(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
17 January 2019 (17.01.2019)

WIPO | PCT

(10) International Publication Number
WO 2019/014385 A1

(51) International Patent Classification:
*H04B 7/06* (2006.01) *H04W 16/28* (2009.01)

(21) International Application Number:
PCT/US2018/041698

(22) International Filing Date:
11 July 2018 (11.07.2018)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
62/532,253 13 July 2017 (13.07.2017) US

(71) Applicant: **INTEL CORPORATION** [US/US]; 2200 Mission College Boulevard, Santa Clara, California 95054 (US).

(72) Inventors: **CORDEIRO, Carlos**; 4038 NW McGrath Ct., Portland, Oregon 97229 (US). **DA SILVA, Claudio**; 3041 NW 111th Ter., Portland, Oregon 97229 (US). **CHEN, Cheng**; 14947 NW Rossetta Street, Portland, Oregon 97229 (US). **LOMAYEV, Artyom**; Turgeneva str 30, Nizhny Novgorod, 603024 (RU).

(74) Agent: **GRIFFIN III, Malvern U.** et al.; Eversheds Sutherland (US) LLP, 999 Peachtree Street NE, Suite 2300, Atlanta, Georgia 30309 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

**Declarations under Rule 4.17:**

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

(54) Title: ENHANCED FAST BEAM REFINEMENT PROTOCOL FRAME PROCESSING MODE FOR WIRELESS COMMUNICATIONS

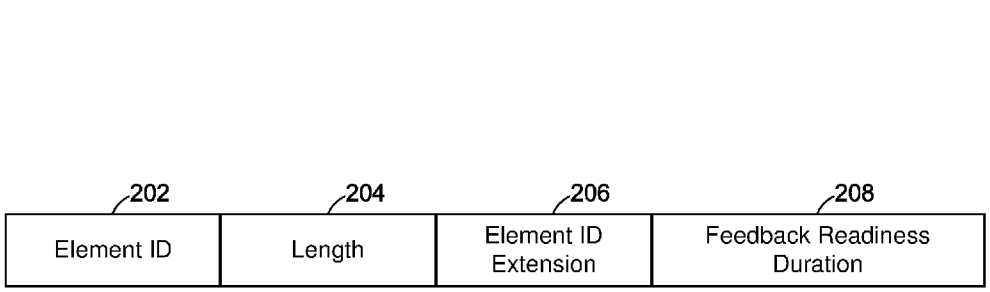



FIG. 2

(57) Abstract: This disclosure describes systems, methods, and devices related to fast beam refinement protocol (BRP) frame processing in wireless communications. A device may determine a BRP mode for a BRP procedure with an enhanced directional multi-gigabit (EDMG) station device. The device may determine a BRP frame including an indication of the BRP mode, the indication indicating a presence of one or more elements of the BRP frame, at least one element having a fixed length. The device may send the BRP frame. The device may receive a BRP response frame from the EDMG station device including a BRP comeback time element indicating a time for measurement feedback to be identified.

WO 2019/014385 A1

[Continued on next page]

**Published:**

— *with international search report (Art. 21(3))*

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

# ENHANCED FAST BEAM REFINEMENT PROTOCOL FRAME PROCESSING MODE FOR WIRELESS COMMUNICATIONS

## CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application No. 62/532,253, filed July 13, 2017, the disclosure of which is incorporated by reference as if set forth in full.

## TECHNICAL FIELD

[0002] This disclosure generally relates to systems and methods for wireless communications and, more particularly, to fast beam refinement protocol (BRP) frame processing.

## BACKGROUND

[0003] Wireless devices are becoming widely prevalent and are increasingly requesting access to wireless channels. Wireless devices in a communication network may improve transmissions through efficient operations.

## BRIEF DESCRIPTION OF THE DRAWINGS

[0004] FIG. 1 depicts a network diagram illustrating an example network, in accordance with one or more example embodiments of the present disclosure.

[0005] FIG. 2 depicts an illustrative beam refinement protocol (BRP) comeback time element format, in accordance with one or more example embodiments of the present disclosure.

[0006] FIG. 3A illustrates a flow diagram of an illustrative process for enhanced fast BRP frame processing, in accordance with one or more example embodiments of the present disclosure.

[0007] FIG. 3B illustrates a flow diagram of an illustrative process for enhanced fast BRP frame processing, in accordance with one or more example embodiments of the present disclosure.

[0008] FIG. 4 illustrates a functional diagram of an example communication station that may be suitable for use as a user device, in accordance with one or more example embodiments of the present disclosure.

[0009] FIG. 5 is a block diagram of an example machine upon which any of one or more techniques (e.g., methods) may be performed, in accordance with one or more example embodiments of the present disclosure.

## DETAILED DESCRIPTION

[0010] The following description and the drawings sufficiently illustrate specific embodiments to enable those skilled in the art to practice them. Other embodiments may incorporate structural, logical, electrical, process, and other changes. Portions and features of some embodiments may be included in, or substituted for, those of other embodiments. Embodiments set forth in the claims encompass all available equivalents of those claims.

[0011] Wireless communications protocols such as Wi-Fi may use beamforming to facilitate directional communications between devices. A device antenna may direct energy from a transmitter in one or more directions for the communication of wireless signals. In an omnidirectional transmission, an antenna transmits using antenna sectors (e.g., directions) which may cover a 360 degree pattern, whereas in a directional transmission, an antenna may direct radiofrequency energy in a particular direction to allow for transmission of longer distances than when using omnidirectional transmissions, for example.

[0012] Beamforming may allow devices to establish optimal antenna configurations to use in a directional communication link with another device. As referred to herein, a device which begins a beamforming process is known as an initiator, and a device which receives an initiator's beamforming request is known as a responder. IEEE 802.11 communication standards define some beamforming processes between devices. For example, beamforming may include a sector-level sweep (SLS), a BRP, and beam tracking (BT). In an SLS procedure, devices may train their respective antennas to select the best antenna configurations to use. In BRP, devices may use the best antenna settings determined in an SLS procedure, and those best antenna settings may change over time.

[0013] Conventional sector sweeps not extended for use with channel bonding and multiple input, multiple output (MIMO) communications may use BRP. The IEEE 802.11 standard defines BRP frames, such as BRP request and BRP response frames, exchanged between an initiator and a responder device performing BRP. The processing time of a BRP frame which includes one or more of new elements defined for enhanced directional multi-gigabit (EDMG) station devices (STAs) may be excessive for some implementations. This is because the BRP frame format is flexible and includes optional elements that may or may not be present depending on whether the frame is used for the request, response, or request and response of a BRP procedure. Also, the length of certain elements included in the BRP frame format may be variable.

[0014] Hardware processing of BRP frames may be more efficient than software processing. For example, software processing may require interaction between hardware and software. Therefore, hardware processing alone may be faster. However, hardware processing may significantly limit flexibility in wireless communications. For example, hardware may not be the most efficient way to process variable length elements of wireless frames, and increased data processing complexity caused by the presence of one or more optional elements in a wirelessly communicated frame may be required. Hardware may need to be designed to process a maximum amount of data, and when less than the maximum amount is processed by hardware, such results in a waste of hardware resources. When an amount of information is more than the hardware may process alone, then the hardware may rely on software to perform some of the processing. Thus, as wireless communication technology develops and IEEE 802.11 standards add communication capabilities, increased hardware complexity may be required to account for additional elements transmitted in frames such as BRP frames. To facilitate processing of additional information in BRP frames and reduce the corresponding increase in hardware, an enhanced fast BRP frame processing may be implemented.

[0015] One way to improve BRP frame processing may be to define a new BRP frame format that includes new elements required to support new communication capabilities of IEEE 802.11 standards. However, the definition of a new BRP frame format may require software processing and/or new hardware. Because software processing may be slower than hardware processing, it may be desirable to process as much information in a BRP frame using hardware. Because the definition of new fields and elements in a frame may require new hardware, however, device changes may be required by a new BRP frame format. Rather than defining a new BRP frame format, the existing BRP frame format may be used, and reserved bits may be reassigned to indicate to the hardware what the content is and what the goal of the BRP frame is (e.g., a legacy mode, a request mode, a response mode, or a request and response mode). This way, for example, hardware may determine which information of a received BRP frame may be processed with the hardware (e.g., which frame elements are present and have a fixed length). Based on the goal of a BRP frame, different elements may be present. The hardware may efficiently process a BRP frame once the hardware determines which fixed length elements are to be processed in the BRP frame.

[0016] After a BRP procedure is performed between an initiator and responder device, the responder device may send feedback regarding the best antenna configurations used in the communication exchange. Processing measurements take to determine the best antenna

configurations may take a significant amount of time, especially for a large amount of antenna configurations to be considered. Timing requirements to process the measurements and provide feedback therefore may be difficult to meet. In some cases, devices may not be able to meet the timing requirements (e.g., short interframe space, BRP interframe space).

[0017] It may be possible to reduce the BRP feedback interval. As a result of increased BRP frame processing complexity and reduced BRP feedback interval, it may be necessary to include new definitions and/or procedures in the IEEE 802.11 standards to ease the processing of a BRP frame.

[0018] It may therefore be desirable to modify an existing BRP frame to facilitate fast BRP frame processing. It also may be desirable to define a BRP comeback time element format to address the timing requirement of BRP feedback.

[0019] Example embodiments of the present disclosure relate to systems, methods, and devices for enhanced fast BRP frame processing for wireless communications.

[0020] In one or more embodiments, the existing BRP frame format may be defined and modified to ease the complexity and processing time of its processing. For example, signaling for a "fast BRP mode" which allows EDMG STAs to more easily parse through different elements of a BRP frame may be defined, and a new feedback element of fixed length may be defined. In addition, a method which reduces the amount of time that a channel remains unused while an STA prepares BRP feedback may be defined. Rather than defining a new BRP frame, the existing BRP frame format defined in the IEEE 802.11ad/ay standards may be reused and redefined for enhanced processing.

[0021] The different fields and elements of a BRP frame serve different purposes – such as requesting a BRP, responding to a BRP request, and/or providing BRP measurements – and may have variable length, which may increase processing requirements. Therefore, the time required to process a BRP frame, particularly if the BRP frame includes an EDMG element and/or a feedback element, may be excessive for some implementations and/or BRP flows, and may vary greatly depending on the elements and their configuration, including length.

[0022] In one or more embodiments, to address the processing problem while using the existing BRP frame format, a "fast BRP mode" may enable faster hardware/firmware processing of BRP frames, and may be used only by EDMG STAs. The "fast BRP mode" of a BRP frame may be indicated using reserved bits in a BRP request field of the BRP frame. For example, by using two bits, the following combinations/configurations could be indicated: 0 – legacy mode (e.g., IEEE 802.11ad), 1 – fast BRP mode request, 2 – fast BRP mode

response, and 3 – fast BRP mode request and response. One field (e.g., a BRP Request field) with two bits may provide the indication, or a respective bit of two different fields (e.g., EDMG-Short-BRP and EDMG-SHORT-FBCK) may provide the indication. Mode 0 may be represented by a bit combination of 00; mode 1 may be represented by a bit combination of 10; mode 2 may be represented by a bit combination of 01; and mode 3 may be represented by a bit combination of 11. Any combination of two bits may be associated with one of the modes. One bit may indicate whether an EDMG BRP field is present following the BRP request field, and another bit may indicate whether an EDMG short feedback (FBCK) field is present following an EDMG BRP field.

[0023] In one or more embodiments, a BRP frame may include the following information: category, unprotected DMG action, dialog token, BRP request field, DGM beam refinement element, zero or more channel measurement feedback elements, EDMG partial sector sweep element, EDMG BRP request element, and/or zero or more EDMG channel measurement feedback elements. The BRP request field is mandatory in BRP frames and has fixed elements/fields, making it easy to process with hardware. Other elements of a BRP frame may be processed in software (e.g., because some elements may be of variable length). The BRP request field may indicate which other information is included in the BRP frame. A device which receives a BRP frame may determine, using the BRP request field or other fields, what the purpose of the BRP frame is and which other fields/elements are present in the BRP frame. For example, when the EDMG-Short-BRP subfield of a BRP frame is one, a BRP action field format may include the category, unprotected DMG action, dialog token, BRP request field, EDMG BRP field, and an optional short BRP feedback field. When the EDMG-Short-FBCK subfield is one, the number of feedback measurements may be capped/fixed to a constant value (e.g., sixteen measurements).

[0024] In one or more embodiments, each of the fast BRP modes defined above may be associated with a certain behavior (e.g., request, response, request + response). For each fast BRP mode, the elements present in the BRP frame and having a fixed length may be defined along with which of their fields are valid or may be ignored. For example, for a given fast BRP mode, which fields of the DMG Beam Refinement element and/or EDMG BRP Request element are valid or ignored may be defined. Defining elements of fixed length present in a BRP frame may allow hardware processing to be more efficient because the hardware of a device may recognize which elements of a BRP to process or ignore.

[0025] In one or more embodiments, to further simplify the processing of BRP frames, a new feedback element may be specified for the fast BRP mode to allow efficient feedback of a certain number of measurements. In this case, the length of such feedback element may be fixed rather than variable as in the elements used for feedback.

[0026] In one or more embodiments, for DMG STAs and EDMG STAs, BRP responses may be separated in time from BRP requests by at most a BRP interframe space (BRPIFS) interval (e.g., 40 μs), which is enough time for the STA preparing the feedback to lose access to the channel. To address this issue, which becomes more of a problem in IEEE 802.11ay communications due to multichannel operations and support to larger antenna arrays, the maximum interval between a BRP response from a BRP request may be defined as medium beamforming interframe space (MBIFS) (e.g., 9 μs) when the fast BRP mode is used. The shortened time difference is possible due to the reduced time required to process a BRP frame using fast BRP mode, and because of the new feedback element associated with the BRP fast mode having a fixed length and a predefined number of measurements.

[0027] In one or more embodiments, to support BRP requests which may require more complex feedback, such as the use of "conventional" Channel Measurement Feedback element or EDMG Channel Measurement Feedback element, and may require more than an MBIFS interval for preparing the BRP feedback, a new BRP Comeback Time element may be included in a BRP frame and may allow an STA to communicate to a peer STA a time when the STA expects feedback to be ready to communicate. This element may be included in the BRP frame and may include a Feedback Readiness Duration field, which may specify in units of milliseconds, when the complex feedback is ready to be returned to the peer STA. Following the expiration of the value of a Feedback Readiness Duration field, the peer STA may send a BRP frame requesting the full feedback. The responder may provide the full feedback in MBIFS or short interframe space (SIFS) time if the feedback is ready to be sent. If the BRP feedback is not ready, the EDMG STA may send an acknowledgment frame to the peer STA to indicate that the feedback is not ready.

[0028] In one or more embodiments, the BRP frame format using fast BRP mode for a request plus response may include the category, unprotected DMG, dialog token, BRP request field, DMG beam refinement element, fast BRP feedback element, and BRP comeback time element. In a request-only mode, the DMG beam refinement element may be present to allow backward compatibility, but its content may be ignored by a device.

[0029] The above descriptions are for purposes of illustration and are not meant to be limiting. Numerous other examples, configurations, processes, etc., may exist, some of which are described in greater detail below. Example embodiments will now be described with reference to the accompanying figures.

[0030] FIG. 1 is a network diagram illustrating an example network environment, according to some example embodiments of the present disclosure. Wireless network 100 may include one or more user device(s) 120 and one or more access point(s) (AP) 102, which may communicate in accordance with IEEE 802.11 communication standards, such as, the IEEE 802.11ay, 802.11ad, Next Generation 60 GHz (NG60), and WiGig specifications. The user device(s) 120 may be mobile devices that are non-stationary and do not have fixed locations.

[0031] In some embodiments, the user device(s) 120 and AP 102 may include one or more computer systems similar to that of the functional diagram of FIG. 5 and/or the example machine/system of FIG. 6.

[0032] One or more illustrative user device(s) 120 and/or AP 102 may be operable by one or more user(s) 110. It should be noted that any addressable unit may be a station (STA). An STA may take on multiple distinct characteristics, each of which shape its function. For example, a single addressable unit might simultaneously be a portable STA, a quality-of-service (QoS) STA, a dependent STA, and a hidden STA. The one or more illustrative user device(s) 120 and the AP(s) 102 may be STAs. The one or more illustrative user device(s) 120 and/or AP 102 may operate as a personal basic service set (PBSS) control point/access point (PCP/AP). The user device(s) 120 (e.g., 124, 126, or 128) and/or AP 102 may include any suitable processor-driven device including, but not limited to, a mobile device or a non-mobile, e.g., a static, device. For example, user device(s) 120 and/or AP 102 may include, for example, a DMG device, an EDMG device, a UE, an MD, a station (STA), an access point (AP), a personal computer (PC), a wearable wireless device (e.g., bracelet, watch, glasses, ring, etc.), a desktop computer, a mobile computer, a laptop computer, an ultrabooktm computer, a notebook computer, a tablet computer, a server computer, a handheld computer, a handheld device, an internet of things (IoT) device, a sensor device, a PDA device, a handheld PDA device, an on-board device, an off-board device, a hybrid device (e.g., combining cellular phone functionalities with PDA device functionalities), a consumer device, a vehicular device, a non-vehicular device, a mobile or portable device, a non-mobile or non-portable device, a mobile phone, a cellular telephone, a PCS device, a PDA device which incorporates a wireless communication device, a mobile or portable GPS device, a DVB device, a relatively small

computing device, a non-desktop computer, a "carry small live large" (CSLL) device, an ultra mobile device (UMD), an ultra mobile PC (UMPC), a mobile internet device (MID), an "origami" device or computing device, a device that supports dynamically composable computing (DCC), a context-aware device, a video device, an audio device, an A/V device, a set-top-box (STB), a blu-ray disc (BD) player, a BD recorder, a digital video disc (DVD) player, a high definition (HD) DVD player, a DVD recorder, a HD DVD recorder, a personal video recorder (PVR), a broadcast HD receiver, a video source, an audio source, a video sink, an audio sink, a stereo tuner, a broadcast radio receiver, a flat panel display, a personal media player (PMP), a digital video camera (DVC), a digital audio player, a speaker, an audio receiver, an audio amplifier, a gaming device, a data source, a data sink, a digital still camera (DSC), a media player, a smartphone, a television, a music player, or the like.

[0033] Any of the user device(s) 120 (e.g., user devices 124, 126, 128), and AP 102 may be configured to communicate with each other via one or more communications networks 130 and/or 135 wirelessly or wired. Any of the communications networks 130 and/or 135 may include, but not limited to, any one of a combination of different types of suitable communications networks such as, for example, broadcasting networks, cable networks, public networks (e.g., the Internet), private networks, wireless networks, cellular networks, or any other suitable private and/or public networks. Further, any of the communications networks 130 and/or 135 may have any suitable communication range associated therewith and may include, for example, global networks (e.g., the Internet), metropolitan area networks (MANs), wide area networks (WANs), local area networks (LANs), or personal area networks (PANs). In addition, any of the communications networks 130 and/or 135 may include any type of medium over which network traffic may be carried including, but not limited to, coaxial cable, twisted-pair wire, optical fiber, a hybrid fiber coaxial (HFC) medium, microwave terrestrial transceivers, radio frequency communication mediums, white space communication mediums, ultra-high frequency communication mediums, satellite communication mediums, or any combination thereof.

[0034] Any of the user device(s) 120 (e.g., user devices 124, 126, 128), and AP 102 may include one or more communications antennae. Communications antenna may be any suitable type of antenna corresponding to the communications protocols used by the user device(s) 120 (e.g., user devices 124, 124 and 128), and AP 102. Some non-limiting examples of suitable communications antennas include Wi-Fi antennas, Institute of Electrical and Electronics Engineers (IEEE) 802.11 family of standards compatible antennas, directional antennas, non-

directional antennas, dipole antennas, folded dipole antennas, patch antennas, multiple-input multiple-output (MIMO) antennas, or the like. The communications antenna may be communicatively coupled to a radio component to transmit and/or receive signals, such as communications signals to and/or from the user device(s) 120.

[0035] Any of the user device(s) 120 (e.g., user devices 124, 126, 128), and/or AP 102 may include any suitable radio and/or transceiver for transmitting and/or receiving radio frequency (RF) signals in the bandwidth and/or channels corresponding to the communications protocols utilized by any of the user device(s) 120 and/or AP 102 to communicate with each other. The radio components may include hardware and/or software to modulate and/or demodulate communications signals according to pre-established transmission protocols. The radio components may further have hardware and/or software instructions to communicate via one or more Wi-Fi and/or Wi-Fi direct protocols, as standardized by the Institute of Electrical and Electronics Engineers (IEEE) 802.11 standards. In certain example embodiments, the radio component, in cooperation with the communications antennas, may be configured to communicate via 2.4 GHz channels (e.g. 802.11b, 802.11g, 802.11n, 802.11ax), 5 GHz channels (e.g. 802.11n, 802.11ac, 802.11ax), or 60 GHZ channels (e.g. 802.11ad, 802.11ay). In some embodiments, non-Wi-Fi protocols may be used for communications between devices, such as Bluetooth, dedicated short-range communication (DSRC), Ultra-High Frequency (UHF) (e.g. IEEE 802.11af, IEEE 802.22), white band frequency (e.g., white spaces), or other packetized radio communications. The radio component may include any known receiver and baseband suitable for communicating via the communications protocols. The radio component may further include a low noise amplifier (LNA), additional signal amplifiers, an analog-to-digital (A/D) converter, one or more buffers, and digital baseband.

[0036] Some demonstrative embodiments may be used in conjunction with a wireless communication network communicating over a frequency band of 60GHz. However, other embodiments may be implemented utilizing any other suitable wireless communication frequency bands, for example, an Extremely High Frequency (EHF) band (the millimeter wave (mmWave) frequency band), e.g., a frequency band within the frequency band of between 20Ghz and 300GHZ, a WLAN frequency band, a WPAN frequency band, a frequency band according to the WGA specification, and the like.

[0037] The phrases "directional multi-gigabit (DMG)" and "directional band" (DBand), as used herein, may relate to a frequency band wherein the channel starting frequency is above 45 GHz. In one example, DMG communications may involve one or more directional links to

communicate at a rate of multiple gigabits per second, for example, at least 1 Gigabit per second, 7 Gigabit per second, or any other rate.

[0038] In some demonstrative embodiments, user device(s) 120 and/or AP 102 may be configured to operate in accordance with one or more specifications, for example, including, one or more IEEE 802.11 specifications, e.g., an IEEE 802.11ay, 802.11ad, NG60, and WiGig specifications and/or any other specification and/or protocol.

[0039] Some specifications, e.g., IEEE 802.11ay, 802.11ad, NG60, and WiGig specifications, may be configured to support a single user (SU) system, in which an STA cannot transmit frames to more than a single STA at a time. Such specifications may not be able, for example, to support a STA transmitting to multiple STAs simultaneously, for example, using an MU-MIMO scheme, e.g., a downlink (DL) MU-MIMO, or any other MU scheme.

[0040] In some demonstrative embodiments, user device(s) 120 and/or AP 102 may be configured to implement one or more Multi-User (MU) mechanisms. For example, user device(s) 120 and/or AP 102 may be configured to implement one or more MU mechanisms, which may be configured to enable MU communication of Downlink (DL) frames using a MIMO scheme, for example, between a device, e.g., AP 102, and a plurality of user devices, e.g., including user device(s) 120 and/or one or more other devices.

[0041] In some demonstrative embodiments, and/or AP 102 may be configured to communicate over a Next Generation 60 GHz (NG60) network, an Extended DMG (EDMG) network, and/or any other network. For example, and/or AP 102 may be configured to communicate MIMO, e.g., DL MU-MIMO, transmissions and/or use channel bonding, for example, for communicating over the NG60 and/or EDMG networks.

[0042] In some demonstrative embodiments, and/or AP 102 may be configured to support one or more mechanisms and/or features, for example, channel bonding, single user (SU) MIMO, and/or and multi user (MU) MIMO, for example, in accordance with an EDMG Standard, IEEE 802.11ay, 802.11ad, NG60, and WiGig specifications and/or any other standard and/or protocol.

[0043] In one embodiment, and with reference to FIG. 1, a device (e.g., AP 102) may be configured to communicate with one or more other devices (e.g., non-AP STAs, such as, user devices 120).

[0044] For example, in order for the AP 102 to establish communication with two devices (e.g., user device 124 and user device 128), the AP 102 may need to perform beamforming training with the user device 124 and the user device 128 using beams 104 and 106. In

beamforming, the AP 102 and/or the user devices 120 may exchange one or more BRP frames 140, whose format may be defined below by Table 1.

[0045] Table 1: BRP Frame Format.

| Order | Information |
|---|---|
| 1 | Category |
| 2 | Unprotected DMG Action |
| 3 | Dialog Token |
| 4 | BRP Request field |
| 5 | DMG Beam Refinement element |
| 6 | Zero or more Channel Measurement Feedback elements |
| 7 | EDMG Partial Sector Sweep element |
| 8 | EDMG BRP Request element (optional) |
| 9 | Zero or more EDMG Channel Measurement Feedback elements |

[0046] In one or more embodiments, a BRP frame may have a fixed number of elements/fields and may be easy to process with hardware. The BRP Request field of a BRP frame may indicate the presence of other subsequent elements in the BRP frame 140 having a fixed length. The different fields and elements of the BRP frame 140 may serve different purposes – such as requesting a BRP, responding to a BRP request, and/or providing BRP measurements – and may have variable length, which may complicate processing. Therefore, the time required to process the BRP frame 140, particularly if the BRP frame 140 includes an EDMG element and/or a feedback element, may be excessive for some implementations and/or BRP flows, and may vary greatly depending on the elements and their configuration. The BRP Request field or any one or more fields of the BRP frame 140 may indicate the type of BRP frame 140 and corresponding elements of fixed length present in the BRP frame 140 to allow hardware of a receiving device to process the one or more fields, determine the type of BRP frame 140, and determine which elements of the BRP frame 140 to process with hardware.

[0047] In one or more embodiments, to address the processing problem while using the existing BRP frame format, a "fast BRP mode" may enable faster hardware/firmware processing of BRP frames, and may be used only by EDMG STAs. The "fast BRP mode" of the BRP frame 140 may be indicated using reserved bits in a BRP request field of the BRP frame 140. For example, by using two bits, the following combinations/configurations could be indicated: 0 – legacy mode (e.g., IEEE 802.11ad), 1 – fast BRP mode request, 2 – fast BRP mode response, and 3 – fast BRP mode request and response. One field with two bits may

provide the indication, or a respective bit of two different fields (e.g., EDMG-Short-BRP and EDMG-SHORT-FBCK) may provide the indication. Mode 0 may be represented by 00; mode 1 may be represented by 10; mode 2 may be represented by 01; and mode 3 may be represented by 11. Any combination of two bits may be associated with one of the modes. One bit may indicate whether an EDMG BRP field is present following the BRP request field, and another bit may indicate whether an EDMG short feedback (FBCK) field is present following an EDMG BRP field.

[0048] In one or more embodiments, a device which receives the BRP frame 140 may determine, using the BRP request field, what the purpose of the BRP frame 140 is and which other fields/elements are present in the BRP frame 140. When the EDMG-Short-BRP subfield of the BRP frame 140 is one, a BRP action field format may include the category, unprotected DMG action, dialog token, BRP request field, EDMG BRP field, and an optional short BRP feedback field. When the EDMG-Short-FBCK subfield is one, the number of feedback measurements may be capped/fixed to a certain value (e.g., sixteen measurements).

[0049] In one or more embodiments, each of the fast BRP modes defined above may be associated with a certain behavior (e.g., request, response, request + response). For each fast BRP mode, the elements present in the BRP frame 140 and having a fixed length may be defined along with which of their fields are valid or may be ignored. For example, for a given fast BRP mode, which fields of the DMG Beam Refinement element and/or EDMG BRP Request element are valid or ignored may be defined.

[0050] The DMG Beam Refinement element and the zero or more channel measurement feedback elements may be included in IEEE 802.11ad BRP frames. The EDMG partial sector sweep element, the EDMG BRP request element, and the zero or more EDMG channel measurement feedback elements may be new elements in IEEE 802.11ay BRP frames. The presence of each of these fields may be indicated by the BRP request field, and the length of each of these elements may be indicated respectively by each element.

[0051] FIG. 2 depicts an illustrative portion 200 of a BRP comeback time element format, in accordance with one or more example embodiments of the present disclosure.

[0052] Referring to FIG. 2, the portion 200 may include one or more fields, such as an element identifier field (element ID 202), a length field 204, an element ID extension field 206, and a feedback readiness duration field 208. The BRP comeback time element may be used to further simplify the processing of BRP frames using the fast BRP mode to allow efficient

feedback of a certain number of measurements. In this case, the length of BRP comeback time element may be fixed rather than variable as in the elements used for feedback.

[0053] In one or more embodiments, the BRP comeback time element may be included in a BRP response frame. For example, a device may receive a BRP request frame including a request for measurement feedback. The BRP response frame may include the requested measurement feedback if available, but if the measurement feedback is not available within a given time (e.g., an interframe space), the BRP response frame may include the BRP comeback time element to indicate when the measurement feedback may be available.

[0054] In one or more embodiments, for DMG STAs, BRP responses may be separated in time from BRP requests by at most a BRPIFS interval (e.g., 40 μs), which is enough time for the STA preparing the feedback to lose access to the channel. To address this issue, which becomes more of a problem in IEEE 802.11ay communications due to multichannel operations and increased antenna sizes, the maximum interval between a BRP response from a BRP request may be defined as MBIFS (e.g., 9 μs) when the fast BRP mode is used. The shortened time difference is possible due to the reduced time required to process a BRP frame using fast BRP mode, and because of the new BRP comeback time element associated with the BRP fast mode having a fixed length and a predefined number of measurements.

[0055] In one or more embodiments, to support BRP requests which may require more complex feedback, such as the use of "conventional" Channel Measurement Feedback element or EDMG Channel Measurement Feedback element, and may require more than an MBIFS interval for preparing the BRP feedback, the new BRP comeback time element may be included in a BRP frame and may allow an STA to communicate to a peer STA a time when the STA expects feedback to be ready to communicate. This element may be included in the BRP frame and may include the feedback readiness duration field 208, which may specify in units of milliseconds, when the complex feedback is ready to be returned to the peer STA. Following the expiration of the value of the feedback readiness duration field 208, the peer STA may send a BRP frame requesting the full feedback. The responder may provide the full feedback in MBIFS or SIFS time if the feedback is ready to be sent. If the BRP feedback is not ready, the EDMG STA may send an acknowledgment frame to the peer STA to indicate that the feedback is not ready. The acknowledgment frame may be used if a transmitting device asks a receiving device to indicate if a measurement may be performed and the associated feedback may be send within a given time. The BRP comeback time element may be included in a BRP frame

instead of feedback to indicate that the device needs more time to perform measurements and send the associated feedback.

[0056] In one or more embodiments, the resulting BRP frame format for a fast BRP mode request + response is shown below in Table 2.

[0057] Table 2: BRP Frame for Fast BRP Mode

| Order | Information |
|---|---|
| 1 | Category |
| 2 | Unprotected DMG |
| 3 | Dialog Token |
| 4 | BRP Request field |
| 5 | DMG Beam Refinement element (fixed size and indicating a fast BRP mode) |
| 6 | Fast BRP Feedback element (fixed size) |
| 7 | BRP Comeback Time element (fixed size) |

[0058] In one or more embodiments, the BRP frame format using fast BRP mode for a request plus response may include the category, unprotected DMG, dialog token, BRP request field, DMG beam refinement element, fast BRP feedback element, and BRP comeback time element. In a request-only mode, the DMG beam refinement element may be present to allow backward compatibility, but its content may be ignored by a device. The fast BRP feedback element and the BRP comeback time element may be included in a BRP response frame.

[0059] It is understood that the above descriptions are for purposes of illustration and are not meant to be limiting.

[0060] FIG. 3A illustrates a flow diagram of an illustrative process 300 for enhanced fast BRP frame processing, in accordance with one or more example embodiments of the present disclosure.

[0061] At block 302, one or more processors of a device (e.g., AP 102 or user device 120 of FIG. 1) may determine a BRP mode for a BRP with an EDMG STA. The BRP mode may be one of a fast BRP mode request, a fast BRP mode response, a fast BRP mode request and response, or a legacy BRP mode, and may be indicated by bits. The bits may be included in a BRP request field of a BRP frame or in the EDMG-Short-BRP and EDMG-SHORT-FBCK fields of a BRP frame. The BRP mode may indicate which elements/fields are included in a BRP frame. The fields including the indication may be processed in hardware, and other fields

[0062] included in the BRP frame may be processed using software. The bits may indicate which fields in a BRP request element may be valid or ignored.

[0063] At block 304, one or more processors of the device may determine a BRP frame (e.g., BRP frame 140 of FIG. 1) comprising an indication of the BRP mode, wherein the indication indicates a presence of one or more elements of the BRP frame. The BRP frame may be a BRP request or response frame according to the BRP mode indicated. The one or more elements may have a fixed length indicated by each of the respective elements.

[0064] At block 306, one or more processors of the device may cause to send the BRP frame to the EDMG STA as part of the BRP. The device may receive a BRP response frame with the feedback or with an indication that the feedback is not ready. A BRP response frame may include a BRP comeback time element, including a feedback readiness duration (e.g., feedback readiness duration field 208 of FIG. 2), which may indicate a time when the device should receive a BRP response with the measurement feedback. An indication of a request for the measurement feedback may be included in a BRP request frame. If the device does not receive the requested measurement feedback within the time indicated by the feedback readiness duration, the device may send another BRP frame to the EDMG STA to request the feedback. If the feedback is ready, the EDMG STA may send the feedback. If the feedback is not ready, the EDMG STA may send an acknowledgment frame indicating that the feedback is not yet ready.

[0065] It is understood that the above descriptions are for purposes of illustration and are not meant to be limiting.

[0066] FIG. 3B illustrates a flow diagram of an illustrative process 350 for enhanced fast BRP frame processing, in accordance with one or more example embodiments of the present disclosure.

[0067] At block 352, one or more processors of a device (e.g., user device 120 of FIG. 1) may identify a BRP frame received from another device (e.g., AP 102 or another user device 120 of FIG. 1). The BRP frame may be a BRP request frame and may include an indication of a BRP mode for a BRP between the devices. The BRP request frame may include an indication of a request for measurement feedback. The BRP mode may be one of a fast BRP mode request, a fast BRP mode response, a fast BRP mode request and response, or a legacy BRP mode, and may be indicated by bits. The bits may be included in a BRP request field of a BRP frame or in the EDMG-Short-BRP and EDMG-SHORT-FBCK fields of a BRP frame. The BRP mode may indicate which elements/fields are included in a BRP frame. The fields

including the indication may be processed in hardware, and other fields included in the BRP frame may be processed using software. The bits may indicate which fields in a BRP request element may be valid or ignored. Knowing which elements/fields are included in the BRP frame, the device may determine which elements/fields may be processed in hardware or software, and may estimate a time needed to process the BRP frame and provide measurement feedback.

[0068] At block 354, one or more processors of the device may determine, based at least in part on the indication, the BRP mode. Knowing which elements/fields are included in the BRP frame, the device may determine which elements/fields are present and may be processed in hardware or software, and may estimate a time needed to process the BRP frame and provide measurement feedback.

[0069] At block 356, one or more processors of the device may determine, based at least in part on the BRP mode, one or more elements present in the BRP frame. The BRP mode may be associated with one or more elements. If the device identifies the BRP mode, the device may identify which elements/fields may be included in the BRP frame, which elements may be ignored, and whether software may be needed to process other elements/fields.

[0070] At block 358, one or more processors of the device may determine, based at least in part on the BRP mode, a fixed length of the one or more elements present in the BRP frame. For example, once the device recognizes the elements present in the BRP frame, the device may process the elements, and each element may indicate its respective length. Therefore, the BRP mode may indicate a fixed length of the elements of the BRP frame.

[0071] At block 360, one or more processors of the device may cause the device to send one or more BRP response frames to the EDMG device. The BRP response frames may include the requested measurement feedback if the measurement feedback is available. Otherwise, the BRP response frame may include a BRP comeback time element with a feedback readiness duration (e.g., feedback readiness duration field 208 of FIG. 2). The BRP comeback time element may have a fixed length. The feedback readiness duration may indicate a time when the EDMG device may expect to receive the measurement feedback. The time may be estimated based on the device's recognition of how long the measurement may require given the BRP mode and other factors related to the devices and their communication channel. After the time has expired, if the device has not provided an indication of the measurement feedback, the device may receive another BRP frame requesting the measurement feedback. If the measurement feedback is ready, the device may provide it. If the measurement feedback is not

ready, the device may send an acknowledgment frame or some other kind of frame to indicate that the device requires more time to provide the measurement feedback.

[0072] It is understood that the above descriptions are for purposes of illustration and are not meant to be limiting.

[0073] FIG. 4 shows a functional diagram of an exemplary communication station 400 in accordance with some embodiments. In one embodiment, FIG. 4 illustrates a functional block diagram of a communication station that may be suitable for use as an AP 102 (FIG. 1) or a user device 120 (FIG. 1) in accordance with some embodiments. The communication station 400 may also be suitable for use as a handheld device, a mobile device, a cellular telephone, a smartphone, a tablet, a netbook, a wireless terminal, a laptop computer, a wearable computer device, a femtocell, a high data rate (HDR) subscriber station, an access point, an access terminal, or other personal communication system (PCS) device.

[0074] The communication station 400 may include communications circuitry 402 and a transceiver 410 for transmitting and receiving signals to and from other communication stations using one or more antennas 401. The communications circuitry 402 may include circuitry that can operate the physical layer (PHY) communications and/or medium access control (MAC) communications for controlling access to the wireless medium, and/or any other communications layers for transmitting and receiving signals. The communication station 400 may also include processing circuitry 406 and memory 408 arranged to perform the operations described herein. In some embodiments, the communications circuitry 402 and the processing circuitry 406 may be configured to perform operations detailed in FIGs. 2, 3A, and 3B.

[0075] In accordance with some embodiments, the communications circuitry 402 may be arranged to contend for a wireless medium and configure frames or packets for communicating over the wireless medium. The communications circuitry 402 may be arranged to transmit and receive signals. The communications circuitry 402 may also include circuitry for modulation/demodulation, upconversion/downconversion, filtering, amplification, etc. In some embodiments, the processing circuitry 406 of the communication station 400 may include one or more processors. In other embodiments, two or more antennas 401 may be coupled to the communications circuitry 402 arranged for sending and receiving signals. The memory 408 may store information for configuring the processing circuitry 406 to perform operations for configuring and transmitting message frames and performing the various operations described herein. The memory 408 may include any type of memory, including non-transitory memory, for storing information in a form readable by a machine (e.g., a computer). For

example, the memory 408 may include a computer-readable storage device, read-only memory (ROM), random-access memory (RAM), magnetic disk storage media, optical storage media, flash-memory devices and other storage devices and media.

[0076] In some embodiments, the communication station 400 may be part of a portable wireless communication device, such as a personal digital assistant (PDA), a laptop or portable computer with wireless communication capability, a web tablet, a wireless telephone, a smartphone, a wireless headset, a pager, an instant messaging device, a digital camera, an access point, a television, a medical device (e.g., a heart rate monitor, a blood pressure monitor, etc.), a wearable computer device, or another device that may receive and/or transmit information wirelessly.

[0077] In some embodiments, the communication station 400 may include one or more antennas 401. The antennas 401 may include one or more directional or omnidirectional antennas, including, for example, dipole antennas, monopole antennas, patch antennas, loop antennas, microstrip antennas, or other types of antennas suitable for transmission of RF signals. In some embodiments, instead of two or more antennas, a single antenna with multiple apertures may be used. In these embodiments, each aperture may be considered a separate antenna. In some multiple-input multiple-output (MIMO) embodiments, the antennas may be effectively separated for spatial diversity and the different channel characteristics that may result between each of the antennas and the antennas of a transmitting station.

[0078] In some embodiments, the communication station 400 may include one or more of a keyboard, a display, a non-volatile memory port, multiple antennas, a graphics processor, an application processor, speakers, and other mobile device elements. The display may be an LCD screen including a touch screen.

[0079] Although the communication station 400 is illustrated as having several separate functional elements, two or more of the functional elements may be combined and may be implemented by combinations of software-configured elements, such as processing elements including digital signal processors (DSPs), and/or other hardware elements. For example, some elements may include one or more microprocessors, DSPs, field- programmable gate arrays (FPGAs), application specific integrated circuits (ASICs), radio- frequency integrated circuits (RFICs) and combinations of various hardware and logic circuitry for performing at least the functions described herein. In some embodiments, the functional elements of the communication station 400 may refer to one or more processes operating on one or more processing elements.

[0080] Certain embodiments may be implemented in one or a combination of hardware, firmware, and software. Other embodiments may also be implemented as instructions stored on a computer-readable storage device, which may be read and executed by at least one processor to perform the operations described herein. A computer-readable storage device may include any non-transitory memory mechanism for storing information in a form readable by a machine (e.g., a computer). For example, a computer-readable storage device may include read-only memory (ROM), random-access memory (RAM), magnetic disk storage media, optical storage media, flash-memory devices, and other storage devices and media. In some embodiments, the communication station 400 may include one or more processors and may be configured with instructions stored on a computer-readable storage device memory.

[0081] FIG. 5 illustrates a block diagram of an example of a machine 500 or system upon which any one or more of the techniques (e.g., methodologies) discussed herein may be performed. In other embodiments, the machine 500 may operate as a standalone device or may be connected (e.g., networked) to other machines. In a networked deployment, the machine 500 may operate in the capacity of a server machine, a client machine, or both in server-client network environments. In an example, the machine 500 may act as a peer machine in peer-to-peer (P2P) (or other distributed) network environments. The machine 500 may be a personal computer (PC), a tablet PC, a set-top box (STB), a personal digital assistant (PDA), a mobile telephone, a wearable computer device, a web appliance, a network router, a switch or bridge, or any machine capable of executing instructions (sequential or otherwise) that specify actions to be taken by that machine, such as a base station. Further, while only a single machine is illustrated, the term "machine" shall also be taken to include any collection of machines that individually or jointly execute a set (or multiple sets) of instructions to perform any one or more of the methodologies discussed herein, such as cloud computing, software as a service (SaaS), or other computer cluster configurations.

[0082] Examples, as described herein, may include or may operate on logic or a number of components, modules, or mechanisms. Modules are tangible entities (e.g., hardware) capable of performing specified operations when operating. A module includes hardware. In an example, the hardware may be specifically configured to carry out a specific operation (e.g., hardwired). In another example, the hardware may include configurable execution units (e.g., transistors, circuits, etc.) and a computer readable medium containing instructions where the instructions configure the execution units to carry out a specific operation when in operation. The configuring may occur under the direction of the executions units or a loading mechanism.

Accordingly, the execution units are communicatively coupled to the computer-readable medium when the device is operating. In this example, the execution units may be a member of more than one module. For example, under operation, the execution units may be configured by a first set of instructions to implement a first module at one point in time and reconfigured by a second set of instructions to implement a second module at a second point in time.

[0083] The machine (e.g., computer system) 500 may include a hardware processor 502 (e.g., a central processing unit (CPU), a graphics processing unit (GPU), a hardware processor core, or any combination thereof), a main memory 504 and a static memory 506, some or all of which may communicate with each other via an interlink (e.g., bus) 508. The machine 500 may further include a power management device 532, a graphics display device 510, an alphanumeric input device 512 (e.g., a keyboard), and a user interface (UI) navigation device 514 (e.g., a mouse). In an example, the graphics display device 510, alphanumeric input device 512, and UI navigation device 514 may be a touch screen display. The machine 500 may additionally include a storage device (i.e., drive unit) 516, a signal generation device 518 (e.g., a speaker), an enhanced beamforming device 519, a network interface device/transceiver 520 coupled to antenna(s) 530, and one or more sensors 528, such as a global positioning system (GPS) sensor, a compass, an accelerometer, or other sensor. The machine 500 may include an output controller 534, such as a serial (e.g., universal serial bus (USB), parallel, or other wired or wireless (e.g., infrared (IR), near field communication (NFC), etc.) connection to communicate with or control one or more peripheral devices (e.g., a printer, a card reader, etc).

[0084] The storage device 516 may include a machine readable medium 522 on which is stored one or more sets of data structures or instructions 524 (e.g., software) embodying or utilized by any one or more of the techniques or functions described herein. The instructions 524 may also reside, completely or at least partially, within the main memory 504, within the static memory 506, or within the hardware processor 502 during execution thereof by the machine 500. In an example, one or any combination of the hardware processor 502, the main memory 504, the static memory 506, or the storage device 516 may constitute machine-readable media.

[0085] The enhanced beamforming device 519 may carry out or perform any of the operations and processes (e.g., process 300 of FIG. 3A, process 350 of FIG. 3B) described and shown above.

[0086] In one or more embodiments, the enhanced beamforming device 519 may modify and define a fast BRP frame to ease the complexity and processing time of its processing. For

example, signaling for a "fast BRP mode" which allows EDMG STAs to more easily parse through different elements of a BRP frame may be defined, and a new feedback element of fixed length may be defined. In addition, a method which reduces the amount of time that a channel remains unused while an STA prepares BRP feedback may be defined. Rather than defining a new BRP frame, the existing BRP frame format defined in the IEEE 802.11ad/ay standards may be reused and defined for enhanced processing. The modifications using the existing BRP frame may address issues required by defining a new BRP frame format.

[0087] In one or more embodiments, to address the processing problem while using the existing BRP frame format, the enhanced beamforming device 519 may use a "fast BRP mode" to enable faster hardware/firmware processing of BRP frames, and may be used only by EDMG STAs. The "fast BRP mode" of a BRP frame may be indicated using reserved bits in a BRP request field of the BRP frame. For example, by using two bits, the following combinations/configurations could be indicated: 0 – legacy mode (e.g., IEEE 802.11ad), 1 – fast BRP mode request, 2 – fast BRP mode response, and 3 – fast BRP mode request and response. One field (e.g., a BRP Request field) with two bits may provide the indication, or a respective bit of two different fields (e.g., EDMG-Short-BRP and EDMG-SHORT-FBCK) may provide the indication. Mode 0 may be represented by a bit combination of 00; mode 1 may be represented by a bit combination of 10; mode 2 may be represented by a bit combination of 01; and mode 3 may be represented by a bit combination of 11. Any combination of two bits may be associated with one of the modes. One bit may indicate whether an EDMG BRP field is present following the BRP request field, and another bit may indicate whether an EDMG short feedback (FBCK) field is present following an EDMG BRP field.

[0088] In one or more embodiments, the enhanced beamforming device 519 may use a fast BRP frame including the following information: category, unprotected DMG action, dialog token, BRP request field, DGM beam refinement element, zero or more channel measurement feedback elements, EDMG partial sector sweep element, EDMG BRP request element, and/or zero or more EDMG channel measurement feedback elements. The BRP request field is mandatory in BRP frames and has fixed elements/fields, making it easy to process with hardware. Other elements of a BRP frame may be processed in software (e.g., because some elements may be of variable length). The BRP request field may indicate which other information is included in the BRP frame. A device which receives a BRP frame may determine, using the BRP request field, what the purpose of the BRP frame is and which other fields/elements are present in the BRP frame. When the EDMG-Short-BRP subfield of a BRP

frame is one, a BRP action field format may include the category, unprotected DMG action, dialog token, BRP request field, EDMG BRP field, and an optional short BRP feedback field. When the EDMG-Short-FBCK subfield is one, the number of feedback measurements may be capped/fixed to a constant value (e.g., sixteen measurements).

[0089] In one or more embodiments, the enhanced beamforming device 519 may use each of the fast BRP modes to indicate a certain behavior (e.g., request, response, request + response). For each fast BRP mode, the elements present in the BRP frame may be defined along with which of their fields are valid or may be ignored. For example, for a given fast BRP mode, which fields of the DMG Beam Refinement element and/or EDMG BRP Request element are valid or ignored may be defined.

[0090] In one or more embodiments, enhanced beamforming device 519 may use a feedback element for the fast BRP mode to allow efficient feedback of a certain number of measurements. In this case, the length of such feedback element may be fixed rather than variable as in the elements used for feedback.

[0091] In one or more embodiments, enhanced beamforming device 519 may separate BRP responses in time from BRP requests by at most a BRPIFS interval (e.g., 40 μs), which is enough time for the STA preparing the feedback to lose access to the channel. To address this issue, which becomes more of a problem in IEEE 802.11ay communications due to multichannel operations, the maximum interval between a BRP response from a BRP request may be defined as MBIFS (e.g., 9 μs) when the fast BRP mode is used. The shortened time difference is possible due to the reduced time required to process a BRP frame using fast BRP mode, and because of the new feedback element associated with the BRP fast mode having a fixed length and a predefined number of measurements.

[0092] In one or more embodiments, the enhanced beamforming device 519 may support BRP requests, which may require more complex feedback, such as the use of "conventional" Channel Measurement Feedback element or EDMG Channel Measurement Feedback element, and may require more than an MBIFS interval for preparing the BRP feedback, a new BRP Comeback Time element may be included in a BRP frame and may allow an STA to communicate to a peer STA a time when the STA expects feedback to be ready to communicate. This element may be included in the BRP frame and may include a Feedback Readiness Duration field, which may specify in units of milliseconds, when the complex feedback is ready to be returned to the peer STA. Following the expiration of the value of a Feedback Readiness Duration field, the peer STA may send a BRP frame requesting the full

feedback. The responder may provide the full feedback in MBIFS or short interframe space (SIFS) time if the feedback is ready to be sent. If the BRP feedback is not ready, the EDMG STA may send an acknowledgment frame to the peer STA to indicate that the feedback is not ready.

[0093] In one or more embodiments, the enhanced beamforming device 519 may use the BRP frame format including a fast BRP mode for a request plus response may include the category, unprotected DMG, dialog token, BRP request field, DMG beam refinement element, fast BRP feedback element, and BRP comeback time element. In a request-only mode, the DMG beam refinement element may be present to allow backward compatibility, but its content may be ignored by a device.

[0094] It is understood that the above are only a subset of what the enhanced beamforming device 519 may be configured to perform and that other functions included throughout this disclosure may also be performed by the enhanced beamforming device 519.

[0095] While the machine-readable medium 522 is illustrated as a single medium, the term "machine-readable medium" may include a single medium or multiple media (e.g., a centralized or distributed database, and/or associated caches and servers) configured to store the one or more instructions 524.

[0096] Various embodiments may be implemented fully or partially in software and/or firmware. This software and/or firmware may take the form of instructions contained in or on a non-transitory computer-readable storage medium. Those instructions may then be read and executed by one or more processors to enable performance of the operations described herein. The instructions may be in any suitable form, such as but not limited to source code, compiled code, interpreted code, executable code, static code, dynamic code, and the like. Such a computer-readable medium may include any tangible non-transitory medium for storing information in a form readable by one or more computers, such as but not limited to read only memory (ROM); random access memory (RAM); magnetic disk storage media; optical storage media; a flash memory, etc.

[0097] The term “machine-readable medium” may include any medium that is capable of storing, encoding, or carrying instructions for execution by the machine 500 and that cause the machine 500 to perform any one or more of the techniques of the present disclosure, or that is capable of storing, encoding, or carrying data structures used by or associated with such instructions. Non-limiting machine-readable medium examples may include solid-state memories and optical and magnetic media. In an example, a massed machine-readable medium

includes a machine-readable medium with a plurality of particles having resting mass. Specific examples of massed machine-readable media may include non-volatile memory, such as semiconductor memory devices (e.g., electrically programmable read-only memory (EPROM), or electrically erasable programmable read-only memory (EEPROM)) and flash memory devices; magnetic disks, such as internal hard disks and removable disks; magneto-optical disks; and CD-ROM and DVD- ROM disks.

[0098] The instructions 524 may further be transmitted or received over a communications network 526 using a transmission medium via the network interface device/transceiver 520 utilizing any one of a number of transfer protocols (e.g., frame relay, internet protocol (IP), transmission control protocol (TCP), user datagram protocol (UDP), hypertext transfer protocol (HTTP), etc.). Example communications networks may include a local area network (LAN), a wide area network (WAN), a packet data network (e.g., the Internet), mobile telephone networks (e.g., cellular networks), plain old telephone (POTS) networks, wireless data networks (e.g., Institute of Electrical and Electronics Engineers (IEEE) 802.11 family of standards known as Wi-Fi®, IEEE 802.16 family of standards known as WiMax®), IEEE 802.15.4 family of standards, and peer-to-peer (P2P) networks, among others. In an example, the network interface device/transceiver 520 may include one or more physical jacks (e.g., Ethernet, coaxial, or phone jacks) or one or more antennas to connect to the communications network 526. In an example, the network interface device/transceiver 520 may include a plurality of antennas to wirelessly communicate using at least one of single-input multiple-output (SIMO), multiple-input multiple-output (MIMO), or multiple-input single-output (MISO) techniques. The term "transmission medium" shall be taken to include any intangible medium that is capable of storing, encoding, or carrying instructions for execution by the machine 500 and includes digital or analog communications signals or other intangible media to facilitate communication of such software. The operations and processes described and shown above may be carried out or performed in any suitable order as desired in various implementations. Additionally, in certain implementations, at least a portion of the operations may be carried out in parallel. Furthermore, in certain implementations, less than or more than the operations described may be performed.

[0099] The word "exemplary" is used herein to mean "serving as an example, instance, or illustration." Any embodiment described herein as "exemplary" is not necessarily to be construed as preferred or advantageous over other embodiments. The terms "computing device," "user device," "communication station," "station," "handheld device," "mobile

device," "wireless device" and "user equipment" (UE) as used herein refers to a wireless communication device such as a cellular telephone, a smartphone, a tablet, a netbook, a wireless terminal, a laptop computer, a femtocell, a high data rate (HDR) subscriber station, an access point, a printer, a point of sale device, an access terminal, or other personal communication system (PCS) device. The device may be either mobile or stationary.

[0100] As used within this document, the term "communicate" is intended to include transmitting, or receiving, or both transmitting and receiving. This may be particularly useful in claims when describing the organization of data that is being transmitted by one device and received by another, but only the functionality of one of those devices is required to infringe the claim. Similarly, the bidirectional exchange of data between two devices (both devices transmit and receive during the exchange) may be described as "communicating," when only the functionality of one of those devices is being claimed. The term "communicating" as used herein with respect to a wireless communication signal includes transmitting the wireless communication signal and/or receiving the wireless communication signal. For example, a wireless communication unit, which is capable of communicating a wireless communication signal, may include a wireless transmitter to transmit the wireless communication signal to at least one other wireless communication unit, and/or a wireless communication receiver to receive the wireless communication signal from at least one other wireless communication unit.

[0101] As used herein, unless otherwise specified, the use of the ordinal adjectives "first," "second," "third," etc., to describe a common object, merely indicates that different instances of like objects are being referred to and are not intended to imply that the objects so described must be in a given sequence, either temporally, spatially, in ranking, or in any other manner.

[0102] The term "access point" (AP) as used herein may be a fixed station. An access point may also be referred to as an access node, a base station, an evolved node B (eNodeB), or some other similar terminology known in the art. An access terminal may also be called a mobile station, user equipment (UE), a wireless communication device, or some other similar terminology known in the art. Embodiments disclosed herein generally pertain to wireless networks. Some embodiments may relate to wireless networks that operate in accordance with one of the IEEE 802.11 standards.

[0103] Some embodiments may be used in conjunction with various devices and systems, for example, a personal computer (PC), a desktop computer, a mobile computer, a laptop computer, a notebook computer, a tablet computer, a server computer, a handheld computer, a handheld device, a personal digital assistant (PDA) device, a handheld PDA device, an on-

board device, an off-board device, a hybrid device, a vehicular device, a non-vehicular device, a mobile or portable device, a consumer device, a non-mobile or non-portable device, a wireless communication station, a wireless communication device, a wireless access point (AP), a wired or wireless router, a wired or wireless modem, a video device, an audio device, an audio-video (A/V) device, a wired or wireless network, a wireless area network, a wireless video area network (WVAN), a local area network (LAN), a wireless LAN (WLAN), a personal area network (PAN), a wireless PAN (WPAN), and the like.

[0104] Some embodiments may be used in conjunction with one way and/or two-way radio communication systems, cellular radio-telephone communication systems, a mobile phone, a cellular telephone, a wireless telephone, a personal communication system (PCS) device, a PDA device which incorporates a wireless communication device, a mobile or portable global positioning system (GPS) device, a device which incorporates a GPS receiver or transceiver or chip, a device which incorporates an RFID element or chip, a multiple input multiple output (MIMO) transceiver or device, a single input multiple output (SIMO) transceiver or device, a multiple input single output (MISO) transceiver or device, a single input single output (SISO) transceiver or device, a device having one or more internal antennas and/or external antennas, digital video broadcast (DVB) devices or systems, multi-standard radio devices or systems, a wired or wireless handheld device, e.g., a smartphone, a wireless application protocol (WAP) device, or the like.

[0105] Some embodiments may be used in conjunction with one or more types of wireless communication signals and/or systems following one or more wireless communication protocols, for example, radio frequency (RF), infrared (IR), frequency-division multiplexing (FDM), orthogonal FDM (OFDM), time-division multiplexing (TDM), time-division multiple access (TDMA), extended TDMA (E-TDMA), general packet radio service (GPRS), extended GPRS, code-division multiple access (CDMA), wideband CDMA (WCDMA), CDMA 2000, single-carrier CDMA, multi-carrier CDMA, multi-carrier modulation (MDM), discrete multi-tone (DMT), Bluetooth®, global positioning system (GPS), Wi-Fi, Wi-Max, ZigBee, ultra-wideband (UWB), global system for mobile communications (GSM), 2G, 2.5G, 3G, 3.5G, 4G, fifth generation (5G) mobile networks, 3GPP, long term evolution (LTE), LTE advanced, enhanced data rates for GSM Evolution (EDGE), or the like. Other embodiments may be used in various other devices, systems, and/or networks.

[0106] Example 1 may include a device, the device comprising storage and processing circuitry configured to: determine a BRP mode for a BRP procedure with an EDMG station

device; determine a BRP frame comprising an indication of the BRP mode, wherein the indication indicates a presence of one or more elements of the BRP frame, the one or more elements having a fixed length; and cause to send the BRP frame.

[0107] Example 2 may include the device of example 1 and/or some other example herein, wherein the BRP mode is one of a fast BRP mode request, a fast BRP mode response, a fast BRP mode request and response, or a legacy BRP mode.

[0108] Example 3 may include the device of example 1 and/or some other example herein, wherein the indication comprises two bits.

[0109] Example 4 may include the device of example 3 and/or some other example herein wherein an EDMG short BRP field of the BRP frame comprises a first bit of the two bits and wherein an EDMG short feedback field of the BRP frame comprises a second bit of the two bits.

[0110] Example 5 may include the device of example 3 and/or some other example herein, wherein a BRP Request field of the BRP frame comprises the two bits.

[0111] Example 6 may include the device of example 1 and/or some other example herein, wherein the storage and processing circuitry are further configured to identify a BRP response frame received from the station device, wherein the BRP response frame comprises an indication of a feedback element having a fixed length.

[0112] Example 7 may include the device of example 1 and/or some other example herein, wherein the storage and processing circuitry are further configured to identify a BRP response frame received from the station device, wherein the BRP response frame comprises a BRP comeback time element indicating a time for measurement feedback to be identified.

[0113] Example 8 may include the device of example 7 and/or some other example herein, wherein the storage and processing circuitry are further configured to: determine that the time for measurement feedback to be identified has passed; and cause to send another BRP frame comprising a request for the measurement feedback.

[0114] Example 9 may include the device of example 8 and/or some other example herein, wherein the storage and processing circuitry are further configured to identify a BRP response frame received from the station device, wherein the BRP response frame comprises the measurement feedback.

[0115] Example 10 may include the device of example 8 and/or some other example herein, wherein the storage and processing circuitry are further configured to identify an acknowledgment frame indicating that the measurement feedback is not available.

[0116] Example 11 may include the device of any one of examples 1-10 and/or some other example herein, further comprising a transceiver configured to transmit and receive wireless signals.

[0117] Example 12 may include the device of example 11 and/or some other example herein, further comprising one or more antennas coupled to the transceiver.

[0118] Example 13 may include a non-transitory computer-readable medium storing computer-executable instructions which when executed by one or more processors result in performing operations comprising: identifying, at a first EDMG device, a BRP frame received from a second EDMG device, wherein the BRP frame comprises an indication of a BRP mode for a BRP procedure between the first EDMG device and the second EDMG device; determining, based at least in part on the indication, the BRP mode; determining, based at least in part on the BRP mode, one or more elements present in the BRP frame; determining, based at least in part on the BRP mode, a fixed length of the one or more elements; and causing to send a BRP response frame to the second EDMG device.

[0119] Example 14 may include the non-transitory computer-readable medium of example 13 and/or some other example herein, wherein the BRP mode is one of a fast BRP mode request, a fast BRP mode response, a fast BRP mode request and response, or a legacy BRP mode.

[0120] Example 15 may include the non-transitory computer-readable medium of example 13 or 14 and/or some other example herein, wherein the indication comprises two bits.

[0121] Example 16 may include the non-transitory computer-readable medium of example 15 and/or some other example herein, wherein an EDMG-Short-BRP field of the BRP frame comprises a first bit of the two bits and wherein an EDMG-SHORT-FBCK field of the BRP frame comprises a second bit of the two bits.

[0122] Example 17 may include the non-transitory computer-readable medium of example 15 and/or some other example herein, wherein a BRP Request field of the BRP frame comprises the two bits.

[0123] Example 18 may include the non-transitory computer-readable medium of example 15 and/or some other example herein, wherein the BRP response frame comprises an indication of a feedback element having a fixed length.

[0124] Example 19 may include the non-transitory computer-readable medium of example 15 and/or some other example herein, wherein the BRP response frame comprises a BRP comeback time element indicating a time for measurement feedback to be identified.

[0125] Example 20 may include the non-transitory computer-readable medium of example 19 and/or some other example herein, the operations further comprising identifying another BRP frame received from the second EDMG station device after the time for measurement feedback to be identified has passed, the other BRP frame comprising a request for the measurement feedback.

[0126] Example 21 may include the non-transitory computer-readable medium of example 20 and/or some other example herein, the operations further comprising causing to send another BRP response frame, wherein the other BRP response frame comprises the measurement feedback.

[0127] Example 22 may include the non-transitory computer-readable medium of example 20 and/or some other example herein, the operations further comprising causing to send an acknowledgment frame indicating that the measurement feedback is not available.

[0128] Example 23 may include a method comprising: determining, by processing circuitry of a first EDMG station device, a BRP mode for a BRP procedure with a second EDMG station device; determining, by the processing circuitry, a BRP frame comprising an indication of the BRP mode, wherein the indication indicates a presence of one or more elements of the BRP frame, the one or more elements having a fixed length; and causing to send, by the processing circuitry, the BRP frame.

[0129] Example 24 may include the method of example 23 and/or some other example herein, wherein the BRP mode is one of a fast BRP mode request, a fast BRP mode response, a fast BRP mode request and response, or a legacy BRP mode.

[0130] Example 25 may include the method any one of examples 23 or 24 and/or some other example herein, wherein the indication comprises two bits.

[0131] Example 26 may include an apparatus comprising means for performing a method as in any one of examples 23 or 24.

[0132] Example 27 may include a system, comprising at least one memory device having programmed instruction that, in response to execution cause at least one processor to perform the method of any one of examples 23 or 24.

[0133] Example 28 may include a machine readable medium including code, when executed, to cause a machine to perform the method of any one of examples 23 or 24.

[0134] Example 29 may include one or more non-transitory computer-readable media comprising instructions to cause an electronic device, upon execution of the instructions by one

or more processors of the electronic device, to perform one or more elements of a method described in or related to any of examples 1-28, or any other method or process described herein.

[0135] Example 30 may include an apparatus comprising logic, modules, and/or circuitry to perform one or more elements of a method described in or related to any of examples 1-28, or any other method or process described herein.

[0136] Example 31 may include a method, technique, or process as described in or related to any of examples 1-28, or portions or parts thereof.

[0137] Example 32 may include an apparatus comprising means for causing the one or more processors to perform the method, techniques, or process as described in or related to any of examples 1-28, or portions thereof.

[0138] Embodiments according to the disclosure are in particular disclosed in the attached claims directed to a method, a storage medium, a device and a computer program product, wherein any feature mentioned in one claim category, e.g., method, can be claimed in another claim category, e.g., system, as well. The dependencies or references back in the attached claims are chosen for formal reasons only. However, any subject matter resulting from a deliberate reference back to any previous claims (in particular multiple dependencies) can be claimed as well, so that any combination of claims and the features thereof are disclosed and can be claimed regardless of the dependencies chosen in the attached claims. The subject-matter which can be claimed comprises not only the combinations of features as set out in the attached claims but also any other combination of features in the claims, wherein each feature mentioned in the claims can be combined with any other feature or combination of other features in the claims. Furthermore, any of the embodiments and features described or depicted herein can be claimed in a separate claim and/or in any combination with any embodiment or feature described or depicted herein or with any of the features of the attached claims.

[0139] The foregoing description of one or more implementations provides illustration and description, but is not intended to be exhaustive or to limit the scope of embodiments to the precise form disclosed. Modifications and variations are possible in light of the above teachings or may be acquired from practice of various embodiments.

[0140] Certain aspects of the disclosure are described above with reference to block and flow diagrams of systems, methods, apparatuses, and/or computer program products according to various implementations. It will be understood that one or more blocks of the block diagrams and flow diagrams, and combinations of blocks in the block diagrams and the flow diagrams, respectively, may be implemented by computer-executable program instructions. Likewise,

some blocks of the block diagrams and flow diagrams may not necessarily need to be performed in the order presented, or may not necessarily need to be performed at all, according to some implementations.

[0141] These computer-executable program instructions may be loaded onto a special-purpose computer or other particular machine, a processor, or other programmable data processing apparatus to produce a particular machine, such that the instructions that execute on the computer, processor, or other programmable data processing apparatus create means for implementing one or more functions specified in the flow diagram block or blocks. These computer program instructions may also be stored in a computer-readable storage media or memory that may direct a computer or other programmable data processing apparatus to function in a particular manner, such that the instructions stored in the computer-readable storage media produce an article of manufacture including instruction means that implement one or more functions specified in the flow diagram block or blocks. As an example, certain implementations may provide for a computer program product, comprising a computer-readable storage medium having a computer-readable program code or program instructions implemented therein, said computer-readable program code adapted to be executed to implement one or more functions specified in the flow diagram block or blocks. The computer program instructions may also be loaded onto a computer or other programmable data processing apparatus to cause a series of operational elements or steps to be performed on the computer or other programmable apparatus to produce a computer-implemented process such that the instructions that execute on the computer or other programmable apparatus provide elements or steps for implementing the functions specified in the flow diagram block or blocks.

[0142] Accordingly, blocks of the block diagrams and flow diagrams support combinations of means for performing the specified functions, combinations of elements or steps for performing the specified functions and program instruction means for performing the specified functions. It will also be understood that each block of the block diagrams and flow diagrams, and combinations of blocks in the block diagrams and flow diagrams, may be implemented by special-purpose, hardware-based computer systems that perform the specified functions, elements or steps, or combinations of special-purpose hardware and computer instructions.

[0143] Conditional language, such as, among others, “can,” “could,” “might,” or “may,” unless specifically stated otherwise, or otherwise understood within the context as used, is generally intended to convey that certain implementations could include, while other implementations do not include, certain features, elements, and/or operations. Thus, such

conditional language is not generally intended to imply that features, elements, and/or operations are in any way required for one or more implementations or that one or more implementations necessarily include logic for deciding, with or without user input or prompting, whether these features, elements, and/or operations are included or are to be performed in any particular implementation.

[0144] Many modifications and other implementations of the disclosure set forth herein will be apparent having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. Therefore, it is to be understood that the disclosure is not to be limited to the specific implementations disclosed and that modifications and other implementations are intended to be included within the scope of the appended claims. Although specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation.

## CLAIMS

What is claimed is:

1. A device, the device comprising storage and processing circuitry configured to:

determine a beam refinement protocol (BRP) mode for a BRP procedure with an enhanced directional multi-gigabit (EDMG) station device;

determine a BRP frame comprising an indication of the BRP mode, wherein the indication indicates a presence of one or more elements of the BRP frame, the one or more elements having a fixed length; and

cause to send the BRP frame.

2. The device of claim 1, wherein the BRP mode is one of a fast BRP mode request, a fast BRP mode response, a fast BRP mode request and response, or a legacy BRP mode.

3. The device of any of claims 1 or 2, wherein the indication comprises two bits.

4. The device of claim 3, wherein an EDMG short BRP field of the BRP frame comprises a first bit of the two bits and wherein an EDMG short feedback field of the BRP frame comprises a second bit of the two bits.

5. The device of claim 3, wherein a BRP Request field of the BRP frame comprises the two bits.

6. The device of claim 1, wherein the storage and the processing circuitry are further configured to identify a BRP response frame received from the station device, wherein the BRP response frame comprises an indication of a feedback element having a fixed length.

7. The device of claim 1, wherein the storage and the processing circuitry are further configured to identify a BRP response frame received from the station device, wherein the BRP response frame comprises a BRP comeback time element indicating a time for measurement feedback to be identified.

8. The device of claim 7, wherein the storage and the processing circuitry are further configured to:

determine that the time for measurement feedback to be identified has passed; and

cause to send another BRP frame comprising a request for the measurement feedback.

9. The device of claim 8, wherein the storage and the processing circuitry are further configured to identify a BRP response frame received from the station device, wherein the BRP response frame comprises the measurement feedback.

10. The device of claim 8, wherein the storage and the processing circuitry are further configured to identify an acknowledgment frame indicating that the measurement feedback is not available.

11. The device of any of claims 1-10, further comprising a transceiver configured to transmit and receive wireless signals.

12. The device of claim 11, further comprising one or more antennas coupled to the transceiver.

13. A non-transitory computer-readable medium storing computer-executable instructions which when executed by one or more processors result in performing operations comprising:

identifying, at a first EDMG device, a beam refinement protocol (BRP) frame received from a second EDMG device, wherein the BRP frame comprises an indication of a BRP mode for a BRP procedure between the first EDMG device and the second EDMG device;

determining, based at least in part on the indication, the BRP mode;

determining, based at least in part on the BRP mode, one or more elements present in the BRP frame;

determining, based at least in part on the BRP mode, a fixed length of the one or more elements; and

causing to send a BRP response frame to the second EDMG device.

14. The non-transitory computer-readable medium of claim 13, wherein the BRP mode is one of a fast BRP mode request, a fast BRP mode response, a fast BRP mode request and response, or a legacy BRP mode.

15. The non-transitory computer-readable medium of any of claims 13 or 14, wherein the indication comprises two bits.

16. The non-transitory computer-readable medium of claim 15, wherein an EDMG-Short-BRP field of the BRP frame comprises a first bit of the two bits and wherein an EDMG-SHORT-FBCK field of the BRP frame comprises a second bit of the two bits.

17. The non-transitory computer-readable medium of claim 15, wherein a BRP Request field of the BRP frame comprises the two bits.

18. The non-transitory computer-readable medium of claim 15, wherein the BRP response frame comprises an indication of a feedback element having a fixed length.

19. The non-transitory computer-readable medium of claim 15, wherein the BRP response frame comprises a BRP comeback time element indicating a time for measurement feedback to be identified.

20. The non-transitory computer-readable medium of claim 19, the operations further comprising identifying another BRP frame received from the second EDMG device after the time for measurement feedback to be identified has passed, the other BRP frame comprising a request for the measurement feedback.

21. The non-transitory computer-readable medium of claim 20, the operations further comprising causing to send another BRP response frame, wherein the other BRP response frame comprises the measurement feedback.

22. The non-transitory computer-readable medium of claim 20, the operations further comprising causing to send an acknowledgment frame indicating that the measurement feedback is not available.

23. A method comprising:

determining, by processing circuitry of a first enhanced directional multi-gigabit (EDMG) station device, a beam refinement protocol (BRP) mode for a BRP procedure with a second EDMG station device;

determining, by the processing circuitry, a BRP frame comprising an indication of the BRP mode, wherein the indication indicates a presence of one or more elements of the BRP frame, the one or more elements having a fixed length; and

causing to send, by the processing circuitry, the BRP frame.

24. The method of claim 23, wherein the BRP mode is one of a fast BRP mode request, a fast BRP mode response, a fast BRP mode request and response, or a legacy BRP mode.

25. The method of any of claims 23 or 24, wherein the indication comprises two bits.

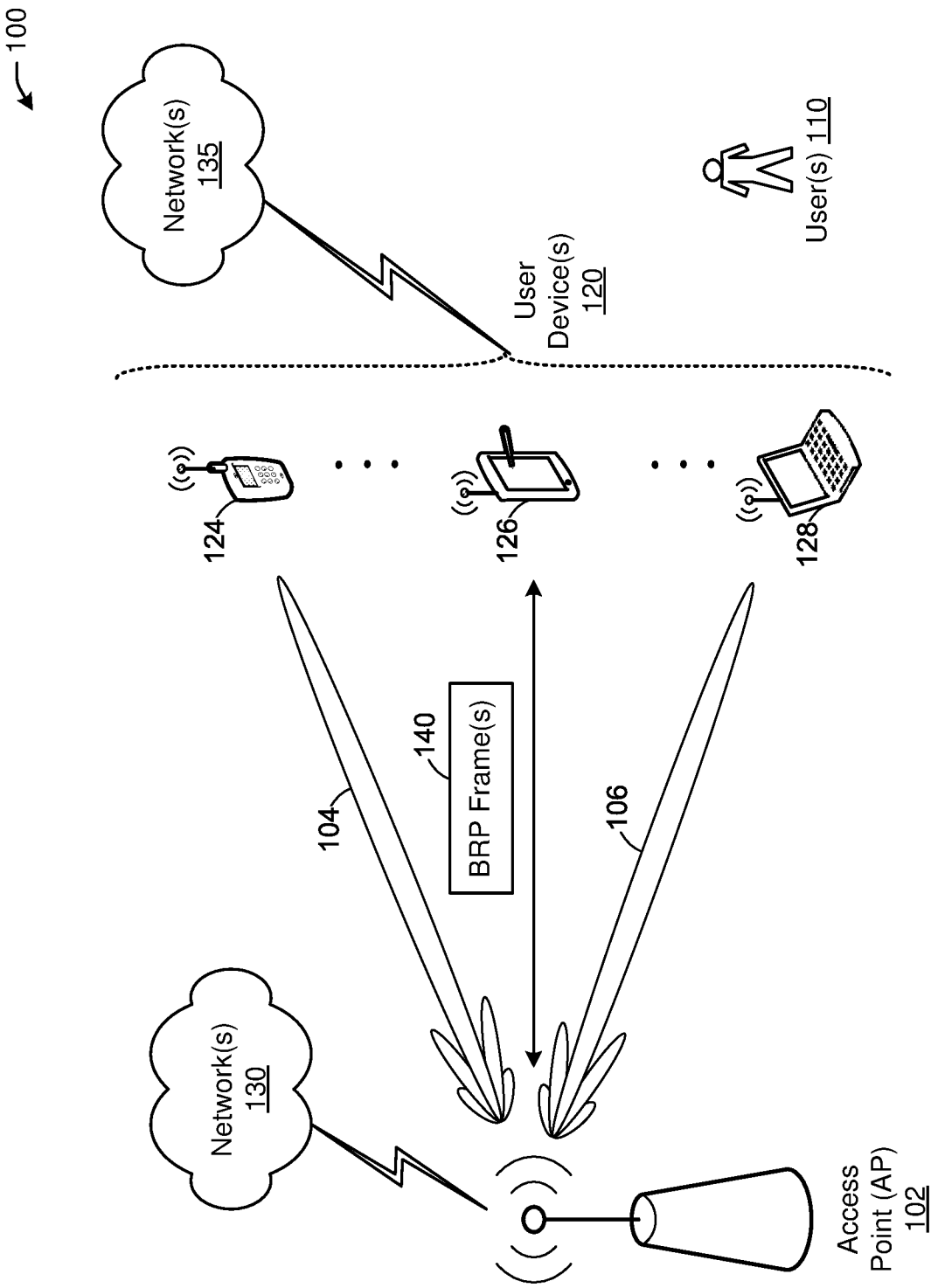

100
Network(s)
135
User(s) 110
User
Device(s)
120
124
126
128
140
BRP Frame(s)
104
106
Network(s)
130
Access
Point (AP)
102

FIG. 1

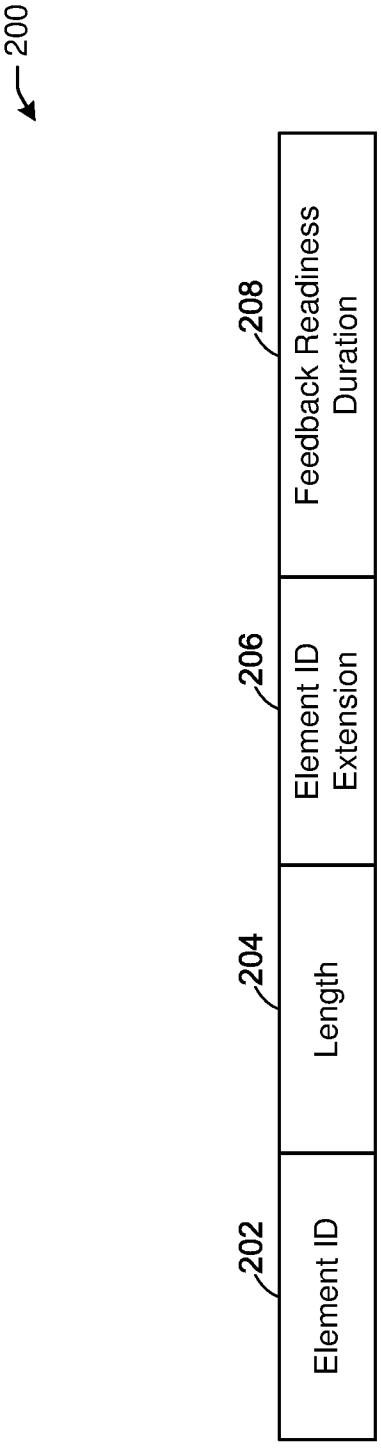

200
202
Element ID
204
Length
206
Element ID Extension
208
Feedback Readiness Duration

FIG. 2

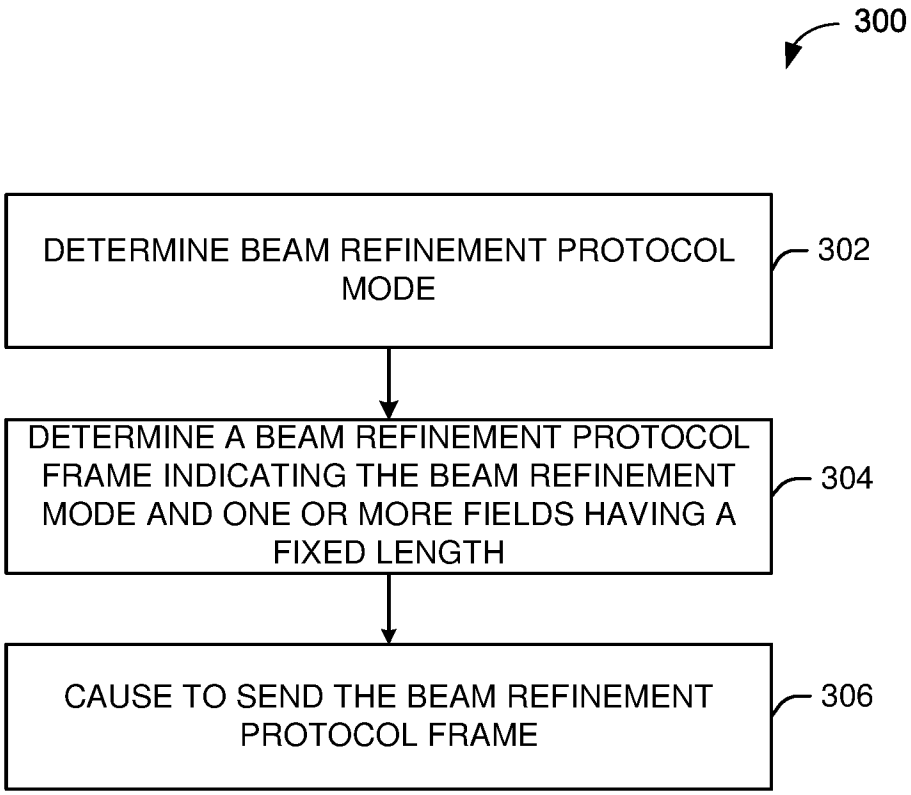

300
DETERMINE BEAM REFINEMENT PROTOCOL MODE
302
DETERMINE A BEAM REFINEMENT PROTOCOL FRAME INDICATING THE BEAM REFINEMENT MODE AND ONE OR MORE FIELDS HAVING A FIXED LENGTH
304
CAUSE TO SEND THE BEAM REFINEMENT PROTOCOL FRAME
306

FIG. 3A

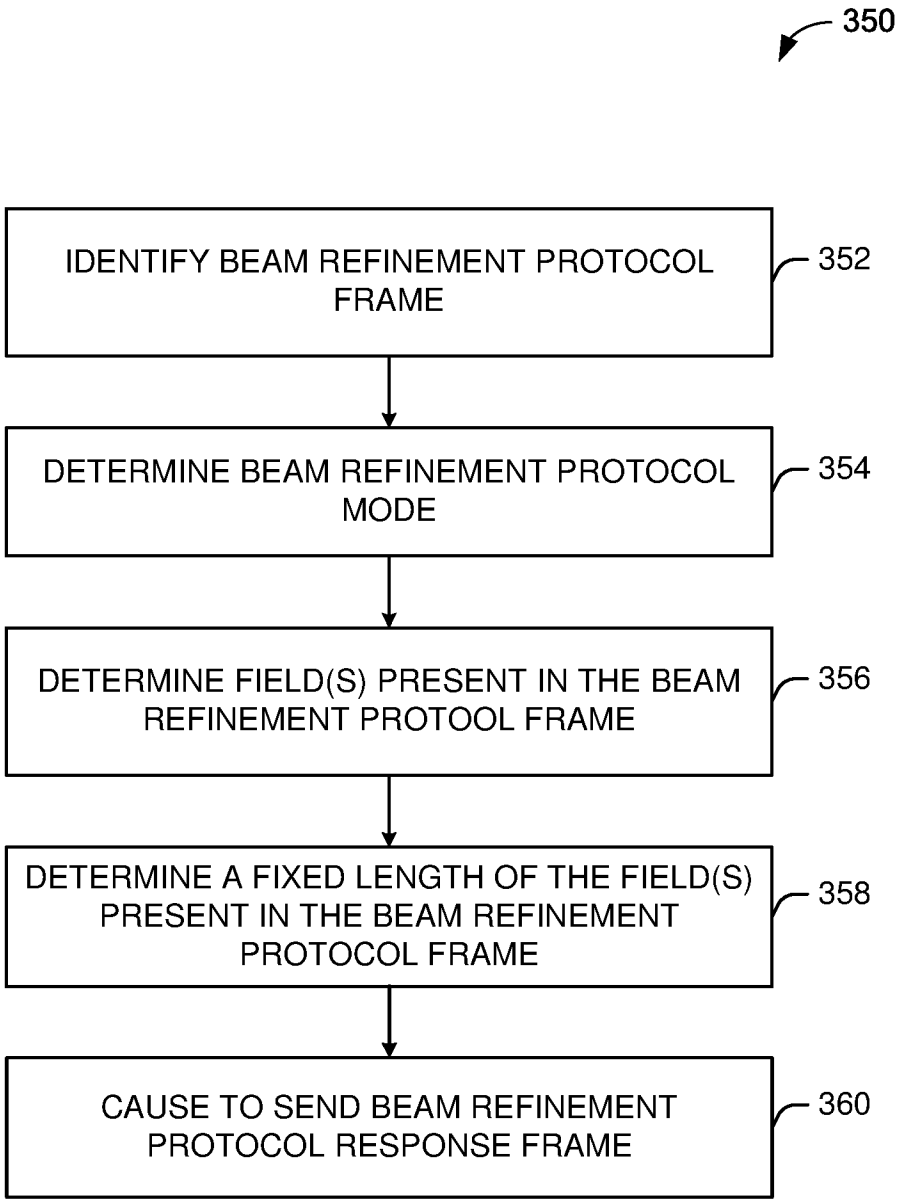

350
IDENTIFY BEAM REFINEMENT PROTOCOL FRAME
352
DETERMINE BEAM REFINEMENT PROTOCOL MODE
354
DETERMINE FIELD(S) PRESENT IN THE BEAM REFINEMENT PROTOOL FRAME
356
DETERMINE A FIXED LENGTH OF THE FIELD(S) PRESENT IN THE BEAM REFINEMENT PROTOCOL FRAME
358
CAUSE TO SEND BEAM REFINEMENT PROTOCOL RESPONSE FRAME
360

FIG. 3B

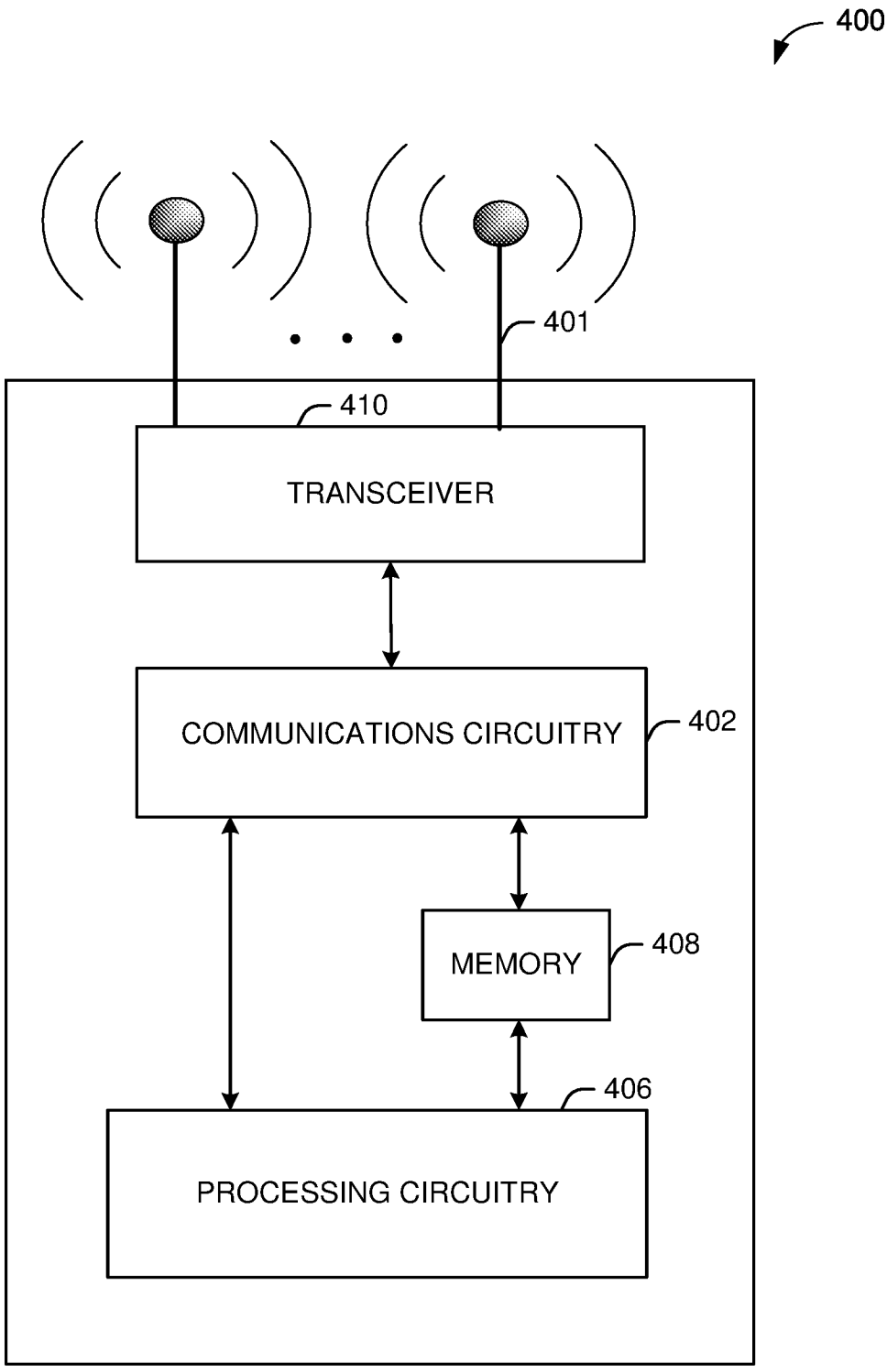

400
401
410
TRANSCEIVER
COMMUNICATIONS CIRCUITRY
402
MEMORY
408
406
PROCESSING CIRCUITRY

FIG. 4

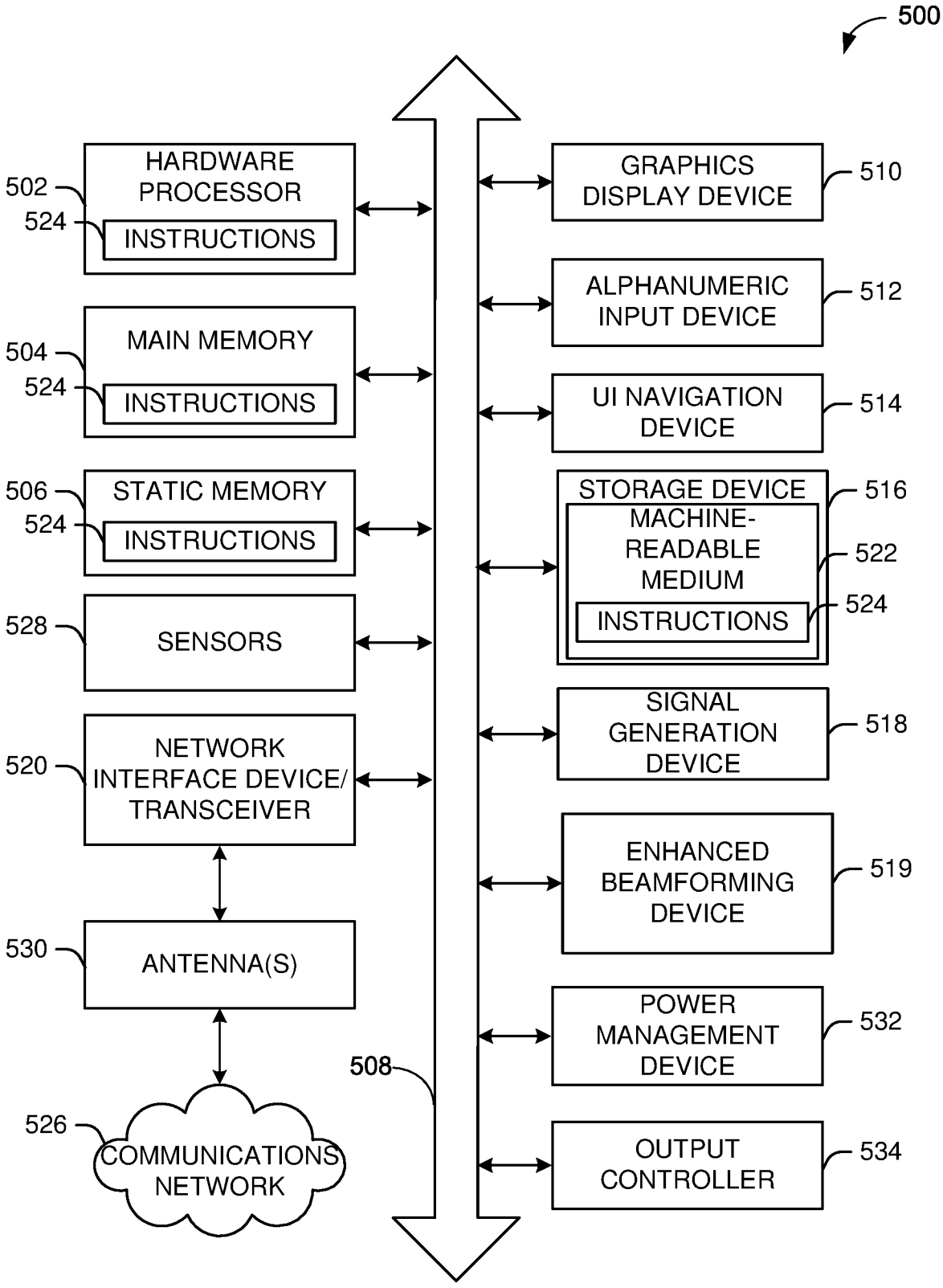

500
HARDWARE PROCESSOR
502
524
INSTRUCTIONS
MAIN MEMORY
504
524
INSTRUCTIONS
STATIC MEMORY
506
524
INSTRUCTIONS
528
SENSORS
NETWORK INTERFACE DEVICE/ TRANSCEIVER
520
530
ANTENNA(S)
526
COMMUNICATIONS NETWORK
508
GRAPHICS DISPLAY DEVICE
510
ALPHANUMERIC INPUT DEVICE
512
UI NAVIGATION DEVICE
514
STORAGE DEVICE
516
MACHINE-READABLE MEDIUM
522
INSTRUCTIONS
524
SIGNAL GENERATION DEVICE
518
ENHANCED BEAMFORMING DEVICE
519
POWER MANAGEMENT DEVICE
532
OUTPUT CONTROLLER
534

FIG. 5

**INTERNATIONAL SEARCH REPORT**

International application No.
**PCT/US2018/041698**

**A. CLASSIFICATION OF SUBJECT MATTER**

**H04B 7/06(2006.01)i, H04W 16/28(2009.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)
H04B 7/06; H04B 17/309; H04B 7/04; H04W 16/28

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & keywords: beam refinement protocol (BRP) mode, enhanced directional multi-gigabit (EDMG) station device, BRP procedure, BRP frame, indication, element, fast

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| A | CLAUDIO DA SILVA et al., `BRP transmit sector sweep', IEEE 802.11-17/0322r1, 13 March 2017<br>See slides 4-13. | 1-25 |
| A | KOME OTERI et al., `Further details on multi-stage, multi-resolution beamforming training in 802.11ay', IEEE 802.11-16/1447r1, 08 November 2016<br>See slides 3-14. | 1-25 |
| A | CLAUDIO DA SILVA, `Proposed resolution to 11ay related CIDs', IEEE 802.11-17/0919r0, 20 June 2017<br>See pages 2-7. | 1-25 |
| A | US 2016-0277087 A1 (SAMSUNG ELECTRONICS CO., LTD.) 22 September 2016<br>See paragraphs [0046]-[0061]; and figure 2. | 1-25 |
| A | WO 2014-074894 A1 (INTERDIGITAL PATENT HOLDINGS, INC.) 15 May 2014<br>See paragraphs [0113]-[0122]; and figures 3-5. | 1-25 |

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 22 November 2018 (22.11.2018) | **22 November 2018 (22.11.2018)** |

Name and mailing address of the ISA/KR
International Application Division
Korean Intellectual Property Office
189 Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea
Facsimile No. +82-42-481-8578

Authorized officer
KANG, Hee Gok
Telephone No. +82-42-481-8264

**INTERNATIONAL SEARCH REPORT**

Information on patent family members

International application No.

**PCT/US2018/041698**

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
|---|---|---|---|
| US 2016-0277087 A1 | 22/09/2016 | EP 3068058 A1 | 14/09/2016 |
| | | KR 10-2015-0052482 A | 14/05/2015 |
| | | WO 2015-069015 A1 | 14/05/2015 |
| WO 2014-074894 A1 | 15/05/2014 | EP 2920890 A1 | 23/09/2015 |
| | | JP 06190889 B2 | 30/08/2017 |
| | | JP 2016-504804 A | 12/02/2016 |
| | | JP 2018-011309 A | 18/01/2018 |
| | | US 2015-0289147 A1 | 08/10/2015 |