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Patil et al.

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(54) **BEAM TRAINING TECHNIQUES IN WIFI FREQUENCY BANDS**

(71) Applicant: **QUALCOMM Incorporated**, San Diego, CA (US)

(72) Inventors: **Abhishek Pramod Patil**, San Diego, CA (US); **George Cherian**, San Diego, CA (US); **Yanjun Sun**, San Diego, CA (US); **Lin Yang**, San Diego, CA (US); **Gaurang Naik**, San Diego, CA (US); **Abdel Karim Ajami**, San Diego, CA (US); **Alfred Asterjadhi**, San Diego, CA (US); **Sai Yiu Duncan Ho**, San Diego, CA (US)

(73) Assignee: **QUALCOMM Incorporated**, San Diego, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

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Related U.S. Application Data

(63) Continuation of application No. 17/942,006, filed on Sep. 9, 2022, now Pat. No. 11,996,920.

(51) **Int. Cl.**

H04B 7/06	(2006.01)
H04W 24/02	(2009.01)
H04W 28/02	(2009.01)

(52) **U.S. Cl.**

CPC ***H04B 7/0617*** (2013.01); ***H04B 7/0695*** (2013.01); ***H04W 24/02*** (2013.01); *H04W 28/0278* (2013.01)

(58) **Field of Classification Search**

CPC .. H04B 7/0617; H04B 7/0408; H04B 7/0456; H04B 7/0634; H04B 7/0626;

(Continued)

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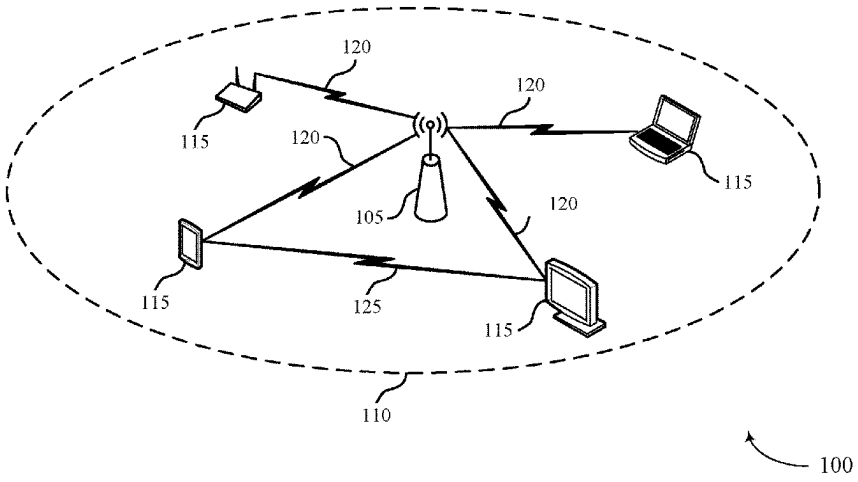
Primary Examiner — Khanh C Tran

(74) *Attorney, Agent, or Firm* — Holland & Hart / QUALCOMM Incorporated

(57) **ABSTRACT**

Methods, systems, and devices for wireless communications are described. A first wireless device (e.g., station (STA), access point (AP)) may transmit to a second wireless device during a service period, an initiating frame using a transmit beam that is based on a first beam training procedure performed between the devices prior to the service period. The first wireless device may perform a second beam training procedure during the service period based on an absence of a response frame from the second wireless device, based on an indication within the response frame received from the second wireless device, or based on identification of a change in a wireless channel relative to a previous beam training interval or previous service period. The first wireless device may then communicate one or more

(Continued)



messages with the second wireless device using one or more beams that are based on the second beam training procedure.

20 Claims, 23 Drawing Sheets

(58) **Field of Classification Search**
CPC ... H04B 7/0639; H04B 7/0695; H04W 24/02; H04W 24/08; H04W 24/10; H04W 24/06; H04W 24/04
See application file for complete search history.

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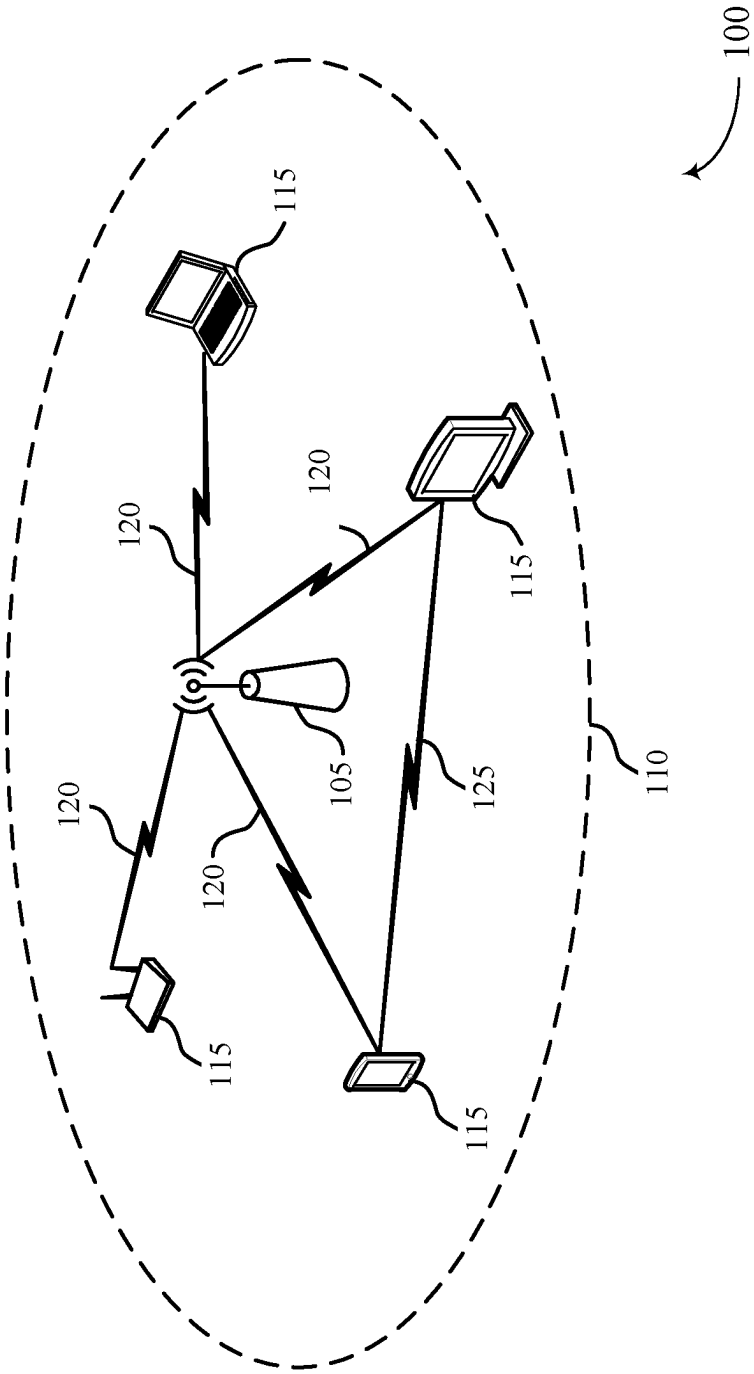


FIG. 1

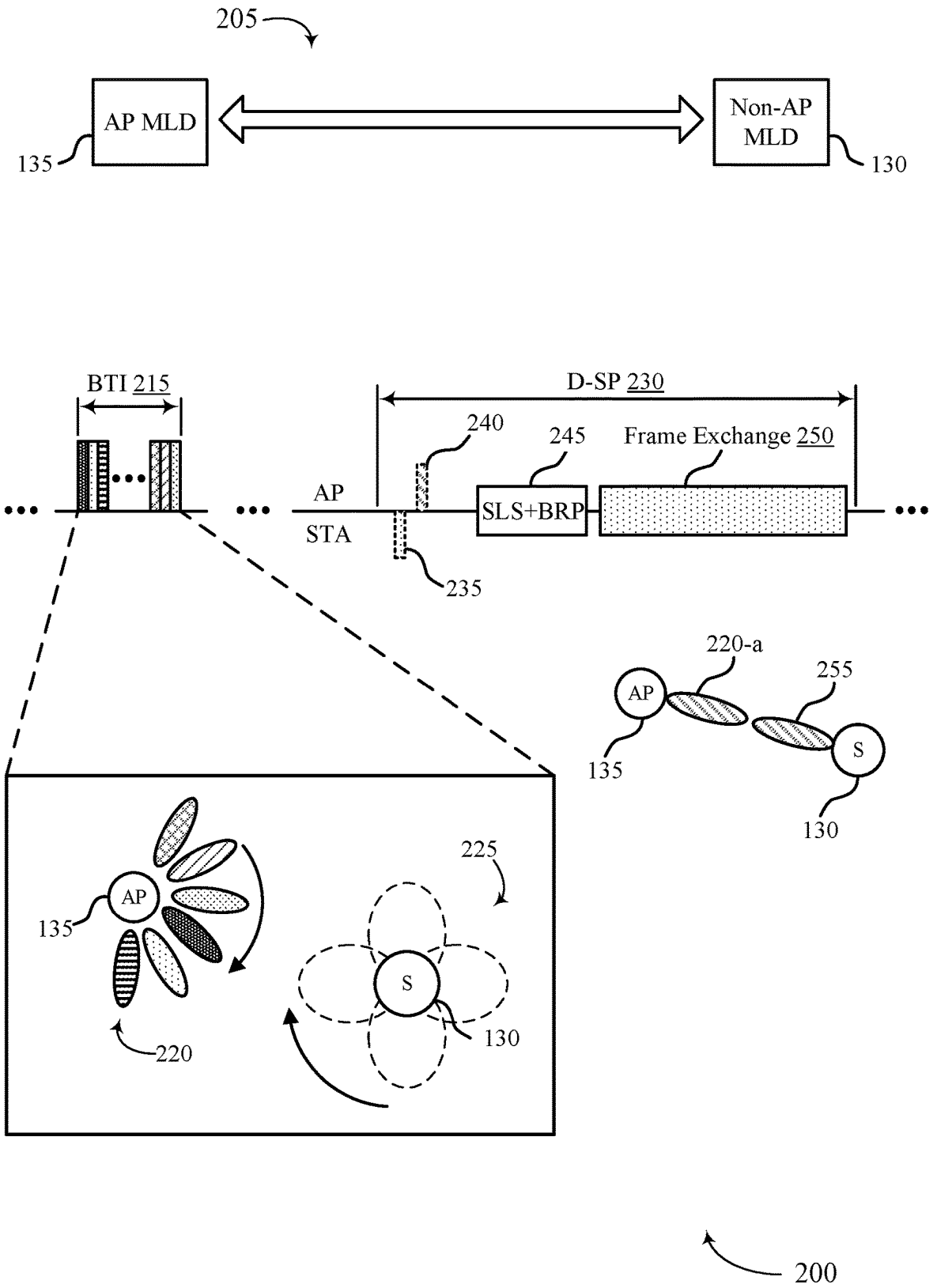

205
AP MLD
Non-AP MLD
135
130
BTI 215
D-SP 230
240
245
Frame Exchange 250
AP
STA
SLS+BRP
235
220-a
255
AP
S
135
130
225
AP
135
S
130
220
200

FIG. 2

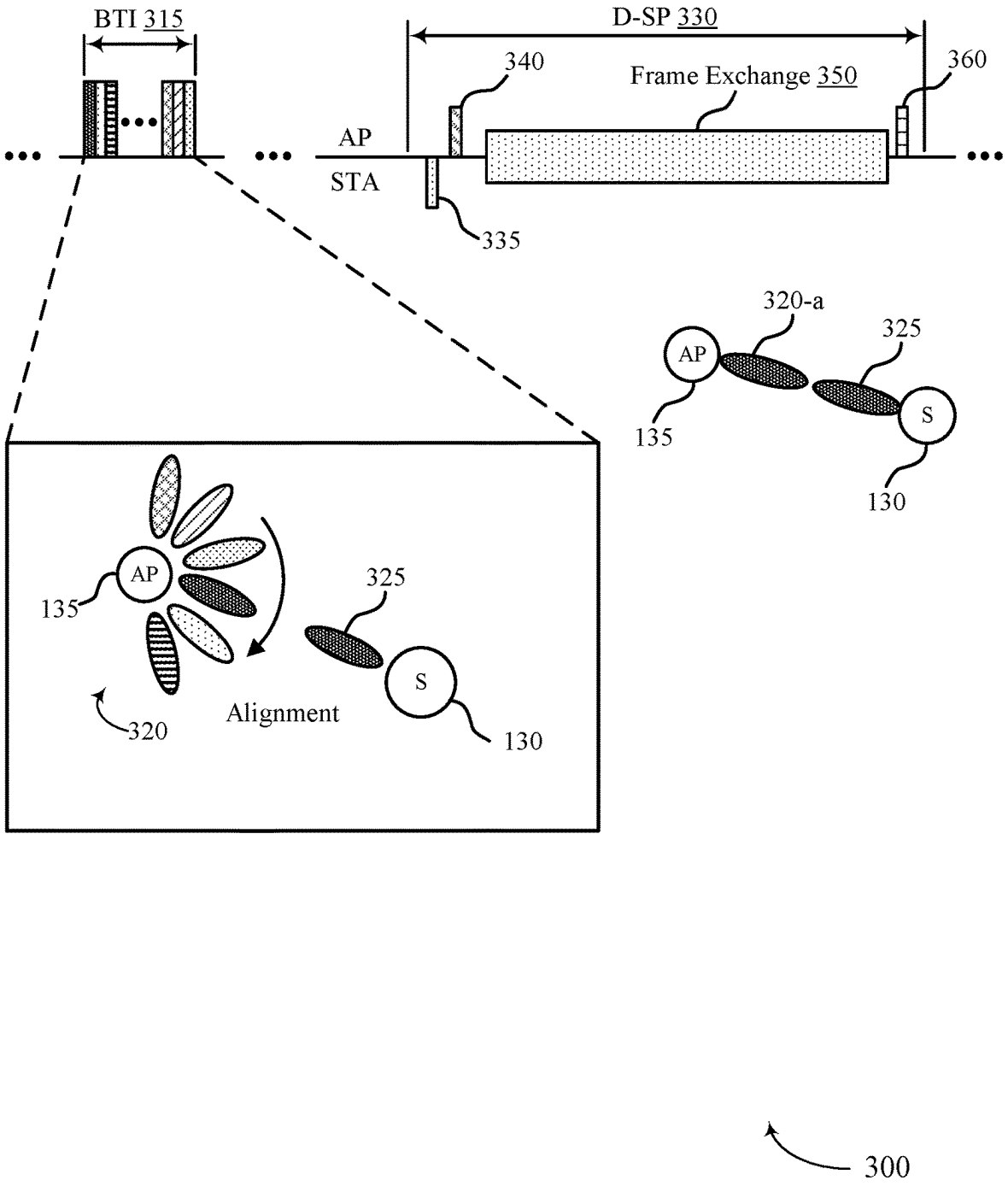
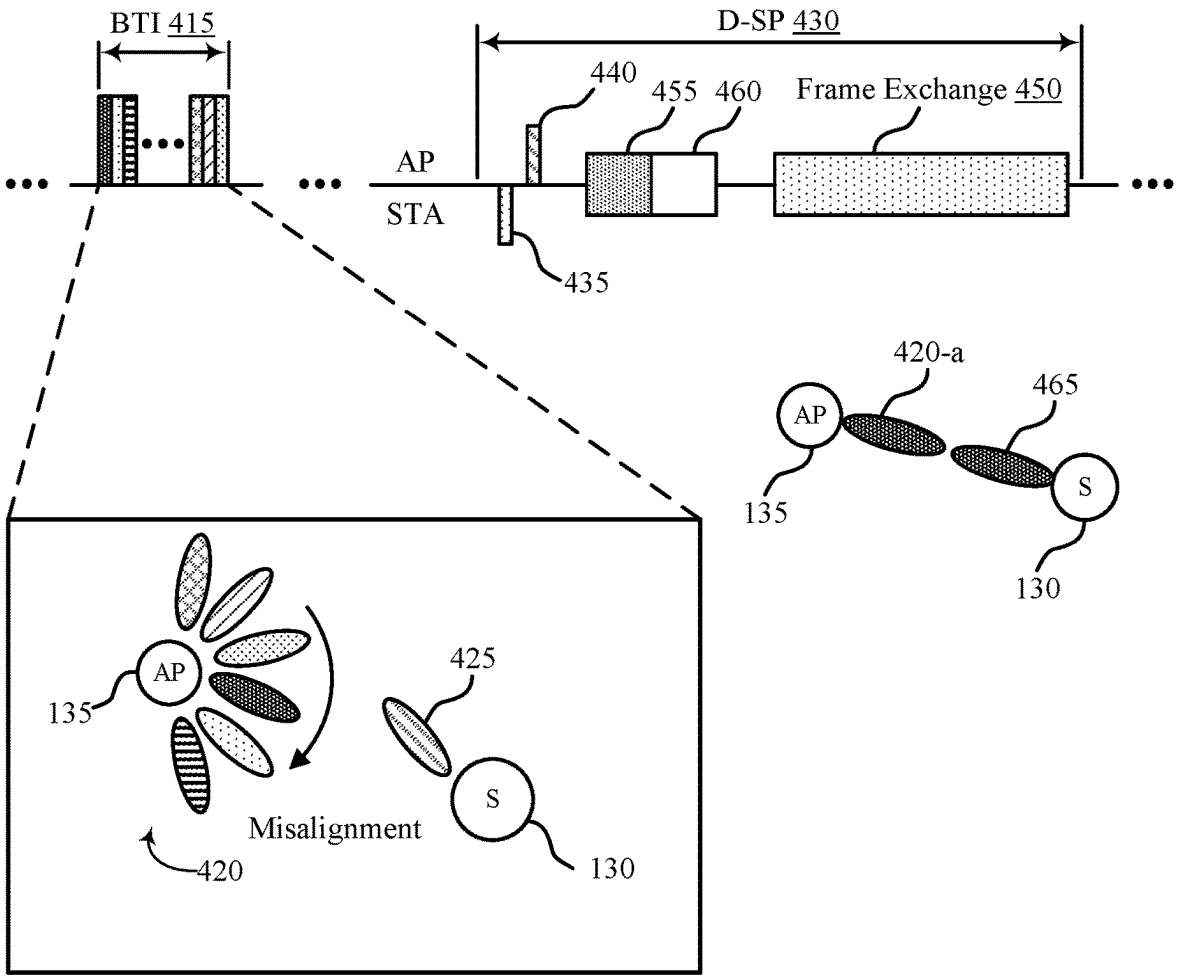

BTI 315
D-SP 330
340
Frame Exchange 350
360
AP
STA
335
320-a
325
AP
S
135
130
AP
135
325
S
Alignment
320
130
300

FIG. 3


BTI 415
D-SP 430
440
455
460
Frame Exchange 450
AP
STA
435
420-a
465
AP
S
135
130
AP
135
425
S
Misalignment
420
130

400

FIG. 4

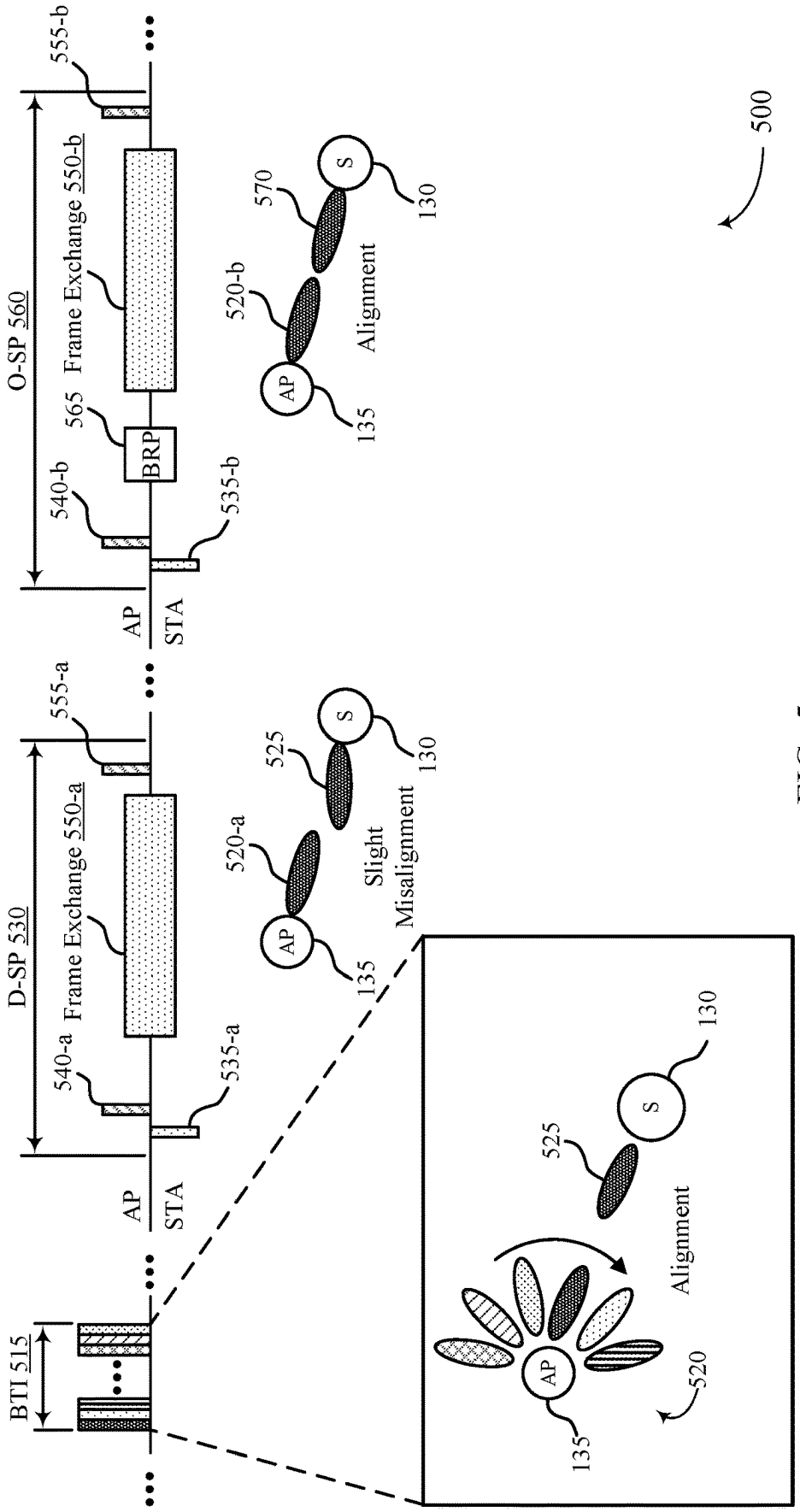

500
BTI 515
D-SP 530
Frame Exchange 550-a
555-a
540-a
535-a
AP
STA
520-a
525
Slight Misalignment
135
130
O-SP 560
Frame Exchange 550-b
555-b
565
BRP
540-b
535-b
520-b
570
Alignment
520

FIG. 5

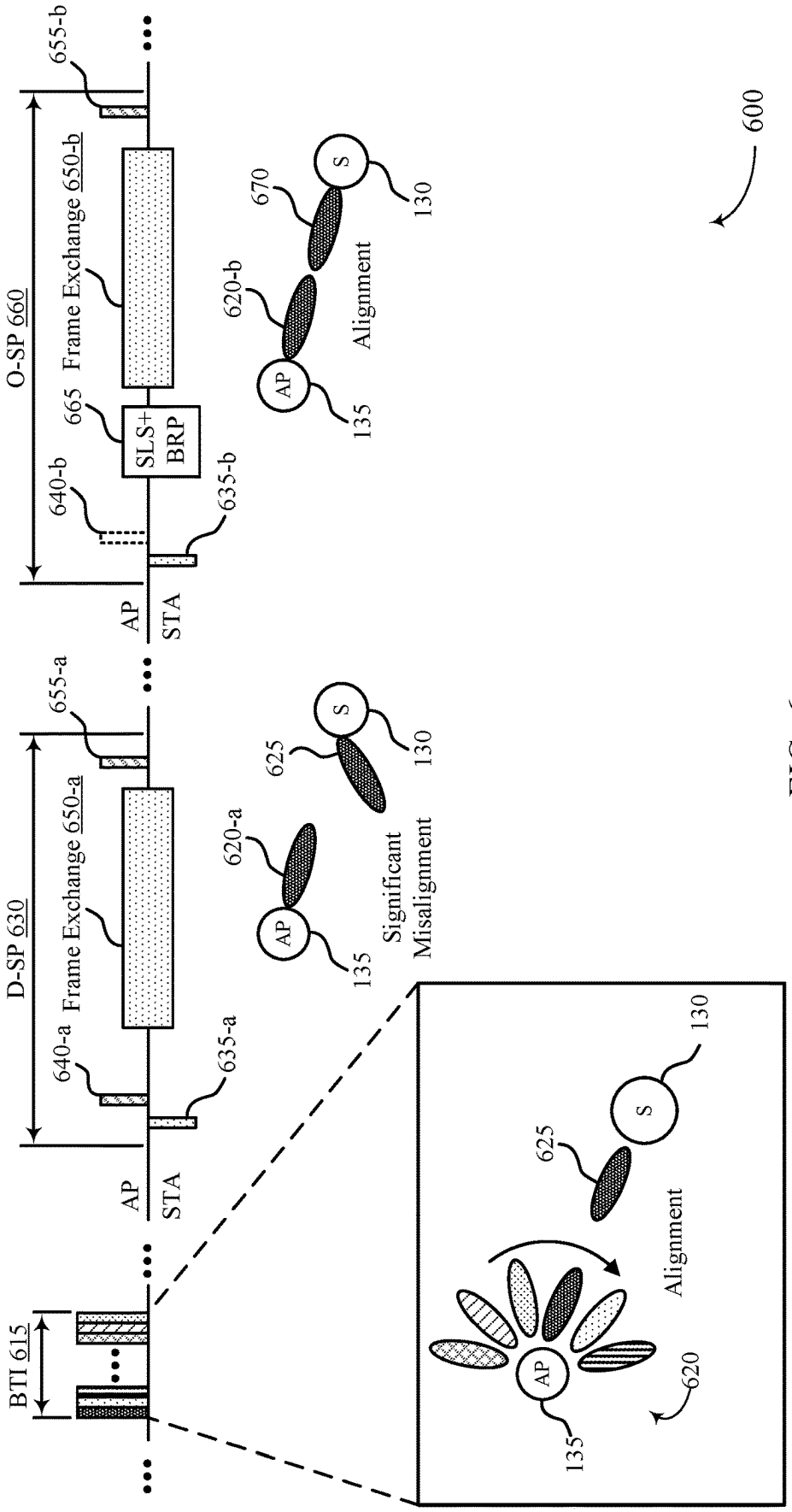
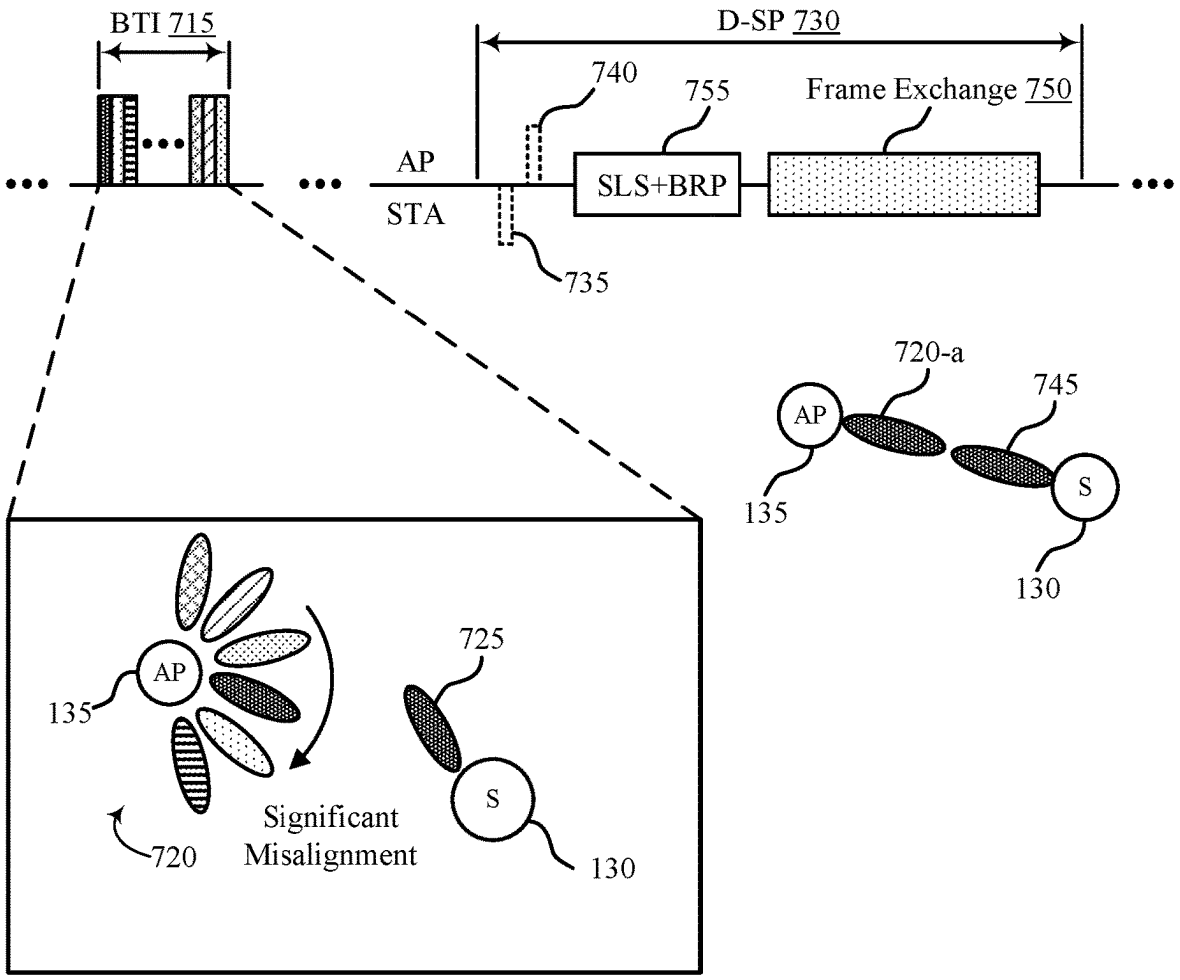

600
BTI 615
D-SP 630
Frame Exchange 650-a
655-a
640-a
635-a
AP
STA
620-a
625
AP
S
135
130
Significant Misalignment
O-SP 660
Frame Exchange 650-b
655-b
640-b
665
SLS+ BRP
635-b
AP
STA
620-b
670
AP
S
135
130
Alignment
AP
S
135
130
625
620
Alignment

FIG. 6


BTI 715
D-SP 730
740
755
Frame Exchange 750
AP
STA
SLS+BRP
735
720-a
745
AP
S
135
130
725
AP
135
S
Significant
Misalignment
720
130

700

FIG. 7

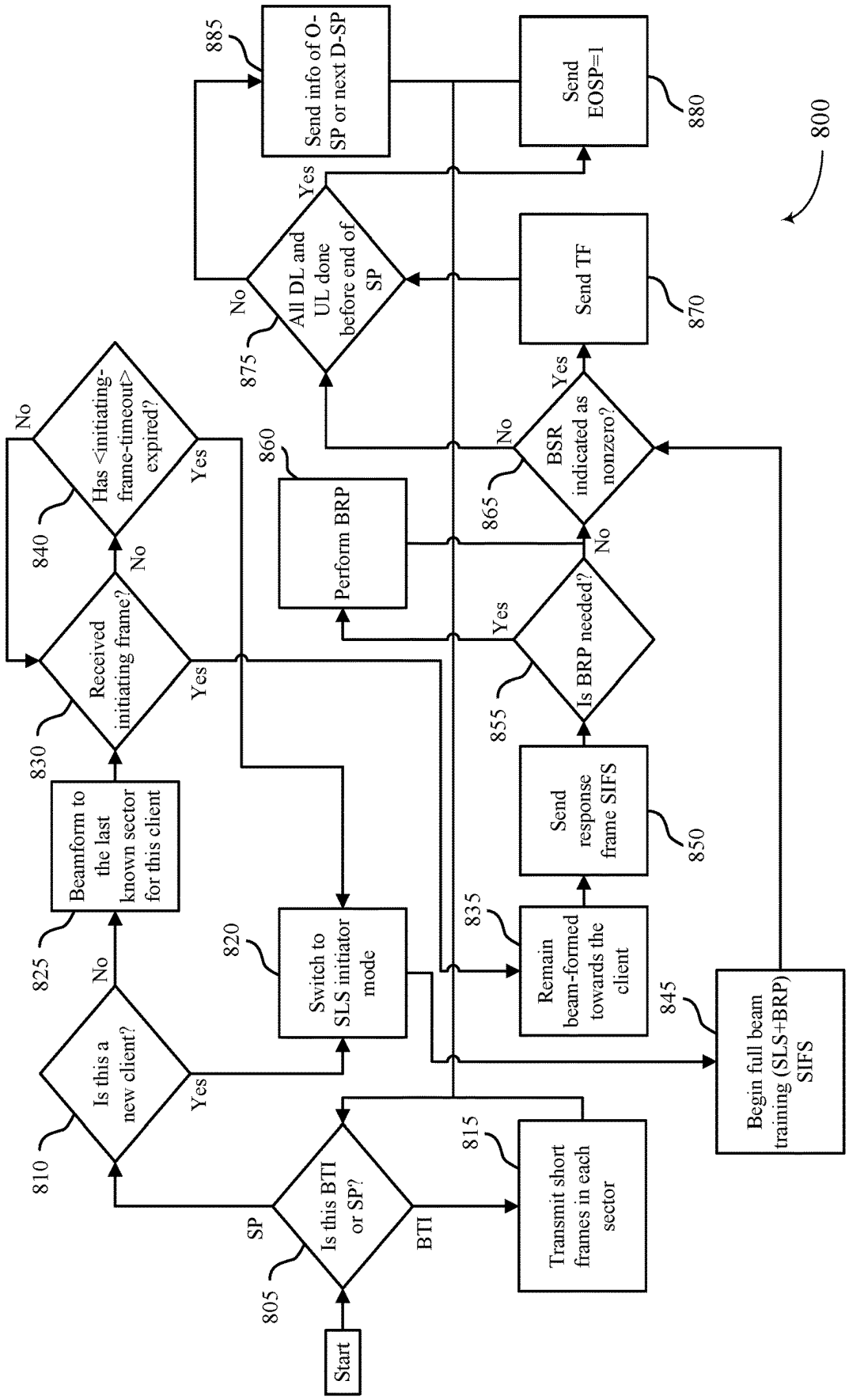

800
Start
805
Is this BTI or SP?
SP
BTI
810
Is this a new client?
No
Yes
815
Transmit short frames in each sector
820
Switch to SLS initiator mode
825
Beamform to the last known sector for this client
830
Received initiating frame?
No
Yes
840
Has <initiating-frame-timeout> expired?
No
Yes
845
Begin full beam training (SLS+BRP) SIFS
850
Send response frame SIFS
855
Is BRP needed?
Yes
No
860
Perform BRP
865
BSR indicated as nonzero?
No
Yes
870
Send TF
875
All DL and UL done before end of SP
No
Yes
880
Send EOSP=1
885
Send info of O-SP or next D-SP
835
Remain beam-formed towards the client

FIG. 8

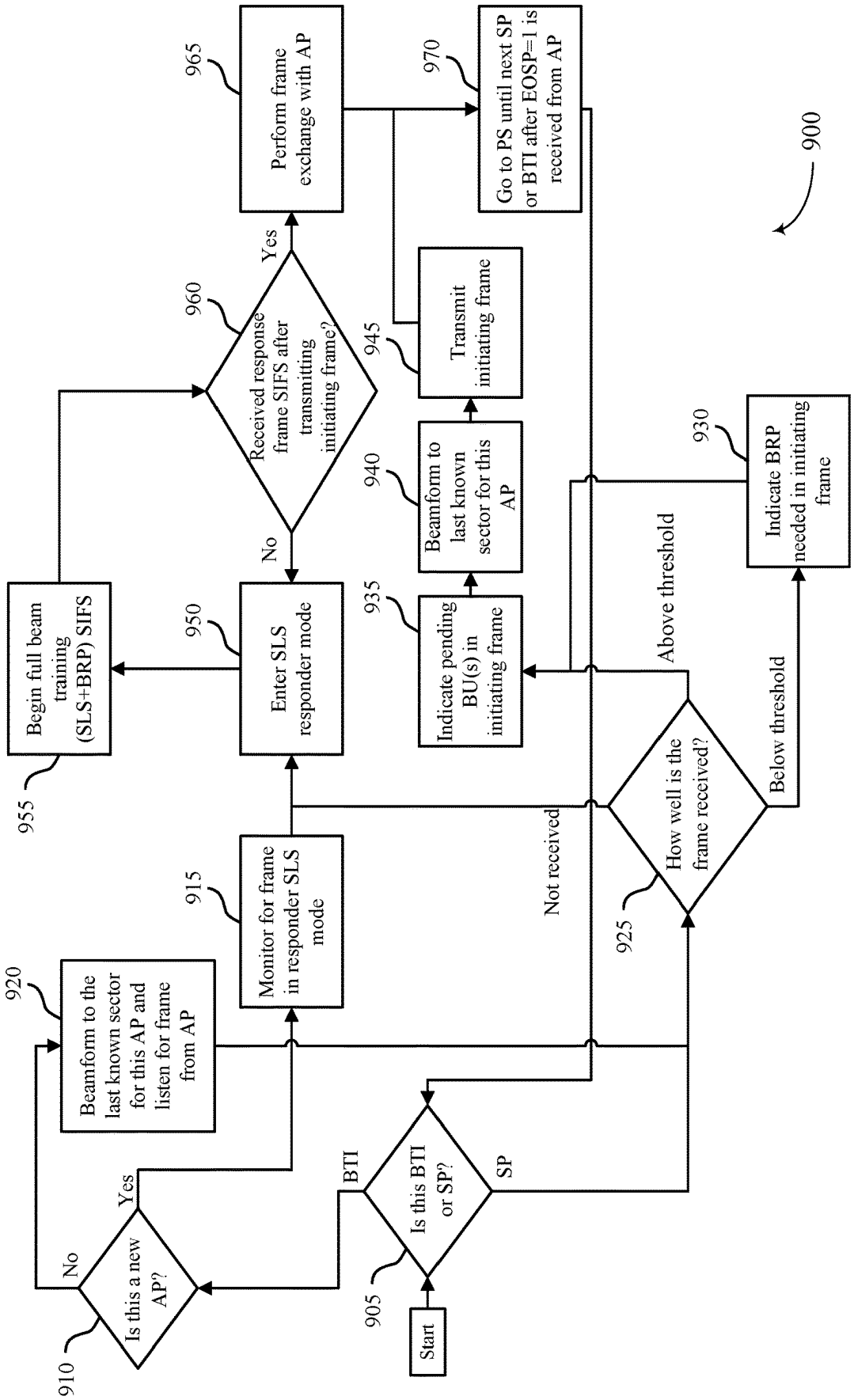
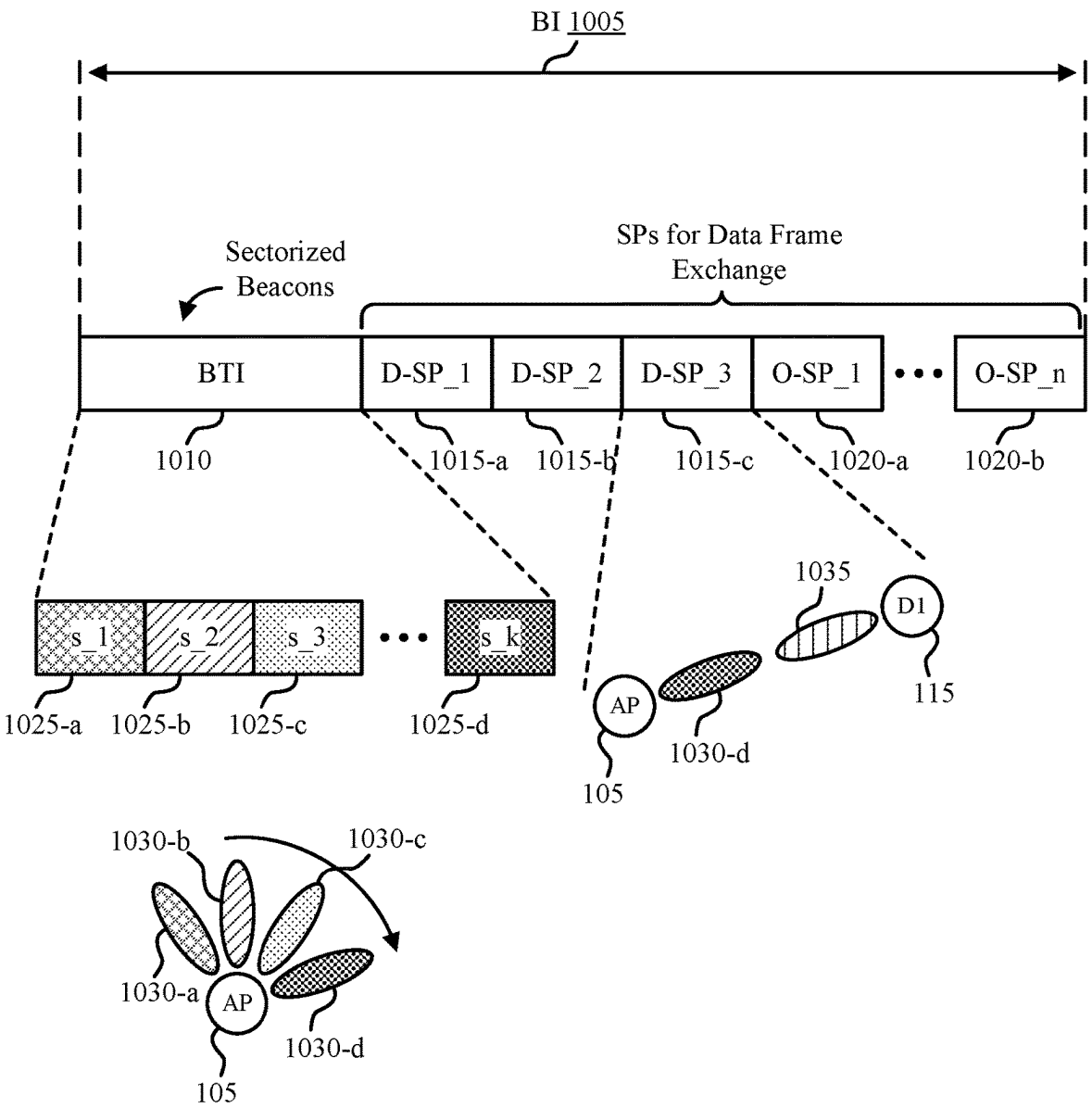

900
Start
905
Is this BTI or SP?
BTI
SP
910
Is this a new AP?
Yes
No
920
Beamform to the last known sector for this AP and listen for frame from AP
915
Monitor for frame in responder SLS mode
925
How well is the frame received?
Not received
Above threshold
Below threshold
930
Indicate BRP needed in initiating frame
935
Indicate pending BU(s) in initiating frame
940
Beamform to last known sector for this AP
945
Transmit initiating frame
955
Begin full beam training (SLS+BRP) SIFS
950
Enter SLS responder mode
960
Received response frame SIFS after transmitting initiating frame?
Yes
No
965
Perform frame exchange with AP
970
Go to PS until next SP or BTI after EOSP=1 is received from AP

FIG. 9


BI 1005
Sectorized Beacons
SPs for Data Frame Exchange
BTI
D-SP_1
D-SP_2
D-SP_3
O-SP_1
O-SP_n
1010
1015-a
1015-b
1015-c
1020-a
1020-b
s_1
s_2
s_3
s_k
1025-a
1025-b
1025-c
1025-d
1035
D1
115
AP
105
1030-d
1030-b
1030-c
1030-a
AP
1030-d
105

1000

FIG. 10

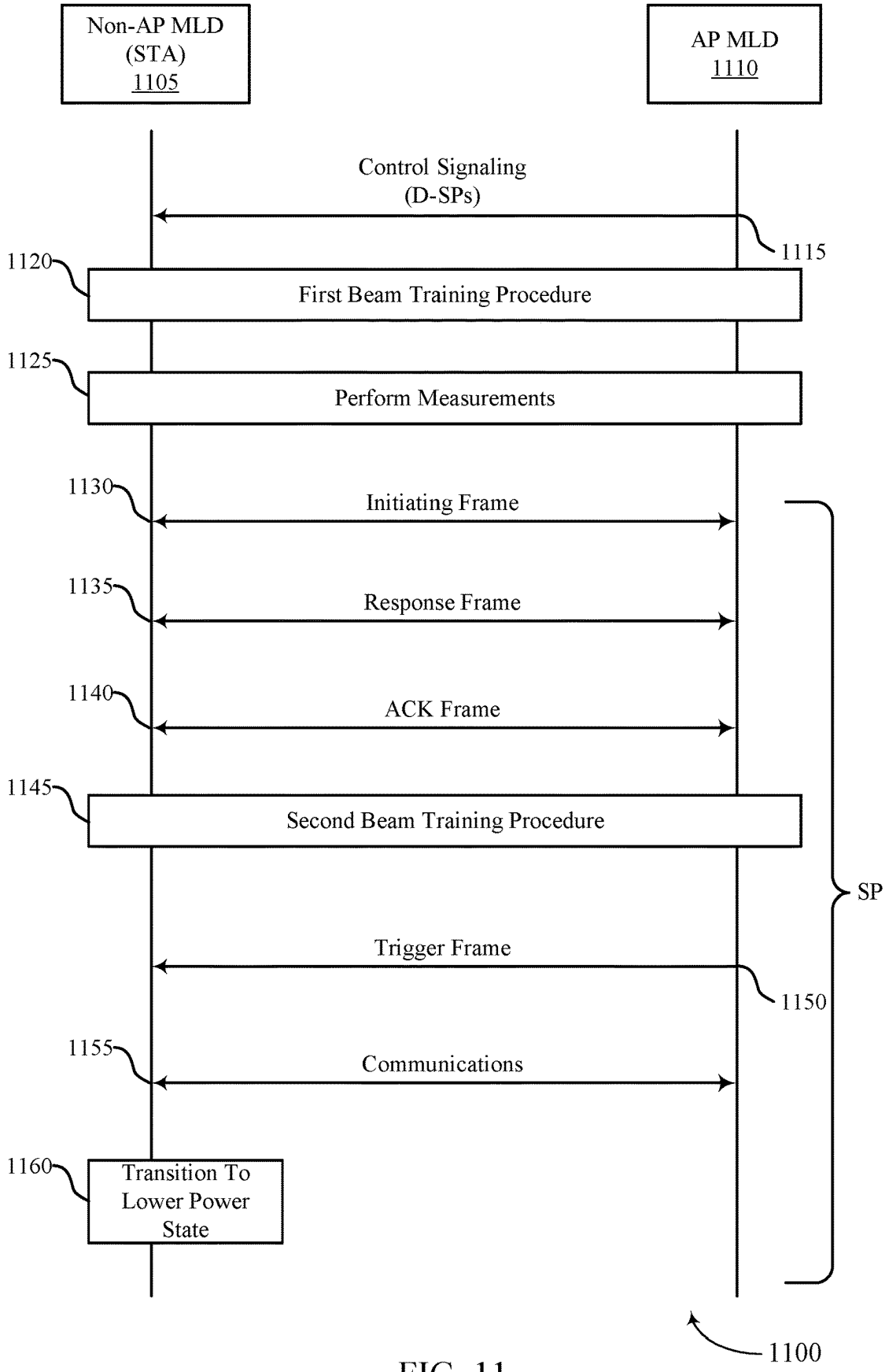

Non-AP MLD
(STA)
1105
AP MLD
1110
Control Signaling
(D-SPs)
1115
1120
First Beam Training Procedure
1125
Perform Measurements
1130
Initiating Frame
1135
Response Frame
1140
ACK Frame
1145
Second Beam Training Procedure
SP
Trigger Frame
1150
1155
Communications
1160
Transition To
Lower Power
State
1100

FIG. 11

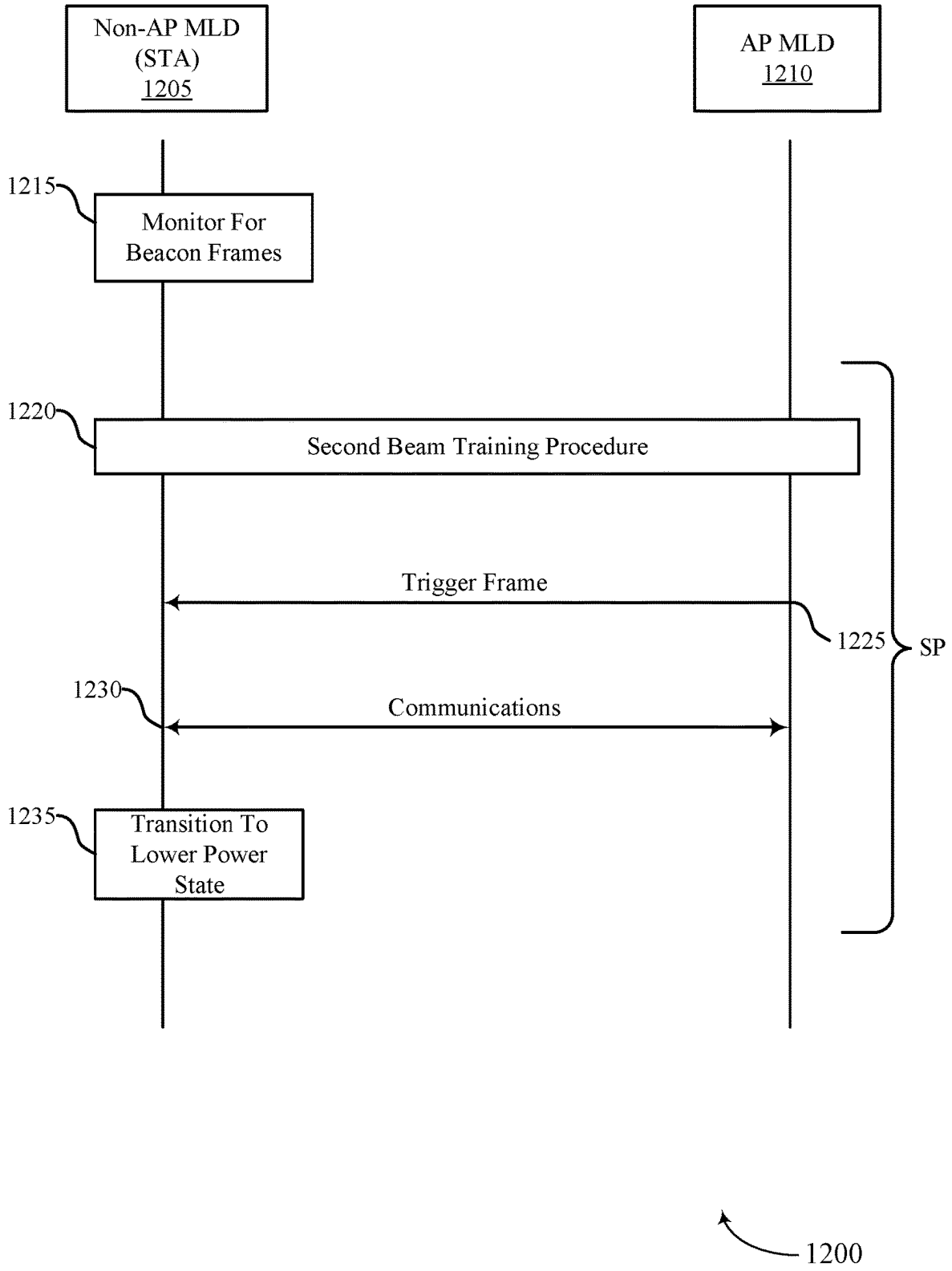

Non-AP MLD
(STA)
1205
AP MLD
1210
1215
Monitor For
Beacon Frames
1220
Second Beam Training Procedure
Trigger Frame
1225
SP
1230
Communications
1235
Transition To
Lower Power
State
1200

FIG. 12

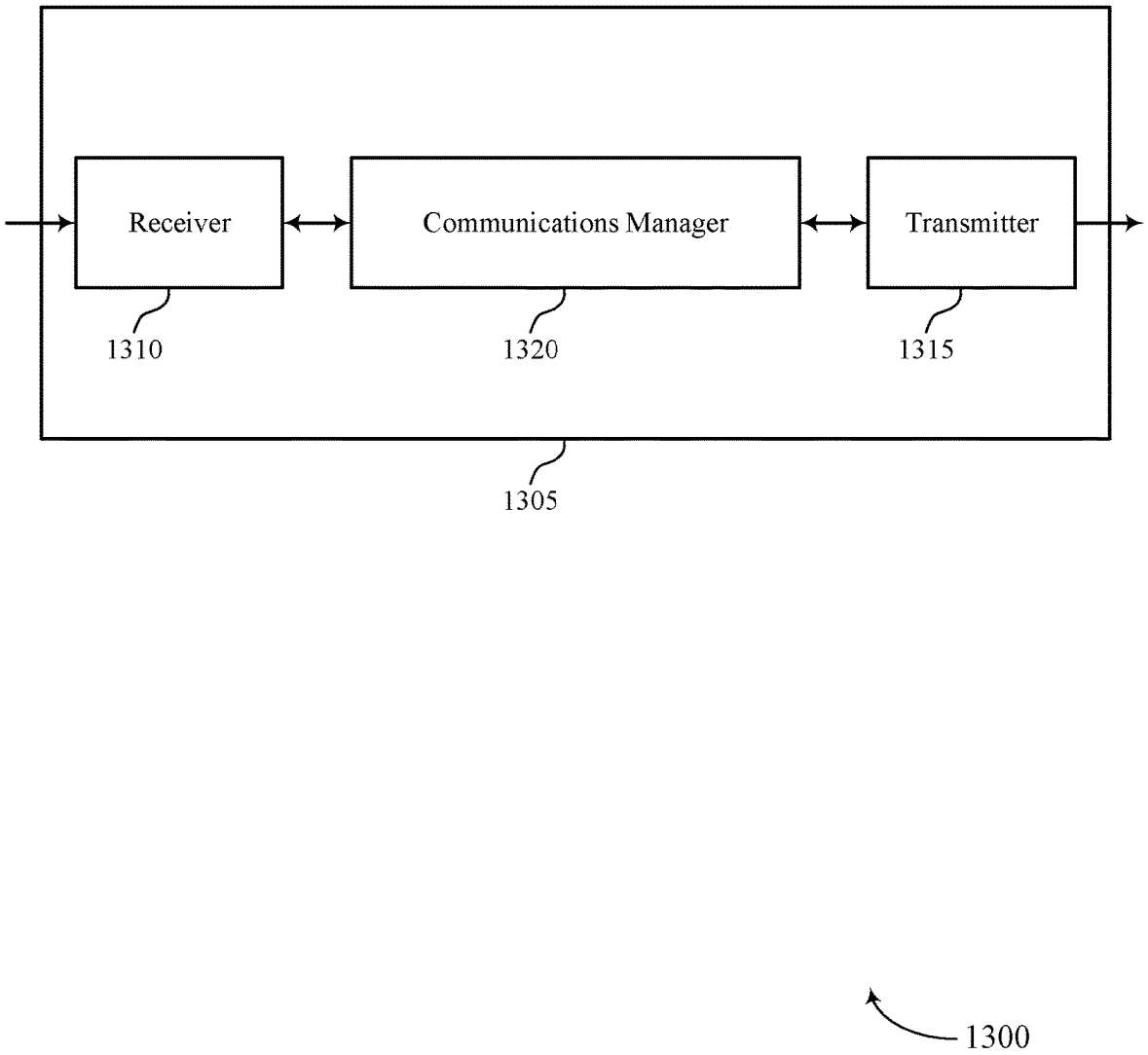

Receiver
Communications Manager
Transmitter
1310
1320
1315
1305
1300

FIG. 13

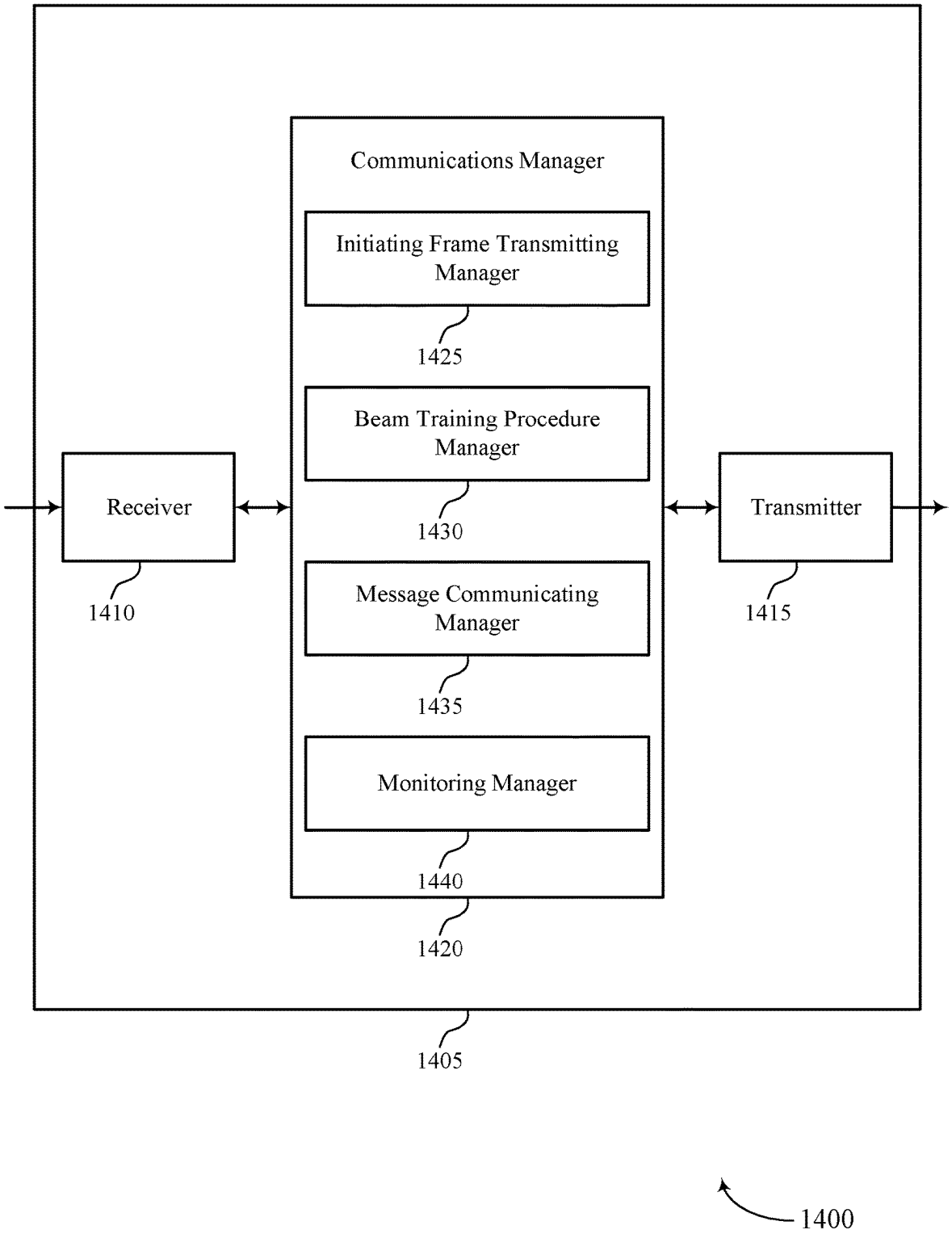

Communications Manager
Initiating Frame Transmitting Manager
1425
Beam Training Procedure Manager
1430
Message Communicating Manager
1435
Monitoring Manager
1440
1420
Receiver
1410
Transmitter
1415
1405
1400

FIG. 14

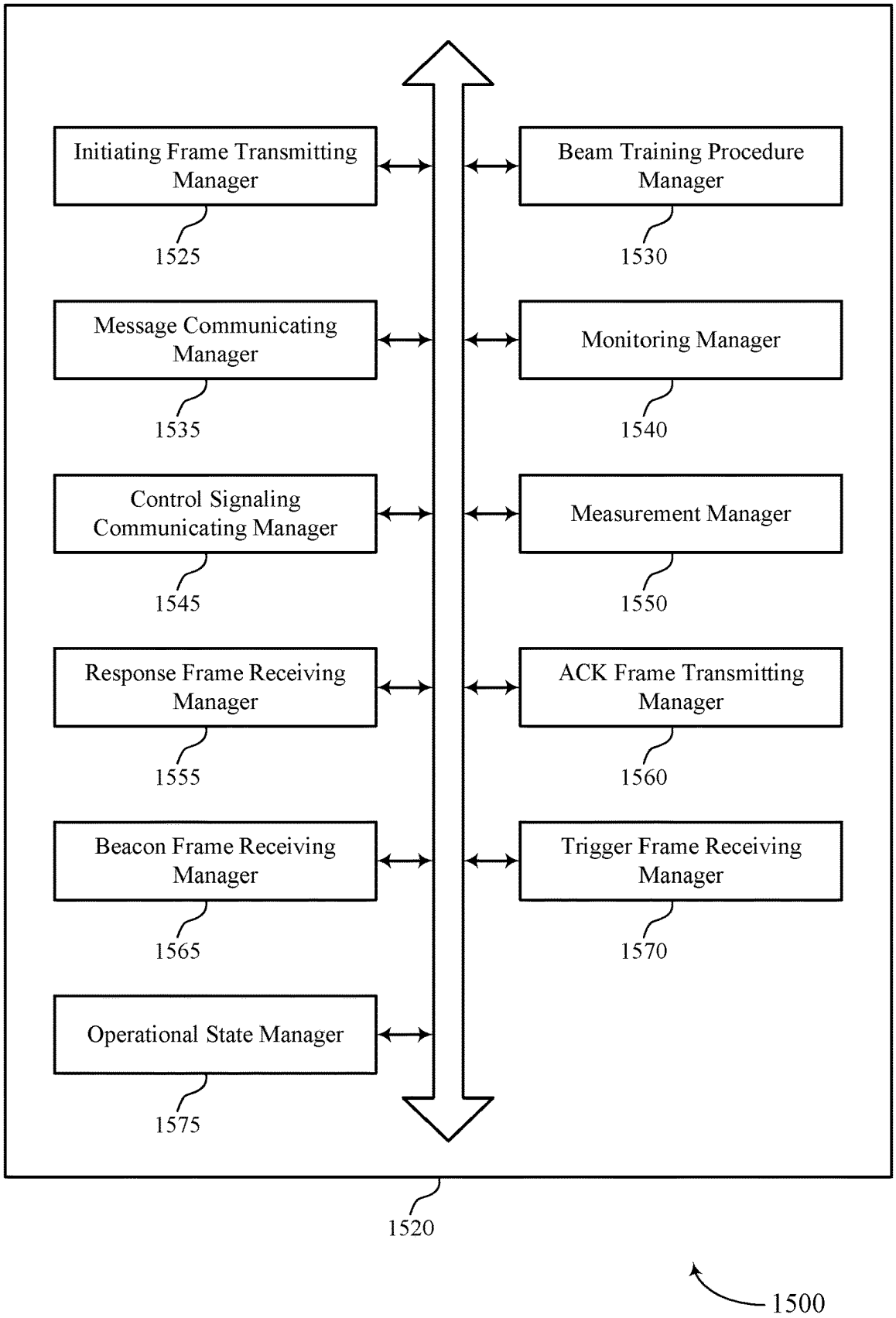

Initiating Frame Transmitting Manager
1525
Beam Training Procedure Manager
1530
Message Communicating Manager
1535
Monitoring Manager
1540
Control Signaling Communicating Manager
1545
Measurement Manager
1550
Response Frame Receiving Manager
1555
ACK Frame Transmitting Manager
1560
Beacon Frame Receiving Manager
1565
Trigger Frame Receiving Manager
1570
Operational State Manager
1575
1520
1500

FIG. 15

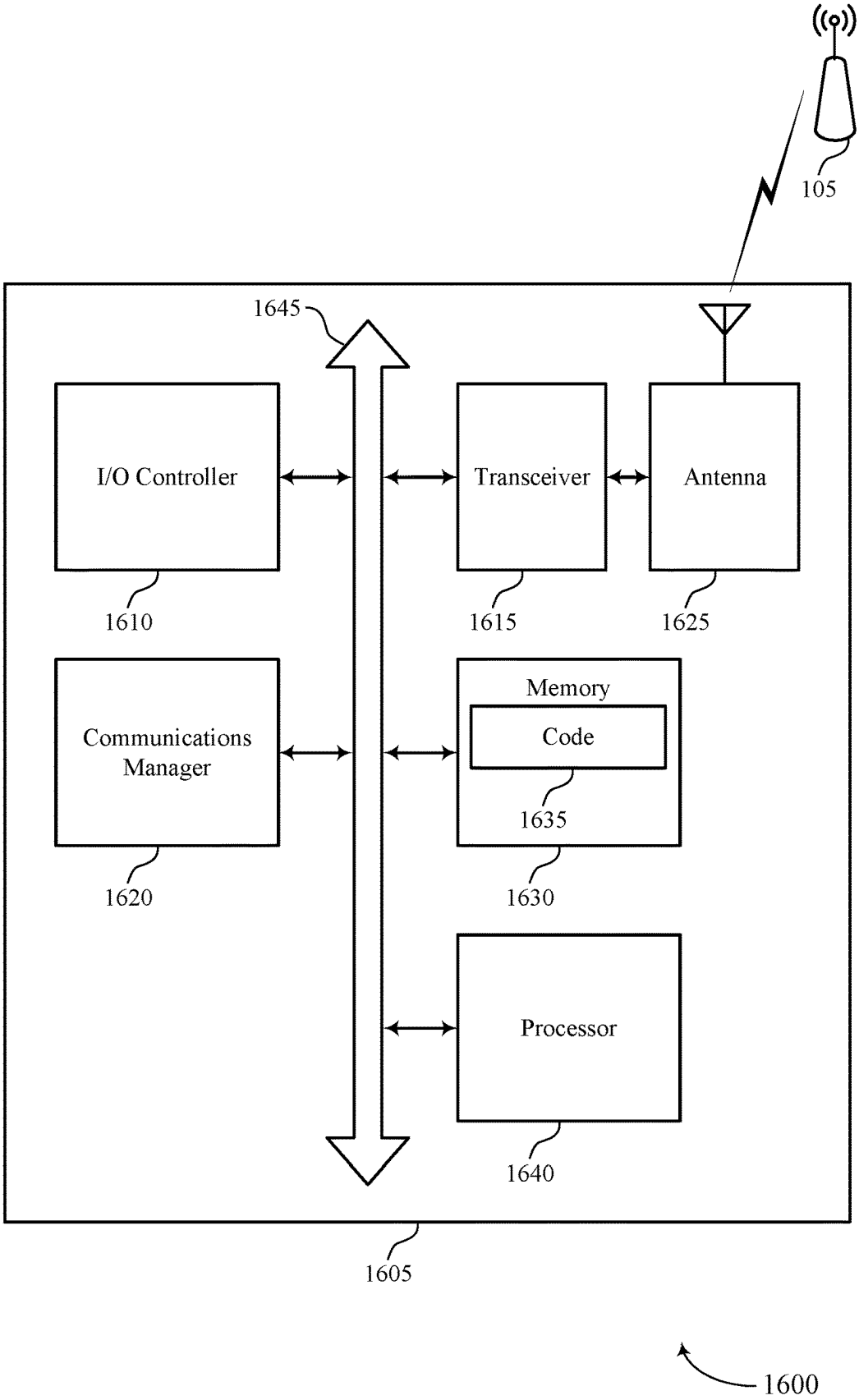
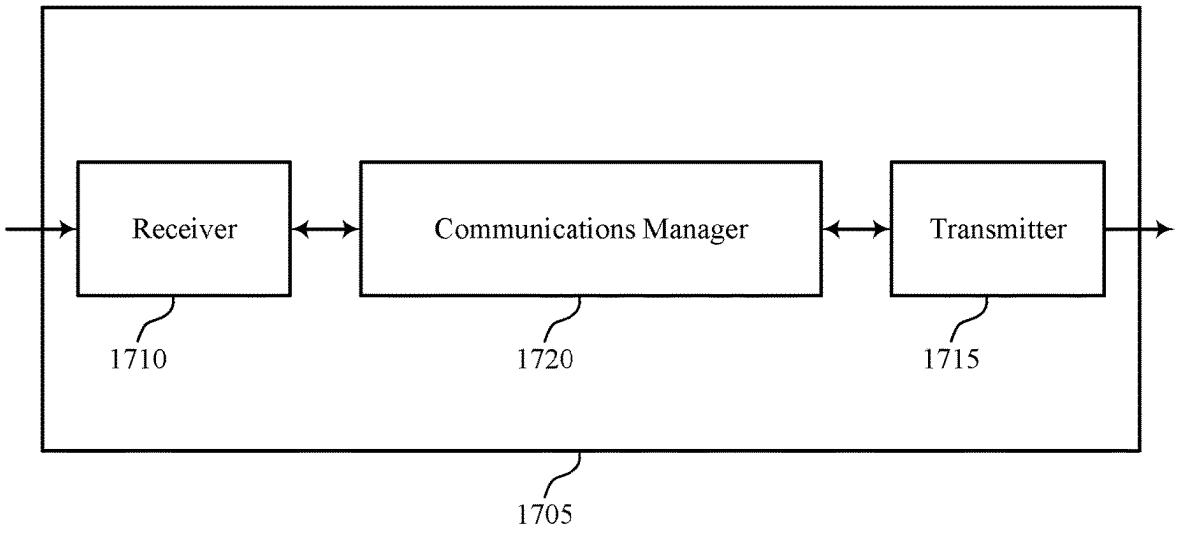
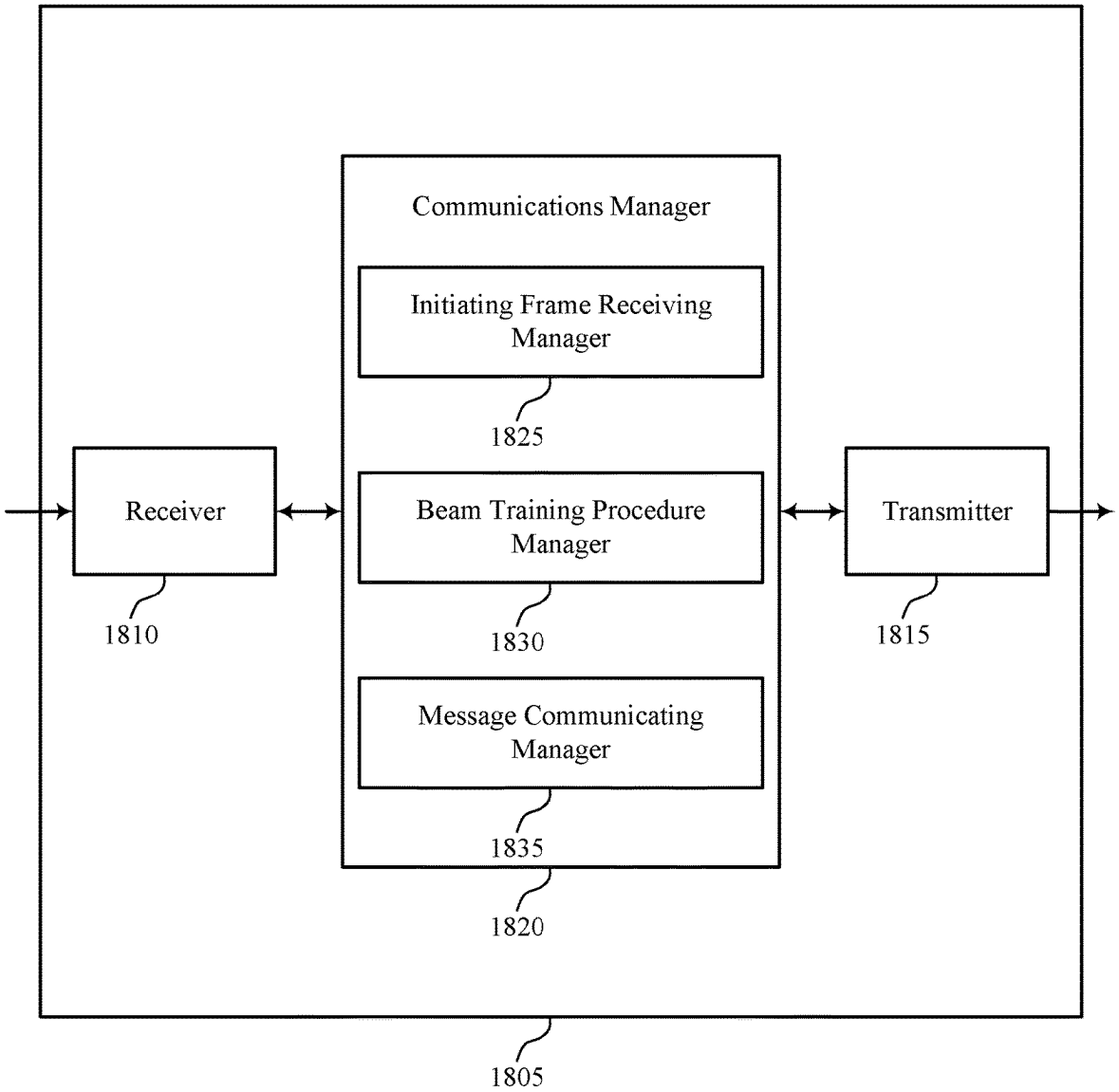

105
1645
I/O Controller
Transceiver
Antenna
1610
1615
1625
Communications Manager
Memory
Code
1635
1620
1630
Processor
1640
1605
1600

FIG. 16


Receiver
Communications Manager
Transmitter
1710
1720
1715
1705

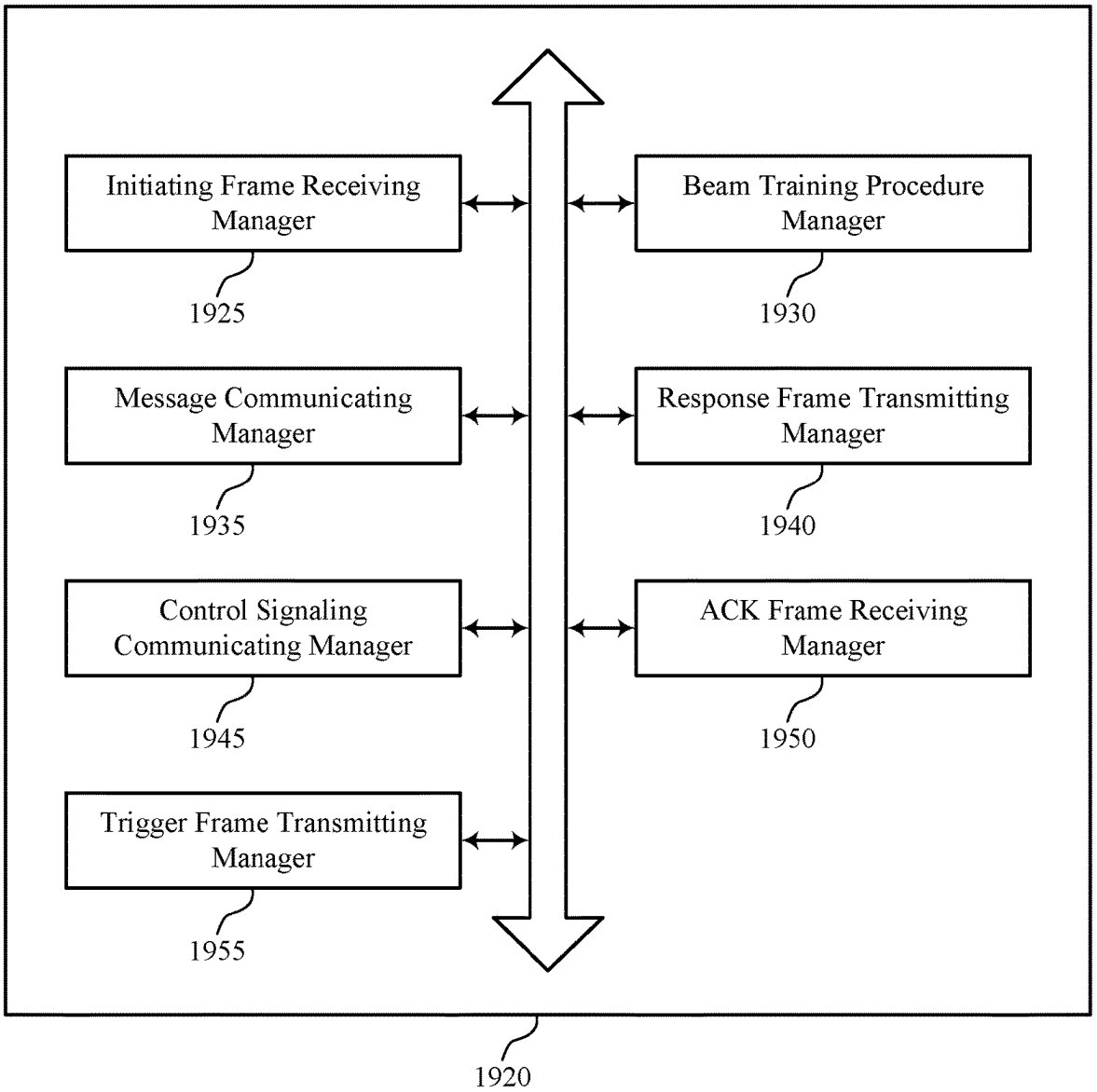
1700

FIG. 17


Communications Manager
Initiating Frame Receiving Manager
1825
Receiver
Beam Training Procedure Manager
Transmitter
1810
1830
1815
Message Communicating Manager
1835
1820
1805

1800

FIG. 18


Initiating Frame Receiving Manager
1925
Beam Training Procedure Manager
1930
Message Communicating Manager
1935
Response Frame Transmitting Manager
1940
Control Signaling Communicating Manager
1945
ACK Frame Receiving Manager
1950
Trigger Frame Transmitting Manager
1955
1920

1900

FIG. 19

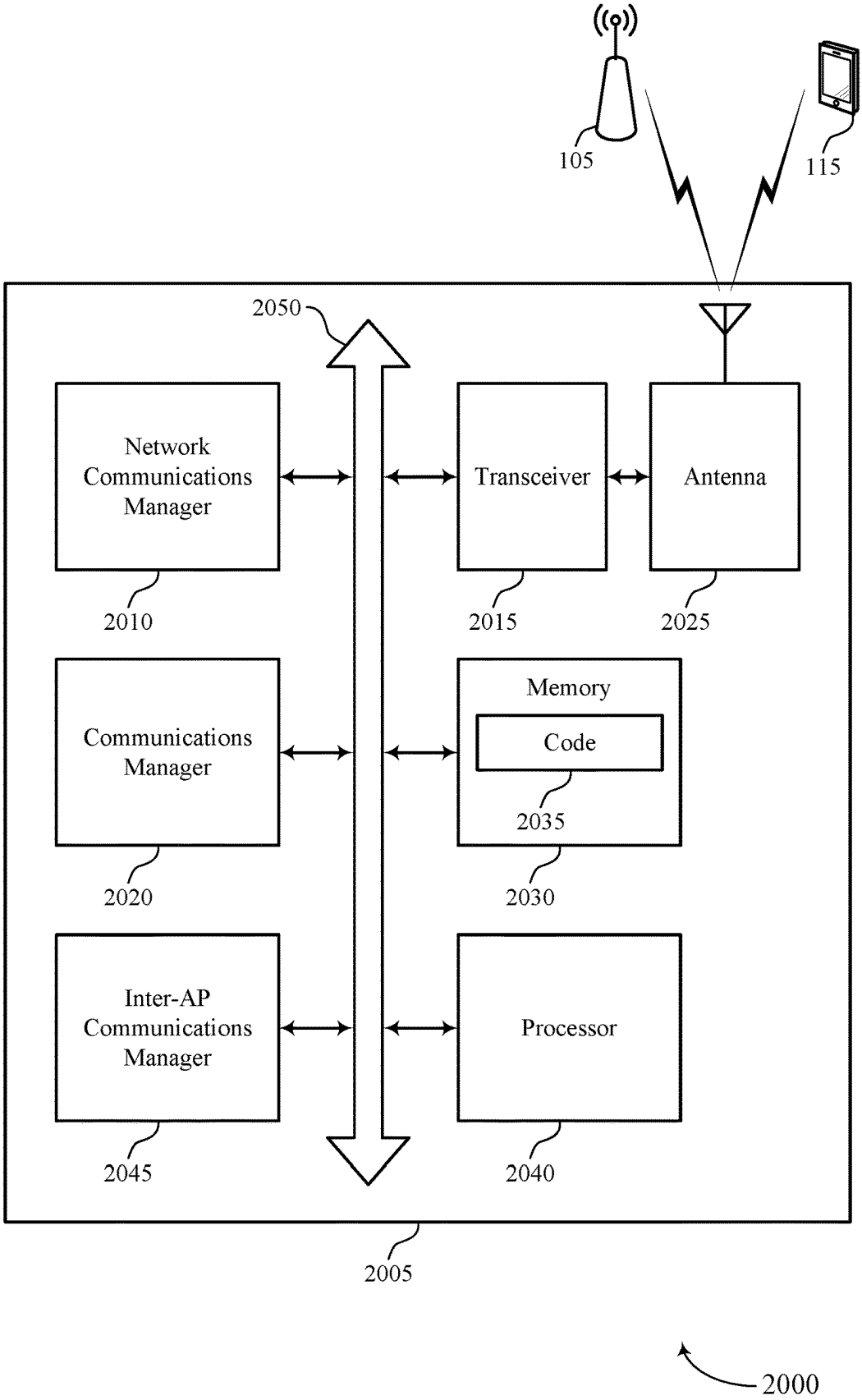

105
115
2050
Network Communications Manager
Transceiver
Antenna
2010
2015
2025
Communications Manager
Memory
Code
2035
2020
2030
Inter-AP Communications Manager
Processor
2045
2040
2005
2000

FIG. 20

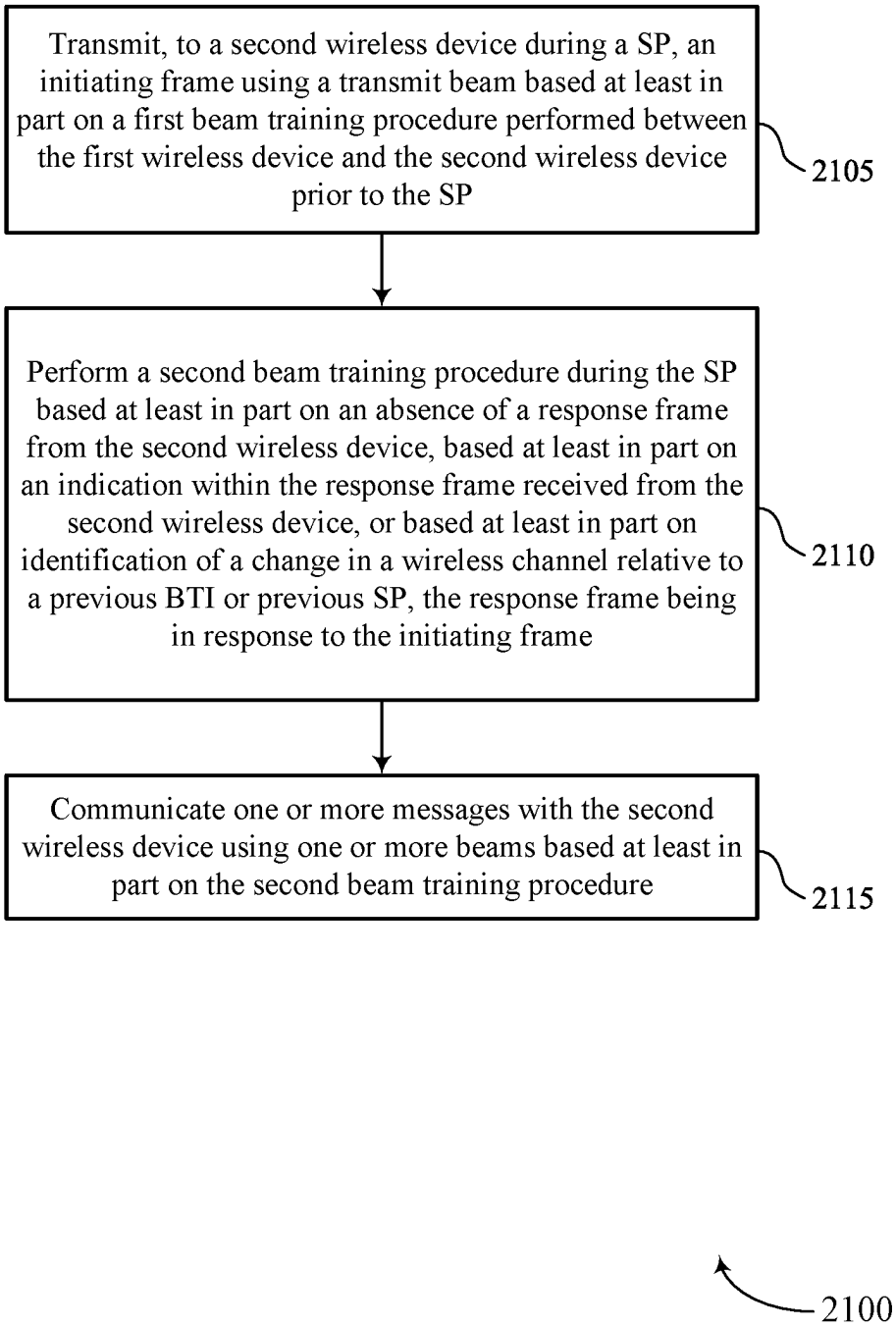

Transmit, to a second wireless device during a SP, an initiating frame using a transmit beam based at least in part on a first beam training procedure performed between the first wireless device and the second wireless device prior to the SP
2105
Perform a second beam training procedure during the SP based at least in part on an absence of a response frame from the second wireless device, based at least in part on an indication within the response frame received from the second wireless device, or based at least in part on identification of a change in a wireless channel relative to a previous BTI or previous SP, the response frame being in response to the initiating frame
2110
Communicate one or more messages with the second wireless device using one or more beams based at least in part on the second beam training procedure
2115
2100

FIG. 21

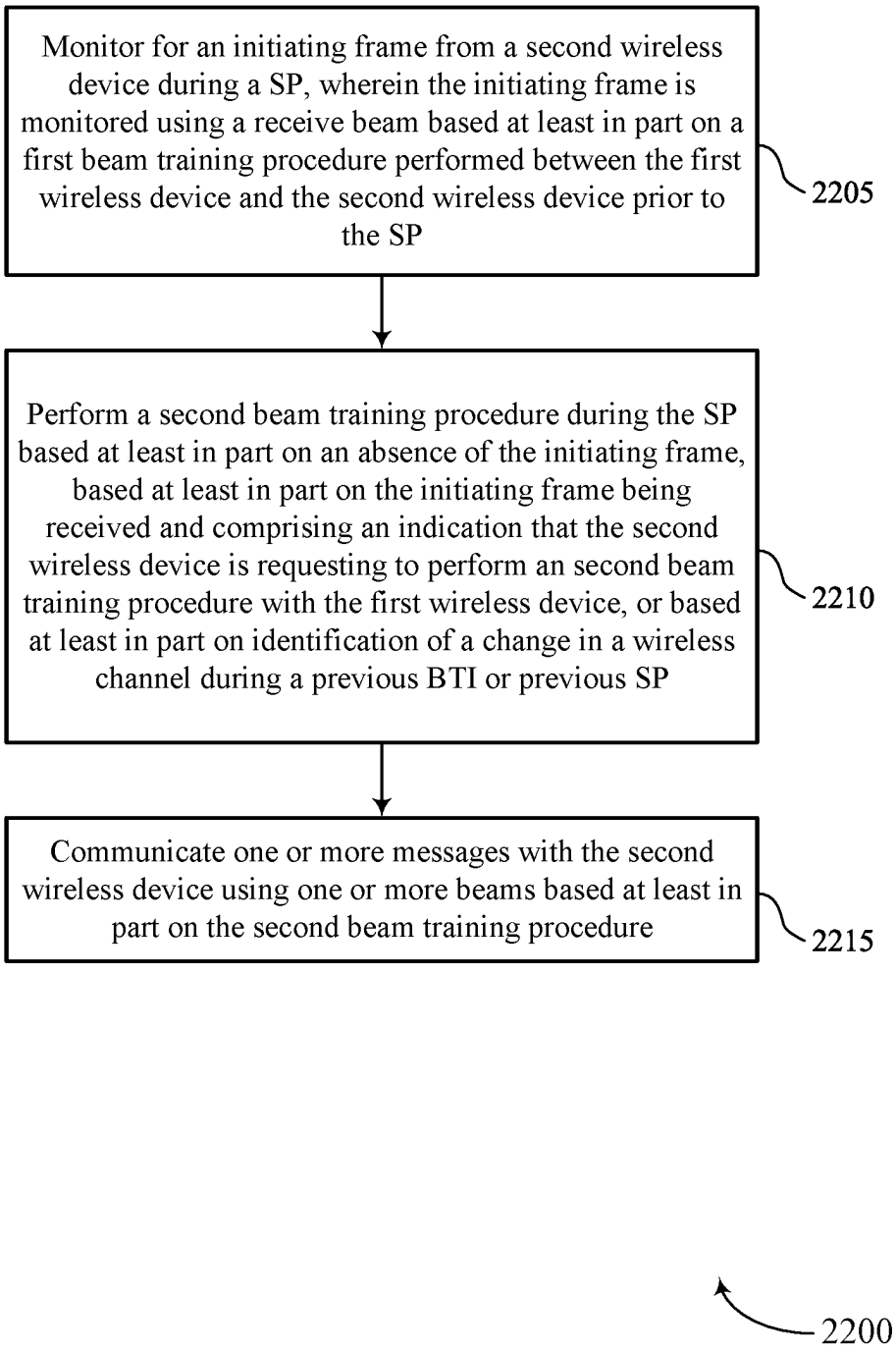

Monitor for an initiating frame from a second wireless device during a SP, wherein the initiating frame is monitored using a receive beam based at least in part on a first beam training procedure performed between the first wireless device and the second wireless device prior to the SP
2205
Perform a second beam training procedure during the SP based at least in part on an absence of the initiating frame, based at least in part on the initiating frame being received and comprising an indication that the second wireless device is requesting to perform an second beam training procedure with the first wireless device, or based at least in part on identification of a change in a wireless channel during a previous BTI or previous SP
2210
Communicate one or more messages with the second wireless device using one or more beams based at least in part on the second beam training procedure
2215
2200

FIG. 22

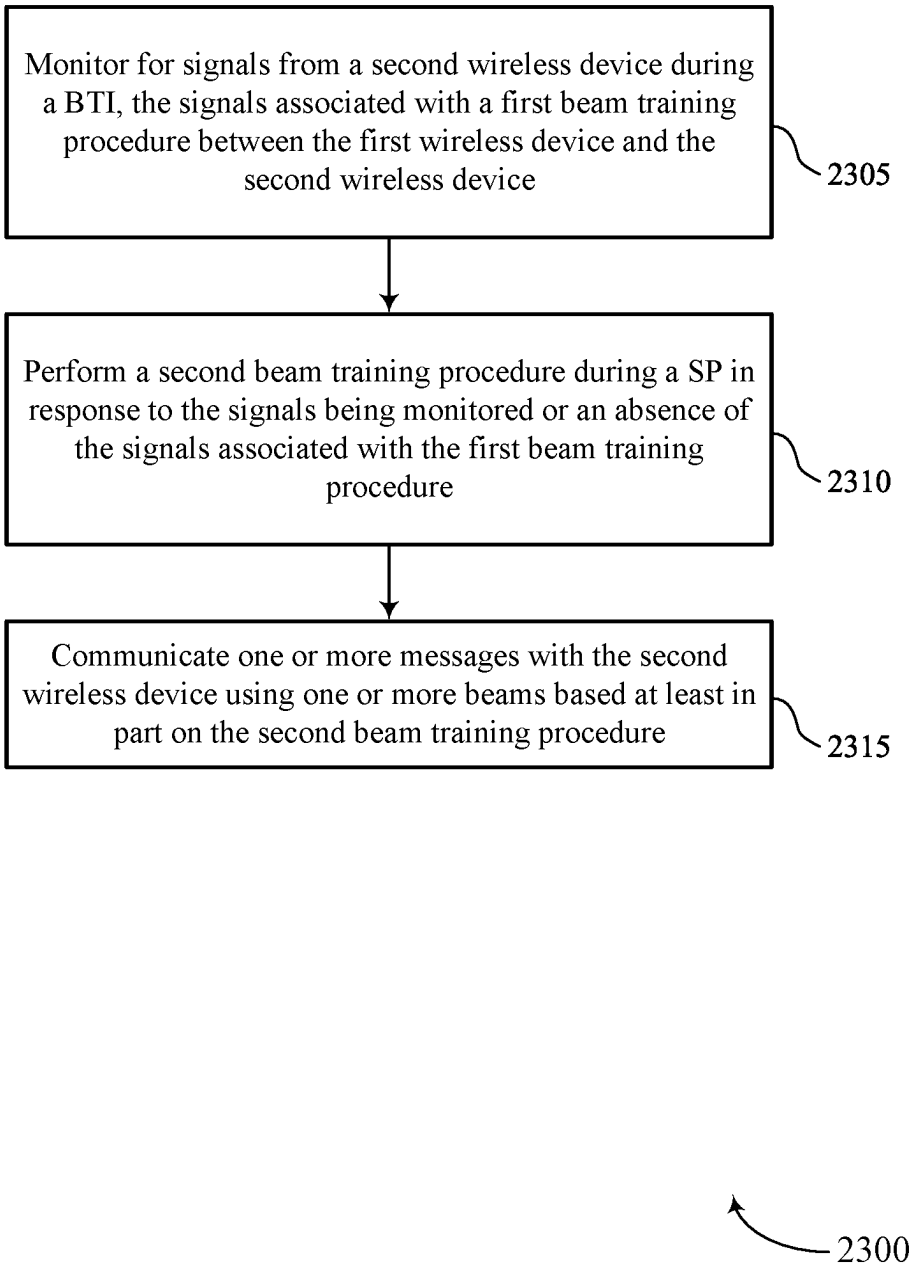

Monitor for signals from a second wireless device during a BTI, the signals associated with a first beam training procedure between the first wireless device and the second wireless device
2305
Perform a second beam training procedure during a SP in response to the signals being monitored or an absence of the signals associated with the first beam training procedure
2310
Communicate one or more messages with the second wireless device using one or more beams based at least in part on the second beam training procedure
2315
2300

FIG. 23

BEAM TRAINING TECHNIQUES IN WIFI FREQUENCY BANDS

CROSS REFERENCE

The present Application for Patent is a Continuation of U.S. patent application Ser. No. 17/942,006 by PATIL et al., entitled "BEAM TRAINING TECHNIQUES IN WIFI FREQUENCY BANDS" filed Sep. 9, 2022, assigned to the assignee hereof, and expressly incorporated by reference in its entirety herein.

TECHNICAL FIELD

The following relates to wireless communications, including beam training techniques in Wi-Fi frequency bands.

BACKGROUND

Wireless communications systems are widely deployed to provide various types of communication content such as voice, video, packet data, messaging, broadcast, and so on. These systems may be multiple-access systems capable of supporting communication with multiple users by sharing the available system resources (e.g., time, frequency, and power). A wireless network, for example a WLAN, such as a Wi-Fi (i.e., Institute of Electrical and Electronics Engineers (IEEE) 802.11) network may include AP that may communicate with one or more stations (STAs) or mobile devices. The AP may be coupled to a network, such as the Internet, and may enable a mobile device to communicate via the network (or communicate with other devices coupled to the access point). A wireless device may communicate with a network device bi-directionally. For example, in a WLAN, a STA may communicate with an associated AP via DL and UL. The DL (or forward link) may refer to the communication link from the AP to the station, and the UL (or reverse link) may refer to the communication link from the station to the AP.

Many Wi-Fi deployments may use 2.4 GHz, 5 GHz, and/or 6 GHz bands, which may be referred to as "sub-7" GHz bands. Future Wi-Fi enhancements aim to leverage multi-link operation techniques to enhance a user experience within other frequency bands, such as a 60 GHz frequency band. While the 60 GHz band may offer a large swath of resources for Wi-Fi devices to use, the 60 GHz band is not widely used due to several challenges, including high propagation loss. As such, there is a need to improve Wi-Fi communications on respective frequency bands, such as the 60 GHz band.

SUMMARY

The described techniques relate to improved methods, systems, devices, or apparatuses that support beam training techniques in Wi-Fi frequency bands. Generally, aspects of the present disclosure are directed to techniques for handshake signaling between wireless devices that enable the wireless devices to determine whether (or what level) of beam training procedures are required for a Wi-Fi band, such as a 60 GHz link. In particular, wireless devices may perform a beam training procedure, and subsequently exchange message frames (e.g., initiating frames, response frames) at the start of subsequent service periods (SPs) to indicate whether the respective devices can communicate using previously-selected beams, or if the devices are expected to perform a new beam training procedure. In some cases, a station (STA), an access point (AP), or both, may be able to explicitly trigger a beam training procedure within an SP via an initiating frame or response frame at the start of the SP. Additionally, or alternatively, a failure of one of the devices to successfully receive the initiating frame and/or response frame may serve as an implicit indication that the devices are to perform a new beam training procedure during the SP.

A method for wireless communications at a first wireless device is described. The method may include transmitting, to a second wireless device during a SP, an initiating frame using a transmit beam based on a first beam training procedure performed between the first wireless device and the second wireless device prior to the SP, performing a second beam training procedure during the SP based on an absence of a response frame from the second wireless device, based on an indication within the response frame received from the second wireless device, or based on identification of a change in a wireless channel relative to a previous beam training interval or previous SP, the response frame being in response to the initiating frame, and communicating one or more messages with the second wireless device using one or more beams based on the second beam training procedure.

An apparatus for wireless communications at a first wireless device is described. The apparatus may include a processor, memory coupled with the processor, and instructions stored in the memory. The instructions may be executable by the processor to cause the apparatus to transmit, to a second wireless device during a SP, an initiating frame using a transmit beam based on a first beam training procedure performed between the first wireless device and the second wireless device prior to the SP, perform a second beam training procedure during the SP based on an absence of a response frame from the second wireless device, based on an indication within the response frame received from the second wireless device, or based on identification of a change in a wireless channel relative to a previous beam training interval or previous SP, the response frame being in response to the initiating frame, and communicate one or more messages with the second wireless device using one or more beams based on the second beam training procedure.

Another apparatus for wireless communications at a first wireless device is described. The apparatus may include means for transmitting, to a second wireless device during a SP, an initiating frame using a transmit beam based on a first beam training procedure performed between the first wireless device and the second wireless device prior to the SP, means for performing a second beam training procedure during the SP based on an absence of a response frame from the second wireless device, based on an indication within the response frame received from the second wireless device, or based on identification of a change in a wireless channel relative to a previous beam training interval or previous SP, the response frame being in response to the initiating frame, and means for communicating one or more messages with the second wireless device using one or more beams based on the second beam training procedure.

A non-transitory computer-readable medium storing code for wireless communications at a first wireless device is described. The code may include instructions executable by a processor to transmit, to a second wireless device during a SP, an initiating frame using a transmit beam based on a first beam training procedure performed between the first wireless device and the second wireless device prior to the SP, perform a second beam training procedure during the SP based on an absence of a response frame from the second wireless device, based on an indication within the response

frame received from the second wireless device, or based on identification of a change in a wireless channel relative to a previous beam training interval or previous SP, the response frame being in response to the initiating frame, and communicate one or more messages with the second wireless device using one or more beams based on the second beam training procedure.

Some examples of the method, apparatuses, and non-transitory computer-readable medium described herein may further include operations, features, means, or instructions for communicating, with the second wireless device, control signaling indicating a set of multiple SPs associated with the first wireless device, the set of multiple SPs including the SP, where the initiating frame may be transmitted based on the control signaling.

In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the initiating frame includes an indication as to whether the first wireless device may be requesting to perform the second beam training procedure with the second wireless device during the SP.

Some examples of the method, apparatuses, and non-transitory computer-readable medium described herein may further include operations, features, means, or instructions for performing one or more measurements on signals received from the second wireless device via a receive beam based on the first beam training procedure, where the initiating frame may be transmitted based on whether the one or more measurements satisfy one or more thresholds.

In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the initiating frame includes an indication that the first wireless device may be requesting to perform the second beam training procedure based on the one or more measurements failing to satisfy the one or more thresholds and the initiating frame includes an indication that the first wireless device may be not requesting to perform the second beam training procedure based on the one or more measurements satisfying the one or more thresholds.

In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the initiating frame includes a BSR associated with traffic to be communicated from the first wireless device to the second wireless device and the method, apparatuses, and non-transitory computer-readable medium may include further operations, features, means, or instructions for transmitting the traffic to the second wireless device using the one or more beams and based on the BSR.

Some examples of the method, apparatuses, and non-transitory computer-readable medium described herein may further include operations, features, means, or instructions for receiving, from the second wireless device, a trigger frame scheduling the traffic based on the BSR, where the traffic may be transmitted based on the trigger frame.

Some examples of the method, apparatuses, and non-transitory computer-readable medium described herein may further include operations, features, means, or instructions for receiving downlink traffic from the second wireless device with the trigger frame.

In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the one or more messages may be received from the second wireless device using a receive beam based on the second beam training procedure and a last frame of the one or more messages indicate an end of the one or more messages, an end of the SP, or both.

In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the first wireless device receives the one or more messages while in a first operational state associated with a first power consumption and the method, apparatuses, and non-transitory computer-readable medium may include further operations, features, means, or instructions for transitioning to a second operational state associated with a second power consumption that may be less than the first power consumption based on the one or more messages indicating the end of the one or more messages, the end of the SP, or both.

Some examples of the method, apparatuses, and non-transitory computer-readable medium described herein may further include operations, features, means, or instructions for communicating one or more additional messages with the second wireless device during a second SP using the one or more beams based on the second beam training procedure.

In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the one or more messages include an indication of the second SP for communications between the first wireless device and the second wireless device and the one or more additional messages may be communicated based on the indication of the second SP.

In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the initiating frame includes the indication that the first wireless device may be requesting to perform the second beam training procedure with the second wireless device and the method, apparatuses, and non-transitory computer-readable medium may include further operations, features, means, or instructions for receiving the response frame from the second wireless device based on the initiating frame, where the response frame includes an acknowledgment of the second beam training procedure, where the second beam training procedure may be performed based on the acknowledgment.

In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the initiating frame includes the indication that the first wireless device may be requesting to perform the second beam training procedure with the second wireless device and the method, apparatuses, and non-transitory computer-readable medium may include further operations, features, means, or instructions for identifying the absence of the response frame from the second wireless device based on the initiating frame and monitoring for signals from the second wireless device as part of the second beam training procedure based on the absence of the response frame.

Some examples of the method, apparatuses, and non-transitory computer-readable medium described herein may further include operations, features, means, or instructions for receiving, via the response frame, an indication that the second wireless device may be requesting to perform the second beam training procedure with the first wireless device, where the second beam training procedure may be performed based on receiving the response frame.

Some examples of the method, apparatuses, and non-transitory computer-readable medium described herein may further include operations, features, means, or instructions for identifying that a quantity of failed frame exchanges between the first wireless device and the second wireless device satisfies a threshold quantity based on transmitting the initiating frame, where the second beam training procedure may be performed based on the identifying.

Some examples of the method, apparatuses, and non-transitory computer-readable medium described herein may

further include operations, features, means, or instructions for receiving the response frame based on the initiating frame being transmitted and transmitting, to the second wireless device, an acknowledgment frame based on the response frame, where the second beam training procedure may be performed based on the acknowledgment frame.

In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the initiating frame includes a quality of service null frame including a control field, the control field including a BSR, the indication as to whether the first wireless device may be requesting to perform the second beam training procedure, or both.

In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the first wireless device includes a station (STA), a first multi-link device, or both, the second wireless device includes an access point (AP), a second multi-link device, or both, the first wireless device includes the AP and, and the second wireless device includes the STA.

A method for wireless communications at a first wireless device is described. The method may include monitoring for an initiating frame from a second wireless device during a SP, where the initiating frame is monitored performed using a receive beam based on a first beam training procedure performed between the first wireless device and the second wireless device prior to the SP, performing a second beam training procedure during the SP based on an absence of the initiating frame, based on the initiating frame being received and including an indication that the second wireless device is requesting to perform a second beam training procedure with the first wireless device, or based on identification of a change in a wireless channel during a previous beam training interval or previous SP, and communicating one or more messages with the second wireless device using one or more beams based on the second beam training procedure.

An apparatus for wireless communications at a first wireless device is described. The apparatus may include a processor, memory coupled with the processor, and instructions stored in the memory. The instructions may be executable by the processor to cause the apparatus to monitor for an initiating frame from a second wireless device during a SP, where the initiating frame is monitored performed using a receive beam based on a first beam training procedure performed between the first wireless device and the second wireless device prior to the SP, perform a second beam training procedure during the SP based on an absence of the initiating frame, based on the initiating frame being received and including an indication that the second wireless device is requesting to perform a second beam training procedure with the first wireless device, or based on identification of a change in a wireless channel during a previous beam training interval or previous SP, and communicate one or more messages with the second wireless device using one or more beams based on the second beam training procedure.

Another apparatus for wireless communications at a first wireless device is described. The apparatus may include means for monitoring for an initiating frame from a second wireless device during a SP, where the initiating frame is monitored performed using a receive beam based on a first beam training procedure performed between the first wireless device and the second wireless device prior to the SP, means for performing a second beam training procedure during the SP based on an absence of the initiating frame, based on the initiating frame being received and including an indication that the second wireless device is requesting to perform a second beam training procedure with the first wireless device, or based on identification of a change in a wireless channel during a previous beam training interval or previous SP, and means for communicating one or more messages with the second wireless device using one or more beams based on the second beam training procedure.

A non-transitory computer-readable medium storing code for wireless communications at a first wireless device is described. The code may include instructions executable by a processor to monitor for an initiating frame from a second wireless device during a SP, where the initiating frame is monitored performed using a receive beam based on a first beam training procedure performed between the first wireless device and the second wireless device prior to the SP, perform a second beam training procedure during the SP based on an absence of the initiating frame, based on the initiating frame being received and including an indication that the second wireless device is requesting to perform a second beam training procedure with the first wireless device, or based on identification of a change in a wireless channel during a previous beam training interval or previous SP, and communicate one or more messages with the second wireless device using one or more beams based on the second beam training procedure.

Some examples of the method, apparatuses, and non-transitory computer-readable medium described herein may further include operations, features, means, or instructions for receiving the initiating frame and transmitting a response frame to the second wireless device based on the initiating frame, where the second beam training procedure may be performed based on the response frame being transmitted.

Some examples of the method, apparatuses, and non-transitory computer-readable medium described herein may further include operations, features, means, or instructions for identifying an absence of the initiating frame from the second wireless device based on the initiating frame being monitored, where the second beam training procedure may be performed based on the absence of the initiating frame.

Some examples of the method, apparatuses, and non-transitory computer-readable medium described herein may further include operations, features, means, or instructions for communicating, with the second wireless device, control signaling indicating a set of multiple SPs associated with the first wireless device, the set of multiple SPs including the SP, where the initiating frame may be monitored for based on the control signaling.

In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the initiating frame includes an indication as to whether the second wireless device may be requesting to perform the second beam training procedure with the first wireless device during the SP.

Some examples of the method, apparatuses, and non-transitory computer-readable medium described herein may further include operations, features, means, or instructions for receiving, via the initiating frame and based on the monitoring, a BSR associated with traffic to be communicated from the second wireless device to the first wireless device and receiving the traffic from the second wireless device using the one or more beams and based on the BSR.

Some examples of the method, apparatuses, and non-transitory computer-readable medium described herein may further include operations, features, means, or instructions for transmitting, to the second wireless device, a trigger frame scheduling the traffic based on the BSR, where the traffic may be received based on the trigger frame.

Some examples of the method, apparatuses, and non-transitory computer-readable medium described herein may

further include operations, features, means, or instructions for transmitting downlink traffic from the second wireless device along with the trigger frame.

In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, a last frame of the one or more messages indicate an end of the one or more messages, an end of the SP, or both.

In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the one or more messages include an indication of a second SP for communications between the first wireless device and the second wireless device and the method, apparatuses, and non-transitory computer-readable medium may include further operations, features, means, or instructions for communicating one or more additional messages with the second wireless device during the second SP using the one or more beams based on the second beam training procedure.

Some examples of the method, apparatuses, and non-transitory computer-readable medium described herein may further include operations, features, means, or instructions for receiving, via the initiating frame and based on the monitoring, the indication that the second wireless device may be requesting to perform the second beam training procedure with the second wireless device and transmitting a response frame to the second wireless device based on the initiating frame, where the response frame includes an acknowledgment of the second beam training procedure, where the second beam training procedure may be performed based on the acknowledgment.

Some examples of the method, apparatuses, and non-transitory computer-readable medium described herein may further include operations, features, means, or instructions for transmitting a response frame based at last in part on receiving the initiating frame, where the response frame includes an indication that the first wireless device may be requesting to perform the second beam training procedure with the second wireless device, where the second beam training procedure may be performed based on the response frame being transmitted.

Some examples of the method, apparatuses, and non-transitory computer-readable medium described herein may further include operations, features, means, or instructions for identifying that a quantity of failed frame exchanges between the first wireless device and the second wireless device satisfies a threshold quantity based on the monitoring, where the second beam training procedure may be performed based on the identifying.

Some examples of the method, apparatuses, and non-transitory computer-readable medium described herein may further include operations, features, means, or instructions for transmitting a response frame based on the initiating frame being received and receiving, from the second wireless device, an acknowledgment frame based on transmitting the response frame, where the second beam training procedure may be performed based on the acknowledgment frame.

In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the initiating frame includes a quality of service null frame including a control field, the control field including a buffer status report, the indication as to whether the first wireless device may be requesting to perform the second beam training procedure, or both.

In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the first wireless device includes an STA, a first multi-link device, or both, the second wireless device includes an AP, a second multi-link device, or both, the first wireless device includes the AP and, and the second wireless device includes the STA.

A method for wireless communications at a first wireless device is described. The method may include monitoring for signals from a second wireless device during a beacon transmit interval (BTI), the signals associated with a first beam training procedure between the first wireless device and the second wireless device, performing a second beam training procedure during a SP in response to the signals being monitored or an absence of the signals associated with the first beam training procedure, and communicating one or more messages with the second wireless device using one or more beams based on the second beam training procedure.

An apparatus for wireless communications at a first wireless device is described. The apparatus may include a processor, memory coupled with the processor, and instructions stored in the memory. The instructions may be executable by the processor to cause the apparatus to monitor for signals from a second wireless device during a BTI, the signals associated with a first beam training procedure between the first wireless device and the second wireless device, perform a second beam training procedure during a SP in response to the signals being monitored or an absence of the signals associated with the first beam training procedure, and communicate one or more messages with the second wireless device using one or more beams based on the second beam training procedure.

Another apparatus for wireless communications at a first wireless device is described. The apparatus may include means for monitoring for signals from a second wireless device during a BTI, the signals associated with a first beam training procedure between the first wireless device and the second wireless device, means for performing a second beam training procedure during a SP in response to the signals being monitored or an absence of the signals associated with the first beam training procedure, and means for communicating one or more messages with the second wireless device using one or more beams based on the second beam training procedure.

A non-transitory computer-readable medium storing code for wireless communications at a first wireless device is described. The code may include instructions executable by a processor to monitor for signals from a second wireless device during a BTI, the signals associated with a first beam training procedure between the first wireless device and the second wireless device, perform a second beam training procedure during a SP in response to the signals being monitored or an absence of the signals associated with the first beam training procedure, and communicate one or more messages with the second wireless device using one or more beams based on the second beam training procedure.

In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the monitoring may include operations, features, means, or instructions for monitoring for a beacon frame in a beam-formed mode.

Some examples of the method, apparatuses, and non-transitory computer-readable medium described herein may further include operations, features, means, or instructions for receiving a beacon frame from the second wireless device based on the signals being monitored, the beacon frame associated with the first beam training procedure and refraining from transmission of an initiating frame within the SP based on the beam training procedure including an initial beam training procedure between the first wireless device and the second wireless device, where the second

beam training procedure may be performed based on the initiating frame being refrained from transmission.

Some examples of the method, apparatuses, and non-transitory computer-readable medium described herein may further include operations, features, means, or instructions for identifying an absence of an initiating frame communicated between the first wireless device and the second wireless device within the SP, where the second beam training procedure may be performed based on the absence of the initiating frame.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates an example of a wireless local area network (WLAN) that supports beam training techniques in Wi-Fi frequency bands in accordance with aspects of the present disclosure.

FIG. **2** illustrates an example of a wireless communications system that supports beam training techniques in Wi-Fi frequency bands in accordance with one or more aspects of the present disclosure.

FIGS. **3** through **7** illustrate examples of beam training procedures that support beam training techniques in Wi-Fi frequency bands in accordance with one or more aspects of the present disclosure.

FIGS. **8** and **9** illustrate examples of flow diagrams that support beam training techniques in Wi-Fi frequency bands in accordance with one or more aspects of the present disclosure.

FIG. **10** illustrates an example of a beam training procedure that supports beam training techniques in Wi-Fi frequency bands in accordance with one or more aspects of the present disclosure.

FIG. **11** illustrates an example of a process flow that supports beam training techniques in Wi-Fi frequency bands in accordance with one or more aspects of the present disclosure.

FIG. **12** illustrates an example of a process flow that supports beam training techniques in Wi-Fi frequency bands in accordance with one or more aspects of the present disclosure.

FIGS. **13** and **14** show block diagrams of devices that support beam training techniques in Wi-Fi frequency bands in accordance with one or more aspects of the present disclosure.

FIG. **15** shows a block diagram of a communications manager that supports beam training techniques in Wi-Fi frequency bands in accordance with one or more aspects of the present disclosure.

FIG. **16** shows a diagram of a system including a device that supports beam training techniques in Wi-Fi frequency bands in accordance with one or more aspects of the present disclosure.

FIGS. **17** and **18** show block diagrams of devices that support beam training techniques in Wi-Fi frequency bands in accordance with one or more aspects of the present disclosure.

FIG. **19** shows a block diagram of a communications manager that supports beam training techniques in Wi-Fi frequency bands in accordance with one or more aspects of the present disclosure.

FIG. **20** shows a diagram of a system including a device that supports beam training techniques in Wi-Fi frequency bands in accordance with one or more aspects of the present disclosure.

FIGS. **21** through **23** show flowcharts illustrating methods that support beam training techniques in Wi-Fi frequency bands in accordance with one or more aspects of the present disclosure.

DETAILED DESCRIPTION

In some deployments, wireless devices (such as wireless fidelity (Wi-Fi) devices) may support multi-link operation (MLO) according to which the devices may communicate via multiple different links. For example, an access point (AP) multi-link device (MLD) may communicate with a non-AP MLD via a 2.4 gigahertz (GHz) link, a 5 GHz link, a 6 GHz link, or any combination thereof, which may generally be referred to as "sub-7" GHz bands. In some systems, an AP MLD and a non-AP MLD may be capable of communication via other radio frequency links, such as 45 GHz and 60 GHz links (e.g., non-sub-7 links), which may provide relatively higher data rates or greater link diversity.

Communication over such other radio frequency links may present several challenges, which may hinder adoption of such other radio frequency links (which may in turn, limit an achievable throughput or diversity of a system). For example, the non-sub-7 bands, such as the 45 GHz and the 60 GHz bands, may be relatively more susceptible to propagation losses as compared to sub-7 bands. As such, beam refinement procedures may be utilized in sub-7 bands and in the 60 GHz band to identify beams within the respective bands that exhibit sufficient performance and are less susceptible to propagation loss. However, beam training procedures may not always be required for different bands, such as the 60 GHz band. As such, performance of beam training procedures, when not required for sufficient performance, may result in wasted communications resources, increased power consumption, and delayed communications within the band.

Accordingly, aspects of the present disclosure are directed to techniques that enable wireless devices (e.g., AP MLD, non-AP MLD) to perform beam training procedures within a service period (SP) used for communications between the respective devices. Wireless devices may perform beam training procedures to identity a transmission beam, a receive beam, or both, for communicating in a beamformed mode, which may include using beamforming for receiving or transmitting signals via a beam. For example, a first wireless device (e.g., AP, STA) may transmit an initiating frame within an SP using a transmit (Tx) beam determined based on a previous beam-training procedure. In some cases, the first wireless device may determine whether to perform the second beam training procedure within the SP based on a response message received from the second wireless device, based on an absence of the response message, based on channel conditions between the first wireless device and the second wireless device, or any combination thereof. Subsequently, the first and second wireless device may communicate messages (e.g., Tx, Rx messages) with one another within the SP using one or more beams determined based on the second beam training procedure. Accordingly, the wireless devices may perform beam training procedures within SPs to enable more efficient and reliable wireless communications between the respective devices.

Particular implementations of the subject matter described in this disclosure can be implemented to realize one or more of the following potential advantages. For example, by exchanging initiating frames and/or response frames within a SP, wireless devices (e.g., AP MLD, non-AP MLD) may be able to determine whether or not the wireless

devices are expected to perform a new beam training procedure within the SP. As such, techniques described herein may enable the wireless devices to perform beam training procedures within SPs to enable more efficient and reliable wireless communications between the respective devices.

Aspects of the disclosure are initially described in the context of a wireless communications system. Additional aspects of the disclosure are described in the context of example beam training procedures, example flow diagrams, and an example process flow. Aspects of the disclosure are further illustrated by and described with reference to apparatus diagrams, system diagrams, and flowcharts that relate to beam training techniques in Wi-Fi frequency bands.

FIG. **1** illustrates a wireless local area network (WLAN) **100** (also known as a Wi-Fi network) configured in accordance with various aspects of the present disclosure. The WLAN **100** may include an AP **105** and multiple associated STAs **115**, which may represent devices such as mobile stations, personal digital assistant (PDAs), other handheld devices, netbooks, notebook computers, tablet computers, laptops, display devices (e.g., TVs, computer monitors, etc.), printers, etc. The AP **105** and the associated stations **115** may represent a BSS or an ESS. The various STAs **115** in the network are able to communicate with one another through the AP **105**. Also shown is a coverage area **110** of the AP **105**, which may represent a BSA of the WLAN **100**. An extended network station (not shown) associated with the WLAN **100** may be connected to a wired or wireless distribution system that may allow multiple APs **105** to be connected in an ESS.

Although not shown in FIG. **1**, a STA **115** may be located in the intersection of more than one coverage area **110** and may associate with more than one AP **105**. A single AP **105** and an associated set of STAs **115** may be referred to as a BSS. An ESS is a set of connected BSSs. A distribution system (not shown) may be used to connect APs **105** in an ESS. In some cases, the coverage area **110** of an AP **105** may be divided into sectors (also not shown). The WLAN **100** may include APs **105** of different types (e.g., metropolitan area, home network, etc.), with varying and overlapping coverage areas **110**. Two STAs **115** may also communicate directly via a direct wireless link **125** regardless of whether both STAs **115** are in the same coverage area **110**. Examples of direct wireless links **120** may include Wi-Fi Direct connections, Wi-Fi Tunneled Direct Link Setup (TDLS) links, and other group connections. STAs **115** and APs **105** may communicate according to the WLAN radio and baseband protocol for physical and MAC layers from IEEE 802.11 and versions including, but not limited to, 802.11b, 802.11g, 802.11a, 802.11n, 802.11ac, 802.11ad, 802.11ah, 802.11ax, etc. In other implementations, peer-to-peer connections or ad hoc networks may be implemented within WLAN **100**.

In some cases, a STA **115** (or an AP **105**) may be detectable by a central AP **105**, but not by other STAs **115** in the coverage area **110** of the central AP **105**. For example, one STA **115** may be at one end of the coverage area **110** of the central AP **105** while another STA **115** may be at the other end. Thus, both STAs **115** may communicate with the AP **105**, but may not receive the transmissions of the other. This may result in colliding transmissions for the two STAs **115** in a contention based environment (e.g., CSMA/CA) because the STAs **115** may not refrain from transmitting on top of each other. A STA **115** whose transmissions are not identifiable, but that is within the same coverage area **110** may be known as a hidden node. CSMA/CA may be supplemented by the exchange of an RTS packet transmitted by a sending STA **115** (or AP **105**) and a CTS packet transmitted by the receiving STA **115** (or AP **105**). This may alert other devices within range of the sender and receiver not to transmit for the duration of the primary transmission. Thus, RTS/CTS may help mitigate a hidden node problem.

In some implementations, the WLAN **100** may support MLO according to which two or more devices may communicate via two or more wireless links, such as two or more radio frequency links. MLO may refer or apply to pre-association or post-association operation. In such implementations, the WLAN **100** may include one or more MLDs that are capable of communicating (such as transmitting or receiving) via multiple links. In some aspects, one or more STAs **115** may be associated or affiliated with a first MLD, such as a non-AP MLD **130**, and one or more APs **105** may be associated or affiliated with a second MLD, such as an AP MLD **135**. The one or more STAs **115** or APs **105** affiliated with an MLD may be associated with multiple functionalities of the MLD.

For example, an MLD may be a device that is capable of communicating via multiple radio frequency links and operation or functionality of the MLD at each of the multiple radio frequency links may be described as being performed by a respective STA **115** (in examples in which the MLD is a non-AP MLD **130**, such that each STA **115** affiliated with a non-AP MLD **130** is a non-AP STA **115**) or a respective AP **105** (in examples in which the MLD is an AP MLD **135**, such that each STA **115** affiliated with an AP MLD **135** is or functions as an AP **105**). As such, a non-AP MLD **130** may communicate (such as transmit or receive) via a first radio frequency link using a first STA **115** and may communicate (such as transmit or receive) via a second radio frequency link using a second STA **115**. Similarly, an AP MLD **135** may communicate (such as transmit or receive) via a first radio frequency link using a first AP **105** and may communicate (such as transmit or receive) via a second radio frequency link using a second AP **105**. For example, a non-AP MLD **130** may effectively communicate with an AP MLD **135** via a wireless link **120**-*a* using a first STA-AP pair and via a wireless link **120**-*b* using a second STA-AP pair.

A non-AP MLD **130** and an AP MLD **135** may communicate via various radio frequency links, including a 2.4 GHz link, a 5 GHz link, and a 6 GHz link, which may generally be referred to as "sub-7 GHz links." In some systems, the 2.4 GHz link, the 5 GHz link, and the 6 GHz link may be relatively easy to access. For example, a non-AP MLD **130** and an AP MLD **135** may access or communicate using (such as transmit or receive via) any one or more of the 2.4 GHz link, the 5 GHz link, and the 6 GHz link without negotiating access on a different link, without an access constraint (such as an access constraint associated with a service type), or without applying techniques associated with mitigating propagation path loss (such as focusing transmission and reception in a specific direction via beamforming). Some other radio frequency links, however, may be associated with an access constraint or difficulty and, in some implementations, a non-AP MLD **130** and an AP MLD **135** may use any one or more of the 2.4 GHz link, the 5 GHz link, and the 6 GHz link to support and facilitate communications via such other radio frequency links.

In some aspects, the WLAN **100** may support techniques that enable wireless devices (e.g., AP MLD **135**, non-AP MLD **130**) to perform beam training procedures within an SP used for communications between the respective devices. For example, a first wireless device (e.g., AP MLD **135**, non-AP MLD **130**) may transmit an initiating frame within an SP using a Tx beam determined based on a previous

beam-training procedure. The initiating frame may indicate whether or not the first wireless device is requesting to perform a second beam training procedure within the SP. In some cases, the first wireless device may determine whether to perform the second beam training procedure within the SP based on a response message received from the second wireless device, based on an absence of the response message, based on channel conditions between the first wireless device and the second wireless device, or any combination thereof. Subsequently, the first and second wireless device may communicate messages (e.g., Tx, Rx messages) with one another within the SP using one or more beams determined based on the second beam training procedure.

In some implementations, a relative quality of communications performed over a 60 GHz link may be used to determine whether a beam training procedure should be performed, or how precise (and therefore power intensive) of a beam training procedure should be performed. In other cases, information determined from other links, such as sub-7 GHz links, may be used to facilitate beam training procedures on the 60 GHz link. For example, position information and/or beam information determined using a sub-7 link may be used to determine whether (or what level of precision) of beam training procedures should be performed on the 60 GHz link.

In some aspects, the first radio frequency link (such as any one or more of the 2.4 GHz link, the 5 GHz link, or the 6 GHz link) may be referred to as a sub-7 GHz link, where a sub-7 GHz link may generally refer to any radio frequency link, or any collection of two or more radio frequency links, at or below 7 GHz. Further, as described herein, the second radio frequency link may refer to any radio frequency link associated with an access constraint or difficulty. Thus, the implementations described herein may be applicable to any radio frequency band or link that has constraints or rules in terms of which devices may obtain access, when devices may obtain access, or how far (in terms of a reachability distance) messaging can be transmitted via that radio frequency band or link.

Further, the devices of the WLAN **100** may support various possible configurations associated with operation at one or more radio frequencies (such as possible configurations for 45 GHz or 60 GHz operation). For example, depending on a radio configuration, a device (such as an AP **105**, a STA **115**, a non-AP MLD **130**, or an AP MLD **135**) may operate in accordance with a single link, single radio (SLSR) configuration according to which a single radio device may operate using one radio frequency (e.g., 60 GHz link), a multi-link, single radio (MLSR) configuration according to which a device may operate using one radio frequency band at a time (but may operate using both sub-7 GHz and 45 GHz or 60 GHz), or a multi-link, multi-radio (MLMR) configuration according to which a device may operate on more than one band simultaneously (with at least one radio operating using a sub-7 GHz band). In accordance with the implementations described herein, an MLD may support an MLSR or an MLMR configuration. As such, the described techniques may apply for devices that can communicate via multiple links simultaneously or devices that can communicate via different links at different times.

Further, although described herein as a non-AP MLD **130**, a non-AP MLD **130** may function as a soft AP device (which may be referred to as a soft AP device). In such examples in which the non-AP MLD **130** functions as a soft AP device, the non-AP MLD **130** may perform the same or similar functions (such as transmit or receive the same or similar signaling) as the AP MLD **135** to one or more other STAs **115** or to one or more other non-AP MLDs **130**. If operating as a soft AP device, which may be a device that operates using a battery or an otherwise limited power supply (or in a power save mode), the non-AP MLD **130** may use a same set of radio frequency chains for soft AP device operation as used for operation as a non-AP MLD **130**. Further, although referred to herein as a soft AP device, such a device may be any client device (such as any battery powered client device) that functions as an AP MLD **135**.

FIG. **2** illustrates an example of a wireless communications system **200** that supports beam training techniques in Wi-Fi frequency bands in accordance with one or more aspects of the present disclosure. Aspects of the wireless communications system **200** may implement, or be implemented by, aspects of the WLAN **100**. For example, the wireless communications system **200** illustrates communication between a non-AP MLD **130** and an AP MLD **135**, which may be examples of the non-AP MLD **130** and the AP MLD **135**, respectively, as illustrated by and described with reference to FIG. **1**.

In some implementations, the non-AP MLD **130** and the AP MLD **135** may communicate via a communication link **205**. In some implementations, the communication link **205** may include one or more different links. For example, in some implementations, the communication link **205** may include a first radio frequency link (e.g., a sub-7 link such as any one or more of a 2.4 GHz link, a 5 GHz link, or a 6 GHz link) and a second radio frequency link (e.g., a non-sub-7 link such as a 45 GHz link, or a 60 GHz link). In this example, the first radio frequency link (e.g., sub-7 link) may support communications performed via the second radio frequency link (e.g., non-sub-7 link). In other words, the first radio frequency link may serve as an anchor or stable link that is used to facilitate communications via the second radio frequency link.

Moreover, in some aspects, a 60 GHz link may be part of an MLO setup involving sub7 link(s). In other words, the AP operating on 60 GHz may be affiliated with the AP MLD **135** that has at least one other AP operating on a sub-7 link. In some implementations, aspects of the present disclosure are directed to utilizing sub-7 links as anchor links to facilitate operations on 60 GHz links, and to reduce management frame overhead. In other words, as will be described in further detail herein, aspects of the present disclosure are directed to utilizing the MLO framework to facilitate operations on a non-sub-7 link, such as a 45 GHz or 60 GHz link.

In some wireless communications systems, wireless communications within a 60 MHz band may be performed within repeating beacon intervals (BIs). Each BI may be divided into three parts: (1) a beacon transmit interval (BTI) (e.g., BTI **215**), (2) dedicated SPs (D-SP) (e.g., D-SP **230**) and opportunistic SPs (O-SPs). During the BTI **215**, an AP **105**, an AP MLD **135**, or a personal basic service set control point (PCP) may transmit multiple directional beacons (e.g., beacon frames). During the A-BFT, one or more STAs **115** or non-AP MLDs **130** may perform beam training for communication with an AP **105**, AP MLD **135**, or PCP.

Some radio frequency bands (such as a 45 GHz or 60 GHz band) may provide a large amount of communication resources (such as a large swath of spectrum) that communicating devices (such as Wi-Fi devices) may use. Operation on relatively higher radio frequency bands (such as 45 GHz or 60 GHz bands) may present several challenges at a device or system level, which may lead to a lack of widespread adoption of the 45 GHz or 60 GHz band for data communications.

For example, transmissions within 45 GHz or 60 GHz bands may suffer from high propagation loss (e.g., high attenuation). As such, omnidirectional transmissions (e.g., non-beamformed transmissions) will not travel far. As a result, wireless devices may be required to perform directional transmissions to take advantage of beamforming antenna gains to form a narrow beam towards the intended peer device. Stated differently, wireless devices communicating within non-sub-7 bands may be required to focus transmissions and receptions to narrow beams in order for the transmissions to reach the intended receivers.

Beam training procedures may be performed to identify narrow beams used to perform beamforming communications in a beamformed mode. During a beam training procedure, transmission/reception planes at a transmitting/receiving devices may be divided up into several sectors, where the wireless devices are configured to identify narrow Tx/Rx beams within a sector that will be used for beamformed communications. Some beam training procedures (e.g., beam training procedures defined by 802.11ad/ay) may include two steps or phases: (1) a sector-level sweep (SLS) phase (e.g., sector-level training procedure), and (2) a beam refinement phase (BRP) (e.g., beam refinement procedure).

While the terms "SLS" and "BRP" (and like terms) are the terms used and defined in 802.11ad/ay, it is noted herein that different terminology may be used to refer to the different steps of a beam training procedure. In particular, future generations of Wi-Fi may adopt different words or phrases that are used to refer to the respective steps of a beam training procedure. Moreover, future generations of Wi-Fi may include additional or alternative steps/phases of a beam training procedure. However, aspects of the present disclosure, which enable wireless devices to skip beam training procedures or perform less-intensive beam training procedures, may be implemented for both the current beam training framework, as well as future beam training framework with additional and/or alternative steps/phases.

During an SLS phase of a beam training procedure, each device may take turns to transmit a frame on each of its sectors while the other device listens in quasi-omni state. The SLS phase may help establish an initial coarse-grain antenna sector configuration, which may be further refined during a subsequent BRP phase. For example, during the SLS phase, the AP MLD **135** may perform a sector sweep of (short) beacon frames during the BTI **215**, as shown in FIG. **2**. In particular, during the SLS phase, the AP-MLD **135** may sweep across sectors/beams **220** while the non-AP MLD **130** listens using beams **225** (e.g., quasi-omnidirectional beams **2250**, such as wide beams **225**) to determine a general direction of the AP-MLD **135**, and identify wide beams **225** that may be used to communicate with the AP-MLD **135** (e.g., identify a sector corresponding to the AM-MLD **135**). In other words, during SLS, the AP MLD **135** may take turns transmitting a short frame on each sector (e.g., each beam **220**), while the non-AP MLD **130** other side listens in a quasi-omnidirectional or omnidirectional mode to help establish a general direction of where the peer wireless device is located, and to use the received beacons/frames to evaluate whether additional beam training is needed or not.

Comparatively, during the BRP (e.g., beam refinement procedure) of the beam training procedure, the respective devices may exchange frames to fine-tune beams that were determined during SLS. As such, the BRP phase may be run after the SLS phase, or may be run without SLS in cases where only small adjustments to beams are needed. In some cases, BRP may be combined with a data frame (e.g., training sequence follows data). For example, during a BRP phase, the wireless devices sweep across narrow beams (e.g., beams that are narrower than the wide beams **225** used in SLS) within the sector/wide beam **225** found during the SLS phase, and identify narrow beams within the identified sector/wide beam **225** that will be used to communicate with the peer device. In other words, the BRP may follow the SLS to further refine the beam information that will be used for wireless communications. Additionally, or alternatively, BRP may be run independently (e.g., without) the SLS to establish a narrow beam directed towards a peer device.

In this regard, depending on the degree of misalignment between beams at the AP-MLD **135** and the non-AP MLD **130**, the devices may be configured to perform a full beam training procedure including SLS and BRP, or may be configured to perform a truncated or abbreviated beam training procedure including only BRP (e.g., no SLS).

In some cases, the AP-MLD **135** and the non-AP MLD **130** may negotiate with one another to determine a configuration of one or more D-SPs **230** that may be used for communications between the respective devices. In some cases, D-SPs **230** may be configured for communications between the respective devices such that the D-SPs **230** do not overlap with one another in the time domain. Moreover, in cases where the AP-MLD **135** is communicatively coupled to multiple clients (e.g., multiple non-AP MLDs **130**, multiple STAs), each respective non-AP MLD **130** may be configured with a separate set of D-SPs **230** (e.g., each set of D-SPs **230** are dedicated to a single non-AP MLD **130**). Moreover, in some cases, the AP-MLD **130** may activate or assign one or more O-SPs (within a BI) to a client to perform additional communications (e.g., flush pending buffer units) if the D-SP **230** was not sufficient to perform all buffered traffic that is to be exchanged between the respective devices.

As noted previously herein, communications over some radio frequency links may present several challenges, which may hinder adoption of such other radio frequency links (which may in turn, limit an achievable throughput or diversity of a system). For example, the non-sub-7 bands, such as the 45 GHz and the 60 GHz bands, may be relatively more susceptible to propagation losses as compared to sub-7 bands. As such, beam refinement procedures may be utilized in sub-7 bands and in the 60 GHz band to identify beams within the respective bands that exhibit sufficient performance and are less susceptible to propagation loss. However, beam training procedures may not always be required for different bands, such as the 60 GHz band. As such, performance of beam training procedures, when not required for sufficient performance, may result in wasted communications resources, increased power consumption, and delayed communications within the band. However, beam training procedures may not always be required for different bands, such as the 60 GHz band. As such, performance of beam training procedures, when not required for sufficient performance, may result in wasted communications resources, increased power consumption, and delayed communications within the band.

Accordingly, aspects of the present disclosure are directed to techniques that enable wireless devices (e.g., AP MLD **135**, non-AP MLD **130**) to perform beam training procedures within a SP (e.g., D-SP **230**) used for communications between the respective devices.

For example, as shown in FIG. **2**, the AP MLD **135** may transmit a short (beacon) frame in each of its sectors (e.g., transmit a beacon frame using each beam **220**) during the dedicated BTI **215** period. The beacon fame(s) transmitting during the BTI **215** may include any short frame carrying an

identifier associated with the AP MLD **135** (e.g., BSSID associated with the AP MLD **135**) and an identifier associated with the corresponding sector/beam **220** used to transmit the respective beacon fame (e.g., transmit sector ID). During the BTI **215**, the non-AP MLD **130** monitor or listens for the beacon frames in a quasi-omnidirectional mode (e.g., using wide beams **225**) to determine whether additional beam training is needed/expected or not. In some cases, the non-AP MLD **130** may listen/monitor during the BTI **215** with a wide beam **225** pointed towards the most recently used sector associated with the AP MLD **135**.

If a beacon frame is received at the non-AP MLD **130** during the BTI **215** with a receive signal strength indicator (RSSI), an reference signal received power (RSRP), or other measurement above a certain threshold, then additional beam training may not be needed or expected (e.g., the beams at the respective devices are sufficiently pointed/directed at one another to perform sufficiently high quality communications). Comparatively, if beacon fames are received at the non-AP MLD **130** during the BTI **215** with an RSRP or other measurement below the threshold, this may imply that the beam **225** at the non-AP MLD **130** is pointing in the general direction of the AP MLD **130**, but may need some refinement (e.g., further refinement through BRP). Further, if the non-AP MLD **130** does not receive any beacon frames during the BTI **215** (e.g., identifying an absence of signaling associated with a first beam training procedure performed during the BTI **225**), this may indicate that the beam **225** at the non-AP MLD **130** is focused in the wrong direction (e.g., not in the general direction of the AP MLD **130**), which may indicate that full beam training is needed or expected (e.g., SLS+BRP).

As used herein, "satisfying a threshold" may depending on the context, refer to a value being greater than the threshold, greater than or equal to the threshold, less than the threshold, less than or equal to the threshold, equal to the threshold, not equal to the threshold, or the like.

Performance of sectorized beaconing during the BTI **215** may achieve several benefits. For example, although duplicating (beacon) frames in each sector may result in signaling overhead, the AP MLD **135**-side sector sweep may be performed "for free" by performing sectorized beaconing, meaning that the AP MLD **135** may not be expected to perform subsequent sectorized beaconing following the BTI **215** in some cases. Therefore, the overhead of beaconing is amortized across multiple clients/non-AP MLDs **130**. In other words, the AP MLD **135** may be able to perform a single sectorized beaconing during the BTI **215** for multiple clients, and may not be expected to repeat the sweep for each respective client. In other words, multiple clients may be able to utilize the information gathered during the BTI **215** for making training decisions (e.g., during subsequent SPs, such as the D-SP **230**).

In the case of a new connection between the AP MLD **135** and the non-AP MLD **130**, the respective devices may not know the sector (e.g., beams **220**, **225**) that is to be used. Accordingly, in such cases, the non-AP MLD **130** may listen/monitor during the BTI **215** in a quasi-omnidirectional mode (e.g., using wide beams).

According to some aspects of the present disclosure, techniques described herein may enable the wireless devices (e.g., AP MLD **135**, non-AP MLD **130**) to perform beam training procedures within (e.g., at the start of) D-SPs **230**, O-SPs, or both. In such cases, information gathered during the BTI **215** may be useful during subsequent beam training procedures within D-SPs **230** and/or O-SPs.

Continuing with reference to FIG. **2**, at the start of each D-SP **230** (and/or O-SP), the non-AP MLD **130** may be configured to transmit an initiating frame **235** that provides a buffer status report (BSR) along with an indication of whether the non-AP MLD **130** expects to perform refinement training during the D-SP **230** (e.g., indication as to whether a full or truncated/shortened beam training procedure is to be performed). The initiating frame **235** transmitted by the non-AP MLD **130** may include a quality of service (QoS) null frame with a control field carrying the BSR and a "BRP required" indication. If the initiating frame **235** is correctly received by the AP MLD **135**, the AP MLD **135** may be configured to transmit a response frame **240** within a short interframe space (SIFS) of the D-SP **230**. In some cases, the response frame **240** may additionally or alternatively indicate whether the AP MLD **135** expects to perform a beam training procedure during the D-SP **230**. The response frame **240** from the AP MLD **135** may include an ACK frame or a blockAck frame with a field (e.g., bit) used to indicate if the AP MLD **135** is requesting BRP during the D-SP **230** (and/or a subsequent SP).

In this regard, at the start of each D-SP **230**, the AP MLD **135**, the non-AP MLD **130**, or both, may be able to explicitly request/trigger a beam training procedure within the D-SP **230** (e.g., via the initiating frame **235** and/or the response frame **240**). Moreover, the absence of a request/trigger for a beam training procedure may serve as an implicit indication that the respective device is not requesting a beam training procedure during the D-SP **230**.

Based on the contents of the initiating frame **235** and the response frame **240** (and/or the failure of either frame being received by the respective device), the AP MLD **135** and the non-AP MLD **130** may or may not perform a beam training procedure during a time interval **245** of the D-SP **230**. In particular, if a condition for performing beam training is satisfied, the AP MLD **135** may initiate a beam training procedure (e.g., BRP) by transmitting an appropriate training frame within the SIFS after the response frame **240**. For example, the devices may be configured to perform a beam training procedure (e.g., SLS+BRP, or just BRP) during the time interval **245** if the initiating frame **235**, the response frame **240**, or both, include an indication of a request/trigger to perform a beam training procedure (e.g., perform beam training if BRP required=true in the initiating frame **235** and/or the response frame **240**).

By way of another example, in cases where either of the initiating frame **235** and/or the response frame **240** are not successfully received by the respective device, this may serve as an implicit indication that the devices are expected to perform a beam training procedure during the D-SP **230**. For instance, if the initiating frame **235** from the non-AP MLD **130** is not successfully received by the AP MLD **130** at the start of the D-SP **230** (or other SP) after a short timeout duration, the AP MLD **130** may enter an SLS initiator mode after some time period (e.g., after {duration of initiating frame-timeout duration>SIFS+<duration of response>+SIFS} time). In other words, if the AP MLD **130** does not successfully receive the initiating frame **235**, the AP MLD **135** may expect to perform a beam training procedure with SLS and BRP during the time interval **245**.

Similarly, if the non-AP MLD **130** does not successfully receive the response frame **240** from the AP MLD **135** during SIFS after transmitting the initiating frame **235**, the non-AP MLD **130** may enter an SLS responder mode after some time period (e.g., after {<duration of response>+SIFS} time). In other words, if the non-AP MLD **130** does not successfully receive the response frame **240**, the non-AP

MLD **130** may expect to perform a beam training procedure with SLS and BRP during the time interval **245**. If the response frame **240** is lost or otherwise not successfully received, the non-AP MLD **130** may enter the SLS responder mode while the AP MLD **135** may continue to operate in a different mode, such as BRP, TF, DL. However, the AP MLD **135** may not receive a frame responsive to the response frame **240** or other communication, and may therefore fall back to the SLS initiator mode to perform a beam training procedure (e.g., SLS+BRP) during the time interval **245**.

In cases where the devices exhibit beam alignment after the BTI **215** (e.g., devices have determined aligned beams **220**-*a* and **255**), the respective devices may be configured to communicate with one another during a frame exchange **250** period of the D-SP **230** using the determined beams **220**-*a*, **255**. Similarly, in cases where the devices perform a beam training procedure during the time interval **245**, the devices may be configured to identify the beams **220**-*a*, **255** that will be used for communications during the frame exchange **250**.

In some aspects, if the BSR in the initiating frame **235** is nonzero (meaning that the non-AP MLD **130** has traffic to communicate), the AP MLD **135** may transmit a trigger frame to solicit the data/traffic (e.g., uplink data) from the non-AP MLD **130**. In some cases, the trigger frame may be aggregated with downlink traffic transmitted by the AP MLD **135** if the AP MLD **135** has pending buffer units to communicate to the non-AP MLD **130**. Similarly, if the AP MLD **135** has pending buffer units (e.g., traffic, data) to communicate to the non-AP MLD **130**, the AP MLD **135** may initiate downlink messages to communicate the buffer units during the frame exchange **250**.

In some aspects, the AP MLD **135** may indicate a last frame of a message to be communicated during the frame exchange **250**, a last symbol or frame of the D-SP **230**, or both. By indicating the last frame of traffic to be communicated and/or the last frame/symbol of the D-SP **230**, the non-AP MLD **130** may be able to enter a lower power operational state (e.g., doze state) for the remainder of the D-SP **230** to reduce power consumption. For example, a last frame of a downlink message transmitted by the AP MLD **130** during the frame exchange **250** may indicate the end of the D-SP **230** (e.g., indicate MORE=0 or EOSP=1). By way of another example, the AP MLD **135** may transmit a QoS null frame indicating the last frame of traffic and/or an end of the D-SP (e.g., QoS null frame indicating MORE=0 or EOSP=1).

In some implementations, techniques shown and described in FIG. **2** may enable the wireless devices to perform beam training within the D-SP **230** in cases where the non-AP MLD **130** is a new client for the AP MLD **130**, in which cases the devices may not have previously performed a beam training procedure. For example, upon establishing a new connection with the non-AP MLD **130**, the AP MLD **135** may transmit beacons within each sector during the BTI **215**, where the non-AP MLD **130** monitors in SLS responder mode (e.g., quasi-omnidirectional state) to identify the best Tx-sector at the AP MLD **135**. In this example, the non-AP MLD **130** may refrain from transmitting an initiating frame **235** at the start of the D-SP **230**, resulting in an initiating frame timeout. Similarly, the AP MLD **135** may not receive an initiating frame **235**, and may therefore refrain from transmitting the response frame **240**. In this example, the AP MLD **135** and the non-AP MLD **130** may perform a full beam training procedure (e.g., SLS+BRP) SIFS after the expected response frame **240** in order to determine the beams **220**-*a*, **225** that will be used during the frame exchange **250** (and/or subsequent SPs).

In some implementations, a client device (e.g., non-AP MLD **130**) may configure itself to operate in a (quasi) omnidirectional mode to receive the beacon frames during the BTI **215**. In such cases, the non-AP MLD **130** may be configured to identify transmit sector ID(s) associated with the AP MLD **135** where the non-AP MLD **130** is able to receive beacon frame(s). In the (quasi) omnidirectional mode, it is possible for the non-AP MLD **130** to receive more than one beacon frame during the BTI **215**. Moreover, the non-AP MLD **130** may be configured to compare RSSI(s) associated with received beacon frames to RSSI(s) (or other measurements) associated with beacon frames received during previous BTIs **215**. In this regard, the non-AP MLD **130** may be able to identify changes in channel conditions from one BTI **215** to another to determine whether new beam training is expected or required. In other words, by comparing the RSSIs and sector IDs associated with beam frames received during each BTI **215**, the non-AP MLD **130** (e.g., STA) may be able to determine if beam training (e.g., SLS+BRP or BRP) is needed or not. For example, if a beacon frame received in a previous BTI **215** has a higher RSSI in a different transmit sector as compared to the beacon frames received in the current BTI **215**, the non-AP MLD **130** may determine that a new beam training procedure should be performed.

In some implementations, the non-AP MLD **130**, the AP MLD **135**, or both, may announce, indicate, and/or negotiate a retry count associated with performance of a beam training procedure. In the context of the present disclosure, the retry count may include a number/quantity of initiating/response frame exchanges that the devices will perform before falling back to training (e.g., before performing a new beam training procedure). For example, if the retry count is set to two, the respective devices may be configured to perform a new beam training procedure after two failed initiating/response frame exchanges. The time computation for fall back may be updated to account for the announced/indicated/negotiated retry count. In scenarios where a non-AP MLD **130** (e.g., STA) is unable to transmit an initiating frame due to channel conditions (such as OBSS), the non-AP MLD **130** may have until the last retry attempt to send the initiating frame.

Different example behaviors of the respective devices are further shown and described with reference to FIGS. **3**-**7**.

While FIGS. **3**-**7** illustrate examples in which a non-AP MLD **130** (e.g., STA) transmits initiating frames, and receives response frames from an AP MLD **135** (e.g., AP), this is not a limitation of the present disclosure, unless noted otherwise herein. In particular, in some cases, the signaling illustrated in the initiating/response frame exchanges may be reversed, in which the AP-MLD **135** transmits an initiating frame at the start of each D-SP/O-SP, and the non-AP MLD **130** transmits a response frame (e.g., CTS) responsive to the initiating frame.

Moreover, in some cases, the respective devices may exchange a third frame (e.g., ACK frame) to confirm that the respective device successfully received the response frame (e.g., successfully received the CTS). Use of an ACK frame may be beneficial in cases where the response frame is lost or otherwise not successfully received. In such cases, if the ACK frame is not successfully received by the respective device (e.g., AP or STA), the STA (and/or the AP) may be configured to enter SLS training SIFS after the expected time of the ACK frame. Further, if either frame (e.g., initiating frame, response frame) is lost or otherwise not successfully received, both devices may be configured to

enter SLS training SIFS+delta time after the expected CTS. For instance, in cases where an AP does not receive a confirmation/ACK frame in response to a response frame, the AP may enter an SLS initiator mode.

FIG. **3** illustrates an example of a beam training procedure **300** that supports beam training techniques in Wi-Fi frequency bands in accordance with one or more aspects of the present disclosure. Aspects of the beam training procedure **300** may implement, or be implemented by, aspects of the WLAN **100**, the wireless communications system **200**, or both. For example, the beam training procedure **300** illustrates communication between a non-AP MLD **130** and an AP MLD **135**, which may be examples of the non-AP MLD **130** and the AP MLD **135**, respectively, as illustrated by and described with reference to FIG. **1**.

As noted previously herein with respect to FIG. **2**, an AP MLD **130** may transmit beacon frames within each sector (e.g., using beams **320**) during a BTI **315**. In this example, a non-AP MLD **130** may monitor or listen for the beacon frames during the BTI **315**, and receive a beacon frame with an RSRP or other measurement that satisfies (e.g., is greater than) a threshold using a beam **325**. In this regard, the respective devices may determine that the beams **320**-*a* and **325** are sufficiently well aligned during BTI **315**. As such, the respective devices may not be expected to perform a beam training procedure during a D-SP **330**. In this regard, the non-AP MLD **130** may transmit an initiating frame **335** towards the beginning of the D-SP **330**, where the initiating frame **335** indicates that the non-AP MLD **130** is not requesting or triggering a beam training procedure during the D-SP **330** (e.g., BRP required=0). Similarly, the AP MLD **135** may transmit a response frame **340** in response to the initiating frame **335**, where the response frame also indicates that the AP MLD **135** is not requesting or triggering a beam training procedure during the D-SP **330** (e.g., BRP required=0).

Accordingly, the respective devices may refrain from performing a beam training procedure during the D-SP **330**, and may communicate messages with one another during the frame exchange **350** using the beams **320**-*a*, **325** determined during the BTI **315**. In some cases, where the AP-MLD **135** and/or the non-AP MLD **130** has additional data to be sent that will not be able to be communicated during the frame exchange **350** and/or D-SP **330**, the respective devices may activate or trigger an additional SP (e.g., O-SP) to continue communications. For example, as shown in FIG. **3**, the AP MLD **135** may transmit a frame **360** that activates, triggers, or otherwise indicates an O-SP that may be used to perform additional communications between the respective devices.

FIG. **4** illustrates an example of a beam training procedure **400** that supports beam training techniques in Wi-Fi frequency bands in accordance with one or more aspects of the present disclosure. Aspects of the beam training procedure **400** may implement, or be implemented by, aspects of the WLAN **100**, the wireless communications system **200**, the beam training procedure **300**, or any combination thereof. For example, the beam training procedure **400** illustrates communication between a non-AP MLD **130** and an AP MLD **135**, which may be examples of the non-AP MLD **130** and the AP MLD **135**, respectively, as illustrated by and described with reference to FIG. **1**.

As noted previously herein with respect to FIG. **2**, an AP MLD **130** may transmit beacon frames within each sector (e.g., using beams **420**) during a BTI **415**. In this example, a non-AP MLD **130** may listen for the beacon frames during the BTI **415**, and receive a beacon frame with an RSRP or other measurement that fails to satisfy (e.g., is less than) a threshold using a beam **425**. In this regard, the non-AP MLD **130** may determine that the beam **425** is (slightly) misaligned with the AP MLD **130** during BTI **415**, and may therefore determine that a beam training procedure may be performed during the D-SP **430**.

As such, the non-AP MLD **130** may transmit an initiating frame **435** during the D-SP **430**, where the initiating frame **435** indicates that the non-AP MLD **130** is requesting or triggering a beam training procedure during the D-SP **430** (e.g., BRP required=1). The AP MLD **135** may receive the initiating frame **435** and transmit a response frame **440** in response to the initiating frame **435**, where the response frame **440** acknowledges the request/trigger for a beam training procedure during the D-SP **430**. In this example, the respective devices may perform a beam training procedure (e.g., BRP) and/or exchange data during time intervals **460** and **455**, respectively. In other words, BRP may be perform standalone (e.g., QoS null+training) or along with data (e.g., QoS data+training). By performing BRP during time interval **460**, the respective devices may be configured to identify beams **420**-*a*, **464** that are sufficiently aligned, and may subsequently perform communications with one another during frame exchange **450** using beams **420**-*a*, **465**.

FIG. **5** illustrates an example of a beam training procedure **500** that supports beam training techniques in Wi-Fi frequency bands in accordance with one or more aspects of the present disclosure. Aspects of the beam training procedure **500** may implement, or be implemented by, aspects of the WLAN **100**, the wireless communications system **200**, the beam training procedures **300**, **400**, or any combination thereof. For example, the beam training procedure **500** illustrates communication between a non-AP MLD **130** and an AP MLD **135**, which may be examples of the non-AP MLD **130** and the AP MLD **135**, respectively, as illustrated by and described with reference to FIG. **1**.

As noted previously herein with respect to FIG. **2**, an AP MLD **135** may transmit beacon frames within each sector (e.g., using beams **520**) during a BTI **515**. In this example, a non-AP MLD **130** may listen for the beacon frames during the BTI **515**, and receive a beacon frame with an RSRP or other measurement that satisfies (e.g., is greater than) a threshold using a beam **525**. In this regard, the non-AP MLD **130** may determine that the beam **525** is aligned with the AP MLD **135**. As such, the respective devices may not be expected to perform a beam training procedure during a D-SP **530**. In this regard, the non-AP MLD **130** may transmit an initiating frame **535**-*a* towards the beginning of the D-SP **530**, where the initiating frame **535**-*a* indicates that the non-AP MLD **130** is not requesting or triggering a beam training procedure during the D-SP **530** (e.g., BRP required=0). Similarly, the AP MLD **135** may transmit a response frame **540**-*a* in response to the initiating frame **535**-*a*, where the response frame also indicates that the AP MLD **135** is not requesting or triggering a beam training procedure during the D-SP **530** (e.g., BRP required=0).

However, in some cases, such as due to mobility of the non-AP MLD **130**, the relative orientations of the non-AP MLD **130** and the AP MLD **135** may change within a beacon interval, thereby causing the beams at the respective devices to misalign. In such cases, initiating frame/response frame sequences at the beginning of each SP may enable the devices to adapt to the latest channel conditions. Moreover, the non-AP MLD **130**, the AP MLD **135**, or both, may be able to detect a misalignment based on the performance of a frame exchange during a previous SP, and trigger a new beam training (e.g., based on RSSI, error rate, retry count, MCS, machine learning, etc.).

For example, over the course of the D-SP **530**, the AP MLD **135**, the non-AP MLD **130**, or both, may detect a misalignment between the beams **520**-*a* and **525** (e.g., based on RSSI, error rate, etc.). In this example, the AP MLD **135**, the non-AP MLD **130**, or both, may transmit a frame **555**-*a* indicating or triggering a new beam training procedure and/or activating an O-SP **560**. In this example, an initiating frame **535**-*b*, a response frame **540**-*b*, or both, within the O-SP **560** may indicate that the respective device(s) is/are requesting to perform a new beam training procedure during the O-SP **560** (e.g., BRP required=1). Subsequently, the devices may perform a beam training procedure (e.g., only BRP) during a time interval **565** to determine one or more new beams (e.g., beams **520**-*b*, **570**) that will be used to perform communications during a frame exchange **550**-*b*.

In some cases, where the AP-MLD **135** and/or the non-AP MLD **130** has additional data to be sent that will not be able to be communicated during the frame exchange **550**-*b* and/or O-SP **560**, the respective devices may activate or trigger an additional SP (e.g., O-SP) to continue communications. For example, as shown in FIG. **5**, the AP MLD **135** may transmit a frame **555**-*b* that activates, triggers, or otherwise indicates an O-SP that may be used to perform additional communications between the respective devices.

FIG. **6** illustrates an example of a beam training procedure **600** that supports beam training techniques in Wi-Fi frequency bands in accordance with one or more aspects of the present disclosure. Aspects of the beam training procedure **600** may implement, or be implemented by, aspects of the WLAN **100**, the wireless communications system **200**, the beam training procedures **300**, **400**, **500**, or any combination thereof. For example, the beam training procedure **600** illustrates communication between a non-AP MLD **130** and an AP MLD **135**, which may be examples of the non-AP MLD **130** and the AP MLD **135**, respectively, as illustrated by and described with reference to FIG. **1**.

As noted previously herein with respect to FIG. **2**, an AP MLD **135** may transmit beacon frames within each sector (e.g., using beams **620**) during a BTI **615**. In this example, a non-AP MLD **130** may listen for the beacon frames during the BTI **615**, and receive a beacon frame with an RSRP or other measurement that satisfies (e.g., is greater than) a threshold using a beam **625**. In this regard, the non-AP MLD **130** may determine that the beam **525** is aligned with the AP MLD **135**. As such, the respective devices may not be expected to perform a beam training procedure during a D-SP **630**. In this regard, the non-AP MLD **130** may transmit an initiating frame **635**-*a* towards the beginning of the D-SP **630**, where the initiating frame **635**-*a* indicates that the non-AP MLD **130** is not requesting or triggering a beam training procedure during the D-SP **630** (e.g., BRP required=0). Similarly, the AP MLD **135** may transmit a response frame **640**-*a* in response to the initiating frame **635**-*a*, where the response frame also indicates that the AP MLD **135** is not requesting or triggering a beam training procedure during the D-SP **630** (e.g., BRP required=0).

Similar to the example shown and described in FIG. **5**, the relative orientations of the non-AP MLD **130** and the AP MLD **135** may change within a beacon interval, thereby causing the beams at the respective devices to misalign. For example, over the course of the D-SP **630**, the AP MLD **135**, the non-AP MLD **130**, or both, may detect a misalignment between the beams **620**-*a* and **625** (e.g., based on RSSI, error rate, etc.). As compared to the misalignment illustrated in FIG. **5**, which may be considered to be a slight or minor misalignment, the misalignment illustrated in FIG. **6** may be considered a significant misalignment which may significantly affect a quality of wireless communications between the devices.

In this example, the AP MLD **135**, the non-AP MLD **130**, or both, may transmit a frame **655**-*a* indicating or triggering a new beam training procedure and/or activating an O-SP **660**. In this example, the non-AP MLD **130** may transmit an initiating frame **635**-*b* which indicates that the non-AP MLD **130** is requesting to perform a new beam training procedure during the O-SP **660** (e.g., BRP required=1). However, due to the significant misalignment between the beams, the initiating frame **635**-*b* may not be successfully received by the AP MLD **135**. As such, the AP MLD **135** may not transmit a response frame **640**-*b*, and the non-AP MLD **130** may not receive any response frame **640**-*b*. As such, due to the failed initiating/response frame exchange, the respective devices may enter into a full beam training procedure (e.g., SLS+BRP) during time interval **665** and after the expected response frame **640**-*b* in order to determine one or more new beams (e.g., beams **620**-*b*, **670**) that will be used to perform communications during a frame exchange **650**-*b*.

In some cases, where the AP-MLD **135** and/or the non-AP MLD **130** has additional data to be sent that will not be able to be communicated during the frame exchange **650**-*b* and/or O-SP **560**, the respective devices may activate or trigger an additional SP (e.g., O-SP) to continue communications. For example, as shown in FIG. **6**, the AP MLD **135** may transmit a frame **655**-*b* that activates, triggers, or otherwise indicates an O-SP that may be used to perform additional communications between the respective devices.

FIG. **7** illustrates an example of a beam training procedure **700** that supports beam training techniques in Wi-Fi frequency bands in accordance with one or more aspects of the present disclosure. Aspects of the beam training procedure **700** may implement, or be implemented by, aspects of the WLAN **100**, the wireless communications system **200**, the beam training procedures **300**, **400**, **500**, **600**, or any combination thereof. For example, the beam training procedure **700** illustrates communication between a non-AP MLD **130** and an AP MLD **135**, which may be examples of the non-AP MLD **130** and the AP MLD **135**, respectively, as illustrated by and described with reference to FIG. **1**.

As noted previously herein with respect to FIG. **2**, an AP MLD **135** may transmit beacon frames within each sector (e.g., using beams **720**) during a BTI **715**. In this example, a non-AP MLD **130** may listen for the beacon frames during the BTI **715**, and receive a beacon frame with an RSRP or other measurement that fails to satisfy (e.g., is less than) a threshold using a beam **725**. In this regard, the non-AP MLD **130** may identify a significant misalignment between the beam **725** and the direction of the AP MLD **135** (e.g., identifying an absence of signaling associated with a first beam training procedure performed during the BTI **715**). For example, the non-AP MLD **130** may be beamformed while listening for beacon frames from the AP MLD **135**, and may not detect any beacon frames using the beam **725** (indicating a significant misalignment).

In this example, both devices may refrain from transmitting an initiating frame **735** and response frame **740** during the D-SP **730** in order to trigger a beam training procedure during the D-SP **730**. Additionally, or alternatively, the non-AP MLD **130** may transmit an initiating frame to trigger beam training, but the initiating frame **735** may not be received by the AP MLD **135** due to the significant misalignment (thereby triggering an initiating frame timeout), in which case the AP MLD **135** may not transmit a response frame **740**. As such, the devices may perform a full beam

training procedure (e.g., SLS+BRP) during a time interval **755** in order to identify beams **720**-*a*, **745** that will be used for communicating during the frame exchange **750**.

FIG. **8** illustrates an example of a flow diagram **800** that supports beam training techniques in Wi-Fi frequency bands in accordance with one or more aspects of the present disclosure. Aspects of the flow diagram **800** may implement, or be implemented by, aspects of the WLAN **100**, the wireless communications system **200**, the beam training procedures **300**, **400**, **500**, **600**, **700**, or any combination thereof.

For example, the flow diagram **800** illustrates logic that may be performed by an AP MLD **135** when determining if, and when, to perform a beam training procedure with a non-AP MLD **130**, as illustrated by and described with reference to FIG. **1**.

At **805**, the AP determines whether the AP is communicating within a BTI or SP. If the AP is communicating within a BTI, the flow diagram **800** proceeds to **815**. At **815**, the AP may transmit short (e.g., beacon) frames in each sector and return to **805**. If the AP is communicating within an SP at **805**, the flow diagram **800** proceeds to **810**. At **810**, the AP determines whether the AP is communicating with a new client. If the AP is communicating with a new client, the flow diagram **800** proceeds to **820**. At **820**, the AP switches to an SLS initiator mode and the flow diagram **800** proceeds to **845**. At **845**, the AP may begin full beam training (SLS+BRP) SIFS after expected time when a response frame is to be sent and proceeds to **865**.

If the AP is not communicating with a new client at **810**, the flow diagram **800** proceeds to **825**. At **825**, the AP beamforms to the last known sector for the client and proceeds to **830**. At **830**, the AP determines whether the AP has received the initiating frame. If the AP has not received the initiating frame, the flow diagram **800** proceeds to **840**. At **840**, the AP determines if <initiating-frame-timeout> has expired. If the <initiating-frame-timeout> has not expired, the flow diagram **800** returns to **830**. If the <initiating-frame-timeout> has expired, the flow diagram **800** proceeds to **820** and may proceed as described above.

If the AP has received the initiating frame at **830**, the flow diagram **800** proceeds to **835**. At **835**, the AP remains beam-formed towards the client and proceeds to **850**. At **850**, The AP sends a response frame SIFS after initiating frame is received, which may indicate if BRP is needed, and proceeds to **855**. At **855**, the AP determines if BRP is needed (e.g., from indication in the initiating or response frames). If BRP is needed, the flow diagram **800** proceeds to **860**. At **860**, the AP performs BRP to refine the beam towards the client and proceeds to **865**. Also, if BRP is not needed at **855**, the flow diagram **800** proceeds to **865**. At **865**, the AP determines if the initiating frame indicates BSR as nonzero. If BSR is indicated as nonzero, the flow diagram **800** proceeds to **870**. At **870**, the AP sends TF to solicit UL from client. TF may be aggregated with DL (e.g., if DL BU(s) are present), and the process flow proceeds to **875**. If BSR is not indicated as nonzero, the flow diagram **800** proceeds to **875**. At **875**, the AP determines if all DL and UL are done before the end of SP. If all DL and UL are done, the flow diagram **800** proceeds to **880**. At **880**, the AP sends EOSP=1 in the last DL frame (e.g., QoS null if no pending DL), and the process flow returns to **805**. If all DL and UL are not done, the flow diagram **800** proceeds to **885**. At **885**, the AP sends information of O-SP and/or next D-SP to continue, and the flow diagram **800** returns to **805**.

FIG. **9** illustrates an example of a flow diagram **900** that supports beam training techniques in Wi-Fi frequency bands in accordance with one or more aspects of the present disclosure. Aspects of the flow diagram **900** may implement, or be implemented by, aspects of the WLAN **100**, the wireless communications system **200**, the beam training procedures **300**, **400**, **500**, **600**, **700**, or any combination thereof.

For example, the flow diagram **900** illustrates logic that may be performed by a non-AP MLD **130** when determining if, and when, to perform a beam training procedure with an AP MLD **135**, as illustrated by and described with reference to FIG. **1**.

At **905**, the client determines whether the client is communicating within a BTI or SP. If the client is communicating within a BTI, the flow diagram **900** proceeds to **910**. At **910**, the client determines if the client is communicating with a new AP. If the AP is new, the flow diagram **900** proceeds to **915**. At **915**, the client monitors for (e.g., beacon) frame in responder SLS mode (e.g., quasi-omni) and proceeds to **950**. At **950**, the client enters SLS responder mode (e.g., quasi-omni) and proceeds to **955**. At **955**, the client begins full beam training (SLS+BRP) SIFS after expected time when response frame is to be received and proceeds to **960**.

At **960**, the client determines if the response frame SIFS was received after transmitting the initiating frame. If the response was not received after transmitting the initiating frame, the flow diagram **900** returns to **950**. If the response was not received after transmitting the initiating frame, the flow diagram **900** proceeds to **965**. At **965**, the client performs frame exchange with the AP while beamformed and proceeds to **970**.

If the AP is not new at **910**, the flow diagram **900** proceeds to **920**. At **920**, the client beamforms to the last known sector for the AP and listens for a (e.g., beacon) frame from the AP. The flow diagram **900** proceeds to **925**. Also, if the client determines that the client is communicating in SP at **905**, the flow diagram **900** proceeds to **925**. At **925**, the client determines how well the (e.g., beacon) frame is received. The client may determine that the frame was received above a threshold, below the threshold, or not received. If the frame is not received, the flow diagram **900** proceeds to **950** and may follow the process as described above. If the frame is received below the threshold, the flow diagram **900** proceeds to **930**. At **930**, the client indicates that BRP is needed in initiating frame and proceeds to **935**. Also, if the frame is received above the threshold, the flow diagram **900** proceeds to **935**.

At **935**, the client indicates pending BUs in the initiating frame and proceeds to **940**. At **940**, the client beamforms to the last know sector for the AP and proceeds to **945**. At **945**, the client transmits the initiating frame and proceeds to **970**. At **970**, the client may go to PS until the next SP or BTI after EOSP=1 is received from the AP, and the flow diagram **900** returns to **905**.

FIG. **10** illustrates an example of a beam training procedure **1000** that supports beam training techniques in Wi-Fi frequency bands in accordance with one or more aspects of the present disclosure. Aspects of the flow diagram **900** may implement, or be implemented by, aspects of the WLAN **100**, the wireless communications system **200**, the beam training procedures **300**, **400**, **500**, **600**, **700**, the flow diagrams **800**, **900**, or any combination thereof.

For example, the beam training procedure **1000** illustrates communication between a non-AP MLD **130** and an AP MLD **135**, which may be examples of the non-AP MLD **130** and the AP MLD **135**, respectively, as illustrated by and described with reference to FIG. **1**.

For example, a STA **115** and an AP **105**, or a non-AP MLD **130** and an AP MLD **135** (which may be an example of a STA **115** and an AP **105**, or a non-AP MLD **130** and an AP MLD **135** as illustrated by or described with reference to FIGS. **1-2**, respectively), may perform the beam training procedure **1000** to measure a signal strength associated with one or more beam pairs and to select a beam pair associated with a suitable or greatest signal strength.

In some implementations, the beam training procedure **1000** may be a beacon frame-based beam training procedure according to which communicating devices may perform beam training via one or more sectorized beacons. The beam training procedure **1000** illustrated in FIG. **10** may include a BI **1005** that is divided up into three parts: (1) a BTI **1010**, (2) D-SPs **1015**, and (3) O-SPs **1020**.

For example, a BI **1005** may include a BTI **1010** during which an AP **105** may transmit sectorized beacons in different beamformed directions during different beam training resources **1025** (which may generally refer to any one or more of a beam training resource **1025**-*a*, a beam training resource **1025**-*b*, a beam training resource **1025**-*c*, and a beam training resource **1025**-*d*). In other words, the AP **105** may perform a sector sweep (e.g., SLS) of short beacon frames during the BTI **1010**. The beacon fames may include short frames that STAs may use as a reference for evaluating if beam training is needed or not.

For instance, as shown in FIG. **10**, a beam training resource **1025**-*a* may be associated with a directional beam **1030**-*a* (which may be denoted as s_1) and the AP **105** may accordingly transmit a sectorized beacon frame during the beam training resource **1025**-*a* using the directional beam **1030**-*a*. Similarly, the beam training resource **1025**-*b* may be associated with a directional beam **1030**-*b* (which may be denoted as s_2), the beam training resource **1025**-*c* may be associated with a directional beam **1030**-*c* (which may be denoted as s_3), and the beam training resource **1025**-*d* may be associated with a directional beam **1030**-*d* (which may be denoted as s_k). As such, the AP **105** may sweep across a set of directional beams **1030** (which may generally refer to any one or more of the directional beam **1030**-*a*, the directional beam **1030**-*b*, the directional beam **1030**-*c*, or the directional beam **1030**-*d*) during the BTI **1010**. A STA **115** may measure the various directional beams **1030** used by the AP **105** using a and identify a suitable beam pair that the AP **105** and the STA **115** may use for exchanging data. Accordingly, the AP **105** and the STA **115** may communicate data during an SP for data frame exchange using the suitable beam pair.

For example, the STA **115** and the AP **105** may communicate during one or more of a D-SP **1015**-*a*, a D-SP **1015**-*b*, and a D-SP **1015**-*c* using the suitable beam pair. Additionally, or alternatively, the STA **115** and the AP **105** may perform beam training during any one or more of the D-SP **1015**-*a*, the D-SP **1015**-*b*, and the D-SP **1015**-*c*. As illustrated by the beam training procedure **1000**, the AP **105** may use the directional beam **1030**-*d* and the STA **115** may use a directional beam **1035** during the D-SP **1015**-*c*. The STA **115** and the AP **105** also may communicate during one or more open SPs (O-SPs) **1020** (which may generally refer to any one or more of an O-SP **1020**-*a* and an O-SP **1020**-*b*).

In accordance with the implementations described herein, a non-AP MLD **130** (or a STA **115** associated with a non-AP MLD **130**) and an AP MLD **135** (or an AP **105** associated with an AP MLD **135**) may perform the beam training procedure **1000** using a 60 GHz link in scenarios in which the non-AP MLD **130** and the AP MLD **135** support 60 GHz link beacon frames. In some implementations, the non-AP MLD **130** and the AP MLD **135** may conditionally support beacon frame transmissions using the 60 GHz link. For example, the AP MLD **135** may transmit one or more sectorized beacon frames to the non-AP MLD **130** using the 60 GHz link in accordance with a satisfaction of a condition associated with 60 GHz link beacon frame transmissions.

The beam training procedure **1000** illustrated in FIG. **10** may be used to illustrate beam training procedures performed between wireless devices following a new association, or a beam training procedure performed between wireless devices after one of the wireless devices has resumes after a long idle period. In particular, different steps of a beam training procedure (e.g., sector-level training procedure (SLS), BRP, or both, may be performed during different portions of the BI **1005** illustrated in FIG. **10**.

For example, in accordance with a first implementation, an STA (e.g., non-AP MLD **130**) may monitors several BTIs **1010** in a quasi-omnidirectional mode to determine the general location of the AP MLD **135**, and may performs responder-side SLS and BRP during an associated D-SP **1015**. In this regard, the AP MLD **130** may transmit signals as part of the SLS during the BTI(s) **1010**, and the non-AP MLD **130** may transmit signals as part of the SLS during D-SPs **1015**, where the BRP is performed during the D-SP(s) **1015**. Stated differently, the non-AP MLD **130** may receive signals as part of the sector-level training procedure using a wide beam within one or more BTIs **1010**, and may transmit signals as part of the sector-level training procedure during one or more D-SPs **1015**. One drawback of this implementation is that the beam training procedure **1000** may take place over several BTIs **1010**, which may result in longer beam training. However, such delay may be acceptable for use cases that do not require frames to be exchanged on 60 GHz immediately after association.

By way of another example, in accordance with a second implementation, the AP MLD **130** and the non-AP MLD **130** (STA) may perform both SLS and BRP during the D-SP **1015**. In this implementation, a portion of the D-SP **1015** (after association or after returning from idle state) may be used towards beam training.

FIG. **11** illustrates an example of a process flow **1100** that supports beam training techniques in Wi-Fi frequency bands in accordance with one or more aspects of the present disclosure. Aspects of the process flow **1100** may implement, or be implemented by, aspects of the WLAN **100**, the wireless communications system **200**, the beam training procedures **300**, **400**, **500**, **600**, **700**, the flow diagrams **800**, **900**, the beam training procedure **1000**, or any combination thereof. For example, the process flow **1100** illustrates hand-shake signaling between a non-AP MLD **1105** and an AP MLD **1110** that may be used to determine whether (or what type/extent) of beam training procedures are expected to be performed during an SP configured for communications between the respective devices, as shown and described with respect to FIGS. **1-10**.

The process flow **1100** may include a non-AP MLD **1105** and an AP MLD **1110**, which may be examples of non-AP MLDs **130**, AP MLDs **135**, STAs, and other wireless devices described with reference to FIGS. **1-10**. For example, the non-AP MLD **1105** and the AP MLD **1110** illustrated in FIG. **11** may include examples of the non-AP MLD **130** and the AP MLD **135**, respectively, as illustrated in FIG. **2**.

In some examples, the operations illustrated in process flow **1100** may be performed by hardware (e.g., including circuitry, processing blocks, logic components, and other components), code (e.g., software) executed by a processor, or any combination thereof. Alternative examples of the following may be implemented, where some steps are per-

formed in a different order than described or are not performed at all. In some cases, steps may include additional features not mentioned below, or further steps may be added.

At **1115**, the non-AP MLD **1105** may receive control signaling from the AP MLD **1110**, where the control signaling indicates a set of SPs (e.g., D-SPs) associated with the first wireless device. In other words, the AP MLD **1110** may configure the non-AP MLD **1105** with a set of D-SPs that may be used for communications between the respective devices.

At **1120**, the non-AP MLD **1105** and the AP MLD **1110** may perform a first beam training procedure with one another. As described previously herein, the respective devices may perform a beam training procedure with one another during a BTI in order to identify beams (e.g., Tx/Rx beams) that will be used for communications with one another, as shown and described in FIG. **2**. The first beam training procedure may include SLS and BRP, or just BRP. In some cases, the devices may perform the first beam training procedure at **1120** based on communicating the control signaling at **1115**.

At **1125**, the non-AP MLD **1105**, the AP MLD **1110**, or both, may perform measurements on signals received from the other respective device. In particular, the devices may perform measurements on signals received using beams (e.g., Rx beams) selected based on the first beam training procedure. In some aspects, the performed measurements may be used by the respective devices to determine whether the devices should perform a new beam training procedure to update beams that will be used for communications with one another. As such, the devices may perform the measurements at **1125** based on communicating the control signaling at **1115**, performing the first beam training procedure at **1120**, or both.

At **1130**, the non-AP MLD **1105** or the AP MLD **1110** may transmit an initiating frame within an SP (e.g., D-SP). In some aspects, the non-AP MLD **1105** or the AP MLD **1110** may transmit the initiating frame using a Tx beam selected based on the first beam training procedure at **1120** (and the other respective device may receive the response frame using an Rx beam selected based on the first beam training procedure). As such, the non-AP MLD **1105** or the AP MLD **1110** may transmit the initiating frame at **1130** based on communicating the control signaling at **1115**, performing the first beam training procedure at **1120**, performing the measurements at **1125**, or any combination thereof.

In some aspects, the initiating frame may include an indication as to whether the non-AP MLD **1105** or the AP MLD **1110** is requesting to perform a second beam training procedure during the SP. In some cases, the initiating frame may indicate a level, type, or extent of beam training (e.g., indicate whether the device is requesting to perform BRP, or SLS+BRP). For example, in cases where the non-AP MLD **1105** transmits the initiating frame, non-AP MLD **1105** may use the initiating frame to request or trigger a second beam training procedure during the SP. For instance, in cases where measurements performed at **1125** fail to satisfy a threshold, the non-AP MLD **1105** may request to perform a new beam training procedure during the SP via the initiating frame. Conversely, in cases where measurements performed at **1125** satisfy a threshold, the initiating frame may indicate that the non-AP MLD **1105** is not requesting to perform a new beam training procedure during the SP. In some cases, an absence of an explicit request for a beam training procedure may serve as an indication that the respective device is not requesting a new beam training procedure.

In some implementations, the initiating frame may include a QoS null frame including a control field. In such cases, the control field may include a buffer status report, the indication as to whether the respective device is requesting to perform the second beam training procedure, or both. For example, in cases where the non-AP MLD **1110** transmits the initiating frame, the initiating frame may include a buffer status report associated with traffic to be communicated from the non-AP MLD **1105** to the AP MLD **1110**.

At **1135**, the non-AP MLD **1105** or the AP MLD **1110** may transmit a response frame within the SP (e.g., D-SP), where the response frame is transmitted based on (e.g., in response to) the initiating frame at **1130**. For example, in cases where the non-AP MLD **1110** transmits the initiating frame at **1130**, the AP MLD **1110** may **1110** may transmit the response frame based on receiving the initiating frame. Conversely, in cases where the AP MLD **1105** transmits the initiating frame at **1130**, the non-AP MLD **1105** may transmit the response frame based on receiving the initiating frame.

As noted previously herein with respect to the initiating frame, the non-AP MLD **1105** or the AP MLD **1110** may transmit the response frame using a Tx beam selected based on the first beam training procedure at **1120** (and the other respective device may receive the response frame using an Rx beam selected based on the first beam training procedure). As such, the non-AP MLD **1105** or the AP MLD **1110** may **1110** may transmit the initiating frame at **1130** based on communicating the control signaling at **1115**, performing the first beam training procedure at **1120**, performing the measurements at **1125**, receiving the initiating frame at **1130**, or any combination thereof.

Moreover, as described with respect to the initiating frame, the response frame may include an indication as to whether the non-AP MLD **1105** or the AP MLD **1110** is requesting to perform a second beam training procedure during the SP. In some cases, the response frame may indicate a level, type, or extent of beam training (e.g., indicate whether the device is requesting to perform BRP, or SLS+BRP). For example, in cases where the AP MLD **1105** transmits the response frame, non-AP MLD **1105** may use the initiating frame to request or trigger a second beam training procedure during the SP. In this regard, any description associated with the initiating frame at **1130** may apply to the response frame at **1135**, unless noted otherwise herein. Moreover, in cases where the initiating frame indicates a request to perform a second beam training procedure, the response frame may include an acknowledgment of the request for the second beam training procedure. Further, the response frame may include a request for the second beam training procedure even in cases where the initiating frame did not include such a request.

At **1140**, the non-AP MLD **1105** or the AP MLD **1110** may transmit an ACK frame within the SP (e.g., D-SP), where the ACK frame is transmitted based on (e.g., in response to) the response frame at **1130**. For example, in cases where the non-AP MLD **1105** receives the response frame at **1135**, the non-AP MLD **1105** may transmit the ACK frame based on receiving the response frame. Conversely, in cases where the AP MLD **1105** receives the response frame at **1135**, the AP MLD **1110** may transmit the ACK frame based on receiving the response frame.

At **1145**, the non-AP MLD **1105** and the AP MLD **1110** may perform a second beam training procedure with one another during the SP (e.g., D-SP). The devices may be configured to perform the second beam training procedure to update or select new Tx/Rx beams that will be used for communications between the respective devices. As noted

previously herein, the second beam training procedure may include BRP, or SLS+BRP. The devices may be configured to perform the second beam training procedure during the SP at **1145** based on communicating the control signaling at **1115**, performing the first beam training procedure at **1120**, performing the measurements at **1125**, communicating the initiating frame at **1130**, communicating the response frame at **1135**, communicating the ACK frame at **1140**, or any combination thereof.

For example, the devices may be configured to perform the second beam training procedure if the initiating frame, the response frame, or both, includes an indication that the respective device is requesting to perform the second beam training procedure. Additionally, or alternatively, the devices may be configured to perform the second beam training procedure if the devices determine that wireless channel conditions between the respective devices have changed relative to a previous BTI or SP (e.g., based on the measurements at **1125**).

Additionally, or alternatively, the devices may be configured to perform the second beam training procedure if the initiating frame, the response frame, the ACK frame, or any combination thereof, is not successfully received by the other respective device. In other words, if either of the initiating frame and/or the response frame is lost or otherwise not successfully received, the devices may fall back or default to a beam training mode (e.g., SLS initiator mode) in order to perform the second beam training procedure during the SP. In this regard, the devices may automatically begin transmitting beacon frames (or monitoring for beacon frames) as part of the second beam training procedure based on identifying an absence of the initiating frame or the response frame (and/or the ACK frame). In some aspects, the devices may signal or negotiate a retry count, and may be configured to perform the second beam training procedure if a quantity of failed frame exchanges (e.g., failed initiating/response frame exchange) satisfies a threshold quantity associated with the retry count.

At **1150**, the non-AP MLD **1105** may receive a trigger frame from the AP MLD **1110**, where the trigger frame schedules traffic (e.g., uplink traffic) from the non-AP MLD **1105** to the AP MLD **1110**. For example, in cases where the non-AP MLD **1105** transmits the initiating frame including a buffer status report, the AP MLD **1105** may transmit the trigger frame scheduling the traffic associated with the buffer status report. In some aspects, the trigger frame may be transmitted with downlink traffic from the AP MLD **1110** to the non-AP MLD **1105**. The AP MLD **1110** may transmit the trigger frame at **1150** based on communicating the control signaling at **1115**, performing the first beam training procedure at **1120**, performing the measurements at **1125**, communicating the initiating frame at **1130**, communicating the response frame at **1135**, communicating the ACK frame at **1140**, performing the second beam training procedure at **1145**, or any combination thereof.

At **1155**, the non-AP MLD **1105** and the AP MLD **1110** may communicate (e.g., transmit, receive) one or more messages with one another using one or more beams (e.g., Tx/Rx beams) that were selected based on the second beam training procedure at **1145**. Moreover, the devices may communicate the messages with one another at **1155** based on communicating the control signaling at **1115**, performing the first beam training procedure at **1120**, performing the measurements at **1125**, communicating the initiating frame at **1130**, communicating the response frame at **1135**, communicating the ACK frame at **1140**, performing the second beam training procedure at **1145**, communicating the trigger frame at **1150**, or any combination thereof.

In some implementations, messages communicated between the respective devices may indicate an end of traffic/communications to be exchanged between the devices, an end of the SP, or both. For example, the non-AP MLD **1105** may receive one or more messages from the AP MLD **1110**, where a last frame of the one or more messages indicate an end of the one or more messages, an end of the SP, or both.

Additionally, or alternatively, the one or more messages (e.g., frames) may indicate or activate additional SPs (e.g., O-SPs) for communications between the devices. For example, in cases where either device has additional traffic that will not be able to be communicated during the SP (e.g., D-SP), the AP MLD **1110** may transmit a message indicating or activating an additional O-SP that will be used to communicate the additional traffic between the devices.

At **1160**, the non-AP MLD **1110** may transition to an operational state associated with a lower power consumption (e.g., sleep state). In particular, the non-AP MLD **1105** may transition to a lower power operational state based on an end of the SP, based on the messages at **1155** indicating an end of the SP and/or an end of traffic to be communicated between the devices, or both.

FIG. **12** illustrates an example of a process flow **1200** that supports beam training techniques in Wi-Fi frequency bands in accordance with one or more aspects of the present disclosure. Aspects of the process flow **1200** may implement, or be implemented by, aspects of the WLAN **100**, the wireless communications system **200**, the beam training procedures **300**, **400**, **500**, **600**, **700**, the flow diagrams **800**, **900**, the beam training procedure **1000**, the process flow **1100**, or any combination thereof. For example, the process flow **1200** illustrates hand-shake signaling between a non-AP MLD **1205** and an AP MLD **1210** that may be used to determine whether (or what type/extent) of beam training procedures are expected to be performed during an SP configured for communications between the respective devices, as shown and described with respect to FIGS. **1-11**.

The process flow **1200** may include a non-AP MLD **1205** and an AP MLD **1210**, which may be examples of non-AP MLDs **130**, AP MLDs **135**, STAs, and other wireless devices described with reference to FIGS. **1-11**. For example, the non-AP MLD **1205** and the AP MLD **1210** illustrated in FIG. **12** may include examples of the non-AP MLD **130** and the AP MLD **135**, respectively, as illustrated in FIG. **2**.

In some examples, the operations illustrated in process flow **1200** may be performed by hardware (e.g., including circuitry, processing blocks, logic components, and other components), code (e.g., software) executed by a processor, or any combination thereof. Alternative examples of the following may be implemented, where some steps are performed in a different order than described or are not performed at all. In some cases, steps may include additional features not mentioned below, or further steps may be added.

At **1215**, the non-AP MLD **1205** may monitor for beacon frames transmitted by the AP MLD **1210**. For example, as shown in FIGS. **2-7**, the non-AP MLD **1205** may monitor for beacon frames during a BTI. In some aspects, the non-AP MLD **1205** may monitor for beacon frames as part of a beam training procedure attempted to be performed between the respective devices. The non-AP MLD **1205** may be configured to monitor for beacon frames in a beam formed or non-beamformed mode (e.g., quasi omnidirectional mode).

For example, in cases where the devices have previously performed a beam training procedure with one another, the

non-AP MLD **1205** may monitor for beacon frames in a beam formed mode using an Rx beam selected based on the previously-performed beam training procedure. Comparatively, in cases where the devices have not previously performed a beam training procedure (such as a new association between the respective devices), the non-AP MLD **1205** may monitor for beacon frames while operating in a quasi omnidirectional mode.

In some aspects, the non-AP MLD **1205** may detect a significant misalignment between beams at the respective devices based on the monitoring at **1215** (as shown in FIG. **7**). Additionally, or alternatively, the non-AP MLD **1205** may not receive or detect any beacon frames from the AP MLD **1210** based on the monitoring (as shown in FIG. **2**). In such cases, the devices may be configured to automatically determine that the devices are to perform a beam training procedure within a subsequent SP. As such, the process flow **1200** may proceed to **1220**.

At **1220**, the non-AP MLD **1205** and the AP MLD **1210** may perform a beam training procedure with one another during the SP (e.g., D-SP). The devices may be configured to perform the beam training procedure to initially select beams that will be used for communications (in the case of a new association with one another), to update or select new Tx/Rx beams that will be used for communications, or both. As noted previously herein, the second beam training procedure may include BRP, or SLS+BRP.

As compared to process flow **1100** illustrated in FIG. **11**, in which the devices exchange initiating and response frames with one another at the beginning of the SP, the devices may perform the beam training procedure at **1220** in process flow **1200** without performing the initiating/response frame exchange. In particular, the devices may refrain from transmitting the initiating/response frames (and proceed directly to the beam training procedure) based on the devices having not performed a previous beam training procedure with one another, based on detecting a significant misalignment between beams at **1215**, or both.

The devices may be configured to perform the second beam training procedure during the SP at **1145** based on communicating the control signaling at **1115**, performing the first beam training procedure at **1120**, performing the measurements at **1125**, communicating the initiating frame at **1130**, communicating the response frame at **1135**, communicating the ACK frame at **1140**, or any combination thereof.

At **1225**, the non-AP MLD **1205** may receive a trigger frame from the AP MLD **1210**, where the trigger frame schedules traffic (e.g., uplink traffic) from the non-AP MLD **1205** to the AP MLD **1210**. In some aspects, the trigger frame may be transmitted with downlink traffic from the AP MLD **1210** to the non-AP MLD **1205**. The AP MLD **1210** may transmit the trigger frame at **1225** performing the beam training procedure at **1220**.

At **1230**, the non-AP MLD **1205** and the AP MLD **1210** may communicate (e.g., transmit, receive) one or more messages with one another using one or more beams (e.g., Tx/Rx beams) that were selected based on the beam training procedure at **1220**. Moreover, the devices may communicate the messages with one another at **1230** based on communicating the trigger frame at **1225**.

In some implementations, messages communicated between the respective devices may indicate an end of traffic/communications to be exchanged between the devices, an end of the SP, or both. For example, the non-AP MLD **1205** may receive one or more messages from the AP MLD **1210**, where a last frame of the one or more messages indicate an end of the one or more messages, an end of the SP, or both. Additionally, or alternatively, the one or more messages (e.g., frames) may indicate or activate additional SPs (e.g., O-SPs) for communications between the devices. For example, in cases where either device has additional traffic that will not be able to be communicated during the SP (e.g., D-SP), the AP MLD **1210** may transmit a message indicating or activating an additional O-SP that will be used to communicate the additional traffic between the devices.

At **1235**, the non-AP MLD **1210** may transition to an operational state associated with a lower power consumption (e.g., sleep state). In particular, the non-AP MLD **1205** may transition to a lower power operational state based on an end of the SP, based on the messages at **1230** indicating an end of the SP and/or an end of traffic to be communicated between the devices, or both.

FIG. **13** shows a block diagram **1300** of a device **1305** that supports beam training techniques in Wi-Fi frequency bands in accordance with one or more aspects of the present disclosure. The device **1305** may be an example of aspects of an STA, an AP, or both, as described herein. The device **1305** may include a receiver **1310**, a transmitter **1315**, and a communications manager **1320**. The device **1305** may also include a processor. Each of these components may be in communication with one another (e.g., via one or more buses).

The receiver **1310** may provide a means for receiving information such as packets, user data, control information, or any combination thereof associated with various information channels (e.g., control channels, data channels, information channels related to beam training techniques in Wi-Fi frequency bands). Information may be passed on to other components of the device **1305**. The receiver **1310** may may utilize a single antenna or a set of multiple antennas.

The transmitter **1315** may provide a means for transmitting signals generated by other components of the device **1305**. For example, the transmitter **1315** may transmit information such as packets, user data, control information, or any combination thereof associated with various information channels (e.g., control channels, data channels, information channels related to beam training techniques in Wi-Fi frequency bands). In some examples, the transmitter **1315** may be co-located with a receiver **1310** in a transceiver module. The transmitter **1315** may utilize a single antenna or a set of multiple antennas.

The communications manager **1320**, the receiver **1310**, the transmitter **1315**, or various combinations thereof or various components thereof may be examples of means for performing various aspects of beam training techniques in Wi-Fi frequency bands as described herein. For example, the communications manager **1320**, the receiver **1310**, the transmitter **1315**, or various combinations or components thereof may support a method for performing one or more of the functions described herein.

In some examples, the communications manager **1320**, the receiver **1310**, the transmitter **1315**, or various combinations or components thereof may be implemented in hardware (e.g., in communications management circuitry). The hardware may include a processor, a DSP, a CPU, an ASIC, an FPGA or other programmable logic device, a microcontroller, discrete gate or transistor logic, discrete hardware components, or any combination thereof configured as or otherwise supporting a means for performing the functions described in the present disclosure. In some examples, a processor and memory coupled with the processor may be configured to perform one or more of the

functions described herein (e.g., by executing, by the processor, instructions stored in the memory).

Additionally, or alternatively, in some examples, the communications manager **1320**, the receiver **1310**, the transmitter **1315**, or various combinations or components thereof may be implemented in code (e.g., as communications management software or firmware) executed by a processor. If implemented in code executed by a processor, the functions of the communications manager **1320**, the receiver **1310**, the transmitter **1315**, or various combinations or components thereof may be performed by a general-purpose processor, a DSP, a CPU, an ASIC, an FPGA, a microcontroller, or any combination of these or other programmable logic devices (e.g., configured as or otherwise supporting a means for performing the functions described in the present disclosure).

In some examples, the communications manager **1320** may be configured to perform various operations (e.g., receiving, obtaining, monitoring, outputting, transmitting) using or otherwise in cooperation with the receiver **1310**, the transmitter **1315**, or both. For example, the communications manager **1320** may receive information from the receiver **1310**, send information to the transmitter **1315**, or be integrated in combination with the receiver **1310**, the transmitter **1315**, or both to obtain information, output information, or perform various other operations as described herein.

The communications manager **1320** may support wireless communications at a first wireless device in accordance with examples as disclosed herein. For example, the communications manager **1320** may be configured as or otherwise support a means for transmitting, to a second wireless device during an SP, an initiating frame using a transmit beam based on a first beam training procedure performed between the first wireless device and the second wireless device prior to the SP. The communications manager **1320** may be configured as or otherwise support a means for performing a second beam training procedure during the SP based on an absence of a response frame from the second wireless device, based on an indication within the response frame received from the second wireless device, or based on identification of a change in a wireless channel relative to a previous beam training interval or previous SP, the response frame being in response to the initiating frame. The communications manager **1320** may be configured as or otherwise support a means for communicating one or more messages with the second wireless device using one or more beams based on the second beam training procedure.

Additionally, or alternatively, the communications manager **1320** may support wireless communications at a first wireless device in accordance with examples as disclosed herein. For example, the communications manager **1320** may be configured as or otherwise support a means for monitoring for signals from a second wireless device during a BTI, the signals associated with a first beam training procedure between the first wireless device and the second wireless device. The communications manager **1320** may be configured as or otherwise support a means for performing a second beam training procedure during an SP in response to the signals being monitored or an absence of the signals associated with the first beam training procedure. The communications manager **1320** may be configured as or otherwise support a means for communicating one or more messages with the second wireless device using one or more beams based on the second beam training procedure.

By including or configuring the communications manager **1320** in accordance with examples as described herein, the device **1305** (e.g., a processor controlling or otherwise coupled with the receiver **1310**, the transmitter **1315**, the communications manager **1320**, or a combination thereof) may support techniques that enable wireless devices (e.g., AP MLD **135**, non-AP MLD **130**) to perform beam training procedures within an SP used for communications between the respective devices. By exchanging initiating frames and/or response frames within a SP, wireless devices (e.g., AP MLD, non-AP MLD) may be able to determine whether or not the wireless devices are expected to perform a new beam training procedure within the SP. As such, techniques described herein may enable the wireless devices to perform beam training procedures within SPs to enable more efficient and reliable wireless communications between the respective devices.

FIG. **14** shows a block diagram **1400** of a device **1405** that supports beam training techniques in Wi-Fi frequency bands in accordance with one or more aspects of the present disclosure. The device **1405** may be an example of aspects of a device **1305** or an STA **115** as described herein. The device **1405** may include a receiver **1410**, a transmitter **1415**, and a communications manager **1420**. The device **1405** may also include a processor. Each of these components may be in communication with one another (e.g., via one or more buses).

The receiver **1410** may provide a means for receiving information such as packets, user data, control information, or any combination thereof associated with various information channels (e.g., control channels, data channels, information channels related to beam training techniques in Wi-Fi frequency bands). Information may be passed on to other components of the device **1405**. The receiver **1410** may **1410** may utilize a single antenna or a set of multiple antennas.

The transmitter **1415** may provide a means for transmitting signals generated by other components of the device **1405**. For example, the transmitter **1415** may **1415** may transmit information such as packets, user data, control information, or any combination thereof associated with various information channels (e.g., control channels, data channels, information channels related to beam training techniques in Wi-Fi frequency bands). In some examples, the transmitter **1415** may be co-located with a receiver **1410** in a transceiver module. The transmitter **1415** may utilize a single antenna or a set of multiple antennas.

The device **1405**, or various components thereof, may be an example of means for performing various aspects of beam training techniques in Wi-Fi frequency bands as described herein. For example, the communications manager **1420** may **1420** may include an initiating frame transmitting manager **1425**, a beam training procedure manager **1430**, a message communicating manager **1435**, a monitoring manager **1440**, or any combination thereof. The communications manager **1420** may be an example of aspects of a communications manager **1320** as described herein. In some examples, the communications manager **1420**, or various components thereof, may be configured to perform various operations (e.g., receiving, obtaining, monitoring, outputting, transmitting) using or otherwise in cooperation with the receiver **1410**, the transmitter **1415**, or both. For example, the communications manager **1420** may receive information from the receiver **1410**, send information to the transmitter **1415**, or be integrated in combination with the receiver **1410**, the transmitter **1415**, or both to obtain information, output information, or perform various other operations as described herein.

The communications manager **1420** may support wireless communications at a first wireless device in accordance with

examples as disclosed herein. The initiating frame transmitting manager **1425** may be configured as or otherwise support a means for transmitting, to a second wireless device during an SP, an initiating frame using a transmit beam based on a first beam training procedure performed between the first wireless device and the second wireless device prior to the SP. The beam training procedure manager **1430** may be configured as or otherwise support a means for performing a second beam training procedure during the SP based on an absence of a response frame from the second wireless device, based on an indication within the response frame received from the second wireless device, or based on identification of a change in a wireless channel relative to a previous beam training interval or previous SP, the response frame being in response to the initiating frame. The message communicating manager **1435** may be configured as or otherwise support a means for communicating one or more messages with the second wireless device using one or more beams based on the second beam training procedure.

Additionally, or alternatively, the communications manager **1420** may **1420** may support wireless communications at a first wireless device in accordance with examples as disclosed herein. The monitoring manager **1440** may be configured as or otherwise support a means for monitoring for signals from a second wireless device during a BTI, the signals associated with a first beam training procedure between the first wireless device and the second wireless device. The beam training procedure manager **1430** may **1430** may be configured as or otherwise support a means for performing a second beam training procedure during an SP in response to the signals being monitored or an absence of the signals associated with the first beam training procedure. The message communicating manager **1435** may be configured as or otherwise support a means for communicating one or more messages with the second wireless device using one or more beams based on the second beam training procedure.

FIG. **15** shows a block diagram **1500** of a communications manager **1520** that supports beam training techniques in Wi-Fi frequency bands in accordance with one or more aspects of the present disclosure. The communications manager **1520** may be an example of aspects of a communications manager **1320**, a communications manager **1420**, or both, as described herein. The communications manager **1520**, or various components thereof, may be an example of means for performing various aspects of beam training techniques in Wi-Fi frequency bands as described herein. For example, the communications manager **1520** may include an initiating frame transmitting manager **1525**, a beam training procedure manager **1530**, a message communicating manager **1535**, a monitoring manager **1540**, a control signaling communicating manager **1545**, a measurement manager **1550**, a response frame receiving manager **1555**, an ACK frame transmitting manager **1560**, a beacon frame receiving manager **1565**, a trigger frame receiving manager **1570**, an operational state manager **1575**, or any combination thereof. Each of these components may communicate, directly or indirectly, with one another (e.g., via one or more buses).

The communications manager **1520** may support wireless communications at a first wireless device in accordance with examples as disclosed herein. The initiating frame transmitting manager **1525** may be configured as or otherwise support a means for transmitting, to a second wireless device during an SP, an initiating frame using a transmit beam based on a first beam training procedure performed between the first wireless device and the second wireless device prior to the SP. The beam training procedure manager **1530** may be configured as or otherwise support a means for performing a second beam training procedure during the SP based on an absence of a response frame from the second wireless device, based on an indication within the response frame received from the second wireless device, or based on identification of a change in a wireless channel relative to a previous beam training interval or previous SP, the response frame being in response to the initiating frame. The message communicating manager **1535** may be configured as or otherwise support a means for communicating one or more messages with the second wireless device using one or more beams based on the second beam training procedure.

In some examples, the control signaling communicating manager **1545** may **1545** may be configured as or otherwise support a means for communicating, with the second wireless device, control signaling indicating a set of multiple SPs associated with the first wireless device, the set of multiple SPs including the SP, where the initiating frame is transmitted based on the control signaling. In some examples, the initiating frame includes an indication as to whether the first wireless device is requesting to perform the second beam training procedure with the second wireless device during the SP.

In some examples, the measurement manager **1550** may be configured as or otherwise support a means for performing one or more measurements on signals received from the second wireless device via a receive beam based on the first beam training procedure, where the initiating frame is transmitted based on whether the one or more measurements satisfy one or more thresholds.

In some examples, the initiating frame includes an indication that the first wireless device is requesting to perform the second beam training procedure based on the one or more measurements failing to satisfy the one or more thresholds. In some examples, the initiating frame includes an indication that the first wireless device is not requesting to perform the second beam training procedure based on the one or more measurements satisfying the one or more thresholds.

In some examples, the initiating frame includes a buffer status report associated with traffic to be communicated from the first wireless device to the second wireless device, and the message communicating manager **1535** may be configured as or otherwise support a means for transmitting the traffic to the second wireless device using the one or more beams and based on the buffer status report.

In some examples, the trigger frame receiving manager **1570** may be configured as or otherwise support a means for receiving, from the second wireless device, a trigger frame scheduling the traffic based on the buffer status report, where the traffic is transmitted based on the trigger frame.

In some examples, the message communicating manager **1535** may be configured as or otherwise support a means for receiving downlink traffic from the second wireless device with the trigger frame. In some examples, the one or more messages are received from the second wireless device using a receive beam based on the second beam training procedure. In some examples, a last frame of the one or more messages indicate an end of the one or more messages, an end of the SP, or both. In some examples, the first wireless device receives the one or more messages while in a first operational state associated with a first power consumption, and the operational state manager **1575** may be configured as or otherwise support a means for transitioning to a second operational state associated with a second power consumption that is less than the first power consumption based on

the one or more messages indicating the end of the one or more messages, the end of the SP, or both.

In some examples, the message communicating manager **1535** may be configured as or otherwise support a means for communicating one or more additional messages with the second wireless device during a second SP using the one or more beams based on the second beam training procedure. In some examples, the one or more messages include an indication of the second SP for communications between the first wireless device and the second wireless device. In some examples, the one or more additional messages are communicated based on the indication of the second SP.

In some examples, the initiating frame includes the indication that the first wireless device is requesting to perform the second beam training procedure with the second wireless device, and the response frame receiving manager **1555** may be configured as or otherwise support a means for receiving the response frame from the second wireless device based on the initiating frame, where the response frame includes an acknowledgment of the second beam training procedure, where the second beam training procedure is performed based on the acknowledgment.

In some examples, the initiating frame includes the indication that the first wireless device is requesting to perform the second beam training procedure with the second wireless device, and the response frame receiving manager **1555** may be configured as or otherwise support a means for identifying the absence of the response frame from the second wireless device based on the initiating frame. In some examples, the initiating frame includes the indication that the first wireless device is requesting to perform the second beam training procedure with the second wireless device, and the monitoring manager **1540** may be configured as or otherwise support a means for monitoring for signals from the second wireless device as part of the second beam training procedure based on the absence of the response frame.

In some examples, the response frame receiving manager **1555** may be configured as or otherwise support a means for receiving, via the response frame, an indication that the second wireless device is requesting to perform the second beam training procedure with the first wireless device, where the second beam training procedure is performed based on receiving the response frame.

In some examples, the initiating frame transmitting manager **1525** may be configured as or otherwise support a means for identifying that a quantity of failed frame exchanges between the first wireless device and the second wireless device satisfies a threshold quantity based on transmitting the initiating frame, where the second beam training procedure is performed based on the identifying.

In some examples, the response frame receiving manager **1555** may be configured as or otherwise support a means for receiving the response frame based on the initiating frame being transmitted. In some examples, the ACK frame transmitting manager **1560** may be configured as or otherwise support a means for transmitting, to the second wireless device, an ACK frame based on the response frame, where the second beam training procedure is performed based on the ACK frame.

In some examples, the initiating frame includes a QoS null frame including a control field, the control field including a buffer status report, the indication as to whether the first wireless device is requesting to perform the second beam training procedure, or both. In some examples, the first wireless device includes an STA, a first MLD, or both. In some examples, the second wireless device includes an AP, a second MLD, or both. In some examples, the first wireless device includes the AP and. In some examples, the second wireless device includes the STA.

Additionally, or alternatively, the communications manager **1520** may **1520** may support wireless communications at a first wireless device in accordance with examples as disclosed herein. The monitoring manager **1540** may be configured as or otherwise support a means for monitoring for signals from a second wireless device during a BTI, the signals associated with a first beam training procedure between the first wireless device and the second wireless device. In some examples, the beam training procedure manager **1530** may be configured as or otherwise support a means for performing a second beam training procedure during an SP in response to the signals being monitored or an absence of the signals associated with the first beam training procedure. In some examples, the message communicating manager **1535** may be configured as or otherwise support a means for communicating one or more messages with the second wireless device using one or more beams based on the second beam training procedure.

In some examples, to support monitoring, the monitoring manager **1540** may **1540** may be configured as or otherwise support a means for monitoring for a beacon frame in a beamformed mode.

In some examples, the beacon frame receiving manager **1565** may be configured as or otherwise support a means for receiving a beacon frame from the second wireless device based on the signals being monitored, the beacon frame associated with the first beam training procedure. In some examples, the initiating frame transmitting manager **1525** may be configured as or otherwise support a means for refraining from transmission of an initiating frame within the SP based on the beam training procedure including an initial beam training procedure between the first wireless device and the second wireless device, where the second beam training procedure is performed based on the initiating frame being refrained from transmission.

In some examples, the initiating frame transmitting manager **1525** may be configured as or otherwise support a means for identifying an absence of an initiating frame communicated between the first wireless device and the second wireless device within the SP, where the second beam training procedure is performed based on the absence of the initiating frame.

FIG. **16** shows a diagram of a system **1600** including a device **1605** that supports beam training techniques in Wi-Fi frequency bands in accordance with one or more aspects of the present disclosure. The device **1605** may be an example of or include the components of a device **1305**, a device **1405**, an STA, an AP, or any combination thereof, as described herein. The device **1605** may include components for bi-directional voice and data communications including components for transmitting and receiving communications, such as a communications manager **1620**, an I/O controller **1610**, a transceiver **1615**, an antenna **1625**, a memory **1630**, code **1635**, and a processor **1640**. These components may be in electronic communication or otherwise coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more buses (e.g., a bus **1645**).

The I/O controller **1610** may manage input and output signals for the device **1605**. The I/O controller **1610** may also manage peripherals not integrated into the device **1605**. In some cases, the I/O controller **1610** may represent a physical connection or port to an external peripheral. In some cases, the I/O controller **1610** may utilize an operating system such as iOS®, ANDROID®, MS-DOS®, MS-WIN-

DOWS®, OS/2®, UNIX®, LINUX®, or another known operating system. In some other cases, the I/O controller **1610** may represent or interact with a modem, a keyboard, a mouse, a touchscreen, or a similar device. In some cases, the I/O controller **1610** may be implemented as part of a processor, such as the processor **1640**. In some cases, a user may interact with the device **1605** via the I/O controller **1610** or via hardware components controlled by the I/O controller **1610**.

In some cases, the device **1605** may include a single antenna **1625**. However, in some other cases the device **1605** may have more than one antenna **1625**, which may be capable of concurrently transmitting or receiving multiple wireless transmissions. The transceiver **1615** may communicate bi-directionally, via the one or more antennas **1625**, wired, or wireless links as described herein. For example, the transceiver **1615** may represent a wireless transceiver and may communicate bi-directionally with another wireless transceiver. The transceiver **1615** may also include a modem to modulate the packets and provide the modulated packets to one or more antennas **1625** for transmission, and to demodulate packets received from the one or more antennas **1625**. The transceiver **1615**, or the transceiver **1615** and one or more antennas **1625**, may be an example of a transmitter **1315**, a transmitter **1415**, a receiver **1310**, a receiver **1410**, or any combination thereof or component thereof, as described herein.

The memory **1630** may include RAM and ROM. The memory **1630** may store computer-readable, computer-executable code **1635** including instructions that, when executed by the processor **1640**, cause the device **1605** to perform various functions described herein. In some cases, the memory **1630** contain, among other things, a BIOS which may control basic hardware or software operation such as the interaction with peripheral components or devices.

The processor **1640** 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 **1640** may be configured to operate a memory array using a memory controller. In some other cases, a memory controller may be integrated into the processor **1640**. The processor **1640** may be configured to execute computer-readable instructions stored in a memory (e.g., the memory **1630**) to cause the device **1605** to perform various functions (e.g., functions or tasks supporting beam training techniques in Wi-Fi frequency bands). For example, the device **1605** or a component of the device **1605** may include a processor **1640** and memory **1630** coupled with or to the processor **1640**, the processor **1640** and memory **1630** configured to perform various functions described herein.

The communications manager **1620** may support wireless communications at a first wireless device in accordance with examples as disclosed herein. For example, the communications manager **1620** may be configured as or otherwise support a means for transmitting, to a second wireless device during an SP, an initiating frame using a transmit beam based on a first beam training procedure performed between the first wireless device and the second wireless device prior to the SP. The communications manager **1620** may be configured as or otherwise support a means for performing a second beam training procedure during the SP based on an absence of a response frame from the second wireless device, based on an indication within the response frame received from the second wireless device, or based on identification of a change in a wireless channel relative to a previous beam training interval or previous SP, the response frame being in response to the initiating frame. The communications manager **1620** may be configured as or otherwise support a means for communicating one or more messages with the second wireless device using one or more beams based on the second beam training procedure.

Additionally, or alternatively, the communications manager **1620** may **1620** may support wireless communications at a first wireless device in accordance with examples as disclosed herein. For example, the communications manager **1620** may be configured as or otherwise support a means for monitoring for signals from a second wireless device during a BTI, the signals associated with a first beam training procedure between the first wireless device and the second wireless device. The communications manager **1620** may be configured as or otherwise support a means for performing a second beam training procedure during an SP in response to the signals being monitored or an absence of the signals associated with the first beam training procedure. The communications manager **1620** may be configured as or otherwise support a means for communicating one or more messages with the second wireless device using one or more beams based on the second beam training procedure.

By including or configuring the communications manager **1620** in accordance with examples as described herein, the device **1605** may support techniques that enable wireless devices (e.g., AP MLD **135**, non-AP MLD **130**) to perform beam training procedures within an SP used for communications between the respective devices. By exchanging initiating frames and/or response frames within a SP, wireless devices (e.g., AP MLD, non-AP MLD) may be able to determine whether or not the wireless devices are expected to perform a new beam training procedure within the SP. As such, techniques described herein may enable the wireless devices to perform beam training procedures within SPs to enable more efficient and reliable wireless communications between the respective devices.

FIG. **17** shows a block diagram **1700** of a device **1705** that supports beam training techniques in Wi-Fi frequency bands in accordance with one or more aspects of the present disclosure. The device **1705** may be an example of aspects of an AP, an STA, or both, as described herein. The device **1705** may include a receiver **1710**, a transmitter **1715**, and a communications manager **1720**. The device **1705** may also include a processor. Each of these components may be in communication with one another (e.g., via one or more buses).

The receiver **1710** may provide a means for receiving information such as packets, user data, control information, or any combination thereof associated with various information channels (e.g., control channels, data channels, information channels related to beam training techniques in Wi-Fi frequency bands). Information may be passed on to other components of the device **1705**. The receiver **1710** may utilize a single antenna or a set of multiple antennas.

The transmitter **1715** may provide a means for transmitting signals generated by other components of the device **1705**. The transmitter **1715** may utilize a single antenna or a set of multiple antennas.

The communications manager **1720**, the receiver **1710**, the transmitter **1715**, or various combinations thereof or various components thereof may be examples of means for performing various aspects of beam training techniques in Wi-Fi frequency bands as described herein. For example, the communications manager **1720**, the receiver **1710**, the trans-

mitter **1715**, or various combinations or components thereof may support a method for performing one or more of the functions described herein.

In some examples, the communications manager **1720**, the receiver **1710**, the transmitter **1715**, or various combinations or components thereof may be implemented in hardware (e.g., in communications management circuitry). The hardware may include a processor, a DSP, a CPU, an ASIC, an FPGA or other programmable logic device, a microcontroller, discrete gate or transistor logic, discrete hardware components, or any combination thereof configured as or otherwise supporting a means for performing the functions described in the present disclosure. In some examples, a processor and memory coupled with the processor may be configured to perform one or more of the functions described herein (e.g., by executing, by the processor, instructions stored in the memory).

Additionally, or alternatively, in some examples, the communications manager **1720**, the receiver **1710**, the transmitter **1715**, or various combinations or components thereof may be implemented in code (e.g., as communications management software or firmware) executed by a processor. If implemented in code executed by a processor, the functions of the communications manager **1720**, the receiver **1710**, the transmitter **1715**, or various combinations or components thereof may be performed by a general-purpose processor, a DSP, a CPU, an ASIC, an FPGA, a microcontroller, or any combination of these or other programmable logic devices (e.g., configured as or otherwise supporting a means for performing the functions described in the present disclosure).

In some examples, the communications manager **1720** may be configured to perform various operations (e.g., receiving, obtaining, monitoring, outputting, transmitting) using or otherwise in cooperation with the receiver **1710**, the transmitter **1715**, or both. For example, the communications manager **1720** may receive information from the receiver **1710**, send information to the transmitter **1715**, or be integrated in combination with the receiver **1710**, the transmitter **1715**, or both to obtain information, output information, or perform various other operations as described herein.

The communications manager **1720** may support wireless communications at a first wireless device in accordance with examples as disclosed herein. For example, the communications manager **1720** may be configured as or otherwise support a means for monitoring for an initiating frame from a second wireless device during an SP, where the initiating frame is monitored using a receive beam based on a first beam training procedure performed between the first wireless device and the second wireless device prior to the SP. The communications manager **1720** may be configured as or otherwise support a means for performing a second beam training procedure during the SP based on an absence of the initiating frame, based on the initiating frame being received and including an indication that the second wireless device is requesting to perform a second beam training procedure with the first wireless device, or based on identification of a change in a wireless channel during a previous beam training interval or previous SP. The communications manager **1720** may be configured as or otherwise support a means for communicating one or more messages with the second wireless device using one or more beams based on the second beam training procedure.

By including or configuring the communications manager **1720** in accordance with examples as described herein, the device **1705** (e.g., a processor controlling or otherwise coupled with the receiver **1710**, the transmitter **1715**, the communications manager **1720**, or a combination thereof) may support techniques that enable wireless devices (e.g., AP MLD **135**, non-AP MLD **130**) to perform beam training procedures within an SP used for communications between the respective devices. By exchanging initiating frames and/or response frames within a SP, wireless devices (e.g., AP MLD, non-AP MLD) may be able to determine whether or not the wireless devices are expected to perform a new beam training procedure within the SP. As such, techniques described herein may enable the wireless devices to perform beam training procedures within SPs to enable more efficient and reliable wireless communications between the respective devices.

FIG. **18** shows a block diagram **1800** of a device **1805** that supports beam training techniques in Wi-Fi frequency bands in accordance with one or more aspects of the present disclosure. The device **1805** may be an example of aspects of a device **1705**, an AP, and/or an STA as described herein. The device **1805** may include a receiver **1810**, a transmitter **1815**, and a communications manager **1820**. The device **1805** may also include a processor. Each of these components may be in communication with one another (e.g., via one or more buses).

The receiver **1810** may provide a means for receiving information such as packets, user data, control information, or any combination thereof associated with various information channels (e.g., control channels, data channels, information channels related to beam training techniques in Wi-Fi frequency bands). Information may be passed on to other components of the device **1805**. The receiver **1810** may utilize a single antenna or a set of multiple antennas.

The transmitter **1815** may provide a means for transmitting signals generated by other components of the device **1805**. The transmitter **1815** may utilize a single antenna or a set of multiple antennas.

The device **1805**, or various components thereof, may be an example of means for performing various aspects of beam training techniques in Wi-Fi frequency bands as described herein. For example, the communications manager **1820** may include an initiating frame receiving manager **1825**, a beam training procedure manager **1830**, a message communicating manager **1835**, or any combination thereof. The communications manager **1820** may be an example of aspects of a communications manager **1720** as described herein. In some examples, the communications manager **1820**, or various components thereof, may be configured to perform various operations (e.g., receiving, obtaining, monitoring, outputting, transmitting) using or otherwise in cooperation with the receiver **1810**, the transmitter **1815**, or both. For example, the communications manager **1820** may receive information from the receiver **1810**, send information to the transmitter **1815**, or be integrated in combination with the receiver **1810**, the transmitter **1815**, or both to obtain information, output information, or perform various other operations as described herein.

The communications manager **1820** may support wireless communications at a first wireless device in accordance with examples as disclosed herein. The initiating frame receiving manager **1825** may be configured as or otherwise support a means for monitoring for an initiating frame from a second wireless device during an SP, where the initiating frame is monitored using a receive beam based on a first beam training procedure performed between the first wireless device and the second wireless device prior to the SP. The beam training procedure manager **1830** may be configured as or otherwise support a means for performing a second beam training procedure during the SP based on an absence

of the initiating frame, based on the initiating frame being received and including an indication that the second wireless device is requesting to perform a second beam training procedure with the first wireless device, or based on identification of a change in a wireless channel during a previous beam training interval or previous SP. The message communicating manager **1835** may be configured as or otherwise support a means for communicating one or more messages with the second wireless device using one or more beams based on the second beam training procedure.

FIG. **19** shows a block diagram **1900** of a communications manager **1920** that supports beam training techniques in Wi-Fi frequency bands in accordance with one or more aspects of the present disclosure. The communications manager **1920** may be an example of aspects of a communications manager **1720**, a communications manager **1820**, or both, as described herein. The communications manager **1920**, or various components thereof, may be an example of means for performing various aspects of beam training techniques in Wi-Fi frequency bands as described herein. For example, the communications manager **1920** may include an initiating frame receiving manager **1925**, a beam training procedure manager **1930**, a message communicating manager **1935**, a response frame transmitting manager **1940**, a control signaling communicating manager **1945**, an ACK frame receiving manager **1950**, a trigger frame transmitting manager **1955**, or any combination thereof. Each of these components may communicate, directly or indirectly, with one another (e.g., via one or more buses).

The communications manager **1920** may support wireless communications at a first wireless device in accordance with examples as disclosed herein. The initiating frame receiving manager **1925** may be configured as or otherwise support a means for monitoring for an initiating frame from a second wireless device during an SP, where the initiating frame is monitored using a receive beam based on a first beam training procedure performed between the first wireless device and the second wireless device prior to the SP. The beam training procedure manager **1930** may be configured as or otherwise support a means for performing a second beam training procedure during the SP based on an absence of the initiating frame, based on the initiating frame being received and including an indication that the second wireless device is requesting to perform a second beam training procedure with the first wireless device, or based on identification of a change in a wireless channel during a previous beam training interval or previous SP. The message communicating manager **1935** may be configured as or otherwise support a means for communicating one or more messages with the second wireless device using one or more beams based on the second beam training procedure.

In some examples, the initiating frame receiving manager **1925** may be configured as or otherwise support a means for receiving the initiating frame. In some examples, the response frame transmitting manager **1940** may be configured as or otherwise support a means for transmitting a response frame to the second wireless device based on the initiating frame, where the second beam training procedure is performed based on the response frame being transmitted.

In some examples, the initiating frame receiving manager **1925** may be configured as or otherwise support a means for identifying an absence of the initiating frame from the second wireless device based on the initiating frame being monitored, where the second beam training procedure is performed based on the absence of the initiating frame.

In some examples, the control signaling communicating manager **1945** may be configured as or otherwise support a means for communicating, with the second wireless device, control signaling indicating a set of multiple SPs associated with the first wireless device, the set of multiple SPs including the SP, where the initiating frame is monitored for based on the control signaling.

In some examples, the initiating frame includes an indication as to whether the second wireless device is requesting to perform the second beam training procedure with the first wireless device during the SP.

In some examples, the initiating frame receiving manager **1925** may be configured as or otherwise support a means for receiving, via the initiating frame and based on the monitoring, a buffer status report associated with traffic to be communicated from the second wireless device to the first wireless device. In some examples, the message communicating manager **1935** may be configured as or otherwise support a means for receiving the traffic from the second wireless device using the one or more beams and based on the buffer status report.

In some examples, the trigger frame transmitting manager **1955** may be configured as or otherwise support a means for transmitting, to the second wireless device, a trigger frame scheduling the traffic based on the buffer status report, where the traffic is received based on the trigger frame.

In some examples, the message communicating manager **1935** may be configured as or otherwise support a means for transmitting downlink traffic from the second wireless device along with the trigger frame. In some examples, a last frame of the one or more messages indicate an end of the one or more messages, an end of the SP, or both.

In some examples, the one or more messages include an indication of a second SP for communications between the first wireless device and the second wireless device, and the message communicating manager **1935** may be configured as or otherwise support a means for communicating one or more additional messages with the second wireless device during the second SP using the one or more beams based on the second beam training procedure.

In some examples, the initiating frame receiving manager **1925** may be configured as or otherwise support a means for receiving, via the initiating frame and based on the monitoring, the indication that the second wireless device is requesting to perform the second beam training procedure with the second wireless device. In some examples, the response frame transmitting manager **1940** may be configured as or otherwise support a means for transmitting a response frame to the second wireless device based on the initiating frame, where the response frame includes an acknowledgment of the second beam training procedure, where the second beam training procedure is performed based on the acknowledgment.

In some examples, the response frame transmitting manager **1940** may be configured as or otherwise support a means for transmitting a response frame based at last in part on receiving the initiating frame, where the response frame includes an indication that the first wireless device is requesting to perform the second beam training procedure with the second wireless device, where the second beam training procedure is performed based on transmitting the response frame.

In some examples, the initiating frame receiving manager **1925** may be configured as or otherwise support a means for identifying that a quantity of failed frame exchanges between the first wireless device and the second wireless device satisfies a threshold quantity based on the monitoring, where the second beam training procedure is performed based on the identifying.

In some examples, the response frame transmitting manager **1940** may be configured as or otherwise support a means for transmitting a response frame based on receiving the initiating frame. In some examples, the ACK frame receiving manager **1950** may be configured as or otherwise support a means for receiving, from the second wireless device, an ACK frame based on transmitting the response frame, where the second beam training procedure is performed based on receiving the ACK frame.

In some examples, the initiating frame includes a QoS null frame including a control field, the control field including a buffer status report, the indication as to whether the first wireless device is requesting to perform the second beam training procedure, or both. In some examples, the first wireless device includes an STA, a first MLD, or both. In some examples, the second wireless device includes an AP, a second MLD, or both. In some examples, the first wireless device includes the AP and. In some examples, the second wireless device includes the STA.

FIG. **20** shows a diagram of a system **2000** including a device **2005** that supports beam training techniques in Wi-Fi frequency bands in accordance with one or more aspects of the present disclosure. The device **2005** may be an example of or include the components of a device **1705**, a device **1805**, or an AP as described herein. The device **2005** may include components for bi-directional voice and data communications including components for transmitting and receiving communications, such as a communications manager **2020**, a network communications manager **2010**, a transceiver **2015**, an antenna **2025**, a memory **2030**, code **2035**, a processor **2040**, and an inter-AP communications manager **2045**. These components may be in electronic communication or otherwise coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more buses (e.g., a bus **2050**).

The network communications manager **2010** may manage communications with a core network (e.g., via one or more wired backhaul links). For example, the network communications manager **2010** may manage the transfer of data communications for client devices, such as one or more STAs **115**.

In some cases, the device **2005** may include a single antenna **2025**. However, in some other cases the device **2005** may have more than one antenna **2025**, which may be capable of concurrently transmitting or receiving multiple wireless transmissions. The transceiver **2015** may communicate bi-directionally, via the one or more antennas **2025**, wired, or wireless links as described herein. For example, the transceiver **2015** may represent a wireless transceiver and may communicate bi-directionally with another wireless transceiver. The transceiver **2015** may also include a modem to modulate the packets and provide the modulated packets to one or more antennas **2025** for transmission, and to demodulate packets received from the one or more antennas **2025**. The transceiver **2015**, or the transceiver **2015** and one or more antennas **2025**, may be an example of a transmitter **1715**, a transmitter **1815**, a receiver **1710**, a receiver **1810**, or any combination thereof or component thereof, as described herein.

The memory **2030** may include RAM and ROM. The memory **2030** may store computer-readable, computer-executable code **2035** including instructions that, when executed by the processor **2040**, cause the device **2005** to perform various functions described herein. In some cases, the memory **2030** contain, among other things, a BIOS which may control basic hardware or software operation such as the interaction with peripheral components or devices.

The processor **2040** 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 **2040** may be configured to operate a memory array using a memory controller. In some other cases, a memory controller may be integrated into the processor **2040**. The processor **2040** may be configured to execute computer-readable instructions stored in a memory (e.g., the memory **2030**) to cause the device **2005** to perform various functions (e.g., functions or tasks supporting beam training techniques in Wi-Fi frequency bands). For example, the device **2005** or a component of the device **2005** may include a processor **2040** and memory **2030** coupled with or to the processor **2040**, the processor **2040** and memory **2030** configured to perform various functions described herein.

The inter-station communications manager **2045** may manage communications with other APs **105**, and may include a controller or scheduler for controlling communications with STAs **115** in cooperation with other APs **105**. For example, the inter-station communications manager **2045** may coordinate scheduling for transmissions to APs **105** for various interference mitigation techniques such as beamforming or joint transmission. In some examples, the inter-station communications manager **2045** may provide an X2 interface within an LTE/LTE-A wireless communication network technology to provide communication between APs **105**.

The communications manager **2020** may support wireless communications at a first wireless device in accordance with examples as disclosed herein. For example, the communications manager **2020** may be configured as or otherwise support a means for monitoring for an initiating frame from a second wireless device during an SP, where the initiating frame is monitored using a receive beam based on a first beam training procedure performed between the first wireless device and the second wireless device prior to the SP. The communications manager **2020** may be configured as or otherwise support a means for performing a second beam training procedure during the SP based on an absence of the initiating frame, based on the initiating frame being received and including an indication that the second wireless device is requesting to perform a second beam training procedure with the first wireless device, or based on identification of a change in a wireless channel during a previous beam training interval or previous SP. The communications manager **2020** may be configured as or otherwise support a means for communicating one or more messages with the second wireless device using one or more beams based on the second beam training procedure.

By including or configuring the communications manager **2020** in accordance with examples as described herein, the device **2005** may support techniques that enable wireless devices (e.g., AP MLD **135**, non-AP MLD **130**) to perform beam training procedures within an SP used for communications between the respective devices. By exchanging initiating frames and/or response frames within a SP, wireless devices (e.g., AP MLD, non-AP MLD) may be able to determine whether or not the wireless devices are expected to perform a new beam training procedure within the SP. As such, techniques described herein may enable the wireless devices to perform beam training procedures within SPs to

enable more efficient and reliable wireless communications between the respective devices.

FIG. **21** shows a flowchart illustrating a method **2100** that supports beam training techniques in Wi-Fi frequency bands in accordance with one or more aspects of the present disclosure. The operations of the method **2100** may be implemented by an STA or its components as described herein. For example, the operations of the method **2100** may be performed by an STA as described with reference to FIGs. FIG. **1** through **16**. In some examples, an STA may execute a set of instructions to control the functional elements of the STA to perform the described functions. Additionally, or alternatively, the STA may perform aspects of the described functions using special-purpose hardware.

At **2105**, the method may include transmitting, to a second wireless device during an SP, an initiating frame using a transmit beam based on a first beam training procedure performed between the first wireless device and the second wireless device prior to the SP. The operations of **2105** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **2105** may be performed by an initiating frame transmitting manager **1525** as described with reference to FIG. **15**.

At **2110**, the method may include performing a second beam training procedure during the SP based on an absence of a response frame from the second wireless device, based on an indication within the response frame received from the second wireless device, or based on identification of a change in a wireless channel relative to a previous beam training interval or previous SP, the response frame being in response to the initiating frame. The operations of **2110** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **2110** may be performed by a beam training procedure manager **1530** as described with reference to FIG. **15**.

At **2115**, the method may include communicating one or more messages with the second wireless device using one or more beams based on the second beam training procedure. The operations of **2115** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **2115** may be performed by a message communicating manager **1535** as described with reference to FIG. **15**.

FIG. **22** shows a flowchart illustrating a method **2200** that supports beam training techniques in Wi-Fi frequency bands in accordance with one or more aspects of the present disclosure. The operations of the method **2200** may be implemented by an AP or its components as described herein. For example, the operations of the method **2200** may be performed by an AP as described with reference to FIGs. FIG. **1** through **12** and **17** through **20**. In some examples, an AP may execute a set of instructions to control the functional elements of the AP to perform the described functions. Additionally, or alternatively, the AP may perform aspects of the described functions using special-purpose hardware.

At **2205**, the method may include monitoring for an initiating frame from a second wireless device during an SP, where the initiating frame is monitored using a receive beam based on a first beam training procedure performed between the first wireless device and the second wireless device prior to the SP. The operations of **2205** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **2205** may be performed by an initiating frame receiving manager **1925** as described with reference to FIG. **19**.

At **2210**, the method may include performing a second beam training procedure during the SP based on an absence of the initiating frame, based on the initiating frame being received and including an indication that the second wireless device is requesting to perform a second beam training procedure with the first wireless device, or based on identification of a change in a wireless channel during a previous beam training interval or previous SP. The operations of **2210** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **2210** may be performed by a beam training procedure manager **1930** as described with reference to FIG. **19**.

At **2215**, the method may include communicating one or more messages with the second wireless device using one or more beams based on the second beam training procedure. The operations of **2215** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **2215** may be performed by a message communicating manager **1935** as described with reference to FIG. **19**.

FIG. **23** shows a flowchart illustrating a method **2300** that supports beam training techniques in Wi-Fi frequency bands in accordance with one or more aspects of the present disclosure. The operations of the method **2300** may be implemented by an STA or its components as described herein. For example, the operations of the method **2300** may be performed by an STA as described with reference to FIGs. FIG. **1** through **16**. In some examples, an STA may execute a set of instructions to control the functional elements of the STA to perform the described functions. Additionally, or alternatively, the STA may perform aspects of the described functions using special-purpose hardware.

At **2305**, the method may include monitoring for signals from a second wireless device during a BTI, the signals associated with a first beam training procedure between the first wireless device and the second wireless device. The operations of **2305** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **2305** may be performed by a monitoring manager **1540** as described with reference to FIG. **15**.

At **2310**, the method may include performing a second beam training procedure during an SP in response to the signals being monitored or an absence of the signals associated with the first beam training procedure. The operations of **2310** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **2310** may be performed by a beam training procedure manager **1530** as described with reference to FIG. **15**.

At **2315**, the method may include communicating one or more messages with the second wireless device using one or more beams based on the second beam training procedure. The operations of **2315** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **2315** may be performed by a message communicating manager **1535** as described with reference to FIG. **15**.

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. Furthermore, aspects from two or more of the methods may be combined.

The following provides an overview of aspects of the present disclosure:

Aspect 1: A method for wireless communications at a first wireless device, comprising: transmitting, to a second wireless device during a SP, an initiating frame using a transmit beam based at least in part on a first beam

training procedure performed between the first wireless device and the second wireless device prior to the SP; performing a second beam training procedure during the SP based at least in part on an absence of a response frame from the second wireless device, based at least in part on an indication within the response frame received from the second wireless device, or based at least in part on identification of a change in a wireless channel relative to a previous beam training interval or previous SP, the response frame being in response to the initiating frame; and communicating one or more messages with the second wireless device using one or more beams based at least in part on the second beam training procedure.

Aspect 2: The method of aspect 1, further comprising: communicating, with the second wireless device, control signaling indicating a plurality of SPs associated with the first wireless device, the plurality of SPs including the SP, wherein the initiating frame is transmitted based at least in part on the control signaling.

Aspect 3: The method of any of aspects 1 through 2, wherein the initiating frame comprises an indication as to whether the first wireless device is requesting to perform the second beam training procedure with the second wireless device during the SP.

Aspect 4: The method of any of aspects 1 through 3, further comprising: performing one or more measurements on signals received from the second wireless device via a receive beam based at least in part on the first beam training procedure, wherein the initiating frame is transmitted based at least in part on whether the one or more measurements satisfy one or more thresholds.

Aspect 5: The method of aspect 4, wherein, the initiating frame comprises an indication that the first wireless device is requesting to perform the second beam training procedure based on the one or more measurements failing to satisfy the one or more thresholds, or the initiating frame comprises an indication that the first wireless device is not requesting to perform the second beam training procedure based on the one or more measurements satisfying the one or more thresholds

Aspect 6: The method of any of aspects 1 through 5, wherein the initiating frame comprises a buffer status report (BSR) associated with traffic to be communicated from the first wireless device to the second wireless device, the method further comprising: transmitting the traffic to the second wireless device using the one or more beams and based at least in part on the BSR.

Aspect 7: The method of aspect 6, further comprising: receiving, from the second wireless device, a trigger frame scheduling the traffic based at least in part on the BSR, wherein the traffic is transmitted based at least in part on the trigger frame.

Aspect 8: The method of aspect 7, further comprising: receiving downlink traffic from the second wireless device with the trigger frame.

Aspect 9: The method of any of aspects 1 through 8, wherein, the one or more messages are received from the second wireless device using a receive beam based at least in part on the second beam training procedure, a last frame of the one or more messages indicate an end of the one or more messages, an end of the SP, or both

Aspect 10: The method of aspect 9, wherein the first wireless device receives the one or more messages while in a first operational state associated with a first power consumption, the method further comprising: transitioning to a second operational state associated with a second power consumption that is less than the first power consumption based at least in part on the one or more messages indicating the end of the one or more messages, the end of the SP, or both.

Aspect 11: The method of any of aspects 1 through 10, further comprising: communicating one or more additional messages with the second wireless device during a second SP using the one or more beams based at least in part on the second beam training procedure.

Aspect 12: The method of aspect 11, wherein the one or more messages comprise an indication of the second SP for communications between the first wireless device and the second wireless device, the one or more additional messages is communicated based at least in part on the indication of the second SP.

Aspect 13: The method of any of aspects 1 through 12, wherein the initiating frame comprises the indication that the first wireless device is requesting to perform the second beam training procedure with the second wireless device, the method further comprising: receiving the response frame from the second wireless device based at least in part on the initiating frame, wherein the response frame comprises an acknowledgment of the second beam training procedure, wherein the second beam training procedure is performed based at least in part on the acknowledgment.

Aspect 14: The method of any of aspects 1 through 13, wherein the initiating frame comprises the indication that the first wireless device is requesting to perform the second beam training procedure with the second wireless device, the method further comprising: identifying the absence of the response frame from the second wireless device based at least in part on the initiating frame; and monitoring for signals from the second wireless device as part of the second beam training procedure based at least in part on the absence of the response frame.

Aspect 15: The method of any of aspects 1 through 14, further comprising: receiving, via the response frame, an indication that the second wireless device is requesting to perform the second beam training procedure with the first wireless device, wherein the second beam training procedure is performed based at least in part on receiving the response frame.

Aspect 16: The method of any of aspects 1 through 15, further comprising: identifying that a quantity of failed frame exchanges between the first wireless device and the second wireless device satisfies a threshold quantity based at least in part on transmitting the initiating frame, wherein the second beam training procedure is performed based at least in part on the identifying.

Aspect 17: The method of any of aspects 1 through 16, further comprising: receiving the response frame based at least in part on the initiating frame being transmitted; and transmitting, to the second wireless device, an acknowledgment frame based at least in part on the response frame, wherein the second beam training procedure is performed based at least in part on the acknowledgment frame.

Aspect 18: The method of any of aspects 1 through 17, wherein the initiating frame comprises a quality of service null frame comprising a control field, the control field comprising a BSR, the indication as to

whether the first wireless device is requesting to perform the second beam training procedure, or both.

Aspect 19: The method of any of aspects 1 through 18, wherein, the first wireless device comprises an STA, a first multi-link device, or both, and the second wireless device comprises an AP, a second multi-link device, or both, or the first wireless device comprises the AP and the second wireless device comprises the STA

Aspect 20: A method for wireless communications at a first wireless device, comprising: monitoring for an initiating frame from a second wireless device during a SP, wherein the initiating frame is monitored performed using a receive beam based at least in part on a first beam training procedure performed between the first wireless device and the second wireless device prior to the SP; performing a second beam training procedure during the SP based at least in part on an absence of the initiating frame, based at least in part on the initiating frame being received and comprising an indication that the second wireless device is requesting to perform a second beam training procedure with the first wireless device, or based at least in part on identification of a change in a wireless channel during a previous beam training interval or previous SP; and communicating one or more messages with the second wireless device using one or more beams based at least in part on the second beam training procedure.

Aspect 21: The method of aspect 20, further comprising: receiving the initiating frame; and transmitting a response frame to the second wireless device based at least in part on the initiating frame, wherein the second beam training procedure is performed based at least in part on the response frame being transmitted.

Aspect 22: The method of any of aspects 20 through 21, further comprising: identifying an absence of the initiating frame from the second wireless device based at least in part on the initiating frame being monitored, wherein the second beam training procedure is performed based at least in part on the absence of the initiating frame.

Aspect 23: The method of any of aspects 20 through 22, further comprising: communicating, with the second wireless device, control signaling indicating a plurality of SPs associated with the first wireless device, the plurality of SPs including the SP, wherein the initiating frame is monitored for based at least in part on the control signaling.

Aspect 24: The method of any of aspects 20 through 23, wherein the initiating frame comprises an indication as to whether the second wireless device is requesting to perform the second beam training procedure with the first wireless device during the SP.

Aspect 25: The method of any of aspects 20 through 24, further comprising: receiving, via the initiating frame and based at least in part on the monitoring, a BSR associated with traffic to be communicated from the second wireless device to the first wireless device; and receiving the traffic from the second wireless device using the one or more beams and based at least in part on the BSR.

Aspect 26: The method of aspect 25, further comprising: transmitting, to the second wireless device, a trigger frame scheduling the traffic based at least in part on the BSR, wherein the traffic is received based at least in part on the trigger frame.

Aspect 27: The method of aspect 26, further comprising: transmitting downlink traffic from the second wireless device along with the trigger frame.

Aspect 28: The method of any of aspects 20 through 27, wherein a last frame of the one or more messages indicate an end of the one or more messages, an end of the SP, or both.

Aspect 29: The method of any of aspects 20 through 28, wherein the one or more messages comprise an indication of a second SP for communications between the first wireless device and the second wireless device, the method further comprising: communicating one or more additional messages with the second wireless device during the second SP using the one or more beams based at least in part on the second beam training procedure.

Aspect 30: The method of any of aspects 20 through 29, further comprising: receiving, via the initiating frame and based at least in part on the monitoring, the indication that the second wireless device is requesting to perform the second beam training procedure with the second wireless device; and transmitting a response frame to the second wireless device based at least in part on the initiating frame, wherein the response frame comprises an acknowledgment of the second beam training procedure, wherein the second beam training procedure is performed based at least in part on the acknowledgment.

Aspect 31: The method of any of aspects 20 through 30, further comprising: transmitting a response frame based at last in part on receiving the initiating frame, wherein the response frame comprises an indication that the first wireless device is requesting to perform the second beam training procedure with the second wireless device, wherein the second beam training procedure is performed based at least in part on the response frame being transmitted.

Aspect 32: The method of any of aspects 20 through 31, further comprising: identifying that a quantity of failed frame exchanges between the first wireless device and the second wireless device satisfies a threshold quantity based at least in part on the monitoring, wherein the second beam training procedure is performed based at least in part on the identifying.

Aspect 33: The method of any of aspects 20 through 32, further comprising: transmitting a response frame based at least in part on the initiating frame being received; and receiving, from the second wireless device, an acknowledgment frame based at least in part on transmitting the response frame, wherein the second beam training procedure is performed based at least in part on the acknowledgment frame.

Aspect 34: The method of any of aspects 20 through 33, wherein the initiating frame comprises a quality of service null frame comprising a control field, the control field comprising a buffer status report, the indication as to whether the first wireless device is requesting to perform the second beam training procedure, or both.

Aspect 35: The method of any of aspects 20 through 34, wherein, the first wireless device comprises an STA, a first multi-link device, or both, and the second wireless device comprises an AP, a second multi-link device, or both, or the first wireless device comprises the AP and the second wireless device comprises the STA

Aspect 36: A method for wireless communications at a first wireless device, comprising: monitoring for signals from a second wireless device during a BTI, the

signals associated with a first beam training procedure between the first wireless device and the second wireless device; performing a second beam training procedure during a SP in response to the signals being monitored or an absence of the signals associated with the first beam training procedure; and communicating one or more messages with the second wireless device using one or more beams based at least in part on the second beam training procedure.

Aspect 37: The method of aspect 36, wherein the monitoring comprises: monitoring for a beacon frame in a beamformed mode.

Aspect 38: The method of any of aspects 36 through 37, further comprising: receiving a beacon frame from the second wireless device based at least in part on the signals being monitored, the beacon frame associated with the first beam training procedure; and refraining from transmission of an initiating frame within the SP based at least in part on the beam training procedure comprising an initial beam training procedure between the first wireless device and the second wireless device, wherein the second beam training procedure is performed based at least in part on the initiating frame being refrained from transmission.

Aspect 39: The method of any of aspects 36 through 38, further comprising: identifying an absence of an initiating frame communicated between the first wireless device and the second wireless device within the SP, wherein the second beam training procedure is performed based at least in part on the absence of the initiating frame.

Aspect 40: An apparatus for wireless communications at a first wireless device, comprising a processor; memory coupled with the processor; and instructions stored in the memory and executable by the processor to cause the apparatus to perform a method of any of aspects 1 through 19.

Aspect 41: An apparatus for wireless communications at a first wireless device, comprising at least one means for performing a method of any of aspects 1 through 19.

Aspect 42: A non-transitory computer-readable medium storing code for wireless communications at a first wireless device, the code comprising instructions executable by a processor to perform a method of any of aspects 1 through 19.

Aspect 43: An apparatus for wireless communications at a first wireless device, comprising a processor; memory coupled with the processor; and instructions stored in the memory and executable by the processor to cause the apparatus to perform a method of any of aspects 20 through 35.

Aspect 44: An apparatus for wireless communications at a first wireless device, comprising at least one means for performing a method of any of aspects 20 through 35.

Aspect 45: A non-transitory computer-readable medium storing code for wireless communications at a first wireless device, the code comprising instructions executable by a processor to perform a method of any of aspects 20 through 35.

Aspect 46: An apparatus for wireless communications at a first wireless device, comprising a processor; memory coupled with the processor; and instructions stored in the memory and executable by the processor to cause the apparatus to perform a method of any of aspects 36 through 39.

Aspect 47: An apparatus for wireless communications at a first wireless device, comprising at least one means for performing a method of any of aspects 36 through 39.

Aspect 48: A non-transitory computer-readable medium storing code for wireless communications at a first wireless device, the code comprising instructions executable by a processor to perform a method of any of aspects 36 through 39.

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. The terms "system" and "network" are often used interchangeably. A code division multiple access (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 time division multiple access (TDMA) system may implement a radio technology such as Global System for Mobile Communications (GSM). An orthogonal frequency division multiple access (OFDMA) system may implement a radio technology such as Ultra Mobile Broadband (UMB), Evolved UTRA (E-UTRA), IEEE 802.11 (Wi-Fi), IEEE 802.16 (WiMAX), IEEE 802.20, Flash-OFDM, etc.

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

The downlink transmissions described herein may also be called forward link transmissions while the uplink transmissions may also be called reverse link transmissions. Each communication link described herein—including, for example, WLAN **100** and **200** of FIGS. **1** and **2**—may include one or more carriers, where each carrier may be a signal made up of multiple sub-carriers (e.g., waveform signals of different frequencies).

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.

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.

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.

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 conventional processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of computing devices (e.g., a combination of a DSP and a microprocessor, multiple microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration).

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 may be implemented using software executed by a processor, hardware, firmware, hardwiring, or combinations of any of these. Features implementing functions may also be physically located at various positions, including being distributed such that portions of functions are implemented at different physical locations. Also, as used herein, including in the claims, "or" as used in a list of items (for example, 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."

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 can comprise RAM, ROM, electrically erasable programmable read-only memory (EEPROM), 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, digital subscriber line (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.

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 first wireless device for wireless communication, comprising:

one or more memories storing processor-executable code; and

one or more processors coupled with the one or more memories and individually or collectively operable to execute the code to cause the first wireless device to:

transmit, to a second wireless device during a service period, an initiating frame using a transmit beam;

perform a beam training procedure during the service period based at least in part on an absence of a response frame from the second wireless device; and

communicate one or more messages with the second wireless device using one or more beams based at least in part on the beam training procedure.

2. The first wireless device of claim **1**, wherein the one or more processors are individually or collectively further operable to execute the code to cause the first wireless device to:

communicate, with the second wireless device, control signaling indicating a plurality of service periods associated with the first wireless device, the plurality of service periods including the service period, wherein the initiating frame is transmitted based at least in part on the control signaling.

3. The first wireless device of claim **1**, wherein the initiating frame comprises an indication as to whether the first wireless device is requesting to perform the beam training procedure with the second wireless device during the service period.

4. The first wireless device of claim **1**, wherein the one or more processors are individually or collectively further operable to execute the code to cause the first wireless device to:

perform one or more measurements on signals received from the second wireless device via a receive beam, wherein the initiating frame is transmitted based at least in part on whether the one or more measurements satisfy one or more thresholds.

5. The first wireless device of claim **4**, wherein the initiating frame comprises an indication that the first wire-

less device is requesting to perform the beam training procedure based on the one or more measurements failing to satisfy the one or more thresholds, or wherein the initiating frame comprises an indication that the first wireless device is not requesting to perform the beam training procedure based on the one or more measurements satisfying the one or more thresholds.

6. The first wireless device of claim **1**, wherein the initiating frame comprises a buffer status report, and wherein the one or more processors are individually or collectively further operable to execute the code to cause the first wireless device to:

transmit traffic to the second wireless device using the one or more beams and based at least in part on the buffer status report.

7. The first wireless device of claim **6**, wherein the one or more processors are individually or collectively further operable to execute the code to cause the first wireless device to:

receive, from the second wireless device, a trigger frame scheduling the traffic based at least in part on the buffer status report, wherein the traffic is transmitted based at least in part on the trigger frame.

8. A method for wireless communication by a first wireless device, comprising:

transmitting, to a second wireless device during a service period, an initiating frame using a transmit beam;

performing a beam training procedure during the service period based at least in part on an absence of a response frame from the second wireless device; and

communicating one or more messages with the second wireless device using one or more beams based at least in part on the beam training procedure.

9. The method of claim **8**, further comprising:

communicate, with the second wireless device, control signaling indicating a plurality of service periods associated with the first wireless device, the plurality of service periods including the service period, wherein the initiating frame is transmitted based at least in part on the control signaling.

10. The method of claim **8**, wherein the initiating frame comprises an indication as to whether the first wireless device is requesting to perform the beam training procedure with the second wireless device during the service period.

11. The method of claim **8**, further comprising:

performing one or more measurements on signals received from the second wireless device via a receive beam, wherein the initiating frame is transmitted based at least in part on whether the one or more measurements satisfy one or more thresholds.

12. The method of claim **11**, wherein the initiating frame comprises an indication that the first wireless device is requesting to perform the beam training procedure based on the one or more measurements failing to satisfy the one or more thresholds, or wherein the initiating frame comprises an indication that the first wireless device is not requesting to perform the beam training procedure based on the one or more measurements satisfying the one or more thresholds.

13. The method of claim **8**, wherein the initiating frame comprises a buffer status report, further comprising:

transmitting traffic to the second wireless device using the one or more beams and based at least in part on the buffer status report.

14. The method of claim **13**, further comprising:

receiving, from the second wireless device, a trigger frame scheduling the traffic based at least in part on the buffer status report, wherein the traffic is transmitted based at least in part on the trigger frame.

15. A non-transitory, computer-readable medium for storing code for wireless communication, the code comprising instructions executable by one or more processors to:

transmit, by a first wireless device and to a second wireless device during a service period, an initiating frame using a transmit beam;

perform a beam training procedure during the service period based at least in part on an absence of a response frame from the second wireless device; and

communicate one or more messages with the second wireless device using one or more beams based at least in part on the beam training procedure.

16. The non-transitory, computer-readable medium of claim **15**, wherein the instructions are further executable by the one or more processors to:

communicate, with the second wireless device, control signaling indicating a plurality of service periods associated with the first wireless device, the plurality of service periods including the service period, wherein the initiating frame is transmitted based at least in part on the control signaling.

17. The non-transitory, computer-readable medium of claim **15**, wherein the initiating frame comprises an indication as to whether the first wireless device is requesting to perform the beam training procedure with the second wireless device during the service period.

18. The non-transitory, computer-readable medium of claim **15**, wherein the instructions are further executable by the one or more processors to:

perform one or more measurements on signals received from the second wireless device via a receive beam, wherein the initiating frame is transmitted based at least in part on whether the one or more measurements satisfy one or more thresholds.

19. The non-transitory, computer-readable medium of claim **18**, wherein the initiating frame comprises an indication that the first wireless device is requesting to perform the beam training procedure based on the one or more measurements failing to satisfy the one or more thresholds, or wherein the initiating frame comprises an indication that the first wireless device is not requesting to perform the beam training procedure based on the one or more measurements satisfying the one or more thresholds.

20. The non-transitory, computer-readable medium of claim **15**, wherein the initiating frame comprises a buffer status report, and wherein the instructions are further executable by the one or more processors to:

transmit traffic to the second wireless device using the one or more beams and based at least in part on the buffer status report.

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