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(54) Title: ENHANCED SPATIAL MULTIPLEXING FOR WIRELESS COMMUNICATIONS

Capability	Capabilities ID
Beamforming	0
Multi-BF	1
Antenna polarization capability	2
PHY Capability	3
Supported Channels	4
MAC Capability	5

FIG. 2A

(57) Abstract: This disclosure describes methods, apparatus, and systems related to enhanced spatial multiplexing for wireless communications. A device may determine one or more station devices to be included in a communication session. The device may determine a frame including an indication, wherein the indication is associated with a type of the communication session. The device may cause to send a frame to the one or more station devices. The device may identify a response frame received from a first station device of the one or more station devices, wherein the response frame comprises an activation indication of one or more receive chains on the first station device.

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ENHANCED SPATIAL MULTIPLEXING FOR WIRELESS COMMUNICATIONS

CROSS-REFERENCE TO RELATED APPLICATION(S)

[0001] This application claims benefit of U.S. Provisional Application No. 62/525,594, filed June 27, 2017, and U.S. Provisional Application No. 62/527,758, filed June 30, 2017,
5 both disclosures of which are incorporated herein 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 enhanced spatial multiplexing.

BACKGROUND

10 [0003] Wireless devices are becoming widely prevalent and are increasingly requesting access to wireless channels. Wireless devices in a communication network may save power through efficient operations.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] FIG. 1 depicts a network diagram illustrating an example network environment,
15 according to one or more example embodiments of the present disclosure.

[0005] FIGs. 2A-2B depict illustrative tables for enhanced spatial multiplexing, in accordance with one or more example embodiments of the present disclosure.

[0006] FIG. 2C depicts an illustrative flow of a negotiation phase and a data delivery phase, in accordance with one or more example embodiments of the present disclosure.

20 [0007] FIG. 3A illustrates a flow diagram of an illustrative process for enhanced spatial multiplexing, in accordance with one or more example embodiments of the present disclosure.

[0008] FIG. 3B illustrates a flow diagram of an illustrative process for enhanced spatial multiplexing, in accordance with one or more example embodiments of the present disclosure.

[0009] FIG. 3C illustrates a flow diagram of an illustrative process for a triggered
25 unscheduled power save delivery system, in accordance with one or more example embodiments of the present disclosure.

[0010] 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.

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[0011] FIG. 5 illustrates 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 embodiments of the present disclosure.

DETAILED DESCRIPTION

5 [0012] 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.

10 [0013] The present disclosure proposes an enhanced spatial multiplexing (SM) power save mechanism that applies to the 802.11 standard, including the 802.11ay communication standard.

[0014] 802.11ay enhanced directional multi-gigabit (EDMG) stations (STAs) are expected to be equipped with multiple receive chains in order to support multiple-input, multiple-output
15 (MIMO) transmissions. An EDMG STA may consume power on all active receive chains, even though they are not necessarily required for the actual frame exchange.

[0015] 802.11n/80.211ac defines a spatial multiplexing power save mechanism, which may enable an STA to operate with only one receive chain for a significant portion of time. 802.11n/80.211ac defines two modes: static and dynamic. In a static SM power save mode,
20 the STA may maintain only a single active receive chain. In a dynamic SM power save mode, the STA may always enable its multiple receive chains when it receives the start of a frame exchange sequence addressed to it. A request to send/clear to send (RTS/CTS) sequence may be used for this purpose. The reason is because the station cannot differentiate a MIMO transmission from a single-input single-output (SISO) transmission since if they both start with
25 the RTS or CTS transmission. There is no indication in the RTS/CTS to indicate the type of transmission (e.g., MIMO or SISO). The STA may use an SM power save frame to communicate its SM power save state. The STA may also use an SM power save subfield in the high throughput (HT) capabilities element of its (re)association request frame to achieve the same purpose. The latter may allow the STA to use only a single receive chain immediately
30 after (re)association.

[0016] However, there may be several issues with the SM power save mechanism used in 802.11n/802.11ac before the SM power save mechanism may be directly applied to 802.11ay, due to a few unique features introduced in 802.11ay. These issues include the following.

[0017] In 802.11n/802.11ac, an STA in a dynamic SM power save mode may always enable its multiple receive chains when it receives the RTS frame addressed to it, because it may not distinguish between an RTS/CTS sequence that precedes a MIMO transmission and any other RTS/CTS (e.g., an RTS/CTS that does not precede a MIMO transmission). This rule may cause unnecessary activations of multiple receive chains if the RTS is followed by a SISO transmission, for example, which may incur additional power waste on multiple receive chains. Also, in 802.11n/802.11ac, maintaining a single receive chain may provide omnitransmit/receive (TX/RX) clear channel assessment (CCA) coverage. Therefore, when an STA activates its other receive chains, there may be no major concern on the network allocation vector (NAV) (e.g., virtual carrier sensing mechanism) observation of these receive chains. As a result, the STA may safely proceed to MIMO transmission. However, in 60 GHz, the CCA observation of one chain may be substantially different from the other receive chains. Consequently, after the activation of multiple receive chains, the EDMG STA may need some time to stabilize multiple receive chains in order to detect active transmissions in the environment to make sure the MIMO channels are idle and can be accessed. This means if an EDMG STA receives an RTS frame indicating an upcoming MIMO transmission, the EDMG STA may not have enough time to perform MIMO CCA on all the receive chains to make sure that the MIMO channels are idle. In this case, the EDMG STA may not be able to respond to the RTS immediately, and thus the MIMO transmission may fail. In 802.11ay, there is directionality. Therefore, a device can listen in the direction that the device is about to transmit on, and therefore the device needs to perform MIMO CCA on all of its receive chains.

[0018] Quality of service (QoS) traffic like voice and video requires periodic delivery service of fixed throughput. For example, typical use case for voice traffic is delivery of approximately 30 KB every 20 ms. For those EDMG STAs that receive the traffic with periodic delivery service, they may want to utilize the power save mode, which allows the STAs to reside efficiently in short time doze state.

[0019] In current solutions provided for IEEE 802.11ad devices, the control point/access point (PCP/AP) can use scheduled allocations (SPs) for the delivery of QoS traffic. However, the allocations of the SPs are not always guaranteed since the allocation is dependent on the overall traffic that needs to be serviced by the PCP/AP. The PCP/AP needs to schedule such SPs in a way that addresses all of its associated stations. Such scheduling is not always possible and is surely considered a complicated task to maintain. For that reason, the contention based access period (CBAP) is a more common allocation scheduled by the PCP/AP. In this allocation, every station contends to access the wireless medium, and the medium is not

guaranteed as in an SP. CBAP provides several existing power save mechanisms in IEEE 802.11ad described as follows:

[0020] Scheduled Power Save: STA and PCP/AP agree on a wakeup schedule consisting of awake beacon intervals (BIs) and doze BIs. This power save cycle is in a granularity of BIs
5 (>100ms). Hence it is not suitable for short time doze states.

[0021] Unscheduled Power Save: STA informs the PCP/AP of entering and exiting the PS by completing a successful frame exchange with the “power management” subfield in the frame control field. However, this mechanism is involved with major overhead associated with communicating the PS transitions. Hence it is not suitable for short time doze states.

10 [0022] Triggered Unscheduled Power Save: An STA that has an unscheduled power save to enter the doze state may offer a reverse direction grant (RDG) to its associated PCP/AP. The PCP/AP may use the offered RDG to transmit one or more bufferable units (BUs) to the STA using the reverse direction protocol. While using this scheme, the STA resides constantly in the doze state, with no power save transition overheads.

15 [0023] However, since cache memory is very costly, issues may occur in cases where the PCP/AP has a limited cache buffer and needs some time to retrieve the data from the back memory. As a result, it will take some time for the PCP/AP to get the data from back memory before it is able to deliver the data to the STA. In this case, the STA has to either stay awake until the PCP/AP is able to deliver the data, or go back to the doze state. For the former choice,
20 the STA needs to wake up again, and this results in delay in getting its data. For the latter choice, it consumes more power.

[0024] A directional multi-gigabyte (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 gigabits per second, or any other rate. An amendment to a DMG
25 operation in a 60 GHz band, e.g., according to an IEEE 802.11ad standard, may be defined, for example, by an IEEE 802.11ay project.

[0025] Distributed coordination function (DCF) is a media access control (MAC) technique of the IEEE 802.11 based WLAN standard. According to DCF, before transmitting a data frame, an STA must sense the channel to determine whether any other station is
30 transmitting. If the medium is found to be idle for an interval longer than the Distributed InterFrame Space (DIFS), the STA continues with its transmission. If the medium is busy, the transmission may be deferred until the end of the ongoing transmission. A random interval, referred to as the backoff time, is then selected, which is used to initialize the backoff timer. The backoff timer is decreased for as long as the channel is sensed as idle, stopped when a

transmission is detected on the channel, and reactivated when the channel is sensed as idle again for more than a DIFS. The STA is enabled to transmit its frame when its backoff timer reaches zero.

[0026] In some demonstrative embodiments, one or more devices may be configured to communicate over a next generation 60 GHz (NG60) network, an enhanced DMG (EDMG) network, and/or any other network. For example, the one or more devices may be configured to communicate over the NG60 or EDMG networks.

[0027] In one or more embodiments, an enhanced spatial multiplexing system may facilitate that prior to the MIMO transmission, an initiator may include such an indication in an RTS/CTS-to-self/grant frame. As a result, an EDMG STA that receives that indication may be able to differentiate such frames that precede a MIMO from such frames that precede a SISO transmission.

[0028] In one or more embodiments, an enhanced spatial multiplexing system may add an SM power save capability field in an EDMG capabilities element to indicate whether an EDMG STA supports an SM power save or not, and if the EDMG STA supports the SM power save, whether the power save mode is a static SM power save, or a dynamic SM power save.

[0029] In one or more embodiments, new rules may be proposed for activation of multiple receive chains for an EDMG STA in a dynamic SM power save mode. Specifically, an EDMG STA may not need to activate its multiple receive chains if the frame (e.g., and the RTS/CTS-to-self/grant frame) that the EDMG STA receives does not have a MIMO indication.

[0030] In one or more embodiments, if a first EDMG STA wants to initiate MIMO transmission with a second EDMG STA that resides in a dynamic SM power save mode, the first EDMG STA may transmit a grant frame with a control trailer prior to attempting to initiate the MIMO transmission. The control trailer may indicate the upcoming transmission may be a MIMO mode transmission that needs the activation of multiple receive chains. In addition, the grant frame may indicate the target time for initiating the MIMO transmission, and this time offset may be at least in the order of a probe delay.

[0031] Currently there is only one known SM power save mechanism defined in 802.11n/802.11ac. However, since the 60 GHz band has several unique features, simply reusing the same SM power save scheme is not feasible. Currently there is no known solution for how to extend and adapt the SM power save scheme so that it can be applied to the 802.11ay environment.

[0032] Example embodiments of the present disclosure relate to systems, methods, and devices for enhanced spatial multiplexing in wireless communications.

[0033] In one or more embodiments, a capability field of MAC capability and a subfield of SM power save within MAC capability may be added to an EDMG capabilities element to signal the capability of the SM power save of the EDMG STAs, as well as the mode of SM power save after (re)association.

5 [0034] In one or more embodiments, the SM power save subfield may indicate the support for a spatial multiplexing power save for an EDMG STA. The SM power save subfield also may indicate the spatial multiplexing power save mode that is in operation immediately after (re)association. This field may be set to 0 for a static SM power save mode, 1 for a dynamic SM power save mode, and 3 for an SM power save disabled or not supported. The value of 2
10 may be reserved.

[0035] In one or more embodiments, the SM power save subfield may be valid only in a (re)association request frame sent to an AP or a PCP. Otherwise, the SM power save subfield may be set to 0 or 3 upon transmission and ignored upon reception. The SM power save subfield may indicate the operational state immediately after (re)association as well as (e.g., if
15 not set to 3) a capability.

[0036] In one or more embodiments, the STA may use the SM power save frame to communicate its SM power save state.

[0037] In one or more embodiments, there may be new rules for activation of multiple receive chains for EDMG STAs that are in a dynamic SM power save mode. If an EDMG
20 STA in a dynamic SM power save receives an RTS/grant/CTS-to-self frame addressed to it, the EDMG STA may not need to activate its multiple receive chains if the frame does not include a MIMO indication, which may be carried in the control trailer appended to the RTS/grant/CTS-to-self frame. Otherwise, if the frame contains a MIMO indication, the EDMG STA may activate its multiple receive chains.

25 [0038] In one or more embodiments, there may be a grant/grant ack frame exchange prior to the MIMO transaction for EDMG STAs in a dynamic SM power save mode.

[0039] In one or more embodiments, if a first EDMG STA wants to initiate a MIMO transmission with a second EDMG STA that resides in a dynamic SM power save mode, the first EDMG STA may transmit a grant frame with a control trailer prior to attempting to initiate
30 the MIMO transmission.

[0040] In one or more embodiments, even if the grant required field in the EDMG capabilities element of the second STA is set to 0, as long as the second EDMG STA is in the dynamic SM power save mode, the first STA may still transmit a grant frame prior to the MIMO transmission.

[0041] In one or more embodiments, the control trailer may indicate the upcoming transmission will be a MIMO mode transmission that may need the activation of multiple receive chains. In addition, the grant frame may indicate the target time for initiating the MIMO transmission, and this time offset may be at least in the order of a probe delay.

5 [0042] In one or more embodiments, after receiving the grant frame, the second EDMG STA shall respond with a grant acknowledgment frame and activate its multiple receive chains, and perform MIMO CCA for the upcoming MIMO channel access attempt that may be initiated by the first EDMG STA at the target time indicated in the grant frame. The grant acknowledgment comprises an indication of confirming the receipt of the grant frame and the
10 need to activate more receive chains. In other words, when the EDMG STA sends the grant acknowledgment back, it is possible that it has not activated multiple receive chains, but it has confirmed that it will activate them before the target time indicated in the received grant frame.

[0043] Further example embodiments of the present disclosure relate to systems, methods, and devices for triggered unscheduled power save delivery.

15 [0044] In one embodiment, a PCP/AP may negotiate with the STA and provide more information for pending data delivery of buffered data when the STA triggers the PCP/AP for its BU.

[0045] In one embodiment, the above negotiation is performed using the existing power save configuration request (PSC-REQ) and/or the power save configuration response (PSC-
20 RSP) frame exchange between the STA and the PCP/AP.

[0046] In one embodiment, the PSC-REQ and PSC-RSP frames may carry additional information contained in an information element.

[0047] In one embodiment, two options may define the information element carrying the information: option 1: define a new triggered unscheduled power save parameters information
25 element; and option 2: reusing the existing traffic specification (TSPEC) information element (IE).

[0048] Existing solutions are not suitable or sufficient to address the issue of QoS data delivery to STAs in a PS mode with a limited cache buffer.

[0049] The above descriptions are for purposes of illustration and are not meant to be
30 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.

[0050] 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 specification. The user device(s) 120 may be mobile devices that are non-stationary and do not have fixed locations.

5 [0051] In some embodiments, the user device(s) 120 and the AP 102 may include one or more computer systems similar to that of the functional diagram of FIG. 4 and/or the example machine/system of FIG. 5.

[0052] 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 the 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 the 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 ultrabook™ 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,

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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.

5 [0053] Any of the user device(s) 120 (e.g., user devices 124, 126, 128), and the 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
10 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).
15 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
20 combination thereof.

[0054] Any of the user device(s) 120 (e.g., user devices 124, 126, 128) and the AP 102 may include one or more communications antennas. A 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, 126 and 128) and the AP 102. Some non-limiting
25 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
30 as communications signals to and/or from the user device(s) 120.

[0055] Any of the user device(s) 120 (e.g., user devices 124, 126, 128) and/or the 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 a digital baseband.

[0056] Some demonstrative embodiments may be used in conjunction with a wireless communication network communicating over a frequency band of 60 GHz. 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 20 GHz and 300 GHz, a WLAN frequency band, a WPAN frequency band, a frequency band according to the WGA specification, and the like.

[0057] 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 gigabits per second, or any other rate.

[0058] In some demonstrative embodiments, the user device(s) 120 and/or the 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 specification and/or any other specification and/or protocol.

[0059] Some specifications, e.g., an IEEE 802.11ay specification, 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 an 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.

[0060] In some demonstrative embodiments, the user device(s) 120 and/or the AP 102 may be configured to implement one or more multi-user (MU) mechanisms. For example, the user
5 device(s) 120 and/or the 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.

[0061] In some demonstrative embodiments, the user devices 120 and/or the AP 102 may
10 be configured to communicate over a Next Generation 60 GHz (NG60) network, an Extended DMG (EDMG) network, and/or any other network. For example, the user devices 120 and/or the 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.

[0062] In some demonstrative embodiments, the user devices 120 and/or the AP 102 may
15 be configured to support one or more mechanisms and/or features, for example, channel bonding, single user (SU) MIMO, and/or multi user (MU) MIMO, for example, in accordance with an EDMG standard, an IEEE 802.11ay standard and/or any other standard and/or protocol.

[0063] In one embodiment, and with reference to FIG. 1, an initiator (e.g., AP 102) may be
20 configured to communicate with one or more responders (e.g., non-AP STAs, such as the user devices 120).

[0064] It is understood that the above descriptions are for purposes of illustration and are not meant to be limiting.

[0065] FIGs. 2A-2B depict illustrative tables for enhanced spatial multiplexing, in
25 accordance with one or more example embodiments of the present disclosure.

[0066] Referring to FIG. 2A, there is shown a Table 200. Table 200 may be comprised of one or more capability indications that may be used by one or more devices to communicate their capabilities during a communication session. Further, Table 200 shows the identifications that correspond to the capabilities. The capabilities may represent capabilities of an STA, such
30 as beamforming, multi-beamforming (multi-BF), antenna polarization capability, PHY capability, supported channels, MAC capability, and other capabilities.

[0067] In one or more embodiments, an enhanced spatial multiplexing system may define a MAC capability field 202.

[0068] Referring to FIG. 2B, there is shown a Table 250. Table 250 shows a subfield (e.g., SM power save subfield 204) of the MAC capability field 202.

[0069] In one or more embodiments, a capability field of the MAC capability field 202 and a subfield (e.g., the SM power save subfield 204) within the MAC capability field 202 may be added to an EDMG capabilities element to signal the capability of the SM power save of the EDMG STAs, as well as the mode of the SM power save after (re)association.

[0070] In one or more embodiments, the SM power save subfield 204 may indicate the support for a spatial multiplexing power save for an EDMG STA. The SM power save subfield 204 also may indicate the spatial multiplexing power save mode that is in operation immediately after (re)association. This field may be set to 0 to indicate a static SM power save mode, 1 to indicate a dynamic SM power save mode, and 3 to indicate an SM power save disabled or not supported. The value of 2 may be reserved.

[0071] In one or more embodiments, the SM power save subfield 204 may be valid only in a (re)association request frame sent to an AP or a PCP. Otherwise, the SM power save subfield may be set to 0 or 3 upon transmission and ignored upon reception. The SM power save subfield may indicate the operational state immediately after (re)association as well as (e.g., if not set to 3) a capability.

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

[0073] FIG. 2C depicts an illustrative flow of a negotiation phase and a data delivery phase, in accordance with one or more example embodiments of the present disclosure.

[0074] In one embodiment, in the negotiation phase 270, the STA 264 may send, to a PCP/AP 262, a PSC-REQ frame including the triggered unscheduled power save parameters (or alternatively TSPEC) IE, which may include the following information: (1) access category/traffic identifier (TID) to be served; (2) information about data delivery period, which is an advisory on the time period in which the station will attempt to retrieve its BU (e.g., 20 ms); and (3) amount of buffered data reserved at the PCP/AP 262 that will be available for immediate transmission (e.g., 64 KB, total of 8 MPDU etc.). PCP/AP 262 may respond with a PSC-RSP frame including the triggered unscheduled power save parameters (or alternatively TSPEC) IE in which it may indicate the information of the corresponding parameters it can support for the upcoming delivery of the buffered data. If STA 264 is not satisfied with the information contained in the PSC-RSP frame transmitted by the PCP/AP 262, it may initiate additional PSC-REQ negotiations with different parameters. This procedure may repeat until

both peers are satisfied. The PSC-REQ and the PSC-RSP frames may contain the triggered unscheduled power save parameters IE (AC/TID, data service period, reserve buffer size, etc.)

[0075] In one embodiment, in the data delivery phase 272, the STA 264 may switch to a doze state and trigger the PCP/AP 262 with a reverse direction grant (RDG) to retrieve its buffered data typically every data delivery period. Per the STA RD grant, PCP/AP 262 may be capable of delivering the agreed size of the BUs to the STA 264.

[0076] In one embodiment, a triggered unscheduled power save delivery may introduce a triggered unscheduled power save parameters information element (IE). In one option, a new triggered unscheduled power save parameters IE may be defined, as shown in the structure of

10 Table 1:

[0077] Table 1: A New Triggered Unscheduled Power Save Parameters IE

	Element ID	Length	Element ID Extension	TID	Reserved Buffer Size	Data Delivery Period
Octets	1	1	1	1	2	2

[0078] The triggered unscheduled power save parameters IE may be used to communicate the triggered unscheduled parameters between the EDMG STA (e.g., STA 264) and PCP/AP (e.g., PCP/AP 262).

15 [0079] The reserved buffer size field may be 2 octets long and may contain an unsigned integer that specifies the size, in units of 64 octets, of the reserved buffer belonging to the TID.

[0080] The data delivery period field may be 2 octets long and may contain an unsigned integer that specifies the typical interval, in milliseconds, between the start of two successive triggers arrived by the station.

20 [0081] In a second option, a triggered unscheduled power save delivery may reuse the existing TSPEC element in 802.11. The TSPEC element already contains information fields like TID, the minimum/maximum service interval. The field of the burst size may be reused to include the information of reserved buffer size in case TSPEC may be sent in PSC frames. It is understood that the above descriptions are for purposes of illustration and are not meant to be limiting.

[0082] FIG. 3A illustrates a flow diagram of an illustrative process 300 for enhanced spatial multiplexing, in accordance with one or more example embodiments of the present disclosure.

[0083] At block 302, a device (e.g., the AP 102 of FIG. 1) may determine one or more station devices (e.g., the user device 120 of FIG. 1) to be included in a communication session.

[0084] At block 304, the device may determine a frame comprising an indication, wherein the indication is associated with a type of the communication session. For example, an AP may include an indication in one of its frames to the one or more user devices that the type of communication session is either MIMO or SISO in order to allow the one or more stations to prepare for the communication session.

[0085] At block 306, the device may cause to send a frame to the one or more station devices. For example, the frame may be a Grant frame that an AP may send to a user device. The Grant frame may include information that will indicate to the one or more user devices that receives the Grant frame that the AP is attempting to initiate a MIMO or SISO communication. For example, a control trailer may be included in the Grant frame to indicate the upcoming transmission may be a MIMO mode transmission that needs the activation of multiple receive chains. In addition, the Grant frame may indicate the target time for initiating the MIMO transmission, and this time offset may be at least in the order of a probe delay.

[0086] At block 308, the device may identify a response frame received from a first station device of the one or more station devices, wherein the response frame comprises an activation indication of one or more receive chains on the first station device. For example, after receiving the Grant frame, the user device may respond with a Grant acknowledgment frame and activate its multiple receive chains, and perform MIMO CCA for the upcoming MIMO channel access attempt that may be initiated by the AP at the target time indicated in the Grant frame. The Grant acknowledgement comprises an indication of confirming the receipt of the Grant frame and the need to activate more receive chains. In other words, when the user device sends the Grant acknowledgment back, it is possible that it has not activated multiple receive chains, but it has confirmed that it will activate them before the target time indicated in the received Grant frame. After receiving the acknowledgment, the AP may then initiate the MIMO based on the indication that the user device is attempting to activate the receive chains before the target time of starting the MIMO communication. This way the user device will have enough time to perform CCA for the upcoming MIMO channel access attempt.

[0087] It is understood that the above descriptions are for purposes of illustration and are not meant to be limiting.

[0088] FIG. 3B illustrates a flow diagram of an illustrative process 350 for enhanced spatial multiplexing, in accordance with one or more example embodiments of the present disclosure.

[0089] At block 352, a device (e.g., the user device(s) 120 of FIG. 1) may identify a first frame received from a first station device, the first frame comprising an indication associated with a type of communication with the device. For example, if the subsequent communication

type is MIMO, then the station device may activate its multiple receive chains. If the subsequent communication type is SISO, then the station device may activate a single receive chain.

[0090] At block 354, the device may determine to activate one or more receive chains on the device based on the indication. For example, an AP may determine that it wants to perform a MIMO communication session or SISO communication session with one or more user devices. The AP may include an indication in one of its frames to the one or more user devices that the type of communication session is either MIMO or SISO in order to allow the one or more stations to prepare for the communication session. For example, the frame may be a Grant frame that an AP may send to a user device. The Grant frame may include information that will indicate to the one or more user devices that receives the Grant frame that the AP is attempting to initiate a MIMO or SISO communication. For example, a control trailer may be included in the Grant frame to indicate the upcoming transmission may be a MIMO mode transmission that needs the activation of multiple receive chains. In addition, the Grant frame may indicate the target time for initiating the MIMO transmission, and this time offset may be at least in the order of a probe delay.

[0091] At block 356, the device may perform clear channel assessment (CCA) on the one or more receive chains. For example, after receiving the Grant frame, the user device may respond with a Grant acknowledgment frame and activate its multiple receive chains, and perform MIMO CCA for the upcoming MIMO channel access attempt that may be initiated by the AP at the target time indicated in the Grant frame.

[0092] At block 358, the device may cause to send an acknowledgment to the first frame, wherein the acknowledgment comprises an indication of the activation of the one or more receive chains. The Grant acknowledgement comprises an indication of confirming the receipt of the Grant frame and the need to activate more receive chains. In other words, when the user device sends the Grant acknowledgment back, it is possible that it has not activated multiple receive chains, but it has confirmed that it will activate them before the target time indicated in the received Grant frame.

[0093] At block 360, the device may identify a second frame received from the first station device, wherein the second frame indicates the start of the communication session.

[0094] It is understood that the above descriptions are for purposes of illustration and are not meant to be limiting.

[0095] FIG. 3C illustrates a flow diagram of an illustrative process 360 for a triggered unscheduled power save delivery system, in accordance with one or more example

embodiments of the present disclosure.

[0096] At block 362, a device (e.g., the user device(s) 120 and/or the AP 102 of FIG. 1) may cause to send a first power save configuration request (PSC-REQ) to a controller device, wherein the PSC-REQ contains a first triggered unscheduled power save information element (IE).

[0097] At block 364, the device may identify a first power save configuration response (PSC-RSP) frame including a second triggered unscheduled power save IE.

[0098] At block 366, the device may cause to send a second PSC-REQ based on the second triggered unscheduled power save IE. It is understood that the above descriptions are for purposes of illustration and are not meant to be limiting.

[0099] 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 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.

[0100] 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 transceiver 410 may be a device comprising both a transmitter and a receiver that are combined and share common circuitry (e.g., communication circuitry 402). The communications circuitry 402 may include amplifiers, filters, mixers, analog to digital and/or digital to analog converters. The transceiver 410 may transmit and receive analog or digital signals. The transceiver 410 may allow reception of signals during transmission periods. This mode is known as full-duplex, and may require the transmitter and receiver to operate on different frequencies to minimize interference between the transmitted signal and the received signal. The transceiver 410 may operate in a half-duplex mode, where the transceiver 410 may transmit or receive signals in one direction at a time.

[0101] The communications circuitry 402 may include circuitry that may 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. 2A, 2B, 2C, 3A, 3B, and 3C.

[0102] 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.

[0103] 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.

[0104] 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.

[0105] 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.

[0106] 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.

[0107] 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.

[0108] 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.

5 [0109] 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.,
10 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 execution 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
15 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.

[0110] 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
20 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
25 512, 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 spatial multiplexing 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
30 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.)).

[0111] 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.

[0112] The enhanced spatial multiplexing device 519 may carry out or perform any of the operations and processes (e.g., process 300 of FIG. 3A, the process 350 of FIG. 3B, and the process 360 of FIG. 3C) described and shown above.

[0113] It is understood that the above are only a subset of what the enhanced spatial multiplexing device 519 may be configured to perform and that other functions included throughout this disclosure may also be performed by the enhanced spatial multiplexing device 519.

[0114] 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.

[0115] 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.

[0116] 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.

[0117] 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.

[0118] 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.

5 [0119] 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
10 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
15 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.

[0120] 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
20 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.

[0121] 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, or some other similar terminology known in the art. An access terminal may also be called a mobile station, user equipment (UE),
25 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.

[0122] Some embodiments may be used in conjunction with various devices and systems,
30 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.

[0123] 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 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.

[0124] 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.

[0125] The following examples pertain to further embodiments.

[0126] Example 1 may include a device comprising storage and processing circuitry configured to: determine one or more station devices to be included in a communication session; determine a frame including an indication, wherein the indication may be associated with a type of the communication session; cause to send a frame to the one or more station

devices; and identify a response frame received from a first station device of the one or more station devices, wherein the response frame comprises an activation indication of one or more receive chains on the first station device.

[0127] Example 2 may include the device of example 1 and/or some other example herein, wherein the indication indicates a medium access control (MAC) capability field, wherein the MAC capability field may include a spatial multiplexing power save subfield.

[0128] Example 3 may include the device of example 2 and/or some other example herein, wherein the spatial multiplexing power save subfield indicates a static spatial multiplexing power save mode or a dynamic spatial multiplexing power save mode.

10 [0129] Example 4 may include the device of example 3 and/or some other example herein, wherein the frame may be a Grant frame comprising one or more fields.

[0130] Example 5 may include the device of example 4 and/or some other example herein, wherein the Grant frame comprises a control trailer field indicating that a subsequent communication type may be multiple input multiple output (MIMO) communication.

15 [0131] Example 6 may include the device of example 5 and/or some other example herein, wherein the Grant frame indicates a time for initiating the MIMO communication.

[0132] Example 7 may include the device of example 1 and/or some other example herein, wherein the time may be associated with a delay to determine one or more clear channels on one or more receive chains of the first station device.

20 [0133] Example 8 may include the device of example 1 and/or some other example herein, wherein the Grant frame comprises a control trailer indicating that a subsequent communication type may be single input single output (SISO).

[0134] Example 9 may include the device of example 6 and/or some other example herein, further comprising a transceiver configured to transmit and receive wireless signals.

25 [0135] Example 10 may include the device of example 8 and/or some other example herein, further comprising one or more antennas coupled to the transceiver.

[0136] Example 11 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: identify a first frame received from a first station device, the first frame including an indication associated with a type of communication with the device; determine to activate one or more receive chains on the device based on the indication; perform clear channel assessment (CCA) on the one or more receive chains; cause to send an acknowledgment, wherein the acknowledgment comprises an indication confirming that the one or more receive chains will be activated before a target time; and identify a second frame

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received from the first station device, wherein the second frame indicates the start of the communication session.

[0137] Example 12 may include the non-transitory computer-readable medium of example 11 and/or some other example herein, wherein the indication indicates a medium access control (MAC) capability field, wherein the MAC capability field may include a spatial multiplexing power save subfield.

[0138] Example 13 may include the non-transitory computer-readable medium of example 12 and/or some other example herein, wherein the spatial multiplexing power save subfield indicates a static spatial multiplexing power save mode or a dynamic spatial multiplexing power save mode.

[0139] Example 14 may include the non-transitory computer-readable medium of example 11 and/or some other example herein, wherein the first frame may be a Grant frame comprising one or more fields.

[0140] Example 15 may include the non-transitory computer-readable medium of example 14 and/or some other example herein, wherein the Grant frame comprises a control trailer field indicating that a subsequent communication type may be multiple input multiple output (MIMO) communication.

[0141] Example 16 may include the non-transitory computer-readable medium of example 11 and/or some other example herein, wherein the Grant frame indicates a time for initiating the MIMO communication.

[0142] Example 17 may include a method comprising: causing to send, by one or more processors, a first power save configuration request (PSC-REQ) to a controller device, wherein the PSC-REQ contains a first triggered unscheduled power save information element (IE); identifying a first power save configuration response (PSC-RSP) frame including a second triggered unscheduled power save IE; and causing to send a second PSC-REQ based on the second triggered unscheduled power save IE.

[0143] Example 18 may include the method of example 17 and/or some other example herein, wherein the first triggered unscheduled power save IE comprises an access category, a data delivery period, or an amount of buffered data.

[0144] Example 19 may include the method of example 17 and/or some other example herein, wherein the second triggered unscheduled power save IE indicates information of corresponding parameters supported for an upcoming delivery of buffered data.

[0145] Example 20 may include the method of example 19 and/or some other example herein, further comprising initiating additional PSC-REQ negotiation with different parameters.

5 [0146] Example 21 may include the method of example 17 and/or some other example herein, wherein the first triggered unscheduled power save IE may be a traffic specification (TSPEC).

[0147] Example 22 may include an apparatus comprising means for: causing to send a first power save configuration request (PSC-REQ) to a controller device, wherein the PSC-REQ contains a first triggered unscheduled power save information element (IE); identifying a first
10 power save configuration response (PSC-RSP) frame including a second triggered unscheduled power save IE; and causing to send a second PSC-REQ based on the second triggered unscheduled power save IE.

[0148] Example 23 may include the apparatus of example 22 and/or some other example herein, wherein the first triggered unscheduled power save IE comprises an access category, a
15 data delivery period, or an amount of buffered data.

[0149] Example 24 may include the apparatus of example 22 and/or some other example herein, wherein the second triggered unscheduled power save IE indicates information of corresponding parameters supported for an upcoming delivery of buffered data.

[0150] Example 25 may include the apparatus of example 22 and/or some other example
20 herein, further comprising means initiating additional PSC-REQ negotiation with different parameters.

[0151] Example 26 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
25 described in or related to any of examples 1-25, or any other method or process described herein

[0152] Example 27 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 1-25, or any other method or process described herein.

30 [0153] Example 28 may include a method, technique, or process as described in or related to any of examples 1-25, or portions or parts thereof.

[0154] Example 29 may include an apparatus comprising: one or more processors and one or more computer readable media comprising instructions that, when executed by the one or

more processors, cause the one or more processors to perform the method, techniques, or process as described in or related to any of examples 1-25, or portions thereof.

[0155] Example 30 may include a method of communicating in a wireless network as shown and described herein.

5 [0156] Example 31 may include a system for providing wireless communication as shown and described herein.

[0157] Example 32 may include a device for providing wireless communication as shown and described herein.

[0158] Embodiments according to the invention are in particular disclosed in the
10 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)
15 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
20 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.

[0159] 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
25 precise form disclosed. Modifications and variations are possible in light of the above teachings or may be acquired from practice of various embodiments.

[0160] 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
30 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.

[0161] 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.

[0162] 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.

[0163] 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.

[0164] 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
5 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 one or more station devices to be included in a communication session;
determine a frame including an indication, wherein the indication is associated with a type of the communication session;
cause to send a frame to the one or more station devices; and
identify a response frame received from a first station device of the one or more station devices, wherein the response frame comprises an activation indication of one or more receive chains on the first station device.
2. The device of claim 1, wherein the indication indicates a medium access control (MAC) capability field, wherein the MAC capability field includes a spatial multiplexing power save subfield.
3. The device of claim 2, wherein the spatial multiplexing power save subfield indicates a static spatial multiplexing power save mode or a dynamic spatial multiplexing power save mode.
4. The device of claim 1, wherein the frame is a grant frame comprising one or more fields.
5. The device of claim 4, wherein the grant frame comprises a control trailer field indicating that a subsequent communication type is multiple-input multiple-output (MIMO) communication.
6. The device of claim 5, wherein the grant frame indicates a time for initiating the MIMO communication.
7. The device of claim 6, wherein the time is associated with a delay to determine one or more clear channels on one or more receive chains of the first station device.

8. The device of any one of claims 1-7, wherein the grant frame comprises a control trailer indicating that a subsequent communication type is single-input single-output (SISO).
9. The device of claim 6, further comprising a transceiver configured to transmit and receive wireless signals.
10. The device of claim 8, further comprising one or more antennas coupled to the transceiver.
11. A non-transitory computer-readable medium storing computer-executable instructions which when executed by one or more processors of a device result in performing operations comprising:
- identifying a first frame received from a first station device, the first frame including an indication associated with a type of communication with the device;
 - determining to activate one or more receive chains on the device based on the indication;
 - performing a clear channel assessment (CCA) on the one or more receive chains;
 - causing to send an acknowledgment, wherein the acknowledgment comprises an indication confirming that the one or more receive chains will be activated before a target time; and
 - identifying a second frame received from the first station device, wherein the second frame indicates the start of the communication session.
12. The non-transitory computer-readable medium of claim 11, wherein the indication indicates a medium access control (MAC) capability field, wherein the MAC capability field includes a spatial multiplexing power save subfield.
13. The non-transitory computer-readable medium of claim 12, wherein the spatial multiplexing power save subfield indicates a static spatial multiplexing power save mode or a dynamic spatial multiplexing power save mode.
14. The non-transitory computer-readable medium of claim 11, wherein the first frame is a grant frame comprising one or more fields.

15. The non-transitory computer-readable medium of claim 14, wherein the grant frame comprises a control trailer field indicating that a subsequent communication type is multiple-input multiple-output (MIMO) communication.
16. The non-transitory computer-readable medium of any one of claims 14-15, wherein the grant frame indicates a time for initiating the MIMO communication.
17. A method comprising:
causing to send, by one or more processors, a first power save configuration request (PSC-REQ) to a controller device, wherein the PSC-REQ contains a first triggered unscheduled power save information element (IE);
identifying a first power save configuration response (PSC-RSP) frame including a second triggered unscheduled power save IE; and
causing to send a second PSC-REQ based on the second triggered unscheduled power save IE.
18. The method of claim 17, wherein the first triggered unscheduled power save IE comprises an access category, a data delivery period, or an amount of buffered data.
19. The method of claim 17, wherein the second triggered unscheduled power save IE indicates information of corresponding parameters supported for an upcoming delivery of buffered data.
20. The method of claim 19, further comprising initiating additional PSC-REQ negotiations with different parameters.
21. The method of any one of claims 17-20, wherein the first triggered unscheduled power save IE is a traffic specification (TSPEC).
22. An apparatus comprising means for:
causing to send a first power save configuration request (PSC-REQ) to a controller device, wherein the PSC-REQ contains a first triggered unscheduled power save information element (IE);

identifying a first power save configuration response (PSC-RSP) frame including a second triggered unscheduled power save IE; and causing to send a second PSC-REQ based on the second triggered unscheduled power save IE.

23. The apparatus of claim 22, wherein the first triggered unscheduled power save IE comprises an access category, a data delivery period, or an amount of buffered data.

24. The apparatus of claim 22, wherein the second triggered unscheduled power save IE indicates information of corresponding parameters supported for an upcoming delivery of buffered data.

25. The apparatus of any one of claims 22-24, further comprising means for initiating additional PSC-REQ negotiations with different parameters.

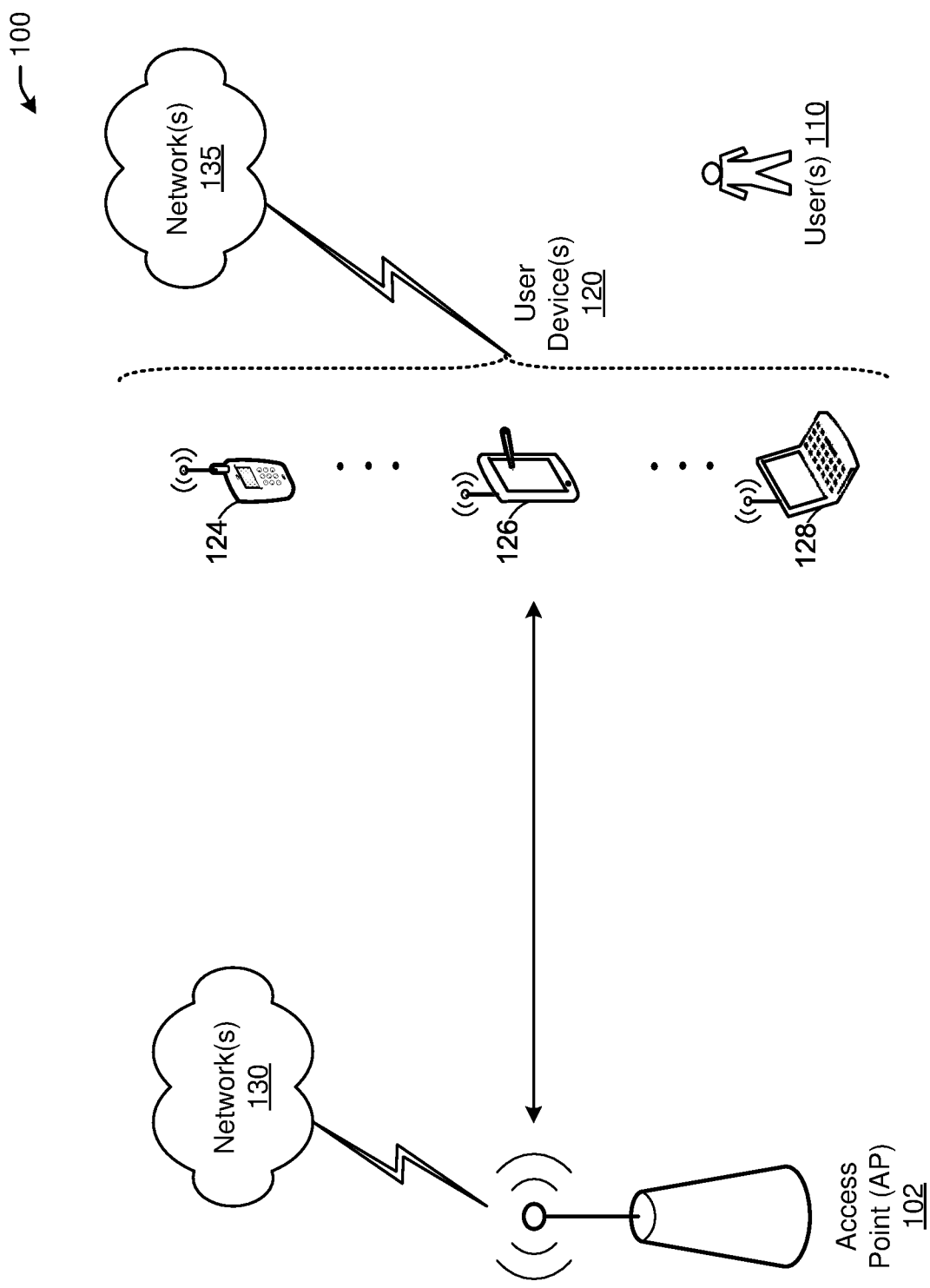


FIG. 1

200

Capability	Capabilities ID
Beamforming	0
Multi-BF	1
Antenna polarization capability	2
PHY Capability	3
Supported Channels	4
MAC Capability	5

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FIG. 2A

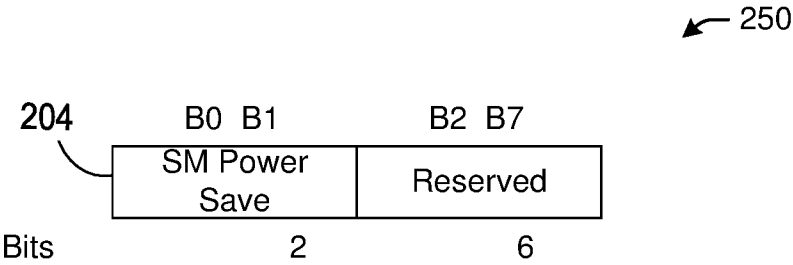


FIG. 2B

FIGs. 2A and 2B

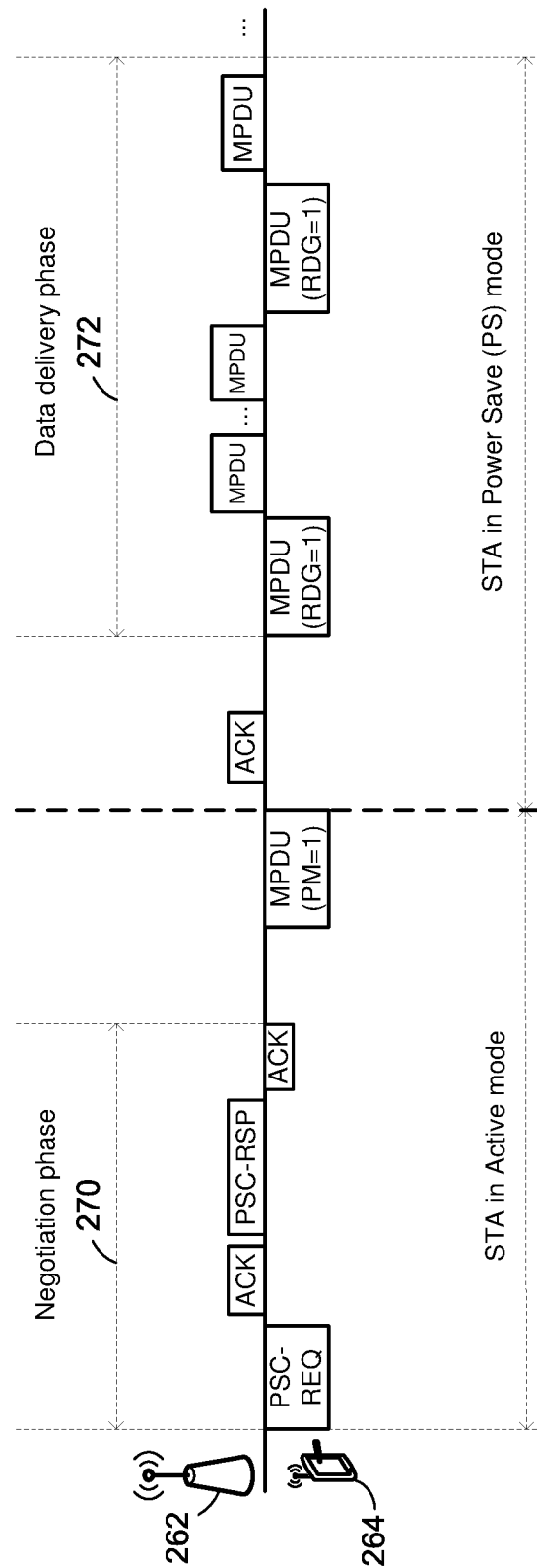


FIG. 2C

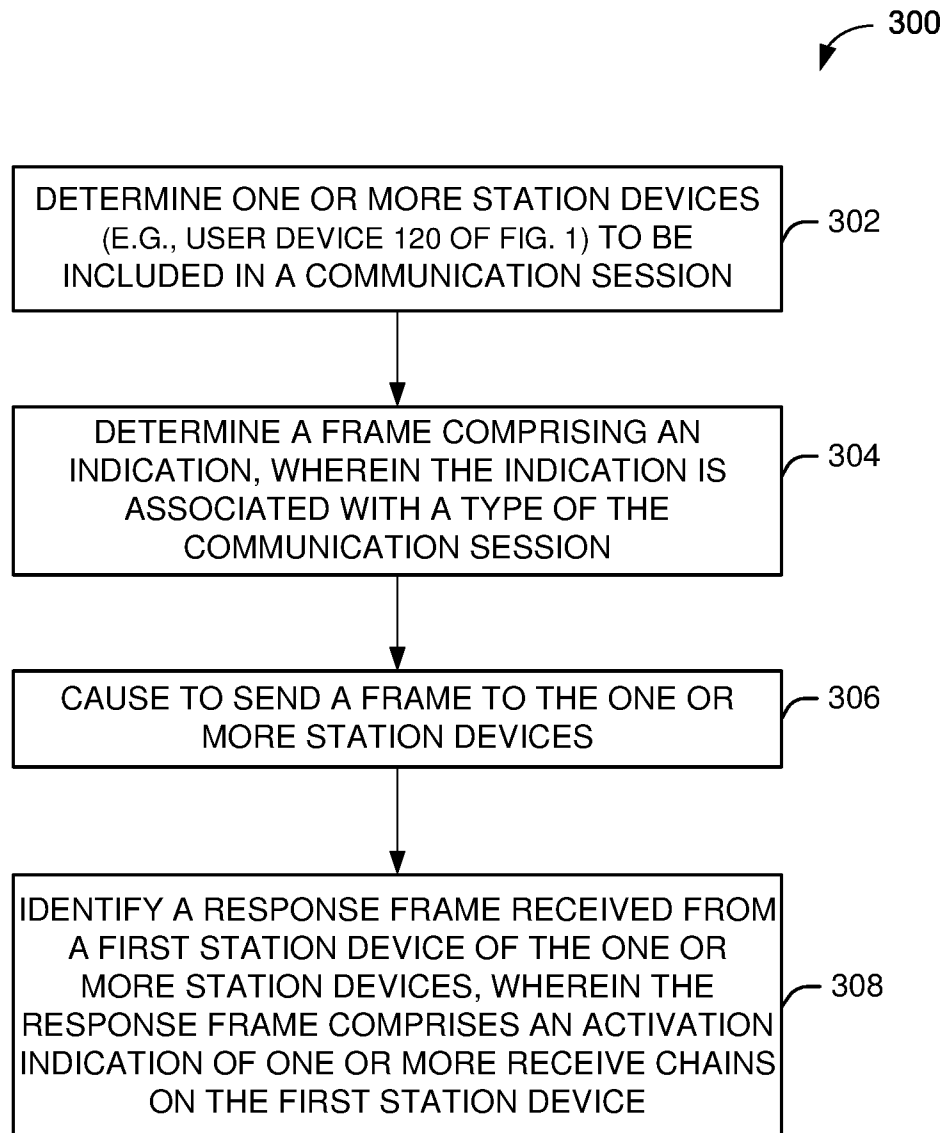


FIG. 3A

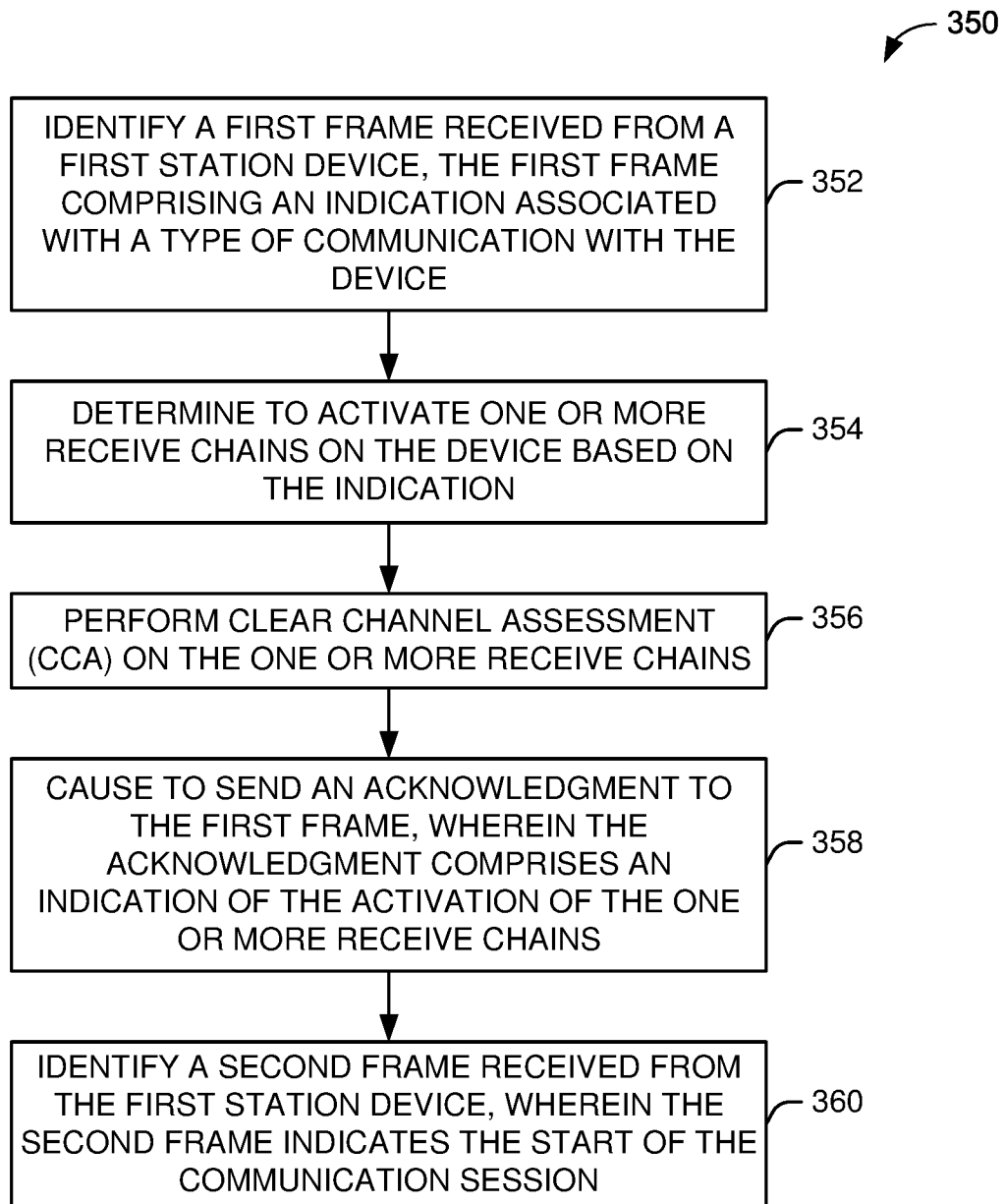


FIG. 3B

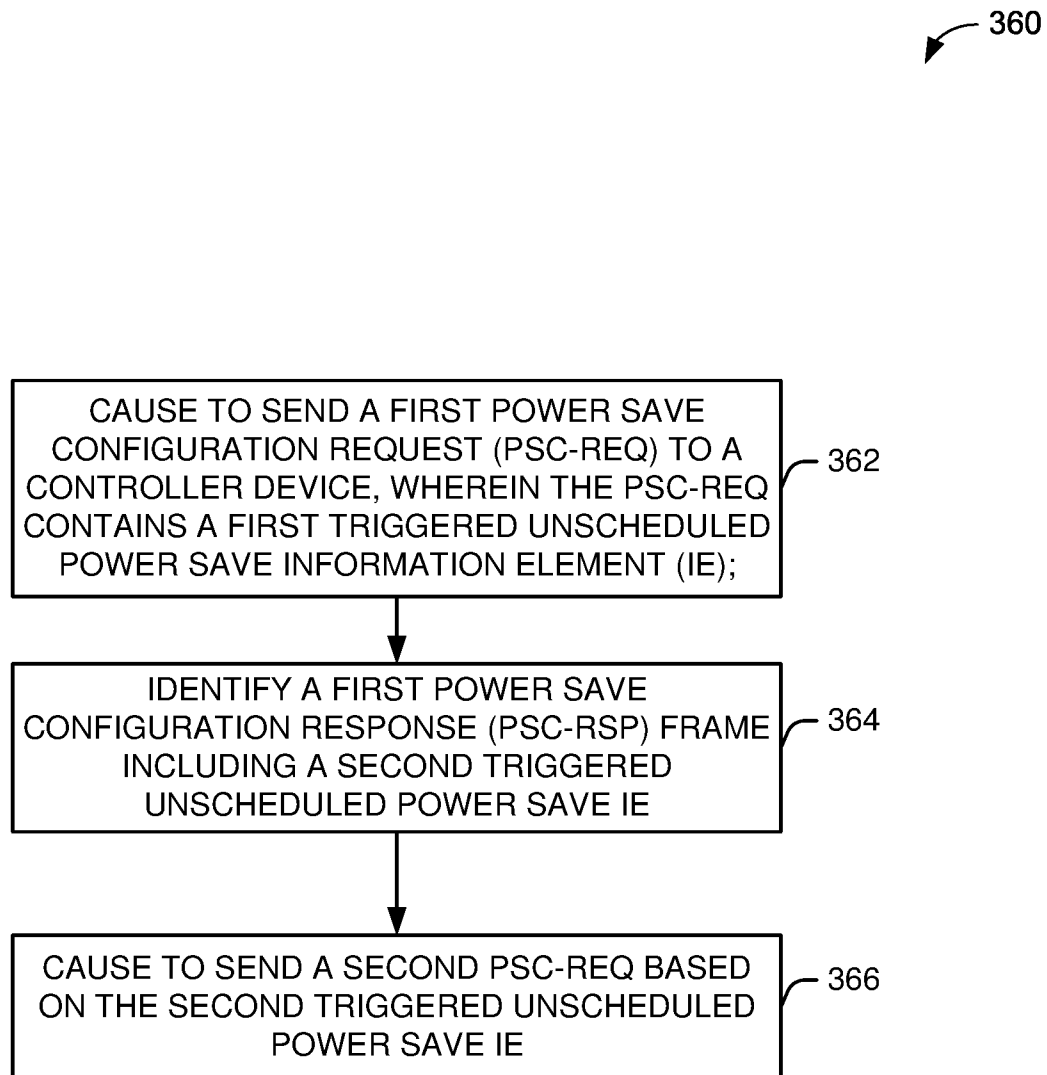


FIG. 3C

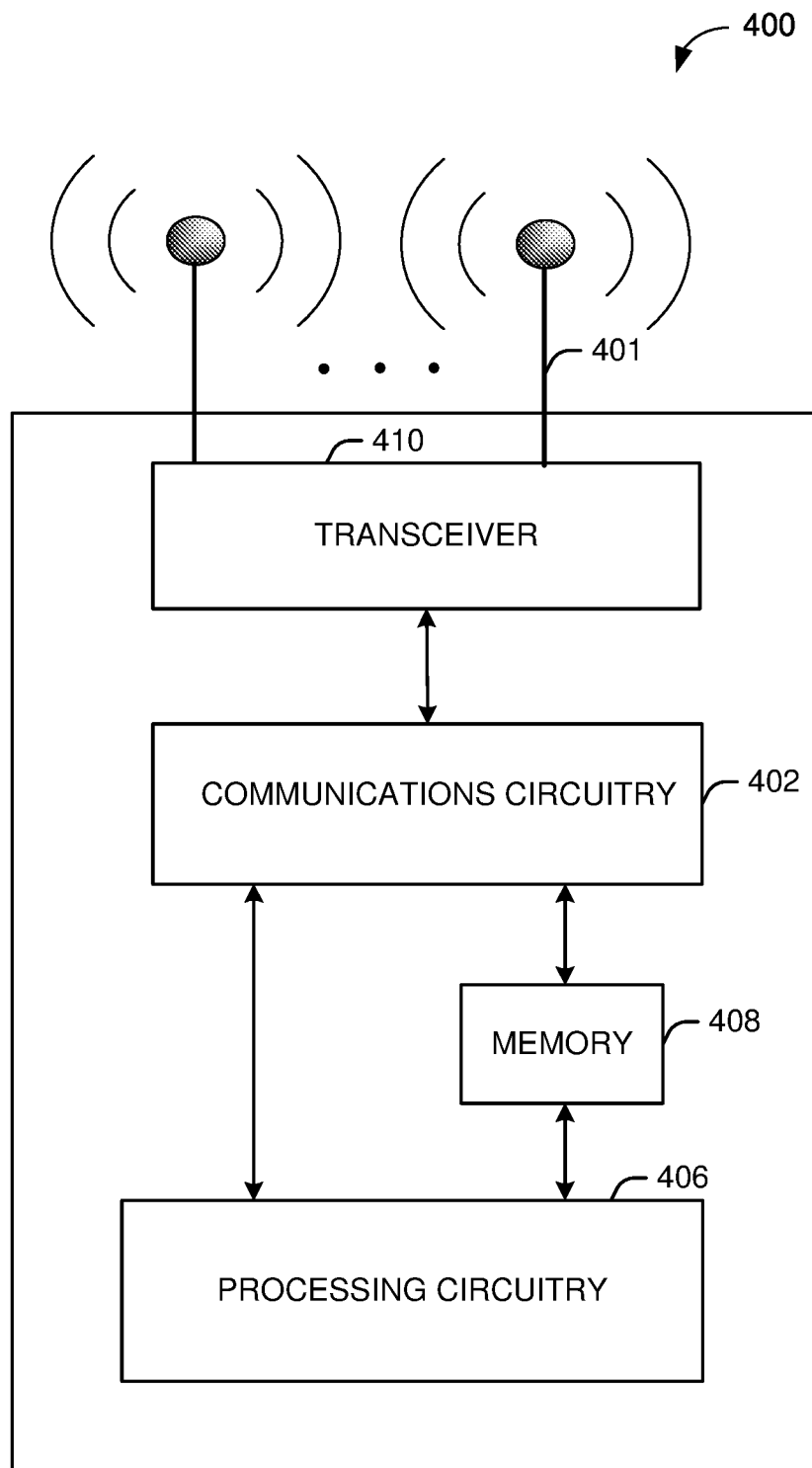


FIG. 4

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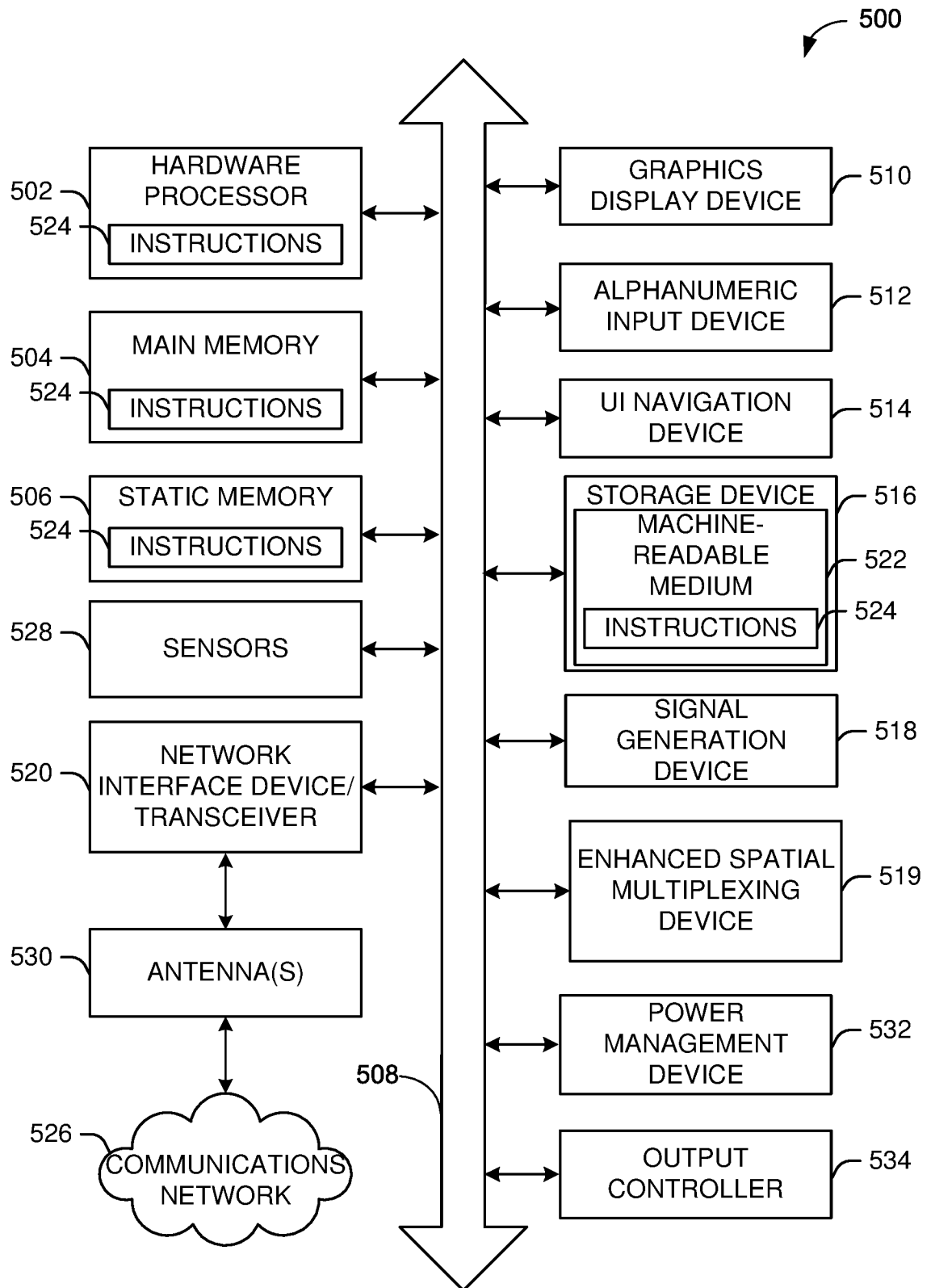


FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2018/039138**A. CLASSIFICATION OF SUBJECT MATTER****H04W 52/02(2009.01)i, H04W 74/08(2009.01)i, H04B 7/0413(2017.01)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)

H04W 52/02; H04B 7/04; H04B 7/08; H04J 3/16; H04Q 7/24; H04W 24/00; H04W 74/08; H04B 7/0413

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: spatial multiplexing(SM), 802.11ay, frame, indication, response frame, activation indication, chain, MAC capability field, grant frame, MIMO, CCA(clear channel assessment)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2014-0269995 A1 (QUALCOMM INCORPORATED) 18 September 2014 See paragraphs [0010], [0023]; and claim 1.	1-16
Y	US 2016-0360489 A1 (APPLE INC.) 08 December 2016 See paragraphs [0021], [0028], [0037]; and figure 3.	1-10, 12-13
Y	CHENG CHEN et al., 'MIMO Channel Access for 11ay', IEEE 802.11-17/0522r1, 29 March 2017 See slides 3-4, 6, 9.	4-16
A	US 2013-0329576 A1 (RAJESH KUMAR SINHA) 12 December 2013 See paragraphs [0032]-[0034], [0045]-[0046].	17-25
A	US 2011-0222524 A1 (ALLAN THOMSON et al.) 15 September 2011 See claims 1, 6-7.	17-25
A	US 2008-0219228 A1 (YONG HO SEOK et al.) 11 September 2008 See claims 1, 8-10.	17-25



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

27 November 2018 (27.11.2018)

Date of mailing of the international search report

27 November 2018 (27.11.2018)

Name and mailing address of the ISA/KR

International Application Division

Korean Intellectual Property Office

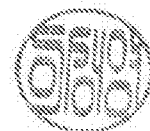
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INTERNATIONAL SEARCH REPORTInternational application No.
PCT/US2018/039138**Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)**

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

Group I: Claims 1-16 directed to a device and a non-transitory computer-readable medium for identifying a frame including an indication associated with a type of a communication session and determining an activation of one or more receive chains on a station device.

Group II: Claims 17-25 directed to a method and an apparatus for sending a first power save configuration request (PSC-REQ) containing a first triggered unscheduled power save information element (IE) and identifying a first power save configuration response (PSC-RSP) frame including a second triggered unscheduled power save IE.

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of any additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☒ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2018/039138

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2014-0269995 A1	18/09/2014	CN 105191238 A EP 2974188 A1 JP 2016-516347 A KR 10-2015-0129800 A US 2015-0063500 A1 US 9060338 B2 US 9167531 B2 WO 2014-158781 A1	23/12/2015 20/01/2016 02/06/2016 20/11/2015 05/03/2015 16/06/2015 20/10/2015 02/10/2014
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US 2008-0219228 A1	11/09/2008	CN 101675625 A CN 101675625 B EP 2122920 A1 EP 2122920 A4 EP 2122920 B1 JP 04980433 B2 JP 2010-521117 A KR 10-1073788 B1 KR 10-2009-0132592 A TW 200901681 A TW I528756 B US 8259632 B2 WO 2008-111826 A1	17/03/2010 17/07/2013 25/11/2009 14/07/2010 10/07/2013 18/07/2012 17/06/2010 13/10/2011 30/12/2009 01/01/2009 01/04/2016 04/09/2012 18/09/2008