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Zhu

(54) **LOW POWER NARROWBAND OPERATION BY AN ENDPOINT**

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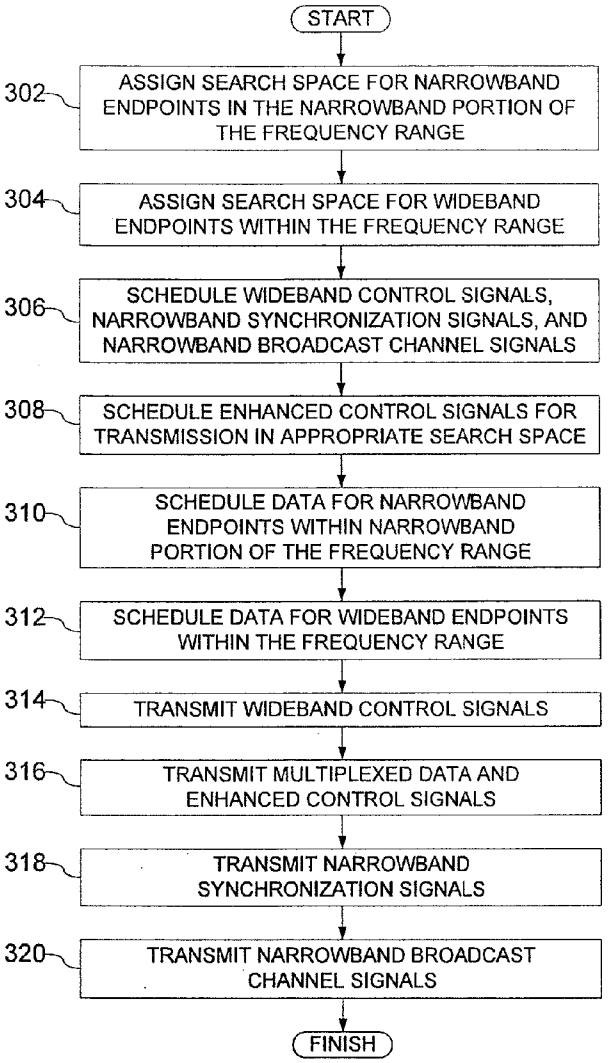
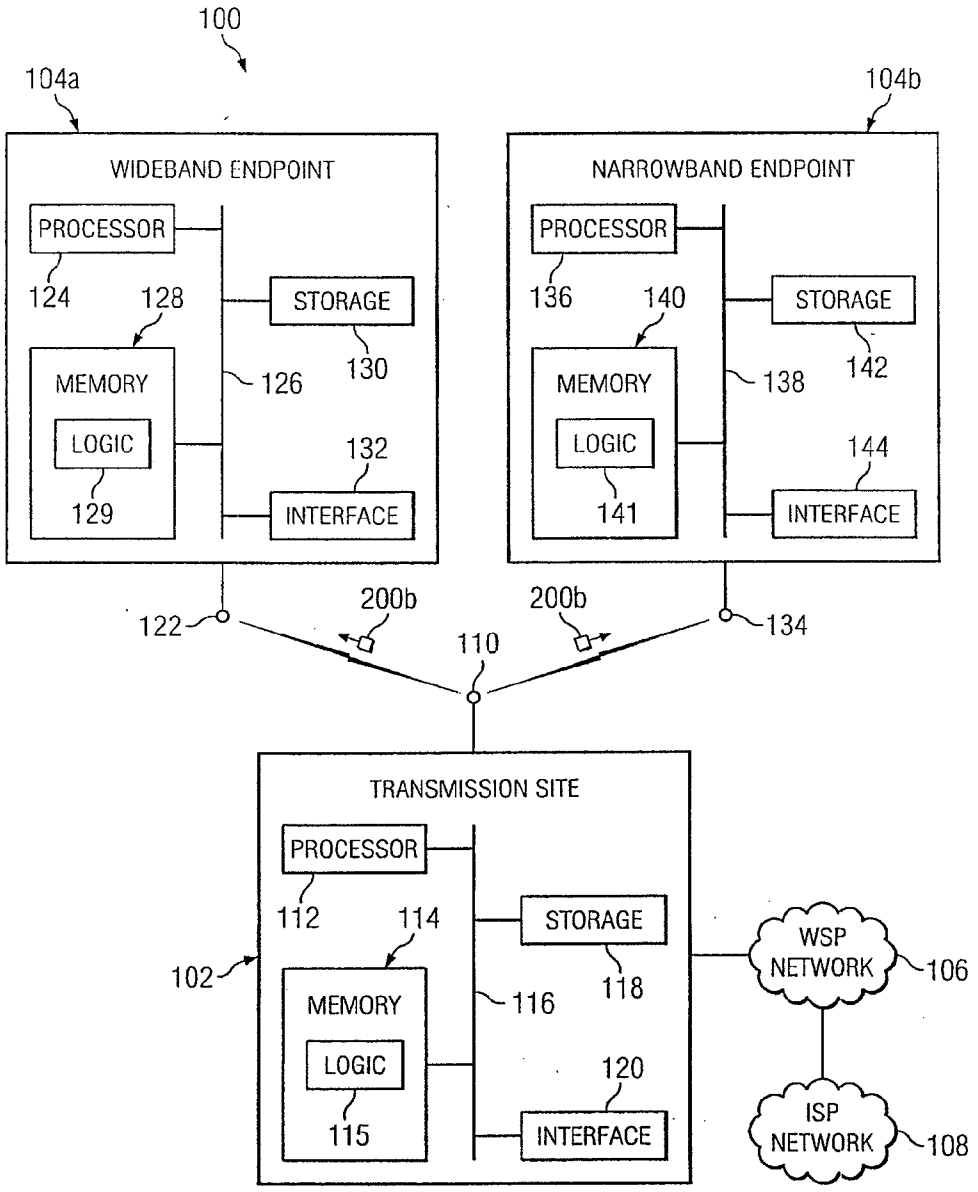
USPC **370/312**

(57) **ABSTRACT**

According to one embodiment, a method includes receiving a communication from a transceiver. An endpoint searches a search space for one or more control signals addressed to the endpoint. The search space includes one or more subcarrier frequencies of the plurality of subcarrier frequencies that are located within the narrowband portion of the frequency range and no subcarrier frequencies located outside the narrowband portion of the frequency range. The endpoint decodes at least one control signal addressed to the endpoint and transmitted using at least subcarrier frequency of the search space. The at least one decoded control signal indicates at least one time and at least one set of subcarrier frequencies of the plurality of subcarrier frequencies used to transmit at least one data signal of the communication to the endpoint. The method further includes recovering, by the endpoint, the at least one data signal transmitted to the endpoint.

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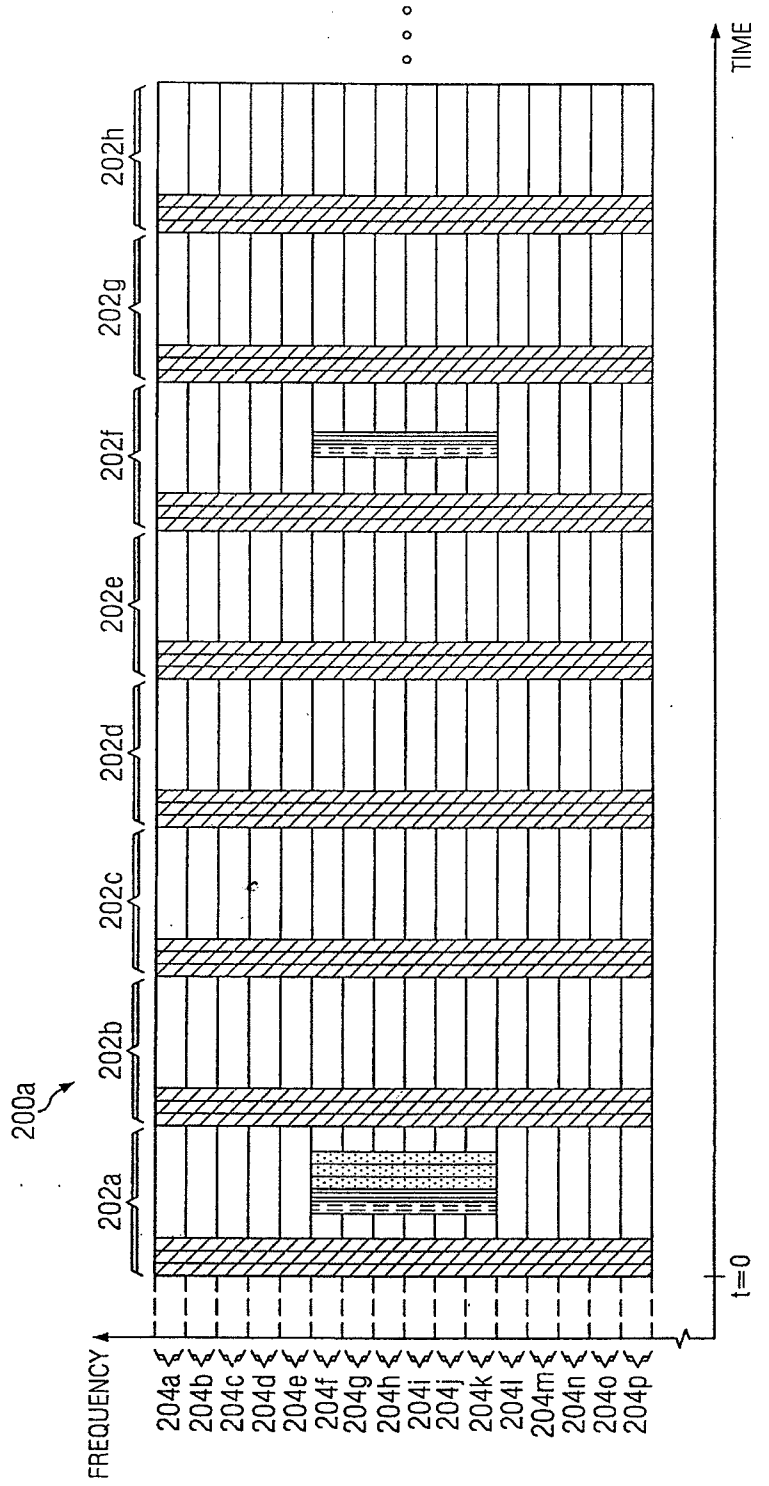
104a
104b
WIDEBAND ENDPOINT
NARROWBAND ENDPOINT
PROCESSOR
124
128
STORAGE
130
MEMORY
126
LOGIC
129
132
INTERFACE
PROCESSOR
136
140
STORAGE
142
MEMORY
138
LOGIC
141
144
INTERFACE
122
200b
200b
134
110
TRANSMISSION SITE
PROCESSOR
112
114
STORAGE
118
102
MEMORY
116
LOGIC
115
120
INTERFACE
WSP NETWORK
106
ISP NETWORK
108

FIG. 1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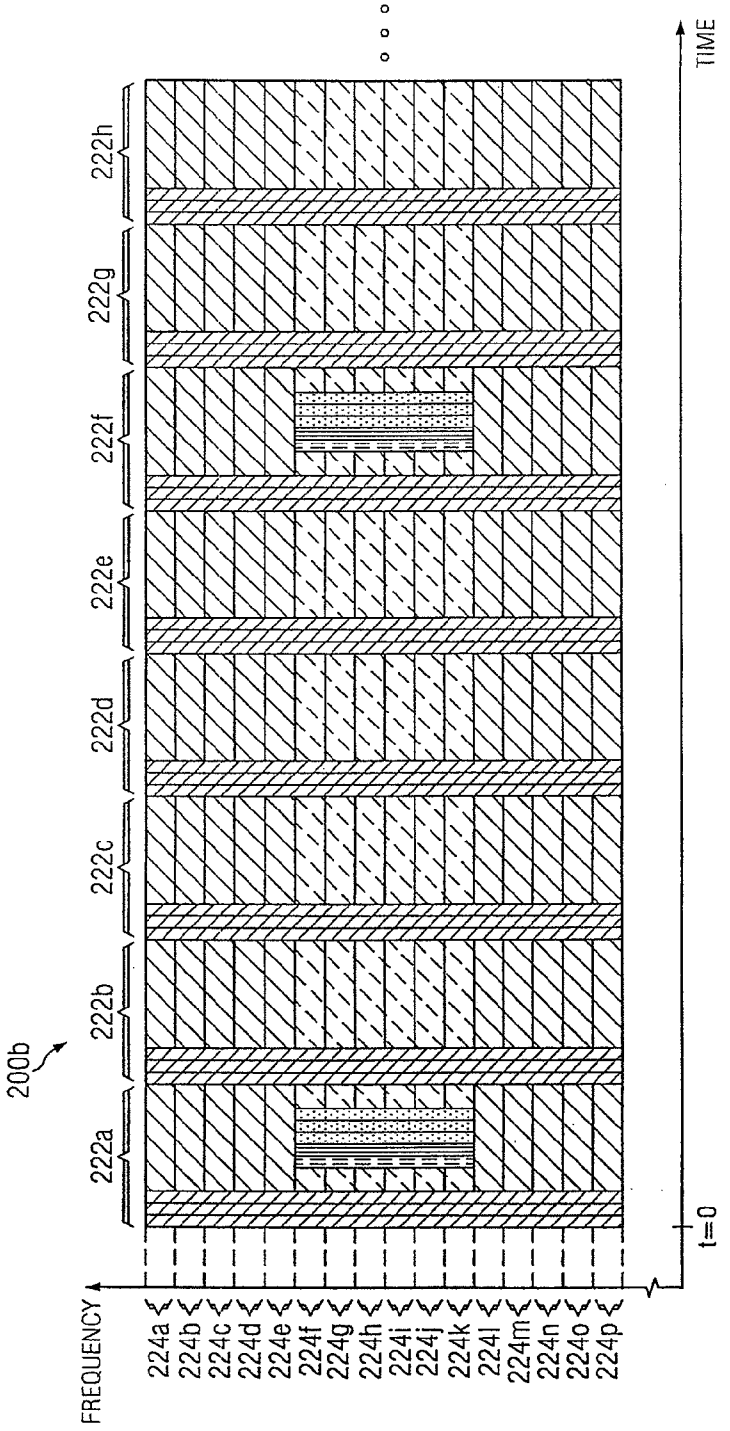
204f
204g
204h
204i
204j
204k
204l
204m
204n
204o
204p
t=0
TIME
SYNCHRONIZATION SIGNALS
206
BROADCAST CHANNEL SIGNALS
208
CONTROL SIGNALS
210
DATA SIGNALS
212

FIG. 2A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222b
222c
222d
222e
222f
222g
222h
FREQUENCY
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224b
224c
224d
224e
224f
224g
224h
224i
224j
224k
224l
224m
224n
224o
224p
t=0
TIME
WIDEBAND ENHANCED CONTROL SIGNALS MULTIPLEXED WITH DATA SIGNALS
214
NARROWBAND ENHANCED CONTROL SIGNALS MULTIPLEXED WITH DATA SIGNALS
216

FIG. 2B

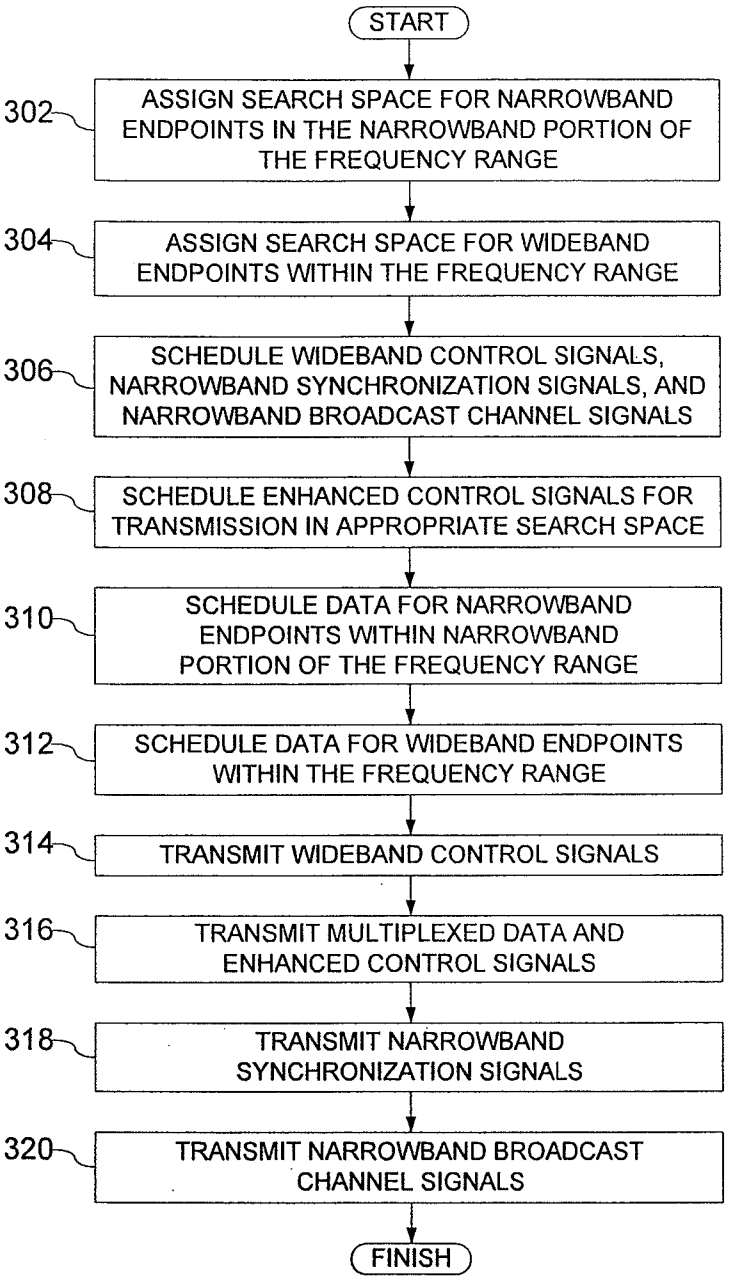
START
302
ASSIGN SEARCH SPACE FOR NARROWBAND ENDPOINTS IN THE NARROWBAND PORTION OF THE FREQUENCY RANGE
304
ASSIGN SEARCH SPACE FOR WIDEBAND ENDPOINTS WITHIN THE FREQUENCY RANGE
306
SCHEDULE WIDEBAND CONTROL SIGNALS, NARROWBAND SYNCHRONIZATION SIGNALS, AND NARROWBAND BROADCAST CHANNEL SIGNALS
308
SCHEDULE ENHANCED CONTROL SIGNALS FOR TRANSMISSION IN APPROPRIATE SEARCH SPACE
310
SCHEDULE DATA FOR NARROWBAND ENDPOINTS WITHIN NARROWBAND PORTION OF THE FREQUENCY RANGE
312
SCHEDULE DATA FOR WIDEBAND ENDPOINTS WITHIN THE FREQUENCY RANGE
314
TRANSMIT WIDEBAND CONTROL SIGNALS
316
TRANSMIT MULTIPLEXED DATA AND ENHANCED CONTROL SIGNALS
318
TRANSMIT NARROWBAND SYNCHRONIZATION SIGNALS
320
TRANSMIT NARROWBAND BROADCAST CHANNEL SIGNALS
FINISH

FIG. 3

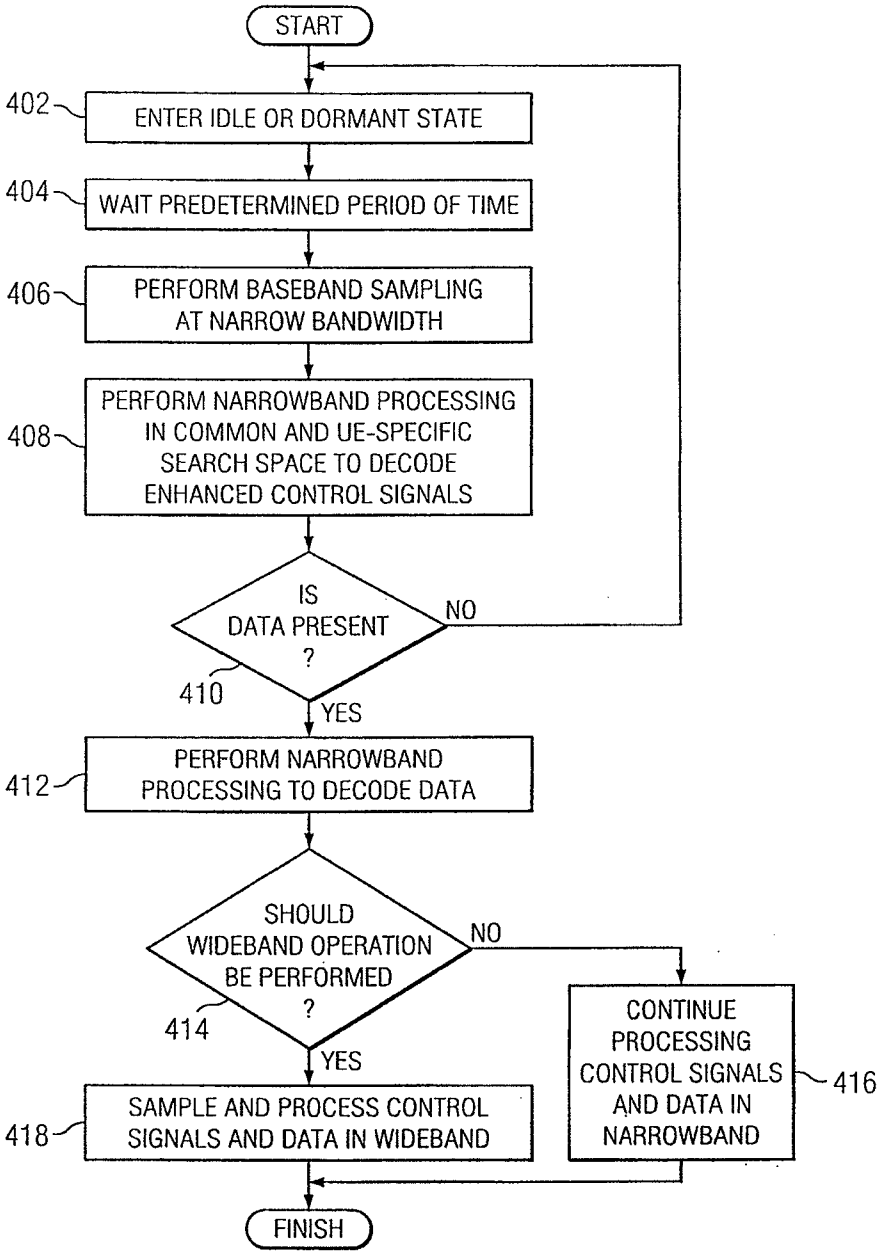
START
402
ENTER IDLE OR DORMANT STATE
404
WAIT PREDETERMINED PERIOD OF TIME
406
PERFORM BASEBAND SAMPLING AT NARROW BANDWIDTH
408
PERFORM NARROWBAND PROCESSING IN COMMON AND UE-SPECIFIC SEARCH SPACE TO DECODE ENHANCED CONTROL SIGNALS
IS DATA PRESENT ?
410
NO
YES
412
PERFORM NARROWBAND PROCESSING TO DECODE DATA
SHOULD WIDEBAND OPERATION BE PERFORMED ?
414
NO
YES
CONTINUE PROCESSING CONTROL SIGNALS AND DATA IN NARROWBAND
416
418
SAMPLE AND PROCESS CONTROL SIGNALS AND DATA IN WIDEBAND
FINISH

FIG. 4

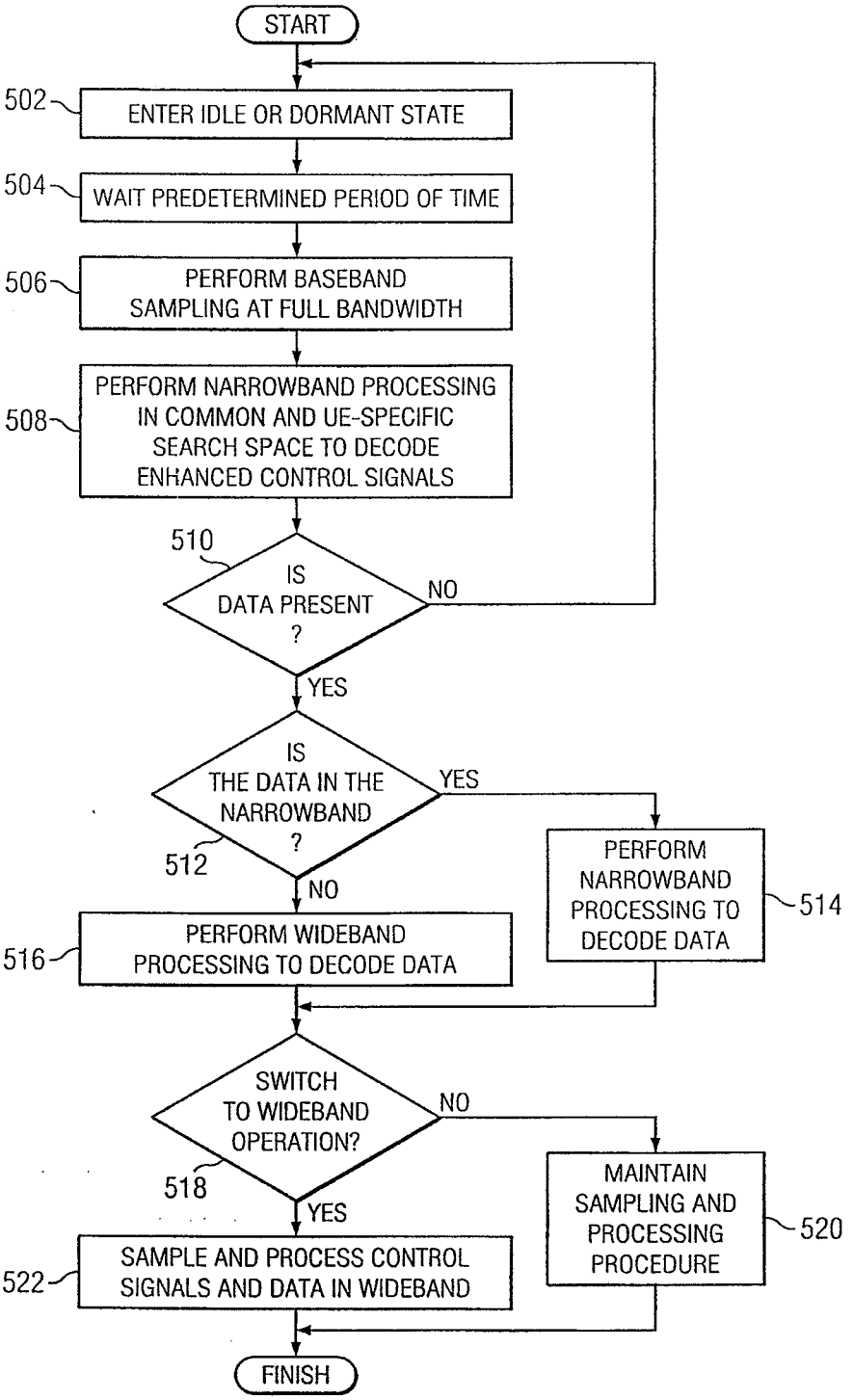
START
502
ENTER IDLE OR DORMANT STATE
504
WAIT PREDETERMINED PERIOD OF TIME
506
PERFORM BASEBAND SAMPLING AT FULL BANDWIDTH
508
PERFORM NARROWBAND PROCESSING IN COMMON AND UE-SPECIFIC SEARCH SPACE TO DECODE ENHANCED CONTROL SIGNALS
510
IS DATA PRESENT ?
NO
YES
IS THE DATA IN THE NARROWBAND ?
512
YES
NO
PERFORM NARROWBAND PROCESSING TO DECODE DATA
514
PERFORM WIDEBAND PROCESSING TO DECODE DATA
516
SWITCH TO WIDEBAND OPERATION?
518
NO
YES
MAINTAIN SAMPLING AND PROCESSING PROCEDURE
520
SAMPLE AND PROCESS CONTROL SIGNALS AND DATA IN WIDEBAND
522
FINISH

FIG. 5

LOW POWER NARROWBAND OPERATION BY AN ENDPOINT

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of priority under 35 U.S.C. §119(e) of U.S. Provisional Application Ser. No. 61/593,705, entitled "IMPROVEMENTS TO DOWNLINK CONTROL CHANNEL IN LTE-A AND ENDPOINT POWER USAGE," filed Feb. 1, 2012, the entire content of which is incorporated herein by reference.

TECHNICAL FIELD OF THE INVENTION

[0002] The present disclosure relates generally to methods and apparatuses for low power narrowband operation by an endpoint.

BACKGROUND OF THE INVENTION

[0003] An antenna system may include multiple transceivers such as transmission sites or endpoints. A transmission site may be a base station (also known as a Radio Element Control or a Baseband Unit) or a remote transmission site (also known as a Radio Element or a Remote Radio Head). Transmission sites provide endpoints with wireless network access. A transmission site may transmit control signals, data signals, and other signals to the endpoints. The control signals may facilitate the processing of the data signals by the endpoints.

SUMMARY OF THE INVENTION

[0004] Various embodiments of the present disclosure relate to low power narrowband operation by an endpoint. For example, in one embodiment, a method includes receiving, by an endpoint, a communication from a transceiver. The communication is transmitted to a plurality of endpoints using a plurality of subcarrier frequencies spanning a frequency range. The communication includes at least one control signal transmitted using at least one subcarrier frequency of the plurality of subcarrier frequencies that is outside of a narrowband portion of the frequency range. The method further includes searching, by the endpoint, a search space for one or more control signals addressed to the endpoint. The search space includes one or more subcarrier frequencies of the plurality of subcarrier frequencies that are located within the narrowband portion of the frequency range and no subcarrier frequencies located outside the narrowband portion of the frequency range. The endpoint decodes at least one control signal addressed to the endpoint and transmitted using at least subcarrier frequency of the search space. The at least one decoded control signal indicates at least one time and at least one set of subcarrier frequencies of the plurality of subcarrier frequencies used to transmit at least one data signal of the communication to the endpoint. The method further includes recovering, by the endpoint, the at least one data signal transmitted to the endpoint.

[0005] The object and advantages of the invention will be realized and achieved by means of the elements and combinations particularly pointed out in the claims.

[0006] It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory and are not restrictive of the invention, as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] For a more complete understanding of particular embodiments and their features and advantages, reference is now made to the following description, taken in conjunction with the accompanying drawings, in which:

[0008] FIG. **1** depicts an example system that includes an example transmission site that communicates with an example wideband endpoint and an example narrowband endpoint;

[0009] FIGS. **2**A and **2**B depicts example communication diagrams that represent signals transmitted by the transmission site of FIG. **1**;

[0010] FIG. **3** depicts an example method for transmitting control signals, data signals, and other signals to wideband and narrowband endpoints that may be performed by the transmission site of FIG. **1**;

[0011] FIG. **4** depicts an example method for processing control signals and data signals that may be performed by the narrowband endpoint of FIG. **1**; and

[0012] FIG. **5** depicts an example method for processing control signals and data signals that may be performed by the narrowband endpoint of FIG. **1**.

DETAILED DESCRIPTION OF THE INVENTION

[0013] FIG. **1** depicts an example system **100** that includes transmission site **102** that communicates with a wideband endpoint **104***a* and a narrowband endpoint **104***b*. System **100** may include any suitable number of transmission sites **102** and endpoints **104** that communicate with each other. System **100** may provide wireless coverage for any suitable number of endpoints **104** over a geographic area, such as a cell. For example, transmission site **102** may be used to provide wireless coverage for an entire building, a city block, a campus, or any other area. Transmission site **102** may be coupled to one or more networks, such as wireless service provider (WSP) network **106** or internet service provider (ISP) network **108**. Transmission site **102** may communicate data between endpoints **104** and one or more nodes coupled to WSP network **106** or ISP network **108**.

[0014] In particular embodiments, transmission site **102** is capable of communicating with both wideband endpoints (such as **104***a*) and narrowband endpoints (such as **104***b*). A wideband endpoint **104***a* is an endpoint that is configured to decode signals transmitted using any subcarrier frequencies within the frequency range (i.e., channel bandwidth) of wireless transmissions (e.g., **200***b*) by transmission site **102** to endpoints **104**. As an example, if transmission site **102** transmits control signals, data signals, and other signals to endpoints **104** using a Long Term Evolution (LTE) or LTE-Advanced (LTE-A) standard (such as that described in 3rd Generation Partnership Project (3GPP) Release 10 or beyond), the frequency range may be 1.4 MHz, 3 MHz, 5 MHz, 10 MHz, 15 MHz, or 20 MHz. Each frequency range may include a plurality of contiguous subcarrier frequencies that are equally spaced apart to reduce or eliminate interference between signals transmitted using neighboring subcarrier frequencies. For example, in LTE or LTE-A, contiguous subcarrier frequencies are spaced 15 kHz apart from each other. In contrast to a wideband endpoint **104***a*, a narrowband endpoint **104***b* is configured to decode signals transmitted using subcarrier frequencies that are within a portion of the frequency range (referred to herein as the "narrowband"). Thus, narrowband endpoint **104***b* is only configured to

decode signals transmitted using a subset of the subcarrier frequencies (i.e., the narrowband) of the frequency range, but is not configured to decode signals transmitted using subcarrier frequencies outside of this subset. Transmission site **102** may communicate with narrowband endpoints **104***b* by limiting the subcarrier frequencies that carry signals for the narrowband endpoints **104***b* to the narrowband.

[0015] Narrowband endpoints **104***b* and methods used to wirelessly communicate with them have various advantages over previous communication schemes. During communication, a narrowband endpoint **104***b* may perform computations that are less complex than computations performed by a wideband endpoint **104***a*. For example, a narrowband endpoint **104***b* may perform smaller size Discrete Fourier Transforms (DFTs) and use an analog to digital converter (ADC) with a lower sampling rate when recovering the signals transmitted to the endpoint. The reduction in computation complexity required may result in a lower construction cost of a narrowband endpoint **104***b* relative to a wideband endpoint **104***a*. For example, low cost endpoints such as machine type communication (MTC) devices or sensor nodes may function as narrowband endpoints. The lower computation complexity also allows narrowband endpoint **104***b* to use less power. In various embodiments, this may greatly increase the battery cycle of a device. For example, an endpoint **104***b* may periodically awake from an idle or dormant state to determine whether a transmission site **102** is currently transmitting data to the device. By only decoding in the narrowband, the endpoint may realize power savings each time it wakes up and checks for data. In particular embodiments, a narrowband endpoint **104***b* may transition to operation as a wideband endpoint **104***a* upon a determination that transmission site **102** has begun to transmit data signals to the narrowband endpoint **104***b*. This may allow the endpoint **104** to receive data at a higher rate than is possible during narrowband operation. Operation of the transmission site **102** and narrowband endpoint **104***b* are explained in greater detail below.

[0016] Transmission site **102** may be any suitable transceiver such as a base station (also known as a Radio Element Control or a Baseband Unit) or a remote transmission site (also known as a Radio Element or a Remote Radio Head (RRH)). In certain situations, a transmission site **102** that is a remote transmission site may function as an extension of another transmission site that is a base station. For example, the remote transmission site may send wireless signals to endpoints **104** that are similar to wireless signals that would be sent by the base station to the endpoint if endpoint **104** were located close to the base station.

[0017] Transmission site **102** may include any combination of hardware, software embedded in a computer readable medium, or encoded logic incorporated in hardware or otherwise stored (e.g., firmware) to implement any number of communication protocols that allow for wired or wireless exchange of information in system **100**. Transmission site **102** may be operable to exchange control signals, data signals, and other signals with endpoints **104**. A transmission site **102** may also be coupled to other transmission sites **102** via one or more wired connections. These wired connections may comprise any suitable material, such as optical fiber. Transmission sites **102** may use any suitable technologies or protocols (e.g., Common Public Radio Interface (CPRI)) to communicate with each other.

[0018] Transmission site **102** may communicate with endpoint **104** using wireless communication via one or more antennas **110**. In particular embodiments, transmission site **102** coordinates with one or more other transmission sites **102** to communicate with endpoint **104**. For example, transmission site **102** may coordinate with one or more other transmission sites **102** to communicate with endpoint **104** using a MIMO transmission scheme where multiple transmitting antennas **110** are placed at different transmission sites **102**, while one or more receiving antennas (e.g., antenna **122**) are located at the endpoint **104**. Accordingly, reference herein to a single transmission site communicating with one or more endpoints **104** may also refer to multiple transmission sites **102** jointly communicating with the one or more endpoints **104**. Transmission site **102** may communicate with endpoints **104** using any of a variety of different wireless technologies, including, but not limited to, orthogonal frequency division multiple access (OFDMA) and the LTE-A protocol as defined in the 3GPP Release 10 or beyond.

[0019] Antennas **110**, **122**, and **134** may be any suitable type of antennas capable of transmitting and receiving data or signals wirelessly. In some embodiments, antennas **110**, **122**, or **134** may comprise one or more omni-directional, sector or panel antennas operable to transmit/receive radio signals at any suitable frequency, such as between 2 GHz and 66 GHz. An omni-directional antenna may be used to transmit/receive radio signals in any direction, a sector antenna may be used to transmit/receive radio signals from devices within a particular area, and a panel antenna may be a line of sight antenna used to transmit/receive radio signals in a relatively straight line.

[0020] System **100** may comprise a network that includes various networks, such as ISP network **108** and WSP network **106**. In some embodiments, a network may comprise one or more networks, such as the Internet, a local area network (LAN), a wide area network (WAN), a metropolitan area network (MAN), a public switched telephone network (PSTN), or some combination of the above. In certain embodiments, ISP network **108** may be coupled to WSP network **106** via one or more networks, including but not limited to, the Internet, a LAN, WAN, MAN, PSTN, or some combination of the above. In some embodiments, an ISP may provide a network node (e.g., a computer system) with home network access. ISP network **108** may include modems, servers, gateways (e.g., an ISP gateway), or other suitable components.

[0021] In particular embodiments, WSP network **106** may comprise various servers, gateways, switches, routers, and other nodes used in providing wireless service. In some embodiments, the servers may comprise one or more servers, such as Operation, Administration, Maintenance and Provisioning (OAM&P) servers, Network Access Provider (NAP) servers, Authentication, Authorization, and Accounting (AAA) servers, Self Organizing Network (SON) servers, or any other servers that the WSP may need to configure/authenticate one or more transmission sites (such as **102**) and provide users with wireless service. The WSP's gateways may comprise any hardware or software needed to couple WSP network **106** with ISP network **108**. For example, in particular embodiments, the gateway may comprise a security gateway and, behind the security gateway, an Access Service Network (ASN) gateway. In some embodiments, the WSP network **106** may support or implement orthogonal frequency-division multiple access (OFDMA).

[0022] Any of the networks coupled to transmission site **102** may be capable of transmitting signals, data, or mes-

sages, including signals, data, or messages transmitted through WebPages, e-mail, text chat, voice over IP (VoIP), and instant messaging in order to provide services and data to endpoints **104**. In particular embodiments, transmission site **102** also communicates with a base station controller that facilitates handoffs between cells and provides other functions.

[0023] Endpoint **104** may comprise any type of wireless device able to send and receive data or signals to and from transmission site **102** directly or via one or more other transmission sites **102**. Some examples of endpoints **104** include desktop computers, PDAs, cell phones, laptops, VoIP phones, MTC devices, or sensor nodes. Endpoints **104** may provide data or network services to a user through any combination of hardware, software embedded in a computer readable medium, or encoded logic incorporated in hardware or otherwise stored (e.g., firmware). Endpoints **104** may also include unattended or automated systems, gateways, other intermediate components or other devices that may send or receive data or signals.

[0024] Transmission site **102**, endpoints **104**, and nodes of WSP network **106** or ISP network **108** may each include one or more portions of one or more computer systems. In particular embodiments, one or more of these computer systems may perform one or more steps of one or more methods described or illustrated herein. In particular embodiments, one or more computer systems may provide functionality described or illustrated herein. In particular embodiments, encoded software running on one or more computer systems may perform one or more steps of one or more methods described or illustrated herein or provide functionality described or illustrated herein.

[0025] The components of a transmission site **102** or endpoints **104** may comprise any suitable physical form, configuration, number, type or layout. As an example, and not by way of limitation, transmission site **102** or endpoint **104** may comprise an embedded computer system, a system-on-chip (SOC), a single-board computer system (SBC) (such as, for example, a computer-on-module (COM) or system-on-module (SOM)), a desktop computer system, a laptop or notebook computer system, an interactive kiosk, a mainframe, a mesh of computer systems, a mobile telephone, a personal digital assistant (PDA), a server, or a combination of two or more of these. Where appropriate, transmission site **102** or endpoint **104** may include one or more computer systems; be unitary or distributed; span multiple locations; span multiple machines; or reside in a cloud, which may include one or more cloud components in one or more networks.

[0026] In the depicted embodiment, transmission site **102** or endpoints **104** each include their own respective processors **112**, **124**, and **136**; memory **114**, **128**, and **140**; storage **118**, **130**, and **142**; interfaces **120**, **132**, and **144**; and buses **116**, **126**, and **138**. Although a particular system is depicted having a particular number of particular components in a particular arrangement, this disclosure contemplates any suitable system **100** having any suitable number of any suitable components in any suitable arrangement. For simplicity, similar components of transmission site **102** and endpoints **104** will be discussed together while referring to the component of transmission site **102**. However, it is not necessary for these devices to have the same components, or the same type of components. For example, processor **112** may be a general purpose microprocessor and processor **124** may be an application specific integrated circuit (ASIC).

[0027] Processor **112** may be a microprocessor, controller, or any other suitable computing device, resource, or combination of hardware, software or encoded logic operable to provide, either alone or in conjunction with other components, (e.g., memory **114**) wireless networking functionality. Such functionality may include providing various wireless features discussed herein. Additional examples and functionality provided, at least in part, by processor **112** will be discussed below.

[0028] In particular embodiments, processor **112** may include hardware for executing instructions, such as those making up a computer program. As an example and not by way of limitation, to execute instructions, processor **112** may retrieve (or fetch) instructions from an internal register, an internal cache, memory **114**, or storage **118**; decode and execute them; and then write one or more results to an internal register, an internal cache, memory **114**, or storage **118**.

[0029] In particular embodiments, processor **112** may include one or more internal caches for data, instructions, or addresses. This disclosure contemplates processor **112** including any suitable number of any suitable internal caches, where appropriate. As an example and not by way of limitation, processor **112** may include one or more instruction caches, one or more data caches, and one or more translation lookaside buffers (TLBs). Instructions in the instruction caches may be copies of instructions in memory **114** or storage **118** and the instruction caches may speed up retrieval of those instructions by processor **112**. Data in the data caches may be copies of data in memory **114** or storage **118** for instructions executing at processor **112** to operate on; the results of previous instructions executed at processor **112** for access by subsequent instructions executing at processor **112**, or for writing to memory **114**, or storage **118**; or other suitable data. The data caches may speed up read or write operations by processor **112**. The TLBs may speed up virtual-address translations for processor **112**. In particular embodiments, processor **112** may include one or more internal registers for data, instructions, or addresses. Depending on the embodiment, processor **112** may include any suitable number of any suitable internal registers, where appropriate. Where appropriate, processor **112** may include one or more arithmetic logic units (ALUs); be a multi-core processor; include one or more processors **112**; or any other suitable processor.

[0030] Memory **114** may be any form of volatile or non-volatile memory including, without limitation, magnetic media, optical media, random access memory (RAM), read-only memory (ROM), flash memory, removable media, or any other suitable local or remote memory component or components. In particular embodiments, memory **114** may include random access memory (RAM). This RAM may be volatile memory, where appropriate. Where appropriate, this RAM may be dynamic RAM (DRAM) or static RAM (SRAM). Moreover, where appropriate, this RAM may be single-ported or multi-ported RAM, or any other suitable type of RAM or memory. Memory **114** may include one or more memories **114**, where appropriate. Memory **114** may store any suitable data or information utilized by transmission site **102**. For example, memory **114** may include logic **115**. Logic **115** may include software embedded in a computer readable medium, or encoded logic incorporated in hardware or otherwise stored (e.g., firmware). In particular embodiments, logic **115** may be executed to perform the functions of transmission site **102**. Similarly, logic **129** and **141** may be executed to perform the functions of wideband endpoint **104***a*

and narrowband endpoint **104***b* respectively. In particular embodiments, memory **114** may include main memory for storing instructions for processor **112** to execute or data for processor **112** to operate on. In particular embodiments, one or more memory management units (MMUs) may reside between processor **112** and memory **114** and facilitate accesses to memory **114** requested by processor **112**.

[0031] As an example and not by way of limitation, transmission site **102** may load instructions from storage **118** or another source (such as, for example, another computer system, another base station, or a remote transmission site) to memory **114**. Processor **112** may then load the instructions from memory **114** to an internal register or internal cache. To execute the instructions, processor **112** may retrieve the instructions from the internal register or internal cache and decode them. During or after execution of the instructions, processor **112** may write one or more results (which may be intermediate or final results) to the internal register or internal cache. Processor **112** may then write one or more of those results to memory **114**. In particular embodiments, processor **112** may execute only instructions in one or more internal registers or internal caches or in memory **114** (as opposed to storage **118** or elsewhere) and may operate only on data in one or more internal registers or internal caches or in memory **114** (as opposed to storage **118** or elsewhere).

[0032] In particular embodiments, storage **118** may include mass storage for data or instructions. As an example and not by way of limitation, storage **118** may include a hard disk drive (HDD), a floppy disk drive, flash memory, an optical disc, a magneto-optical disc, magnetic tape, or a Universal Serial Bus (USB) drive or a combination of two or more of these. Storage **118** may include removable or non-removable (or fixed) media, where appropriate. Storage **118** may be internal or external to transmission site **102**, where appropriate. In particular embodiments, storage **118** may be non-volatile, solid-state memory. In particular embodiments, storage **118** may include read-only memory (ROM). Where appropriate, this ROM may be mask-programmed ROM, programmable ROM (PROM), erasable PROM (EPROM), electrically erasable PROM (EEPROM), electrically alterable ROM (EAROM), or flash memory or a combination of two or more of these. Storage **118** may take any suitable physical form and may comprise any suitable number or type of storage. Storage **118** may include one or more storage control units facilitating communication between processor **112** and storage **118**, where appropriate.

[0033] In particular embodiments, interface **120** may include hardware, encoded software, or both providing one or more interfaces for communication (such as, for example, packet-based communication) between transmission sites **102**, endpoints **104**, any networks, any network devices, or any other computer systems. As an example and not by way of limitation, communication interface **120** may include a network interface controller (NIC) or network adapter for communicating with an Ethernet or other wire-based network or a wireless NIC (WNIC) or wireless adapter for communicating with a wireless network.

[0034] In some embodiments, interface **120** comprises one or more radios coupled to one or more antenna ports **110**. In such an embodiment, interface **120** receives digital data that is to be sent out to wireless devices, such as endpoints **104**, via a wireless connection. The radio may convert the digital data into a radio signal having the appropriate center frequency, bandwidth parameters, and transmission power. Similarly, the radios may convert radio signals received via one or more receiving antennas into digital data to be processed by, for example, processor **112**.

[0035] Depending on the embodiment, interface **120** may be any type of interface suitable for any type of network for which system **100** is used. As an example and not by way of limitation, system **100** may communicate with an ad-hoc network, a personal area network (PAN), a LAN, a WAN, a MAN, or one or more portions of the Internet or a combination of two or more of these. One or more portions of one or more of these networks may be wired or wireless. As an example, system **100** may communicate with a wireless PAN (WPAN) (such as, for example, a BLUETOOTH WPAN), a WI-FI network, a WI-MAX network, an LTE network, an LTE-A network, a cellular telephone network (such as, for example, a Global System for Mobile Communications (GSM) network), or any other suitable wireless network or a combination of two or more of these. Transmission site **102** may include any suitable interface **120** for any one or more of these networks, where appropriate.

[0036] In some embodiments, interface **120** may include one or more interfaces for one or more I/O devices. One or more of these I/O devices may enable communication between a person and transmission site **102**. As an example and not by way of limitation, an I/O device may include a keyboard, keypad, microphone, monitor, mouse, printer, scanner, speaker, still camera, stylus, tablet, touchscreen, trackball, video camera, another suitable I/O device or a combination of two or more of these. An I/O device may include one or more sensors. Particular embodiments may include any suitable type or number of I/O devices and any suitable type or number of interfaces **120** for them. Where appropriate, interface **120** may include one or more drivers enabling processor **112** to drive one or more of these I/O devices. Interface **120** may include one or more interfaces **120**, where appropriate.

[0037] Bus **116** may include any combination of hardware, software embedded in a computer readable medium, or encoded logic incorporated in hardware or otherwise stored (e.g., firmware) to couple components of transmission site **102** to each other. As an example and not by way of limitation, bus **116** may include an Accelerated Graphics Port (AGP) or other graphics bus, an Enhanced Industry Standard Architecture (EISA) bus, a front-side bus (FSB), a HYPERTRANSPORT (HT) interconnect, an Industry Standard Architecture (ISA) bus, an INFINIBAND interconnect, a low-pin-count (LPC) bus, a memory bus, a Micro Channel Architecture (MCA) bus, a Peripheral Component Interconnect (PCI) bus, a PCI-Express (PCI-X) bus, a serial advanced technology attachment (SATA) bus, a Video Electronics Standards Association local (VLB) bus, or any other suitable bus or a combination of two or more of these. Bus **116** may include any number, type, or configuration of buses **116**, where appropriate. In particular embodiments, one or more buses **116** (which may each include an address bus and a data bus) may couple processor **112** to memory **114**. Bus **116** may include one or more memory buses.

[0038] Herein, reference to a computer-readable storage medium encompasses one or more tangible computer-readable storage media possessing structures. As an example and not by way of limitation, a computer-readable storage medium may include a semiconductor-based or other integrated circuit (IC) (such, as for example, a field-programmable gate array (FPGA) or an application-specific IC

(ASIC)), a hard disk, an HDD, a hybrid hard drive (HHD), an optical disc, an optical disc drive (ODD), a magneto-optical disc, a magneto-optical drive, a floppy disk, a floppy disk drive (FDD), magnetic tape, a holographic storage medium, a solid-state drive (SSD), a RAM-drive, a SECURE DIGITAL card, a SECURE DIGITAL drive, a flash memory card, a flash memory drive, or any other suitable tangible computer-readable storage medium or a combination of two or more of these, where appropriate.

[0039] Particular embodiments may include one or more computer-readable storage media implementing any suitable storage. In particular embodiments, a computer-readable storage medium implements one or more portions of processor **112** (such as, for example, one or more internal registers or caches), one or more portions of memory **114**, one or more portions of storage **118**, or a combination of these, where appropriate. In particular embodiments, a computer-readable storage medium implements RAM or ROM. In particular embodiments, a computer-readable storage medium implements volatile or persistent memory. In particular embodiments, one or more computer-readable storage media embody encoded software.

[0040] Herein, reference to encoded software may encompass one or more applications, bytecode, one or more computer programs, one or more executables, one or more instructions, logic, machine code, one or more scripts, or source code, and vice versa, where appropriate, that have been stored or encoded in a computer-readable storage medium. In particular embodiments, encoded software includes one or more application programming interfaces (APIs) stored or encoded in a computer-readable storage medium. Particular embodiments may use any suitable encoded software written or otherwise expressed in any suitable programming language or combination of programming languages stored or encoded in any suitable type or number of computer-readable storage media. In particular embodiments, encoded software may be expressed as source code or object code. In particular embodiments, encoded software is expressed in a higher-level programming language, such as, for example, C, Perl, or a suitable extension thereof. In particular embodiments, encoded software is expressed in a lower-level programming language, such as assembly language (or machine code). In particular embodiments, encoded software is expressed in JAVA. In particular embodiments, encoded software is expressed in Hyper Text Markup Language (HTML), Extensible Markup Language (XML), or other suitable markup language.

[0041] Although FIG. **1** has been described above as including particular components, the system of FIG. **1** may include any combination of any of the described components and any of the options or features described herein, as would be understood by one of ordinary skill in the art. For example, any of the options or features described herein may be utilized in combination with the illustrated embodiments of FIG. **1** or any number of the other options or features also described herein as would be understood by one of ordinary skill in the art.

[0042] While various implementations and features are discussed with respect to multiple embodiments, it should be understood that such implementations and features may be combined in various embodiments. For example, features and functionality discussed with respect to a particular figure, such as FIG. **1**, may be used in connection with features and functionality discussed with respect to another such figure, such as FIG. **2**, **3**, **4** or **5**, according to operational needs or desires.

[0043] FIGS. **2**A and **2**B depict example communication diagrams that illustrate communications **200** used by transmission site **102** to transmit information to one or more wideband endpoints **104***a* and one or more narrowband endpoints **104***b*. The diagram of FIG. **2**A depicts communication **200***a* used to transmit information to wideband endpoints **104***a* while the diagram of FIG. **2**B depicts communication **200***b* used to transmit information to wideband endpoints **104***a* and narrowband endpoints **104***b*. The horizontal axis of each diagram is time and the vertical axis is frequency.

[0044] Communication **200***a* is divided into units of time (subframes **202**) and frequency sets **204**, that each include one or more subcarrier frequencies. In the embodiment depicted, each subframe **202** represents the amount of time required to transmit twelve symbols (e.g., 1 ms in an LTE-A transmission scheme) and each frequency set **204***a* represents twelve contiguous subcarrier frequencies. The subcarrier frequencies may be equally spaced apart to reduce or eliminate interference between signals transmitted using neighboring subcarrier frequencies. By way of example, a set of contiguous subcarrier frequencies may include 3.000060 GHz, 3.000075 GHz, 3.000090 GHz, 3.000105 GHz, and so on. The aggregation of frequency sets **204** represents the frequency range of the communication **200***a*. That is, the frequency range spans from the lowest frequency of set **204***a* to the highest frequency of set **204***p* and includes each subcarrier frequency in between these two frequencies.

[0045] In particular implementations, a set **204** of contiguous subcarrier frequencies used to transmit one or more signals for a particular amount of time may form a block. A block may include any suitable number of subcarrier frequencies and any suitable number of data symbols. For example, in an LTE-A communication scheme, twelve contiguous subcarrier frequencies each transmitting six or seven data symbols in a given amount of time (e.g., 0.5 ms) form a physical resource block (PRB). Accordingly, the area of communication **200***a* bounded by subframe **202***a* and frequency set **204***a* may represent two PRBs.

[0046] A data symbol is a complex number with real or imaginary components that map a group of bits to one or more modulation characteristics of a carrier wave transmitted at a particular subcarrier frequency. Groups of bits of data signals, control signals, or other signals to be transmitted may be encoded into data symbols associated with the signals. The data symbols may be transmitted (generally after one or more processing steps) to one or more endpoints **104** via carrier waves with modulated characteristics defined by the data symbols (or the data symbols that result from the processing of the original data symbols). As an example, a data symbol may define a phase modulation or an amplitude modulation of a carrier wave. The modulation characteristics defined by the data symbol are determined by the bits of the data signals, control signals, or other signals. Particular embodiments may use quadrature phase-shift keying (QPSK), quadrature amplitude modulation (QAM)16, or QAM64 modulation to generate data symbols from the bits of the signals.

[0047] Various types of information may be sent between transmission site **102** and endpoints **104**. Examples of information types include data signals **212**, control signals **210**, and other signals. Data signals **212** are carried over a connection between a transmission site **102** and an endpoint **104**. For

example and not by way of limitation, data signals **212** may include information that transmission site **102** receives from a network coupled to the transmission site **102** (such as WSP network **106** or ISP network **108**) or from another endpoint **104** located in the same cell or a different cell. In a particular embodiment, data signals **212** are sent from a transmission site **102** to an endpoint **104** via a physical downlink shared channel (PDSCH) as defined in the LTE-A protocol.

[0048] Control signals **210** and other signals (such as synchronization signals **206** and broadcast channel signals **208**) sent from a transmission site **102** to an endpoint **104** may be used to setup and maintain a connection between the transmission site **102** and the endpoint **104**. Control signals **210** may also include information (e.g., scheduling or demodulation information) that allows endpoint **104** to recover data signals **112** sent to the endpoint **104**. In particular embodiments, at least some of the control signals **210** and other signals may conform to the LTE-A standard. For example, in the embodiment depicted, synchronization signals **206** may include primary synchronization signals (PSS) and secondary synchronization signals (SSS), broadcast channel signals **208** may include physical broadcast channel (PBCH) signals, and control signals **210** may include physical control format indicator channel (PCFICH) signals and physical downlink control channel (PDCCH) signals.

[0049] Synchronization signals **206** may include one or more sequences that are known to endpoints **104**. In the embodiment depicted, synchronization signals **206** are transmitted in the first subframe **202***a* and the sixth subframe **202***f*. In particular embodiments, the transmission of synchronization signals **206** may be repeated periodically (e.g., twice every ten subframes). When an endpoint **104** begins receiving signals from transmission site **102** (e.g., upon powering on or entering a range of the transmission site **102**), the endpoint may search for synchronization signals **206** to determine a reference point in order to synchronize to the communication from the transmission site **102**. In particular embodiments, the synchronization signals **206** are transmitted using only a portion of the frequency range of the communication. For example, the synchronization signals **206** may be transmitted using subcarrier frequencies located in the narrowband. In the embodiment depicted, synchronization signals **206** are transmitted using frequency sets **204***f*-**204***k*.

[0050] Broadcast channel signals **208** may also be transmitted periodically using subcarrier frequencies located in the narrowband. In the embodiment depicted, broadcast channel signals **208** are transmitted using the same subcarrier frequencies as the synchronization signals **206**. The broadcast channel signals **208** may include configuration information of transmission site **102** and may indicate how particular signals from transmission site **102** should be decoded. Broadcast channel signals **208** may include information that is common to all endpoints, such as the frequency range used by the transmission site **102**.

[0051] Control signals **210** facilitate decoding of data signals **212**. Control signals **210** may indicate which blocks of a communication (e.g., a subframe **202**) from transmission site **102** include data signals **212** transmitted to each endpoint **104**. For example, the control signals **210** transmitted in a particular subframe **202***a* may indicate particular blocks of the subframe **202***a* that include data signals for a particular endpoint **104**. Control signals **210** may also indicate a modulation and code rate of any of the blocks that include data signals **212**. Control signals **210** may also include information regarding a transmission scheme used by transmission site **102**, such as spatial multiplex, transmission diversity, open loop MIMO, or closed loop MIMO. A portion of control signals **210** may indicate the length (e.g., number of data symbols) of another portion of control signals **210**. For example, in an LTE-A scheme, a PCFICH signal included in control signals **210** may indicate the length of a PDCCH signal included in control signals **210**.

[0052] In the embodiment depicted, control signals **210** are transmitted in wideband. That is, control signals **210** are transmitted using subcarrier frequencies that span the entire frequency range of the communication. Accordingly, only a wideband endpoint **104***a* that is configured to sample the entire frequency range and decode signals transmitted using any subcarrier frequency of the frequency range may properly recover the control signals **210** and use the control signals **210** to recover the data signals **212** sent to the wideband endpoint **104***a*. Accordingly, the method of communication depicted in communication **200***a* is not compatible with narrowband endpoints **104***b*.

[0053] Communication **200***b* represents a type of communication that is compatible with both wideband endpoints **104***a* and narrowband endpoints **104***b*. Similar to communication **200***a*, communication **200***b* is divided into units of time (subframes **222**) and frequency sets **224**. Communication **200***b* may have any suitable characteristics of communication **200***a* described above.

[0054] Similar to communication **200***a*, communication **200***b* depicts the periodic transmission of synchronization signals **206** and broadcast channel signals **208** using subcarrier frequencies within the narrowband. In the embodiment depicted, the narrowband includes frequency sets **224***f*-**224***k*. Communication **200***b* also includes wideband enhanced control signals multiplexed with data signals **214** and narrowband enhanced control signals multiplexed with data signals **216**.

[0055] The enhanced control signals present in signals **214** and **216** may include any suitable information, such as that described above with respect to control signals **210**. Communication methods utilizing these enhanced control signals may provide various advantages over communication schemes that are limited to transmission of control signals **210**. For example, the enhanced control signals may allow transmission site **102** to communicate with a narrowband endpoint **104***b*. As other examples, the enhanced control signals may support increased control channel capacity and improved spatial reuse of control channel resources relative to communication schemes using only control signals **210**. The enhanced control signals may also support frequency-domain inter-cell interference coordination (ICIC), beamforming, or diversity. In particular embodiments, the enhanced control signals present in signals **214** and **216** may implement one or more features of the enhanced PDCCH set forth in 3GPP LTE-A Release 11.

[0056] Signals **216** include narrowband enhanced control signals multiplexed with data signals using frequency division multiplexing. That is, at any particular time, some subcarrier frequencies within the narrowband may be transmitting enhanced control signals and some may be transmitting data signals. In particular embodiments, these signals are multiplexed according to blocks of two or more subcarrier frequencies. For example, the subcarrier frequencies of a particular block (such as a PRB) may each carry the same type of signal—either an enhanced control signal or a data signal.

Signals **214** are multiplexed in a similar manner, but these signals are transmitted using subcarrier frequencies that are outside of the narrowband.

[0057] A control signal (such as a control signal **210** or an enhanced control signal) may be addressed to one or more particular endpoints **104** or it may be addressed to all of the endpoints **104** that transmission site **102** communicates with. A control signal may be addressed to one or more endpoints **104** in any suitable manner. In particular embodiments, a control signal may explicitly identify the one or more endpoints to which the control signal is addressed. A control signal may alternatively include a portion that is based on the particular endpoint or endpoints that the control signal is addressed to. For example, in a particular embodiment, cyclic redundancy check (CRC) data of the control signal may be determined based on an identifier of the destination endpoint. Accordingly, the endpoint **104** may detect that the control signal is addressed to the endpoint by analyzing the CRC data of the control signal in combination with the identifier of the endpoint **104**. The identifier may be any suitable information, such as a physical address of the endpoint **104**. In particular embodiments, a control signal may be implicitly addressed to one or more endpoints **104** by sending a message prior to the sending of the control signal that indicates the subcarrier frequencies and times that will be used to send the control signal. As another example, endpoints **104** may be preconfigured to expect a particular control signal that is sent to all endpoints **104** using a particular set of frequencies and times.

[0058] To facilitate the processing of control signals, one or more search spaces may be defined for the endpoints **104**. A common search space is a group of subcarrier frequencies that are designated to transmit control signals that are common to all endpoints **104**. An endpoint-specific search space is a group of subcarrier frequencies that are designated for the transmission of control signals to a particular endpoint **104**. Accordingly, each endpoint **104** may locate control signals that are addressed to the endpoint **104** by searching the common search space and its own endpoint-specific search space. The search spaces may be identified by the endpoints **104** in any suitable manner. For example, the endpoints **104** may be preconfigured with one or more of the search spaces or the search spaces may be transmitted to the endpoints by transmission site **102**. Because a common search space is broadcast in nature, transmission site **102** may communicate control signals using subcarrier frequencies in the common search space using space-frequency block coding (SFBC) or open-loop MIMO, while avoiding beamforming or closed loop MIMO.

[0059] The narrowband portion of the frequency range that includes the narrowband enhanced control signals multiplexed with data signals **216** may be located anywhere within the frequency range. Because a narrowband endpoint **104***b* should be able to sample and decode a frequency range that includes synchronization signals **206** and broadcast channel signals **208** to operate properly, in particular embodiments the narrowband includes the frequencies at which the synchronization signals **206** and broadcast channel signals **208** are transmitted. For example, in the embodiment depicted, the narrowband includes the frequencies within frequency sets **224***f*-**224***k*. However, the narrowband portion may be widened to include additional frequencies or narrowed to include less frequencies. Although the narrowband is centered around the middle of the frequency range, the narrowband portion may be located anywhere within the frequency range. For example, the narrowband may include frequency sets **224***a*-**224***f*, **224***k*-**224***p*, or any other suitable combination of contiguous subcarrier frequencies.

[0060] FIG. **3** depicts an example method for transmitting control signals, data signals, and other signals to wideband endpoints **104***a* and narrowband endpoints **104***b* that may be performed by transmission site **102**. For purposes of simplicity, the illustrated steps of the method of FIG. **3** are described from the perspective of a transmission site **102** though they could be performed by any suitable transceiver or multiple transceivers. The method begins at step **302**, where at least one search space is assigned for the narrowband endpoints in the narrowband portion of the frequency range. For example, transmission site **102** may designate one or more subcarrier frequencies for transmission of control signals that are addressed to the narrowband endpoints **104***b*. These subcarrier frequencies are located within the narrowband. The search spaces may be endpoint-specific search spaces designated for control signals that are addressed to one or more particular narrowband endpoints **104***b* or common search spaces for control signals addressed to all of the endpoints **104***b* (assuming that the transmission site **102** communicates with at least one narrowband endpoint **104***b*). In particular embodiments, the search spaces applicable to a particular narrowband endpoint **104***b* (i.e., the subcarrier frequencies that will transmit control signals addressed to the narrowband endpoint **104***b*) may be communicated to the narrowband endpoint **104***b* by transmission site **102** before a communication **200***b* including data for the narrowband endpoint **104***b* is sent to narrowband endpoint **104***b*.

[0061] At step **304**, at least one search space is assigned for the wideband endpoints within the frequency range. For example, transmission site **102** may designate one or more subcarrier frequencies for transmission of control signals that are addressed to the wideband endpoints **104***a*. These subcarrier frequencies may be located anywhere within the frequency range, including the narrowband if frequencies are available. These search spaces may be designated for control signals that are addressed to one or more particular wideband endpoints **104***a* (e.g., the search spaces may be endpoint-specific search spaces). In particular embodiments, the search space applicable to a particular wideband endpoint **104***a* (i.e., the subcarrier frequencies that will transmit control signals addressed to the wideband endpoint **104***a*) may be communicated to the wideband endpoint **104***a* by transmission site **102** before a communication **200***b* including data for the wideband endpoint **104***a* is sent to wideband endpoint **104***a*.

[0062] At step **306**, wideband control signals, narrowband synchronization signals, and narrowband broadcast channel signals are scheduled. Scheduling a signal may include determining one or more subcarrier frequencies that will transmit the signal and one or more times at which the designated subcarrier frequencies will transmit the signal. As an example of step **302**, transmission site **102** may schedule control signals **210**, synchronization signals **206**, and broadcast signals **208**. A wideband control signal refers to a control signal that is transmitted using at least one subcarrier frequency located outside of the narrowband portion of the frequency range. A narrowband synchronization signal refers to a synchronization signal that is transmitted using subcarrier frequencies that are each inside of the narrowband. Similarly, a narrowband broadcast channel signal refers to a broadcast channel signal that is transmitted using subcarrier frequencies that are each inside of the narrowband.

[0063] At step **308**, enhanced control signals are scheduled for transmission in appropriate search spaces. For example, in an enhanced control signal is addressed to all endpoints **104**, it is placed in a common search space in the narrowband. As another example, if an enhanced control signal is addressed to one or more particular narrowband endpoints **104***b*, then the enhanced control signal is scheduled within the appropriate endpoint-specific search space(s) in the narrowband. As yet another example, if an enhanced control signal is addressed to one or more particular wideband endpoints **104***a*, then it may be placed within the appropriate endpoint-specific search space(s) in either the narrowband or the outside of the narrowband.

[0064] At step **310**, data is scheduled for narrowband endpoints within the narrowband portion of the frequency range. As an example, transmission site **102** may schedule data signals for transmission to one or more narrowband endpoints **104***b* using blocks with subcarrier frequencies located within the narrowband that are not used for the transmission of other signals, such as synchronization signals **206**, broadcast channel signals **208**, or enhanced control signals. In particular embodiments, transmission site **102** may schedule data signals for transmission to one or more narrowband endpoints **104***b* using blocks with subcarrier frequencies located outside the narrowband if the narrowband endpoint **104***b* is capable of decoding these data signals using control signals transmitted using subcarrier frequencies in the narrowband as illustrated in further detail in FIG. **5**.

[0065] At step **312**, data is scheduled for wideband endpoints within the frequency range. As an example, transmission site **102** may schedule data signals for transmission to one or more wideband endpoints **104***a* using any available blocks that are not used for the transmission of other signals, such as synchronization signals **206**, broadcast channel signals **208**, or enhanced control signals.

[0066] At step **314**, wideband control signals are transmitted. For example, transmission site **102** may transmit control signals **210** via subcarrier frequencies that span the entire frequency range. As depicted in communication diagram **200***b*, the control signals **210** are sent at the beginning of each subframe **222**.

[0067] At step **316**, multiplexed data and enhanced control signals are transmitted. For example, transmission site **102** may transmit wideband enhanced control signals multiplexed with data signals **214** and narrowband enhanced control signals multiplexed with data signals **216**. The enhanced control signals and the data signals may be multiplexed using frequency division multiplexing. Accordingly, at any given time, particular subcarrier frequencies may transmit data signals while other subcarrier frequencies may transmit enhanced control signals. At a different point in time, a different set of subcarrier frequencies may transmit data signals while other subcarrier frequencies transmit enhanced control signals.

[0068] At step **318**, narrowband synchronization signals are transmitted. For example, transmission site may transmit synchronization signals **206** using subcarrier frequencies within the narrowband. Simultaneously with this transmission, wideband enhanced control signals multiplexed with data signals **214** may be transmitted outside of the narrowband. In embodiments, where the narrowband includes subcarrier frequencies that are not utilized during transmission of synchronization signals **206**, these subcarrier frequencies may be used to transmit narrowband enhanced control signals multiplexed with data signals **216** simultaneously with the transmission of synchronization signals **206**.

[0069] At step **320**, narrowband broadcast channel signals are transmitted and the method ends. For example, transmission site may transmit broadcast channel signals **208** using subcarrier frequencies within the narrowband. Simultaneously with this transmission, wideband enhanced control signals multiplexed with data signals **214** may be transmitted outside of the narrowband. In embodiments, where the narrowband includes subcarrier frequencies that are not utilized during transmission of broadcast channel signals **208**, these subcarrier frequencies may be used to transmit narrowband enhanced control signals multiplexed with data signals **216** simultaneously with the transmission of broadcast channel signals **208**.

[0070] Some of the steps illustrated in FIG. **3** may be combined, modified or deleted where appropriate, and additional steps may also be added to the flowchart. Any of the steps may be repeated. Additionally, steps may be performed in any suitable order without departing from the scope of particular embodiments. Moreover, two or more of the steps of the method may be performed simultaneously in particular embodiments. Although, the steps of FIG. **3** have been described with respect to a transmission site **102**, they may be performed by any suitable transceiver.

[0071] FIG. **4** depicts an example method for processing control signals and data signals that may be performed by narrowband endpoint **104***b*. For purposes of simplicity, the illustrated steps of the method of FIG. **4** are described from the perspective of an endpoint **104** although they could be performed by any suitable transceiver. The method begins at step **402** in which narrowband endpoint **104***b* enters an idle or dormant state. When endpoint **104***b* is in an idle state, it does not transmit or receive data, and thus operates in a power conserving mode. The endpoint **104***b* may periodically wake up and analyze a communication from transmission site **102** to determine whether the communication includes a paging message for the endpoint **104***b* that indicates that data is to be transmitted to the endpoint. If a paging message is not present, the endpoint **104***b* may return to the idle state until it is scheduled to wake up and check again for a paging message. In the idle state, endpoint **104***b* may not have an active connection to a transmission site **102**, so the endpoint **104***b* may need to perform a random access procedure to establish a connection with transmission site **102** before transmitting or receiving data signals. When endpoint **104***b* is in a dormant state, it does not transmit or receive data, and thus operates in a power conserving mode. However, a dormant endpoint **104***b* is connected to at least one transmission site **102** and wakes up more often than an idle endpoint. Upon waking up, the endpoint **104***b* may check to see if a communication from a transmission site **102** includes data signals for the endpoint **104***b*. If the communication does not, endpoint **104***b* will go back to a dormant state. If a dormant endpoint has not received data for a predetermined period of time, it may enter an idle state.

[0072] At step **404**, the endpoint waits a predetermined period of time before waking up. As an example and not by way of limitation, a dormant endpoint may wait five seconds and an idle endpoint may wait two hundred milliseconds. At step **406**, endpoint **104***b* wakes up and performs baseband sampling at the narrow bandwidth (i.e., in the narrowband). That is, endpoint **104***b* samples a transmission from transmission site **102** at a sufficient rate to recover the narrowband

portion of the frequency range. The sampling rate of an ADC that samples at the narrowband may be lower than the sampling rate required that samples at the entire frequency range. The narrowband sampling also results in a reduction of the amount of memory required to store the samples.

[0073] At step **408**, narrowband processing is performed in the common search space and the endpoint-specific search space associated with the endpoint **104***b* to decode enhanced control signals. Processing may include any suitable operations that facilitate decoding of the enhanced control signals. For example, processing may include filtering the sampled signals, performing discrete Fourier transforms (DFT) on the sampled signals, demodulation of the sampled signals, or other suitable processing. The processed signals are then analyzed to determine whether any of these signals include an enhanced control signal addressed to the endpoint **104***b*. In particular embodiments, this analysis may include checking a CRC value of an enhanced control signal in combination with a physical address of the endpoint **104***b* to determine whether the enhanced control signal is addressed to the endpoint **104**. As other examples, this analysis may involve a determination that an enhanced control signal is a control signal addressed to all endpoints **104** because it was transmitted using a particular block or because it includes information indicating that it is addressed to all endpoints **104**.

[0074] At step **410**, the control signals addressed to the endpoint **104***b* are decoded and it is determined whether the communication from transmission site **102** includes data for endpoint **104***b*. For example, the communication may include at least a portion of a paging message or one or more data signals sent to the endpoint **104***b*. If there is no data present, endpoint **104***b* returns to an idle or dormant state at step **402**. If data for the endpoint **104***b* is present, the endpoint performs narrowband processing to decode the data at step **412**. That is, the endpoint may perform processing on information transmitted using subcarrier frequencies that are within the narrowband. The processing performed to decode the data signals may be similar to the processing performed to decode the enhanced control signals. In particular embodiments, the enhanced control signals may specify which blocks of the transmission include data signals for the endpoint **104***b*. The endpoint **104***b* may use this information to decode these blocks to recover the data signals.

[0075] At step **414**, endpoint **104***b* determines whether wideband operation should be performed. That is, endpoint **104***b* determines whether it should change its configuration to operate as a wideband endpoint **104***a*. If endpoint **104***b* determines that it should not change its configuration, then it continues processing communications from transmission site **102** in a narrowband mode. That is, endpoint **104***b* will perform sampling at the narrowband portion and will only decode control signals transmitted via subcarrier frequencies located in the narrowband. If endpoint **104***b* determines that it should change its configuration, then the endpoint samples and processes future communications from transmission site **102** in a wideband mode at step **418**. That is, endpoint **104** may perform sampling on the entire frequency range and may decode control signals transmitted via any of the subcarrier frequencies of the frequency range, including those outside of the narrowband. Such functionality allows endpoint **104** to conserve power by operating in a narrowband mode as it repeatedly wakes up from an idle or dormant state to check a communication for data and then to reconfigure to a wideband mode to receive data more quickly when data is being transmitted to the endpoint **104**. If a narrowband endpoint **104***b* is only capable of operating in a narrowband mode, steps **414** and **418** may be omitted from the method. In particular embodiments, transmission site **102** may be operable to detect that a narrowband endpoint **104***b* is configured to switch to a wideband mode and thus only limits control signals and data signals to the narrowband portion on the first communication (e.g., subframe), while the control signals and data signals may be transmitted using any suitable subcarrier frequencies within the frequency range in subsequent communications.

[0076] Some of the steps illustrated in FIG. **4** may be combined, modified or deleted where appropriate, and additional steps may also be added to the flowchart. Any of the steps may be repeated. Additionally, steps may be performed in any suitable order without departing from the scope of particular embodiments. Moreover, two or more of the steps of the method may be performed simultaneously in particular embodiments. Although, the steps of FIG. **4** have been described with respect to an endpoint **104**, they may be performed by any suitable transceiver.

[0077] FIG. **5** depicts an example method for processing control signals and data signals that may be performed by the narrowband endpoint **104***b*. Steps **502** and **504** are similar to steps **402** and **404** of FIG. **4**. At step **506**, endpoint **104***b* performs baseband sampling at full bandwidth. That is, endpoint **104***b* samples a transmission from transmission site **102** at a sufficient rate to recover the entire frequency range. While this may require a faster ADC sampling rate and additional memory to store the samples as compared to baseband sampling at the narrowband, this method allows data signals sent to the endpoint **104***b* to be included in the wideband portion of the frequency range on the first transmission, as explained in greater detail below.

[0078] At step **508**, narrowband processing in the common search space and the endpoint-specific search space is performed to decode enhanced control signals transmitted using subcarrier frequencies within the narrowband. This step may be similar to step **408** of FIG. **4**. At step **510**, it is determined whether data for the endpoint **104***b* is included in the communication. If there is no data present, the method returns to step **502**. If there is data present, endpoint **104***b* determines whether the data is limited to the narrowband portion of the frequency range. That is, endpoint **104***b* may determine whether data signals for the endpoint are transmitted using only subcarrier frequencies in the narrowband. If so, step **514**, which is similar to step **412**, is performed. If at least one data signal is transmitted using subcarrier frequencies outside of the narrowband, then wideband processing is performed to decode the data signals. The wideband processing may include any suitable operations that facilitate decoding of the data signals. For example, processing may include filtering the sampled signals, performing discrete fourier transforms (DFT) on the sampled signals, demodulation of the sampled signals, or other suitable processing. Wideband processing may include more complex processing than narrowband processing. For example, wideband processing may include performing larger DFTs on the sampled signals. Wideband processing results in the recovery of data signals transmitted using subcarrier frequencies that are outside of the narrowband portion of the frequency range. In particular embodiments, enhanced control signals located within the narrowband portion of the frequency range may specify blocks outside of the narrowband that include data signals for the

endpoint **104***b*. The endpoint **104***b* may use this information to decode these blocks to recover the data signals.

[0079] At step **518**, endpoint **104***b* determines whether wideband operation should be performed. This step may be similar to step **414** of FIG. **4**. If endpoint **104***b* determines that it should not change its configuration to wideband operation, endpoint **104***b* maintains its sampling and processing procedure at step **520**. For example, endpoint **104***b* may continue processing communications in the manner described in steps **502-516**. If endpoint **104***b* determines that it should change its configuration to wideband operation, then the endpoint samples and processes future communications from transmission site **102** in a wideband mode. That is, endpoint **104** will perform sampling on the entire frequency range and will decode signals transmitted via any of the subcarrier frequencies of the frequency range, including those outside of the narrowband.

[0080] The method of FIG. **5** allows data signals to be transmitted using subcarrier frequencies outside of the narrowband to an endpoint that is only configured to decode control signals transmitted via subcarrier frequencies located in the narrowband. Such embodiments may speed up the data transfer process.

[0081] Some of the steps illustrated in FIG. **5** may be combined, modified or deleted where appropriate, and additional steps may also be added to the flowchart.

[0082] Any of the steps may be repeated. Additionally, steps may be performed in any suitable order without departing from the scope of particular embodiments. Moreover, two or more of the steps of the method may be performed simultaneously in particular embodiments. Although, the steps of FIG. **5** have been described with respect to an endpoint **104**, they may be performed by any suitable transceiver.

[0083] Various embodiments of the present disclosure may provide one or more technical advantages. Technical advantages of particular embodiments include performing less complex computations when sampling and processing a communication from a transmission site. Another technical advantage may include a decreased cost for manufacturing an endpoint. Another technical advantage may include less power consumption. Other technical advantages will be readily apparent to one of ordinary skill in the art from the following figures, descriptions, and claims. Moreover, while specific advantages have been enumerated above, various embodiments may include all, some, or none of the enumerated advantages.

[0084] Although particular embodiments have been described in detail, it should be understood that various other changes, substitutions, and alterations may be made hereto without departing from the spirit and scope of particular embodiments. For example, although an embodiment has been described with reference to a number of elements included within transmission site **102** and endpoints **104** such as a processors, memories, storages, interfaces, and buses, these elements may be combined, rearranged or positioned in order to accommodate particular wireless architectures or needs. In addition, any of these elements may be provided as separate external components to transmission site **102**, endpoints **104**, or each other where appropriate. Particular embodiments contemplate great flexibility in the arrangement of these elements as well as their internal components.

[0085] Numerous other changes, substitutions, variations, alterations and modifications may be ascertained by those skilled in the art and it is intended that particular embodiments encompass all such changes, substitutions, variations, alterations and modifications as falling within the spirit and scope of the appended claims.

What is claimed is:

1. An endpoint comprising:

an interface configured to receive a communication from a transceiver, the communication transmitted to a plurality of endpoints using a plurality of subcarrier frequencies spanning a frequency range, the communication including at least one control signal transmitted using at least one subcarrier frequency of the plurality of subcarrier frequencies that is outside of a narrowband portion of the frequency range;

a processor coupled to the interface and configured to:

search a search space for one or more control signals addressed to the endpoint, the search space including one or more subcarrier frequencies of the plurality of subcarrier frequencies that are located within the narrowband portion of the frequency range and no subcarrier frequencies located outside the narrowband portion of the frequency range;

decode at least one control signal addressed to the endpoint and transmitted using at least subcarrier frequency of the search space, the at least one decoded control signal indicating at least one time and at least one set of subcarrier frequencies of the plurality of subcarrier frequencies used to transmit at least one data signal of the communication to the endpoint; and

recover the at least one data signal transmitted to the endpoint.

2. The endpoint of claim **1**, wherein the processor is further configured to perform analog-to-digital conversion (ADC) sampling on only the narrowband portion of the frequency range.

3. The endpoint of claim **1**, wherein the processor is further configured to perform ADC sampling on the entire frequency range.

4. The endpoint of claim **3**, wherein the at least one data signal recovered by the endpoint is transmitted to the endpoint using at least one set of contiguous frequencies of the plurality of contiguous frequencies that is outside the narrowband portion of the frequency range.

5. The endpoint of claim **1**, wherein the processor is further configured to awake from an idle or dormant state prior to searching the search space for the one or more control signals addressed to the endpoint.

6. The endpoint of claim **1**, wherein the search space is a first search space and the processor is further configured to:

receive a subsequent communication from the transceiver, the subsequent communication transmitted using the same plurality of subcarrier frequencies spanning the frequency range; and

search a second search space for one or more additional control signals addressed to the endpoint, the second search space including one or more subcarrier frequencies of the plurality of subcarrier frequencies that are located outside the narrowband portion of the frequency range.

7. The endpoint of claim **1**, wherein the communication from the transceiver includes a plurality of data signals and control signals that are multiplexed in time using frequency division multiplexing.

8. A method comprising:

receiving, by an endpoint, a communication from a transceiver, the communication transmitted to a plurality of endpoints using a plurality of subcarrier frequencies spanning a frequency range, the communication including at least one control signal transmitted using at least one subcarrier frequency of the plurality of subcarrier frequencies that is outside of a narrowband portion of the frequency range;

searching, by the endpoint, a search space for one or more control signals addressed to the endpoint, the search space including one or more subcarrier frequencies of the plurality of subcarrier frequencies that are located within the narrowband portion of the frequency range and no subcarrier frequencies located outside the narrowband portion of the frequency range;

decoding, by the endpoint, at least one control signal addressed to the endpoint and transmitted using at least subcarrier frequency of the search space, the at least one decoded control signal indicating at least one time and at least one set of subcarrier frequencies of the plurality of subcarrier frequencies used to transmit at least one data signal of the communication to the endpoint; and

recovering, by the endpoint, the at least one data signal transmitted to the endpoint.

9. The method of claim **8**, further comprising performing analog-to-digital conversion (ADC) sampling on only the narrowband portion of the frequency range.

10. The method of claim **8**, further comprising performing ADC sampling on the entire frequency range

11. The method of claim **10**, wherein the at least one data signal recovered by the endpoint is transmitted to the endpoint using at least one set of contiguous frequencies of the plurality of contiguous frequencies that is outside the narrowband portion of the frequency range.

12. The method of claim **8**, further comprising awaking from an idle or dormant state prior to searching the search space for the one or more control signals addressed to the endpoint.

13. The method of claim **8**, wherein the search space is a first search space and the method further comprises:

receiving a subsequent communication from the transceiver, the subsequent communication transmitted using the same plurality of subcarrier frequencies spanning the frequency range; and

searching a second search space for one or more additional control signals addressed to the endpoint, the second search space including one or more subcarrier frequencies of the plurality of subcarrier frequencies that are located outside the narrowband portion of the frequency range.

14. The method of claim **8**, wherein the communication from the transceiver includes a plurality of data signals and control signals that are multiplexed in time using frequency division multiplexing.

15. One or more non-transitory computer-readable storage media embodying logic that when executed by a processor is configured to:

receive, at an endpoint, a communication from a transceiver, the communication transmitted to a plurality of endpoints using a plurality of subcarrier frequencies spanning a frequency range, the communication including at least one control signal transmitted using at least one subcarrier frequency of the plurality of subcarrier frequencies that is outside of a narrowband portion of the frequency range;

search a search space for one or more control signals addressed to an endpoint, the search space including one or more subcarrier frequencies of the plurality of subcarrier frequencies that are located within the narrowband portion of the frequency range and no subcarrier frequencies located outside the narrowband portion of the frequency range;

decode at least one control signal addressed to the endpoint and transmitted using at least subcarrier frequency of the search space, the at least one decoded control signal indicating at least one time and at least one set of subcarrier frequencies of the plurality of subcarrier frequencies used to transmit at least one data signal of the communication to the endpoint; and

recover the at least one data signal transmitted to the endpoint.

16. The media of claim **15**, the logic further configured to perform analog-to-digital conversion (ADC) sampling on only the narrowband portion of the frequency range.

17. The media of claim **15**, the logic further configured to perform ADC sampling on the entire frequency range.

18. The media of claim **17**, wherein the at least one data signal recovered by the endpoint is transmitted to the endpoint using at least one set of contiguous frequencies of the plurality of contiguous frequencies that is outside the narrowband portion of the frequency range.

19. The media of claim **15**, the logic further configured to awake the endpoint from an idle or dormant state prior to searching the search space for the one or more control signals addressed to the endpoint.

20. The media of claim **15**, wherein the search space is a first search space and the logic is further configured to:

receive a subsequent communication from the transceiver, the subsequent communication transmitted using the same plurality of subcarrier frequencies spanning the frequency range; and

search a second search space for one or more additional control signals addressed to the endpoint, the second search space including one or more subcarrier frequencies of the plurality of subcarrier frequencies that are located outside the narrowband portion of the frequency range.

21. The media of claim **15**, wherein the communication from the transceiver includes a plurality of data signals and control signals that are multiplexed in time using frequency division multiplexing.

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