common for people to use client-side devices to communicate with other devices via cellular wireless communication systems operated by wireless-service providers (i.e., service provider networks (SPNs)), whether those devices are directly connected to the same SPN or to another system (such as another SPN or a transport network, as examples) to which that SPN directly or indirectly provides access. These client-side devices are generally referred to in this disclosure as mobile devices, though this term is intended to broadly encompass various devices known by terms such as mobile stations, access terminals, user equipment, cellphones, smartphones, wireless-communication devices, personal digital assistants (PDAs), tablets, laptops, air cards, Universal Serial Bus (USB) devices, and/or any other device (s) capable of functioning as a mobile device according to this disclosure. Via the SPN, mobile devices generally engage in communications such as voice calls, packet-data sessions, text messaging (e.g., Short Message Service (SMS) messaging), and the like.

Furthermore, the wireless communication between the SPN and a given mobile device is typically bidirectional in nature. The component of that communication that is sent from the SPN to the mobile device is described as being sent on what is known as the forward link, while the component that is sent from the mobile device to the SPN is described as being sent on what is known as the reverse link. On both links, the wireless communications are typically formatted in accordance with a wireless-communication protocol, one example type of which is code division multiple access (CDMA), where CDMA networks that operate according to industry specifications (IS) such as IS 95 and IS 2000 are often referred to as 1xRTT (or "1x") networks, where 1xRTT stands for Single Carrier Radio Transmission Technology.

Some SPNs operate in accordance with a particular type of CDMA protocol known as Evolution Data Optimized (EV DO). These SPNs are generally configured to operate according to one or more versions of IS 856, and are designed to provide high-rate packet-data service to access terminals using a technique on the forward link known as time-division multiplexing (TDM) and using what is essentially 1x technology on the reverse link. More generally, SPNs can be arranged to operate according to any of numerous other protocols, some examples of which are Long Term Evolution (LTE), Universal Mobile Telecommunications System (UMTS), WiMAX (IEEE 802.16), time division multiple access (TDMA), Global System for Mobile Communications (GSM), Wi Fi (IEEE 802.11), and the like. And certainly some SPNs are arranged to provide service in accordance with multiple protocols.

In typical SPNs, the entities with which mobile devices communicate over the air interface are known by terms such as base station and access node, terms that are used at different times in different ways to refer to different entities. For example, the term base station is sometimes used to refer simply to a device also known as a base transceiver station (BTS), which contains the hardware, antennas, and other components that cooperate to actually conduct the over-the-air communication with the mobile devices on behalf of the SPN. In LTE networks, a BTS is typically referred to as an eNodeB, which stands for Evolved Node B, named as being an evolved version of a Node B in a UMTS Terrestrial RAN (UTRAN). At times, however, the term base station or access node is used to refer in combination to (i) one or more BTSs and (ii) a device known as a base station controller (BSC) (or radio network controller (RNC)), which controls the BTS(s) and connects it (them) to the rest of the network and beyond.

The base stations for these networks are typically not associated with any subscriber or small group of subscribers in particular; rather, they are placed in publicly-accessible locations and are used by the provider's customers generally. These base stations collectively blanket large geographic areas with coverage; as such, they are referred to generally and herein as "macro-network base stations" or "macro base stations" and the network they collectively form, or to which they collectively belong, is referred to generally and herein as the "macro network."

Mobile devices and macro base stations conduct communication sessions (e.g. voice calls and data sessions) over what are known as carrier frequencies. Furthermore, macro base stations may provide service in a given coverage area on one carrier frequency, or on more than one carrier frequency. Mobile devices in the coverage area are configured to wirelessly communicate with the macro base station—and thus with the SPN—by tuning to at least one of the carrier frequencies on which the SPN provides service in the coverage area.

Procedures for initiating and managing wireless communication between macro base stations and mobile devices vary depending on the network architecture employed. Generally, coverage areas in the SPN emit pilot or reference signals to enable mobile devices to connect to such coverage areas. Mobile devices in the SPN regularly scan for such signals to identify coverage areas with which to connect, or to which to hand off. Thus, a mobile device may measure signal strengths of detected pilot signals and send a message that includes an indication of the measured signal strengths. The message may be received by a base station, and the SPN may then determine how to manage communication with the mobile device, such as whether to initiate a communication link, whether to instruct the mobile device and base stations to hand off an ongoing call, and so on. Such management determinations can be made by a centralized controller, such as an RNC in a CDMA system, or by distributed network controllers co-located with the base stations, such in an LTE system.

2. Femtocells

To address gaps in macro-network coverage (e.g., in buildings) and for other reasons, macro-network service providers may also offer devices referred to herein as femtocells. A typical femtocell may be approximately the size of a desktop phone or Wi-Fi access point, and is functionally a low-power, low-capacity version of a macro base station. A typical femtocell uses a normal power outlet, perhaps with a transformer providing a DC power supply. The femtocell may have a wired (e.g., Ethernet) or wireless (e.g. Wi-Fi) connection with the user's router, and would thus have connectivity to the Internet and/or one or more other packet-data networks. A femtocell may establish a virtual-private-network (VPN) connection over the Internet with an entity (e.g., a VPN terminator) on the macro-network provider's core network. The femtocell can then securely communicate with the VPN terminator and thereby communicate with other entities of the macro network.

A typical femtocell also has a wireless-communication interface configured to wirelessly communicate with mobile devices according to wireless protocols such as CDMA, LTE, and the like. The femtocell may act as a micro base station to provide local wireless coverage on the macro-network provider's network via the user's Internet connection. Typically, a femtocell will provide service on a single carrier frequency (or on a single carrier frequency per technology, where multiple technologies, such as CDMA and EV-DO, are supported). The femtocell will typically also transmit a pilot beacon, which includes administrative messages and parameters that mobile devices can use to connect with the femtocell. The pilot beacon may include information to facilitate a handoff of a mobile device from a macro base station to the femtocell. To inform mobile devices of the femtocell, the pilot beacon may be transmitted on one or more of the macro-network carrier frequencies on which the SPN provides service in that area.

OVERVIEW

As noted above, femtocells are designed to have low transmission-power capabilities, and consequently to provide coverage areas that are relatively limited in comparison with those of typical macro base stations. As examples, a typical femtocell may be designed to provide a coverage area that is the size of a dorm room, an apartment, a house, and so on. And along with limited transmission power, femtocells are also designed to have a relatively low capacity for serving mobile stations. For example, a femtocell may provide service on a single carrier frequency and have the capacity (e.g., channel elements) to provide service to up to five mobile devices at any given time, though any suitable number of channel elements (and/or femtocell carrier frequencies) may be used in a given implementation.

As described, femtocells typically emit a pilot beacon that includes administrative messages and parameters that mobile devices can use to facilitate handoffs from the macro network to the femtocell's carrier frequency. Thus, among the purposes of the femtocell's pilot beacon is to advertise the femtocell's carrier frequency in the femtocell's coverage area, such that mobile devices can opt to tune to that carrier frequency and communicate via the femtocell. As such, the femtocell transmits its pilot beacon on the one or more macro-network carriers in the surrounding area.

In particular, and typically after an initial auto-configuration process, a femtocell will transmit either what is known as and referred to herein as a "fixed" pilot beacon, or what is known as and referred to herein as a "frequency-hopping" pilot beacon. If the one or more macro base stations in the surrounding area all provide service on the same macro-network carrier frequency, the femtocell will transmit its pilot beacon on only that macro-network carrier frequency (i.e., a fixed pilot beacon). If, however, service is provided on multiple macro-network carrier frequencies by the surrounding macro network, the femtocell will cycle through those carrier frequencies, transmitting its pilot beacon on each macro-network carrier frequency for (typically) a fixed period of time (i.e., a frequency-hopping pilot beacon), such as a few hundred milliseconds or one or two seconds.

In the case of a frequency-hopping pilot beacon, the femtocell will typically transmit its pilot-beacon information on each macro-network carrier frequency in a set of macro-network carrier frequencies for a fixed amount of time, and then repeat. Thus, the overall cycle takes a finite amount of time, and the femtocell typically needs to spend some minimum amount of time on each carrier frequency. Taken together, this limits the total number of carriers on which the femtocell can transmit its pilot-beacon information each cycle to some upper-bound number of carrier frequencies. However, the total number of macro-network carrier frequencies on which service is provided by the surrounding macro network may exceed this upper bound. As such, the femtocell's pilot beacon may not hop to some macro-network carrier frequencies, which may cause mobile stations operating on those carrier frequencies to not be aware of the femtocell. And even if the femtocell frequency-hopping pilot beacon can and does hop on every macro-network carrier frequency on which service is provided in the surrounding area, mobile devices that are operating on macro-network carrier frequencies that are later in the repeated sequence may on average have to wait longer before being informed of the presence of the femtocell.

As such, to address these and other drawbacks of prior implementations, presently disclosed are systems and methods for dynamically configuring a femtocell pilot beacon based on macro-network load. In accordance with the present disclosure, a femtocell prioritizes certain macro-network carrier frequencies in its frequency-hopping pilot beacon. In particular, the femtocell prioritizes macro-network carrier frequencies based on macro-network loading.

In various different embodiments, the femtocell may prioritize a particular frequency by, for example, transmitting a frequency-hopping pilot beacon that hops on the particular frequency more often than on another frequency in at least one cycle of the frequency-hopping pilot beacon. Additionally or alternatively, the femtocell may prioritize the particular frequency by, for example, transmitting the frequency-hopping pilot beacon on the particular frequency for a longer cumulative duration as compared to one or more shorter cumulative durations during which the femtocell transmits the frequency-hopping pilot beacon on another frequency. Additionally or alternatively, the femtocell may prioritize the particular frequency by, for example, transmitting the frequency-hopping pilot beacon on the particular frequency at a greater transmission power as compared to transmission powers at which the femtocell transmits the frequency-hopping pilot beacon on another frequency. And certainly other manners of prioritizing could be used.

In some embodiments, the femtocell may prioritize transmission of its frequency-hopping pilot beacon on particular macro-network carrier frequencies according to the loading conditions on those carriers in the macro-network. For example, the femtocell and/or femtocell-control elements in the macro-network may determine the loading of macro-network carriers, identify a particular one of the macro-network carriers that is more heavily loaded than another one of the macro-network carriers, and then cause the femtocell to prioritize transmission on the particular one of the macro-network carriers as compared to the other one of the macro-network carriers. In some embodiments, the femtocell and/or femtocell-control elements in the macro-network may additionally or alternatively select a pilot-beacon-transmission pattern that prioritizes transmission on the macro-network carriers according to the determined loading of the macro-network carriers relative to one another, and then causes the femtocell to transmit the frequency-hopping pilot beacon according to the selected pilot-beacon-transmission pattern.

These as well as other aspects and advantages will become apparent to those of ordinary skill in the art by reading the following detailed description, with reference where appropriate to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Various exemplary embodiments are described herein with reference to the following drawings, in which like numerals denote like entities, and in which:

FIG. **1** depicts an example communication system.

FIG. **2** depicts an example mobile device.

FIG. **3** depicts an example femtocell base station.

FIG. **4**A depicts functions carried out in accordance with at least one embodiment.

FIG. **4**B depicts functions carried out in accordance with at least one embodiment.

FIG. **4**C depicts functions carried out in accordance with at least one embodiment.

DETAILED DESCRIPTION OF THE DRAWINGS

1. Introduction

The present systems and methods will now be described with reference to the figures. It should be understood, however, that numerous variations from the depicted arrangements and functions are possible while remaining within the scope and spirit of the claims. For instance, one or more elements may be added, removed, combined, distributed, substituted, re-positioned, re-ordered, and/or otherwise changed. Further, where this description refers to one or more functions being implemented on and/or by one or more devices, one or more machines, and/or one or more networks, it should be understood that one or more of such entities could carry out one or more of such functions by themselves or in cooperation, and may do so by application of any suitable combination of hardware, firmware, and/or software. For instance, one or more processors may execute one or more sets of programming instructions as at least part of carrying out of one or more of the functions described herein.

2. Example Architecture

A. Example Communication System

Referring now to the drawings, FIG. **1** is a simplified block diagram of an example cellular wireless communication system **100**. For purposes of explanation and example only, the wireless communication system **100** shown in FIG. **1** is generally arranged and described according to CDMA system architecture. It should be understood, however, that an LTE system architecture could be used instead or in addition, as could an architecture according to one or more other protocols mentioned herein and/or any others now known or later developed.

As shown in FIG. **1**, a communication system **100** includes a mobile device (MD) **102**, a macro BTS **104**, a BSC **106**, a mobile switching center (MSC) **108**, an SPN **110**, a gateway **112**, a packet-data network (PDN) **114**, femtocell (or femto base station (FBS)) **116**, a media gateway **118**, a VPN terminator (VPN-T) **120**, a femtocell controller **122**, a public switched telephone network (PSTN) **124**, and a femtocell switch **126**. And additional entities could be present as well, such as additional mobile devices in communication with BTS **104**, additional entities in communication with PDN **114** and/or PSTN **124**, etc. Also, there could be one or more devices and/or networks making up at least part of one or more communication links. For example, there could be one or more routers, cable modems, and/or other devices or networks on the link between femtocell **116** and PDN **114**. Mobile station **102** is described more fully in connection with FIG. **2**, while FBS **116** is described more fully in connection with FIG. **3**.

Service-provider network **110** may encompass all of the network elements depicted in FIG. **1** as being included in its dashed-cloud shape. In general, there may be more and/or different communication links among entities within SPN **110**, and there may be more and/or different connections between SPN **110** and outside entities. Furthermore, there may be a core packet network (not depicted) making up part of SPN **110**, which may enable devices therein to communicate with each other. There may also be one or more other packet-data networks and/or elements, one or more circuit-switched networks and/or elements, one or more signaling networks and/or elements, and/or one or more of any other suitable network(s) and/or element(s).

Gateway **112** may act as a network access server between (a) PDN **114** and (b)(i) BSCs such as BSC **106** and (ii) VPN terminators such as VPN terminator **120**, facilitating packet-data communication by mobile stations on PDN **114**, which may be the well-known global packet-data network generally referred to as the Internet, but could also be or include one or more other packet-data networks. PDN **114** may include one or more wide area networks, one or more local area networks, one or more public networks, one or more private networks, one or more wired networks, one or more wireless networks, and/or one or more networks of any other type. Devices in communication with PDN **114** may exchange data using a packet-switched protocol such as the Internet Protocol (IP), and may be identified by an address such as an IP address.

MG **118** may be arranged to (a) receive packet-based communications from entities on SPN **110**, convert those to circuit-switched communications, and pass them to MSC **108** and/or PSTN **124** and (b) receive circuit-switched communications from MSC **108** and/or PSTN **124**, convert those to packet-based communications, and pass them to entities on SPN **110**.

VPN terminator **120** may be arranged to establish secure VPN connections over PDN **114** with femtocells such as femtocell **116**, enabling the femtocells to securely communicate with devices on SPN **110** and beyond. Femtocell controller **122** may be arranged to communicate via VPN terminator **120** with femtocells such as femtocell **116**, perhaps to receive requests from various femtocells for configuration data, and to accordingly select various operational parameters for femtocells (e.g. carrier frequency, PN offset, whether to broadcast a pilot beacon, contents of any pilot beacon to be broadcast, transmission-power level), and to transmit those parameters to femtocells, perhaps along with other configuration data and messaging. Femtocell switch **126** may be arranged to act as a switch between MSC **108** and VPN terminator **120**, enabling mobile devices communicating via femtocells to engage in calls over PSTN **124** via MSC **108**. And certainly many other configurations are possible, as the described configuration is provided by way of example and not limitation.

B. Example Mobile Device

FIG. **2** depicts mobile device **102** as including a wireless-communication interface **130**, a user interface **132**, a processor **134**, and data storage **136**, all of which may be coupled together by a system bus, network, or other communication mechanism **138**.

Wireless-communication interface **130** may comprise one or more antennae and one or more chipsets for communicating with one or more base stations over respective air interfaces. As an example, one such chip set could be suited for LTE communication. As another example, one such chipset could be suited for CDMA communication. Wireless-communication interface **130** may also or instead be arranged to communicate according to one or more other types of wireless communication (e.g., protocols) mentioned herein and/or any others now known or later developed. User interface **132** may include one or more input devices such as a touchscreen, one or more buttons, a microphone, and the like for receiving inputs from users, as well as one or more output devices such as a display, one or more indicator lights, a speaker, and the like for communicating outputs to users.

Processor **134** may comprise one or more general-purpose processors and/or one or more special-purpose processors, and may be integrated in whole or in part with wireless-communication interface **130**. Data storage **136** may comprise one or more volatile and/or non-volatile storage components (such as magnetic, optical, flash, or other non-transitory storage), and may be integrated in whole or in part with processor **134**. And certainly other configurations are possible. Data storage **136** may contain program instructions executable by processor **134** for carrying out various mobile-device functions described herein.

C. Example Femtocell

FIG. **3** depicts an exemplary diagram of femtocell (or femto base station (FBS)) **116**, which includes a wireless-communication interface **150**, a GPS receiver **152**, a PDN interface **154**, a processor **156**, and data storage **160**, all of which may be coupled together by a system bus, network, or other communication mechanism **158**. Note that femtocell **116** could have additional and/or different components, and that this structure is provided by way of example.

Wireless-communication interface **150** may include one or more antennas, one or more chip sets, a set of one or more channel elements, and/or one or more other components suitable for providing a wireless coverage according to a wireless-communication protocol such as CDMA or LTE (and/or one or more other technologies). GPS receiver **152** may be any known or hereafter-developed GPS receiver, suitable for receiving and decoding GPS signals for location and timing purposes, perhaps among other purposes. In some embodiments, a femtocell may have a location module in addition to or instead of a GPS receiver.

PDN interface **154** may provide a (e.g., wired) packet-data interface for communicating with a device such as a router or cable modem, and in general for communicating over one or more packet-data networks such as PDN **114**. Processor **156** may comprise multiple (e.g., parallel) processors, such as a general purpose microprocessor and/or a discrete digital signal processor. The data storage **160** may take various forms, in one or more parts, such as a non-volatile storage block and/or a removable storage medium, and may contain program instructions executable by processor **156** for carrying out the femtocell functions described herein, as well as any other operational, configuration, and/or other type of data deemed suitable in a given femtocell implementation.

3. Example Operation

Mobile devices in communication with SPN **110** may be configured to scan the macro-network carrier frequencies used by SPN **110**, in order to identify coverage areas to which the mobile devices can connect. The femtocell **116** transmitting the frequency-hopping pilot beacon on the frequencies used as macro-network carriers allows mobile devices in range of the femtocell **116** to detect the frequency-hopping pilot beacon in the course of typical scanning operations.

In some arrangements, the femtocell **116** can be configured to identify carrier frequencies used in one or more coverage areas of the SPN **110** that are near the location of the femtocell **116**. The femtocell **116** may do so by using geographic location information derived from the GPS receiver **152** (or other location information, such as indicated by a Wi-Fi access point, router, cable modem, and/or the like) and then communicating with the femtocell controller **122** to identify frequencies used as macro-network carriers in coverage areas of the SPN **110** located near the femtocell **116**. The frequency-hopping pilot beacon can then be transmitted to hop on one or more of the identified frequencies.

As described above and as further described in the examples explained below, the femtocell **116** can be further configured to prioritize transmission of its frequency-hopping pilot beacon on particular ones of those macro-network carriers, relative to others. Prioritizing particular frequencies allows the femtocell **116** to more readily attract mobile devices operating on the prioritized frequencies.

Furthermore, prioritization can take different forms. For example, the frequency-hopping pilot beacon may be transmitted on only particular frequencies identified for prioritization. Additionally or alternatively, the frequency-hopping pilot beacon may be transmitted more often, with greater cumulative duration, and/or with greater power on particular frequencies identified for prioritization. And certainly other manners of prioritization could be used as well.

In general, and as used herein, the functional components that operate to prioritize particular frequencies in the frequency-hopping pilot beacon may be referred to herein as a femtocell system. The femtocell system may operate to dynamically identify particular frequencies for prioritization, select a suitable hopping pattern that prioritizes the particular frequencies, and then transmit the frequency-hopping pilot beacon according to the selected pattern. The femtocell system may include the femtocell **116** (e.g., via the processor **156** executing programming logic **162**) and/or network elements in the SPN **110**, such as the femtocell controller **122**, which operate alone or in combination to provide the functions described herein.

Example methods for identifying frequencies for prioritization according to macro-network loading conditions are described in connection with FIGS. **4**A-**4**C.

A. First Example Process

FIG. **4**A is a flowchart of an example process **400** that can be carried out by a femtocell system, such as the femtocell system described in connection with the communication system **100** of FIG. **1**. In particular, FIG. **4**A depicts a process **400** for a femtocell system to determine macro-network loading on each of a plurality of frequencies, determine that one of the frequencies is more heavily loaded than another, and prioritize transmissions of its frequency-hopping pilot beacon on the more heavily loaded frequency. The process **400** thereby causes the femtocell **116** to prioritize frequencies of the frequency-hopping pilot beacon according to the relative loading on the frequencies in the macro network.

As shown in FIG. **4**A, the process **400** begins at block **405**, when femtocell **116** transmits a frequency-hopping pilot beacon among a plurality of frequencies. At block **410**, the femtocell system determines the macro-network loading on each of the frequencies. At block **415**, the femtocell system determines that a particular one of the frequencies is more heavily loaded than another one of the frequencies. At block **420**, the femtocell system prioritizes transmission of the frequency-hopping pilot beacon on the particular one of the frequencies as compared to the other one identified in block **415**. The steps are more fully explained below.

i. Transmit a Frequency-Hopping Pilot Beacon

At block **405**, femtocell **116** begins transmitting a frequency-hopping pilot beacon among a plurality of frequencies. The frequency-hopping pilot beacon transmitted by the femtocell **116** repeatedly cycling through transmitting pilot-beacon information on each frequency in a group of frequencies. The femtocell system can cause the pilot beacon to cyclically hop among multiple macro-network carriers for coverage areas of the SPN **110** in the vicinity of the femtocell **116**. For example, the frequency-hopping pilot beacon can be transmitted on macro-network carriers that are retrieved, for example, from a licensee database maintained by the FCC based on a current location of the femtocell **116**. Alternatively, a group of frequencies could be retrieved from a cell site database (not shown) accessible by the femtocell controller **122** within the SPN **110**. Other methods could also be used to identify a group of frequencies on which to transmit the frequency-hopping pilot beacon, including methods that are automatically undertaken upon startup of the femtocell **116** as part of an auto-configuration routine.

Mobile devices **102** served by a macro-network carrier may detect the frequency-hopping pilot beacon and send a request to the femtocell **116** and/or SPN **110** to handoff from their current coverage area to the femtocell's coverage area. Such a request may be generated by the mobile device **102** for any number of reasons, including a reduction in signal strength of the mobile device's current serving signal, for example. To facilitate this detection process, the mobile device **102** may monitor signal conditions (e.g., carrier-to-interference (C/I) ratio and/or a signal-to-interference-plus-noise ratio (SINR)) on a plurality of macro-network carriers to detect pilot signals and/or pilot beacons from a combination of macro-network coverage areas and/or femtocell coverage areas. The mobile device **102** may then select, request, and receive service in the coverage area with the best signal conditions (i.e., the "strongest" coverage area) and/or based on one or more other criteria deemed suitable in a given implementation.

ii. Determine Macro-Network Loading

At block **410**, the femtocell system determines macro-network loading on each of the frequencies used by the macro-network, or a subset of such frequencies used by coverage areas in the vicinity of the femtocell **116**. The macro-network loading refers to the amount of network traffic on the SPN **110** that is conveyed over each frequency (i.e., each macro-network carrier). Determining the macro-network loading may include determining the amount of data traffic communicated on each of the frequencies and/or the available capacity (e.g., available bandwidth) of each frequency. Additionally or alternatively, determining the macro-network loading may include determining a number of mobile devices served by each of the frequencies. Such loading determinations may be made for particular coverage areas of the SPN **110**, such as coverage areas in the vicinity of the femtocell **116**.

The loading on each frequency may be estimated according to information tracked by network elements within the SPN **110**. That is, network control components, such as a radio network controller (RNC) and the like, may keep track of wireless traffic conditions on the SPN **110** and at least temporarily store indications of such traffic conditions. For example, the SPN **110** may store indications of network loading on the frequencies used by the SPN **110** to provide service to mobile devices (i.e., the macro-network carriers). The indications of network loading may be updated intermittently (e.g., periodically) and may include indications of the number of mobile devices being served on each frequency and/or the bandwidth being used to serve such mobile devices. Additionally or alternatively, loading information can be estimated according to information obtained by intermittent diagnostics and the like performed by the SPN **110** at any given time or over a given duration. Moreover, the SPN **110** may keep track of loading on particular coverage areas of the SPN **110**.

In some embodiments, the macro-network loading may be determined according to the then-current indication(s) of loading on each frequency (e.g., according to the most recent update of such information). The loading may also be determined according to more than one indication(s) of loading on each frequency, including some that are not the most current, such as an example that estimates network loading according to a running median or average of the N most recent updates of loading information, where N is greater than one.

In some embodiments, the SPN **110** and/or femtocell **116** may estimate the network loading of the SPN **110** at the specific location of the femtocell **116**. For example, location information based on the GPS receiver **152** in the femtocell **116** may be used to identify coverage areas in the vicinity of the femtocell **116** and the loading can be estimated for such coverage areas. Additionally or alternatively, the network loading on each frequency may be estimated at the femtocell **116** by measuring signal strengths of incident RF signals at each of the frequencies. The signal strengths can be due to network activity of the SPN **110** on each frequency. Thus, the measured signal strengths can then be associated with estimates of network loading, such as by a relationship that correlates received power from the RF signals with macro-network loading. And numerous other ways of determining loading may be used instead or in addition, as known to those of skill in the art.

iii. Determine that a Particular Frequency is More Heavily Loaded than Another One

At block **415**, the femtocell system determines that a particular one of the frequencies is more heavily loaded than another one of the frequencies. For example, the macro-network loading of each of the frequencies determined in block **410** can be compared with one another. Based on the comparison, one of the frequencies that is more heavily loaded than another one can be identified. That is, a frequency that carries a relatively greater amount of network traffic than another one can be identified.

In some examples, the particular frequency identified can be the one that is most heavily loaded, relative to the others. Block **415** may therefore include determining the frequency that carries (or is currently carrying) the most network traffic.

Moreover, some embodiments of the present disclosure may include identifying a plurality of frequencies with relatively greater loading than others. Some embodiments may include identifying the top M most heavily loaded frequencies, where M is a number greater than one. For example, the frequencies can be sorted, in order, according to the macro-network loading of each frequency determined in block **410**, and identifying the top M frequencies on the sorted list.

iv. Prioritize Transmission of the Frequency-Hopping Pilot Beacon on the More Heavily Loaded Frequency

At block **420**, the femtocell system prioritizes transmission of the frequency-hopping pilot beacon on the particular one of the frequencies as compared to the other one. Once the femtocell system has determined the particular frequency (or frequencies) that are more heavily loaded than others, the femtocell **116** may use that information in subsequent cycles of its frequency-hopping pilot beacon to prioritize the particular frequency (or frequencies) as compared to others.

The femtocell **116** may prioritize a particular frequency by transmitting the frequency-hopping pilot beacon on the particular frequency more often than others in at least one subsequent cycle of the frequency-hopping pilot beacon. In an example in which the frequency-hopping pilot beacon is transmitted in a cyclic pattern, the femtocell **116** may transmit (hop) on the particular frequency more than once during a given cycle in which the femtocell transmits (hops) on the other frequencies only once. Additionally or alternatively, in a given cycle of the frequency-hopping pilot beacon, the femtocell **116** may transmit on the particular frequency for a longer continuous duration as compared to shorter continuous durations in which the femtocell **116** transmits on another frequency. Additionally or alternatively, in a given cycle of the frequency-hopping pilot beacon, the femtocell **116** may transmit on the first carrier for a longer cumulative duration as compared to shorter cumulative durations in which the femtocell **116** transmits on another frequency. Additionally or alternatively, in a given cycle of the frequency-hopping pilot beacon, the femtocell **116** may transmit on the particular frequency with a relatively greater transmission power than a transmission power with which the femtocell **116** transmits on another frequency.

For example, the femtocell **116** may transmit its frequency-hopping pilot beacon on one or more of five different frequencies F**1**, F**2**, F**3**, F**4**, and F**5**. Without prioritizing carriers, the femtocell **116** may cycle through frequencies F**1**-F**5**, transmitting its pilot beacon on each of those frequencies for a fixed period of time (i.e., a conventional frequency-hopping pilot beacon), such as for a few hundred milliseconds or one to four seconds, before cycling back to the beginning of the list. However, according to some embodiments disclosed herein, the femtocell **116** and/or SPN **110** may cause the femtocell **116** to prioritize transmission of a particular one of the frequencies F**1**-F**5** based on the relative macro-network loading of the frequencies F**1**-F**5**. The femtocell system may determine, for example, that the frequency F**1** is more heavily loaded than at least one other frequency (e.g., in block **415**). The femtocell **116** can then prioritize F**1** relative to the other frequencies F**2**-F**5** during subsequent transmissions of the frequency-hopping pilot beacon.

Upon prioritizing the carrier F**1**, the femtocell **116** may transmit its frequency-hopping pilot beacon on carrier F**1** more often than another frequency, during a given cycle. For example, the femtocell **116** may transmit its pilot beacon in the following order: F**1**→F**2**→F**3**→F**1**→F**4**, before repeating the cycle again. In the next cycle, the femtocell **116** may transmit on the same frequencies again, or may include other remaining carriers. For example, in the next cycle, the femtocell **116** may transmit its pilot beacon in the following order: F**1**→F**2**→F**3**→F**1**→F**5**.

By transmitting on the higher priority frequency more often in a given cycle, the femtocell **116** is more likely to be transmitting its pilot beacon to a mobile device **102** in the region during its respective slot cycle, in which the mobile device **102** scans for coverage areas to connect with. In subsequent cycles of the frequency-hopping pilot beacon, the order of frequencies may be switched in order to allow for mobile stations **102** having varying slot cycles an opportunity to receive the frequency-hopping pilot beacon. For example, a subsequent cycle in which frequency F**1** is still prioritized may take the form of: F**2**→F**3**→F**1**→F**5**→F**1**, before repeating the cycle again. In other embodiments, the femtocell **116** may not be limited to five frequencies, and more or less than five frequencies could be used in each cycle. Additionally or alternatively, the femtocell **116** may prioritize more than one frequency at a time. For example, the femtocell may prioritize both carriers F**1** and F**2** by transmitting its pilot beacon in the following manner: F**1**→F**2**→F**3**→F**1**→F**2**, before repeating the cycle again. Other orders could also be used.

Additionally or alternatively, the femtocell **116** may prioritize the carrier F**1** by transmitting its frequency-hopping pilot beacon on carrier F**1** for a longer continuous duration as compared to a continuous duration in which the femtocell **116** transmits on one or more of the other frequencies F**2**-F**5**. For example, the femtocell **116** may transmit its pilot beacon in the following order and for the following times: F**1** (3.84 s)→F**2** (2 s)→F**3** (2 s)→F**4** (2 s)→F**5** (2 s), before repeating the cycle. Similar to the above, in subsequent cycles of the frequency-hopping pilot beacon, the order of frequencies may be switched in order to allow for mobile devices having varying slot cycles an opportunity to receive the pilot beacon. For example, a subsequent cycle in which carrier F**1** is still prioritized may take the form of: F**2** (2 s)→F**3** (2 s)→F**4** (2 s)→F**1** (3.84 s)→F**5** (2 s), before repeating the cycle again. Additionally or alternatively, the femtocell **116** may prioritize more than one carrier at a time. For example, the femtocell **116** may prioritize both carriers F**1** and F**2** by broadcasting its pilot beacon in the following manner: F**1** (3.84 s)→F**2** (3.84 s)→F**3** (1.4 s)→F**4** (1.4 s)→F**5** (1.4 s).

Additionally or alternatively, the femtocell **116** may prioritize the frequency F**1** by transmitting on the frequency F**1** for a greater cumulative duration as compared to a cumulative duration in which the femtocell **116** transmits on another one of the frequencies F**2**-F**5**. For example, the femtocell **116** may transmit its pilot beacon in the following order and for the following times: F**1** (1.4 s)→F**2** (2 s)→F**1** (1.4 s)→F**3** (2 s)→F**1** (1.4 s)→F**4** (2 s)→F**1** (1.4 s)→F**5** (2 s), before repeating the cycle. Similar to the above, in subsequent cycles of the frequency-hopping pilot beacon, the order of frequencies may be switched in order to allow for mobile devices having varying slot cycles an opportunity to receive the pilot beacon, and moreover the femtocell **116** may prioritize more than frequency at a time.

Additionally or alternatively, the femtocell **116** may prioritize the frequency F**1** by transmitting on the frequency F**1** with a transmission power P_{high} greater than a transmission power P_{low} with which the femtocell **116** transmits on one or more of the other frequencies F**2**-F**5**. For example, the femtocell **116** may transmit its pilot beacon in the following order and at the following transmission powers: F**1** (P_{high})→F**2** (P_{low})→F**3** (P_{low})→F**4** (P_{low})→F**5** (P_{low}), before repeating the cycle. Similar to the above, in subsequent cycles of the frequency-hopping pilot beacon, the order of frequencies may be switched in order to allow for mobile devices having varying slot cycles an opportunity to receive the pilot beacon, and moreover the femtocell may prioritize more than frequency at a time.

Other possibilities exist for prioritizing frequencies, including combinations of the above techniques for prioritizing one or more of the frequencies relative to others, which were described separately for convenience in explanation only. For example, the femtocell may prioritize transmission by selecting a hopping pattern that prioritizes one or more frequencies by providing a combination of number of hops per cycle, cumulative and/or continuous transmission durations, and/or transmission power for one or more prioritized frequencies that results in the pilot beacon being more readily detectable at the one or more prioritized frequencies than at the other frequencies.

Prioritizing the particular frequency allows mobile devices operating on the frequency in the SPN **110** to detect the femtocell **116** faster and/or from a greater range. The femtocell **116** can thus preferentially attract mobile devices operating on the frequency and thereby assist the SPN **110** in handling network traffic by preferentially absorbing (offloading) network traffic from the most heavily loaded macro-network carriers.

B. Second Example Process

FIG. **4**B is a flowchart of another example process **401**. In the process **401**, the femtocell system (e.g., the femtocell **116** and/or SPN **110**) operates according to blocks **405**, **410**, and **415**, but before carrying out block **420** to prioritize the frequency identified in block **415**, the identified frequency is compared with a threshold level, at block **417**. If the macro-network loading of the frequency identified in block **415** does not exceed the threshold level, the process **401** returns to block **405** to continue transmitting without adjusting the prioritization of the frequency-hopping pilot beacon. If the loading does exceed the threshold level, the process **401** continues to block **420** to adjust the prioritization of the frequency-hopping pilot beacon so as to prioritize the frequency identified in block **415**.

The threshold level the macro-network loading is compared to in block **417** can be specified as an absolute threshold level (e.g., an absolute macro-network loading requirement). Alternatively the threshold in block **417** can be specified as a relative threshold level (e.g., a relative difference in macro-network loading between different ones of the frequencies).

The threshold level in block **417** may be dynamically adjusted according to macro-network loading, such as according to total macro-network loading and/or macro-network loading of coverage areas in the vicinity of the femtocell **116**, for example. For example, the threshold in block **417** may be set to specify that identified frequencies are only prioritized in block **420** if the macro-network loading on such frequencies is at least beyond a threshold capacity (e.g., exceeding a percentage of available bandwidth on the particular macro-network carrier). Moreover, the threshold specified by block **417** may be adjusted or even turned off (i.e., set to zero) on a dynamic basis by the femtocell system according to, for example, overall traffic on the SPN **110**. For example, the threshold in block **417** can be adjusted so as to cause the femtocell **116** to begin offloading traffic from loaded frequencies of the macro-network as the macro-network approaches a peak traffic condition. In some embodiments, the threshold block **417** can be used to cause the femtocell **116** to offload macro-network traffic only when the macro-network approaches and/or reaches a peak traffic condition.

Further still, the femtocell system may adjust its frequency-hopping pilot beacon according to the available capacity on the femtocell **116**. For example, when the femtocell **116** is being used to serve traffic that exceeds a threshold level (e.g., based on number of calls, number of devices, and/or data carried) the femtocell system may cause the femtocell **116** to decrease its frequency-hopping pilot beacon so as to attract fewer mobile devices to the femtocell **116**. In some examples, the femtocell system may even turn off the frequency-hopping pilot beacon based on the available capacity of the femtocell **116**.

Additionally or alternatively, the loading (or available capacity) of the macro-network and/or femtocell **116** may be used by the femtocell system to selectively activate one or more additional femtocells in the vicinity of the femtocell **116**. For example, in the event that both the femtocell **116** and the nearest macro-network coverage areas are loaded beyond their respective threshold levels at the same time, the femtocell system (e.g., the femtocell controller **122**) can operate to activate an additional femtocell in the general geographic vicinity of the femtocell **116**, and thereby offload additional traffic from the macro network and/or femtocell **116**.

C. Third Example Process

FIG. **4**C is a flowchart of another example process **402**. In the process **402**, the femtocell system (e.g., the femtocell **116** and/or SPN **110**) operates according to blocks **405** and **410**. After the macro-network loading of each frequency is determined in block **410**, the femtocell system selects, in block **425**, a pilot beacon transmission pattern that prioritizes transmission on the frequencies according to the determined loading of the frequencies relative to one another. In block **430**, the femtocell system then causes the femtocell **116** to transmit the frequency-hopping pilot beacon according to the pattern selected in block **425**.

In block **425**, a pilot beacon transmission pattern may be selected that provides a transmission sequence specifying one or more of transmission frequency, duration, transmission power for the frequency-hopping pilot beacon. For example, the selected frequency hopping transmission pattern may specify an ordered sequence for a cycle of the frequency-hopping pilot beacon that specifies transmission parameters for each frequency for which loading was determined in block **410**. The frequency hopping transmission pattern may specify transmission parameters that prioritize one or more of the frequencies relative to others. The one or more frequencies to prioritize may be determined according to the macro-network loading is determined in block **410**. The one or more frequencies may be more heavily loaded ones of the frequencies, relative to others, and may be the most heavily loaded ones of the frequencies.

A variety of possibilities exist for prioritizing frequencies, including any of those discussed in connection with block **415** above, and combinations thereof. For example, the selected frequency hopping transmission pattern may prioritize transmission by providing a combination of number of hops per cycle, cumulative and/or continuous transmission durations, and transmission power for one or more prioritized frequencies that results in the pilot beacon being more readily detectable at the one or more prioritized frequencies than at the other frequencies.

The frequency hopping transmission pattern selected in block **425** may be dynamically generated by the femtocell system according to macro-network loading on the different frequencies relative to one another as determined in block **410**. The various transmission parameters specified by the transmission pattern (e.g., power, duration, and the like) can be selected so as to assign desired degrees of prioritization to one or more of the frequencies, which can be determined on the basis of the macro-network loading on those frequencies relative to one another as determined in block **410**. As used herein, the degree of prioritization may refer, in general, to the likelihood of a mobile device in range of the femtocell **116** detecting the frequency-hopping pilot beacon on a particular frequency, which likelihood of detection is greater for more highly prioritized frequencies (due to transmissions being more often, for greater durations, and/or at higher power).

Alternatively, the transmission pattern selected in block **425** can be chosen from among a group of predetermined transmission patterns. For example, the femtocell system can store a group of predetermined transmission patterns which provide varying degrees of prioritization of the different frequencies relative to one another. The femtocell system can then select one of the predetermined transmission patterns based on a desired amount of prioritization to assign to one or more of the frequencies, which can be determined on the basis of the macro-network loading on those frequencies relative to one another as determined in block **410**.

4. Alternatives

In some examples, the transmission pattern of the frequency-hopping pilot beacon can be chosen based in part on characteristics of mobile devices served by the femtocell **116**. In an example where particular mobile devices are registered with the femtocell **116** (e.g., users of the femtocell **116** included on a “white list”), a hopping pattern can be based in part on substantially unique identifiers associated with such particular mobile devices. For example, a hopping pattern can be deduced in part from a hashing algorithm applied to mobile directory numbers (MDNs) of such registered mobile devices. Embodiments using such a hashing algorithm may advantageously align subsequent hopping cycles on particular frequencies with frequencies favored by registered mobile devices, which may determine scanning frequencies for their slot cycles according to a similar hashing algorithm.

In some embodiments, the femtocell **116** may continue transmitting in the manner set forth above for an indeterminate amount of time. Alternatively, the femtocell **116** can intermittently re-determine the prioritization, and modify the transmission of the frequency-hopping pilot beacon accordingly, which is indicated by the dashed line in FIGS. **4**A-**4**C. Therefore, processes **400-402** disclosed herein may include updating the prioritization of the frequency-hopping pilot beacon according to updated network loading information after an initial prioritization. The femtocell **116** and/or SPN **110** may determine updated particular one(s) of the frequencies to prioritize in subsequent transmissions of the frequency-hopping pilot beacon based on the particular one(s) being more heavily loaded than others. Such updated prioritization can be determined according to updated network loading information. For example, the femtocell **116** and/or SPN **110** may re-determine prioritization of the frequency-hopping pilot beacon before every pilot beacon transmission cycle. Other timings could also be used.

The processes **400-402** disclosed herein may be used to allow the femtocell **116** to dynamically adjust its hopping pattern according to current loading on the macro-network. The processes **400-402** may allow the femtocell **116** to preferentially off-loading network traffic from the SPN **110** that is on the most-heavily loaded macro-network carriers. When operating according to the processes **400-402**, the femtocell **116** may thereby assist the SPN **110** in handling peak traffic conditions, for example. Toward that end, some embodiments of the present disclosure may include causing the femtocells to operate in accordance with the processes **400-402** disclosed herein during peak traffic conditions, and/or during times of the day when peak conditions are expected to occur.

In some embodiments discussed herein, the femtocell **116** can be a first base station that provides service to mobile devices on a first frequency (e.g., an RF carrier used by the femtocell **116** to communicate with the mobile device **102**). Similarly, the transceiver stations of the SPN **110** (e.g., BTSs **104**, BSCs **106**, and/or eNBs) can be considered a group of second base stations that provide service to mobile device on a plurality of second frequencies (e.g., macro-network carriers used to communicate between the SPN **110** and mobile devices).

5. Conclusion

While some example embodiments have been described above, those of ordinary skill in the art will appreciate that numerous changes to the described embodiments could be made without departing from the scope and spirit of the claims.

What is claimed is:

1. A method of operating a wireless network system, wherein the wireless network system includes a first base station operating on a first base station frequency to serve mobile devices, and one or more second base stations operating on a plurality of second base station frequencies, the method comprising:

the first base station transmitting a frequency-hopping pilot beacon among the plurality of second base station frequencies;

determining loading on each of the second base station frequencies;

determining, based on the determined loading, that a particular one of the second base station frequencies is more heavily loaded than another one of the second base station frequencies; and

responsive to determining that the particular one of the second base station frequencies is more heavily loaded than the other one of the second base station frequencies, prioritizing transmission of the frequency-hopping pilot beacon on the particular one of the second base station frequencies as compared to the other one of the second base station frequencies, wherein the prioritizing transmission includes:

selecting a pilot beacon transmission pattern that prioritizes transmission on the second base station frequencies according to the determined loading of the second base station frequencies relative to one another and causing the first base station to transmit the frequency-hopping pilot beacon according to the selected pilot beacon transmission pattern, and

wherein the selected pilot beacon transmission pattern defines a sequence of hopping among the second base station frequencies such that, during a transmission cycle in which the frequency-hopping pilot beacon is transmitted on each of the plurality of second base station frequencies, the first base station transmits, on one or more of the second base station frequencies that are more heavily loaded than others of the second base station frequencies, for a greater cumulative duration than a cumulative duration in which the first base station transmits on the others of the plurality of second base station frequencies.

2. The method of claim **1**, further comprising:

based on the determined loading, determining that the particular one of the second base station frequencies is loaded beyond a threshold level, and

wherein the prioritizing transmission is further responsive to determining that the particular one of the second base station frequencies is loaded beyond the threshold level.

3. The method of claim **1**, further comprising dynamically adjusting the frequency-hopping pilot beacon according to loading on the second base station frequencies by repeatedly carrying out the following functions:

determining updated loading on each of the second base station frequencies;

selecting an updated pilot beacon transmission pattern that prioritizes transmission on the second base station frequencies according to the determined updated loading of the second base station frequencies relative to one another; and

causing the first base station to transmit the frequency-hopping pilot beacon according to the selected updated pilot beacon transmission pattern.

4. The method of claim **1**,

wherein transmitting the frequency-hopping pilot beacon includes repeatedly cycling through transmitting on each of the plurality of second base station frequencies, and

wherein the prioritizing transmission includes, during at least one of the repeated cycles of the frequency-hopping pilot beacon, transmitting on the particular one of the second base station frequencies for a greater cumulative duration than a cumulative duration in which the frequency-hopping pilot beacon is transmitted on the other one of the second base station frequencies.

5. The method of claim **1**,

wherein transmitting the frequency-hopping pilot beacon includes repeatedly cycling through transmitting on each of the plurality of second base station frequencies, and

wherein the prioritizing transmission includes, during at least one of the repeated cycles of the frequency-hopping pilot beacon, transmitting on the particular one of the second base station frequencies with a greater transmission power than a transmission power with which the frequency-hopping pilot beacon is transmitted on the other one of the second base station frequencies.

6. The method of claim **1**,

wherein transmitting the frequency-hopping pilot beacon includes repeatedly cycling through transmitting on each of the plurality of second base station frequencies; and

wherein the prioritizing transmission includes, during at least one of the repeated cycles of the frequency-hopping pilot beacon, transmitting more often on the particular one of the second base station frequencies than the frequency-hopping pilot beacon is transmitted on the other one of the second base station frequencies.

7. The method of claim **1**, wherein the determining loading on each of the second base station frequencies includes, for each of the second base station frequencies:

determining a signal strength of the second base station frequency; and

determining the loading of the second base station frequency based on the determined signal strength.

8. The method of claim **1**, wherein the determining loading on each of the second base station frequencies includes receiving data indicating the loading on each of the second base station frequencies.

9. A wireless network system comprising:

a first base station including (i) an internet interface, and (ii)

one or more antenna structures; and

a controller,

wherein the internet interface is configured to communicate with a network,

wherein the one or more antenna structures are configured to (i) transmit a frequency-hopping pilot beacon among a plurality of second base station frequencies, and (ii) wirelessly communicate, on a first base station frequency, with mobile devices served by the first base station to thereby link the mobile devices served by the first base station to the network via the internet interface, and

wherein the controller is configured to (i) determine loading on each of the second base station frequencies, (ii) determine, based on the determined loading, that a particular one of the second base station frequencies is more heavily loaded than another one of the second base station frequencies, (iii) responsive to determining that the particular one of the second base station frequencies is more heavily loaded than the other one of the second base station frequencies, prioritize transmission of the frequency-hopping pilot beacon on the particular one of the second base station frequencies as compared to the other one of the second base station frequencies, wherein the controller is configured to prioritize transmission by selecting a pilot beacon transmission pattern that prioritizes transmission on the second base station frequencies according to the determined loading of the second base station frequencies relative to one another and causing the first base station to transmit the frequency-hopping pilot beacon according to the selected pilot beacon transmission pattern, and

wherein the selected pilot beacon transmission pattern defines a sequence of hopping among the second base station frequencies such that, during a transmission cycle in which the frequency-hopping pilot beacon is transmitted on each of the plurality of second base station frequencies, the first base station transmits, on one or more of the second base station frequencies that are more heavily loaded than others of the second base station frequencies, for a greater cumulative duration than a cumulative duration in which the first base station transmits on the others of the second base station frequencies.

10. The wireless network system of claim **9**,

wherein the controller is further configured to determine, based on the determined loading, that the particular one of the second base station frequencies is loaded beyond a threshold level, and

wherein the controller is further configured such that the transmission of the frequency-hopping pilot beacon on the particular one of the second base station frequencies is further responsive to determining that the particular one of the second base station frequencies is loaded beyond the threshold level.

11. The wireless network system of claim **9**,

wherein the first base station is configured to transmit the frequency-hopping pilot beacon via the one or more antenna structures by repeatedly cycling through transmitting on each of the plurality of second base station frequencies, and

wherein the controller is configured to prioritize transmission by, during at least one of the repeated cycles of the frequency-hopping pilot beacon, causing the first base station to transmit on the particular one of the second base station frequencies for a greater cumulative duration than a cumulative duration in which the frequency-hopping pilot beacon is transmitted on the other one of the second base station frequencies.

12. The wireless network system of claim **9**,

wherein the first base station is configured to transmit the frequency-hopping pilot beacon via the one or more antenna structures by repeatedly cycling through transmitting on each of the plurality of second base station frequencies, and

wherein the controller is configured to prioritize transmission by, during at least one of the repeated cycles of the frequency-hopping pilot beacon, causing the first base station to transmit on the particular one of the second base station frequencies with a greater transmission power than a transmission power with which the frequency-hopping pilot beacon is transmitted on the other one of the second base station frequencies.

13. The wireless network system of claim **9**,

wherein the first base station is configured to transmit the frequency-hopping pilot beacon via the one or more antenna structures by repeatedly cycling through transmitting on each of the plurality of second base station frequencies, and

wherein the controller is configured to prioritize transmission by, during at least one of the repeated cycles of the frequency-hopping pilot beacon, causing the first base station to transmit more often on the particular one of the second base station frequencies than the frequency-hopping pilot beacon is transmitted on the other one of the second base station frequencies.

14. The wireless network system of claim **9**,

wherein the controller is configured to determine the loading on each of the second base station frequencies by, for each of the second base station frequencies: (i) determining a signal strength of the second base station frequency, and (ii) determining the loading of the second base station frequency based on the determined signal strength.

15. A method of operating a wireless network system, wherein the wireless network system includes a first base station operating on a first base station frequency to serve mobile devices, and one or more second base stations operating on a plurality of second base station frequencies, the method comprising:

the first base station transmitting a frequency-hopping pilot beacon among the plurality of second base station frequencies;

determining loading on each of the second base station frequencies;

selecting a pilot beacon transmission pattern that prioritizes transmission on the second base station frequencies according to the determined loading of the second base station frequencies relative to one another, wherein the selected pilot beacon transmission pattern defines a sequence of hopping among the second base station frequencies such that, during a transmission cycle in which the frequency-hopping pilot beacon is transmitted on each of the plurality of second base station frequencies, the first base station transmits, on one or more of the second base station frequencies that are more heavily loaded than others of the second base station frequencies, for a greater cumulative duration than a cumulative duration in which the first base station transmits on the others of the plurality of second base station frequencies; and

causing the first base station to transmit the frequency-hopping pilot beacon according to the selected pilot beacon transmission pattern.

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