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(54) **BEAM-BASED DETECTION FOR INTERFERENCE MITIGATION**

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H04B 17/336	(2006.01)

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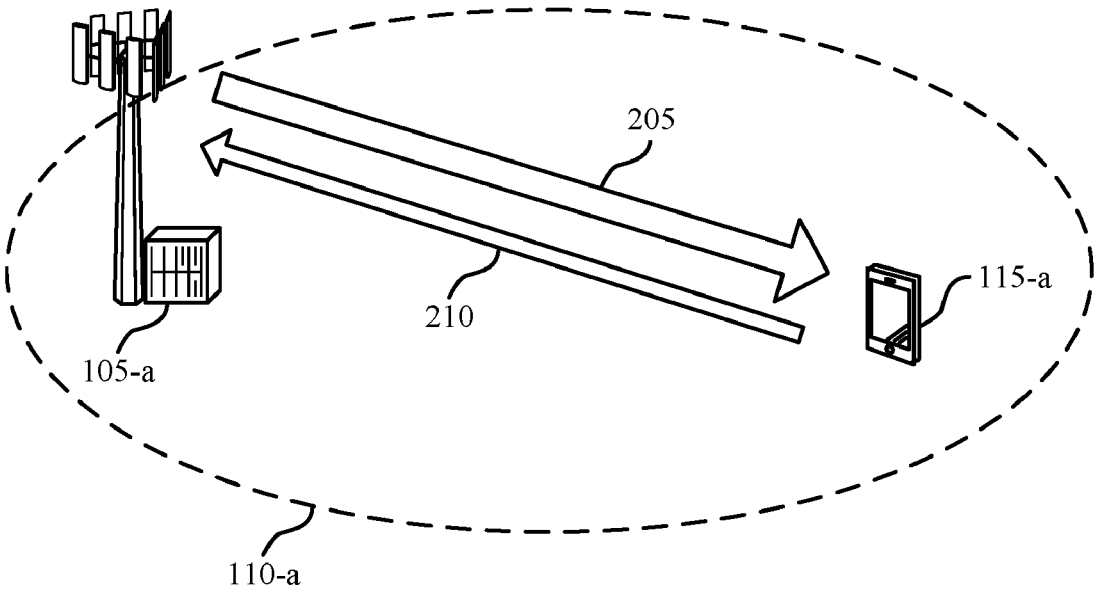
(57) **ABSTRACT**

Methods, systems, and devices for wireless communications are described. The method includes receiving a transmission parameter of a second wireless network, scanning, based on the transmission parameter, for transmission activity of the second wireless network using a set of beams generated in accordance with a beamforming codebook, and opportunistically communicating with a second wireless device of the first wireless network using the beamforming codebook based on the scanning.



200

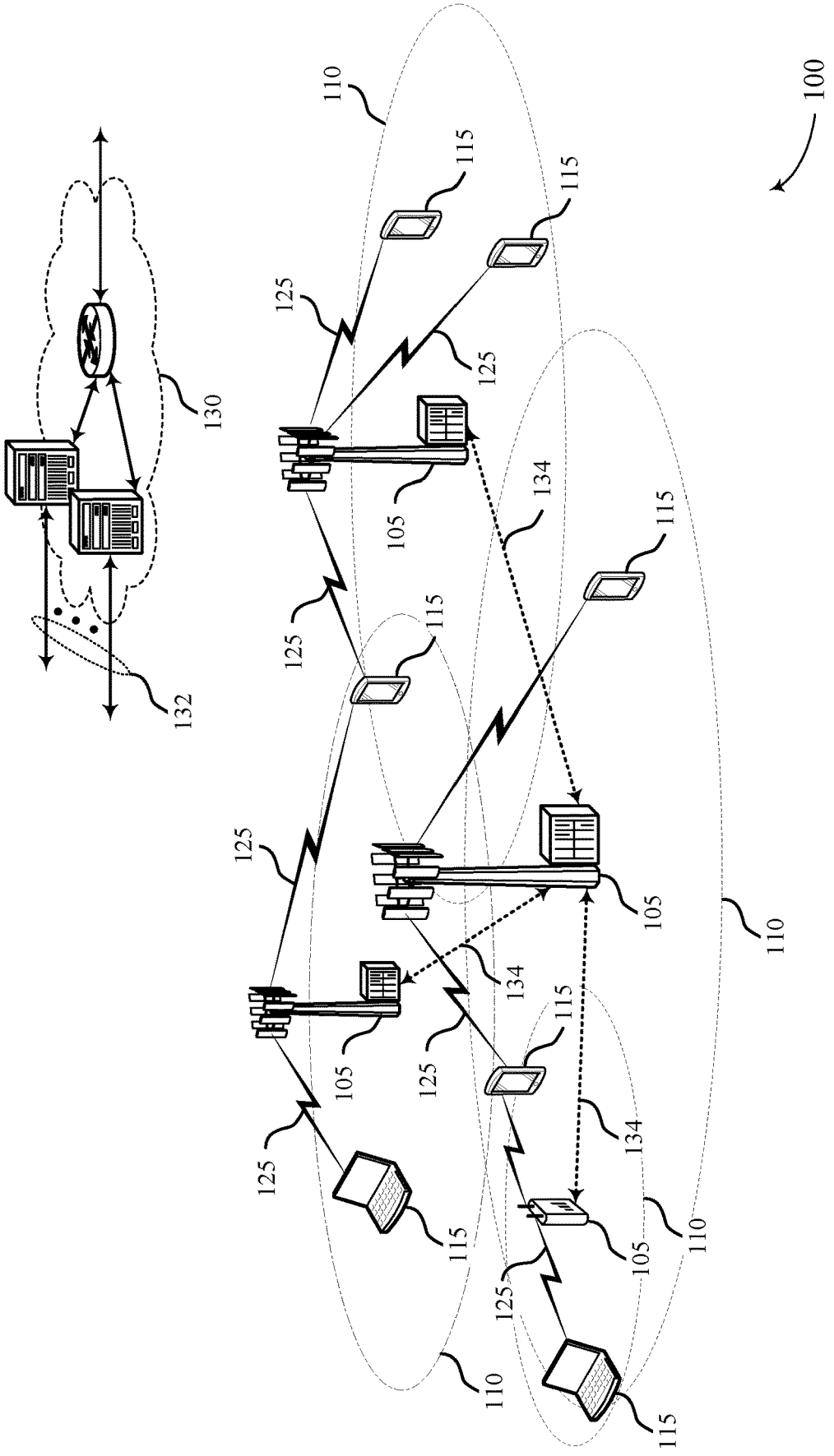


FIG. 1

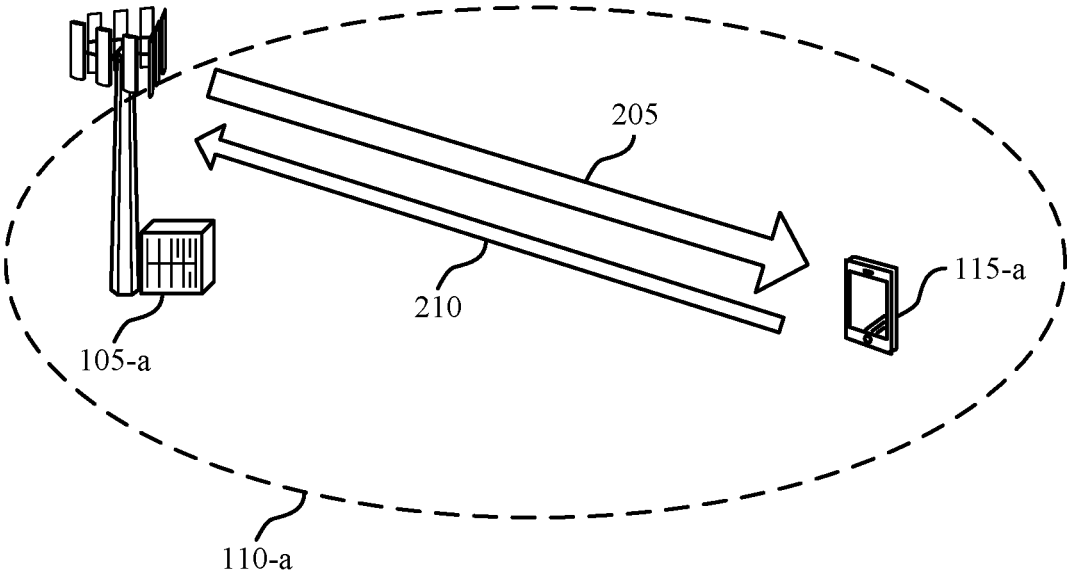
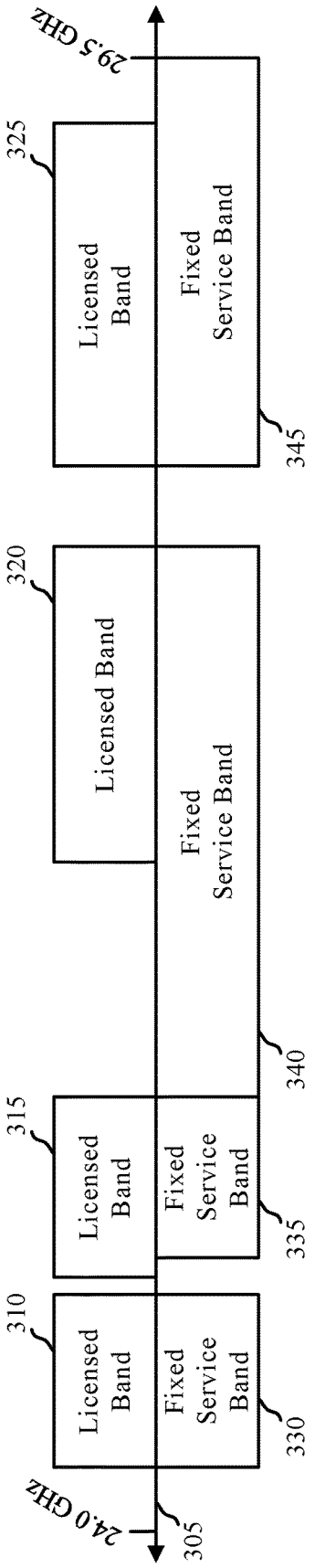


FIG. 2


29.5 GHz
325
Licensed Band
Fixed Service Band
345
320
Licensed Band
Fixed Service Band
340
315
Licensed Band
Fixed Service Band
335
310
Licensed Band
Fixed Service Band
330
24.0 GHz
305

300

FIG. 3

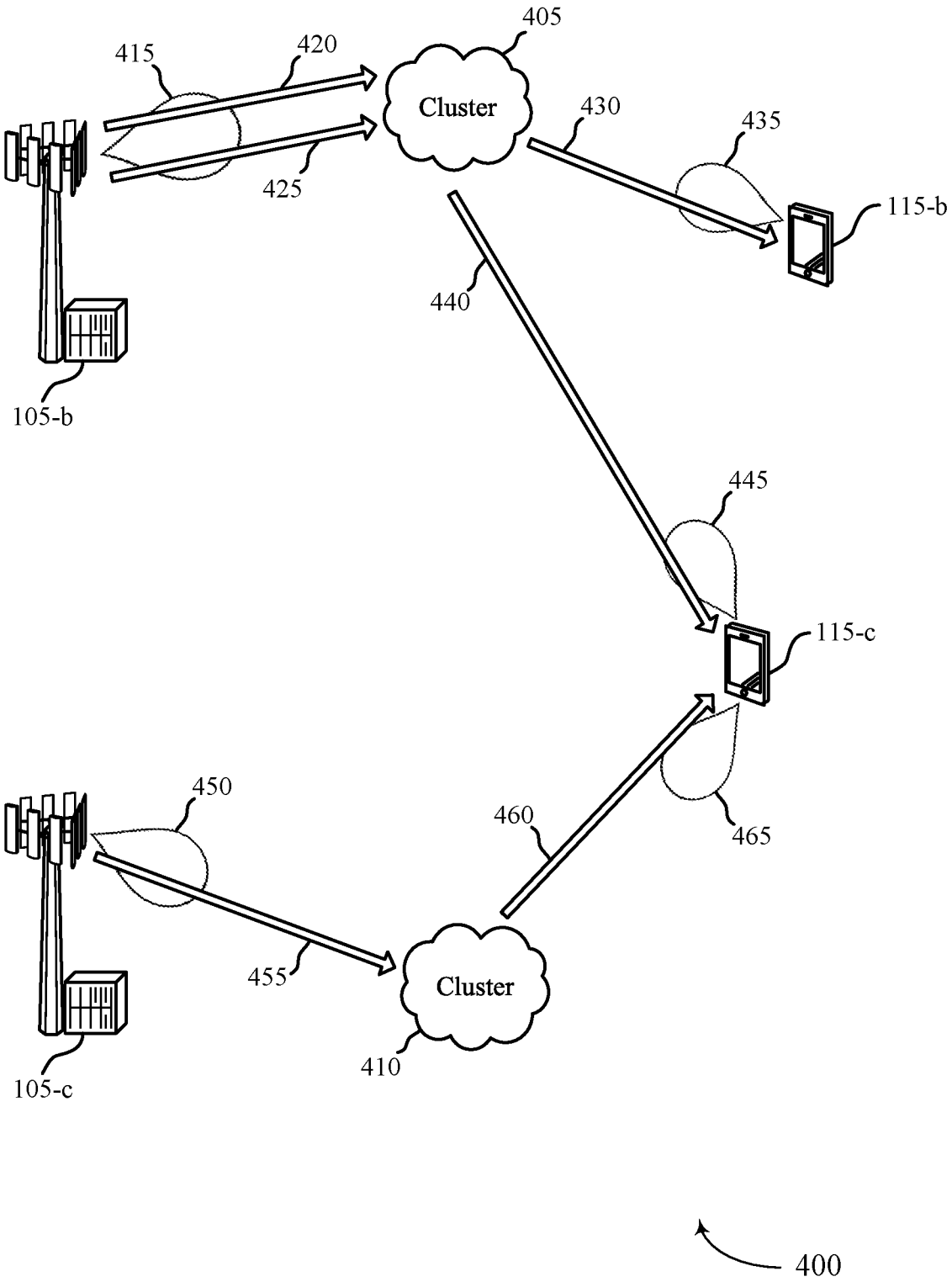

405
415
420
Cluster
430
435
425
115-b
440
105-b
445
115-c
450
460
465
455
Cluster
410
105-c
400

FIG. 4

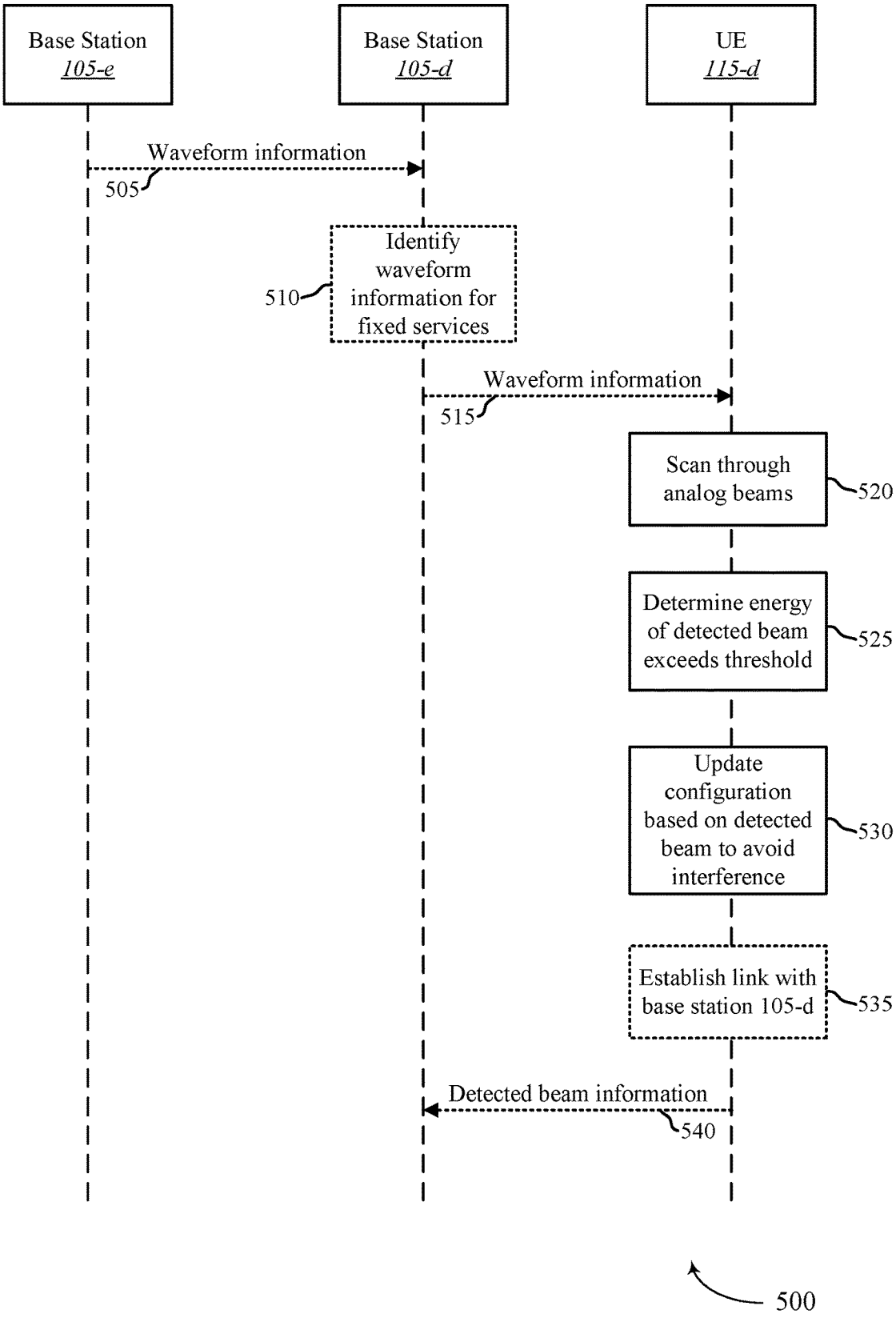

Base Station
105-e
Base Station
105-d
UE
115-d
Waveform information
505
Identify waveform information for fixed services
510
Waveform information
515
Scan through analog beams
520
Determine energy of detected beam exceeds threshold
525
Update configuration based on detected beam to avoid interference
530
Establish link with base station 105-d
535
Detected beam information
540
500

FIG. 5

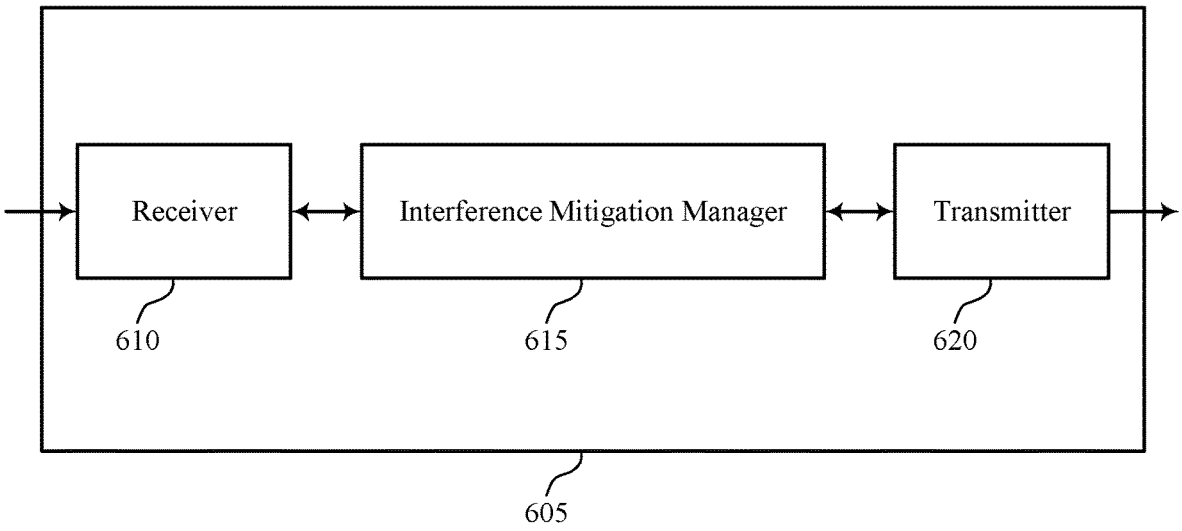

Receiver
Interference Mitigation Manager
Transmitter
610
615
620
605
600

FIG. 6

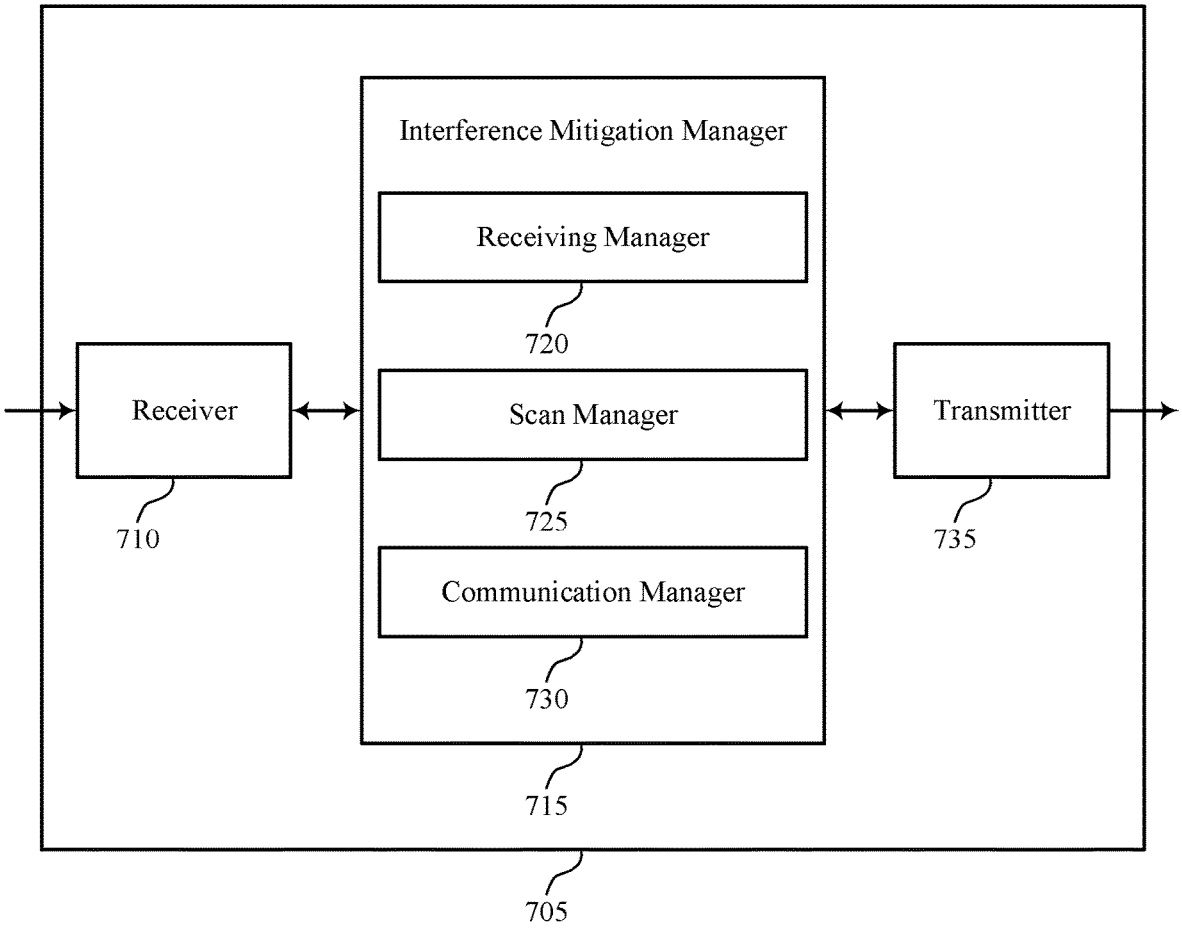

Interference Mitigation Manager
Receiving Manager
720
Receiver
Scan Manager
Transmitter
710
725
735
Communication Manager
730
715
705
700

FIG. 7

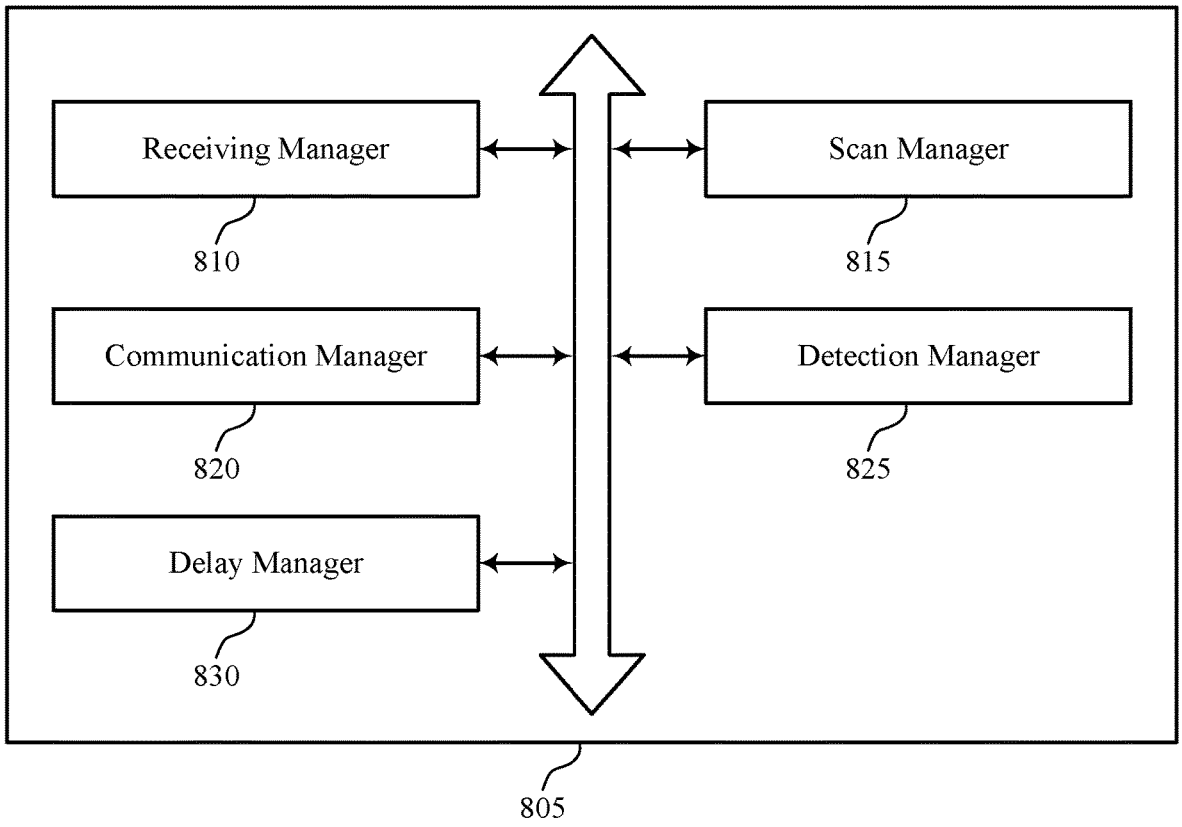

Receiving Manager
Scan Manager
Communication Manager
Detection Manager
Delay Manager
810
815
820
825
830
805
800

FIG. 8

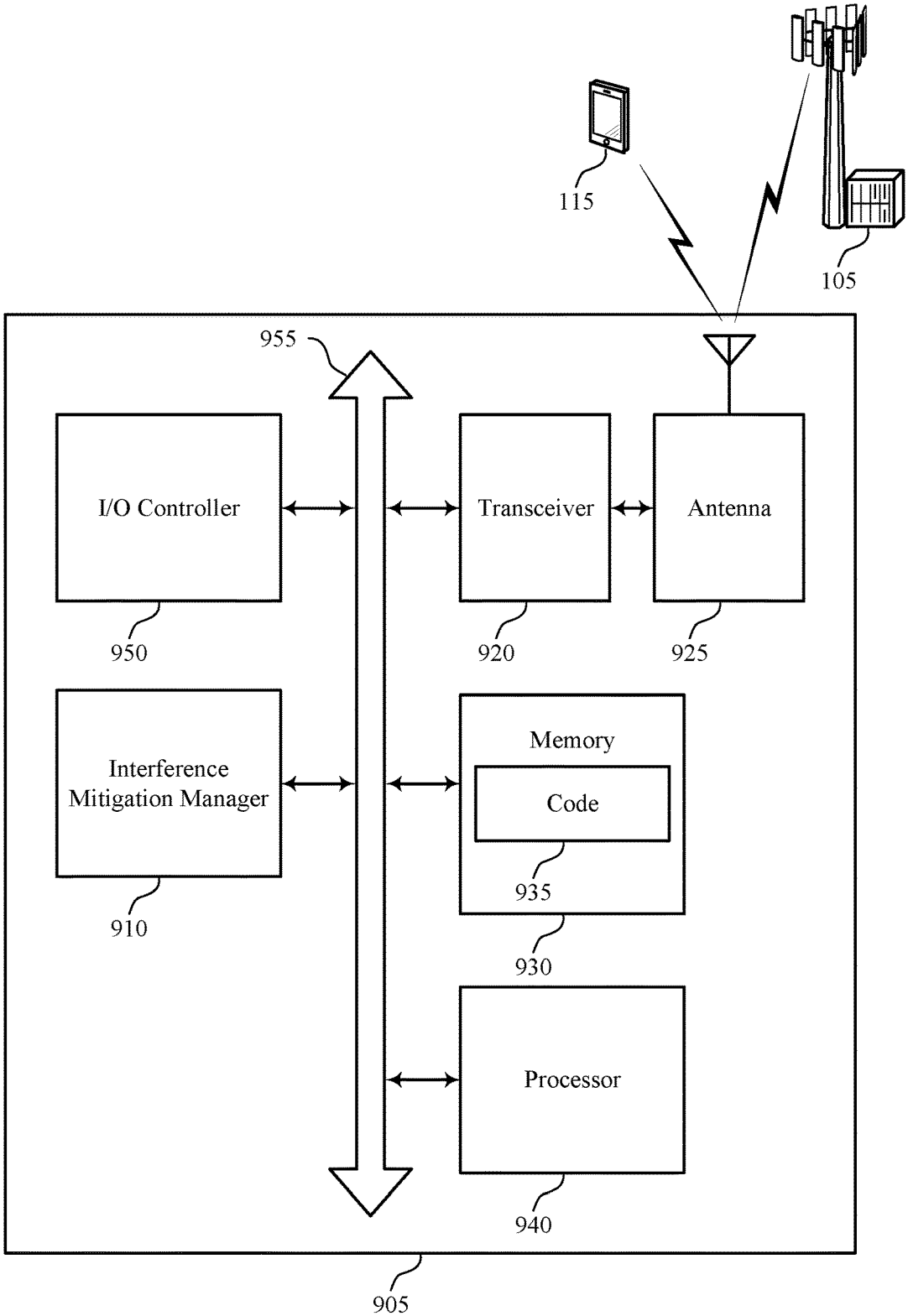

115
105
955
I/O Controller
950
Transceiver
920
Antenna
925
Interference Mitigation Manager
910
Memory
Code
935
930
Processor
940
905
900

FIG. 9

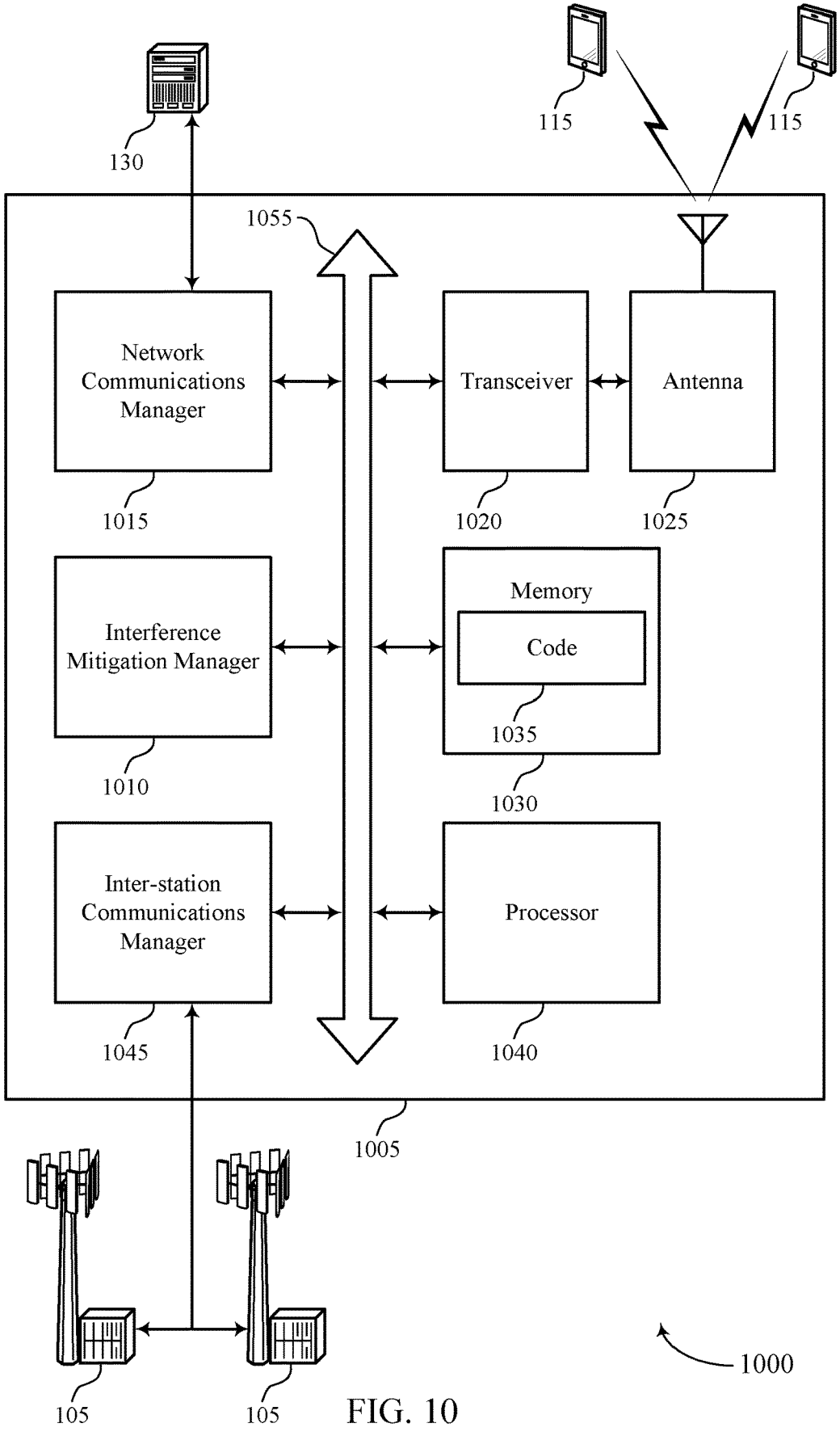

130
115
115
1055
Network Communications Manager
Transceiver
Antenna
1015
1020
1025
Interference Mitigation Manager
Memory
Code
1035
1010
1030
Inter-station Communications Manager
Processor
1045
1040
1005
105
105
1000

FIG. 10

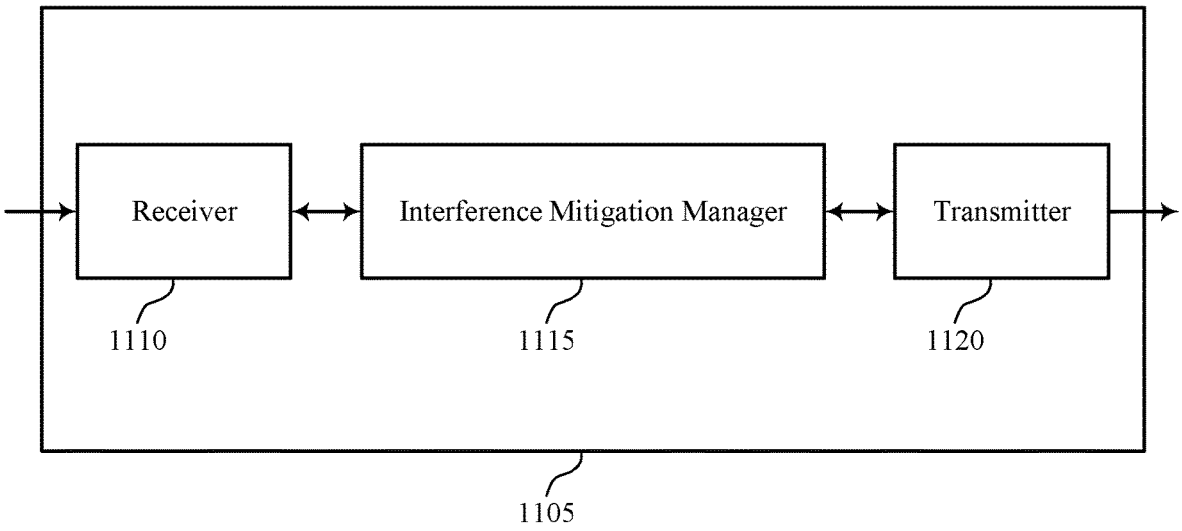

Receiver
Interference Mitigation Manager
Transmitter
1110
1115
1120
1105
1100

FIG. 11

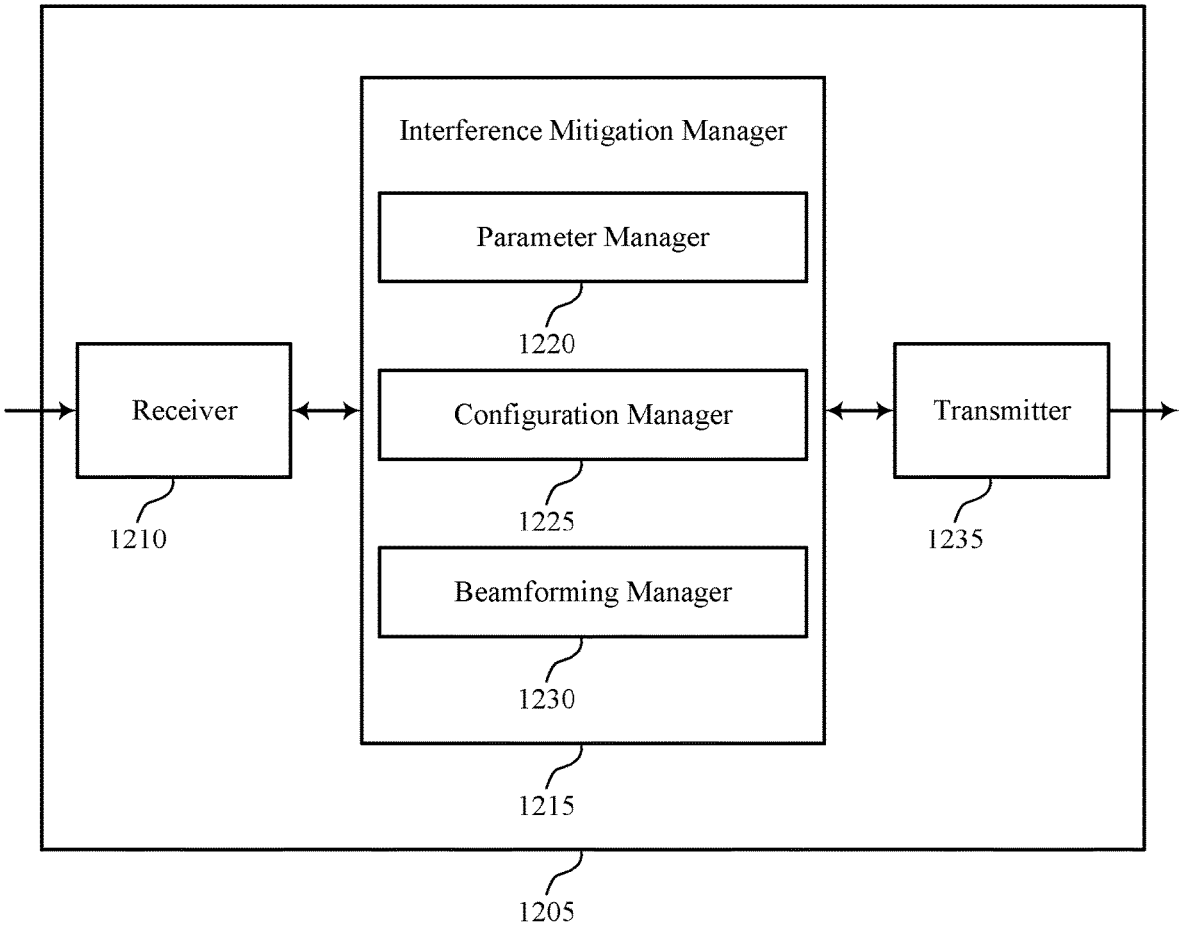

Interference Mitigation Manager
Parameter Manager
1220
Receiver
Configuration Manager
Transmitter
1210
1225
1235
Beamforming Manager
1230
1215
1205
1200

FIG. 12

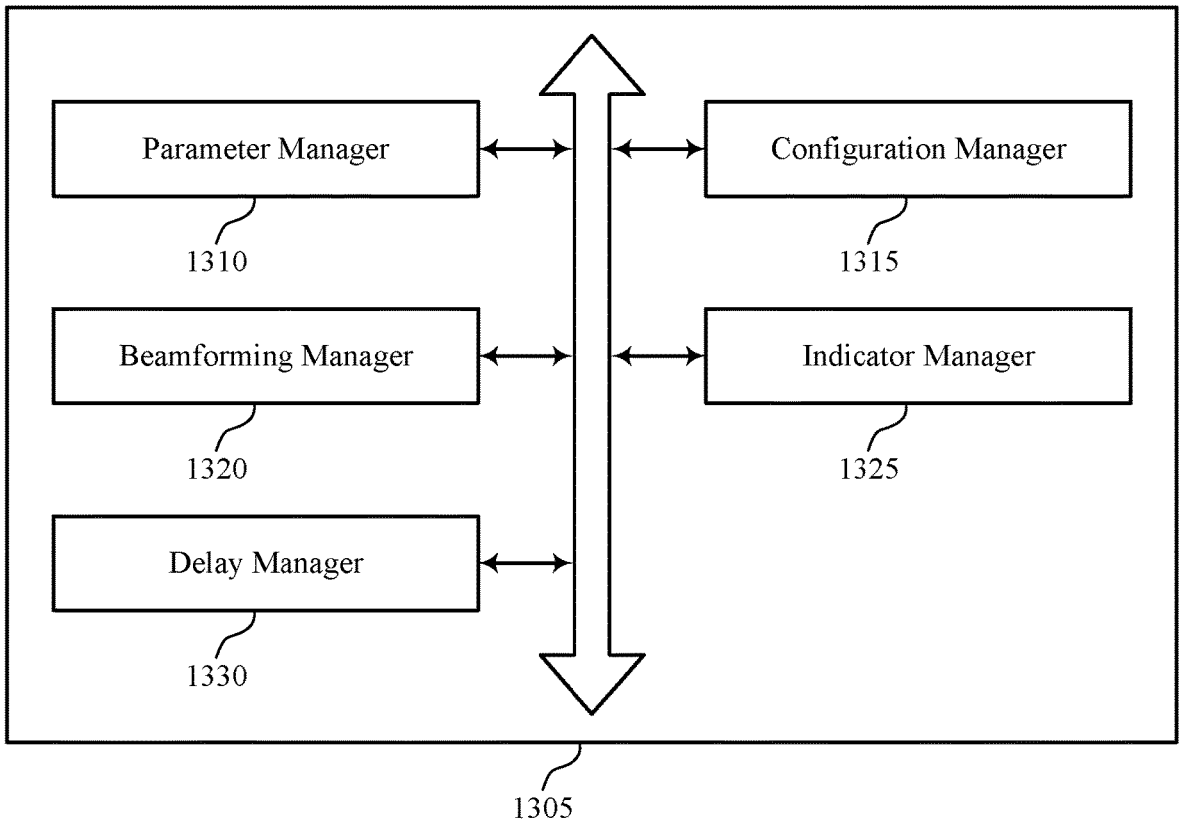

Parameter Manager
1310
Configuration Manager
1315
Beamforming Manager
1320
Indicator Manager
1325
Delay Manager
1330
1305
1300

FIG. 13

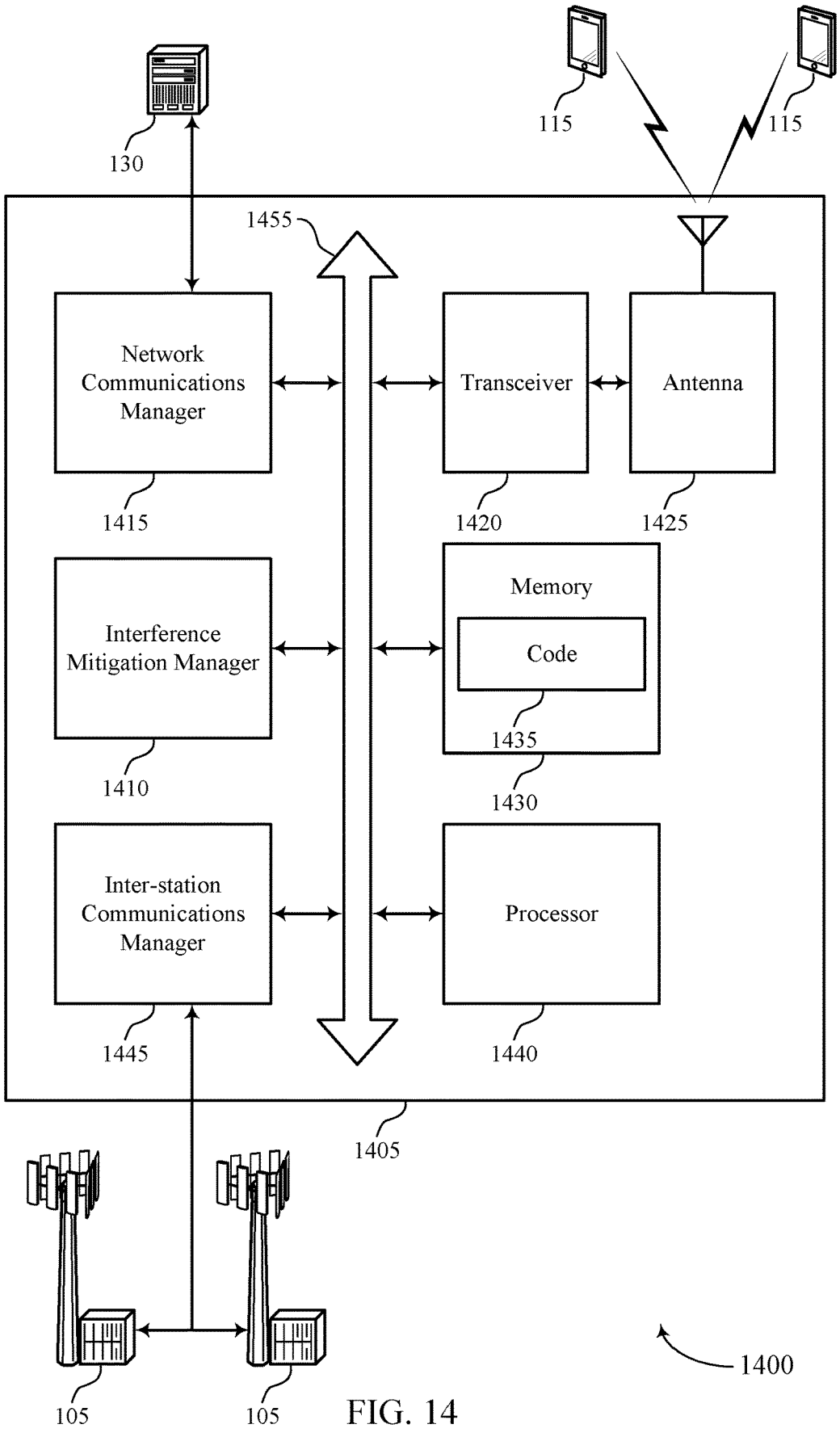

130
115
115
1455
Network Communications Manager
Transceiver
Antenna
1415
1420
1425
Memory
Code
1435
Interference Mitigation Manager
1410
1430
Inter-station Communications Manager
Processor
1445
1440
1405
105
105
1400

FIG. 14

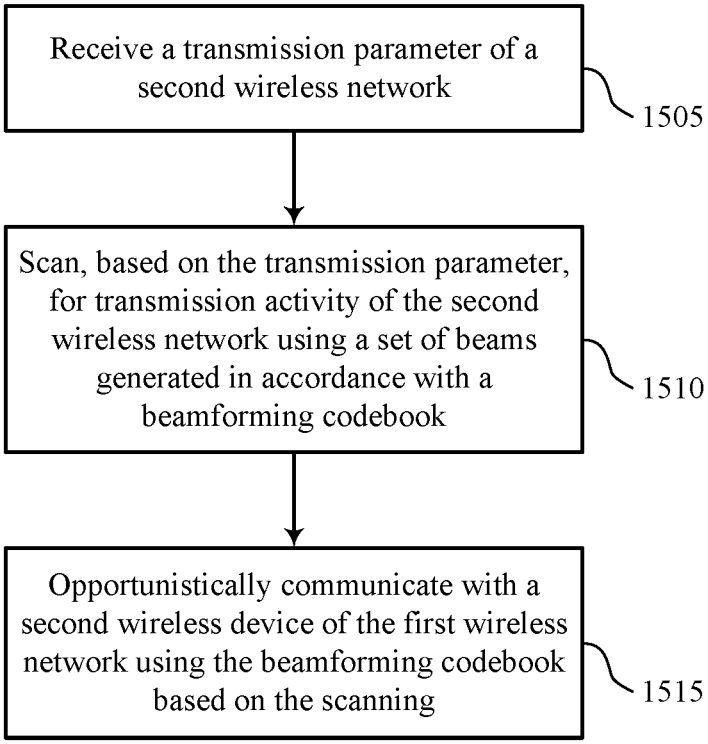

Receive a transmission parameter of a second wireless network
1505
Scan, based on the transmission parameter, for transmission activity of the second wireless network using a set of beams generated in accordance with a beamforming codebook
1510
Opportunistically communicate with a second wireless device of the first wireless network using the beamforming codebook based on the scanning
1515
1500

FIG. 15

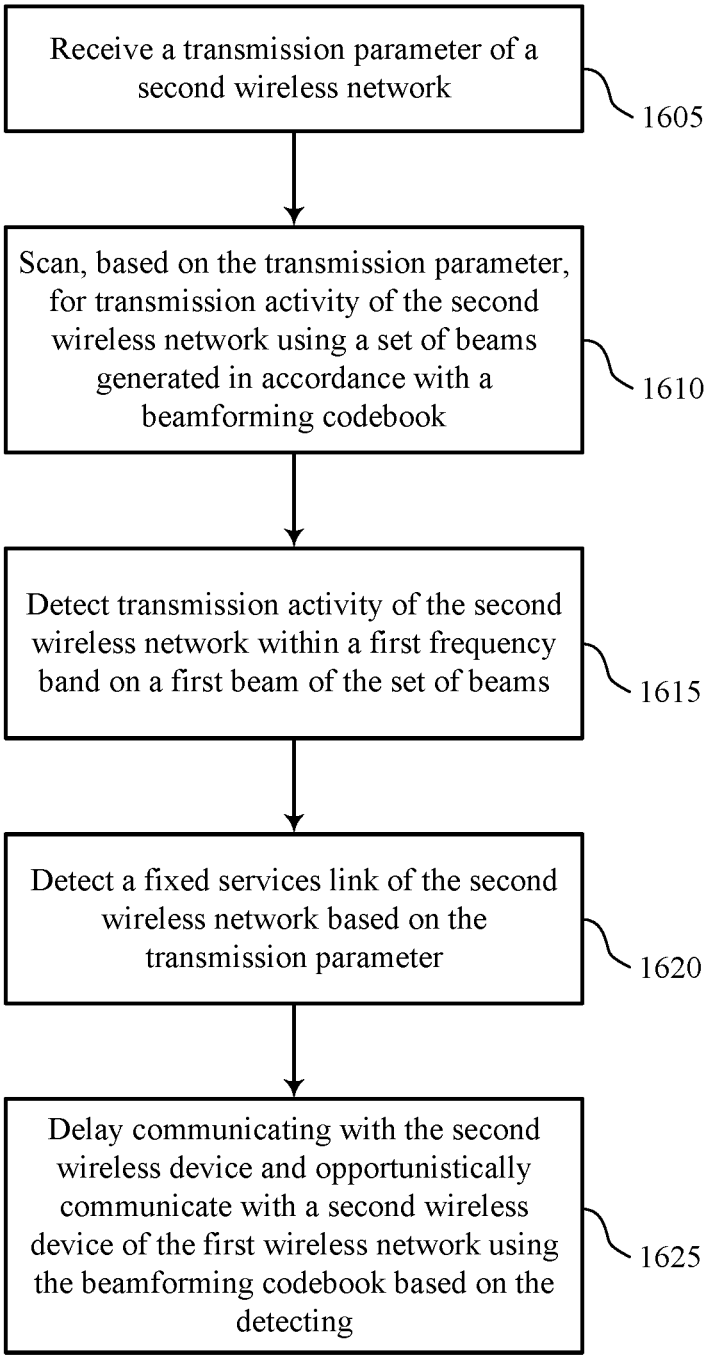

Receive a transmission parameter of a second wireless network
1605
Scan, based on the transmission parameter, for transmission activity of the second wireless network using a set of beams generated in accordance with a beamforming codebook
1610
Detect transmission activity of the second wireless network within a first frequency band on a first beam of the set of beams
1615
Detect a fixed services link of the second wireless network based on the transmission parameter
1620
Delay communicating with the second wireless device and opportunistically communicate with a second wireless device of the first wireless network using the beamforming codebook based on the detecting
1625
1600

FIG. 16

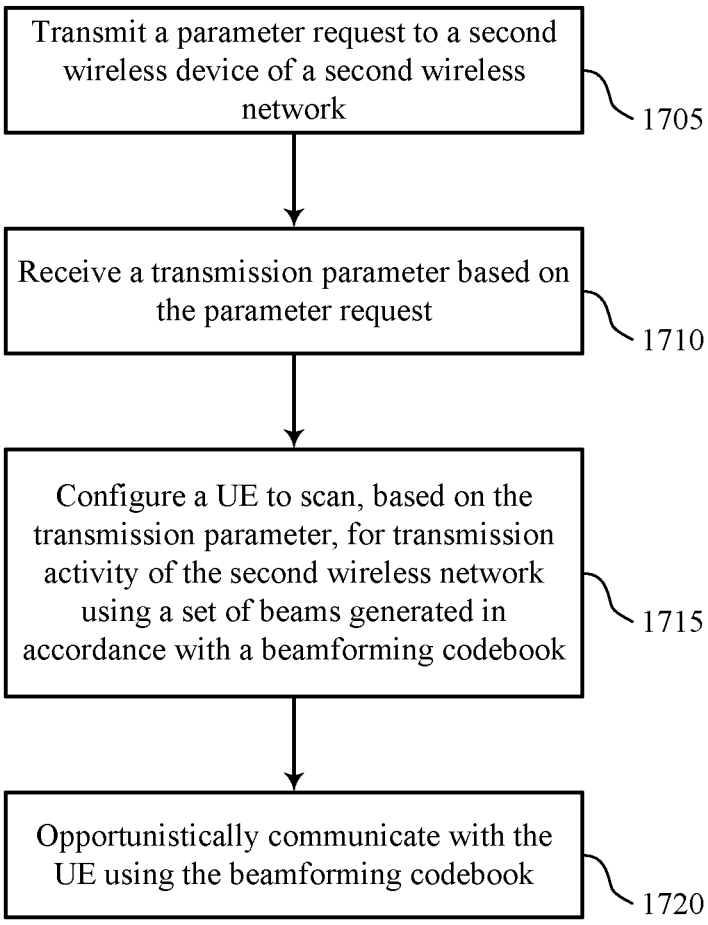

Transmit a parameter request to a second wireless device of a second wireless network
1705
Receive a transmission parameter based on the parameter request
1710
Configure a UE to scan, based on the transmission parameter, for transmission activity of the second wireless network using a set of beams generated in accordance with a beamforming codebook
1715
Opportunistically communicate with the UE using the beamforming codebook
1720
1700

FIG. 17

BEAM-BASED DETECTION FOR INTERFERENCE MITIGATION

CROSS REFERENCE

[0001] The present Application for Patent claims the benefit of U.S. Provisional Patent Application No. 62/794,862 by RAGHAVAN et al., entitled "BEAM-BASED DETECTION FOR INTERFERENCE MITIGATION," filed Jan. 21, 2019, assigned to the assignee hereof, and expressly incorporated herein.

BACKGROUND

[0002] The following relates generally to wireless communications, and more specifically to beam-based detection for interference mitigation.

[0003] Wireless communications systems are widely deployed to provide various types of communication content such as voice, video, packet data, messaging, broadcast, and so on. These systems may be capable of supporting communication with multiple users by sharing the available system resources (e.g., time, frequency, and power). Examples of such multiple-access systems include fourth generation (4G) systems such as Long Term Evolution (LTE) systems, LTE-Advanced (LTE-A) systems, or LTE-A Pro systems, and fifth generation (5G) systems which may be referred to as New Radio (NR) systems. These systems may employ technologies such as code division multiple access (CDMA), time division multiple access (TDMA), frequency division multiple access (FDMA), orthogonal frequency division multiple access (OFDMA), or discrete Fourier transform spread orthogonal frequency division multiplexing (DFT-S-OFDM). A wireless multiple-access communications system may include a number of base stations or network access nodes, each simultaneously supporting communication for multiple communication devices, which may be otherwise known as user equipment (UE).

[0004] In some wireless communications systems, beamforming techniques may be used. With beamforming, rather than broadcasting a signal omnidirectionally in all directions, a base station or network access node may focus a signal in a directionally concentrated manner (e.g., via a beam) toward a UE. However, in some cases, beamforming techniques may be deficient in some circumstances due to overlapping signals or networks. Accordingly, wireless communications systems may benefit from improved beamforming techniques.

SUMMARY

[0005] The described techniques relate to improved methods, systems, devices, and apparatuses that support beam-based detection for interference mitigation. Generally, the described techniques provide for a UE in a mobile wireless network (e.g., at millimeter wave carrier frequencies) detecting the presence of a fixed services network (e.g., operating also at millimeter wave carrier frequencies), and taking steps to avoid interfering with the fixed services network communication. In some cases, a wireless device (e.g., a UE or base station) may receive a transmission parameter of a second wireless network and scan, based at least in part on the transmission parameter, for transmission activity of the second wireless network using a plurality of beams generated in accordance with a beamforming codebook. In some cases, the wireless device may opportunistically communicate with a second wireless device of the first wireless network using the beamforming codebook based at least in part on the scanning.

[0006] A method of wireless communication by a first wireless device of a first wireless network is described. The method may include receiving a transmission parameter of a second wireless network, scanning, based on the transmission parameter, for transmission activity of the second wireless network using a set of beams generated in accordance with a beamforming codebook, and opportunistically communicating with a second wireless device of the first wireless network using the beamforming codebook based on the scanning.

[0007] An apparatus for wireless communication by a first wireless device of a first wireless network is described. The apparatus may include a processor, memory in electronic communication with the processor, and instructions stored in the memory. The instructions may be executable by the processor to cause the apparatus to receive a transmission parameter of a second wireless network, scan, based on the transmission parameter, for transmission activity of the second wireless network using a set of beams generated in accordance with a beamforming codebook, and opportunistically communicate with a second wireless device of the first wireless network using the beamforming codebook based on the scanning.

[0008] Another apparatus for wireless communication by a first wireless device of a first wireless network is described. The apparatus may include means for receiving a transmission parameter of a second wireless network, scanning, based on the transmission parameter, for transmission activity of the second wireless network using a set of beams generated in accordance with a beamforming codebook, and opportunistically communicating with a second wireless device of the first wireless network using the beamforming codebook based on the scanning.

[0009] A non-transitory computer-readable medium storing code for wireless communication by a first wireless device of a first wireless network is described. The code may include instructions executable by a processor to receive a transmission parameter of a second wireless network, scan, based on the transmission parameter, for transmission activity of the second wireless network using a set of beams generated in accordance with a beamforming codebook, and opportunistically communicate with a second wireless device of the first wireless network using the beamforming codebook based on the scanning.

[0010] In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, scanning for transmission activity of the second wireless network further may include operations, features, means, or instructions for detecting transmission activity of the second wireless network within a first frequency band on a first beam of the set of beams.

[0011] In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, detecting the transmission activity of the second wireless network further may include operations, features, means, or instructions for detecting transmission activity of the second wireless network based on determining that a signal strength measurement generated using the first beam satisfies a threshold.

[0012] In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, opportunistically communicating with the second wireless device further may include operations, features, means, or instructions for communicating with the second wireless device via a second beam of the set of beams that differs from the first beam. In some examples, a peak or dominant array gain direction of the first beam may differ from a peak or dominant array gain direction of the second beam.

[0013] In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, opportunistically communicating with the second wireless device further may include operations, features, means, or instructions for transmitting a beam indicator that indicates the second beam to the second wireless device.

[0014] In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, opportunistically communicating with the second wireless device further may include operations, features, means, or instructions for communicating with the second wireless device via the second beam in a second frequency band that differs from the first frequency band.

[0015] In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, opportunistically communicating with the second wireless device further may include operations, features, means, or instructions for transmitting a frequency band indicator to the second wireless device that indicates the first frequency band, the second frequency band, or both. In some examples, the first frequency band may be a first contiguous or non-contiguous frequency band, and the second frequency band may be a second contiguous or non-contiguous frequency band.

[0016] In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, opportunistically communicating with the second wireless device further may include operations, features, means, or instructions for delaying communicating with the second wireless device based on the detecting.

[0017] In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, delaying communicating with the second wireless device further may include operations, features, means, or instructions for transmitting a time-delay indicator to the second wireless device.

[0018] In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, detecting the transmission activity of the second wireless network further may include operations, features, means, or instructions for detecting a fixed services link of the second wireless network based on the transmission parameter.

[0019] In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, detecting the transmission activity of the second wireless network further may include operations, features, means, or instructions for detecting a master information block or a system information block of the second wireless network based on the transmission parameter.

[0020] In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the beamforming codebook corresponds to a first frequency band, the method further may include operations, features, means, or instructions for selecting a second beamforming codebook that corresponds to a second frequency band, and scanning the second frequency band for transmission activity of the second wireless network or a third wireless network using a second set of beams generated in accordance with the second beamforming codebook.

[0021] In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the beamforming codebook provides the first wireless device with only a partial spherical coverage, and where opportunistically communicating with the second wireless device further may include operations, features, means, or instructions for delaying communicating with the second wireless device based on determining that a set of signal strength measurements generated using a respective beam of the set the beams does not satisfy a threshold. In some examples, the transmission parameter may indicate the threshold.

[0022] In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the beamforming codebook provides the first wireless device with a partial spherical coverage, and where opportunistically communicating with the second wireless device further may include operations, features, means, or instructions for communicating with the second wireless device based on determining that at least one signal strength measurement generated using at least one beam of the set the beams satisfies a threshold.

[0023] In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the first wireless network is a Fifth Generation New Radio (5G-NR) wireless network at millimeter wave carrier frequencies and the second wireless network is a fixed services wireless network at millimeter wave carrier frequencies. In some examples, the transmission parameter may indicate a waveform type used in the second wireless network, a duration over which to scan for transmission activity, a beamwidth to use for scanning for transmission activity, or any combination thereof.

[0024] In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the transmission parameter may indicate a detection threshold to use when scanning for transmission activity. In some examples, the detection threshold may be a signal to noise ratio threshold, a signal to interference plus noise ratio, an energy threshold, or a received power threshold. In some examples, the detection threshold may be based at least in a part on a defined false alarm rate or a defined misdetection rate, or a tradeoff between false alarms and misdetections.

[0025] In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the plurality of beams generated in accordance with the codebook may provide the first wireless device with spherical coverage for signal reception over channel clusters in different directions over an entire sphere. In some examples, the first wireless device may be a base station, a user equipment, a backhaul node, or a point to point wireless device.

[0026] A method of wireless communication by a first wireless device of a first wireless network is described. The method may include transmitting a parameter request to a second wireless device of a second wireless network, receiving a transmission parameter based on the parameter request, configuring a UE to scan, based on the transmission parameter, for transmission activity of the second wireless network using a set of beams generated in accordance with a beam-

forming codebook, and opportunistically communicating with the UE using the beamforming codebook.

[0027] An apparatus for wireless communication by a first wireless device of a first wireless network is described. The apparatus may include a processor, memory in electronic communication with the processor, and instructions stored in the memory. The instructions may be executable by the processor to cause the apparatus to transmit a parameter request to a second wireless device of a second wireless network, receive a transmission parameter based on the parameter request, configure a UE to scan, based on the transmission parameter, for transmission activity of the second wireless network using a set of beams generated in accordance with a beamforming codebook, and opportunistically communicate with the UE using the beamforming codebook.

[0028] Another apparatus for wireless communication by a first wireless device of a first wireless network is described. The apparatus may include means for transmitting a parameter request to a second wireless device of a second wireless network, receiving a transmission parameter based on the parameter request, configuring a UE to scan, based on the transmission parameter, for transmission activity of the second wireless network using a set of beams generated in accordance with a beamforming codebook, and opportunistically communicating with the UE using the beamforming codebook.

[0029] A non-transitory computer-readable medium storing code for wireless communication by a first wireless device of a first wireless network is described. The code may include instructions executable by a processor to transmit a parameter request to a second wireless device of a second wireless network, receive a transmission parameter based on the parameter request, configure a UE to scan, based on the transmission parameter, for transmission activity of the second wireless network using a set of beams generated in accordance with a beamforming codebook, and opportunistically communicate with the UE using the beamforming codebook.

[0030] In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, opportunistically communicating with the UE further may include operations, features, means, or instructions for receiving a beam indicator indicating a first beam of the set of beams may have been selected by the UE, and communicating with the UE using a second beam that corresponds to the first beam.

[0031] In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, opportunistically communicating with the UE further may include operations, features, means, or instructions for receiving a frequency band indicator from the UE that indicates a first frequency band, a second frequency band, or both, and communicating with the UE based on the frequency band indicator. In some examples, the first frequency band may be a first contiguous or non-contiguous frequency band, and the second frequency band may be a second contiguous or non-contiguous frequency band

[0032] In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, opportunistically communicating with the UE further may include operations, features, means, or instructions for receiving a delay indicator from the UE, and delaying communicating with the UE based on the delay indicator.

[0033] In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the first wireless network may be a Fifth Generation New Radio (5G-NR) wireless network at millimeter wave carrier frequencies and the second wireless network may be a fixed services wireless network at millimeter wave carrier frequencies.

[0034] In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the transmission parameter may indicate a waveform type used in the second wireless network, a duration over which to scan for transmission activity, a beamwidth to use for scanning for transmission activity, or any combination thereof. In some examples, the transmission parameter may indicate a detection threshold to use when scanning for transmission activity. In some examples, the detection threshold may be a signal to noise ratio threshold, a signal to interference plus noise ratio, an energy threshold, or a received power threshold. In some examples, the detection threshold may be based at least in a part on a defined false alarm rate or a defined misdetection rate, or a tradeoff between false alarms and misdetections.

[0035] In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the plurality of beams generated in accordance with the codebook may provide the UE with spherical coverage for signal reception over channel clusters in different directions over an entire sphere. In some examples, the first wireless device may be a base station, a backhaul node, or a point to point wireless device.

BRIEF DESCRIPTION OF THE DRAWINGS

[0036] FIG. **1** illustrates an example of a system for wireless communications in accordance with aspects of the present disclosure.

[0037] FIG. **2** illustrates an example of a wireless communication subsystem in accordance with various aspects of the present disclosure.

[0038] FIG. **3** illustrates an example of a diagram of a millimeter wave spectrum in accordance with aspects of the present disclosure.

[0039] FIG. **4** illustrates an example of a wireless communication subsystem in accordance with aspects of the present disclosure.

[0040] FIG. **5** illustrates an example of a diagram in accordance with aspects of the present disclosure.

[0041] FIGS. **6** and **7** show block diagrams of devices in accordance with aspects of the present disclosure.

[0042] FIG. **8** shows a block diagram of an interference mitigation manager in accordance with aspects of the present disclosure.

[0043] FIG. **9** shows a diagram of a system including a user equipment (UE) in accordance with aspects of the present disclosure.

[0044] FIG. **10** shows a diagram of a system including a base station in accordance with aspects of the present disclosure.

[0045] FIGS. **11** and **12** show block diagrams of devices in accordance with aspects of the present disclosure.

[0046] FIG. **13** shows a block diagram of an interference mitigation manager in accordance with aspects of the present disclosure.

[0047] FIG. **14** shows a diagram of a system including a device in accordance with aspects of the present disclosure.

[0048] FIGS. **15** through **17** show flowcharts illustrating methods in accordance with aspects of the present disclosure.

DETAILED DESCRIPTION

[0049] In some cases, spectrum in some bands (e.g., millimeter wave band, etc.) may include overlapping allocations. For example, allocations for mobile services may overlap with allocations for fixed services (e.g., fixed wireless connections, wireless Internet Service Providers (WISPs), satellite connections, etc.) resulting in fixed services potentially interfering with mobile services. Examples of fixed service networks may include individual towers that provide (e.g., predominantly provide) line of sight (LOS) service to customers as opposed to mobile services (e.g., cellular wireless services) where the customer devices may remain connected while being mobile (e.g., not necessarily within LOS of a tower).

[0050] To avoid interference, a separation in frequency use may be implemented (e.g., a mobile service network avoiding transmissions in fixed services bands, etc.), or coordination between a fixed service network and a mobile service network may be implemented. In some cases, separation in frequency use may include avoiding fixed service channels in some locations by not assigning relatively wide contiguous blocks to a mobile service operator while operating in those some locations. However, separation in frequency use may result in an inefficient use of the overlapping frequency bands (e.g., available spectral resources may not be efficiently or fully utilized). However, in those locations with fixed services, not all the spectral bands are allocated for fixed services. Accordingly, the present techniques may include detection mechanisms for detecting channel allocations to fixed services.

[0051] The present techniques relate to a UE in a wireless cellular network detecting the presence of a fixed services network, and taking steps to avoid interfering with the fixed services network communication. In some cases, a UE may include a beamforming codebook and may scan for fixed services network communication using the beams indicated in the codebook looking for fixed services network transmission activity (e.g., fixed services network transmissions are currently ongoing within one or more frequency bands). In some cases, a base station may coordinate with a fixed services network to obtain a parameter that improves the ability of the UE to detect fixed services network communication (e.g., a waveform type used by the fixed services network). Based on whether the UE detected fixed services network transmission activity, the UE may select which beam it uses, may delay (e.g., in time) the use of a particular beam or frequency band, or may avoid using a frequency band altogether. In some cases, the UE may opportunistically communicate with a base station based on whether fixed services transmission activity is detected. In some cases, a base station may perform virtually the same operations of detecting fixed services transmission activity to opportunistically communicate with the UE.

[0052] In some examples, the present techniques may include a mobile service device (e.g., a user equipment, base station, a backhaul node, etc.) configured to detect fixed service links (e.g., detect when and where fixed service links exist). In one example, a mobile service network may be configured to detect channelizations allocated for fixed services. In some cases, mobile service networks of the present techniques may be configured to opportunistically transmit/receive with contiguous or non-contiguous carrier aggregation schemes when there are no detected fixed service allocations. In some cases, the mobile service networks of the present techniques may be configured to leverage beam-based detection schemes in the millimeter wave band for efficient use of the spectrum

[0053] Aspects of the disclosure are initially described in the context of a wireless communications system. Aspects of the disclosure are further illustrated by and described with reference to wireless communications subsystems, wireless spectrums, and process flows. Aspects of the disclosure are further illustrated by and described with reference to apparatus diagrams, system diagrams, and flowcharts that relate to beam-based detection for interference mitigation.

[0054] FIG. **1** illustrates an example of a wireless communications system **100** in accordance with aspects of the present disclosure. The wireless communications system **100** includes base stations **105**, UEs **115**, and a core network **130**. In some examples, the wireless communications system **100** may be a Long Term Evolution (LTE) network, an LTE-Advanced (LTE-A) network, an LTE-A Pro network, or a New Radio (NR) network. In some cases, wireless communications system **100** may support enhanced broadband communications, ultra-reliable (e.g., mission critical) communications, low latency communications, or communications with low-cost and low-complexity devices.

[0055] Base stations **105** may wirelessly communicate with UEs **115** via one or more base station antennas. Base stations **105** described herein may include or may be referred to by those skilled in the art as a base transceiver station, a radio base station, an access point, a radio transceiver, a NodeB, an eNodeB (eNB), a next-generation NodeB or giga-NodeB (either of which may be referred to as a gNB), a Home NodeB, a Home eNodeB, or some other suitable terminology. Wireless communications system **100** may include base stations **105** of different types (e.g., macro or small cell base stations). The UEs **115** described herein may be able to communicate with various types of base stations **105** and network equipment including macro eNBs, small cell eNBs, gNBs, relay base stations, and the like.

[0056] Each base station **105** may be associated with a particular geographic coverage area **110** in which communications with various UEs **115** is supported. Each base station **105** may provide communication coverage for a respective geographic coverage area **110** via communication links **125**, and communication links **125** between a base station **105** and a UE **115** may utilize one or more carriers. Communication links **125** shown in wireless communications system **100** may include uplink transmissions from a UE **115** to a base station **105**, or downlink transmissions from a base station **105** to a UE **115**. Downlink transmissions may also be called forward link transmissions while uplink transmissions may also be called reverse link transmissions.

[0057] The geographic coverage area **110** for a base station **105** may be divided into sectors making up a portion of the geographic coverage area **110**, and each sector may be associated with a cell. For example, each base station **105** may provide communication coverage for a macro cell, a small cell, a hot spot, or other types of cells, or various combinations thereof. In some examples, a base station **105** may be movable and therefore provide communication coverage for a moving geographic coverage area **110**. In

some examples, different geographic coverage areas **110** associated with different technologies may overlap, and overlapping geographic coverage areas **110** associated with different technologies may be supported by the same base station **105** or by different base stations **105**. The wireless communications system **100** may include, for example, a heterogeneous LTE/LTE-A/LTE-A Pro or NR network in which different types of base stations **105** provide coverage for various geographic coverage areas **110**.

[0058] The term "cell" refers to a logical communication entity used for communication with a base station **105** (e.g., over a carrier), and may be associated with an identifier for distinguishing neighboring cells (e.g., a physical cell identifier (PCID), a virtual cell identifier (VCID)) operating via the same or a different carrier. In some examples, a carrier may support multiple cells, and different cells may be configured according to different protocol types (e.g., machine-type communication (MTC), narrowband Internet-of-Things (NB-IoT), enhanced mobile broadband (eMBB), or others) that may provide access for different types of devices. In some cases, the term "cell" may refer to a portion of a geographic coverage area **110** (e.g., a sector) over which the logical entity operates.

[0059] UEs **115** may be dispersed throughout the wireless communications system **100**, and each UE **115** may be stationary or mobile. A UE **115** may also be referred to as a mobile device, a wireless device, a remote device, a handheld device, or a subscriber device, or some other suitable terminology, where the "device" may also be referred to as a unit, a station, a terminal, or a client. A UE **115** may also be a personal electronic device such as a cellular phone, a personal digital assistant (PDA), a tablet computer, a laptop computer, or a personal computer. In some examples, a UE **115** may also refer to a wireless local loop (WLL) station, an Internet of Things (IoT) device, an Internet of Everything (IoE) device, or an MTC device, or the like, which may be implemented in various articles such as appliances, vehicles, meters, or the like.

[0060] Some UEs **115**, such as MTC or IoT devices, may be low cost or low complexity devices, and may provide for automated communication between machines (e.g., via Machine-to-Machine (M2M) communication). M2M communication or MTC may refer to data communication technologies that allow devices to communicate with one another or a base station **105** without human intervention. In some examples, M2M communication or MTC may include communications from devices that integrate sensors or meters to measure or capture information and relay that information to a central server or application program that can make use of the information or present the information to humans interacting with the program or application. Some UEs **115** may be designed to collect information or enable automated behavior of machines. Examples of applications for MTC devices include smart metering, inventory monitoring, water level monitoring, equipment monitoring, healthcare monitoring, wildlife monitoring, weather and geological event monitoring, fleet management and tracking, remote security sensing, physical access control, and transaction-based business charging.

[0061] Some UEs **115** may be configured to employ operating modes that reduce power consumption, such as half-duplex communications (e.g., a mode that supports one-way communication via transmission or reception, but not transmission and reception simultaneously). In some examples, half-duplex communications may be performed at a reduced peak rate. Other power conservation techniques for UEs **115** include entering a power saving "deep sleep" mode when not engaging in active communications, or operating over a limited bandwidth (e.g., according to narrowband communications). In some cases, UEs **115** may be designed to support critical functions (e.g., mission critical functions), and a wireless communications system **100** may be configured to provide ultra-reliable communications for these functions.

[0062] In some cases, a UE **115** may also be able to communicate directly with other UEs **115** (e.g., using a peer-to-peer (P2P) or device-to-device (D2D) protocol). One or more of a group of UEs **115** utilizing D2D communications may be within the geographic coverage area **110** of a base station **105**. Other UEs **115** in such a group may be outside the geographic coverage area **110** of a base station **105**, or be otherwise unable to receive transmissions from a base station **105**. In some cases, groups of UEs **115** communicating via D2D communications may utilize a one-to-many (1:M) system in which each UE **115** transmits to every other UE **115** in the group. In some cases, a base station **105** facilitates the scheduling of resources for D2D communications. In other cases, D2D communications are carried out between UEs **115** without the involvement of a base station **105**.

[0063] Base stations **105** may communicate with the core network **130** and with one another. For example, base stations **105** may interface with the core network **130** through backhaul links **132** (e.g., via an S1, N2, N3, or other interface). Base stations **105** may communicate with one another over backhaul links **134** (e.g., via an X2, Xn, or other interface) either directly (e.g., directly between base stations **105**) or indirectly (e.g., via core network **130**).

[0064] The core network **130** may provide user authentication, access authorization, tracking, Internet Protocol (IP) connectivity, and other access, routing, or mobility functions. The core network **130** may be an evolved packet core (EPC), which may include at least one mobility management entity (MME), at least one serving gateway (S-GW), and at least one Packet Data Network (PDN) gateway (P-GW). The MME may manage non-access stratum (e.g., control plane) functions such as mobility, authentication, and bearer management for UEs **115** served by base stations **105** associated with the EPC. User IP packets may be transferred through the S-GW, which itself may be connected to the P-GW. The P-GW may provide IP address allocation as well as other functions. The P-GW may be connected to the network operators IP services. The operators IP services may include access to the Internet, Intranet(s), an IP Multimedia Subsystem (IMS), or a Packet-Switched (PS) Streaming Service.

[0065] At least some of the network devices, such as a base station **105**, may include subcomponents such as an access network entity, which may be an example of an access node controller (ANC). Each access network entity may communicate with UEs **115** through a number of other access network transmission entities, which may be referred to as a radio head, a smart radio head, or a transmission/reception point (TRP). In some configurations, various functions of each access network entity or base station **105** may be distributed across various network devices (e.g., radio heads and access network controllers) or consolidated into a single network device (e.g., a base station **105**).

[0066] Wireless communications system **100** may operate using one or more frequency bands, typically in the range of 300 megahertz (MHz) to 300 gigahertz (GHz). Generally, the region from 300 MHz to 3 GHz is known as the ultra-high frequency (UHF) region or decimeter band, since the wavelengths range from approximately one decimeter to one meter in length. UHF waves may be blocked or redirected by buildings and environmental features. However, the waves may penetrate structures sufficiently for a macro cell to provide service to UEs **115** located indoors. Transmission of UHF waves may be associated with smaller antennas and shorter range (e.g., less than 100 km) compared to transmission using the smaller frequencies and longer waves of the high frequency (HF) or very high frequency (VHF) portion of the spectrum below 300 MHz.

[0067] Wireless communications system **100** may also operate in a super high frequency (SHF) region using frequency bands from 3 GHz to 30 GHz, also known as the centimeter band. The SHF region includes bands such as the 5 GHz industrial, scientific, and medical (ISM) bands, which may be used opportunistically by devices that may be capable of tolerating interference from other users.

[0068] Wireless communications system **100** may also operate in an extremely high frequency (EHF) region of the spectrum (e.g., from 30 GHz to 300 GHz), also known as the millimeter band. In some examples, wireless communications system **100** may support millimeter wave (mmW) communications between UEs **115** and base stations **105**, and EHF antennas of the respective devices may be even smaller and more closely spaced than UHF antennas. In some cases, this may facilitate use of antenna arrays within a UE **115**. However, the propagation of EHF transmissions may be subject to even greater atmospheric attenuation and shorter range than SHF or UHF transmissions. Techniques disclosed herein may be employed across transmissions that use one or more different frequency regions, and designated use of bands across these frequency regions may differ by country or regulating body.

[0069] In some cases, wireless communications system **100** may utilize both licensed and unlicensed radio frequency spectrum bands. For example, wireless communications system **100** may employ License Assisted Access (LAA), LTE-Unlicensed (LTE-U) radio access technology, or NR technology in an unlicensed band such as the 5 GHz ISM band. When operating in unlicensed radio frequency spectrum bands, wireless devices such as base stations **105** and UEs **115** may employ listen-before-talk (LBT) procedures to ensure a frequency channel is clear before transmitting data. In some cases, operations in unlicensed bands may be based on a carrier aggregation configuration in conjunction with component carriers operating in a licensed band (e.g., LAA). Operations in unlicensed spectrum may include downlink transmissions, uplink transmissions, peer-to-peer transmissions, or a combination of these. Duplexing in unlicensed spectrum may be based on frequency division duplexing (FDD), time division duplexing (TDD), or a combination of both.

[0070] In some examples, base station **105** or UE **115** may be equipped with multiple antennas, which may be used to employ techniques such as transmit diversity, receive diversity, multiple-input multiple-output (MIMO) communications, or beamforming. For example, wireless communications system **100** may use a transmission scheme between a transmitting device (e.g., a base station **105**) and a receiving device (e.g., a UE **115**), where the transmitting device is equipped with multiple antennas and the receiving device is equipped with one or more antennas. MIMO communications may employ multipath signal propagation to increase the spectral efficiency by transmitting or receiving multiple signals via different spatial layers, which may be referred to as spatial multiplexing. The multiple signals may, for example, be transmitted by the transmitting device via different antennas or different combinations of antennas. Likewise, the multiple signals may be received by the receiving device via different antennas or different combinations of antennas. Each of the multiple signals may be referred to as a separate spatial stream, and may carry bits associated with the same data stream (e.g., the same codeword) or different data streams. Different spatial layers may be associated with different antenna ports used for channel measurement and reporting. MIMO techniques include single-user MIMO (SU-MIMO) where multiple spatial layers are transmitted to the same receiving device, and multiple-user MIMO (MU-MIMO) where multiple spatial layers are transmitted to multiple devices.

[0071] Beamforming, which may also be referred to as spatial filtering, directional transmission, or directional reception, is a signal processing technique that may be used at a transmitting device or a receiving device (e.g., a base station **105** or a UE **115**) to shape or steer an antenna beam (e.g., a transmit beam or receive beam) along a spatial path between the transmitting device and the receiving device. Beamforming may be achieved by combining the signals communicated via antenna elements of an antenna array such that signals propagating at particular orientations with respect to an antenna array experience constructive interference while others experience destructive interference. The adjustment of signals communicated via the antenna elements may include a transmitting device or a receiving device applying amplitude and phase offsets to signals carried via each of the antenna elements associated with the device. The adjustments associated with each of the antenna elements may be defined by a beamforming weight set associated with a particular orientation (e.g., with respect to the antenna array of the transmitting device or receiving device, or with respect to some other orientation).

[0072] In one example, a base station **105** may use multiple antennas or antenna arrays to conduct beamforming operations for directional communications with a UE **115**. For instance, some signals (e.g., synchronization signals, reference signals, beam selection signals, or other control signals) may be transmitted by a base station **105** multiple times in different directions, which may include a signal being transmitted according to different beamforming weight sets associated with different directions of transmission. Transmissions in different beam directions may be used to identify (e.g., by the base station **105** or a receiving device, such as a UE **115**) a beam direction for subsequent transmission and/or reception by the base station **105**.

[0073] Some signals, such as data signals associated with a particular receiving device, may be transmitted by a base station **105** in a single beam direction (e.g., a direction associated with the receiving device, such as a UE **115**). In some examples, the beam direction associated with transmissions along a single beam direction may be determined based at least in in part on a signal that was transmitted in different beam directions. For example, a UE **115** may receive one or more of the signals transmitted by the base

station **105** in different directions, and the UE **115** may report to the base station **105** an indication of the signal it received with a highest signal quality, or an otherwise acceptable signal quality. Although these techniques are described with reference to signals transmitted in one or more directions by a base station **105**, a UE **115** may employ similar techniques for transmitting signals multiple times in different directions (e.g., for identifying a beam direction for subsequent transmission or reception by the UE **115**), or transmitting a signal in a single direction (e.g., for transmitting data to a receiving device).

[0074] A receiving device (e.g., a UE **115**, which may be an example of a mmW receiving device) may try multiple receive beams when receiving various signals from the base station **105**, such as synchronization signals, reference signals, beam selection signals, or other control signals. For example, a receiving device may try multiple receive directions by receiving via different antenna subarrays, by processing received signals according to different antenna subarrays, by receiving according to different receive beamforming weight sets applied to signals received at a plurality of antenna elements of an antenna array, or by processing received signals according to different receive beamforming weight sets applied to signals received at a plurality of antenna elements of an antenna array, any of which may be referred to as "listening" according to different receive beams or receive directions. In some examples, a receiving device may use a single receive beam to receive along a single beam direction (e.g., when receiving a data signal). The single receive beam may be aligned in a beam direction determined based at least in part on listening according to different receive beam directions (e.g., a beam direction determined to have a highest signal strength, highest signal-to-noise ratio, or otherwise acceptable signal quality based at least in part on listening according to multiple beam directions).

[0075] In some cases, the antennas of a base station **105** or UE **115** may be located within one or more antenna arrays, which may support MIMO operations, or transmit or receive beamforming. For example, one or more base station antennas or antenna arrays may be co-located at an antenna assembly, such as an antenna tower. In some cases, antennas or antenna arrays associated with a base station **105** may be located in diverse geographic locations. A base station **105** may have an antenna array with a number of rows and columns of antenna ports that the base station **105** may use to support beamforming of communications with a UE **115**. Likewise, a UE **115** may have one or more antenna arrays that may support various MIMO or beamforming operations.

[0076] In some cases, wireless communications system **100** may be a packet-based network that operate according to a layered protocol stack. In the user plane, communications at the bearer or Packet Data Convergence Protocol (PDCP) layer may be IP-based. A Radio Link Control (RLC) layer may perform packet segmentation and reassembly to communicate over logical channels. A Medium Access Control (MAC) layer may perform priority handling and multiplexing of logical channels into transport channels. The MAC layer may also use hybrid automatic repeat request (HARD) to provide retransmission at the MAC layer to improve link efficiency. In the control plane, the Radio Resource Control (RRC) protocol layer may provide establishment, configuration, and maintenance of an RRC connection between a UE **115** and a base station **105** or core network **130** supporting radio bearers for user plane data. At the Physical layer, transport channels may be mapped to physical channels.

[0077] In some cases, UEs **115** and base stations **105** may support retransmissions of data to increase the likelihood that data is received successfully. HARQ feedback is one technique of increasing the likelihood that data is received correctly over a communication link **125**. HARQ may include a combination of error detection (e.g., using a cyclic redundancy check (CRC)), forward error correction (FEC), and retransmission (e.g., automatic repeat request (ARQ)). HARQ may improve throughput at the MAC layer in poor radio conditions (e.g., signal-to-noise conditions). In some cases, a wireless device may support same-slot HARQ feedback, where the device may provide HARQ feedback in a specific slot for data received in a previous symbol in the slot. In other cases, the device may provide HARQ feedback in a subsequent slot, or according to some other time interval.

[0078] Time intervals in LTE or NR may be expressed in multiples of a basic time unit, which may, for example, refer to a sampling period of T_s=1/30,720,000 seconds. Time intervals of a communications resource may be organized according to radio frames each having a duration of 10 milliseconds (ms), where the frame period may be expressed as T_f=307,200 T_s. The radio frames may be identified by a system frame number (SFN) ranging from 0 to 1023. Each frame may include 10 subframes numbered from 0 to 9, and each subframe may have a duration of 1 ms. A subframe may be further divided into 2 slots each having a duration of 0.5 ms, and each slot may contain 6 or 7 modulation symbol periods (e.g., depending on the length of the cyclic prefix prepended to each symbol period). Excluding the cyclic prefix, each symbol period may contain 2048 sampling periods. In some cases, a subframe may be the smallest scheduling unit of the wireless communications system **100**, and may be referred to as a transmission time interval (TTI). In other cases, a smallest scheduling unit of the wireless communications system **100** may be shorter than a subframe or may be dynamically selected (e.g., in bursts of shortened TTIs (sTTIs) or in selected component carriers using sTTIs).

[0079] In some wireless communications systems, a slot may further be divided into multiple mini-slots containing one or more symbols. In some instances, a symbol of a mini-slot or a mini-slot may be the smallest unit of scheduling. Each symbol may vary in duration depending on the subcarrier spacing or frequency band of operation, for example. Further, some wireless communications systems may implement slot aggregation in which multiple slots or mini-slots are aggregated together and used for communication between a UE **115** and a base station **105**.

[0080] The term "carrier" refers to a set of radio frequency spectrum resources having a defined physical layer structure for supporting communications over a communication link **125**. For example, a carrier of a communication link **125** may include a portion of a radio frequency spectrum band that is operated according to physical layer channels for a given radio access technology. Each physical layer channel may carry user data, control information, or other signaling. A carrier may be associated with a pre-defined frequency channel (e.g., an evolved universal mobile telecommunication system terrestrial radio access (E-UTRA) absolute radio frequency channel number (EARFCN)), and may be posi-

tioned according to a channel raster for discovery by UEs **115**. Carriers may be downlink or uplink (e.g., in an FDD mode), or be configured to carry downlink and uplink communications (e.g., in a TDD mode). In some examples, signal waveforms transmitted over a carrier may be made up of multiple sub-carriers (e.g., using multi-carrier modulation (MCM) techniques such as orthogonal frequency division multiplexing (OFDM) or discrete Fourier transform spread OFDM (DFT-S-OFDM)).

[0081] The organizational structure of the carriers may be different for different radio access technologies (e.g., LTE, LTE-A, LTE-A Pro, NR). For example, communications over a carrier may be organized according to TTIs or slots, each of which may include user data as well as control information or signaling to support decoding the user data. A carrier may also include dedicated acquisition signaling (e.g., synchronization signals or system information, etc.) and control signaling that coordinates operation for the carrier. In some examples, (e.g., in a carrier aggregation configuration), a carrier may also have acquisition signaling or control signaling that coordinates operations for other carriers.

[0082] Physical channels may be multiplexed on a carrier according to various techniques. A physical control channel and a physical data channel may be multiplexed on a downlink carrier, for example, using time division multiplexing (TDM) techniques, frequency division multiplexing (FDM) techniques, or hybrid TDM-FDM techniques. In some examples, control information transmitted in a physical control channel may be distributed between different control regions in a cascaded manner (e.g., between a common control region or common search space and one or more UE-specific control regions or UE-specific search spaces).

[0083] A carrier may be associated with a particular bandwidth of the radio frequency spectrum, and in some examples the carrier bandwidth may be referred to as a "system bandwidth" of the carrier or the wireless communications system **100**. For example, the carrier bandwidth may be one of a number of predetermined bandwidths for carriers of a particular radio access technology (e.g., 1.4, 3, 5, 10, 15, 20, 40, or 80 MHz). In some examples, each served UE **115** may be configured for operating over portions or all of the carrier bandwidth. In other examples, some UEs **115** may be configured for operation using a narrowband protocol type that is associated with a predefined portion or range (e.g., set of subcarriers or RBs) within a carrier (e.g., "in-band" deployment of a narrowband protocol type).

[0084] In a system employing MCM techniques, a resource element may consist of one symbol period (e.g., a duration of one modulation symbol) and one subcarrier, where the symbol period and subcarrier spacing are inversely related. The number of bits carried by each resource element may depend on the modulation scheme (e.g., the order of the modulation scheme). Thus, the more resource elements that a UE **115** receives and the higher the order of the modulation scheme, the higher the data rate may be for the UE **115**. In MIMO systems, a wireless communications resource may refer to a combination of a radio frequency spectrum resource, a time resource, and a spatial resource (e.g., spatial layers), and the use of multiple spatial layers may further increase the data rate for communications with a UE **115**.

[0085] Devices of the wireless communications system **100** (e.g., base stations **105** or UEs **115**) may have a hardware configuration that supports communications over a particular carrier bandwidth, or may be configurable to support communications over one of a set of carrier bandwidths. In some examples, the wireless communications system **100** may include base stations **105** and/or UEs **115** that support simultaneous communications via carriers associated with more than one different carrier bandwidth.

[0086] Wireless communications system **100** may support communication with a UE **115** on multiple cells or carriers, a feature which may be referred to as carrier aggregation or multi-carrier operation. A UE **115** may be configured with multiple downlink component carriers and one or more uplink component carriers according to a carrier aggregation configuration. Carrier aggregation may be used with both FDD and TDD component carriers.

[0087] In some cases, wireless communications system **100** may utilize enhanced component carriers (eCCs). An eCC may be characterized by one or more features including wider carrier or frequency channel bandwidth, shorter symbol duration, shorter TTI duration, or modified control channel configuration. In some cases, an eCC may be associated with a carrier aggregation configuration or a dual connectivity configuration (e.g., when multiple serving cells have a suboptimal or non-ideal backhaul link). An eCC may also be configured for use in unlicensed spectrum or shared spectrum (e.g., where more than one operator is allowed to use the spectrum). An eCC characterized by wide carrier bandwidth may include one or more segments that may be utilized by UEs **115** that are not capable of monitoring the whole carrier bandwidth or are otherwise configured to use a limited carrier bandwidth (e.g., to conserve power).

[0088] In some cases, an eCC may utilize a different symbol duration than other component carriers, which may include use of a reduced symbol duration as compared with symbol durations of the other component carriers. A shorter symbol duration may be associated with increased spacing between adjacent subcarriers. A device, such as a UE **115** or base station **105**, utilizing eCCs may transmit wideband signals (e.g., according to frequency channel or carrier bandwidths of 20, 40, 60, 80 MHz, etc.) at reduced symbol durations (e.g., 16.67 microseconds). A TTI in eCC may consist of one or multiple symbol periods. In some cases, the TTI duration (that is, the number of symbol periods in a TTI) may be variable.

[0089] Wireless communications system **100** may be an NR system that may utilize any combination of licensed, shared, and unlicensed spectrum bands, among others. The flexibility of eCC symbol duration and subcarrier spacing may allow for the use of eCC across multiple spectrums. In some examples, NR shared spectrum may increase spectrum utilization and spectral efficiency, specifically through dynamic vertical (e.g., across the frequency domain) and horizontal (e.g., across the time domain) sharing of resources.

[0090] In one example, a device (e.g., UE **115** or base station **105**) may perform beam-based detection for interference mitigation. For example, a device (e.g., UE **115** or base station **105**) may receive a transmission parameter of a second wireless network and scan, based at least in part on the transmission parameter, for transmission activity of the second wireless network using one or more beams. In some cases, the one or more beams may be generated in accor-

dance with a beamforming codebook. Additionally or alternatively, a device (e.g., UE **115** or base station **105**) may communicate with a second wireless device of the first wireless network using the beamforming codebook based at least in part on the scanning.

[0091] FIG. **2** illustrates an example of a wireless communications subsystem **200** in accordance with various aspects of the present disclosure. In some examples, the wireless communications subsystem **200** may include a mobile services network. In some cases, wireless communications subsystem **200** may coexist with a fixed services network.

[0092] As illustrated, wireless communications subsystem **200** may include UE **115**-*a* and base station **105**-*a*, which may be examples of a UE **115** or a base station **105**, as described above with reference to FIG. **1**. Wireless communications subsystem **200** may also include downlink **205** and uplink **210**. Base station **105**-*a* may use downlink **205** to convey control and/or data information to UE **115**-*a*. And UE **115**-*a* may use uplink **210** to convey control and/or data information to base station **105**-*a*. In some cases, downlink **205** may use different time and/or frequency resources than uplink **210**.

[0093] In some examples, a mobile services device (e.g., UE **115**-*a* or base station **105**-*a*) may include one or more beamforming codebooks (e.g., one or more analog beamforming codebooks for every band configured for transmissions or receptions). A beamforming codebook may provide directional analog beamforming weights that provide up to full spherical coverage. Full spherical coverage corresponds to the UE's capability to receive or transmit via distinct spatial clusters in distinct directions over the entire sphere around the UE. Full spherical coverage allows the UE to establish a communication link with any base station in any cell, independent of its directional orientation or location or path trajectory. Lack of full spherical coverage (also known as partial spherical coverage) can lead to diminished beamforming performance as some direction(s) over the sphere are left uncovered or unavailable for establishing communications links. Partial spherical coverage could be necessitated by the presence of spatial blockers (e.g., self-blockage in the form of hand, human body, etc. or other blockers such as foliage, buildings, other humans, vehicles, etc. blocking a signal). In contrast to LTE or sub-6 GHz bands, blockage is more common at millimeter wave bands due to the smaller wavelengths. In some cases, the mobile services device may obtain the beamforming codebook from an internal device-level implementation. In some case, the codebook may also be obtained from a server or from a base station (e.g., in response to querying the server, querying the base station, etc.). In some cases, UE **115**-*a* may obtain a beamforming codebook in response to querying base station **105**-*a*.

[0094] In some examples, the mobile services device may scan one or more beams listed in the one or more beamforming codebooks. In some cases, UE **115**-*a* may attempt to detect energy (e.g., an energy estimate) from one or more scanned beams representing whether there currently is transmission within a fixed services network within a particular frequency band or bands along a set of directions. In some cases, UE **115**-*a* may update its configuration to avoid transmissions that would interfere with the one or more detected beams. In some cases, UE **115**-*a* may delay using a detected beam or using a frequency band of a detected beam for a set period of time. In some cases, UE **115**-*a* may communicate with base station **105**-*a* (e.g., via downlink **205** and uplink **210**), including sending information to base station **105**-*a* regarding the detected beams to base station **105**-*a*. After receiving the information regarding the detected beams, base station **105**-*a* may update its configuration to avoid transmissions that would interfere with the one or more detected beams. In some cases, after receiving the information regarding the detected beams, base station **105**-*a* may communicate with UE **115**-*a* (e.g., via downlink **205** and uplink **210**), instructing UE **115**-*a* to update a configuration of UE **115**-*a* to avoid transmissions that would interfere with the one or more detected beams.

[0095] FIG. **3** illustrates an example of a diagram of a spectrum **300** associated with beam-based detection for interference mitigation in accordance with aspects of the present disclosure. In some examples, spectrum **300** may implement aspects of wireless communication system **100** or wireless communications subsystem **200**.

[0096] As illustrated, spectrum **300** may include a spectrum of frequency bands (e.g., a millimeter wave spectrum from 24 Gigahertz (GHz) to 29.5 GHz in the illustrated example, FR2 that includes 24-52.6 GHz, or the like). In some cases, the illustrated spectrum **300** may include multiple licensed bands and multiple fixed service bands. The licensed bands may include licensed band **310**, licensed band **315**, licensed band **320**, and licensed band **325**. The fixed service bands may include fixed service band **330**, fixed service band **335**, fixed service band **340**, and fixed service band **345**.

[0097] In the illustrated example, licensed bands for mobile services in some geographic area may include a mobile service band from 24.25 GHz to 24.45 GHz (e.g., licensed band **310**), a mobile service band from 24.75 GHz to 25.25 GHz (e.g., licensed band **315**), a mobile service band from 25.5 GHz to 27 GHz (e.g., licensed band **320**), and a mobile service band from 27.5 GHz to 28.35 GHz (e.g., licensed band **325**), etc. In the illustrated example, fixed service bands in the geographic area may include a fixed service band from 24.25 GHz to 24.45 GHz (e.g., fixed service band **330**), a fixed service band from 25.05 GHz to 25.25 GHz (e.g., fixed service band **335**), a fixed service band from 25.25 GHz to 27 GHz (e.g., fixed service band **340**), and a fixed service band from 27.5 GHz to 29.5 GHz (e.g., fixed service band **345**), etc. As shown in the illustrated example, some of the fixed service bands are shared with mobile service bands. Thus, interference may occur when a mobile service device transmits in a band currently being used by a fixed service device.

[0098] In some geographic areas, a frequency band for fixed services may be assigned as a paired band with the Tx/Rx separation fixed at 1,008 MHz. In the case of existing block assignment in geographic areas, a mobile services frequency block assigned to an operator in the 26 GHz band may be assumed to be at least 200 MHz wide or more. As a consequence, portions of a fixed services band within spectrum **300** (e.g., either in the "Go" or "Return" channel blocks) may overlap with a mobile services spectrum block assigned to a mobile services operator.

[0099] In some examples, mobile services operating within spectrum **300** may differ from previous approaches (e.g., those used in sub-6 GHz spectrum allocations) in one or more ways. For example, the mobile services may use sparser channels with a smaller number of dominant clus-

ters. Additionally, the mobile services may use smaller wavelengths with more antennas packed within a given aperture, resulting in smaller beamwidths and directional signaling. In some cases, the present techniques use the directional nature of signaling in the millimeter wave band for interference detection.

[0100] In some cases, a wireless device (e.g., a UE operating within spectrum **300**) may use a beamforming codebook designed for spherical coverage properties, where relatively good signal to noise ratio (SNR) performance is realized irrespective of the direction in which dominant clusters are observed by the wireless device, whether the wireless device is attached to a fixed services network or to a mobile services network. In some cases, beamforming codebooks used by the wireless device may be robust over the millimeter wave band (e.g., from 24 GHz to 52 GHz, etc.). In some examples, the same analog codebooks may be reused in different mobile service networks and/or different fixed service networks for SNR detection without significant loss in performance.

[0101] It is noted that the present techniques differ in multiple ways over previous interference mitigation schemes. For example, the present techniques differ from the process of a UE searching for neighbor cells. For example, in a typical neighbor cell search, a UE detects primary synchronization signals (PSS) and/or secondary synchronization signals (SSS) of neighbor cells for either handover or base-station cooperation reasons. With UEs searching for neighbor cells, the detection algorithm is constructed due to knowledge of structure of PSS/SSS symbols. In some cases, PSS may be used for synchronization and PSS/SSS may be used for physical cell ID computation. The UE searching for neighbor cells uses the fact that the structure of PSS/SSS symbols are known (e.g., Zadoff-Chu sequence, m-sequence, Gold sequence, etc.) and differ (e.g., differ only) in terms of parameters used in the precise sequence which are tailored appropriately for some transmissions.

[0102] In contrast, based on the protocol used for fixed service links the frame structure may be significantly different from the frame structure for a mobile network where a UE searches for neighbor cells. For example, even if the fixed service link uses orthogonal frequency-division multiplexing (OFDM) transmissions, the Fast Fourier Transform (FFT) sizes of the two networks (fixed service network and mobile service network) may be different leading to interference from multiple subcarriers of one network on the other. Nevertheless, since each network operates at millimeter wave frequencies, the present techniques take advantage of the detectability of the beam-based transmissions from the multiple antennas of both networks. While the transmitter in the fixed services network may or may not use multiple antennas (e.g., dish antennas or Yagi antennas may be used) to allow directional transmissions at the transmitter end, multiple antennas at the UE end in both networks allow the use of beam-based detection techniques. In particular, the present techniques leverage the common beam-based protocol for SNR estimation as the beams used in mobile service networks may be reused at other or similar millimeter wave frequencies used for fixed services (e.g., with a small performance degradation). Specifically, some examples of the present techniques may use Rx beamforming to detect concurrent transmissions.

[0103] FIG. **4** illustrates an example of a wireless communications subsystem **400** in accordance with various aspects of the present disclosure.

[0104] As illustrated, wireless communications subsystem **400** may include UE **115**-*b*, UE **115**-*c*, base station **105**-*b*, and base station **105**-*c*, which may be examples of a UE **115** or a base station **105**, as described above with reference to FIG. **1** or **2**. Wireless communications subsystem **400** may also include cluster **405** and cluster **410**. A cluster is an object in the channel environment by which communications between the transmitter and the receiver may happen. Typical examples of clusters include reflecting objects such as lamp posts, glass window panes, metallic objects, cars, vehicles, etc. The channel environment may be characterized by the dominant clusters and a directional beam-based communication allows the focusing of energy from the transmitter to the receiver via the dominant clusters in the channel.

[0105] In one example, base station **105**-*b*, cluster **405**, and UE **115**-*b* are part of and configured to determine a fixed services network link, while base station **105**-*c*, cluster **410**, and UE **115**-*c* are part of and configured to determine a mobile services network link. As shown, directional beam **415** and directional beam **435** may be used to establish a link between base station **105**-*b* and UE **115**-*b*. In the illustrated example, transmission **420** may be sent to cluster **405** over directional beam **415**, and cluster **405** may relay/reflect the transmission **420** to UE **115**-*b* via transmission **430**. As shown, UE **115**-*b* may receive transmission **430** via directional beam **435**. Also, directional beam **450** and directional beam **465** may be used to establish a link between base station **105**-*c* and UE **115**-*c*. In the illustrated example, transmission **455** may be sent to cluster **410** over directional beam **450**, and cluster **410** may relay transmission **455** to UE **115**-*c* via transmission **460**. As shown, UE **115**-*c* may receive transmission **460** via directional beam **465**.

[0106] In some examples, UE **115**-*c* may perform scans to detect the use of potentially-interfering transmission from a fixed services network. In some examples, UE **115**-*c* may scan for beams associated with a mobile services network (e.g., corresponding to beams used in a fixed services network). In one example, UE **115**-*c* may include a beamforming codebook. In some cases, the beamforming codebook may list beams used in a mobile services network. In some cases, UE **115**-*c* may scan (e.g., scan in Rx mode) beams in a beamforming codebook stored at UE **115**-*c*. In some examples, UE **115**-*c* may scan for beams in an analog beamforming codebook (e.g., using a codebook meant for a mobile services network) before attaching to a mobile services network (e.g., establishing a link with base station **105**-*c*). In some cases, UE **115**-*c* may scan for beams in a beamforming codebook to determine the existence of transmissions in one or more bands (e.g., transmission activity in a fixed services band). In some examples, the beamforming codebook may provide the UE **115**-*c* with up to full spherical coverage (e.g., may generate a beam pointing in any direction over a sphere or deliver at least a minimal SNR over any direction over the sphere).

[0107] In the illustrated example, UE **115**-*c* may detect transmission **440** from cluster **405** based on a scan using beam **445**. In some cases, UE **115**-*c* may detect the presence of a transmission in a band when a SNR associated with the transmission exceeds a set threshold (e.g., SNR of a beam pair in the band exceeds the set threshold). For example, UE

115-*c* may determine transmission activity exists in a fixed services band associated with beam **445** after determining a SNR associated with transmission **440** exceeds a set threshold. With up to full spherical coverage made possible with the beamforming codebook, a viable link with sufficient SNR (e.g., SNR of the link satisfies a set threshold) may be established between base station **105**-*b* of the fixed service network and UE **115**-*c* of the mobile services network via directional beam **415** and directional beam **445**. For example, transmission **425** different from transmission **420** may be sent between base station **105**-*b* and cluster **405**, and transmission **440** different from transmission **430** may be sent between cluster **405** and UE **115**-*c*. Accordingly, UE **115**-*c* may test the beams in its beamforming codebook for reception in one or more frequency bands used by a fixed services network and detect, on at least one of the beams (e.g., measure energy on at least one beam that satisfies a threshold), transmission activity of the fixed services network by base station **105**-*b*.

[0108] In some cases, UE **115**-*c* may opportunistically communicate with base station **105**-*c* of the first wireless network using the beamforming codebook and based at least in part on the scanning. In some cases, opportunistically communicating with the second wireless device may include UE **115**-*c* communicating with base station **105**-*c* via a second beam of the plurality of beams that differs from the detected beam. In some cases, opportunistically communicating with the second wireless device may include UE **115**-*c* communicating with base station **105**-*c* via a second beam in a second frequency band that differs from a frequency band of the detected beam. In some cases, UE **115**-*c* opportunistically communicating with base station **105**-*c* may include UE **115**-*c* transmitting a frequency band indicator to base station **105**-*c* that indicates the frequency band of the detected beam, the frequency band of the second beam (e.g., to use to avoid interfering with a frequency band occupied by the fixed services network), or both. In some cases, the frequency band of the detected beam is a first contiguous or non-contiguous frequency band, and the frequency band of the second beam is a second contiguous or non-contiguous frequency band. In some cases, a peak or dominant array gain direction of the detected beam differs from a peak or dominant array gain direction of the second beam used by UE **115**-*c* and base station **105**-*c*.

[0109] In some cases, UE **115**-*c* may have full or partial knowledge of waveforms used in fixed services network to improve the ability of UE **115**-*c* in detecting the presence of transmissions in one or more bands (e.g., using coherent detection). In some cases, UE **115**-*c* may correlate the known waveforms (e.g., for fixed services) with received signals on one more beams in one or more spectral bands. If the spectral band is allocated for fixed services, correlation determination by UE **115**-*c* may show a peak (e.g., that exceeds a set threshold) using one or more beams and band occupancy may thus be confirmed by UE **115**-*c* (e.g., transmission activity of the fixed services network is detected within that band on at least one beam).

[0110] In some examples, UE **115**-*c* may assume no knowledge (e.g., non-coherent detection) of waveforms used for fixed services. With non-coherent detection, UE **115**-*c* may estimate received energy associated with transmissions for fixed services (e.g., transmission **440**). When the spectral band is allocated for fixed services, energy associated with the transmission may be relatively high (e.g., the energy crosses a set threshold) and band occupancy may thus be confirmed by UE **115**-*c*.

[0111] In some examples, UE **115**-*c* may detect transmissions for fixed services based on a mixed scheme of partial knowledge where coherent detection (e.g., full knowledge) is combined with non-coherent detection (assumption of no knowledge) in some manner. For example, UE **115**-*c* may assume partial knowledge of waveforms used for fixed services (e.g., statistical information based on outdated data, a range of parameters used in generating waveforms, etc.) combined with a non-coherent determination of whether energy associated with a transmission exceeds a set threshold. Additionally or alternatively, UE **115**-*c* may use geo-databases, licensed assistance, crowd sourcing, etc., to detect and confirm band occupancy.

[0112] In some examples, UE **115**-*c* may use one or more detection algorithms to detect the presence of transmissions in one or more bands scanned by UE **115**-*c*. In some examples, UE **115**-*c* may configure or set one or more parameters of the detection algorithm to improve the detection of transmissions in the one or more bands scanned by UE **115**-*c*. The mobile services network may, for example, obtain one or more transmission parameter from the fixed services network and signal the one or more transmission parameters (e.g., via DCI, RRC signaling, MAC-CE, or the like) to UE **115**-*c*. The UE **115**-*c* may use the one or more transmission parameters to scan for presence of fixed services network transmissions in one or more bands using one or more beams generated in accordance with the beamforming codebook. In some examples, the transmission parameter may indicate a waveform type used for transmissions in the fixed services network, and the UE **115**-*c* may use the indicated waveform type to perform coherent detection.

[0113] In some examples, the parameters of the detection algorithm may include a duration over which UE **115**-*c* listens in a particular direction, which determines how much energy UE **115**-*c* accumulates from that particular direction. In some cases, temporal diversity may improve the ability of UE **115**-*c* in detecting the presence of transmissions in one or more bands. Additionally or alternatively, parameters of the detection algorithm may include directivity (e.g., beamwidth) for detection relative to an intended directivity for communications. Additionally or alternatively, parameters of the detection algorithm may include one or more thresholds (e.g., SNR threshold, receiver power threshold, energy threshold, etc.) for detecting fixed services network activity using a beam within a codebook. For example, UE **115**-*c* may compare a measured SNR of a detected beam to a preset SNR threshold and determine a beam is detected when the measured SNR of the detected beam exceeds the SNR threshold. In some examples, UE **115**-*c* may determine a highest (or best) energy estimate of a received signal that exceeds a threshold when scanning using the beams (e.g., analog beams generated in accordance with the beamforming codebook). In some cases, a threshold may be determined based on coordination between a fixed services network and a mobile services network (e.g., between base station **105**-*b* and base station **105**-*c*). In some cases, a threshold may be set to a value determined to reduce a misdetection probability (e.g., determined by base station **105**-*b* or base station **105**-*c*). In some cases, a threshold may be set to a value to reduce false alarms. In some cases, setting the one or more thresholds may be indicated in

accordance with one or more messages exchanged between a fixed services network and a mobile services network (e.g., between base station **105**-*b* and base station **105**-*c*, etc.).

[0114] In some examples, UE **115**-*c* may use two or more different analog beamforming codebooks to check for transmissions. In one example, UE **115**-*c* may use a different analog beamforming codebook for every band it checks for transmissions by a fixed services network. For example, each beamforming codebook may include a set of beam weights for each band possibly occupied by the fixed services network. In some examples, base station **105**-*c* may designate one or more beamforming codebooks for UE **115**-*c* to use to check for transmissions in one or more bands. In some cases, UE **115**-*c* may load one or more codebooks from memory (e.g., mobile device management memory, radio frequency integrated circuit memory, etc.) corresponding to the one or more bands the UE **115**-*c* is monitoring for transmissions by a fixed services network.

[0115] In some cases, full spherical coverage with an analog beamforming codebook may not be possible. For example, blockage due to hand/body (a hand blocking an antenna of UE **115**-*c*, etc.) or low latency assumptions for initial cell acquisition (e.g., smaller codebook size or lesser number of antenna panels/modules) may result in full spherical coverage not being possible. In such scenarios, when a best-case (e.g., highest or cleanest) SNR of all beam pairs (e.g., in that band) detected when scanning using the beams of the codebook not exceeding a threshold (e.g., highest SNR measured by UE **115**-*c* using any of the beams does not exceed the threshold) may not guarantee a low probability of false alarm as transmissions may be happening through directions in the coverage blockage(s) of the beamforming codebook. Accordingly, in some cases a customized or modified threshold may be determined based on coordination between a fixed services network (e.g., base station **105**-*b*, cluster **405**, UE **115**-*b*, etc.) and a mobile services network (e.g., base station **105**-*c*, cluster **410**, UE **115**-*c*, etc.). For example, the fixed services network may indicate to the mobile services network a minimum threshold a highest measured SNR is configured to meet using at least one of the beams of the codebook. If a highest measured SNR detected using any of the beams does not satisfy the threshold, then the UE **115**-*c* determines that blockage is occurring. As such, the UE **115**-*c* may determine to delay communicating with base station **105**-*c* until at least one measured SNR detected using any of the beams satisfies the threshold.

[0116] FIG. **5** illustrates an example of a process **500** in accordance with aspects of the present disclosure. In some examples, process **500** may implement aspects of wireless communication system **100**, wireless communications subsystem **200**, or wireless communications subsystem **400**.

[0117] As illustrated, process **500** may include UE **115**-*d*, base station **105**-*d*, and base station **105**-*e*, which may be examples of a UE **115** or a base station **105**, as described above with reference to FIG. **1**, **2**, or **4**. In some examples, base station **105**-*d* and UE **115**-*d* are part of and configured to operate in a mobile services network, while base station **105**-*e* may be part of and configured to operate in a fixed services network.

[0118] At **505**, base station **105**-*e* may optionally provide waveform information to base station **105**-*d*. In one example, base station **105**-*d* may include waveform information (e.g., the discrete or continuous time filter functions on which the symbols are modulated) and base station **105**-*e* may provide base station **105**-*d* with additional waveform information (e.g., waveform information associated with a fixed services network). In some cases, base station **105**-*d* may detect base station **105**-*e*, and based on this detection, may query base station **105**-*e* for the waveform information at **505**. In some cases, base station **105**-*d* may transmit a parameter request to base station **105**-*e* and receive (e.g., at **505**) a transmission parameter from base station **105**-*e* based at least in part on the parameter request.

[0119] At **510**, base station **105**-*d* may optionally identify waveform information for fixed services. For example, base station **105**-*d* may identify waveform information based on waveform information received at **505**. Alternatively, base station **105**-*d* may use a beamforming codebook to scan for fixed services network communications using the beams indicated in the codebook looking for fixed services network transmission activity. In some cases, base station **105**-*d* may receive (e.g., at **505**) a transmission parameter from base station **105**-*e* and scan, based at least in part on the transmission parameter, for transmission activity of base station **105**-*e* using a plurality of beams generated in accordance with a beamforming codebook. In some cases, base station **105**-*d* may opportunistically communicate with UE **115**-*d* using the beamforming codebook based at least in part on this scanning.

[0120] At **515**, base station **105**-*d* may optionally provide waveform information to UE **115**-*d*. In some cases, the waveform information at **515** may indicate fixed services network transmission activity detected by base station **105**-*d* and/or fixed services network transmission activity provided to base station **105**-*d* by base station **105**-*e* at **505**. In some cases, base station **105**-*d* may configure UE **115**-*d* to scan, based at least in part on the transmission parameter, for transmission activity of base station **105**-*e* using a plurality of beams generated in accordance with a beamforming codebook. In some cases, base station **105**-*d* may opportunistically communicate with UE **115**-*d* using the beamforming codebook.

[0121] At **520**, UE **115**-*d* may scan through analog beams. In one example, UE **115**-*d* may include one or more analog beamforming codebook and may use at least one of the beamforming codebooks to scan for fixed services network communications, scanning the beams indicated in the codebook to detect fixed services network transmission activity in one or more frequency bands. In some cases, UE **115**-*d* may scan through the beams indicated in the codebook before establishing a connection with base station **105**-*d*. In some examples, UE **115**-*d* may scan through the beams indicated in the codebook in one or more frequency bands after establishing a connection with base station **105**-*d*. In some cases, UE **115**-*d* may scan through the beams indicated in the codebook before and after establishing a connection with base station **105**-*d*. In some cases, UE **115**-*d* may generate a plurality of beams based on the codebook. In some examples, the plurality of beams generated in accordance with the codebook may provide UE **115**-*d* with spherical coverage for signal reception over channel clusters in different directions over at least a portion of an entire sphere.

[0122] At **525**, UE **115**-*d* may determine whether energy of a detected beam exceeds a set threshold. For example, upon detecting energy from a beam, UE **115**-*d* may determine an energy level associated with the detected beam

(e.g., SNR, etc.), and may compare the determined energy level to a set threshold. Upon determining the energy level of the detected beam exceeds the set threshold, UE **115**-*d* may confirm that the detected beam indicates fixed services network transmission activity in one or more frequency bands. In some cases, UE **115**-*d* may detect transmission activity of base station **105**-*e*. In some cases, UE **115**-*d* detecting transmission activity of base station **105**-*e* may include UE **115**-*d* detecting a master information block or a system information block of base station **105**-*e* based at least in part on a transmission parameter (e.g., a transmission parameter UE **115**-*d* receives from base station **105**-*d* at **515**, etc.). If the UE **115**-*d* is able to detect the master information block or a system information block using one or more beams of its codebook in one or more frequency bands, the UE **115**-*d* may detect transmission activity is presently ongoing within the one or more frequency bands. In some cases, the transmission parameter may indicate one or more thresholds, a waveform type used by base station **105**-*e*, a duration over UE **115**-*d* is to scan for transmission activity, a beamwidth for UE **115**-*d* to use for scanning for transmission activity, or any combination thereof.

[0123] In some cases, the one or more thresholds may include a detection threshold used by UE **115**-*d* to determine whether a strength of a detected beam satisfies a criteria for a detected beam. In some cases, the detection threshold may be a signal to noise ratio threshold, a signal to interference plus noise ratio, an energy threshold, or a received power threshold, or any combination thereof. In some cases, the detection threshold may be based at least in a part on a defined false alarm rate or a defined misdetection rate, or a tradeoff between false alarms and misdetections.

[0124] At **530**, UE **115**-*d* may update its configuration (e.g., configuration of UE **115**-*d*) based on the detected fixed services network transmission activity. In one example, UE **115**-*d* may update its configuration to avoid sending a transmission that UE **115**-*d* determines would interfere with the detected fixed services network transmission activity. In one example, UE **115**-*d* may delay using a detected beam or using a frequency band of a detected beam for a set period of time.

[0125] At **535**, UE **115**-*d* may optionally establish a link with base station **105**-*d*. In some examples, UE **115**-*d* may establish a link with base station **105**-*d* before scanning through analog beams at **520**, or before base station **105**-*d* optionally sends waveform information at **515**, or before base station **105**-*d* optionally identifies waveform information for fixed services at **510**, or before base station **105**-*e* optionally sends waveform information to base station **105**-*d* at **505**. In some cases, UE **115**-*d* may establish a link with base station **105**-*d* and after the link is established, base station **105**-*d* may send the waveform information to UE **115**-*d* at **515**.

[0126] In some cases, UE **115**-*d* may receive (e.g., at **515**) a transmission parameter associated with base station **105**-*e* and scan (e.g., at **520**), based at least in part on the transmission parameter, for transmission activity of base station **105**-*e* using a plurality of beams generated in accordance with a beamforming codebook. In some cases, UE **115**-*d* may opportunistically communicate with base station **105**-*d* using the beamforming codebook based at least in part on the scanning. Opportunistically communicating may include, for example, delaying communication due to detection of ongoing transmission activity, communicating using a different beam pointed in a different direction than a beam on which ongoing transmission activity is detected, communicating using a different frequency band than a frequency band on which ongoing transmission activity is detected, any combination thereof, or the like.

[0127] At **540**, UE **115**-*d* may send information regarding the detected beam to base station **105**-*d*. In some cases, the information regarding the detected beam received at **540** may enable base station **105**-*d* to avoid sending a transmission that UE **115**-*d* or base station **105**-*d* determines would interfere with the detected fixed services network transmission activity. In some cases, at **540** UE **115**-*d* may transmit a beam indicator to base station **105**-*d* that indicates the detected beam. In some examples, at **515** base station **105**-*d* may transmit a beam indicator to UE **115**-*d* that indicates a detected beam and/or its direction (e.g., beam **445**) or a second beam to be used for communication (e.g., beam **465**). In some cases, UE **115**-*d* opportunistically communicating with base station **105**-*d* may include UE **115**-*d* delaying communicating with base station **105**-*d* based at least in part on the detected beam. In some cases, UE **115**-*d* delaying communicating with base station **105**-*d* may include UE **115**-*d* transmitting a time-delay indicator to base station **105**-*d* for indicating an amount of time to delay communication.

[0128] It is noted that while some operations are described with reference to base station **105**-*d*, base station **105**-*e*, and UE **115**-*d*, it is understood that each operation may be performed by base station **105**-*d*, or base station **105**-*e*, or UE **115**-*d*, or a backhaul node (e.g., an integrated access and backhaul node), or a point to point wireless device, or any device in a 5G-NR network.

[0129] FIG. **6** shows a block diagram **600** of a device **605** in accordance with aspects of the present disclosure. The device **605** may be an example of aspects of a UE **115** or base station **105** as described herein. The device **605** may include a receiver **610**, an interference mitigation manager **615**, and a transmitter **620**. The device **605** may also include a processor. Each of these components may be in communication with one another (e.g., via one or more buses).

[0130] Receiver **610** may receive information such as packets, user data, or control information associated with various information channels (e.g., control channels, data channels, and information related to beam-based detection for interference mitigation, etc.). Information may be passed on to other components of the device **605**. The receiver **610** may be an example of aspects of the transceiver **920** or **1020** as described with reference to FIGS. **9** and **10**. The receiver **610** may utilize a single antenna or a set of antennas.

[0131] The interference mitigation manager **615** may receive a transmission parameter of a second wireless network, scan, based on the transmission parameter, for transmission activity of the second wireless network using a set of beams generated in accordance with a beamforming codebook, and opportunistically communicate with a second wireless device of the first wireless network using the beamforming codebook based on the scanning. The interference mitigation manager **615** may be an example of aspects of the interference mitigation manager **910** or **1010** as described herein.

[0132] The interference mitigation manager **615**, or its sub-components, may be implemented in hardware, code (e.g., software or firmware) executed by a processor, or any combination thereof. If implemented in code executed by a

processor, the functions of the interference mitigation manager **615**, or its sub-components may be executed by a general-purpose processor, a DSP, an application-specific integrated circuit (ASIC), a FPGA or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described in the present disclosure.

[0133] The interference mitigation manager **615**, or its sub-components, may be physically located at various positions, including being distributed such that portions of functions are implemented at different physical locations by one or more physical components. In some examples, the interference mitigation manager **615**, or its sub-components, may be a separate and distinct component in accordance with various aspects of the present disclosure. In some examples, the interference mitigation manager **615**, or its sub-components, may be combined with one or more other hardware components, including but not limited to an input/output (I/O) component, a transceiver, a network server, another computing device, one or more other components described in the present disclosure, or a combination thereof in accordance with various aspects of the present disclosure.

[0134] Transmitter **620** may transmit signals generated by other components of the device **605**. In some examples, the transmitter **620** may be collocated with a receiver **610** in a transceiver module. For example, the transmitter **620** may be an example of aspects of the transceiver **920** or **1020** as described with reference to FIGS. **9** and **10**. The transmitter **620** may utilize a single antenna or a set of antennas.

[0135] FIG. **7** shows a block diagram **700** of a device **705** in accordance with aspects of the present disclosure. The device **705** may be an example of aspects of a device **605**, a UE **115**, or a base station **105** as described herein. The device **705** may include a receiver **710**, an interference mitigation manager **715**, and a transmitter **735**. The device **705** may also include a processor. Each of these components may be in communication with one another (e.g., via one or more buses).

[0136] Receiver **710** may receive information such as packets, user data, or control information associated with various information channels (e.g., control channels, data channels, and information related to beam-based detection for interference mitigation, etc.). Information may be passed on to other components of the device **705**. The receiver **710** may be an example of aspects of the transceiver **920** or **1020** as described with reference to FIGS. **9** and **10**. The receiver **710** may utilize a single antenna or a set of antennas.

[0137] The interference mitigation manager **715** may be an example of aspects of the interference mitigation manager **615** as described herein. The interference mitigation manager **715** may include a receiving manager **720**, a scan manager **725**, and a communication manager **730**. The interference mitigation manager **715** may be an example of aspects of the interference mitigation manager **910** or **1010** as described herein.

[0138] The receiving manager **720** may receive a transmission parameter of a second wireless network. The scan manager **725** may scan, based on the transmission parameter, for transmission activity of the second wireless network using a set of beams generated in accordance with a beamforming codebook. The communication manager **730** may opportunistically communicate with a second wireless device of the first wireless network using the beamforming codebook based on the scanning.

[0139] Transmitter **735** may transmit signals generated by other components of the device **705**. In some examples, the transmitter **735** may be collocated with a receiver **710** in a transceiver module. For example, the transmitter **735** may be an example of aspects of the transceiver **920** or **1020** as described with reference to FIGS. **9** and **10**. The transmitter **735** may utilize a single antenna or a set of antennas.

[0140] FIG. **8** shows a block diagram **800** of an interference mitigation manager **805** in accordance with aspects of the present disclosure. The interference mitigation manager **805** may be an example of aspects of an interference mitigation manager **615**, an interference mitigation manager **715**, or an interference mitigation manager **910** described herein. The interference mitigation manager **805** may include a receiving manager **810**, a scan manager **815**, a communication manager **820**, a detection manager **825**, and a delay manager **830**. Each of these modules may communicate, directly or indirectly, with one another (e.g., via one or more buses).

[0141] The receiving manager **810** may receive a transmission parameter of a second wireless network. The scan manager **815** may scan, based on the transmission parameter, for transmission activity of the second wireless network using a set of beams generated in accordance with a beamforming codebook. In some examples, the scan manager **815** may select a second beamforming codebook that corresponds to a second frequency band.

[0142] In some examples, the scan manager **815** may scan the second frequency band for transmission activity of the second wireless network or a third wireless network using a second set of beams generated in accordance with the second beamforming codebook. The communication manager **820** may opportunistically communicate with a second wireless device of the first wireless network using the beamforming codebook based on the scanning.

[0143] In some examples, the communication manager **820** may communicate with the second wireless device via a second beam of the set of beams that differs from the first beam. In some examples, the communication manager **820** may transmit a beam indicator that indicates the second beam to the second wireless device. In some examples, the communication manager **820** may communicate with the second wireless device via the second beam in a second frequency band that differs from the first frequency band.

[0144] In some examples, the communication manager **820** may transmit a frequency band indicator to the second wireless device that indicates the first frequency band, the second frequency band, or both. In some examples, the communication manager **820** may communicate with the second wireless device based on determining that at least one signal strength measurement generated using at least one beam of the set the beams satisfies a threshold.

[0145] The detection manager **825** may detect transmission activity of the second wireless network within a first frequency band on a first beam of the set of beams. In some examples, the detection manager **825** may detect transmission activity of the second wireless network based on determining that a signal strength measurement generated using the first beam satisfies a threshold. In some examples, the detection manager **825** may detect a fixed services link of the second wireless network based on the transmission parameter. In some examples, the detection manager **825**

may detect a master information block or a system information block of the second wireless network based on the transmission parameter.

[0146] The delay manager **830** may delay communicating with the second wireless device based on the detecting. In some examples, the delay manager **830** may transmit a time-delay indicator to the second wireless device. In some examples, the delay manager **830** may delay communicating with the second wireless device based on determining that a set of signal strength measurements generated using a respective beam of the set the beams does not satisfy a threshold.

[0147] FIG. **9** shows a diagram of a system **900** including a device **905** in accordance with aspects of the present disclosure. The device **905** may be an example of or include the components of device **605**, device **705**, or a UE **115** as described herein. The device **905** may include components for bi-directional voice and data communications including components for transmitting and receiving communications, including an interference mitigation manager **910**, a transceiver **920**, an antenna **925**, memory **930**, a processor **940**, and an I/O controller **950**. These components may be in electronic communication via one or more buses (e.g., bus **955**).

[0148] The interference mitigation manager **910** may receive a transmission parameter of a second wireless network, scan, based on the transmission parameter, for transmission activity of the second wireless network using a set of beams generated in accordance with a beamforming codebook, and opportunistically communicate with a second wireless device of the first wireless network using the beamforming codebook based on the scanning.

[0149] Transceiver **920** may communicate bi-directionally, via one or more antennas, wired, or wireless links as described herein. For example, the transceiver **920** may represent a wireless transceiver and may communicate bi-directionally with another wireless transceiver. The transceiver **920** may also include a modem to modulate the packets and provide the modulated packets to the antennas for transmission, and to demodulate packets received from the antennas.

[0150] In some cases, the wireless device may include a single antenna **925**. However, in some cases the device may have more than one antenna **925**, which may be capable of concurrently transmitting or receiving multiple wireless transmissions.

[0151] The memory **930** may include RAM, ROM, or a combination thereof. The memory **930** may store computer-readable code **935** including instructions that, when executed by a processor (e.g., the processor **940**) cause the device to perform various functions described herein. In some cases, the memory **930** may contain, among other things, a BIOS which may control basic hardware or software operation such as the interaction with peripheral components or devices.

[0152] The processor **940** may include an intelligent hardware device, (e.g., a general-purpose processor, a DSP, a CPU, a microcontroller, an ASIC, an FPGA, a programmable logic device, a discrete gate or transistor logic component, a discrete hardware component, or any combination thereof). In some cases, the processor **940** may be configured to operate a memory array using a memory controller. In other cases, a memory controller may be integrated into the processor **940**. The processor **940** may be configured to execute computer-readable instructions stored in a memory (e.g., the memory **930**) to cause the device **905** to perform various functions (e.g., functions or tasks supporting beam-based detection for interference mitigation).

[0153] The I/O controller **950** may manage input and output signals for the device **905**. The I/O controller **950** may also manage peripherals not integrated into the device **905**. In some cases, the I/O controller **950** may represent a physical connection or port to an external peripheral. In some cases, the I/O controller **950** may utilize an operating system such as iOS®, ANDROID®, MS-DOS®, MS-WINDOWS®, OS/2®, UNIX®, LINUX®, or another known operating system. In other cases, the I/O controller **950** may represent or interact with a modem, a keyboard, a mouse, a touchscreen, or a similar device. In some cases, the I/O controller **950** may be implemented as part of a processor. In some cases, a user may interact with the device **905** via the I/O controller **950** or via hardware components controlled by the I/O controller **950**.

[0154] The code **935** may include instructions to implement aspects of the present disclosure, including instructions to support wireless communications. The code **935** may be stored in a non-transitory computer-readable medium such as system memory or other type of memory. In some cases, the code **935** may not be directly executable by the processor **940** but may cause a computer (e.g., when compiled and executed) to perform functions described herein.

[0155] FIG. **10** shows a diagram of a system **1000** including a device **1005** in accordance with aspects of the present disclosure. The device **1005** may be an example of or include the components of device **605**, device **705**, or a base station **105** as described herein. The device **1005** may include components for bi-directional voice and data communications including components for transmitting and receiving communications, including an interference mitigation manager **1010**, a network communications manager **1015**, a transceiver **1020**, an antenna **1025**, memory **1030**, a processor **1040**, and an inter-station communications manager **1045**. These components may be in electronic communication via one or more buses (e.g., bus **1055**).

[0156] The interference mitigation manager **1010** may receive a transmission parameter of a second wireless network, scan, based on the transmission parameter, for transmission activity of the second wireless network using a set of beams generated in accordance with a beamforming codebook, and opportunistically communicate with a second wireless device of the first wireless network using the beamforming codebook based on the scanning.

[0157] Network communications manager **1015** may manage communications with the core network (e.g., via one or more wired backhaul links). For example, the network communications manager **1015** may manage the transfer of data communications for client devices, such as one or more UEs **115**.

[0158] Transceiver **1020** may communicate bi-directionally, via one or more antennas, wired, or wireless links as described herein. For example, the transceiver **1020** may represent a wireless transceiver and may communicate bi-directionally with another wireless transceiver. The transceiver **1020** may also include a modem to modulate the packets and provide the modulated packets to the antennas for transmission, and to demodulate packets received from the antennas.

[0159] In some cases, the wireless device may include a single antenna **1025**. However, in some cases the device may have more than one antenna **1025**, which may be capable of concurrently transmitting or receiving multiple wireless transmissions.

[0160] The memory **1030** may include RAM, ROM, or a combination thereof. The memory **1030** may store computer-readable code **1035** including instructions that, when executed by a processor (e.g., the processor **1040**) cause the device to perform various functions described herein. In some cases, the memory **1030** may contain, among other things, a BIOS which may control basic hardware or software operation such as the interaction with peripheral components or devices.

[0161] The processor **1040** may include an intelligent hardware device, (e.g., a general-purpose processor, a DSP, a CPU, a microcontroller, an ASIC, an FPGA, a programmable logic device, a discrete gate or transistor logic component, a discrete hardware component, or any combination thereof). In some cases, the processor **1040** may be configured to operate a memory array using a memory controller. In other cases, a memory controller may be integrated into the processor **1040**. The processor **1040** may be configured to execute computer-readable instructions stored in a memory (e.g., the memory **1030**) to cause the device **1005** to perform various functions (e.g., functions or tasks supporting beam-based detection for interference mitigation).

[0162] Inter-station communications manager **1045** may manage communications with other base station **105**, and may include a controller or scheduler for controlling communications with UEs **115** in cooperation with other base stations **105**. For example, the inter-station communications manager **1045** may coordinate scheduling for transmissions to UEs **115** for various interference mitigation techniques such as beamforming or joint transmission. In some examples, inter-station communications manager **1045** may provide an X2 interface within an LTE/LTE-A wireless communication network technology to provide communication between base stations **105**.

[0163] The code **1035** may include instructions to implement aspects of the present disclosure, including instructions to support wireless communications. The code **1035** may be stored in a non-transitory computer-readable medium such as system memory or other type of memory. In some cases, the code **1035** may not be directly executable by the processor **1040** but may cause a computer (e.g., when compiled and executed) to perform functions described herein.

[0164] FIG. **11** shows a block diagram **1100** of a device **1105** in accordance with aspects of the present disclosure. The device **1105** may be an example of aspects of a base station **105** as described herein. The device **1105** may include a receiver **1110**, an interference mitigation manager **1115**, and a transmitter **1120**. The device **1105** may also include a processor. Each of these components may be in communication with one another (e.g., via one or more buses).

[0165] The receiver **1110** may receive information such as packets, user data, or control information associated with various information channels (e.g., control channels, data channels, and information related to beam-based detection for interference mitigation, etc.). Information may be passed on to other components of the device **1105**. The receiver **1110** may be an example of aspects of the transceiver **1420** described with reference to FIG. **14**. The receiver **1110** may utilize a single antenna or a set of antennas.

[0166] The interference mitigation manager **1115** may transmit a parameter request to a second wireless device of a second wireless network, receive a transmission parameter based on the parameter request, configure a UE to scan, based on the transmission parameter, for transmission activity of the second wireless network using a set of beams generated in accordance with a beamforming codebook, and opportunistically communicate with the UE using the beamforming codebook. The interference mitigation manager **1115** may be an example of aspects of the interference mitigation manager **1410** described herein.

[0167] The interference mitigation manager **1115**, or its sub-components, may be implemented in hardware, code (e.g., software or firmware) executed by a processor, or any combination thereof. If implemented in code executed by a processor, the functions of the interference mitigation manager **1115**, or its sub-components may be executed by a general-purpose processor, a DSP, an application-specific integrated circuit (ASIC), a FPGA or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described in the present disclosure.

[0168] The interference mitigation manager **1115**, or its sub-components, may be physically located at various positions, including being distributed such that portions of functions are implemented at different physical locations by one or more physical components. In some examples, the interference mitigation manager **1115**, or its sub-components, may be a separate and distinct component in accordance with various aspects of the present disclosure. In some examples, the interference mitigation manager **1115**, or its sub-components, may be combined with one or more other hardware components, including but not limited to an input/output (I/O) component, a transceiver, a network server, another computing device, one or more other components described in the present disclosure, or a combination thereof in accordance with various aspects of the present disclosure.

[0169] The transmitter **1120** may transmit signals generated by other components of the device **1105**. In some examples, the transmitter **1120** may be collocated with a receiver **1110** in a transceiver module. For example, the transmitter **1120** may be an example of aspects of the transceiver **1420** described with reference to FIG. **14**. The transmitter **1120** may utilize a single antenna or a set of antennas.

[0170] FIG. **12** shows a block diagram **1200** of a device **1205** in accordance with aspects of the present disclosure. The device **1205** may be an example of aspects of a device **1105**, or a base station **105** as described herein. The device **1205** may include a receiver **1210**, an interference mitigation manager **1215**, and a transmitter **1235**. The device **1205** may also include a processor. Each of these components may be in communication with one another (e.g., via one or more buses).

[0171] The receiver **1210** may receive information such as packets, user data, or control information associated with various information channels (e.g., control channels, data channels, and information related to beam-based detection for interference mitigation, etc.). Information may be passed on to other components of the device **1205**. The receiver **1210** may be an example of aspects of the transceiver **1420**

described with reference to FIG. **14**. The receiver **1210** may utilize a single antenna or a set of antennas.

[0172] The interference mitigation manager **1215** may be an example of aspects of the interference mitigation manager **1115** as described herein. The interference mitigation manager **1215** may include a parameter manager **1220**, a configuration manager **1225**, and a beamforming manager **1230**. The interference mitigation manager **1215** may be an example of aspects of the interference mitigation manager **1410** described herein.

[0173] The parameter manager **1220** may transmit a parameter request to a second wireless device of a second wireless network and receive a transmission parameter based on the parameter request. The configuration manager **1225** may configure a UE to scan, based on the transmission parameter, for transmission activity of the second wireless network using a set of beams generated in accordance with a beamforming codebook. The beamforming manager **1230** may opportunistically communicate with the UE using the beamforming codebook.

[0174] The transmitter **1235** may transmit signals generated by other components of the device **1205**. In some examples, the transmitter **1235** may be collocated with a receiver **1210** in a transceiver module. For example, the transmitter **1235** may be an example of aspects of the transceiver **1420** described with reference to FIG. **14**. The transmitter **1235** may utilize a single antenna or a set of antennas.

[0175] FIG. **13** shows a block diagram **1300** of an interference mitigation manager **1305** in accordance with aspects of the present disclosure. The interference mitigation manager **1305** may be an example of aspects of an interference mitigation manager **1115**, an interference mitigation manager **1215**, or an interference mitigation manager **1410** described herein. The interference mitigation manager **1305** may include a parameter manager **1310**, a configuration manager **1315**, a beamforming manager **1320**, an indicator manager **1325**, and a delay manager **1330**. Each of these modules may communicate, directly or indirectly, with one another (e.g., via one or more buses).

[0176] The parameter manager **1310** may transmit a parameter request to a second wireless device of a second wireless network. In some examples, the parameter manager **1310** may receive a transmission parameter based on the parameter request. The configuration manager **1315** may configure a UE to scan, based on the transmission parameter, for transmission activity of the second wireless network using a set of beams generated in accordance with a beamforming codebook.

[0177] The beamforming manager **1320** may opportunistically communicate with the UE using the beamforming codebook. In some examples, the beamforming manager **1320** may communicate with the UE using a second beam that corresponds to the first beam. In some examples, the beamforming manager **1320** may communicate with the UE based on the frequency band indicator.

[0178] The indicator manager **1325** may receive a beam indicator indicating a first beam of the set of beams has been selected by the UE. In some examples, the indicator manager **1325** may receive a frequency band indicator from the UE that indicates a first frequency band, a second frequency band, or both. In some examples, the indicator manager **1325** may receive a delay indicator from the UE. The delay manager **1330** may delay communicating with the UE based on the delay indicator.

[0179] FIG. **14** shows a diagram of a system **1400** including a device **1405** in accordance with aspects of the present disclosure. The device **1405** may be an example of or include the components of device **1105**, device **1205**, or a base station **105** as described herein. The device **1405** may include components for bi-directional voice and data communications including components for transmitting and receiving communications, including an interference mitigation manager **1410**, a network communications manager **1415**, a transceiver **1420**, an antenna **1425**, memory **1430**, a processor **1440**, and an inter-station communications manager **1445**. These components may be in electronic communication via one or more buses (e.g., bus **1455**).

[0180] The interference mitigation manager **1410** may transmit a parameter request to a second wireless device of a second wireless network, receive a transmission parameter based on the parameter request, configure a UE to scan, based on the transmission parameter, for transmission activity of the second wireless network using a set of beams generated in accordance with a beamforming codebook, and opportunistically communicate with the UE using the beamforming codebook.

[0181] The network communications manager **1415** may manage communications with the core network (e.g., via one or more wired backhaul links). For example, the network communications manager **1415** may manage the transfer of data communications for client devices, such as one or more UEs **115**.

[0182] The transceiver **1420** may communicate bi-directionally, via one or more antennas, wired, or wireless links as described herein. For example, the transceiver **1420** may represent a wireless transceiver and may communicate bi-directionally with another wireless transceiver. The transceiver **1420** may also include a modem to modulate the packets and provide the modulated packets to the antennas for transmission, and to demodulate packets received from the antennas.

[0183] In some cases, the wireless device may include a single antenna **1425**. However, in some cases the device may have more than one antenna **1425**, which may be capable of concurrently transmitting or receiving multiple wireless transmissions.

[0184] The memory **1430** may include RAM, ROM, or a combination thereof. The memory **1430** may store computer-readable code **1435** including instructions that, when executed by a processor (e.g., the processor **1440**) cause the device to perform various functions described herein. In some cases, the memory **1430** may contain, among other things, a BIOS which may control basic hardware or software operation such as the interaction with peripheral components or devices.

[0185] The processor **1440** may include an intelligent hardware device, (e.g., a general-purpose processor, a DSP, a CPU, a microcontroller, an ASIC, an FPGA, a programmable logic device, a discrete gate or transistor logic component, a discrete hardware component, or any combination thereof). In some cases, the processor **1440** may be configured to operate a memory array using a memory controller. In some cases, a memory controller may be integrated into processor **1440**. The processor **1440** may be configured to execute computer-readable instructions stored in a memory

(e.g., the memory **1430**) to cause the device **1405** to perform various functions (e.g., functions or tasks supporting beam-based detection for interference mitigation).

[0186] The inter-station communications manager **1445** may manage communications with other base station **105**, and may include a controller or scheduler for controlling communications with UEs **115** in cooperation with other base stations **105**. For example, the inter-station communications manager **1445** may coordinate scheduling for transmissions to UEs **115** for various interference mitigation techniques such as beamforming or joint transmission. In some examples, the inter-station communications manager **1445** may provide an X2 interface within an LTE/LTE-A wireless communication network technology to provide communication between base stations **105**.

[0187] The code **1435** may include instructions to implement aspects of the present disclosure, including instructions to support wireless communications. The code **1435** may be stored in a non-transitory computer-readable medium such as system memory or other type of memory. In some cases, the code **1435** may not be directly executable by the processor **1440** but may cause a computer (e.g., when compiled and executed) to perform functions described herein.

[0188] FIG. **15** shows a flowchart illustrating a method **1500** in accordance with aspects of the present disclosure. The operations of method **1500** may be implemented by a UE **115** or base station **105** or its components as described herein. For example, the operations of method **1500** may be performed by an interference mitigation manager as described with reference to FIGS. **6** through **10**. In some examples, a UE or base station may execute a set of instructions to control the functional elements of the UE or base station to perform the functions described herein. Additionally or alternatively, a UE or base station may perform aspects of the functions described herein using special-purpose hardware.

[0189] At **1505**, the UE or base station may receive a transmission parameter of a second wireless network. The operations of **1505** may be performed according to the methods described herein. In some examples, aspects of the operations of **1505** may be performed by a receiving manager as described with reference to FIGS. **6** through **10**.

[0190] At **1510**, the UE or base station may scan, based on the transmission parameter, for transmission activity of the second wireless network using a set of beams generated in accordance with a beamforming codebook. The operations of **1510** may be performed according to the methods described herein. In some examples, aspects of the operations of **1510** may be performed by a scan manager as described with reference to FIGS. **6** through **10**.

[0191] At **1515**, the UE or base station may opportunistically communicate with a second wireless device of the first wireless network using the beamforming codebook based on the scanning. The operations of **1515** may be performed according to the methods described herein. In some examples, aspects of the operations of **1515** may be performed by a communication manager as described with reference to FIGS. **6** through **10**.

[0192] FIG. **16** shows a flowchart illustrating a method **1600** in accordance with aspects of the present disclosure. The operations of method **1600** may be implemented by a UE **115** or base station **105** or its components as described herein. For example, the operations of method **1600** may be performed by an interference mitigation manager as described with reference to FIGS. **6** through **10**. In some examples, a UE or base station may execute a set of instructions to control the functional elements of the UE or base station to perform the functions described herein. Additionally or alternatively, a UE or base station may perform aspects of the functions described herein using special-purpose hardware.

[0193] At **1605**, the UE or base station may receive a transmission parameter of a second wireless network. The operations of **1605** may be performed according to the methods described herein. In some examples, aspects of the operations of **1605** may be performed by a receiving manager as described with reference to FIGS. **6** through **10**.

[0194] At **1610**, the UE or base station may scan, based on the transmission parameter, for transmission activity of the second wireless network using a set of beams generated in accordance with a beamforming codebook. The operations of **1610** may be performed according to the methods described herein. In some examples, aspects of the operations of **1610** may be performed by a scan manager as described with reference to FIGS. **6** through **10**.

[0195] At **1615**, the UE or base station may detect transmission activity of the second wireless network within a first frequency band on a first beam of the set of beams. The operations of **1615** may be performed according to the methods described herein. In some examples, aspects of the operations of **1615** may be performed by a detection manager as described with reference to FIGS. **6** through **10**.

[0196] At **1620**, the UE or base station may detect a fixed services link of the second wireless network based on the transmission parameter. The operations of **1620** may be performed according to the methods described herein. In some examples, aspects of the operations of **1620** may be performed by a detection manager as described with reference to FIGS. **6** through **10**.

[0197] At **1625**, the UE or base station may delay communicating with the second wireless device and opportunistically communicate with a second wireless device of the first wireless network using the beamforming codebook based on the detecting. The operations of **1625** may be performed according to the methods described herein. In some examples, aspects of the operations of **1625** may be performed by a delay manager as described with reference to FIGS. **6** through **10**.

[0198] FIG. **17** shows a flowchart illustrating a method **1700** in accordance with aspects of the present disclosure. The operations of method **1700** may be implemented by a base station **105** or its components as described herein. For example, the operations of method **1700** may be performed by an interference mitigation manager as described with reference to FIGS. **11** through **14**. In some examples, a base station may execute a set of instructions to control the functional elements of the base station to perform the functions described herein. Additionally or alternatively, a base station may perform aspects of the functions described herein using special-purpose hardware.

[0199] At **1705**, the base station may transmit a parameter request to a second wireless device of a second wireless network. The operations of **1705** may be performed according to the methods described herein. In some examples, aspects of the operations of **1705** may be performed by a parameter manager as described with reference to FIGS. **11** through **14**.

[0200] At **1710**, the base station may receive a transmission parameter based on the parameter request. The operations of **1710** may be performed according to the methods described herein. In some examples, aspects of the operations of **1710** may be performed by a parameter manager as described with reference to FIGS. **11** through **14**.

[0201] At **1715**, the base station may configure a UE to scan, based on the transmission parameter, for transmission activity of the second wireless network using a set of beams generated in accordance with a beamforming codebook. The operations of **1715** may be performed according to the methods described herein. In some examples, aspects of the operations of **1715** may be performed by a configuration manager as described with reference to FIGS. **11** through **14**.

[0202] At **1720**, the base station may opportunistically communicate with the UE using the beamforming codebook. The operations of **1720** may be performed according to the methods described herein. In some examples, aspects of the operations of **1720** may be performed by a beamforming manager as described with reference to FIGS. **11** through **14**.

[0203] It should be noted that the methods described herein describe possible implementations, and that the operations and the steps may be rearranged or otherwise modified and that other implementations are possible. Further, aspects from two or more of the methods may be combined.

[0204] Techniques described herein may be used for various wireless communications systems such as code division multiple access (CDMA), time division multiple access (TDMA), frequency division multiple access (FDMA), orthogonal frequency division multiple access (OFDMA), single carrier frequency division multiple access (SC-FDMA), and other systems. A CDMA system may implement a radio technology such as CDMA2000, Universal Terrestrial Radio Access (UTRA), etc. CDMA2000 covers IS-2000, IS-95, and IS-856 standards. IS-2000 Releases may be commonly referred to as CDMA2000 1×, 1×, etc. IS-856 (TIA-856) is commonly referred to as CDMA2000 1×EV-DO, High Rate Packet Data (HRPD), etc. UTRA includes Wideband CDMA (WCDMA) and other variants of CDMA. A TDMA system may implement a radio technology such as Global System for Mobile Communications (GSM).

[0205] An OFDMA system may implement a radio technology such as Ultra Mobile Broadband (UMB), Evolved UTRA (E-UTRA), Institute of Electrical and Electronics Engineers (IEEE) 802.11 (Wi-Fi), IEEE 802.16 (WiMAX), IEEE 802.20, Flash-OFDM, etc. UTRA and E-UTRA are part of Universal Mobile Telecommunications System (UMTS). LTE, LTE-A, and LTE-A Pro are releases of UMTS that use E-UTRA. UTRA, E-UTRA, UMTS, LTE, LTE-A, LTE-A Pro, NR, and GSM are described in documents from the organization named "3rd Generation Partnership Project" (3GPP). CDMA2000 and UMB are described in documents from an organization named "3rd Generation Partnership Project 2" (3GPP2). The techniques described herein may be used for the systems and radio technologies mentioned herein as well as other systems and radio technologies. While aspects of an LTE, LTE-A, LTE-A Pro, or NR system may be described for purposes of example, and LTE, LTE-A, LTE-A Pro, or NR terminology may be used in much of the description, the techniques described herein are applicable beyond LTE, LTE-A, LTE-A Pro, or NR applications.

[0206] A macro cell generally covers a relatively large geographic area (e.g., several kilometers in radius) and may allow unrestricted access by UEs with service subscriptions with the network provider. A small cell may be associated with a lower-powered base station, as compared with a macro cell, and a small cell may operate in the same or different (e.g., licensed, unlicensed, etc.) frequency bands as macro cells. Small cells may include pico cells, femto cells, and micro cells according to various examples. A pico cell, for example, may cover a small geographic area and may allow unrestricted access by UEs with service subscriptions with the network provider. A femto cell may also cover a small geographic area (e.g., a home) and may provide restricted access by UEs having an association with the femto cell (e.g., UEs in a closed subscriber group (CSG), UEs for users in the home, and the like). An eNB for a macro cell may be referred to as a macro eNB. An eNB for a small cell may be referred to as a small cell eNB, a pico eNB, a femto eNB, or a home eNB. An eNB may support one or multiple (e.g., two, three, four, and the like) cells, and may also support communications using one or multiple component carriers.

[0207] The wireless communications systems described herein may support synchronous or asynchronous operation. For synchronous operation, the base stations may have similar frame timing, and transmissions from different base stations may be approximately aligned in time. For asynchronous operation, the base stations may have different frame timing, and transmissions from different base stations may not be aligned in time. The techniques described herein may be used for either synchronous or asynchronous operations.

[0208] Information and signals described herein may be represented using any of a variety of different technologies and techniques. For example, data, instructions, commands, information, signals, bits, symbols, and chips that may be referenced throughout the description may be represented by voltages, currents, electromagnetic waves, magnetic fields or particles, optical fields or particles, or any combination thereof.

[0209] The various illustrative blocks and modules described in connection with the disclosure herein may be implemented or performed with a general-purpose processor, a DSP, an ASIC, an FPGA, or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general-purpose processor may be a microprocessor, but in the alternative, the processor may be any processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of computing devices (e.g., a combination of a DSP and a microprocessor, multiple microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration).

[0210] The functions described herein may be implemented in hardware, software executed by a processor, firmware, or any combination thereof. If implemented in software executed by a processor, the functions may be stored on or transmitted over as one or more instructions or code on a computer-readable medium. Other examples and implementations are within the scope of the disclosure and appended claims. For example, due to the nature of software, functions described herein can be implemented using software executed by a processor, hardware, firmware, hardwir-

ing, or combinations of any of these. Features implementing functions may also be physically located at various positions, including being distributed such that portions of functions are implemented at different physical locations.

[0211] Computer-readable media includes both non-transitory computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. A non-transitory storage medium may be any available medium that can be accessed by a general purpose or special purpose computer. By way of example, and not limitation, non-transitory computer-readable media may include random-access memory (RAM), read-only memory (ROM), electrically erasable programmable ROM (EEPROM), flash memory, compact disk (CD) ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other non-transitory medium that can be used to carry or store desired program code means in the form of instructions or data structures and that can be accessed by a general-purpose or special-purpose computer, or a general-purpose or special-purpose processor. Also, any connection is properly termed a computer-readable medium. For example, if the software is transmitted from a website, server, or other remote source using a coaxial cable, fiber optic cable, twisted pair, digital subscriber line (DSL), or wireless technologies such as infrared, radio, and microwave, then the coaxial cable, fiber optic cable, twisted pair, DSL, or wireless technologies such as infrared, radio, and microwave are included in the definition of medium. Disk and disc, as used herein, include CD, laser disc, optical disc, digital versatile disc (DVD), floppy disk and Blu-ray disc where disks usually reproduce data magnetically, while discs reproduce data optically with lasers. Combinations of the above are also included within the scope of computer-readable media.

[0212] As used herein, including in the claims, "or" as used in a list of items (e.g., a list of items prefaced by a phrase such as "at least one of" or "one or more of") indicates an inclusive list such that, for example, a list of at least one of A, B, or C means A or B or C or AB or AC or BC or ABC (i.e., A and B and C). Also, as used herein, the phrase "based on" shall not be construed as a reference to a closed set of conditions. For example, an exemplary step that is described as "based on condition A" may be based on both a condition A and a condition B without departing from the scope of the present disclosure. In other words, as used herein, the phrase "based on" shall be construed in the same manner as the phrase "based at least in part on."

[0213] In the appended figures, similar components or features may have the same reference label. Further, various components of the same type may be distinguished by following the reference label by a dash and a second label that distinguishes among the similar components. If just the first reference label is used in the specification, the description is applicable to any one of the similar components having the same first reference label irrespective of the second reference label, or other subsequent reference label.

[0214] The description set forth herein, in connection with the appended drawings, describes example configurations and does not represent all the examples that may be implemented or that are within the scope of the claims. The term "exemplary" used herein means "serving as an example, instance, or illustration," and not "preferred" or "advantageous over other examples." The detailed description includes specific details for the purpose of providing an understanding of the described techniques. These techniques, however, may be practiced without these specific details. In some instances, well-known structures and devices are shown in block diagram form in order to avoid obscuring the concepts of the described examples.

[0215] The description herein is provided to enable a person skilled in the art to make or use the disclosure. Various modifications to the disclosure will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other variations without departing from the scope of the disclosure. Thus, the disclosure is not limited to the examples and designs described herein, but is to be accorded the broadest scope consistent with the principles and novel features disclosed herein.

What is claimed is:

1. A method for wireless communication by a first wireless device of a first wireless network, comprising:

receiving a transmission parameter of a second wireless network;

scanning, based at least in part on the transmission parameter, for transmission activity of the second wireless network using a plurality of beams generated in accordance with a beamforming codebook; and

opportunistically communicating with a second wireless device of the first wireless network using the beamforming codebook based at least in part on the scanning.

2. The method of claim **1**, wherein scanning for transmission activity of the second wireless network further comprises:

detecting transmission activity of the second wireless network within a first frequency band on a first beam of the plurality of beams.

3. The method of claim **2**, wherein detecting the transmission activity of the second wireless network further comprises:

detecting transmission activity of the second wireless network based at least in part on determining that a signal strength measurement generated using the first beam satisfies a threshold.

4. The method of claim **2**, wherein opportunistically communicating with the second wireless device further comprises:

communicating with the second wireless device via a second beam of the plurality of beams that differs from the first beam.

5. The method of claim **4**, wherein opportunistically communicating with the second wireless device further comprises:

transmitting a beam indicator that indicates the second beam to the second wireless device.

6. The method of claim **4**, wherein opportunistically communicating with the second wireless device further comprises:

communicating with the second wireless device via the second beam in a second frequency band that differs from the first frequency band.

7. The method of claim **6**, wherein opportunistically communicating with the second wireless device further comprises:

transmitting a frequency band indicator to the second wireless device that indicates the first frequency band, the second frequency band, or both.

8. The method of claim 6, wherein the first frequency band is a first contiguous or non-contiguous frequency band, and the second frequency band is a second contiguous or non-contiguous frequency band.

9. The method of claim 4, wherein a peak or dominant array gain direction of the first beam differs from a peak or dominant array gain direction of the second beam.

10. The method of claim 2, wherein opportunistically communicating with the second wireless device further comprises:

delaying communicating with the second wireless device based at least in part on the detecting.

11. The method of claim 10, wherein delaying communicating with the second wireless device further comprises:

transmitting a time-delay indicator to the second wireless device.

12. The method of claim 2, wherein detecting the transmission activity of the second wireless network further comprises:

detecting a fixed services link of the second wireless network based at least in part on the transmission parameter.

13. The method of claim 2, wherein detecting the transmission activity of the second wireless network further comprises:

detecting a master information block or a system information block of the second wireless network based at least in part on the transmission parameter.

14. The method of claim 1, wherein the beamforming codebook corresponds to a first frequency band, the method further comprises:

selecting a second beamforming codebook that corresponds to a second frequency band; and

scanning the second frequency band for transmission activity of the second wireless network or a third wireless network using a second plurality of beams generated in accordance with the second beamforming codebook.

15. The method of claim 1, wherein the beamforming codebook provides the first wireless device with only a partial spherical coverage, and wherein opportunistically communicating with the second wireless device further comprises:

delaying communicating with the second wireless device based at least in part on determining that a plurality of signal strength measurements generated using a respective beam of the plurality of beams does not satisfy a threshold.

16. The method of claim 15, wherein the transmission parameter indicates the threshold.

17. The method of claim 1, wherein the beamforming codebook provides the first wireless device with a partial spherical coverage, and wherein opportunistically communicating with the second wireless device further comprises:

communicating with the second wireless device based at least in part on determining that at least one signal strength measurement generated using at least one beam of the plurality of beams satisfies a threshold.

18. The method of claim 1, wherein the first wireless network is a Fifth Generation New Radio (5G-NR) wireless network at millimeter wave carrier frequencies and the second wireless network is a fixed services wireless network at millimeter wave carrier frequencies.

19. The method of claim 1, wherein the transmission parameter indicates a waveform type used in the second wireless network, a duration over which to scan for transmission activity, a beamwidth to use for scanning for transmission activity, or any combination thereof.

20. The method of claim 1, wherein the transmission parameter indicates a detection threshold to use when scanning for transmission activity, and wherein the detection threshold is a signal to noise ratio threshold, a signal to interference plus noise ratio, an energy threshold, or a received power threshold.

21. A method for wireless communication by a first wireless device of a first wireless network, comprising:

transmitting a parameter request to a second wireless device of a second wireless network;

receiving a transmission parameter based at least in part on the parameter request;

configuring a user equipment (UE) to scan, based at least in part on the transmission parameter, for transmission activity of the second wireless network using a plurality of beams generated in accordance with a beamforming codebook; and

opportunistically communicating with the UE using the beamforming codebook.

22. The method of claim 21, wherein opportunistically communicating with the UE further comprises:

receiving a beam indicator indicating a first beam of the plurality of beams has been selected by the UE; and

communicating with the UE using a second beam that corresponds to the first beam.

23. The method of claim 21, wherein opportunistically communicating with the UE further comprises:

receiving a frequency band indicator from the UE that indicates a first frequency band, a second frequency band, or both; and

communicating with the UE based at least in part on the frequency band indicator.

24. The method of claim 23, wherein the first frequency band is a first contiguous or non-contiguous frequency band, and the second frequency band is a second contiguous or non-contiguous frequency band.

25. The method of claim 21, wherein opportunistically communicating with the UE further comprises:

receiving a delay indicator from the UE; and

delaying communicating with the UE based at least in part on the delay indicator.

26. The method of claim 21, wherein the first wireless network is a Fifth Generation New Radio (5G-NR) wireless network at millimeter wave carrier frequencies and the second wireless network is a fixed services wireless network at millimeter wave carrier frequencies.

27. The method of claim 21, wherein the transmission parameter indicates a waveform type used in the second wireless network, a duration over which to scan for transmission activity, a beamwidth to use for scanning for transmission activity, or any combination thereof.

28. The method of claim 21, wherein the transmission parameter indicates a detection threshold to use when scanning for transmission activity, and wherein the detection threshold is a signal to noise ratio threshold, a signal to interference plus noise ratio, an energy threshold, or a received power threshold.

29. An apparatus of a first wireless network, comprising:

a processor,

memory in electronic communication with the processor; and

instructions stored in the memory and executable by the processor to cause the apparatus to:

receive, via a receiver, a transmission parameter of a second wireless network;

scan, based at least in part on the transmission parameter, for transmission activity of the second wireless network using a plurality of beams generated in accordance with a beamforming codebook; and

opportunistically communicate with a second wireless device of the first wireless network using the beamforming codebook based at least in part on the scanning.

30. An apparatus of a first wireless network, comprising:

a processor,

memory in electronic communication with the processor; and

instructions stored in the memory and executable by the processor to cause the apparatus to:

transmit a parameter request to a second wireless device of a second wireless network;

receive a transmission parameter based at least in part on the parameter request;

configure a user equipment (UE) to scan, based at least in part on the transmission parameter, for transmission activity of the second wireless network using a plurality of beams generated in accordance with a beamforming codebook; and

opportunistically communicate with the UE using the beamforming codebook.

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