US 20250267708A1

(19) **United States**

(12) **Patent Application Publication** (10) **Pub. No.: US 2025/0267708 A1**

Zhang et al. (43) **Pub. Date: Aug. 21, 2025**

(54) **MULTI-AP TRANSMISSION SCHEME SELECTION**

(71) Applicant: **Ofinno, LLC**, Reston, VA (US)

(72) Inventors: **Jiayi Zhang**, Rockville, MD (US); **Jeongki Kim**, Fairfax, VA (US); **Esmael Hejazi Dinan**, McLean, VA (US); **Leonardo Alisasis Lanante**, Reston, VA (US)

(73) Assignee: **Ofinno, LLC**, Reston, VA (US)

(21) Appl. No.: **19/188,600**

(22) Filed: **Apr. 24, 2025**

Related U.S. Application Data

(63) Continuation of application No. PCT/US2023/035767, filed on Oct. 24, 2023.

(60) Provisional application No. 63/419,357, filed on Oct. 26, 2022.

Publication Classification

(51) **Int. Cl.**

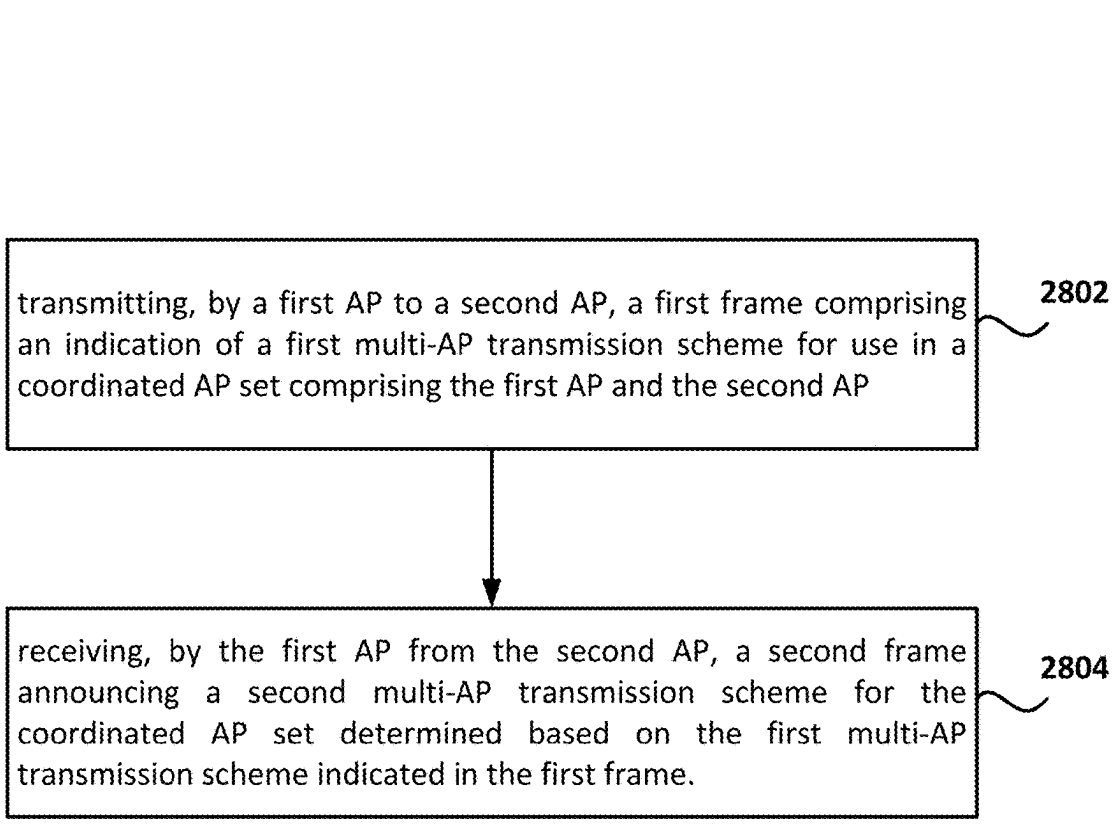
H04W 74/0816	(2024.01)
H04W 74/00	(2009.01)
H04W 74/04	(2009.01)

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

CPC ***H04W 74/0816*** (2013.01); ***H04W 74/002*** (2013.01); ***H04W 74/04*** (2013.01)

(57) **ABSTRACT**

A first access point (AP) receives from a second AP a first frame comprising an indication of a first multi-AP transmission scheme for use in a coordinated AP set comprising the first AP and the second AP. The first AP transmits a second frame announcing a second multi-AP transmission scheme determined based on the first multi-AP transmission scheme indicated in the first frame. The first multi-AP transmission scheme may correspond to a preferred scheme for the second AP for use in the coordinated AP set.



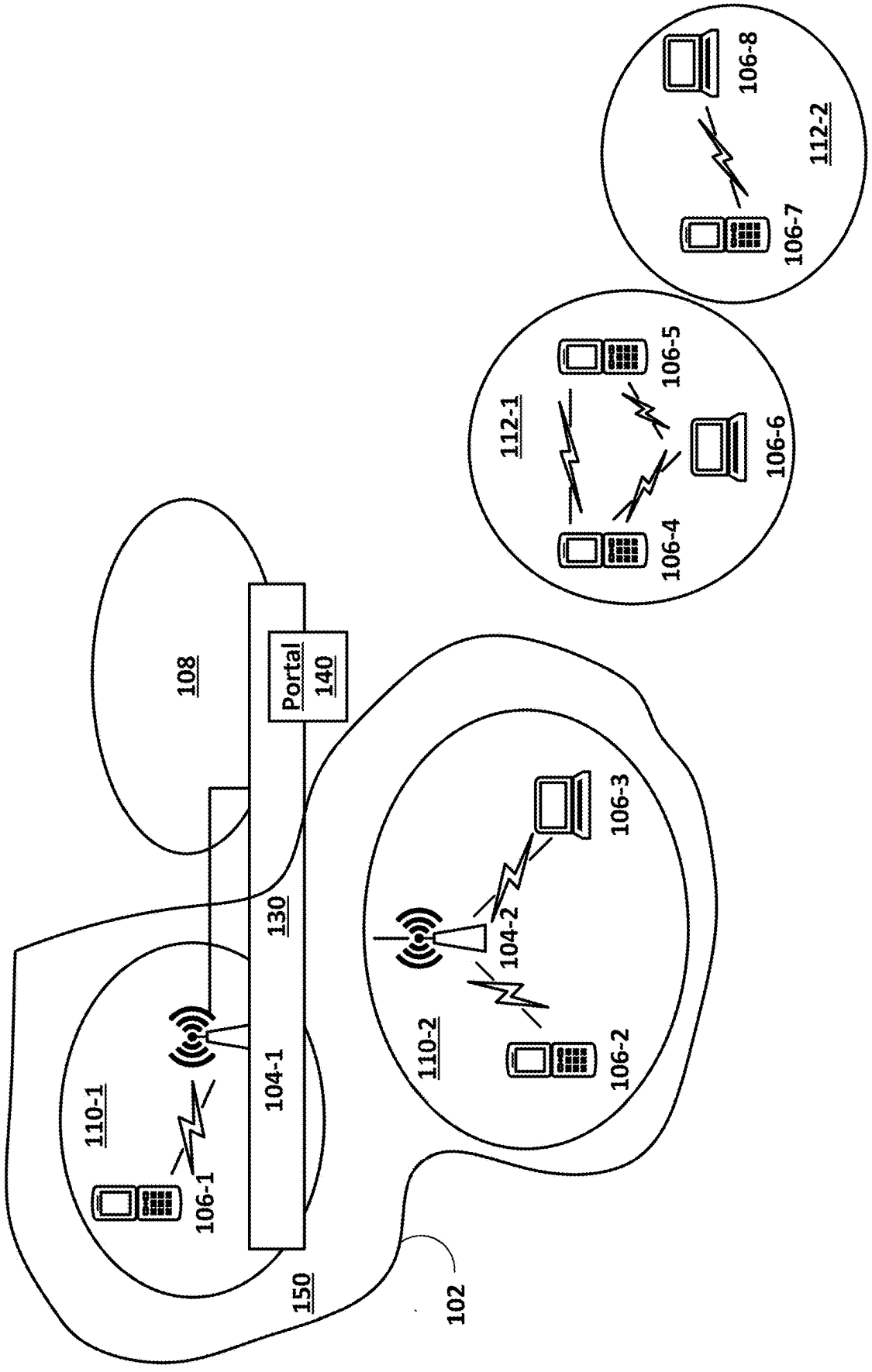

102
150
110-1
106-1
104-1
130
Portal
140
108
110-2
104-2
106-2
106-3
112-1
106-4
106-5
106-6
112-2
106-7
106-8

FIG. 1

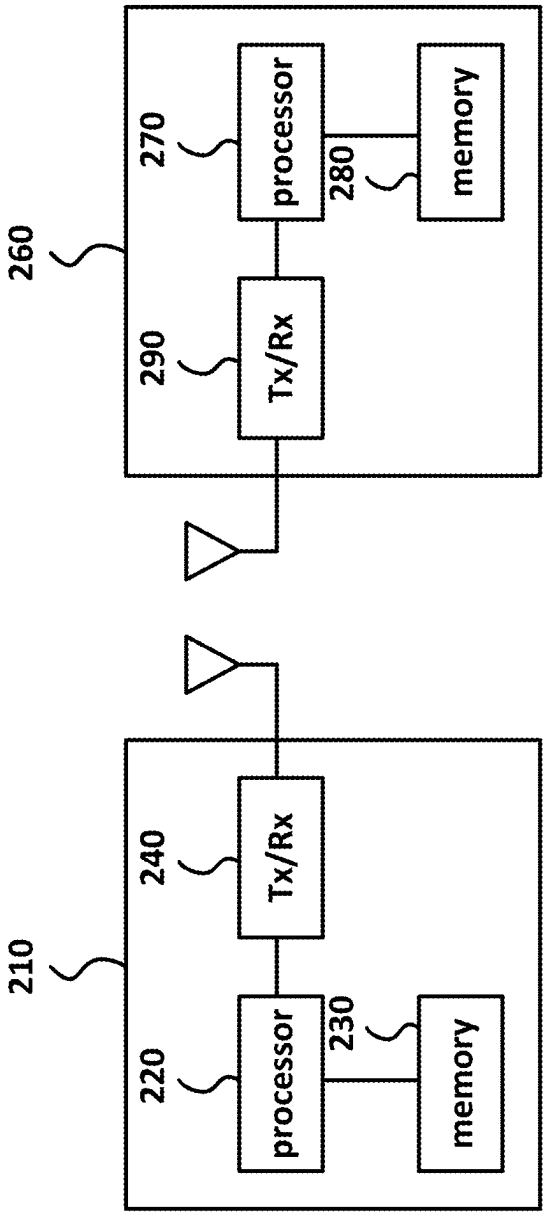

260
270
processor
280
memory
290
Tx/Rx
210
240
Tx/Rx
220
processor
230
memory

FIG. 2

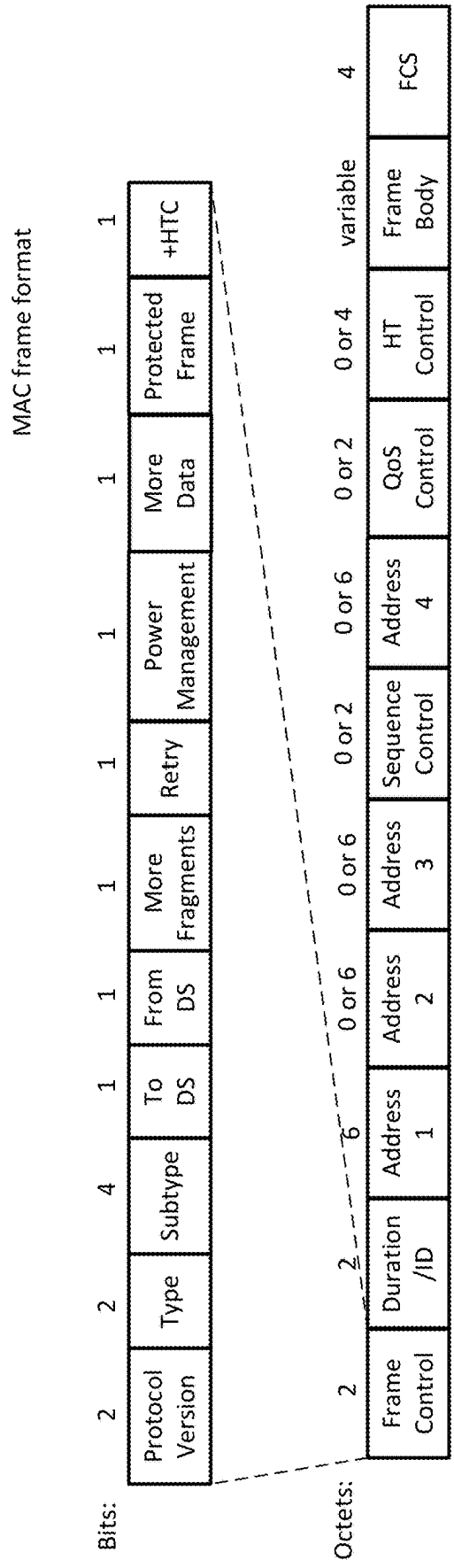

MAC frame format
Bits:
Octets:
Protocol Version
Type
Subtype
To DS
From DS
More Fragments
Retry
Power Management
More Data
Protected Frame
+HTC
Frame Control
Duration /ID
Address 1
Address 2
Address 3
Sequence Control
Address 4
QoS Control
HT Control
Frame Body
FCS
2
2
4
1
1
1
1
1
1
1
1
2
6
0 or 6
0 or 6
0 or 2
0 or 6
0 or 2
0 or 4
variable
4
MAC Header

FIG. 3

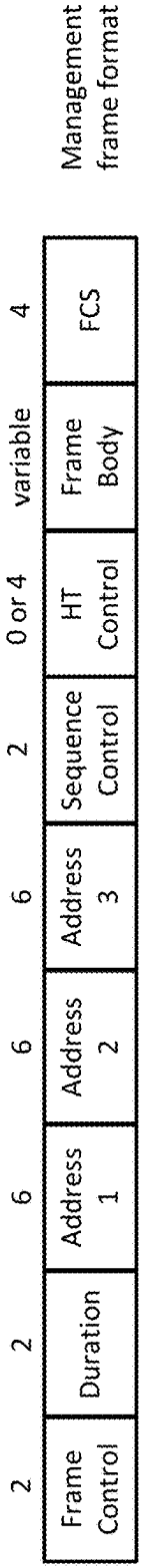

Octets:
2
2
6
6
6
2
0 or 4
variable
4
Frame Control
Duration
Address 1
Address 2
Address 3
Sequence Control
HT Control
Frame Body
FCS
MAC Header
Management frame format

FIG. 4A

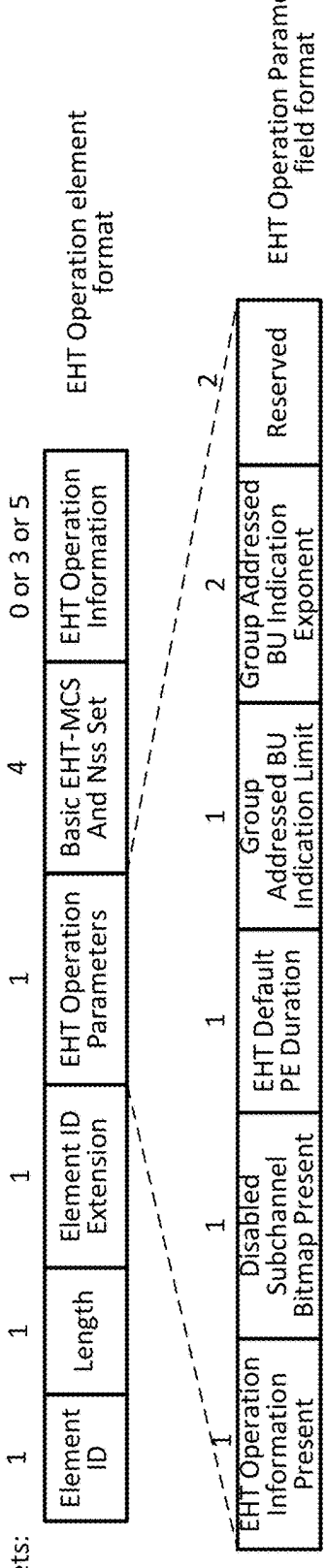

Octets:
1
1
1
1
4
0 or 3 or 5
Element ID
Length
Element ID Extension
EHT Operation Parameters
Basic EHT-MCS And Nss Set
EHT Operation Information
EHT Operation element format
Bits:
1
1
1
1
1
2
2
EHT Operation Information Present
Disabled Subchannel Bitmap Present
EHT Default PE Duration
Group Addressed BU Indication Limit
Group Addressed BU Indication Exponent
Reserved
EHT Operation Parameters field format

FIG. 4B

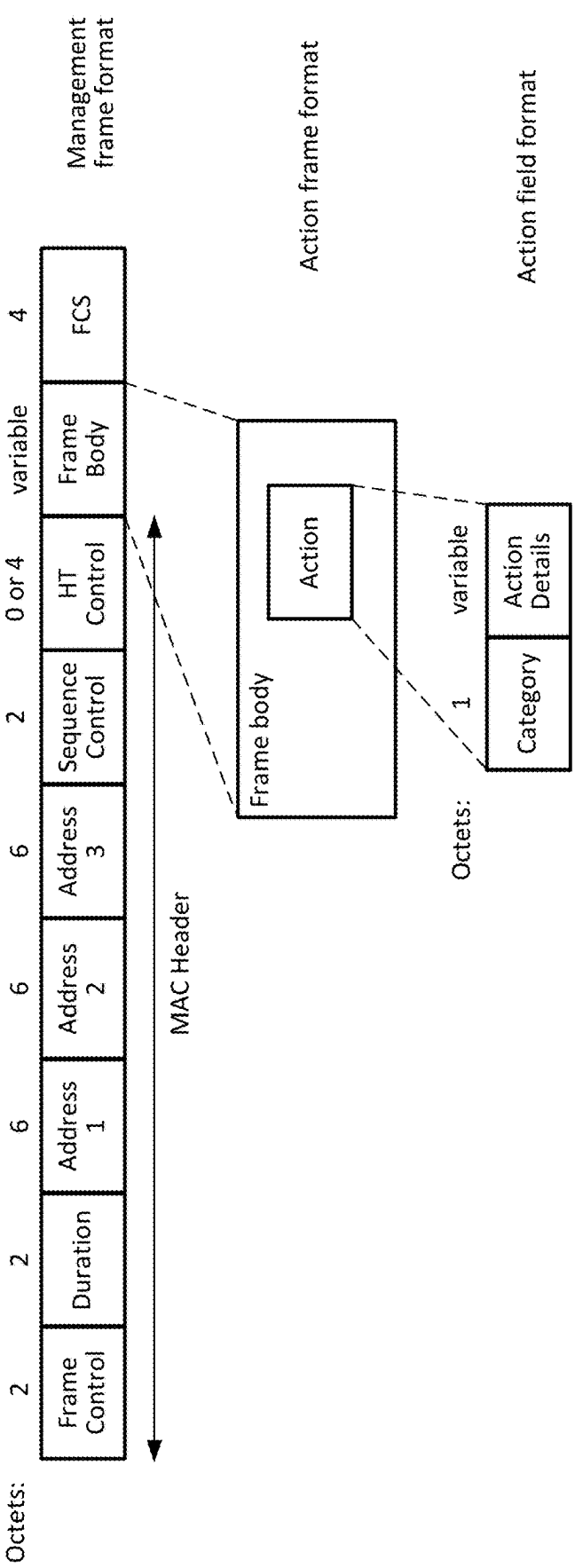

Management frame format
Octets:
2
2
6
6
6
2
0 or 4
variable
4
Frame Control
Duration
Address 1
Address 2
Address 3
Sequence Control
HT Control
Frame Body
FCS
MAC Header
Action frame format
Frame body
Action
Action field format
Octets:
1
variable
Category
Action Details

FIG. 5A

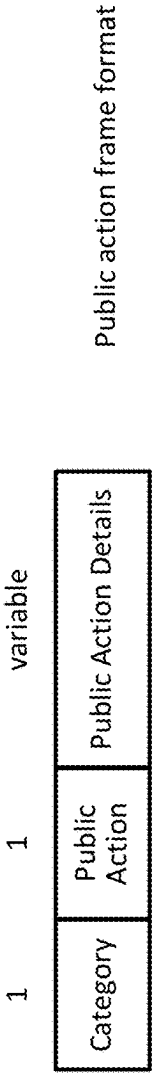

Public action frame format
Octets:
1
1
variable
Category
Public Action
Public Action Details

FIG. 5B

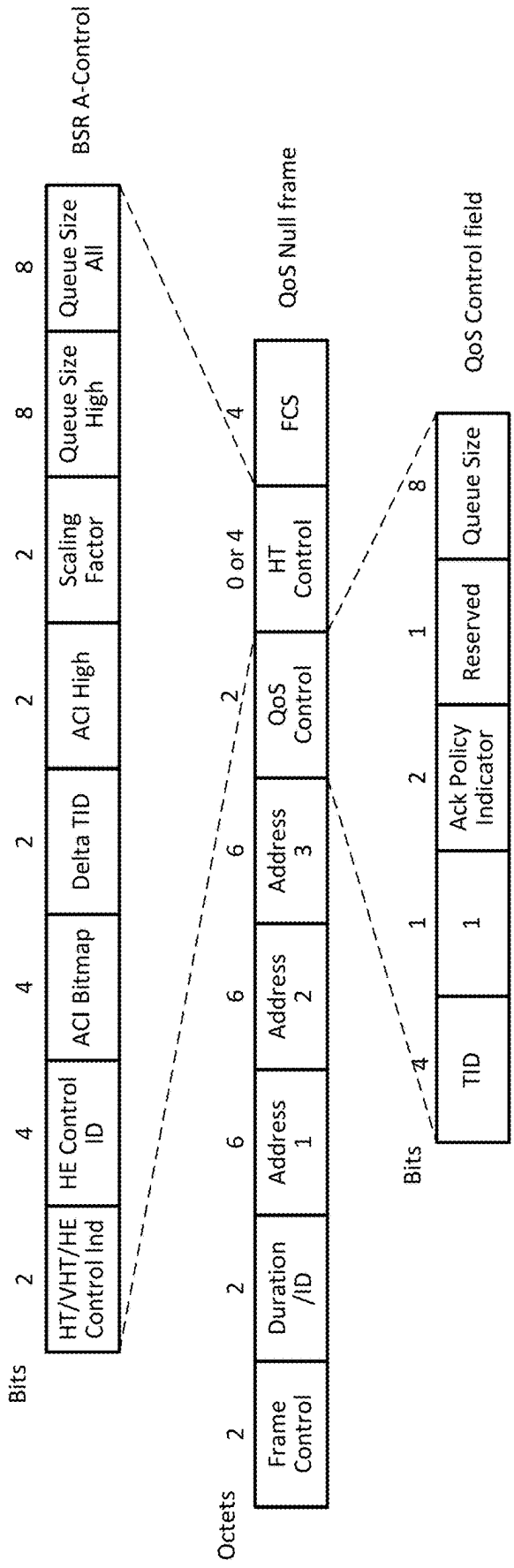

Octets
2
2
6
6
6
2
2
0 or 4
4
Frame Control
Duration /ID
Address 1
Address 2
Address 3
QoS Control
HT Control
FCS
QoS Null frame
Bits
2
4
4
2
2
2
2
8
8
HT/VHT/HE Control Ind
HE Control ID
ACI Bitmap
Delta TID
ACI High
Scaling Factor
Queue Size High
Queue Size All
BSR A-Control
Bits
4
1
1
2
1
8
TID
Ack Policy Indicator
Reserved
Queue Size
QoS Control field

FIG. 6

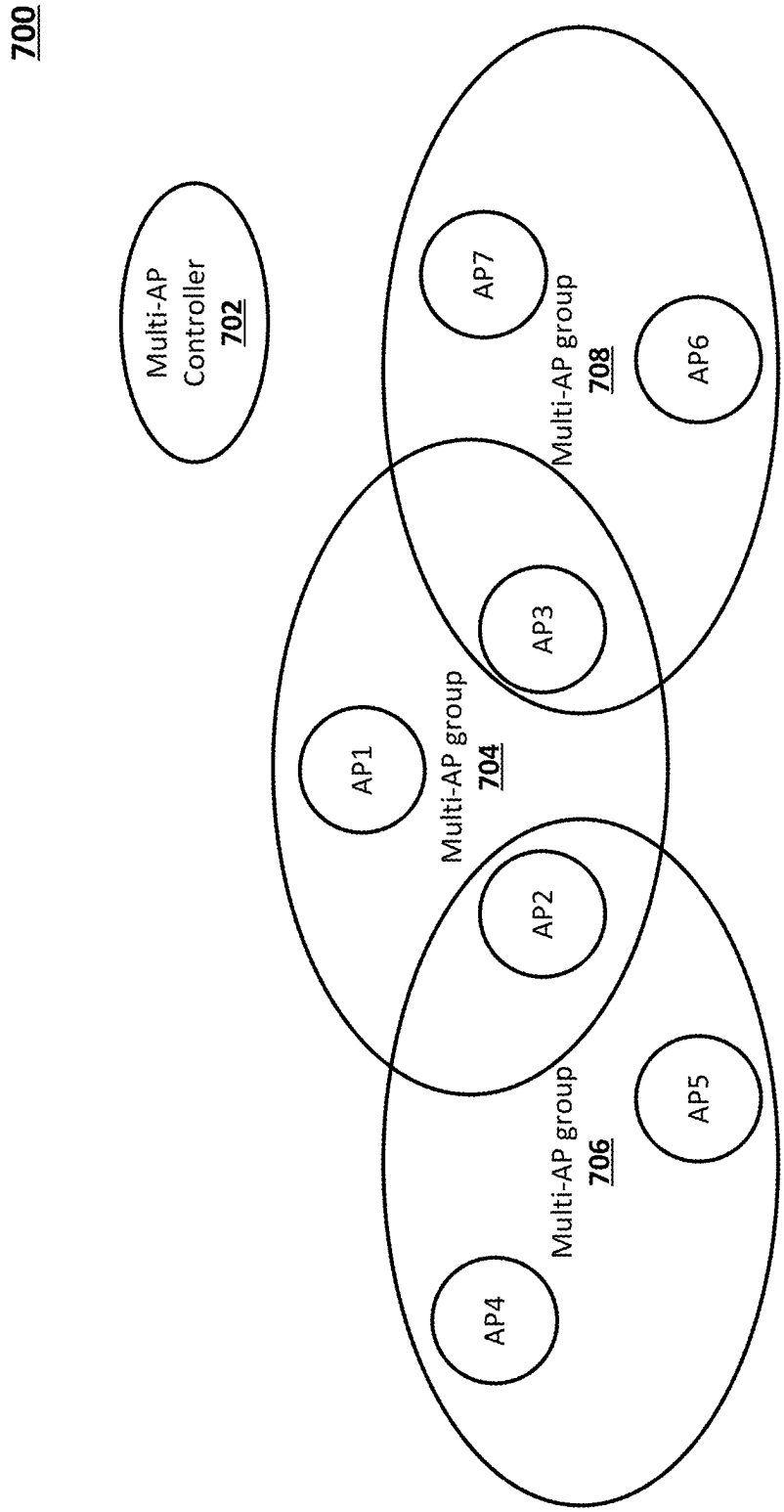

700
Multi-AP Controller 702
AP1
AP2
AP3
AP4
AP5
AP6
AP7
Multi-AP group 704
Multi-AP group 706
Multi-AP group 708

FIG. 7

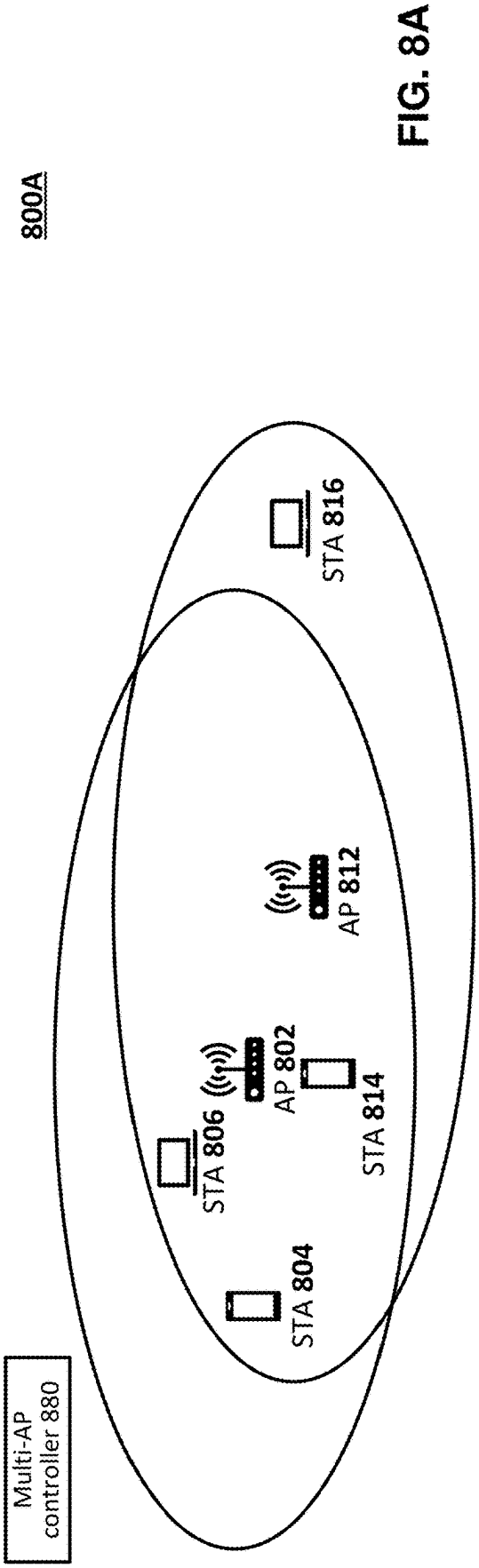

800A
Multi-AP controller 880
STA 804
STA 806
AP 802
AP 812
STA 814
STA 816

FIG. 8A

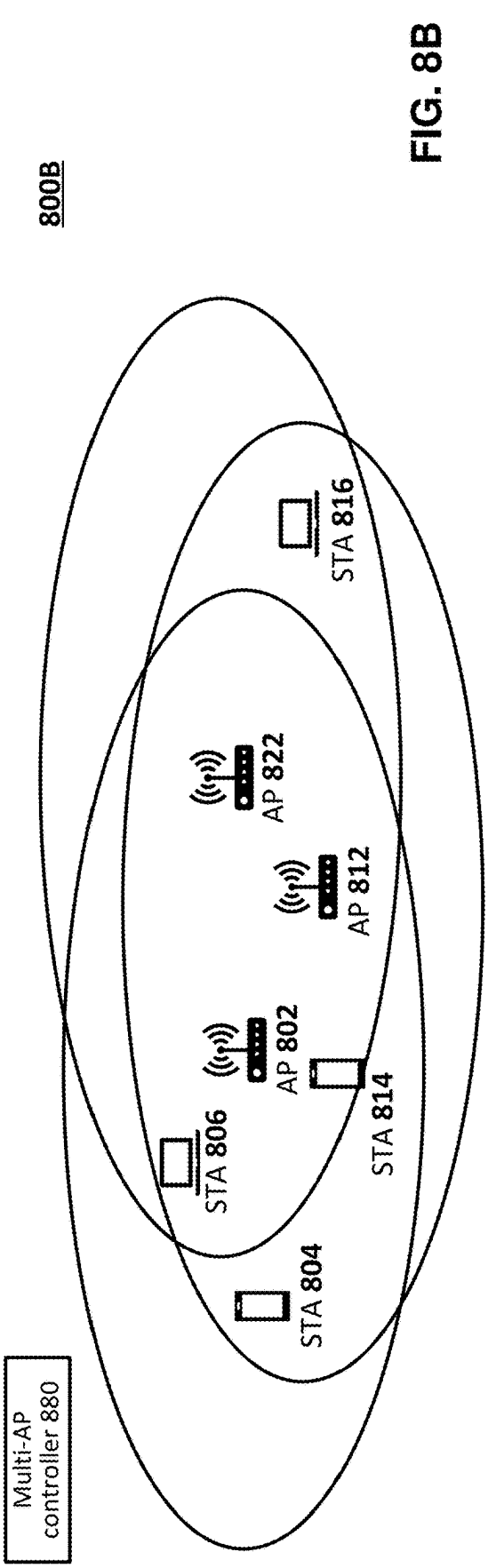

800B
Multi-AP controller 880
STA 804
STA 806
AP 802
AP 812
AP 822
STA 814
STA 816

FIG. 8B

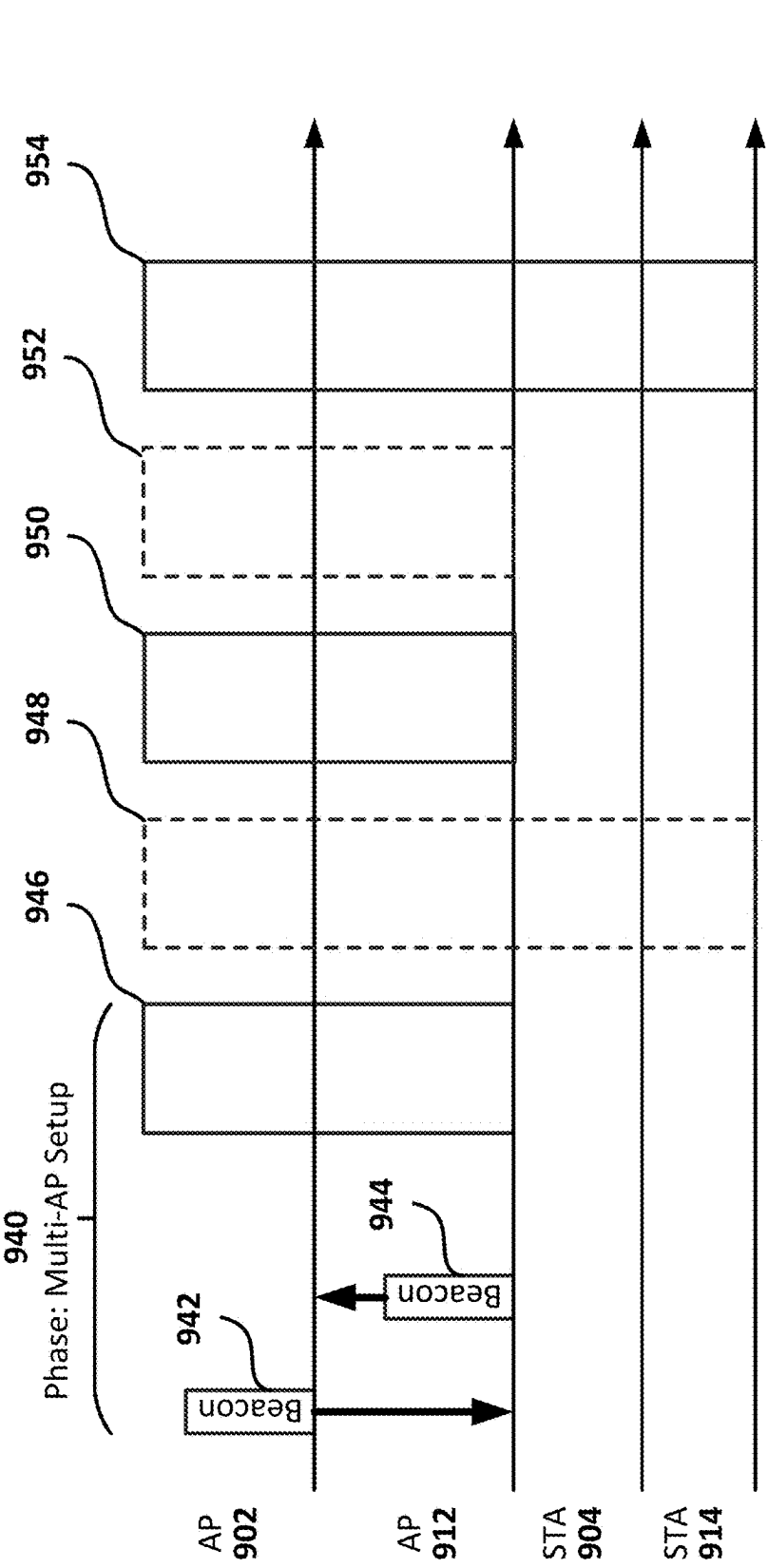

900
954
952
950
948
946
940
Phase: Multi-AP Setup
944
Beacon
942
Beacon
AP 902
AP 912
STA 904
STA 914

FIG. 9

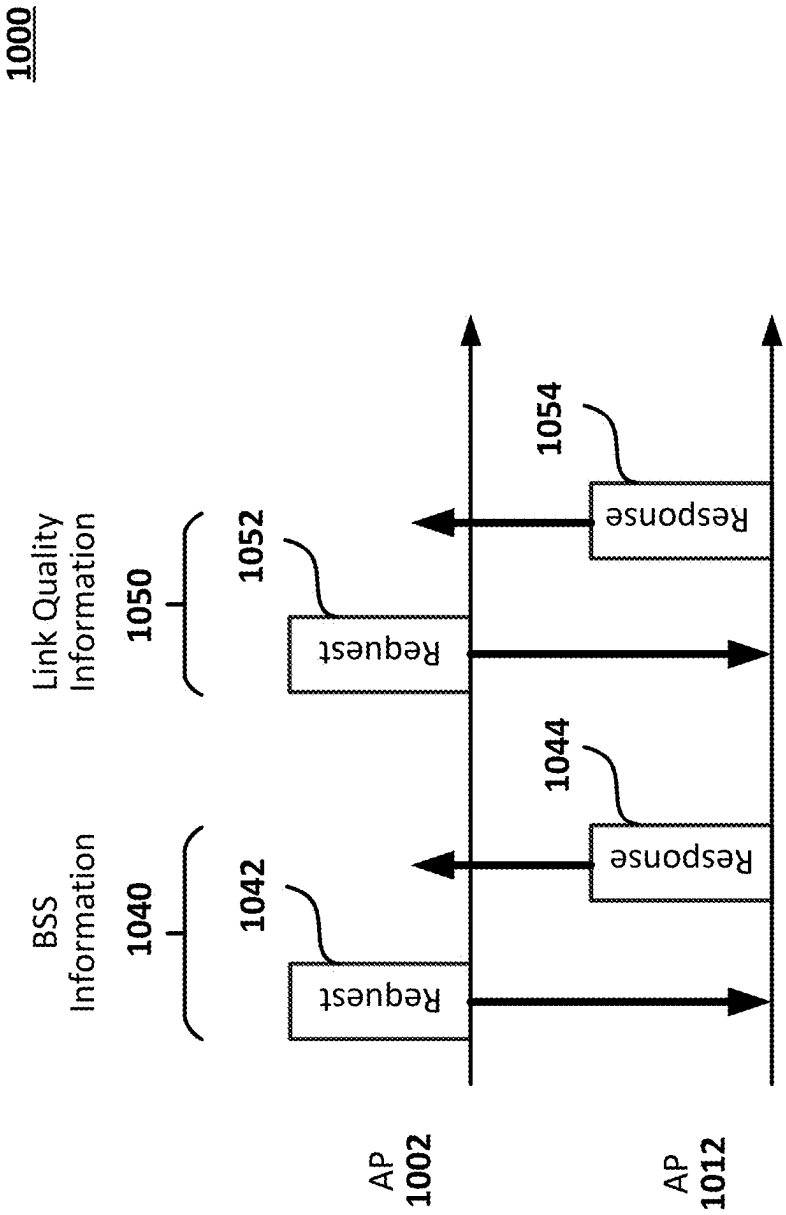

1000
AP
1002
AP
1012
BSS
Information
1040
1042
Request
1044
Response
Link Quality
Information
1050
1052
Request
1054
Response

FIG. 10

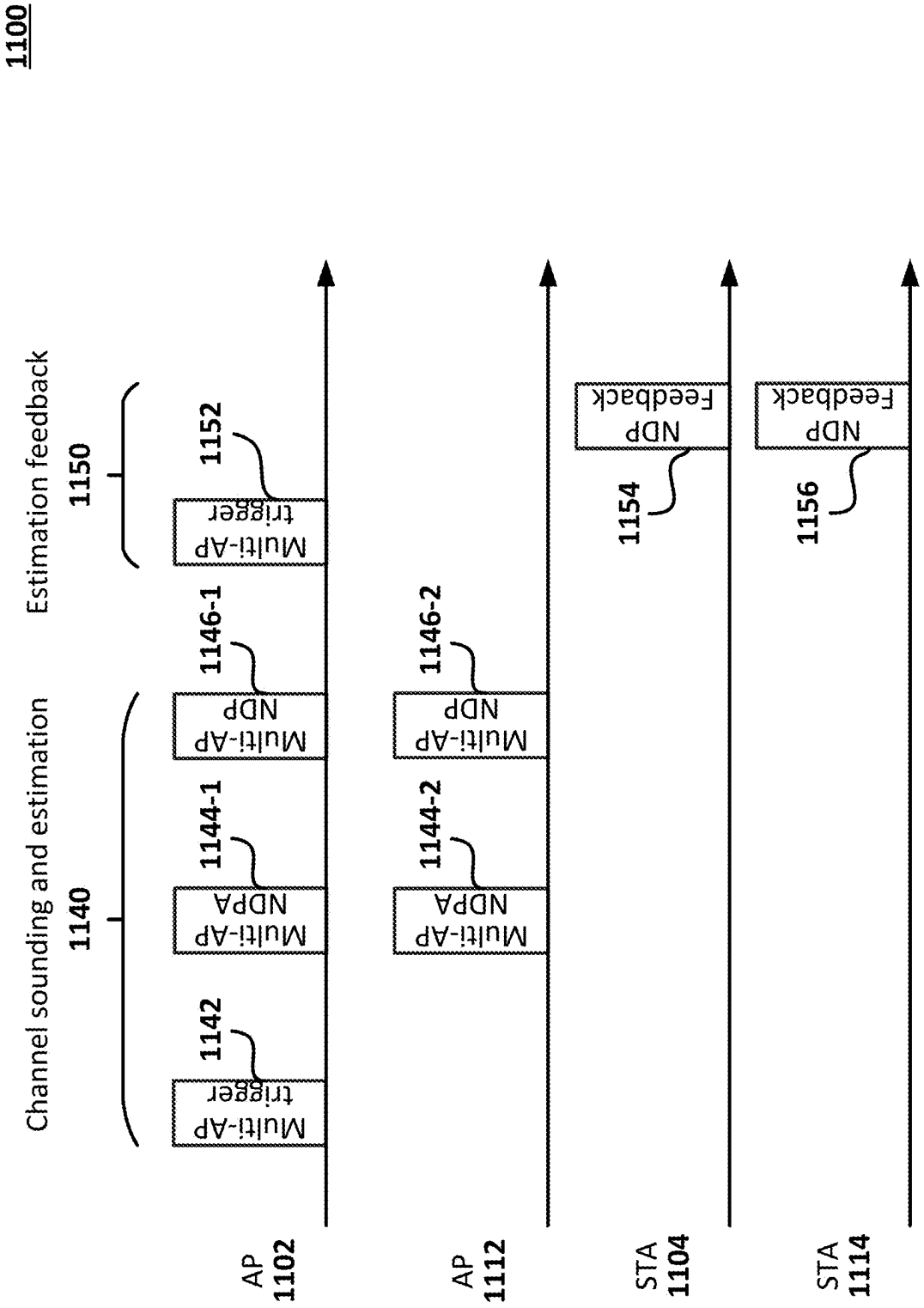

1100
Channel sounding and estimation
1140
Estimation feedback
1150
1142
1144-1
1146-1
1152
1144-2
1146-2
1154
1156
Multi-AP trigger
Multi-AP NDPA
Multi-AP NDP
NDP Feedback
AP 1102
AP 1112
STA 1104
STA 1114

FIG. 11

1200

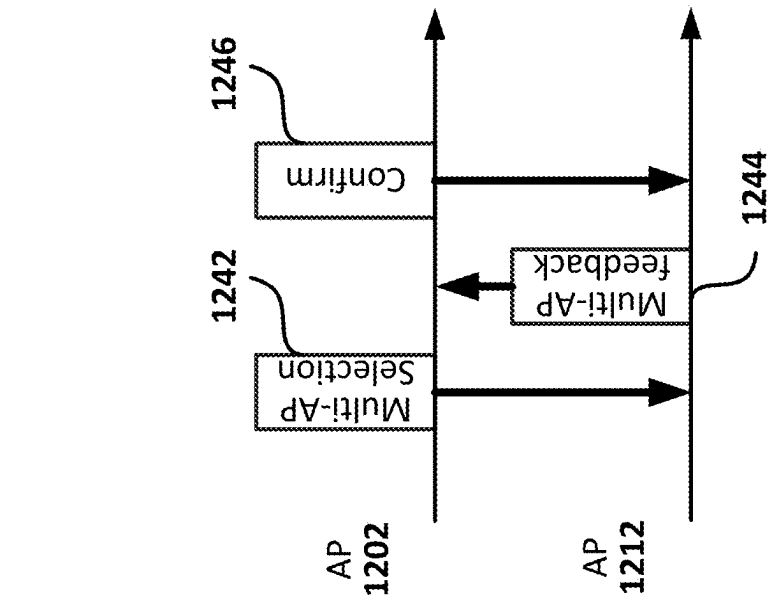

AP
1202
AP
1212
1242
Multi-AP
Selection
1244
Multi-AP
feedback
1246
Confirm

FIG. 12

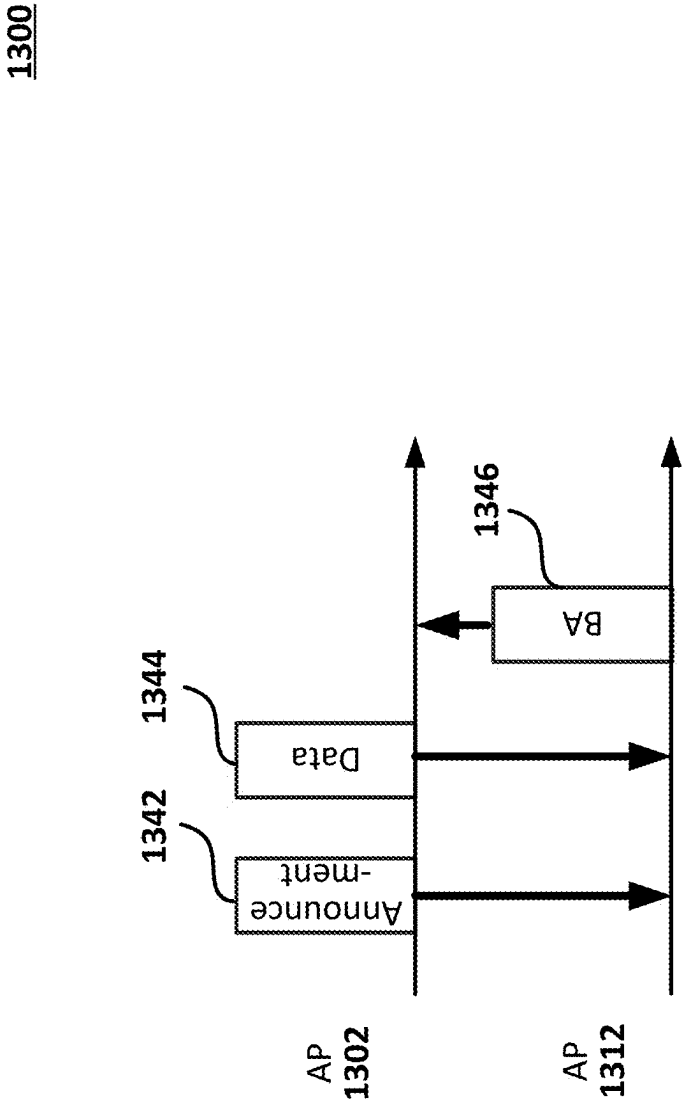


FIG. 13

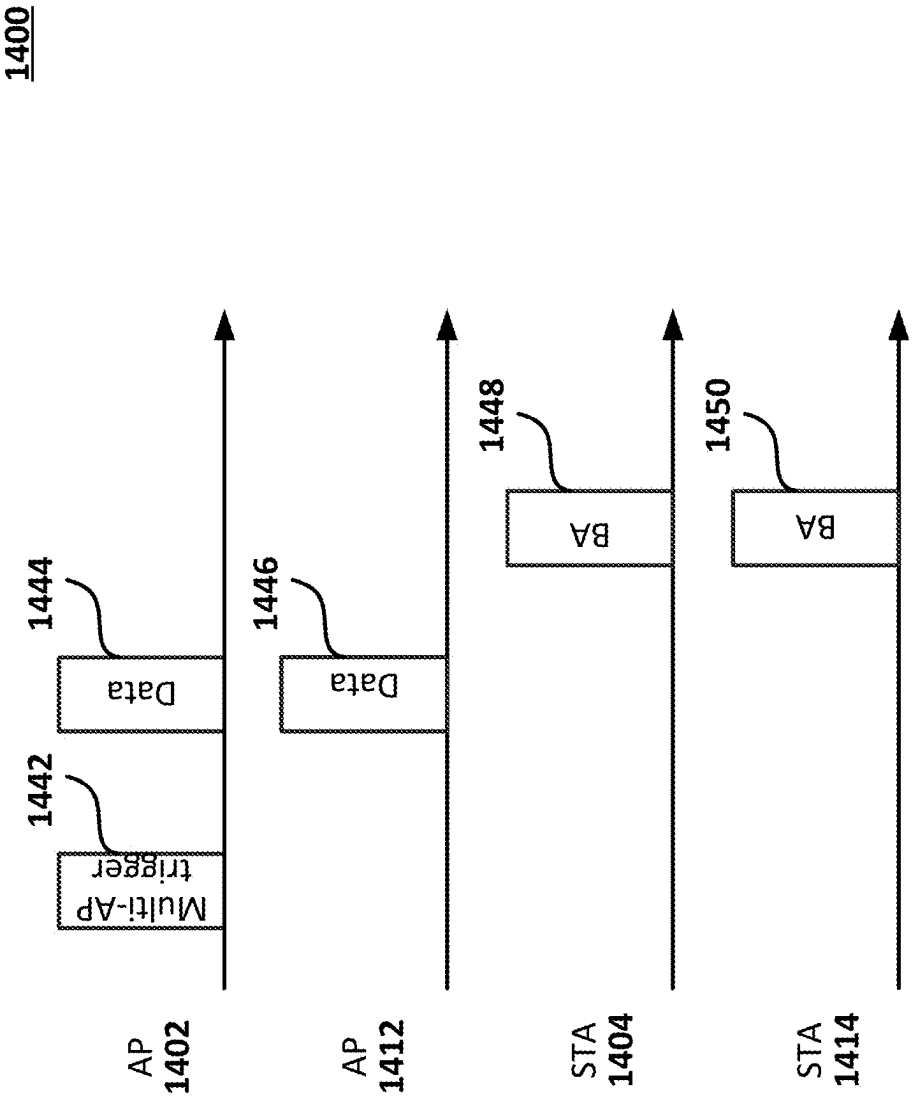

1400
AP 1402
AP 1412
STA 1404
STA 1414
Multi-AP trigger
Data
Data
BA
BA
1442
1444
1446
1448
1450

FIG. 14

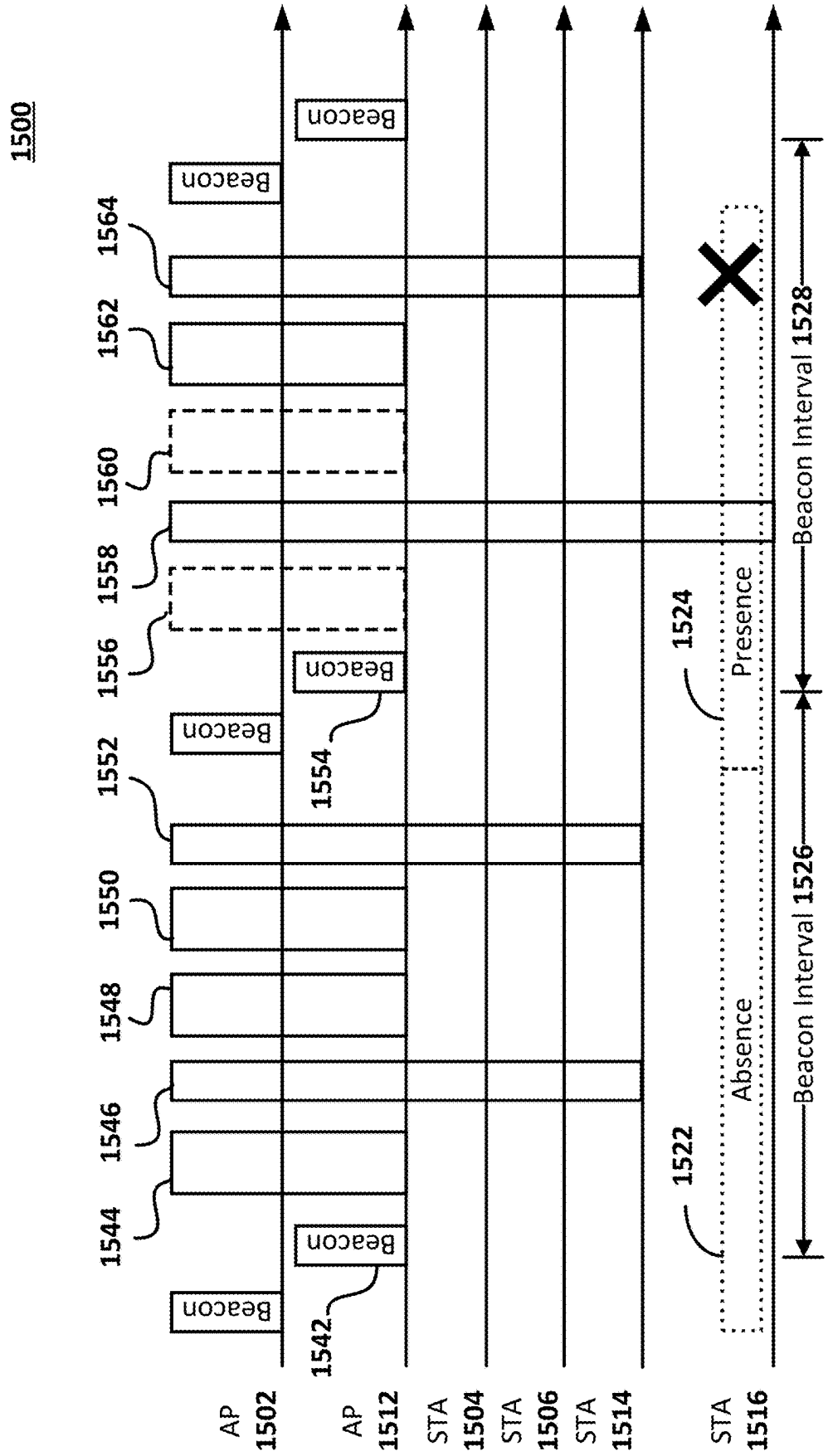

1500
AP 1502
AP 1512
STA 1504
STA 1506
STA 1514
STA 1516
Beacon
1542
1544
1546
1548
1550
1552
1554
1556
1558
1560
1562
1564
1522
1524
Absence
Presence
Beacon Interval 1526
Beacon Interval 1528

FIG. 15

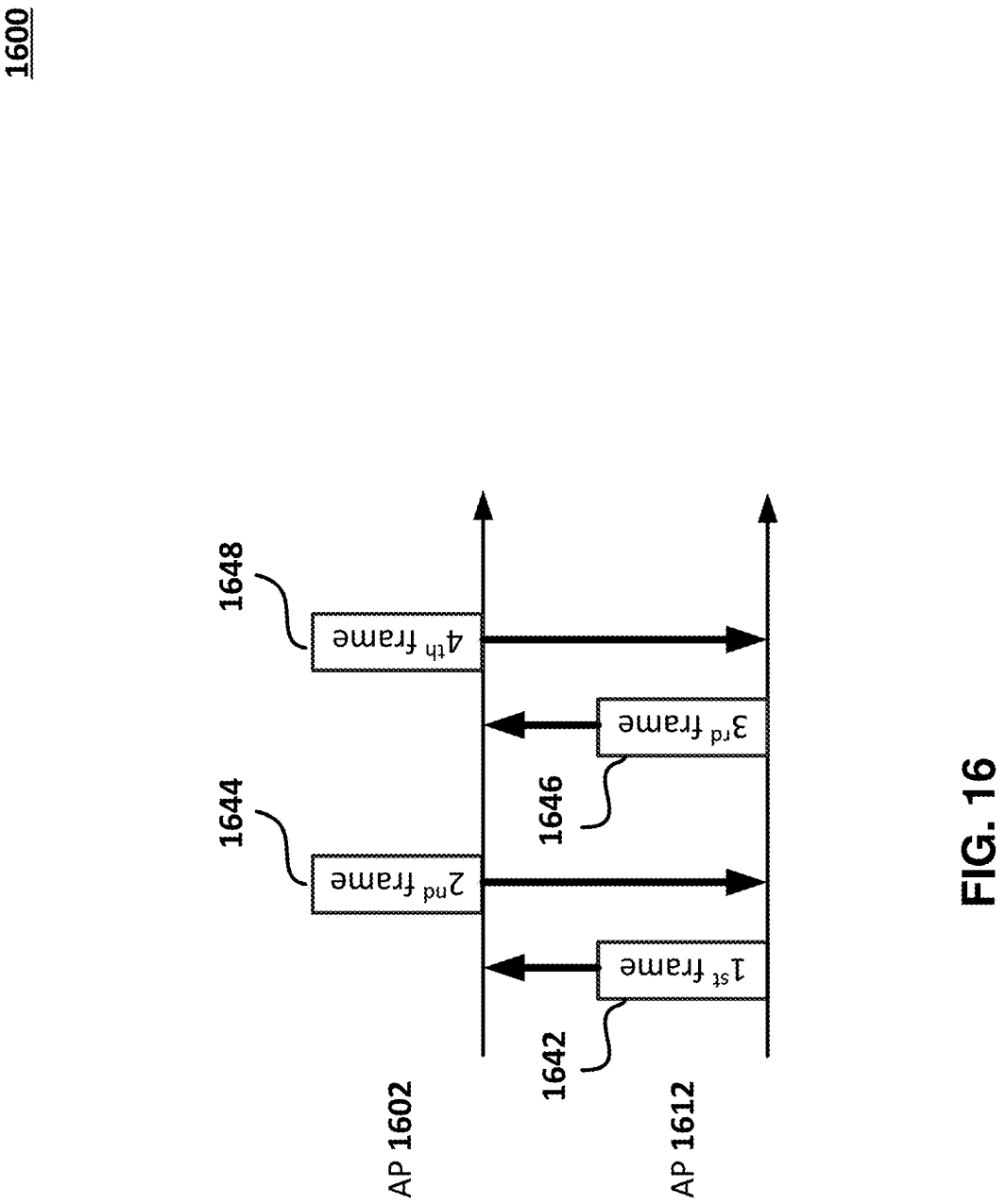

1600
AP 1602
AP 1612
1642
1644
1646
1648
1st frame
2nd frame
3rd frame
4th frame

FIG. 16

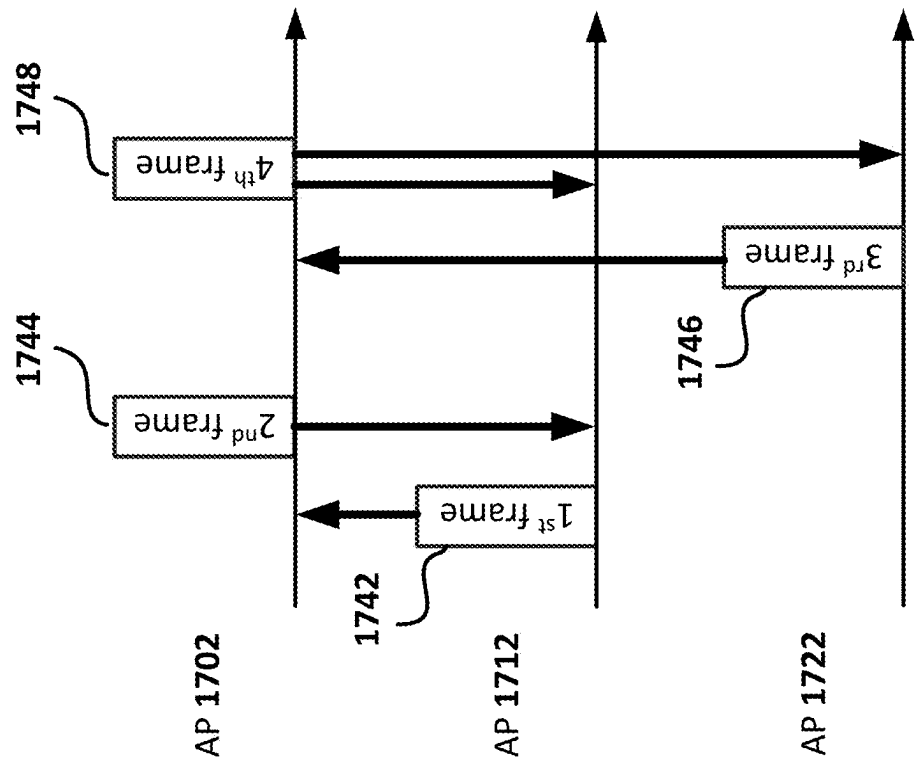

1700
AP 1702
AP 1712
AP 1722
1742
1744
1746
1748
1st frame
2nd frame
3rd frame
4th frame

FIG. 17

1800A

Scheme Index	Binary Code	Scheme meaning
0	000	No preference
1	001	CSR
2	010	CTDMA
3	011	CFDMA
4	100	CBF
5	101	JT
6	110	JR
...	...	...

FIG. 18A

1800B

Bitmap order	Bitmap subfield meaning
0	No preference
1	CSR
2	CTDMA
3	CFDMA
4	CBF
5	JT
6	JR
...	...

FIG. 18B

1900

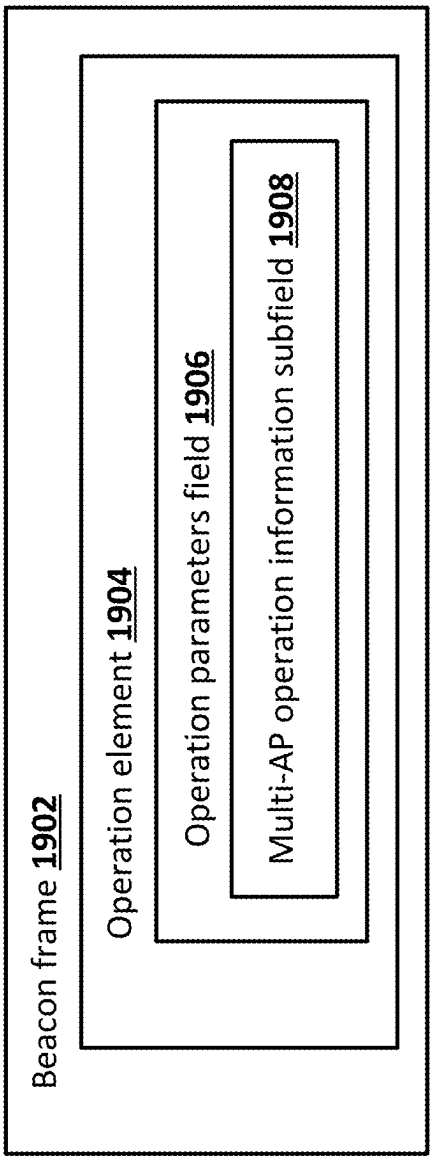

Beacon frame 1902
Operation element 1904
Operation parameters field 1906
Multi-AP operation information subfield 1908

FIG. 19

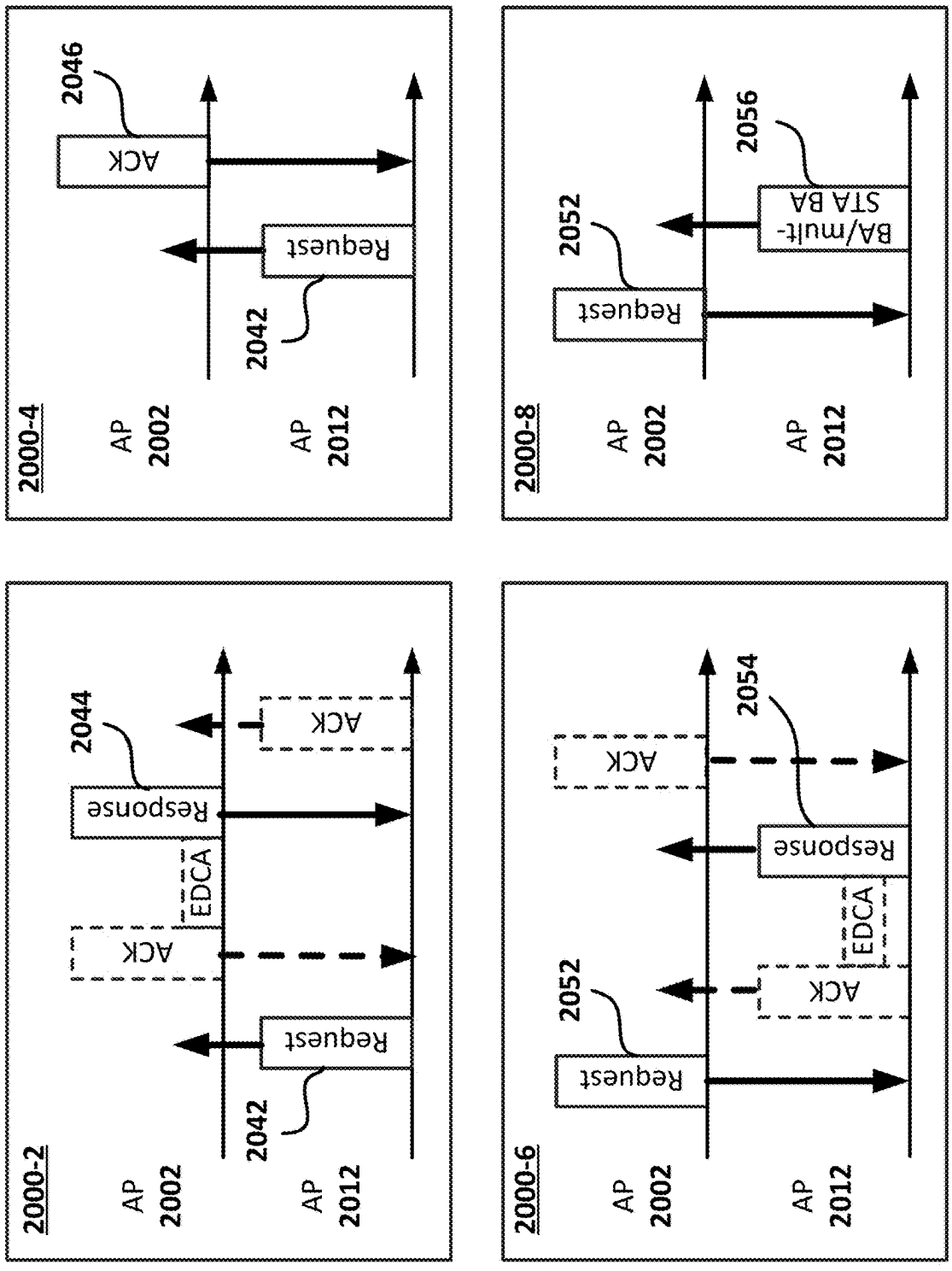

2000-2
AP 2002
AP 2012
2042
Request
EDCA
ACK
2044
Response
ACK
2000-4
AP 2002
AP 2012
2042
Request
2046
ACK
2000-6
AP 2002
AP 2012
2052
Request
EDCA
ACK
2054
Response
ACK
2000-8
AP 2002
AP 2012
2052
Request
2056
BA/multi-STA BA

FIG. 20

2100

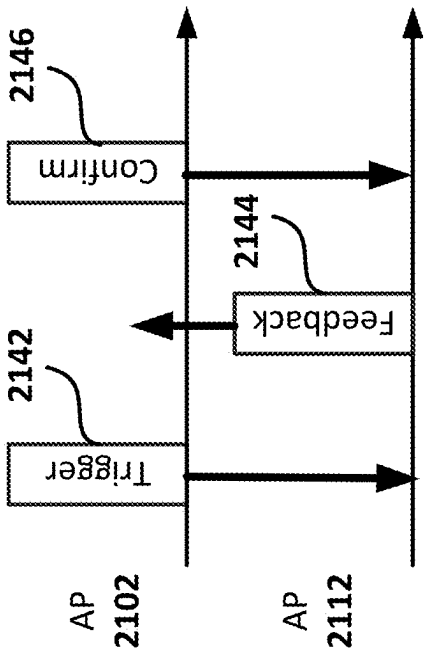


FIG. 21

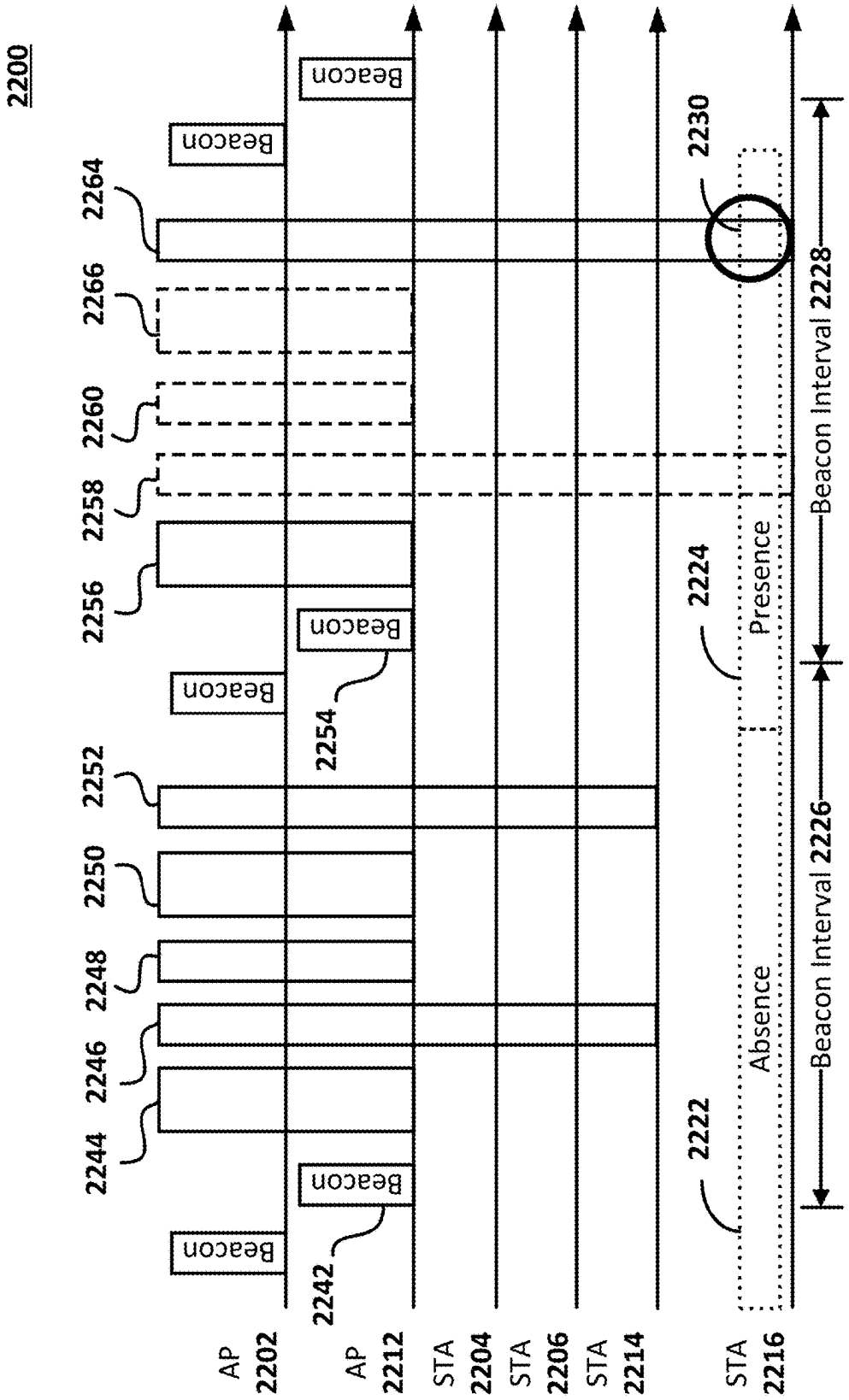

2200
AP 2202
AP 2212
STA 2204
STA 2206
STA 2214
STA 2216
Beacon
2242
2244
2246
2248
2250
2252
2254
2256
2258
2260
2262
2264
2222
2224
Absence
Presence
2230
Beacon Interval 2226
Beacon Interval 2228

FIG. 22

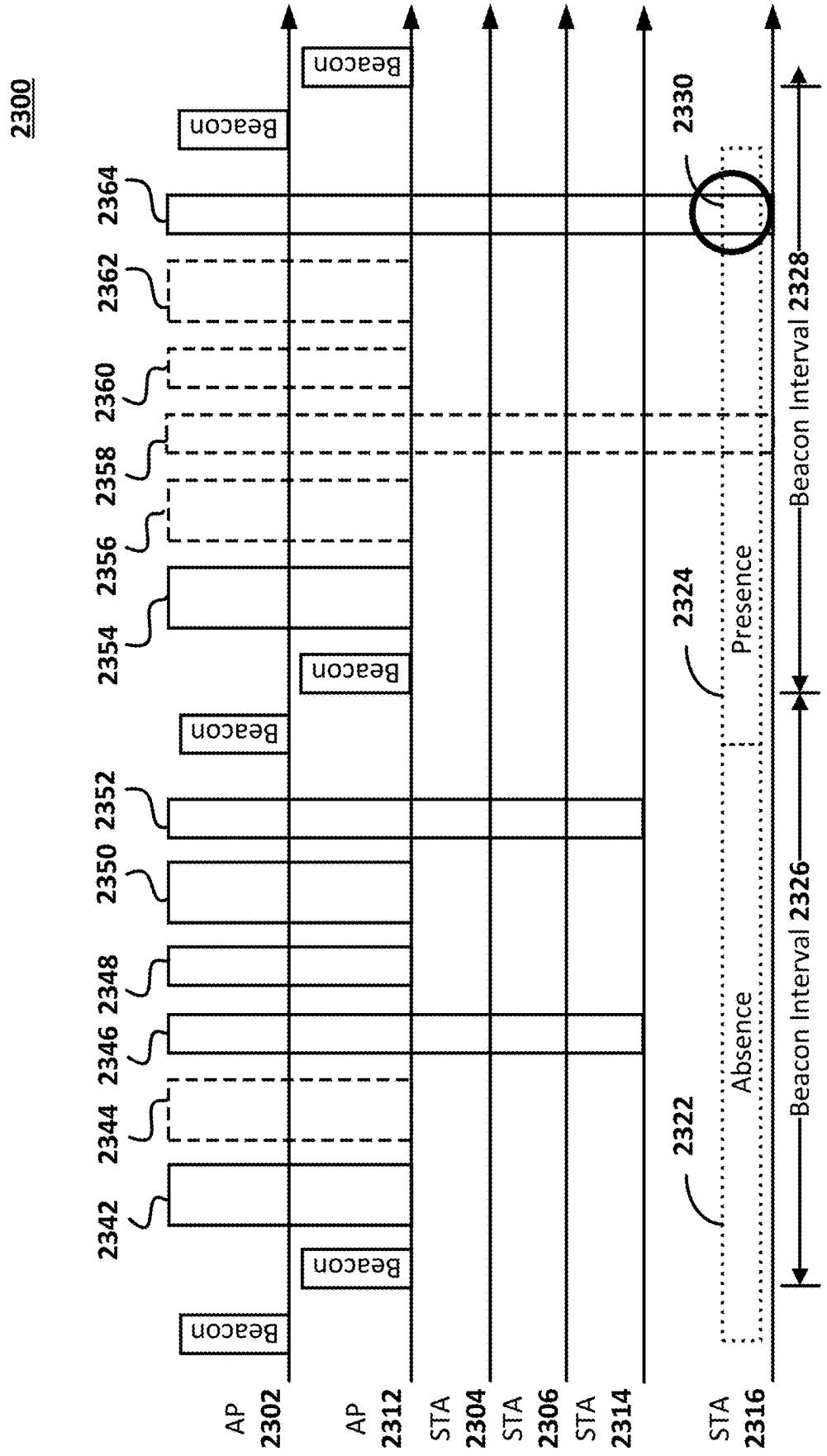

2300
AP 2302
AP 2312
STA 2304
STA 2306
STA 2314
STA 2316
Beacon
2342
2344
2346
2348
2350
2352
2354
2356
2358
2360
2362
2364
2322
2324
2330
Absence
Presence
Beacon Interval 2326
Beacon Interval 2328

FIG. 23

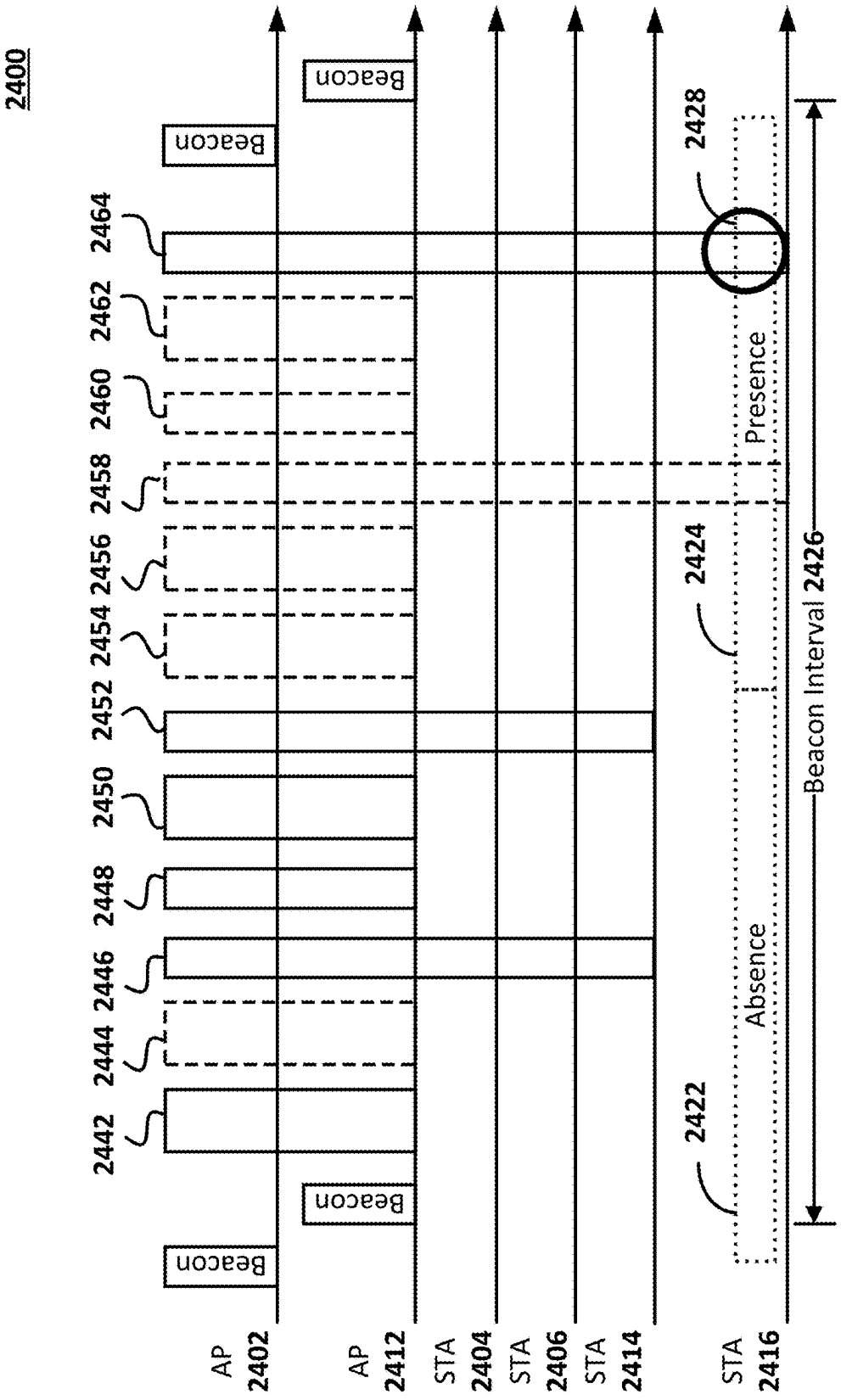

2400
AP 2402
AP 2412
STA 2404
STA 2406
STA 2414
STA 2416
Beacon
2442
2444
2446
2448
2450
2452
2454
2456
2458
2460
2462
2464
2422
2424
2428
Absence
Presence
Beacon Interval 2426

FIG. 24

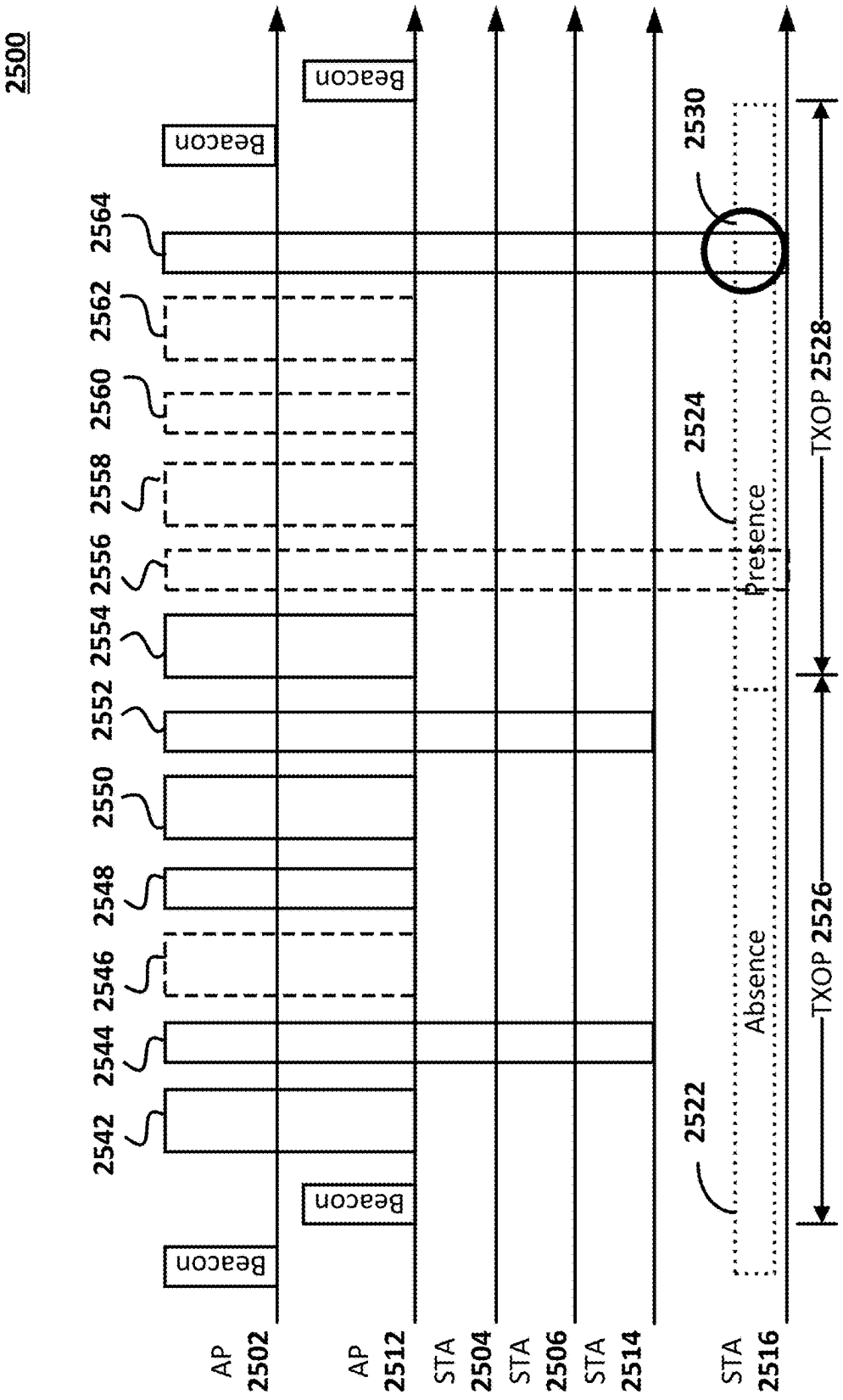

2500
AP 2502
AP 2512
STA 2504
STA 2506
STA 2514
STA 2516
Beacon
Beacon
Beacon
2542
2544
2546
2548
2550
2552
2554
2556
2558
2560
2562
2564
2522
2524
2530
Absence
Presence
TXOP 2526
TXOP 2528

FIG. 25

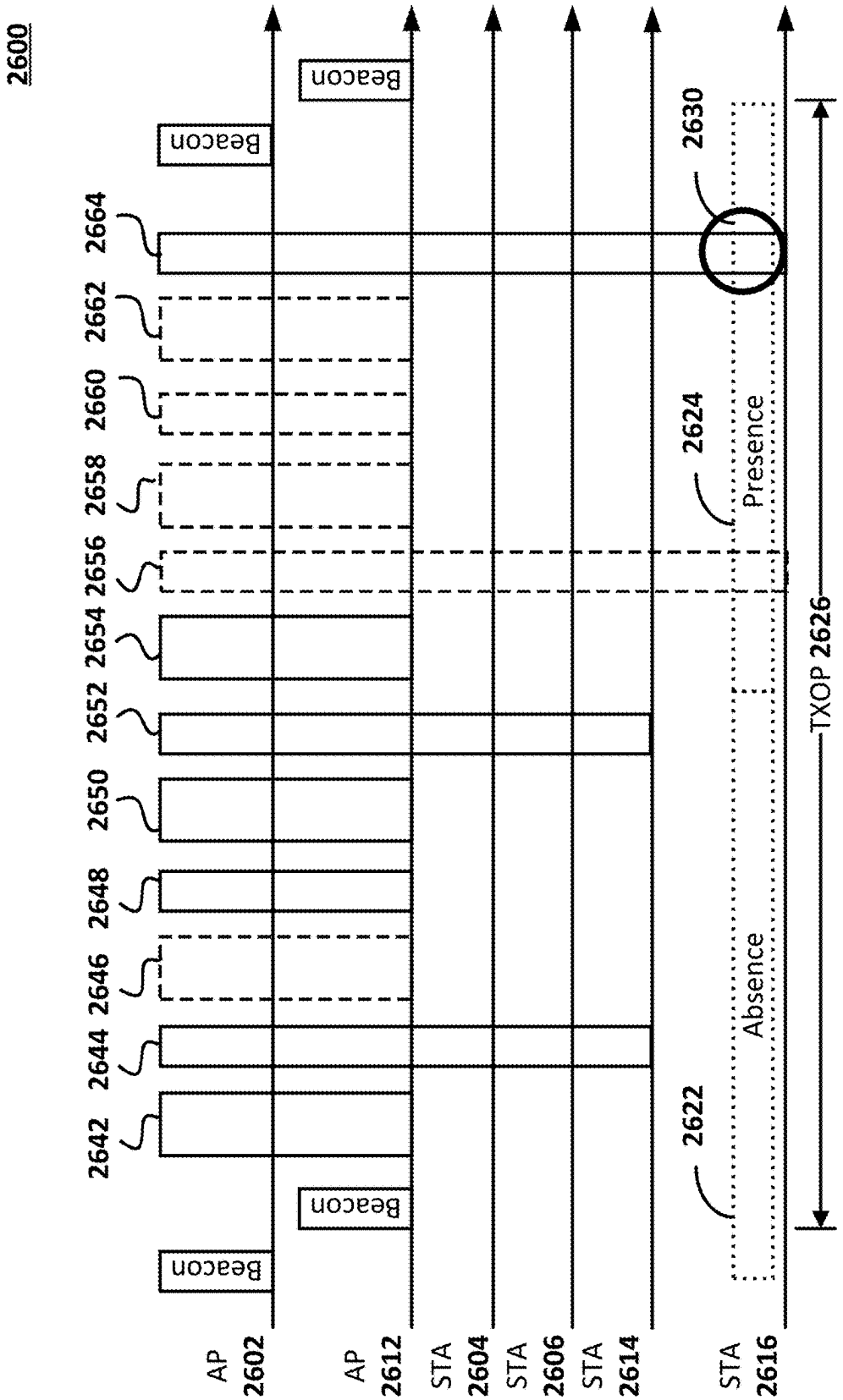

2600
AP 2602
AP 2612
STA 2604
STA 2606
STA 2614
STA 2616
Beacon
Beacon
Beacon
Beacon
2642
2644
2646
2648
2650
2652
2654
2656
2658
2660
2662
2664
2622
2624
2630
Absence
Presence
TXOP 2626

FIG. 26

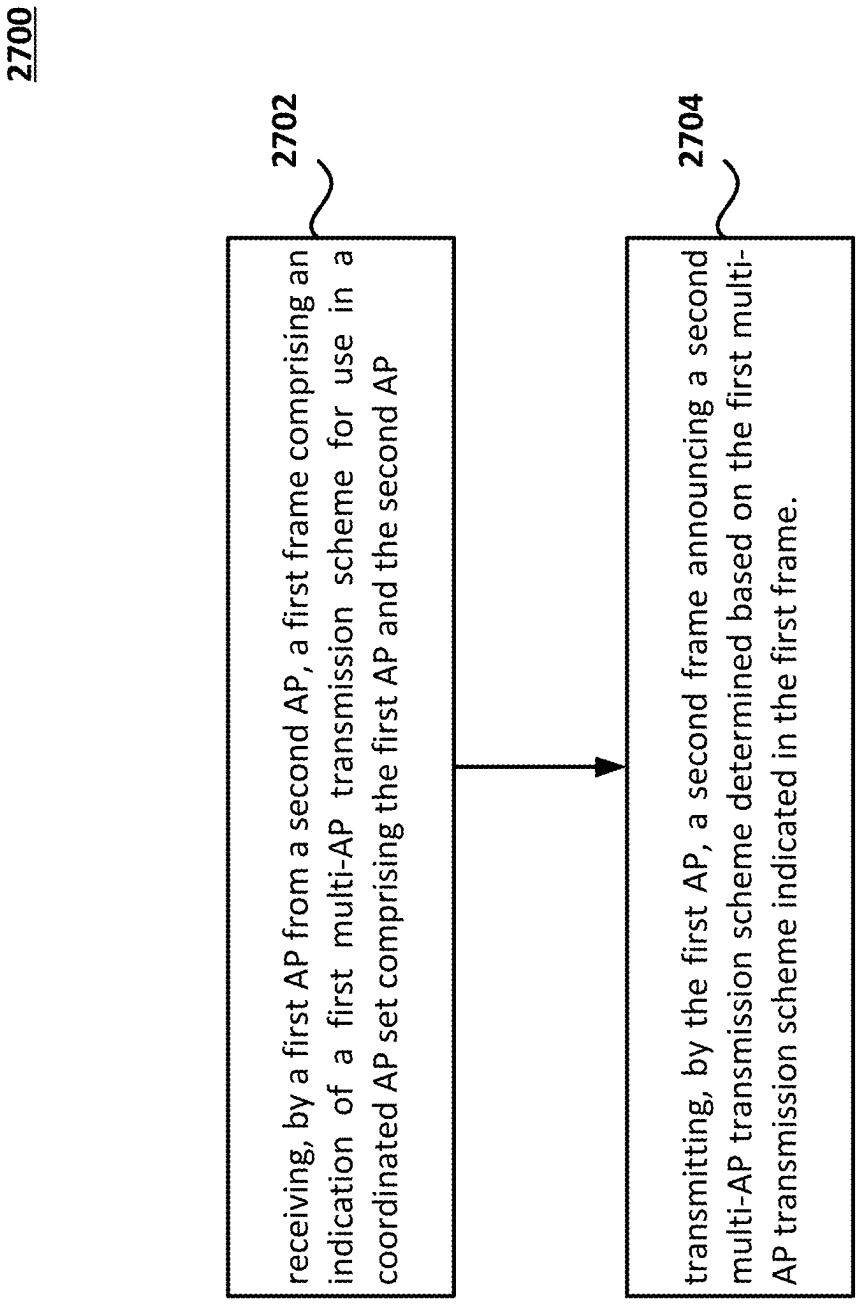

2700
2702
receiving, by a first AP from a second AP, a first frame comprising an indication of a first multi-AP transmission scheme for use in a coordinated AP set comprising the first AP and the second AP
2704
transmitting, by the first AP, a second frame announcing a second multi-AP transmission scheme determined based on the first multi-AP transmission scheme indicated in the first frame.

FIG. 27

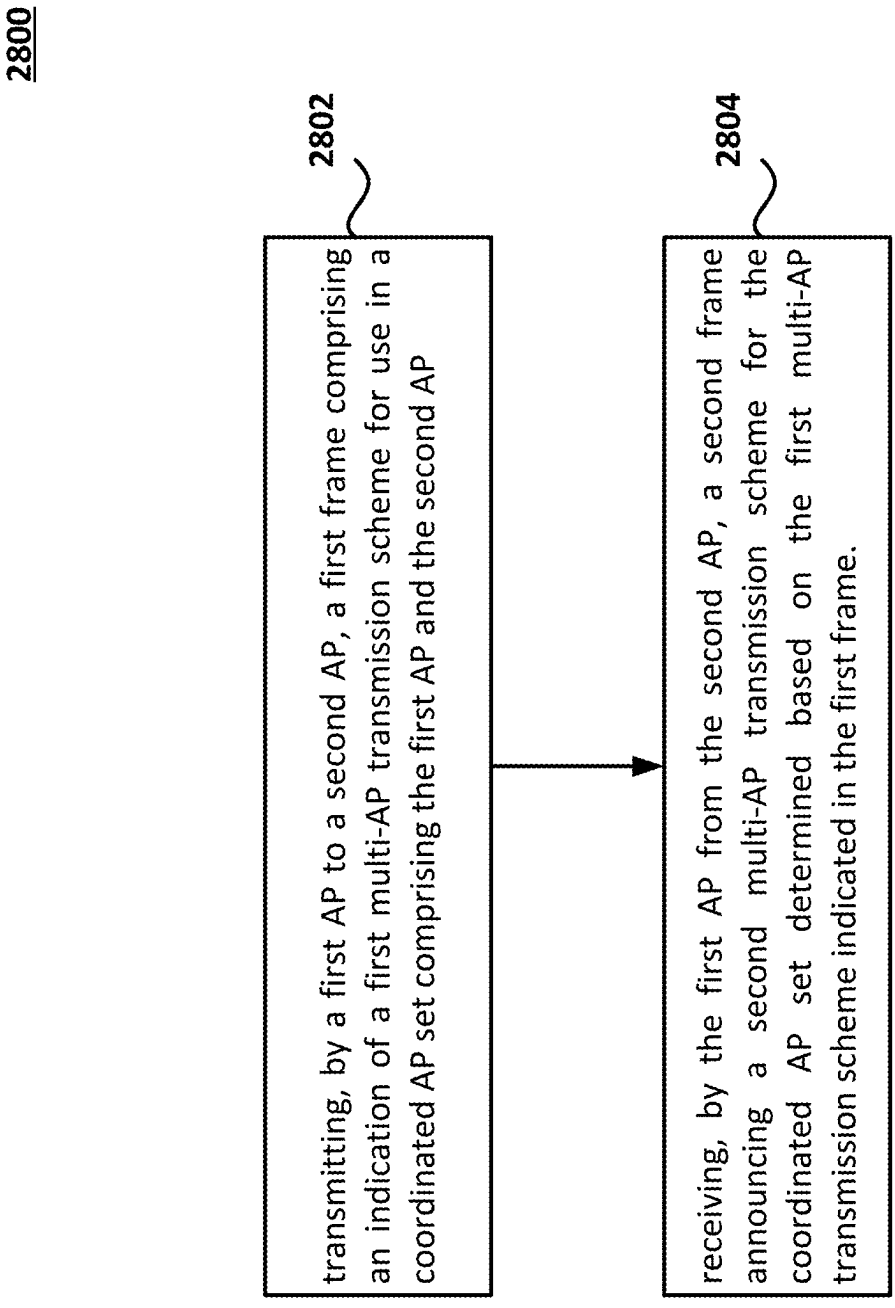

2800
2802
transmitting, by a first AP to a second AP, a first frame comprising an indication of a first multi-AP transmission scheme for use in a coordinated AP set comprising the first AP and the second AP
2804
receiving, by the first AP from the second AP, a second frame announcing a second multi-AP transmission scheme for the coordinated AP set determined based on the first multi-AP transmission scheme indicated in the first frame.

FIG. 28

MULTI-AP TRANSMISSION SCHEME SELECTION

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation of International Application No. PCT/US2023/035767, filed Oct. 24, 2023, which claims the benefit of U.S. Provisional Application No. 63/419,357, filed Oct. 26, 2022, all of which are hereby incorporated by reference in their entireties.

BRIEF DESCRIPTION OF THE DRAWINGS

[0002] Examples of several of the various embodiments of the present disclosure are described herein with reference to the drawings.

[0003] FIG. **1** illustrates example wireless communication networks in which embodiments of the present disclosure may be implemented.

[0004] FIG. **2** is a block diagram illustrating example implementations of a station (STA) and an access point (AP).

[0005] FIG. **3** illustrates an example of a Medium Access Control (MAC) frame format.

[0006] FIG. **4**A illustrates an example of a management frame format.

[0007] FIG. **4**B illustrates an example EHT Operation element format.

[0008] FIG. **5**A illustrates an example of a management frame used as an action frame.

[0009] FIG. **5**B illustrates an example public action frame format.

[0010] FIG. **6** illustrates an example of a Quality of Service (QoS) null frame.

[0011] FIG. **7** illustrates an example multi-AP network.

[0012] FIGS. **8**A-**8**B illustrate another two examples of multi-AP networks.

[0013] FIG. **9** illustrates an example multi-AP operation procedure.

[0014] FIG. **10** illustrates an example multi-AP information exchange phase.

[0015] FIG. **11** illustrates an example multi-AP sounding phase.

[0016] FIG. **12** illustrates an example multi-AP selection phase.

[0017] FIG. **13** illustrates an example multi-AP data sharing phase.

[0018] FIG. **14** illustrates an example multi-AP data transmission phase.

[0019] FIG. **15** is an example that illustrates a problem that may arise in multi-AP operation using the procedure illustrated in FIG. **9**.

[0020] FIG. **16** illustrates an example of frame exchanges including preferred multi-AP transmission scheme information for a coordinated AP set.

[0021] FIG. **17** illustrates another example of frame exchanges including preferred multi-AP transmission scheme information for a coordinated AP set.

[0022] FIGS. **18**A-**18**B illustrate two example mappings for preferred multi-AP transmission scheme information.

[0023] FIG. **19** illustrates an example of a beacon frame including preferred multi-AP transmission scheme information.

[0024] FIG. **20** illustrate examples of frame exchanges using action frames including preferred multi-AP transmission scheme information.

[0025] FIG. **21** illustrates an example of frame exchanges using a data frame including preferred multi-AP transmission scheme information.

[0026] FIG. **22** illustrates an example procedure which may be used to carry out a multi-AP operation according to an embodiment.

[0027] FIG. **23** illustrates another example procedure which may be used to carry out a multi-AP operation according to an embodiment.

[0028] FIG. **24** illustrates another example procedure which may be used to carry out a multi-AP operation according to an embodiment.

[0029] FIG. **25** illustrates another example procedure which may be used to carry out a multi-AP operation according to an embodiment.

[0030] FIG. **26** illustrates another example procedure which may be used to carry out a multi-AP operation according to an embodiment.

[0031] FIG. **27** illustrates an example process according to an embodiment.

[0032] FIG. **28** illustrates an example process according to an embodiment.

DETAILED DESCRIPTION

[0033] In the present disclosure, various embodiments are presented as examples of how the disclosed techniques may be implemented and/or how the disclosed techniques may be practiced in environments and scenarios. It will be apparent to persons skilled in the relevant art that various changes in form and detail can be made therein without departing from the scope. After reading the description, it will be apparent to one skilled in the relevant art how to implement alternative embodiments. The present embodiments may not be limited by any of the described exemplary embodiments. The embodiments of the present disclosure will be described with reference to the accompanying drawings. Limitations, features, and/or elements from the disclosed example embodiments may be combined to create further embodiments within the scope of the disclosure. Any figures which highlight the functionality and advantages, are presented for example purposes only. The disclosed architecture is sufficiently flexible and configurable, such that it may be utilized in ways other than that shown. For example, the actions listed in any flowchart may be re-ordered or only optionally used in some embodiments.

[0034] Embodiments may be configured to operate as needed. The disclosed mechanism may be performed when certain criteria are met, for example, in a station, an access point, a radio environment, a network, a combination of the above, and/or the like. Example criteria may be based, at least in part, on for example, wireless device or network node configurations, traffic load, initial system set up, packet sizes, traffic characteristics, a combination of the above, and/or the like. When the one or more criteria are met, various example embodiments may be applied. Therefore, it may be possible to implement example embodiments that selectively implement disclosed protocols.

[0035] In this disclosure, "a" and "an" and similar phrases are to be interpreted as "at least one" and "one or more." Similarly, any term that ends with the suffix "(s)" is to be interpreted as "at least one" and "one or more." In this

disclosure, the term "may" is to be interpreted as "may, for example." In other words, the term "may" is indicative that the phrase following the term "may" is an example of one of a multitude of suitable possibilities that may, or may not, be employed by one or more of the various embodiments. The terms "comprises" and "consists of", as used herein, enumerate one or more components of the element being described. The term "comprises" is interchangeable with "includes" and does not exclude unenumerated components from being included in the element being described. By contrast, "consists of" provides a complete enumeration of the one or more components of the element being described. The term "based on", as used herein, may be interpreted as "based at least in part on" rather than, for example, "based solely on". The term "and/or" as used herein represents any possible combination of enumerated elements. For example, "A, B, and/or C" may represent A; B; C; A and B; A and C; B and C; or A, B, and C.

[0036] If A and B are sets and every element of A is an element of B, A is called a subset of B. In this specification, only non-empty sets and subsets are considered. For example, possible subsets of B={STA1, STA2} are: {STA1}, {STA2}, and {STA1, STA2}. The phrase "based on" (or equally "based at least on") is indicative that the phrase following the term "based on" is an example of one of a multitude of suitable possibilities that may, or may not, be employed to one or more of the various embodiments. The phrase "in response to" (or equally "in response at least to") is indicative that the phrase following the phrase "in response to" is an example of one of a multitude of suitable possibilities that may, or may not, be employed to one or more of the various embodiments. The phrase "depending on" (or equally "depending at least to") is indicative that the phrase following the phrase "depending on" is an example of one of a multitude of suitable possibilities that may, or may not, be employed to one or more of the various embodiments. The phrase "employing/using" (or equally "employing/using at least") is indicative that the phrase following the phrase "employing/using" is an example of one of a multitude of suitable possibilities that may, or may not, be employed to one or more of the various embodiments.

[0037] The term configured may relate to the capacity of a device whether the device is in an operational or non-operational state. Configured may refer to specific settings in a device that effect the operational characteristics of the device whether the device is in an operational or non-operational state. In other words, the hardware, software, firmware, registers, memory values, and/or the like may be "configured" within a device, whether the device is in an operational or nonoperational state, to provide the device with specific characteristics. Terms such as "a control message to cause in a device" may mean that a control message has parameters that may be used to configure specific characteristics or may be used to implement certain actions in the device, whether the device is in an operational or non-operational state.

[0038] In this disclosure, parameters (or equally called, fields, or Information elements: IEs) may comprise one or more information objects, and an information object may comprise one or more other objects. For example, if parameter (IE) N comprises parameter (IE) M, and parameter (IE) M comprises parameter (IE) K, and parameter (IE) K comprises parameter (information element) J. Then, for example, N comprises K, and N comprises J. In an example embodiment, when one or more messages/frames comprise a plurality of parameters, it implies that a parameter in the plurality of parameters is in at least one of the one or more messages/frames but does not have to be in each of the one or more messages/frames.

[0039] Many features presented are described as being optional through the use of "may" or the use of parentheses. For the sake of brevity and legibility, the present disclosure does not explicitly recite each and every permutation that may be obtained by choosing from the set of optional features. The present disclosure is to be interpreted as explicitly disclosing all such permutations. For example, a system described as having three optional features may be embodied in seven ways, namely with just one of the three possible features, with any two of the three possible features or with three of the three possible features.

[0040] Many of the elements described in the disclosed embodiments may be implemented as modules. A module is defined here as an element that performs a defined function and has a defined interface to other elements. The modules described in this disclosure may be implemented in hardware, software in combination with hardware, firmware, wetware (e.g., hardware with a biological element) or a combination thereof, which may be behaviorally equivalent. For example, modules may be implemented as a software routine written in a computer language configured to be executed by a hardware machine (such as C, C++, Fortran, Java, Basic, Matlab or the like) or a modeling/simulation program such as Simulink, Stateflow, GNU Octave, or LabVIEWMathScript. It may be possible to implement modules using physical hardware that incorporates discrete or programmable analog, digital and/or quantum hardware. Examples of programmable hardware comprise computers, microcontrollers, microprocessors, application-specific integrated circuits (ASICs); field programmable gate arrays (FPGAs); and complex programmable logic devices (CPLDs). Computers, microcontrollers and microprocessors are programmed using languages such as assembly, C, C++ or the like. FPGAs, ASICs and CPLDs are often programmed using hardware description languages (HDL) such as VHSIC hardware description language (VHDL) or Verilog that configure connections between internal hardware modules with lesser functionality on a programmable device. The mentioned technologies are often used in combination to achieve the result of a functional module.

[0041] FIG. **1** illustrates example wireless communication networks in which embodiments of the present disclosure may be implemented.

[0042] As shown in FIG. **1**, the example wireless communication networks may include an Institute of Electrical and Electronic Engineers (IEEE) 802.11 (WLAN) infrastructure network **102**. WLAN infra-structure network **102** may include one or more basic service sets (BSSs) **110** and **120** and a distribution system (DS) **130**.

[0043] BSS **110-1** and **110-2** each includes a set of an access point (AP or AP STA) and at least one station (STA or non-AP STA). For example, BSS **110-1** includes an AP **104-1** and a STA **106-1**, and BSS **110-2** includes an AP **104-2** and STAs **106-2** and **106-3**. The AP and the at least one STA in a BSS perform an association procedure to communicate with each other.

[0044] DS **130** may be configured to connect BSS **110-1** and BSS **110-2**. As such, DS **130** may enable an extended

service set (ESS) **150**. Within ESS **150**, APs **104-1** and **104-2** are connected via DS **130** and may have the same service set identification (SSID).

[0045] WLAN infra-structure network **102** may be coupled to one or more external networks. For example, as shown in FIG. **1**, WLAN infra-structure network **102** may be connected to another network **108** (e.g., 802.X) via a portal **140**. Portal **140** may function as a bridge connecting DS **130** of WLAN infra-structure network **102** with the other network **108**.

[0046] The example wireless communication networks illustrated in FIG. **1** may further include one or more ad-hoc networks or independent BSSs (IBSSs). An ad-hoc network or IBSS is a network that includes a plurality of STAs that are within communication range of each other. The plurality of STAs are configured so that they may communicate with each other using direct peer-to-peer communication (i.e., not via an AP).

[0047] For example, in FIG. **1**, STAs **106-4**, **106-5**, and **106-6** may be configured to form a first IBSS **112-1**. Similarly, STAs **106-7** and **106-8** may be configured to form a second IBSS **112-2**. Since an IBSS does not include an AP, it does not include a centralized management entity. Rather, STAs within an IBSS are managed in a distributed manner. STAs forming an IBSS may be fixed or mobile.

[0048] A STA as a predetermined functional medium may include a medium access control (MAC) layer that complies with an IEEE 802.11 standard. A physical layer interface for a radio medium may be used among the APs and the non-AP stations (STAs). The STA may also be referred to using various other terms, including mobile terminal, wireless device, wireless transmit/receive unit (WTRU), user equipment (UE), mobile station (MS), mobile subscriber unit, or user. For example, the term "user" may be used to denote a STA participating in uplink Multi-user Multiple Input, Multiple Output (MU MIMO) and/or uplink Orthogonal Frequency Division Multiple Access (OFDMA) transmission.

[0049] A physical layer (PHY) protocol data unit (PPDU) may be a composite structure that includes a PHY preamble and a payload in the form of a PHY service data unit (PSDU). For example, the PSDU may include a PHY preamble and header and/or one or more MAC protocol data units (MPDUs). The information provided in the PHY preamble may be used by a receiving device to decode the subsequent data in the PSDU. In instances in which PPDUs are transmitted over a bonded channel (channel formed through channel bonding), the preamble fields may be duplicated and transmitted in each of the multiple component channels. The PHY preamble may include both a legacy portion (or "legacy preamble") and a non-legacy portion (or "non-legacy preamble"). The legacy preamble may be used for packet detection, automatic gain control and channel estimation, among other uses. The legacy preamble also may generally be used to maintain compatibility with legacy devices. The format of, coding of, and information provided in the non-legacy portion of the preamble is based on the particular IEEE 802.11 protocol to be used to transmit the payload.

[0050] A frequency band may include one or more sub-bands or frequency channels. For example, PPDUs conforming to the IEEE 802.11n, 802.11ac, 802.11ax and/or 802.11be standard amendments may be transmitted over the 2.4 GHz, 5 GHz, and/or 6 GHz bands, each of which may be divided into multiple 20 MHz channels. The PPDUs may be transmitted over a physical channel having a minimum bandwidth of 20 MHz. Larger channels may be formed through channel bonding. For example, PPDUs may be transmitted over physical channels having bandwidths of 40 MHz, 80 MHz, 160 MHz, or 320 MHz by bonding together multiple 20 MHz channels.

[0051] FIG. **2** is a block diagram illustrating example implementations of a STA **210** and an AP **260**. As shown in FIG. **2**, STA **210** may include at least one processor **220**, a memory **230**, and at least one transceiver **240**. AP **260** may include at least one processor **270**, a memory **280**, and at least one transceiver **290**. Processor **220**/**270** may be operatively connected to memory **230**/**280** and/or to transceiver **240**/**290**.

[0052] Processor **220**/**270** may implement functions of the PHY layer, the MAC layer, and/or the logical link control (LLC) layer of the corresponding device (STA **210** or AP **260**). Processor **220**/**270** may include one or more processors and/or one or more controllers. The one or more processors and/or one or more controllers may comprise, for example, a general-purpose processor, a digital signal processor (DSP), a microcontroller, an application specific integrated circuit (ASIC), a field programmable gate array (FPGA), a logic circuit, or a chipset, for example.

[0053] Memory **230**/**280** may include a read-only memory (ROM), a random-access memory (RAM), a flash memory, a memory card, a storage medium, and/or other storage unit. Memory **230**/**280** may comprise one or more non-transitory computer readable mediums. Memory **230**/**280** may store computer program instructions or code that may be executed by processor **220**/**270** to carry out one or more of the operations/embodiments discussed in the present application. Memory **230**/**280** may be implemented (or positioned) within processor **220**/**270** or external to processor **220**/**270**. Memory **230**/**280** may be operatively connected to processor **220**/**270** via various means known in the art.

[0054] Transceiver **240**/**290** may be configured to transmit/receive radio signals. In an embodiment, transceiver **240**/**290** may implement a PHY layer of the corresponding device (STA **210** or AP **260**). In an embodiment, STA **210** and/or AP **260** may be a multi-link device (MLD), that is a device capable of operating over multiple links as defined by the IEEE 802.11 standard. As such, STA **210** and/or AP **260** may each implement multiple PHY layers. The multiple PHY layers may be implemented using one or more of transceivers **240**/**290**.

[0055] FIG. **3** illustrates an example format of a MAC frame. In operation, a STA may construct a subset of MAC frames for transmission and may decode a subset of received MAC frames upon validation. The particular subsets of frames that a STA may construct and/or decode may be determined by the functions supported by the STA. A STA may validate a received MAC frame using the frame check sequence (FCS) contained in the frame and may interpret certain fields from the MAC headers of all frames.

[0056] As shown in FIG. **3**, a MAC frame includes a MAC header, a variable length frame body, and a frame check sequence (FCS).

[0057] The MAC header includes a frame control field, an optional duration/ID field, address fields, an optional sequence control field, an optional QoS control field, and an optional HT control field.

[0058] The frame control field includes the following subfields: protocol version, type, subtype, To DS, From DS, more fragments, retry, power management, more data, protected frame, and +HTC.

[0059] The protocol version subfield is invariant in size and placement across all revisions of the IEEE 802.11 standard. The value of the protocol version subfield is 0 for MAC frames.

[0060] The type and subtype subfields together identify the function of the MAC frame. There are three frame types: control, data, and management. Each of the frame types has several defined subtypes. Bits within the subtype subfield are used to indicate a specific modification of the basic data frame (subtype 0). For example, in data frames, the most significant bit (MSB) of the subtype subfield, bit 7 (B7) of the frame control field, is defined as the QoS subfield. When the QoS subfield is set to 1, it indicates a QoS subtype data frame, which is a data frame that contains a QoS control field in its MAC header. The second MSB of the subtype field, bit 6 (B6) of the frame control field, when set to 1 in data subtypes, indicates a data frame that contain no frame body field.

[0061] The To DS subfield indicates whether a data frame is destined to the distribution system (DS). The From DS subfield indicates whether a data frame originates from the DS.

[0062] The more fragments subfield is set to 1 in all data or management frames that have another fragment to follow of the MAC service data unit (MSDU) or MAC management protocol data unit (MMPDU) carried by the MAC frame. It is set to 0 in all other frames in which the more fragments subfield is present.

[0063] The retry subfield is set to 1 in any data or management frame that is a retransmission of an earlier frame. It is set to 0 in all other frames in which the retry subfield is present. A receiving STA uses this indication to aid it in the process of eliminating duplicate frames. These rules do not apply for frames sent by a STA under a block agreement.

[0064] The power management subfield is used to indicate the power management mode of a STA.

[0065] The More Data subfield indicates to a STA in power save (PS) mode that bufferable units (BUs) are buffered for that STA at the AP. The more data subfield is valid in individually addressed data or management frames transmitted by an AP to a STA in PS mode. The more data subfield is set to 1 to indicate that at least one additional buffered BU is present for the STA.

[0066] The protected frame subfield is set to 1 if the frame body field contains information that has been processed by a cryptographic encapsulation algorithm.

[0067] The +HTC subfield indicates that the MAC frame contains an HT control field.

[0068] The duration/ID field of the MAC header indicates various contents depending on frame type and subtype and the QoS capabilities of the sending STA. For example, in control frames of the power save poll (PS-Poll) subtype, the duration/ID field carries an association identifier (AID) of the STA that transmitted the frame in the 14 least significant bits (LSB), and the 2 most significant bits (MSB) are both set to 1. In other frames sent by STAs, the duration/ID field contains a duration value (in microseconds) which is used by a recipient to update a network allocation vector (NAV). The NAV is a counter that it indicates to a STA an amount of time during which it must defer from accessing the shared medium.

[0069] There can be up to four address fields in the MAC frame format. These fields are used to indicate the basic service set identifier (BSSID), source address (SA), destination address (DA), transmitting address (TA), and receiving address (RA). Certain frames might not contain some of the address fields. Certain address field usage may be specified by the relative position of the address field (1-4) within the MAC header, independent of the type of address present in that field. Specifically, the address 1 field always identifies the intended receiver(s) of the frame, and the address 2 field, where present, always identifies the transmitter of the frame.

[0070] The sequence control field includes two subfields, a sequence number subfield and a fragment number subfield. The sequence number subfield in data frames indicates the sequence number of the MSDU (if not in an Aggregated MSDU (A-MSDU)) or A-MSDU. The sequence number subfield in management frames indicates the sequence number of the frame. The fragment number subfield indicates the number of each fragment of an MSDU or MMPDU. The fragment number is set to 0 in the first or only fragment of an MSDU or MMPDU and is incremented by one for each successive fragment of that MSDU or MMPDU. The fragment number is set to 0 in a MAC protocol data unit (MPDU) containing an A-MSDU, or in an MPDU containing an MSDU or MMPDU that is not fragmented. The fragment number remains constant in all retransmissions of the fragment.

[0071] The QoS control field identifies the traffic category (TC) or traffic stream (TS) to which the MAC frame belongs. The QoS control field may also indicate various other QoS related, A-MSDU related, and mesh-related information about the frame. This information can vary by frame type, frame subtype, and type of transmitting STA. The QoS control field is present in all data frames in which the QoS subfield of the subtype subfield is equal to 1.

[0072] The HT control field is present in QoS data, QoS null, and management frames as determined by the +HTC subfield of the frame control field.

[0073] The frame body field is a variable length field that contains information specific to individual frame types and subtypes. It may include one or more MSDUs or MMPDUs. The minimum length of the frame body is 0 octets.

[0074] The FCS field contains a 32-bit Cyclic Redundancy Check (CRC) code. The FCS field value is calculated over all of the fields of the MAC header and the frame body field.

[0075] FIG. **4**A illustrates an example of a management frame format. As shown in FIG. **4**A, the management frame includes a MAC header, a variable length frame body, and a frame check sequence (FCS). The MAC header includes a frame control field, a duration field, an address 1 field, an address 2 field, an address 3 field, a sequence control field, and an optional HT control field. The presence of the HT control field is determined by the setting of a +HTC subfield of the frame control field.

[0076] In an example, the management frame becomes a beacon frame when a subtype field of the frame control field takes the value 1000. A frame body of the beacon frame includes the fields that are elements for operation of extreme high throughput (EHT) STAs. The operation of EHT STAs in an EHT basic service set (BSS) may be controlled by the

following: a) an high throughput (HT) operation element, an high efficiency (HE) operation element, and an EHT operation element if operating in the 2.4 GHz band; b) the HT operation element, a very high throughput (VHT) operation element (if present), the HE operation element, and the EHT operation element if operating in the 5 GHz band.

[0077] FIG. **4**B illustrates an example EHT Operation element format. As shown in FIG. **4**B, the EHT operation element includes an element ID field, a Length field, an element ID extension field (if present), an EHT operation parameters field, a basic EHT-MCS and Nss set field, and an EHT operation information field. The EHT operation parameters field includes an EHT operation information present subfield, a disabled subchannel bitmap present subfield, an EHT default PE duration subfield, a group addressed BU indication limit, a group addressed BU indication exponent subfield, and a reserved subfield.

[0078] FIG. **5**A illustrates an example of a management frame used as an action frame. As shown in FIG. **5**A, when used as an action frame, the frame body of a management frame includes an action field that includes a category field and an action details field. The action field provides a mechanism for specifying extended management actions. The category field indicates a category of the action frame. When the category field is set to 4, the action frame is a public action frame. The public action frame may allow the following: a) Inter-basic service set (BSS) and AP to unassociated-STA communications; b) Intra-BSS communication; c) generic advertisement service (GAS). The action details field contains the details of the action, such as the public action details for a public action frame.

[0079] FIG. **5**B illustrates an example public action frame format. As shown in FIG. **5**B, the public action frame format includes a public action field, in the octet immediately after the category field, followed by a variable length public action details field.

[0080] FIG. **6** illustrates an example of a QoS null frame indicating buffer status information. A QoS null frame refers to a QoS data frame with an empty frame body. A QoS null frame includes a QoS control field and an optional HT control field which may contain a buffer status report (BSR) control subfield. A QoS null frame indicating buffer status information may be transmitted by a STA to an AP.

[0081] The QoS control field may include a traffic identifier (TID) subfield, an ack policy indicator subfield, and a queue size subfield (or a transmission opportunity (TXOP) duration requested subfield).

[0082] The TID subfield identifies the TC or TS of traffic for which a TXOP is being requested, through the setting of the TXOP duration requested or queue size subfield. The encoding of the TID subfield depends on the access policy (e.g., Allowed value 0 to 7 for enhanced distributed channel access (EDCA) access policy to identify user priority for either TC or TS).

[0083] The ack policy indicator subfield, together with other information, identifies the acknowledgment policy followed upon delivery of the MPDU (e.g., normal ack, implicit block ack request, no ack, block ack, etc.)

[0084] The queue size subfield is an 8-bit field that indicates the amount of buffered traffic for a given TC or TS at the STA for transmission to the AP identified by the receiver address of the frame containing the subfield. The queue size subfield is present in QoS null frames sent by a STA when bit 4 of the QoS control field is set to 1. The AP may use information contained in the queue size subfield to determine the TXOP duration assigned to the STA or to determine the uplink (UL) resources assigned to the STA.

[0085] In a frame sent by or to a non-high efficiency (non-HE) STA, the following rules may apply to the queue size value:

[0086] The queue size value is the approximate total size, rounded up to the nearest multiple of 256 octets and expressed in units of 256 octets, of all MSDUs and A-MSDUs buffered at the STA (excluding the MSDU or A-MSDU contained in the present QoS Data frame) in the delivery queue used for MSDUs and A-MSDUs with TID values equal to the value indicated in the TID subfield of the QoS Control field.

[0087] A queue size value of 0 is used solely to indicate the absence of any buffered traffic in the queue used for the specified TID.

[0088] A queue size value of 254 is used for all sizes greater than 64 768 octets.

[0089] A queue size value of 255 is used to indicate an unspecified or unknown size.

[0090] In a frame sent by an HE STA to an HE AP, the following rules may apply to the queue size value.

[0091] The queue size value, QS, is the approximate total size in octets, of all MSDUs and A-MSDUs buffered at the STA (including the MSDUs or A-MSDUs contained in the same PSDU as the frame containing the queue size subfield) in the delivery queue used for MSDUs and A-MSDUs with TID values equal to the value indicated in the TID subfield of the QoS control field.

[0092] The queue size subfield includes a scaling factor subfield in bits B14-B15 of the QoS control field and an unscaled value, UV, in bits B8-B13 of the QoS control field. The scaling factor subfield provides the scaling factor, SF.

[0093] A STA obtains the queue size, QS, from a received QoS control field, which contains a scaling factor, SF, and an unscaled value, UV, as follows:

$$QS = 16 \times UV, \text{ if } SF \text{ is equal to } 0;$$

$$1024 + 256 \times UV, \text{ if } SF \text{ is equal to } 1;$$

$$17\,408 + 2048 \times UV, \text{ if } SF \text{ is equal to } 2;$$

$$148\,480 + 32\,768 \times UV, \text{ if } SF \text{ is equal to } 3 \text{ and } UV \text{ is less than } 62;$$

$$> 2\,147\,328, \text{ if } SF \text{ equal to is } 3 \text{ and } UV \text{ is equal to } 62;$$

[0094] Unspecified or Unknown, if SF is equal to 3 and UV is equal to 63.

[0095] The TXOP duration requested subfield, which may be included instead of the queue size subfield, indicates the duration, in units of 32 microseconds (us), that the sending STA determines it needs for its next TXOP for the specified TID. The TXOP duration requested subfield is set to 0 to indicate that no TXOP is requested for the specified TID in the current service period (SP). The TXOP duration requested subfield is set to a nonzero value to indicate a requested TXOP duration in the range of 32 us to 8160 us in increments of 32 us.

[0096] The HT control field may include a BSR control subfield which may contain buffer status information used for UL MU operation. The BSR control subfield may be formed from an access category index (ACI) bitmap sub-

field, a delta TID subfield, an ACI high subfield, a scaling factor subfield, a queue size high subfield, and a queue size all subfield of the HT control field.

[0097] The ACI bitmap subfield indicates the access categories for which buffer status is reported (e.g., B0: best effort (AC_BE), B1: background (AC_BK), B2: video (AC_VI), B3: voice (AC_VO), etc.). Each bit of the ACI bitmap subfield is set to 1 to indicate that the buffer status of the corresponding AC is included in the queue size all subfield, and set to 0 otherwise, except that if the ACI bitmap subfield is 0 and the delta TID subfield is 3, then the buffer status of all 8 TIDs is included.

[0098] The delta TID subfield, together with the values of the ACI bitmap subfield, indicate the number of TIDs for which the STA is reporting the buffer status.

[0099] The ACI high subfield indicates the ACI of the AC for which the BSR is indicated in the queue size high subfield. The ACI to AC mapping is defined as ACI value 0 mapping to AC_BE, ACI value 1 mapping to AC_BK, ACI value 2 mapping to AC_VI, and ACI value 3 mapping to AC_VO.

[0100] The scaling factor subfield indicates the unit SF, in octets, of the queue size high and queue size all subfields.

[0101] The queue size high subfield indicates the amount of buffered traffic, in units of SF octets, for the AC identified by the ACI high subfield, that is intended for the STA identified by the receiver address of the frame containing the BSR control subfield.

[0102] The queue size all subfield indicates the amount of buffered traffic, in units of SF octets, for all ACs identified by the ACI Bitmap subfield, that is intended for the STA identified by the receiver address of the frame containing the BSR control subfield.

[0103] The queue size values in the queue size high and queue size all subfields are the total sizes, rounded up to the nearest multiple of SF octets, of all MSDUs and A-MSDUs buffered at the STA (including the MSDUs or A-MSDUs contained in the same PSDU as the frame containing the BSR control subfield) in delivery queues used for MSDUs and A-MSDUs associated with AC(s) that are specified in the ACI high and ACI bitmap subfields, respectively.

[0104] A queue size value of 254 in the queue size high and queue size all subfields indicates that the amount of buffered traffic is greater than 254×SF octets. A queue size value of 255 in the queue size high and queue size all subfields indicates that the amount of buffered traffic is an unspecified or unknown size. The queue size value of QoS data frames containing fragments may remain constant even if the amount of queued traffic changes as successive fragments are transmitted.

[0105] MAC service provides peer entities with the ability to exchange MSDUs. To support this service, a local MAC uses the underlying PHY-level service to transport the MSDUs to a peer MAC entity. Such asynchronous MSDU transport is performed on a connectionless basis.

[0106] FIG. **7** illustrates an example multi-AP network **700**. Example multi-AP network **700** may be a multi-AP network in accordance with the Wi-Fi Alliance standard specification for multi-AP networks. As shown in FIG. **7**, multi-AP network **700** may include a multi-AP controller **702** and a plurality of multi-AP groups (or multi-AP sets) **704**, **706**, and **708**.

[0107] Multi-AP controller **702** may be a logical entity that implements logic for controlling the APs in multi-AP network **700**. Multi-AP controller **702** may receive capability information and measurements from the APs and may trigger AP control commands and operations on the APs. Multi-AP controller **702** may also provide onboarding functionality to onboard and provision APs onto multi-AP network **700**.

[0108] Multi-AP groups **704**, **706**, and **708** may each include a plurality of APs. APs in a multi-AP group are in communication range of each other. However, the APs in a multi-AP group are not required to have the same primary channel. As used herein, the primary channel for an AP refers to a default channel that the AP monitors for management frames and/or uses to transmit beacon frames. For a STA associated with an AP, the primary channel refers to the primary channel of the AP, which is advertised through the AP's beacon frames.

[0109] In one approach, one of the APs in a multi-AP group may be designated as a master AP. The designation of the master AP may be done by multi-AP controller **702** or by the APs of the multi-AP group. The master AP of a multi-AP group may be fixed or may change over time between the APs of the multi-AP group. An AP that is not the master AP of the multi-AP group is known as a slave AP.

[0110] In one approach, APs in a multi-AP group may coordinate with each other, including coordinating transmissions within the multi-AP group. One aspect of coordination may include coordination to perform multi-AP transmissions within the multi-AP group. As used herein, a multi-AP transmission is a transmission event in which multiple APs (of a multi-AP group or a multi-AP network) transmit simultaneously over a period. The period of simultaneous AP transmission may be a continuous period.

[0111] Multi-AP group coordination may be enabled by the multi-AP controller and/or by the master AP of the multi-AP group. In one approach, the multi-AP controller and/or the master AP may control time and/or frequency sharing in a TXOP. For example, when one of the APs (e.g., the master AP) in the multi-AP group obtains a TXOP, the multi-AP controller and/or the master AP may control how time/frequency resources of the TXOP are to be shared with other APs of the multi-AP group. In an implementation, the AP of the multi-AP group that obtains a TXOP becomes the master AP of the multi-AP group. The master AP may then share a portion of its obtained TXOP (which may be the entire TXOP) with one or more other APs of the multi-AP group.

[0112] Multi-AP operation may be enabled by at least two APs that support multi-AP coordination within one or more multi-AP groups. The APs may support multi-AP transmission schemes in a multi-AP network. A master AP may coordinate with slave AP(s) to enable multi-AP coordination and to support a multi-AP transmission. Slave AP(s) may participate in a multi-AP transmission. The master AP may select the slave AP(s) which are suitable for the multi-AP transmission. Slave APs may be candidates for a multi-AP transmission before being designated by the master AP.

[0113] Multi-AP transmission schemes may include transmission schemes such as coordinated OFDMA, coordinated time division multiple access (TDMA), coordinated spatial reuse, coordinated beamforming, joint transmission or reception (JT/JR), or a combination of two or more of the aforementioned schemes.

[0114] Coordinated OFDMA and coordinated TDMA may be categorized as coordinated TXOP, in which frequency or

time resources of a TXOP may be used to coordinate the interference. Coordinated spatial reuse (CSR) may provide reuse of spatial domain of neighboring BSSs by adjusting the transmit powers of coordinated APs. Coordinated beamforming (CBF) may provide dedicated null steering with spatial radiation based on channel state information (CSI) feedback from coordinated APs with the aid of multiple antennas to suppress the interference. Joint transmission or reception (JT/JR) may use distributed MIMO precoding or detection, via shared CSI, for data streams among multiple APs.

[0115] FIG. **8**A illustrates another example **800**A of a multi-AP network. Example multi-AP network **800**A may be an embodiment of multi-AP network **700** with the number of multi-AP groups being equal to one. As shown in FIG. **8**A, example multi-AP network **800**A may include a multi-AP controller **880**, a first BSS, and a second BSS. In an implementation, the multi-AP controller **880** may be implemented in a master AP of the first BSS or the second BSS. The first BSS may include an AP **802** and a plurality of STAs **804** and **806**. STAs **804** and **806** may be associated with AP **802**. The second BSS may include an AP **812** and a plurality of STAs **814** and **816**. STAs **814** and **816** may be associated with AP **812**. In an example, AP **802** and AP **812** may form a multi-AP group. AP **802** may be the master AP while AP **812** may be a slave AP of the multi-AP group. For example, AP **802** may obtain a TXOP making it the master AP of the multi-AP group. Alternatively, AP **802** may be designated as the master AP, manually by a human administrator (e.g., through a user interface of AP **802**) or by a multi-AP controller.

[0116] FIG. **8**B illustrates another example **800**B of a multi-AP network. Example multi-AP network **800**B may be an embodiment of multi-AP network **700** with the number of multi-AP groups being equal to one. As shown in FIG. **8**B, example multi-AP network **800**B may include a multi-AP controller **880**, a first BSS, a second BSS, and a third BSS. In an implementation, the multi-AP controller **880** may be implemented in a master AP of the first BSS, the second BSS, or the third BSS. The first BSS may include an AP **802** and a plurality of STAs **804** and **806**. STAs **804** and **806** may be associated with AP **802**. The second BSS may include an AP **812** and a plurality of STAs **814** and **816**. STAs **814** and **816** may be associated with AP **812**. The third BSS may include an AP **822**. In an example, AP **802**, AP **812**, and AP **822** may form a multi-AP group. AP **802** may be the master AP while AP **812** and AP **822** may be slave APs of the multi-AP group. For example, AP **802** may obtain a TXOP making it the master AP of the multi-AP group. Alternatively, AP **802** may be designated as the master AP, manually by a human administrator (e.g., through a user interface of AP **802**) or by a multi-AP controller.

[0117] FIG. **9** illustrates an example **900** of a multi-AP operation procedure. In example **900**, the multi-AP operation procedure is illustrated with respect to a multi-AP network that includes APs **902** and **912** and STAs **904** and **914**. In an example, APs **902** and **912** may form a multi-AP group. AP **902** may be the master AP and AP **912** may be a slave AP of the multi-AP group. For example, AP **902** may obtain a TXOP making it the master AP of the multi-AP group. Alternatively, AP **902** may be designated as the master AP by a multi-AP controller.

[0118] As shown in FIG. **9**, the multi-AP operation procedure may include a series of phases in time, each of which may contain a plurality of frame exchanges within the multi-AP network. Specifically, the multi-AP operation procedure may include a multi-AP setup phase **940**, a multi-AP information exchange phase **946**, an optional multi-AP sounding phase **948**, a multi-AP selection phase **950**, an optional multi-AP data sharing phase **952**, and a multi-AP data transmission phase **954**.

[0119] Multi-AP setup phase **940** may include the initialization and setup for multi-AP operation. During this phase, APs may transmit frames to notify of their availability and exchange information that may be required for establishing a multi-AP group. For example, as shown in FIG. **9**, in phase **940**, AP **902** may broadcast a frame **942** which may be received by AP **912**. Similarly, AP **912** may broadcast a frame **944** which may be received by AP **902**. Frames **942** and **944** may be beacon frames. In frames **942** and **944**, APs **902** and **912** may include information regarding AP capability. In an implementation, the AP capability information may include information regarding whether the AP supports multi-AP operation.

[0120] Multi-AP information exchange phase **946** may be used to exchange information related to multi-AP network operation, including BSS information of APs and link quality information between each AP and its associated STAs, for example. The BSS information of an AP may include a BSS ID of the BSS of the AP, identifiers and/or capabilities of STAs belonging to the BSS, information regarding sounding capabilities of the STAs, buffer status information associated with the BSS of AP, MIMO configuration of AP, etc. In an implementation, multi-AP information exchange phase **946** may be part of multi-AP setup phase **940**. Link quality information may include received signal strength indicator (RSSI), signal-to-noise ratio (SNR), signal-to-interference-plus-noise-ratio (SINR), channel state information (CSI), channel quality indicator (CQI).

[0121] Multi-AP sounding phase **948** may include procedures for multi-AP channel sounding, including channel estimation and feedback of channel estimates among the master AP, candidate slave AP(s), and associated STAs. Phase **948** may be optional for some multi-AP transmission schemes. For example, phase **948** may be optional for coordinated spatial reuse (CSR) as channel information is not required.

[0122] Multi-AP selection phase **950** may include procedures for soliciting, selecting, or designating slave AP(s) for a multi-AP group by a master AP. Phase **950** may include the same procedures for reselecting another candidate slave AP, when a candidate slave AP being solicited is not available during the selection.

[0123] Multi-AP data sharing phase **952** may include procedures for sharing the data frames to be transmitted to associated STAs among the master AP and designated slave AP(s) via direct connections between APs. Phase **952** may be optional for some multi-AP data transmission schemes. For example, phase **952** may be required forjoint transmission or reception (JT/JR) as data frames may be exchanged between APs before or after the multi-AP data transmission phase **954**.

[0124] Multi-AP data transmission phase **954** may include exchange of data frames between the master AP, designated slave AP(s), and their associated STAs based on multi-AP transmission scheme(s) determined by the master AP. Depending on the multi-AP transmission scheme(s) to be used, phase **954** may include optional synchronization

between APs within the multi-AP group before exchanging data frames between APs and STAs within the multi-AP network.

[0125] The order of phases **946** to **954** may be different than shown in FIG. **9**. Further, as mentioned above, some phases may be optional and may or may not be present. For example, optional phase **948** may not be required for CSR. However, optional phase **952** may be required for JT/JR. Further, in JT, phase **952** may occur prior to phase **954**, whereas, in JR, phase **952** may occur after phase **954**.

[0126] FIG. **10** illustrates an example **1000** of a multi-AP information exchange phase. Multi-AP information exchange phase **1000** may be an example of multi-AP information exchange phase **946**. As shown in FIG. **10**, example **1000** may include a master AP **1002** and a slave AP **1012** of a multi-AP group. In an example, AP **1002** and AP **1012** may have exchanged beacon frames in a prior phase (e.g., multi-AP setup phase **940**). AP **1012** may be a candidate slave AP when phase **1000** occurs during a multi-AP setup phase or before AP **1012** is selected or designated as a slave AP in a subsequent multi-AP selection phase (e.g., multi-AP selection phase **950**). By contrast, AP **1012** may be a designated slave AP when phase **1000** occurs (or repeats) after AP **1012** is selected or designated as a slave AP in a multi-AP selection phase.

[0127] As shown in FIG. **10**, phase **1000** may include subphases **1040** and **1050**. In an example, during subphase **1040**, AP **1002** may send a frame **1042** to AP **1012** to request BSS information from AP2. Frame **1042** may be a BSS information request frame. In response, AP **1012** may send to AP **1002** a frame **1044** including the BSS information of AP **1012**. Frame **1044** may be a BSS information response frame.

[0128] In an example, during subphase **1050**, AP **1002** may send a further frame **1052** to AP **1012** to request link quality information from AP **1012**. In response, AP **1012** may send to AP **1002** a frame **1054** including the requested link quality information. Frame **1052** may be a link quality information response frame.

[0129] FIG. **11** illustrates an example **1100** of a multi-AP sounding phase. Multi-AP sounding phase **1100** may be an example of multi-AP sounding phase **948**. As shown in FIG. **11**, example **1100** may include a master AP **1102** and a slave AP **1112** of a multi-AP group. Example **1100** may further include a STA **1104** associated with AP **1102** and a STA **1114** associated with AP **1112**.

[0130] As shown in FIG. **11**, multi-AP sounding phase **1100** may include frame exchanges to allow AP **1102** (the master AP) to acquire channel state information (CSI) of channels in the multi-AP network. In an implementation, phase **1100** may include a first subphase **1140** and a second subphase **1150**.

[0131] During the first subphase **1140**, APs may initiate channel sounding and STAs may estimate channel state information (CSI) based on the sounding results of each AP and its associated STAs. For example, AP **1102** may transmit a frame **1142** to AP **1112** (the slave AP) to trigger multi-AP sounding. Frame **1142** may be a multi-AP trigger frame. Subsequently, both APs **1102** and **1112** may transmit announcement frames to their associated STAs to announce the transmission of sounding frames. For example, APs **1102** and **1112** may transmit frames **1144-1** and **1144-2** to their associated STAs **1104** and **1114**, respectively. Frames **1144-1** and **1144-2** may be a multi-AP null data packet (NDP) announcement frame and may be transmitted simultaneously. Next, APs may transmit frames to their associated STAs to perform sounding for corresponding AP-to-STA channels. For example, APs **1102** and **1112** may transmit frames **1146-1** an **1145-2** to STAs **1104** and **1114** respectively. Frames **1146-1** and **1146-2** may be multi-AP NDP frames. STAs **1104** and **1114** receive frames **1146-1** and **1146-2** respectively and perform channel estimation of the channels from AP **1102** to STA **1104** and from AP **1112** to STA **1114** respectively.

[0132] During the second subphase **1150**, APs may initiate the procedure for STAs to feed back the channel estimates to the APs. For example, AP **1102** may transmit a frame **1152** to trigger STAs **1104** and **1114** to transmit their channel estimates to APs **1102** and **1112**. Frame **1152** may be a multi-AP trigger frame. In response, STAs **1104** and **1114** may transmit respectively frames **1154** and **1156** including feedback of channel estimates to APs **1102** and **1112**. Frames **1154** and **1156** may be NDP feedback frames. The feedback of channel estimates may include NDP feedback, CSI-related information, beamforming report (BFR), or channel quality indication (CQI) report.

[0133] FIG. **12** illustrates an example **1200** of a multi-AP selection phase. Multi-AP selection phase **1200** may be an example of multi-AP selection phase **950**. As shown in FIG. **12**, example **1200** may include a master AP **1202** and a slave AP **1212** of a multi-AP group.

[0134] As shown in FIG. **12**, multi-AP selection phase **1200** may include frame exchanges to allow master AP **1202** to determine whether candidate slave AP **1212** may participate in a multi-AP transmission. For example, AP **1202** may transmit a frame **1242** including information regarding selection for a multi-AP transmission to AP **1212**. In an example, frame **1242** may be a control frame, e.g., a trigger frame. For example, frame **1242** is a multi-AP trigger frame. In another example, frame **1242** may be an action frame, e.g., a public action frame. For example, frame **1242** is a multi-AP selection frame. Frame **1242** may include content requesting information related to the buffer status of AP **1212**. Frame **1242** may also include antenna or stream information of AP **1212**. Frame **1242** may be used for synchronization between APs **1202** and **1212**.

[0135] In response to frame **1242**, AP **1212** may transmit a frame **1244** to AP **1202**. If AP **1212** is available to participate in the multi-AP transmission, frame **1244** may include information related to buffer status and available frequency resources of AP **1212**. In an example, when frame **1242** is a trigger frame, e.g., a multi-AP trigger frame, frame **1244** may be a data frame that includes a trigger-based (TB) PPDU in response to the trigger frame. In another example, when frame **1242** is a public action frame, e.g., a multi-AP selection request frame, frame **1244** may be a multi-AP selection response frame.

[0136] If AP **1212** is unavailable to transmit frame **1244** in response to frame **1242**, AP **1202** may solicit another slave AP for selection for the multi-AP transmission.

[0137] Based on receiving frame **1244**, AP **1202** may confirm AP **1212** as a designated AP for the multi-AP transmission by transmitting a frame **1246**.

[0138] FIG. **13** illustrates an example **1300** of a multi-AP data sharing phase. Multi-AP data sharing phase **1300** may be an example of multi-AP data sharing phase **952**. As shown in FIG. **13**, example **1300** may include a master AP **1302** and a slave AP **1312** of a multi-AP group. As men-

tioned with reference to FIG. **9** above, phase **1300** may be optional for some multi-AP transmission schemes.

[0139] As shown in FIG. **13**, multi-AP data sharing phase **1300** may include frame exchanges to allow master AP **1302** to share data frames with slave AP **1312** which is designated for a multi-AP transmission. The multi-AP transmission scheme may be joint transmission or reception (JT/JR), for example. Master AP **1302** may initiate the procedure by transmitting an announcement frame **1342** to notify AP **1312** of upcoming data sharing. Frame **1342** may include information related to AP **1312**, for example, an identifier of AP **1312**. Frame **1342** may be a broadcast frame, a management frame, or a trigger frame. Subsequently, AP **1302** may transmit a data frame **1344** to AP **1312**. Data frame **1344** may correspond to a data frame transmitted or to be transmitted during the multi-AP transmission. Frame **1344** may include information related to a resource unit (RU) for transmitting an acknowledgment frame by AP **1312**. AP **132** may transmit a BlockAck (BA) frame **1346** to AP **1302** using the RU indicated in frame **1344** to confirm successful reception of data frame **1344**.

[0140] FIG. **14** illustrates an example **1400** of a multi-AP data transmission phase. Multi-AP data transmission phase **1400** may be an example of multi-AP data transmission phase **954**. As shown in FIG. **14**, example **1400** may include a master AP **1402** and a slave AP **1412** of a multi-AP group. Example **1400** may further include a STA **1404** associated with AP **1402**, and a STA **1414** associated with AP **1412**.

[0141] As shown in FIG. **14**, multi-AP data transmission phase **1400** may include frame exchanges to enable master AP **1402** to coordinate with designated slave AP **1412** to perform specific multi-AP transmission schemes with their associated STAs. For example, master AP **1402** and slave AP **1412** may perform multi-AP transmission schemes with STAs **1404** and **1414** respectively. The multi-AP transmission schemes may include coordinated OFDMA, coordinated time division multiple access (TDMA), coordinated spatial reuse, coordinated beamforming, joint transmission or reception (JT/JR), or a combination of two or more of the aforementioned schemes.

[0142] As shown in FIG. **14**, master AP may begin phase **1400** by transmitting a frame **1442** to AP **1412**. Frame **1442** may include information related to AP **1412** (e.g., an identifier of AP **1412**), synchronization information, information related to a specific multi-AP transmission scheme to be used, and/or information related to an RU for use by AP **1412** to acknowledge frame **1442**. Frame **1442** may be a control frame. For example, frame **1442** may be a multi-AP trigger frame.

[0143] Slave AP **1412** may receive frame **1442** and may use the synchronization information to synchronize with master AP **1402**. Subsequently, APs **1402** and **1412** may perform data transmission to their associated STAs **1404** and **1414** respectively. Specifically, AP **1402** may transmit a data frame **1444** to its associated STA **1404**, and AP **1412** may transmit a data frame **1446** to its associated STA **1414**. Depending on the multi-AP transmission scheme being used, frames **1444** and **1446** may also be transmitted by APs **1402** and **1412** respectively to STAs in different BSSs. For example, when the multi-AP transmission scheme is JT/JR, AP **1402** may also transmit frame **1444** to STA **1414** associated with slave AP **1412**, and AP **1412** may also transmit frame **1446** to STA **1404** associated with AP **1402**. The resources for transmitting and receiving frames **1444** and **1446** may depend on the specific multi-AP transmission scheme adopted.

[0144] STAs **1404** and **1414** may acknowledge frames **1444** and **1446** respectively. For example, STA **1404** may transmit a frame **1448** to AP **1402**, and STA **1414** may transmit a frame **1450** to AP **1402**. Frames **1448** and **1450** may be BA frames. When the multi-AP transmission scheme used requires so, STAs **1404** and **1414** may also transmit frames **1448** and **1450** to APs in different BSSs. For example, when the multi-AP transmission scheme is JT/JR, STA **1404** may also transmit frame **1448** to AP **1412**, and STA **1414** may also transmit frame **1450** to AP **1402**. The resources for transmitting and receiving frames **1448** and **1450** may depend on the specific multi-AP transmission scheme adopted.

[0145] As previously mentioned, a multi-AP network may carry out a multi-AP operation based on a specific multi-AP transmission scheme. During the multi-AP setup phase, a slave AP may inform the master AP of capability information related to the slave AP, including the capabilities of supporting one or more multi-AP transmission schemes. During the multi-AP information exchange frame, the slave AP may inform the master AP of BSS information of the BSS of the slave AP and of link quality information for STAs associated with the slave AP. The master AP may receive information related to all available slave APs. The information related to slave APs may include capability information, BSS information, and link quality information. Based on the information provided by available slave APs, the master AP may determine during a multi-AP selection phase the slave APs to be designated for a multi-AP transmission and a specific multi-AP transmission scheme to be used during the multi-AP transmission.

[0146] Multi-AP transmission may have various advantages and disadvantages when using different transmission schemes. Each multi-AP transmission scheme may have suitable use cases and specific requirements.

[0147] Different multi-AP transmission schemes may be suitable for different use cases in terms of privacy protection, including whether transmitted data may be shared with other BSSs in the multi-AP network. For example, some multi-AP transmission schemes, such as CSR, C-TDMA, C-FDMA, and CBF, enable a master AP to coordinate slave APs by sharing control information among APs, without requiring the sharing of user data among APs. The control information may include BSS information of APs, link quality information of channels between each AP and its associated STAs, and information related to resources to be used to achieve multiplexing in power, time, frequency, or special domains for multi-AP transmission. The control information exchanged among a master AP and slave APs may be used for interference avoidance or nulling to avoid or null co-channel interference introduced to neighboring BSSs in a multi-AP network. Interference avoidance or interference nulling require that data transmissions between an AP and STAs are only within the same BSS. In other words, each AP transmits or receives data frames to or from its associated STAs, while each STA receives or transmits data frames to or from its associating AP. By contrast, other multi-AP transmission schemes may enable a master AP to coordinate slave APs by sharing both control information and user data among APs in a multi-AP group. Control information may include BSS information related of APs

and link quality information of channels between each AP and its associated STAs. By having user data exchanged over backhaul, master AP and slave APs may perform data transmission jointly based on control signals to achieve diversity in spatial domain per distributed MIMO principle, for example, JT for downlink or JR for uplink. It requires that data transmissions between AP and STAs are not only within the same BSS, but also cross different BSSs. In other words, each AP transmits or receives the data frames to or from its associated STAs and the STAs associated with other APs participating in multi-AP transmission, while each STA receives or transmits data frames to or from multiple APs.

[0148] Different multi-AP transmission schemes may be suitable for different use cases in terms of signal reception levels at STAs or APs within a multi-AP network. For example, CBF and JT/JR require that each STA involved in a multi-AP transmission be located within a common area of signal coverage of the APs involved in the multi-AP transmission. Generally, CBF may be suitable when a receiving STA suffers from potential interference from other APs in the multi-AP group. By using channel related information such as CSI, CQI, or compressed BF feedback exchanged among APs, an AP may pre-code a signal to be transmitted to form a beam that increases power toward a target STA while reducing the power that interferes with a STA associated with a neighboring AP. Use cases of JT/JR may require a sufficient received signal power at receiving STAs for JT and a sufficient received signal power at receiving APs for JR. By contrast, CSR may perform multi-AP transmission in an interference coordination manner. The received signal power at a STA associated with an AP transmitting data may be required to be much higher than the received interference power.

[0149] Different multi-AP transmission schemes may require different synchronization levels and may operate with or without a backhaul between a master AP and slave APs in a multi-AP group. For example, CSR may require PPDU-level synchronization, whereas CBF may require symbol-level synchronization. On the other hand, JT/JR may require tight time/frequency/phase-level synchronization as well as backhaul for data sharing between APs in the multi-AP group.

[0150] Different multi-AP transmission schemes may have different complexity levels with regard to coordination between a master AP and slave APs in a multi-AP group. For example, JT/JR may require very high complexity due to both CSI and user data being shared between APs. CBF may require medium complexity due to the sharing of CSI. C-FDMA and C-TDMA may require medium or relatively low complexity due to the CSI and time/frequency resources to be shared between APs. CSR may require low complexity as the amount of information related to spatial reuse and traffic that needs to be exchanged between APs may be low.

[0151] Existing procedures as illustrated in FIG. **9** adopt a static multi-AP operation including a static multi-AP transmission scheme for a multi-AP network. However, a multi-AP network may be dynamic due to various reasons. For example, a STA may join or leave the multi-AP network, a STA may switch to a power save mode, or an AP or a STA may change its location. Such changes may lead to changes in the conditions underlying the selection of the multi-AP transmission scheme and may cause certain requirements (e.g., synchronization, backhaul, coordination, etc.) for the multi-AP transmission scheme to be lost. This results in an inferior quality of transmissions in the multi-AP network.

[0152] FIG. **15** illustrate an example **1500** of a problem that may arise in multi-AP operation using the existing procedure illustrated in FIG. **9**. Example **1500** includes a multi-AP network including a first BSS and a second BSS. The first BSS may include an AP **1502** and a plurality of STAs **1504** and **1506**. STAs **1504** and **1506** may be associated with AP **1502**. The second BSS may include an AP **1512** and a plurality of STAs **1514** and **1516**. STAs **1514** and **1516** may be associated with AP **1512**. In an example, AP **1502** and AP **1512** may form a multi-AP group. AP **1502** may be the master AP and AP **1512** may be a slave AP of the multi-AP group. For example, AP **1502** may obtain a TXOP making it the master AP of the multi-AP group. Alternatively, AP **1502** may be designated as the master AP by a multi-AP controller.

[0153] In an example, as shown in FIG. **15**, the status of STA **1516** may change over time. For example, STA **1516** may be absent during a first period **1522** and may be present during a second period **1524**. In an example, STA **1504**, **1506**, **1514** are located in an area within signal coverage of both APs **1502** and **1512**, while STA **1516** is located outside the signal coverage of AP **1502** but within the signal coverage of AP **1512**. In an example, example **1500** may span a plurality of beacon intervals **1526** and **1528**.

[0154] As shown in FIG. **15**, example **1500** may begin with a multi-AP setup phase which may start at the beginning of beacon interval **1526** during the first period **1522** in the absence of STA **1516**. Master AP **1502** may receive a frame **1542** that may include information related to the capabilities of supporting multi-AP transmission schemes for AP **1512**. The multi-AP transmission schemes may include C-FDMA, C-TDMA, CSR, CBF, and JT/JR.

[0155] Subsequently, APs **1502** and **1512** may complete a multi-AP information exchange phase **1544**. An example of frame exchanges during phase **1544** is described above in example **1000** of FIG. **10**. Next, APs **1502** and **1512** may perform a multi-AP sounding phase **1546** with available STAs **1504**, **1506**, and **1514**. An example of frame exchanges during phase **1544** is described above in example **1100** of FIG. **11**.

[0156] In multi-AP selection phase **1548**, master AP **1502** designates slave AP **1512** for a multi-AP transmission and determines the specific multi-AP transmission scheme based on the capabilities of AP **1512** for supporting multi-AP transmission schemes. As STA **1516** is absent at the time of multi-AP selection phase **1540**, AP **1502** designates AP **1512** for the multi-AP transmission without considering STA **1516**. An example of frame exchanges during phase **1548** is described above in example **1200** of FIG. **12**. In an implementation, when AP **1512** has capabilities to support two or more multi-AP transmission schemes, e.g., CSR and JT, master AP **1502** may select one of the supported schemes, e.g., JT, based on available information. In an example, master AP **1502** may adopt JT as the multi-AP transmission scheme. As such, APs **1502** and **1512** may perform a multi-AP data sharing phase **1550** as required by JT. An example of frame exchanges during phase **1550** is described above in example **1300** of FIG. **13**. Upon completion of phase **1550**, APs **1502** and **1512** may perform a multi-AP data transmission phase **1552** using JT. An example of frame exchanges during phase **1552** is described above in example **1400** of FIG. **14**. It is noted, as shown in FIG. **15**, that phase

1552 does not include a frame exchange related to STA **1516** as STA **1516** is absent during first period **1522**.

[0157] Subsequently, APs **1502** and **1512** may again exchange beacon frames. A beacon interval **1528** starts at the time of transmission by AP **1512** of a beacon frame **1554**. In an example, STA **1516** becomes present in the multi-AP network before the start of beacon interval **1528**. As mentioned above, AP **1512** may support two or more multi-AP transmission schemes, e.g., CSR and JT. In an example, as AP **1512** already participated in multi-AP data transmission phase **1552** in first period **1522**, multi-AP information exchange phase **1556** may be optional in period **1524**.

[0158] In contrast to multi-AP sounding phase **1546**, multi-AP sounding phase **1558** in second period **1524** includes STA **1516** allowing master AP **1502** to obtain CSI for the channels between AP **1512** and STA **1416**. In an example, AP **1512** continues to serve as a designated slave AP, in which case multi-AP selection phase **1560** may be optional. As such, AP **1502** may use the same information obtained during the first beacon interval **1526** and may continue to adopt the same multi-AP transmission scheme used in multi-AP data transmission phase **1552** (for example, JT) for multi-AP data transmission phase **1564**. In an example, a multi-AP data sharing phase **1562** may take place before multi-AP data transmission phase **1564**. An example of frame exchanges during phase **1564** is described above in example **1400** of FIG. **14**. It is noted, as shown in FIG. **15**, that phase **1564** does not include a frame exchange related to STA **1516**, even if STA **1516** is present during first period **1522**.

[0159] However, as mentioned above, STA **1516**, which became present in second period **1524**, is outside the signal coverage of AP **1502**. STA **1516** may thus fail to receive the signal from AP **1502** during the JT transmission performed during phase **1564**. As a result, the expected performance enhancement due to multi-AP transmission is not realized for STA **1516**.

[0160] The problem illustrated in FIG. **15** occurs due to shortcomings in the existing procedure for multi-AP operation. In a first aspect, the existing procedure relies on the master AP determining a multi-AP transmission scheme for a multi-AP transmission without consideration of whether the selected scheme can be adequately performed in the BSS of a slave AP. In another aspect, as illustrated in example **1500**, the existing procedure may use static and/or stale information in selecting the multi-AP transmission scheme. However, the dynamic nature of a multi-AP network may lead to a selected multi-AP transmission scheme becoming sub-optimal or inadequate. As such, existing procedures for establishing and maintaining multi-AP transmissions may result in situations of unsuccessful communication between a participating AP of the multi-AP transmission and one or more STAs. Such situations not only cause inefficient coordination and resource waste for the multi-AP transmission but also may cause a latency increase, throughput decrease, and QoS performance decrease for the multi-AP network.

[0161] Embodiments of the present disclosure, as further described below, provide enhanced procedures which may be used to setup, coordinate, perform, and/or update multi-AP transmissions using specific multi-AP transmission schemes. The proposed procedures mitigate the above-discussed situations of unsuccessful communications. In one aspect, the proposed procedures reduce such situations, particularly for dynamic multi-AP networks. As such, coordination efficiency, resource utilization, latency reduction and QoS performance may be improved within the multi-AP network.

[0162] FIG. **16** illustrates an example **1600** of frame exchanges including preferred multi-AP transmission scheme information in a multi-AP network. Example **1600** is provided for the purpose of illustration only and is not limiting. Like example **1500** described above, example **1600** includes a plurality of APs, AP **1602** and AP **1612**. In an example, APs **1602** and **1612** form a multi-AP group. AP **1602** may be the master AP while AP **1612** may be a slave AP of the multi-AP group. For example, AP **1602** may obtain a TXOP making it the master AP of the multi-AP group. Alternatively, AP **1602** may be designated as the master AP by a multi-AP controller. AP **1602** and AP **1612** may exchange frames to set up a multi-AP transmission and form a coordinated AP set. The coordinated AP set corresponds to the set of APs that participate in the multi-AP transmission. APs **1602**, **1622**, and **1622** within the coordinated AP set may exchange frames to coordinate, perform, and/or update the multi-AP transmission. The coordinated AP set may be part of the multi-AP group.

[0163] In an example, each of AP **1602** and AP **1612** may have one or more associated STAs (not shown in FIG. **16**). For the purpose of illustration, it is assumed that APs **1602** and **1612** may exchange a plurality of frames, for example, a first frame **1642**, a second frame **1644**, a third frame **1646**, and a fourth frame **1648**, during a multi-AP operation procedure. It is further assumed, for the purpose of illustration, that the order of frames shown in FIG. **16** may or may not relate to the order of the frames being transmitted by APs **1602** and **1612**. It is also assumed that the multi-AP network may change its status dynamically during a plurality of consecutive periods. It is additionally assumed that two or more multi-AP transmission schemes are supported by each of APs **1602** and **1612** in the multi-AP group. The multi-AP transmission schemes may include transmission schemes such as coordinated OFDMA, coordinated TDMA, coordinated spatial reuse (CSR), coordinated beamforming (CBF), joint transmission or reception (JT/JR), or a combination of two or more of the aforementioned schemes. In an embodiment, prior to the beginning of example **1600** (not shown in FIG. **16**), AP **1602** and AP **1612** may exchange frames to exchange capability information. In an example, AP **1602** may transmit to AP **1612** a first indication of support by AP **1602** of two or more multi-AP transmission schemes. In another example, AP **1612** may transmit to AP **1602** a second indication of support by AP **1612** of two or more multi-AP transmission schemes. In an embodiment, AP **1602** may transmit to AP **1612** a third indication of support by AP **1602** of a multi-AP transmission scheme selection capability. In another embodiment, AP **1612** may transmit to AP **1602** a fourth indication of support by AP **1612** of the multi-AP transmission scheme selection capability. It is assumed in example **1600** that both AP **1602** and AP **1612** support the multi-AP transmission scheme selection capability. In an example, supporting multi-AP transmission scheme selection capability allows AP **1612** to transmit frames (such as frames **1642**, **1646**) to share information of multi-AP transmission scheme with AP **1602**. In an example, supporting multi-AP transmission scheme selection capability allows AP **1602** to receive and process frames (such as frames **1642**, **1646**) to determine the selection of multi-AP transmission scheme. In an example, supporting multi-AP trans-

mission scheme selection capability allows AP **1602** to transmit frames (such as frames **1644**, **1648**) to announce the designation of multi-AP transmission scheme.

[0164] In an embodiment, slave AP **1612** transmits first frame **1642** to master AP **1602**. The AP **1612** may be a candidate slave AP that wishes to participate in a multi-AP transmission. Frame **1642** comprises an indication of a first multi-AP transmission scheme for use in a coordinated AP set comprising APs **1602** and **1612**. The coordinated AP set corresponds to the set of APs that participate in the multi-AP transmission. The first multi-AP transmission scheme corresponds to a preferred multi-AP transmission scheme for AP **1612** for use in the coordinated AP set. The preferred multi-AP transmission schemes for AP **1612** may be determined by AP **1612** from among one or more supported multi-AP transmission schemes, based on information related to AP **1612**. The information related to the AP **1612** may include BSS information of AP **1612**, link quality information of AP **1612**, and levels of synchronization and complexity supported by AP **1612**. BSS information of AP **1612** may include a BSS ID of the BSS of the AP **1612**, identifiers and/or capabilities of STAs belonging to the BSS of the AP **1612**, information regarding sounding capabilities of the STAs associated with AP **1612**, buffer status information associated with the BSS of AP **1612**, MIMO configuration of AP **1612**, etc. Link quality information may include received signal strength indicator (RSSI), signal-to-noise ratio (SNR), signal-to-interference-plus-noise ratio (SINR), channel state information (CSI), and channel quality indicator (CQI). Frame **1642** may be a management frame or a data frame. The coordinated AP set may be part of the multi-AP group comprising AP **1602** and AP **1612**.

[0165] In an embodiment, receiving of the first frame **1642** occurs during a setup phase of the coordinated AP set. In an embodiment, receiving of the first frame **1642** occurs after a setup phase of the coordinated AP set.

[0166] In an embodiment, the indication of the first multi-AP transmission scheme includes no preference for a multi-AP transmission scheme.

[0167] In an embodiment, AP **1602** transmits a second frame **1644** announcing a second multi-AP transmission scheme to be used by the coordinated AP set. The second multi-AP transmission scheme may be determined based on the first multi-AP transmission scheme indicated in frame **1642**. Frame **1644** may be a management frame. In an example, the second multi-AP transmission scheme indicated in frame **1644** is the same as or different than the first multi-AP transmission scheme indicated in frame **1642**.

[0168] In an implementation, AP **1602** determines the second multi-AP transmission scheme to improve the performance of the multi-AP network by analyzing link quality information available at APs **1602** and **1612**. For example, the link quality information may be measured by STAs and fed back or reported to APs. Link quality information may include received signal strength indicator (RSSI), signal-to-noise ratio (SNR), signal-to-interference-plus-noise ratio (SINR), channel state information (CSI), and channel quality indicator (CQI). For example, if the link quality information at AP **1612** indicates a significantly lower link quality between AP **1612** and its associated STAs than between AP **1602** and its associated STAs, AP **1602** may prioritize multi-AP transmission schemes (e.g., CSR or CBF) that may boost signal-to-interference ratio at the associated STAs of AP **1612**.

[0169] As discussed above, the dynamic status of the multi-AP network may impact the use cases and/or the conditions for using multi-AP transmission schemes over time. In an embodiment, the procedure including the exchange of first and second frames **1642** and **1644** may be used to establish a subsequent multi-AP transmission using a multi-AP transmission scheme determined based on a preferred multi-AP transmission scheme of slave AP **1612**. Further proposed procedures with frame exchanges may be used for coordinating and/or updating an existing multi-AP transmission with the intention to change the specific multi-AP transmission scheme.

[0170] In an example, slave AP **1612** may transmit a third frame **1646** to master AP **1602**. Frame **1646** may include an indication of a third multi-AP transmission scheme for the coordinated AP set comprising APs **1602** and **1612**. Frame **1646** may be a management frame or a data frame. The third multi-AP transmission scheme may correspond to an update of the first multi-AP transmission scheme for AP **1612**. The update of the first multi-AP transmission scheme for AP **1612** may be determined based on an update of information related to AP **1612**. The update of information related to AP **1612** may include an update of BSS information of AP **1612**, an update of link quality information of AP **1612**, and/or an update of a level of synchronization or complexity supported by AP **1612**. In an example, the third multi-AP transmission scheme is different from the first multi-AP transmission scheme indicated in frame **1642** or the second multi-AP transmission scheme indicated in **1644**.

[0171] In response to frame **1646**, AP **1602** may transmit a fourth frame **1648** announcing a fourth multi-AP transmission scheme to be used for the coordinated AP set. The fourth multi-AP transmission scheme may be determined based on the second multi-AP transmission scheme indicated in frame **1644** and/or the third multi-AP transmission scheme indicated in frame **1646**. Frame **1648** may be a management frame.

[0172] In an implementation, AP **1602** determines the fourth multi-AP transmission scheme to improve the performance of the multi-AP network by analyzing link quality information available at APs **1602** and **1612**. For example, the link quality information may be measured by STAs and fed back or reported to APs. Link quality information may include received signal strength indicator (RSSI), signal-to-noise ratio (SNR), signal-to-interference-plus-noise ratio (SINR), channel state information (CSI), and channel quality indicator (CQI). For example, if the link quality information at AP **1612** indicates a significantly lower link quality between AP **1612** and its associated STAs than between AP **1602** and its associated STAs, AP **1602** may prioritize multi-AP transmission schemes (e.g., CSR or CBF) that may boost signal-to-interference ratio at the associated STAs of AP **1612**.

[0173] FIG. **17** illustrates an example **1700** of frame exchanges including preferred multi-AP transmission scheme information in a multi-AP network. Example **1700** is provided for the purpose of illustration only and is not limiting. Like example **1600** described above, example **1700** includes a plurality of APs, AP **1702**, AP **1712**, and AP **1722**. In an example, APs **1702**, **1712**, and **1722** form a multi-AP group. AP **1702** may be the master AP while APs **1712** and **1722** may be slave APs of the multi-AP group. For example, AP **1702** may obtain a TXOP making it the master AP of the multi-AP group. Alternatively, AP **1702** may be designated

as the master AP by a multi-AP controller. APs **1702**, **1722**, and **1722** may exchange frames to set up a multi-AP transmission and form a coordinated AP set. APs **1702**, **1722**, and **1722** within the coordinated AP set may exchange frames to coordinate, perform, and/or update multi-AP transmissions. The coordinated AP set may be part of the multi-AP group.

[0174] In an example, each of APs **1702**, **1712**, and **1722** in example **1700** may have one or more associated STAs (not shown in FIG. **17**). For the purpose of illustration, it is assumed that APs **1702**, **1712**, and **1722** may exchange a plurality of frames, for example, a first frame **1742**, a second frame **1744**, a third frame **1746**, and a fourth frame **1748**, during a multi-AP operation procedure. It is further assumed, for the purpose of illustration, that the order of frames shown in FIG. **17** may or may not relate to the order of the frames being transmitted by APs **1702**, **1712**, and **1722**. It is also assumed that the multi-AP network may change its status dynamically during a plurality of consecutive periods. It is additionally assumed that two or more multi-AP transmission schemes are supported by each of APs **1702**, **1712**, and **1722** in the multi-AP group. The multi-AP transmission schemes may include transmission schemes such as coordinated OFDMA, coordinated TDMA, coordinated spatial reuse (CSR), coordinated beamforming (CBF), joint transmission or reception (JT/JR), or a combination of two or more of the aforementioned schemes. In an embodiment, prior to the beginning of example **1700** (not shown in FIG. **17**), APs **1702**, **1712**, and **1722** may exchange frames to exchange capability information. In an example, AP **1702** may transmit to APs **1712** and **1722** a first indication of support by AP **1702** of two or more multi-AP transmission schemes. In an example, AP **1712** may transmit to APs **1702** and **1722** a second indication of support by AP **1712** of two or more multi-AP transmission schemes. In an example, AP **1722** may transmit to APs **1702** and **1712** a third indication of support by AP **1722** of two or more multi-AP transmission schemes. In an embodiment, AP **1702** may transmit to APs **1712** and **1722** a fourth indication of support by AP **1702** of a multi-AP transmission scheme selection capability. In embodiment, AP **1712** may transmit to APs **1702** and **1722** a fifth indication of support by AP **1712** of the multi-AP transmission scheme selection capability. In another embodiment, AP **1722** may transmit to APs **1702** and **1712** a sixth indication of support by AP **1722** of the multi-AP transmission scheme selection capability. It is assumed in example **1700** that all APs **1702**, **1712**, and **1722** support the multi-AP transmission scheme selection capability.

[0175] In an embodiment, a slave AP **1712** transmits first frame **1742** to master AP **1702**. The AP **1712** may be a candidate slave AP that wishes to participate in a multi-AP transmission. Frame **1742** comprises an indication of a first multi-AP transmission scheme for used in a coordinated AP set comprising APs **1702** and **1712**. The coordinated AP set corresponds to the set of APs that participate in the multi-AP transmission. The first multi-AP transmission scheme corresponds to a preferred multi-AP transmission scheme for AP **1712** for used in the coordinated AP set. The preferred multi-AP transmission schemes for AP **1712** may be determined by AP **1712** from among one or more supported multi-AP transmission schemes, based on information related to AP **1712**. The information related to AP **1612** may include BSS information of AP **1712**, link quality information of AP **1712**, and levels of synchronization and complexity supported by AP **1712**. BSS information of AP **1712** may include a BSS ID of the BSS of the AP **1712**, identifiers and/or capabilities of STAs belonging to the BSS of the AP **1712**, information regarding sounding capabilities of the STAs associated with AP **1712**, buffer status information associated with the BSS of AP **1712**, MIMO configuration of AP **1712**, etc. Link quality information may include received signal strength indicator (RSSI), signal-to-noise ratio (SNR), signal-to-interference-plus-noise ratio (SINR), channel state information (CSI), and channel quality indicator (CQI). Frame **1742** may be a management frame or a data frame. The coordinated AP set may be part of the multi-AP group comprising AP **1702**, **1712**, and AP **1722**.

[0176] In an embodiment, receiving of the first frame **1742** occurs during a setup phase of the coordinated AP set. In an embodiment, receiving of the first frame **1742** occurs after a setup phase of the coordinated AP set.

[0177] In an embodiment, the indication of the first multi-AP transmission scheme includes no preference for a multi-AP transmission scheme.

[0178] In an embodiment, AP **1702** transmits a second frame **1744** announcing a second multi-AP transmission scheme to be used by the coordinated AP set. The second multi-AP transmission scheme may be determined based on the first multi-AP transmission scheme indicated in frame **1742**. Frame **1744** may be a management frame. In an example, the second multi-AP transmission scheme indicated in frame **1744** is the same as or different than the first multi-AP transmission scheme indicated in frame **1742**.

[0179] In an implementation, AP **1702** determines the second multi-AP transmission scheme to improve the performance of the multi-AP network by analyzing link quality information available at APs **1702** and **1712**. For example, the link quality information may be measured by STAs and fed back or reported to APs. Link quality information may include received signal strength indicator (RSSI), signal-to-noise ratio (SNR), signal-to-interference-plus-noise ratio (SINR), channel state information (CSI), and channel quality indicator (CQI). For example, if the link quality information at AP **1712** indicates a significantly lower link quality between AP **1712** and its associated STAs than between AP **1702** and its associated STAs, AP **1702** may prioritize multi-AP transmission schemes (e.g., CSR or CBF) that may boost signal-to-interference ratio at the associated STAs of AP **1712**.

[0180] As discussed above, the dynamic status of the multi-AP network may impact the use cases and/or the conditions for using multi-AP transmission schemes over time. In an embodiment, the procedure including the exchange of first and second frames **1742** and **1744** may be used to establish a subsequent multi-AP transmission using a multi-AP transmission scheme determined based on a preferred multi-AP transmission scheme of slave AP **1712**. Further proposed procedures with frame exchanges may be used for coordinating and updating an existing multi-AP transmission with the intention to change the specific multi-AP transmission scheme.

[0181] In an embodiment, slave AP **1722** transmits a third frame **1746** to master AP **1702**. In an example, AP **1722** is another slave AP designated to participate in the multi-AP transmission. Frame **1746** includes an indication of a third multi-AP transmission scheme for use in the coordinated AP set comprising APs **1702**, **1712**, and **1722**. The third multi-

AP transmission scheme may correspond to a preferred multi-AP transmission scheme for AP **1722**. Frame **1746** may be a management frame or a data frame.

[0182] In an embodiment, AP **1702** transmits a fourth frame **1748** announcing a fourth multi-AP transmission scheme to be used for the coordinated AP set determined based on the second multi-AP transmission scheme indicated in frame **1744** and/or the third multi-AP transmission scheme indicated in frame **1746**. The fourth multi-AP transmission scheme indicated in frame **1748** may be the same as the first multi-AP transmission scheme indicated in frame **1742** or the third multi-AP transmission scheme indicated in frame **1746**, or different than the first multi-AP transmission scheme indicated in frame **1742**, and the third multi-AP transmission scheme indicated in frame **1746**.

[0183] In an example, the order of frames **1744** and frame **1746** may be different than shown in FIG. **17**. In an embodiment, when frame **1746** is received by AP **1702** before the transmission of frame **1744** by AP **1702**, AP **1702** may transmit frame **1748** only. The fourth multi-AP transmission scheme indicated in frame **1748** may be the same as the first multi-AP transmission scheme indicated in frame **1742** or the third multi-AP transmission scheme indicated in frame **1746**, or different than the first multi-AP transmission scheme indicated in frame **1742** and the third multi-AP transmission scheme indicated in frame **1746**.

[0184] In an implementation, AP **1702** determines the fourth multi-AP transmission scheme to improve the performance of the multi-AP network by analyzing link quality information available at APs **1702** and **1712**. For example, the link quality information may be measured by STAs and fed back or reported to APs. Link quality information may include received signal strength indicator (RSSI), signal-to-noise ratio (SNR), signal-to-interference-plus-noise ratio (SINR), channel state information (CSI), and channel quality indicator (CQI). For example, if the link quality information at AP **1722** indicates a significantly lower link quality between AP **1722** and its associated STAs than between AP **1702** and its associated STAs, AP **1702** may prioritize multi-AP transmission schemes (e.g., CSR or CBF) that may boost signal-to-interference ratio at the associated STAs of AP **1722**.

[0185] In an implementation, the indication by an AP of a multi-AP transmission scheme and/or of an update of a multi-AP transmission scheme may be encoded using a mapping as illustrated by example mapping **1800**A of FIG. **18**A or example mapping **1800**B of FIG. **18**B. As shown in FIG. **18**A, the mapping **1800**A associates a plurality of multi-AP transmission schemes with a respective plurality of indices. The indices may correspond to binary codes as shown in FIG. **18**A. To signal a particular multi-AP transmission scheme and/or an update of a multi-AP transmission scheme, the corresponding code may be indicated in a field of the frame carrying the indication of the multi-AP transmission scheme and/or of the update of a multi-AP transmission scheme. As shown in FIG. **18**B, the mapping **1800**B associates a plurality of multi-AP transmission schemes with a respective plurality of sequences. The sequence may correspond to an order of a bitmap. To signal a particular multi-AP transmission scheme and/or an update of a multi-AP transmission scheme, the corresponding sequence may be indicated in a field of the frame carrying the indication of the multi-AP transmission scheme and/or of the update of a multi-AP transmission scheme.

[0186] As mentioned above, first frames **1642** and **1742** and third frames **1646** and **1746** may include management frames or data frames.

[0187] In an embodiment, frames **1642**, **1646**, **1742**, and **1746** may be management frames, such as beacon frames. For example, the indication of the first multi-AP transmission scheme and/or the indication of the third multi-AP transmission scheme may be included in an operation element of a beacon frame. FIG. **19** illustrates an example **1900** of a beacon frame **1902** including an indication of a preferred multi-AP transmission scheme or of an update of the preferred multi-AP transmission scheme. As shown in FIG. **19**, beacon frame **1902** may include an operation element **1904**. The operation element **1904** may include an operation Parameters field **1906**. The operation Parameters field **1906** may include a multi-AP operation information subfield **1908**. In an embodiment, the multi-AP operation information subfield **1908** may include the indication of the preferred multi-AP transmission scheme or the indication of the update of the preferred multi-AP transmission scheme.

[0188] In another embodiment, frames **1642**, **1646**, **1742**, and **1746** may be management frames, such as action frames or control frames. FIG. **20** illustrates examples **2000-2**, **2000-4**, **2000-6**, and **2000-8** for procedures in which the indication of the first multi-AP transmission scheme and/or the indication of the third multi-AP transmission scheme may be provided in action or control frames. As described above, the first multi-AP transmission scheme may correspond to the scheme indicated in frames **1642** or **1742**, while the third multi-AP transmission scheme may correspond to the scheme indicated in frames **1646** or **1746**.

[0189] In examples **2000-2** and **2000-4**, slave AP **2012** may transmit an action frame **2042** including the indication of the first multi-AP transmission scheme or the indication of the third multi-AP transmission scheme to master AP **2002**. In an example, frame **2042** may be a public action frame. In an embodiment, frame **2042** may be a request frame providing BSS information of AP **2012** along with the indication of the preferred multi-AP transmission scheme for AP **2012** or the indication of the update of the preferred multi-AP transmission scheme for AP **2012**. For example, frame **2042** may be a BSS information request frame. In an embodiment, frame **2042** may be a request frame providing the indication of the preferred multi-AP transmission scheme or the indication of the update of the preferred multi-AP transmission scheme for AP **2012**. For example, frame **2042** may be a multi-AP information update request frame. Frame **2042** may include a Category field, a Public Action field, and a multi-AP information field. The multi-AP information field may include the indication of the preferred multi-AP transmission scheme or the indication of the update of the preferred multi-AP transmission scheme.

[0190] As shown in example **2000-2**, AP **2002** receives frame **2042** and optionally transmits an ACK frame to AP **2012**. After an optional period of EDCA, AP **2002** transmits a response frame **2044** to confirm the reception of frame **2042**. AP **2012** may optionally transmit an ACK frame to AP **2002**. By contrast, example **2000-4** shows a simplified procedure, in which the AP **2002** confirms the reception of frame **2042** by transmitting an ACK frame.

[0191] In examples **2000-6** and **2000-8**, master AP **2002** may transmit an action frame **2052** to slave AP **2012** to request the indications of the first multi-AP transmission scheme or of the third multi-AP transmission scheme. In an

embodiment, frame **2052** may be a request frame that requests the BSS information of AP **2012** along with the indication of the preferred multi-AP transmission scheme for AP **2012** or the indication of the update of the preferred multi-AP transmission scheme for AP **2012**. For example, frame **2052** may be a BSS information request frame. In an embodiment, frame **2042** may be a request frame requesting the indication of the preferred multi-AP transmission scheme or the indication of the update of the preferred multi-AP transmission scheme for AP **2012**. For example, frame **2052** may be a multi-AP information update request frame.

[0192] As shown in example **2000-6**, AP **2012** receives frame **2052** and optionally transmits an ACK frame to AP **2002**. After an optional period of EDCA, AP **2012** transmits a response frame **2054** to AP **2002** including the information requested by frame **2042**. In an example, frame **2054** may be a public action frame. In an embodiment, frame **2054** includes the BSS information of the AP **2012** along with the indication of the preferred multi-AP transmission scheme for AP **2012** or the indication of the update of the preferred multi-AP transmission scheme for AP **2012**. For example, frame **2054** may be a BSS information response frame. In an embodiment, frame **2054** provides the indication of the preferred multi-AP transmission scheme for AP **2012** or the indication of the update of the preferred multi-AP transmission scheme for AP **2012**. For example, frame **2054** may be a multi-AP information update response frame. Frame **2054** may include a Category field, a Public Action field, and a multi-AP information field. The multi-AP information field may include the indication of the preferred multi-AP transmission scheme or the indication of the update of the preferred multi-AP transmission scheme. AP **2002** may optionally transmit an ACK frame to confirm the reception of frame **2054**. By contrast, example **2000-8** shows a simplified procedure, in which AP **2012** transmits a control frame, for example, a BA frame or a multi-STA BA frame, including the indication of the preferred multi-AP transmission scheme for AP **2012** or the indication of the update of the preferred multi-AP transmission scheme for AP **2012**.

[0193] In an embodiment, frames **1642**, **1646**, **1742**, and **1746** may be data frames. FIG. **21** illustrates an example **2100** of a procedure in which the indication of the first multi-AP transmission scheme and/or the indication of the third multi-AP transmission scheme may be provided in data frames. As described above, the first multi-AP transmission scheme may correspond to the scheme indicated in frames **1642** or **1742**, while the third multi-AP transmission scheme may correspond to the scheme indicated in frames **1646** or **1746**.

[0194] As shown in FIG. **21**, master AP **2102** may transmit a trigger frame **2142** to solicit a trigger-based (TB) PPDU transmission from slave AP **2112**. In an example, AP **2112** may be a candidate slave AP for a multi-AP transmission. As such, frame **2142** may be a multi-AP trigger frame that solicits AP **2112** whether AP **2112** wishes to participate in the multi-AP transmission. For example, frame **2142** may be a multi-AP selection trigger frame. In an embodiment, AP **2112** responds to frame **2142** with a frame **2144** that includes its intention to participate in the multi-AP transmission as well as an indication of a preferred multi-AP transmission scheme for AP **2112**. The preferred multi-AP transmission scheme for AP **2112** may be the first multi-AP transmission scheme or the third multi-AP transmission schemes discussed in examples **1600** and **1700** above.

[0195] In another example, AP **2112** may be a designated slave AP for a multi-AP transmission. As such, frame **2142** may be a trigger frame that solicits from AP **2112** an indication of a preferred multi-AP transmission scheme or an indication of an update of the preferred multi-AP transmission scheme. For example, frame **2142** may be a multi-AP trigger frame. In an embodiment, AP **2112** responds to frame **2142** with a frame **2144** including the indication of the preferred multi-AP transmission scheme or the indication of the update of the preferred multi-AP transmission scheme for AP **2112**. The preferred multi-AP transmission scheme or the update of the preferred multi-AP transmission scheme for AP **2112** may be the third multi-AP transmission scheme discussed in example **1600** or **1700** above.

[0196] In an embodiment, frame **2144** may be a QoS null frame. As described above with reference to FIG. **6**, a QoS null frame refers to a QoS data frame with an empty frame body. For example, a QoS null frame may include, among other fields, a QoS control field and an HT control field. The QoS control field and/or the HT control field may include a BSR. In another embodiment, frame **2144** may be a QoS data frame, which includes similar fields as a QoS null frame. In an embodiment, where frame **2144** is a QoS null frame or a QoS data frame, the indication of the first multi-AP transmission scheme or the indication of the third multi-AP transmission scheme may be provided in the QoS Control field or the HT Control field of the QoS null frame or the QoS data frame.

[0197] In an embodiment, master AP **2102** may transmit to slave AP **2112** a frame **2146** confirming AP **2112** for participation in the multi-AP transmission with a multi-AP transmission scheme determined based on previously received frames. In an example, when frame **2144** includes the first multi-AP transmission scheme (e.g., frame **2144** is an embodiment of frame **1642** in example **1600**), the determination of the multi-AP transmission scheme indicated in frame **2146** may be based on frame **2144**. In an example, when frame **2144** includes the indication of the third multi-AP transmission scheme (e.g., frame **2144** is an embodiment of frame **1646** or **1746** in example **1600**), the determination of the multi-AP transmission scheme indicated in frame **2146** may be based on the second and the third multi-AP transmission schemes discussed above as shown in example **1600**.

[0198] Recalling example **1600** illustrated in FIG. **16**, master AP **1602** may receive the third frame **1646** in various durations after receiving the first frame **1642**. Similarly, in example **1700** illustrated in FIG. **17**, master AP **1702** may receive the third frame **1746** in various durations after receiving first frame **1742**. In embodiments, the third frame may be received at least a beacon interval, less than a beacon interval, at least a TXOP, or less than a TXOP, after receiving the first frame. In an embodiment, the various durations may be classified into a long-term, a medium-term, and a short-term category. The long-term category may include receiving the third frame at least a beacon interval after receiving the first frame. The medium-term category may include receiving the third frame less than a beacon interval but at least a TXOP after receiving the first frame. The short-term category may include receiving the third frame less than a TXOP after receiving the first frame. The long-term, medium-term, and short-term categories allow

the master AP to determine the multi-AP transmission scheme based on both the latest preferred multi-AP transmission scheme for slave APs and the latest multi-AP transmission scheme determined by the master AP.

[0199] Referring to example **1900** of FIG. **19**, example **2000** of FIG. **20** and example **2100** of FIG. **21**, the first or third frame may belong to different frame types for different durations or categories of durations. Also, the first frame and the third frame may belong to different types for a given category of duration. In an embodiment, the first frame and the third frame include a management frame, such as a beacon frame and an action frame, a control frame, or a data frame. In an embodiment, the second frame and the fourth frame may be a control frame.

[0200] FIG. **22** illustrates an example **2200** of multi-AP operation according to the proposed procedure. Like example **1500** of FIG. **15**, example **2200** may include a first BSS and a second BSS. The first BSS may include an AP **2202** and a plurality of STAs **2204** and **2206**. STAs **2204** and **2206** may be associated with AP **2202**. The second BSS may include an AP **2212** and a plurality of STAs **2214** and **2216**. STAs **2214** and **2216** may be associated with AP **2212**. In an example, AP **2202** and AP **2212** may form a multi-AP group. AP **2202** may be the master AP and AP **2212** may be a slave AP of the multi-AP group. AP **2202** and AP **2212** may exchange frames to set up multi-AP transmission and form a coordinated AP set. The coordinated AP set corresponds to the set of APs that participate in the multi-AP transmission. The coordinated AP set may be a part of a multi-AP group. In an embodiment, during a multi-AP setup phase, AP **2202** and AP **2212** may exchange frames to exchange capability information. In an example, AP **2202** may transmit to AP **2212** a first indication of support by AP **2202** of two or more multi-AP transmission schemes. In another example, AP **2202** may transmit to AP **2212** a second indication of support by AP **2202** of two or more multi-AP transmission schemes. In an embodiment, AP **2202** may transmit to AP **2212** a third indication of support by AP **2202** of a multi-AP transmission scheme selection capability. In another embodiment, AP **2212** may transmit to AP **2202** a fourth indication of support by AP **2212** of the multi-AP transmission scheme selection capability. It is assumed in example **2200** that both AP **2202** and AP **2212** support the multi-AP transmission scheme selection capability.

[0201] In an example, the status of STA **2216** may change over time. For example, STA **2216** may be absent during a first period **2222** and may be present during a second period **2224**. In an example, STA **2204**, **2206**, **2214** are located in an area within signal coverage of both APs **2202** and **2212**, while STA **2216** is located outside the signal coverage of AP **2202** but within the signal coverage of AP **2212**. In an example, example **2200** may span a plurality of beacon intervals **2226** and **2228**.

[0202] As shown in FIG. **22**, example operation **2200** includes a plurality of phases as described above with reference to FIG. **9**. The plurality of phases may span a plurality of beacon intervals, for example, beacon intervals **2226** and **2228**. In an embodiment, AP **2202** receives a third frame **2254** (which is an embodiment of frame **1646** of example **1600**) in period **2224** at least a beacon interval after receiving a first frame **2242** (which is an embodiment of frame **1642** of example **1600**) in period **2222**. In example **2200**, slave AP **2212** transmits a first frame **2242**, which may be a beacon frame, to master AP **2202** to start the multi-AP setup phase during the first period **2222**. In an embodiment, the first frame **2242** includes an indication of the first multi-AP transmission scheme for use in the coordinated AP set, wherein the first multi-AP transmission scheme corresponds to the preferred multi-AP transmission scheme for AP **2212**. In example **2200**, the preferred multi-AP transmission scheme indicated in frame **2242** is joint transmission (JT). As discussed in example **1900**, the indications of the first multi-AP transmission scheme may be included in the operation parameters field of an operation element of frame **2242**.

[0203] As shown in FIG. **22**, after the transmission of frame **2242**, a multi-AP information exchange phase **2244** and a multi-AP sounding phase **2246** take place. Phases **2244** and **2246** are similar to phases **1544** and **1546** described above. In example **1500**, master AP **1502** designates the slave AP **1512** and determines a multi-AP transmission scheme in phase **1548** based on the capabilities of AP **1512** supporting multi-AP transmission schemes indicated in frame **1542**. In contrast to example **1500**, in example **2200**, master AP **2202** transmits a confirmation frame announcing the designed slave AP **2212** and a second multi-AP transmission scheme in multi-AP selection phase **2248**. As discussed in example **1600**, the second multi-AP transmission scheme corresponds to the multi-AP transmission scheme determined by master AP **2202** based on the first multi-AP transmission scheme indicated in the first frame **2242** for the coordinated AP set. In example **2200**, AP **2202** adopts JT as the second multi-AP transmission scheme. Similar to example **1500**, as AP **2212** is designated in example **2200**, APs **2202** and **2212** may perform a multi-AP data sharing phase **2250** (which may be required for JT) followed by a multi-AP data transmission phase **2252** using JT with associated STAs **2204**, **2206**, **2214**. In an example, master AP **2202** may transmit a second frame announcing the second multi-AP transmission scheme in multi-AP data sharing phase **2250**, (e.g., the second frame may be similar to frame **1342** of example **1300**). In another example, master AP **2202** may transmit the second frame announcing the second multi-AP transmission scheme in multi-AP data transmission phase **2252** (e.g., the second frame may be similar to frame **1442** of example **1400**).

[0204] During period **2224**, slave AP **2212** may transmit a third frame **2254**, which may be a beacon frame, including an indication of a third multi-AP transmission scheme for the coordinated AP set. In an embodiment, frame **2254** is received by AP **2202** at least a beacon interval after the receiving first frame **2242**. As discussed in example **1600**, the third multi-AP transmission scheme may correspond to an update of the first multi-AP transmission scheme. Similar to frame **2242**, the indications of the third multi-AP transmission scheme may be included in an operation parameters field of an operation element of frame **2254**. In example **2200**, the update of the first multi-AP transmission scheme indicated in frame **2254** is coordinated spatial reuse (CSR).

[0205] As shown in FIG. **22**, after the transmission of frame **2254**, APs **2202** and **2212** may perform a multi-AP information exchange phase **2256** and obtain information related to the presence of STA **2216** during period **2224**. In an embodiment, AP **2202** determines the fourth multi-AP transmission scheme based on the second multi-AP transmission scheme announced in phase **2248** and the third multi-AP transmission scheme indicated in frame **2254**. In example **2200**, AP **2202** adopts CSR as the fourth multi-AP

transmission scheme, without changing the slave AP **2212**. Therefore, a multi-AP sounding phase **2258**, a multi-AP selection phase **2260**, and a multi-AP data sharing phase **2266** may be optional. AP **2202** may announce the fourth multi-AP transmissions scheme at the beginning of a multi-AP transmission data transmission phase **2264**, for example, using a frame similar to frame **1442** described above with reference to FIG. **14**. By performing CSR in phase **2264**, all associated STAs in the multi-AP network can be served by APs **2022** and **2012**, even with STA **2216** being out of the coverage of AP **2202**. For example, upon coordination between APs **2202** and **2212** for spatial reuse, STAs **2204** and **2206** may successfully receive a data frame transmitted from AP **2202**, while STAs **2214** and **2216** may successfully receive a data frame transmitted from AP **2212** (as illustrated by marker **2230** in FIG. **22**).

[0206] FIG. **23** illustrates an example **2300** of multi-AP operation according to the proposed procedure. Like example **2200** of FIG. **22**, example **2300** may include a first BSS and a second BSS. The first BSS may include an AP **2302** and a plurality of STAs **2304** and **2306**. STAs **2304** and **2306** may be associated with AP **2302**. The second BSS may include an AP **2312** and a plurality of STAs **2314** and **2316**. STAs **2314** and **2316** may be associated with AP **2312**. In an example, AP **2302** and AP **2312** may form a multi-AP group. AP **2302** may be the master AP and AP **2312** may be a slave AP of the multi-AP group. AP **2302** and AP **2312** may exchange frames to set up a multi-AP transmission and form a coordinated AP set. The coordinated AP set corresponds to the set of APs that participate in the multi-AP transmission. The coordinated AP set may be a part of the multi-AP group. In an embodiment, during a multi-AP setup phase, AP **2302** and AP **2312** may exchange frames to exchange capability information. In an example, AP **2302** may transmit to AP **2312** a first indication of support by AP **2302** of two or more multi-AP transmission schemes. In another example, AP **2302** may transmit to AP **2312** a second indication of support by AP **2302** of two or more multi-AP transmission schemes. In an embodiment, AP **2302** may transmit to AP **2312** a third indication of support by AP **2302** of a multi-AP transmission scheme selection capability. In another embodiment, AP **2312** may transmit to AP **2302** a fourth indication of support by AP **2312** of the multi-AP transmission scheme selection capability. It is assumed in example **2300** that both AP **2302** and AP **2312** support the multi-AP transmission scheme selection capability.

[0207] In an embodiment, AP **2302** receives from AP **2312** a third frame in period **2324** as an action frame at least one beacon interval, for example, beacon interval **2326**, after receiving a first frame from AP **2312** in period **2322**. The first frame may include an indication of a first multi-AP transmission scheme for use in the coordinated AP set. The third frame may include an indication of a third multi-AP transmission scheme for the coordinated AP set. The first frame (which may correspond to frame **1642** of example **1600**) may be received by AP **2302** in either a multi-AP information exchange phase **2342** or a multi-AP information update phase **2344** (the first frame may be similar to frames **2042**, **2054**, or **2056** from examples in FIG. **20**). The third frame (which may correspond to frame **1646** of example **1600**) may be received by AP **2302** in either a multi-AP information exchange phase **2354** or a multi-AP information update phase **2356** (the third frame may be similar to frames **2042**, **2054**, or **2056** from examples in FIG. **20**).

[0208] In an embodiment, optional phases **2344** and **2356** may be absent in example **2300**. In an embodiment, when the first frame is included in phase **2342**, AP **2312** transmits the first frame including the indication of the first multi-AP transmission scheme together with BSS information to AP **2302**. In an example, after the phase **2342**, a multi-AP sounding phase **2346** takes place. Phase **2346** is similar to phase **1546** described above. In an embodiment, when the third frame is included in phase **2354**, AP **2312** transmits the third frame including the indication of the third multi-AP transmission scheme together with an update of BSS information and link quality information related to STA **2316**. In an example, after the phase **2354**, an optional multi-AP sounding phase **2358** takes place. Phase **2358** is similar to phase **1558** described above.

[0209] In another embodiment, optional phases **2344** and **2356** may be present in example **2300**. In an embodiment, when the first frame is included in phase **2344**, AP **2312** transmits the first frame including the indication of the first multi-AP transmission scheme to AP **2302**. In an example, after the phase **2344**, a multi-AP sounding phase **2346** takes place. Phase **2346** is similar to phase **1546** described above. In an embodiment, when the third frame is included in phase **2356**, AP **2312** transmits the third frame including the indication of the third multi-AP transmission scheme to AP **2302**. AP **2312** may transmit to AP **2302** an update of BSS information and link quality information related to STA **2316** in either phase **2354** or **2356**. In an example, after the phase **2356**, an optional multi-AP sounding phase **2358** takes place. Phase **2358** is similar to phase **1558** described above.

[0210] In an example, to announce the second multi-AP transmission scheme for the coordinated AP set in period **2322**, the second frame (which may correspond to frame **1644** of example **1600**) may be transmitted by AP **2302** in multi-AP selection phase **2348** (e.g., the second frame may be similar to frame **1246** in example **1200**). Similar to example **1500**, as AP **2312** is designated in example **2300**, APs **2302** and **2312** may perform a multi-AP data sharing phase **2350** (which may be required for JT) followed by a multi-AP data transmission phase **2352** using JT with associated STAs **2304**, **2306**, **2314**. In an example, the second multi-AP transmission scheme is JT serving STAs **2304**, **2306** and **2314** in multi-AP data transmission phase **2352**. In an example, the second frame may be transmitted by AP **2302** in multi-AP data sharing phase **2350** (e.g., the second frame may be similar to frame **1342** of example **1300**). In another example, the second frame may be transmitted by AP **2302** in multi-AP data transmission phase **2352**, (e.g., the second frame may be similar to frame **1442** of example **1400**).

[0211] In an embodiment, AP **2302** transmits a fourth frame (which may correspond to frame **1648** of example **1600**) to announce the fourth multi-AP transmission scheme for coordinated AP set in period **2324**. In an example, the fourth frame may be transmitted by AP **2302** in phase **2354** (the fourth frame may be similar to frame **2044** of example **2000-2**). In an example, the fourth frame may be transmitted by AP **2302** in phase **2356** (the fourth frame may be similar to frame **2044** of example **2000-2**). In an example, the fourth frame may be transmitted by AP **2302** in multi-AP data transmission phase **2364** (the fourth frame may be similar to frame **1442** in example **1400**). In example **2300**, AP **2302** adopts CSR as the fourth multi-AP transmission scheme,

without changing the slave AP **2312**. Therefore, a multi-AP sounding phase **2358**, a multi-AP selection phase **2360**, and a multi-AP data sharing phase **2362** may be optional. In example **2300**, the fourth multi-AP transmission scheme is CSR serving STAs **2304**, **2306**, **2314** and **2316** in phase **2364**, as indicated by marker **2330**.

[0212] FIG. **24** illustrates an example **2400** of multi-AP operation according to the proposed procedure. Like example **2300** of FIG. **23**, example **2400** may include a first BSS and a second BSS. The first BSS may include an AP **2402** and a plurality of STAs **2404** and **2406**. STAs **2404** and **2406** may be associated with AP **2402**. The second BSS may include an AP **2412** and a plurality of STAs **2414** and **2416**. STAs **2414** and **2416** may be associated with AP **2412**. In an example, AP **2402** and AP **2412** may form a multi-AP group. AP **2402** may be the master AP and AP **2412** may be a slave AP of the multi-AP group. AP **2402** and AP **2412** may exchange frames to set up a multi-AP transmission and form a coordinated AP set. The coordinated AP set corresponds to the set of APs that participate in the multi-AP transmission. The coordinated AP set may be a part of the multi-AP group. In an embodiment, during a multi-AP setup phase, AP **2402** and AP **2412** may exchange frames to exchange capability information. In an example, AP **2402** may transmit to AP **2412** a first indication of support by AP **2402** of two or more multi-AP transmission schemes. In another example, AP **2402** may transmit to AP **2412** a second indication of support by AP **2402** of two or more multi-AP transmission schemes. In an embodiment, AP **2402** may transmit to AP **2412** a third indication of support by AP **2402** of a multi-AP transmission scheme selection capability. In another embodiment, AP **2412** may transmit to AP **2402** a fourth indication of support by AP **2412** of the multi-AP transmission scheme selection capability. It is assumed in example **2400** that both AP **2402** and AP **2412** support the multi-AP transmission scheme selection capability.

[0213] In an embodiment, AP **2402** receives a third frame from AP **2412** in period **2424** within a beacon interval **2426** after receiving a first frame from AP **2412** in period **2422**. The first frame includes an indication of a first multi-AP transmission scheme for use in the coordinated AP set, and the third frame includes an indication of a third multi-AP transmission scheme for the coordinated AP set.

[0214] In an embodiment, during period **2422**, frame exchanges including the receiving of the first frame in a multi-AP info exchange phase **2442** or a multi-AP info update phase **2444** may take place. Phases **2442** and **2444** may be similar to phases **2342** and **2344** respectively described above with reference to example **2300**. In an example, after the phase **2442**, a multi-AP sounding phase **2446** takes place. Phase **2446** is similar to phase **1546** described above. Similar to example **1500**, as AP **2412** is designated in example **2400**, APs **2402** and **2412** may perform a multi-AP data sharing phase **2450** (which may be required for JT) followed by a multi-AP data transmission phase **2452** using JT with associated STAs **2404**, **2406**, **2414**. In an example, AP **2402** may transmit a second frame to announce a second multi-AP transmission scheme for the coordinated AP set in period **2422**. In an example, the second frame may be transmitted by AP **2402** in multi-AP selection phase **2448** (e.g., the second frame may be similar to frame **1246** of example **1200**). In an example, the second frame may be transmitted by AP **2402** in multi-AP data sharing phase **2450** (e.g., the second frame may be similar to frame **1342** of example **1300**). In another example, the second frame may be transmitted by AP **2402** in multi-AP data transmission phase **2452**, (e.g., the second frame may be similar to frame **1442** of example **1400**). Similarly, during period **2424**, exchanges including the receiving of the third frame in a multi-AP info exchange phase **2454** or a multi-AP info update phase **2456** may take place. Phases **2454** and **2456** may be similar to phases **2354** and **2356** respectively described above with reference to example **2300**. In an example, after the phase **2456**, an optional multi-AP sounding phase **2458** takes place. Phase **2458** is similar to phase **1558** described above. In example **2400**, AP **2402** adopts CSR as the fourth multi-AP transmission scheme, without changing the slave AP **2412**. Therefore, a multi-AP sounding phase **2458**, a multi-AP selection phase **2460**, and a multi-AP data sharing phase **2462** may be optional. In example **2400**, the fourth multi-AP transmission scheme is CSR serving STAs **2404**, **2406**, **2414** and **2416** in a multi-AP data transmission phase **2464**, as indicated by marker **2430**.

[0215] FIG. **25** illustrates an example **2500** for multi-AP operation using the proposed procedure. Like example **2400** of FIG. **24**, example **2500** may include a first BSS and a second BSS. The first BSS may include an AP **2502** and a plurality of STAs **2504** and **2506**. STAs **2504** and **2506** may be associated with AP **2502**. The second BSS may include an AP **2512** and a plurality of STAs **2514** and **2516**. STAs **2514** and **2516** may be associated with AP **2512**. In an example, AP **2502** and AP **2512** may form a multi-AP group. AP **2502** may be the master AP and AP **2512** may be a slave AP of the multi-AP group. AP **2502** and AP **2512** may exchange frames to set up a multi-AP transmission and form a coordinated AP set. The coordinated AP set corresponds to the set of APs that participate in the multi-AP transmission. The coordinated AP set may be a part of the multi-AP group. In an embodiment, during a multi-AP setup phase, AP **2502** and AP **2512** may exchange frames to exchange capability information. In an example, AP **2502** may transmit to AP **2512** a first indication of support by AP **2502** of two or more multi-AP transmission schemes. In another example, AP **2502** may transmit to AP **2512** a second indication of support by AP **2502** of two or more multi-AP transmission schemes. In an embodiment, AP **2502** may transmit to AP **2512** a third indication of support by AP **2502** of a multi-AP transmission scheme selection capability. In another embodiment, AP **2512** may transmit to AP **2502** a fourth indication of support by AP **2512** of the multi-AP transmission scheme selection capability. It is assumed in example **2500** that both AP **2502** and AP **2512** support the multi-AP transmission scheme selection capability.

[0216] In an embodiment, AP **2502** receives a third frame from AP **2512** in period **2524** at least a TXOP duration, for example, TXOP **2526**, after receiving a first frame in period **2522**. The first frame includes an indication of a first multi-AP transmission scheme for use in the coordinated AP set, and the third frame includes an indication of a third multi-AP transmission scheme for the coordinated AP set.

[0217] In an example, during period **2522**, after the transmission of a beacon frame, a multi-AP information exchange phase **2542** and a multi-AP sounding phase **2544** take place. Phases **2542** and **2544** are similar to phases **1544** and **1546** described above. In an embodiment, during period **2522**, frame exchanges including the receiving of the first frame in a multi-AP coordination update phase **2546** or a multi-AP selection phase **2548** may take place. Frame

exchanges for phases **2546** and **2548** may be similar to the procedures regarding frames **2142**, **2144**, and **2146** in example **2100** of FIG. **21**. In an example, AP **2512** is designated in example **2500**, APs **2502** and **2512** may perform a multi-AP data sharing phase **2550** (which may be required for JT) followed by a multi-AP data transmission phase **2552** using JT with associated STAs **2504**, **2506**, **2514**. In an example, AP **2502** may transmit a second frame to announce a second multi-AP transmission scheme for the coordinated AP set in period **2522**. In an example, the second frame may be transmitted by AP **2502** in multi-AP selection phase **2548** (e.g., the second frame may be similar to frame **1246** of example **1200**). In an example, the second frame may be transmitted by AP **2502** in multi-AP data sharing phase **2550** (e.g., the second frame may be similar to frame **1342** of example **1300**). In another example, the second frame may be transmitted by AP **2502** in multi-AP data transmission phase **2552** (e.g., the second frame may be similar to frame **1442** of example **1400**). In an example, after the frame exchanges in phase **2552**, a multi-AP information exchange phase **2554** and an optional multi-AP sounding phase **2556** take place. Phases **2554** and **2556** are similar to phases **1544** and **1546** described above. Similarly, during period **2524**, frame exchanges including the receiving of the third frame in a multi-AP coordination update phase **2558** or a multi-AP selection phase **2560** may take place. Frame exchanges for phases **2558** and **2560** may be similar to the procedures regarding frames **2142**, **2144**, and **2146** in example **2100** of FIG. **21**. In example **2500**, during period **2524**, AP **2502** adopts CSR as the fourth multi-AP transmission scheme, without changing the slave AP **2512**. Therefore, a multi-AP data sharing phase **2562** may be optional. In example **2500**, the fourth multi-AP transmission scheme is CSR serving STAs **2504**, **2406**, **2514** and **2516** in a multi-AP data transmission phase **2564**, as indicated by marker **2530**.

[0218] In an example, when the optional phase **2560** is present in example **2500**, the optional phases **2546** and **2558** may be absent. In an embodiment, when the AP **2512** transmits the first frame in phase **2548**, the first frame may be similar to frame **2144** of example **2100**. The first frame may include the indication of the first multi-AP transmission scheme together with an indication of the intention of AP **2512** to participate in a multi-AP transmission. In an embodiment, when AP **2512** transmits the third frame in phase **2560**, the third frame may be similar to frame **2144** of example **2100**. The third frame may include the indication of the third multi-AP transmission scheme together with an indication of the intention of AP **2512** to participate in a multi-AP transmission. The second frame announcing the second multi-AP transmission scheme may be similar to frame **2146** of example **2100** transmitted by AP **2502** in phases **2548**, while the fourth frame announcing the fourth multi-AP transmission scheme may be similar to frame **2146** of example **2100** transmitted by AP **2502** in phases **2560**.

[0219] In an example, when the optional phase **2560** is present in example **2500**, the optional phases **2546** and **2558** may be also present. In an embodiment, when the AP **2512** transmits the first frame in phase **2546**, the first frame may be similar to frame **2144** of example **2100**. The first frame may include the indication of the first multi-AP transmission scheme. In an embodiment, when AP **2512** transmits the third frame in phase **2558**, the third frame may be similar to frame **2144** of example **2100**. The third frame may include the indication of the third multi-AP transmission scheme. AP **2512** may transmit to AP **2502** an update of BSS information and link quality information related to STA **2316** in multi-AP info exchange phase **2554**. The second frame announcing the second multi-AP transmission scheme may be similar to frame **2146** of example **2100** transmitted by AP **2502** in phase **2548**, while the fourth frame announcing the fourth multi-AP transmission scheme may be similar to frame **2146** of example **2100** transmitted by AP **2502** in phase **2560**.

[0220] In an example, when the optional phase **2560** is absent in example **2500**, the optional phase **2558** is present. In an embodiment, when the AP **2512** transmits the third frame in phase **2558**, the third frame may be similar to frame **2144** of example **2100**. The third frame may include the indication of the third multi-AP transmission scheme. The second frame announcing the second multi-AP transmission scheme may be similar to frame **2146** of example **2100** transmitted by AP **2502** in phase **2548**, while the fourth frame announcing the fourth multi-AP transmission scheme may be similar to frame **2146** of example **2100** transmitted by AP **2502** in phase **2558**.

[0221] FIG. **26** illustrates an example **2600** for multi-AP operation using the proposed procedure. Like example **2500** of FIG. **25**, example **2400** may include a first BSS and a second BSS. The first BSS may include an AP **2602** and a plurality of STAs **2604** and **2606**. STAs **2604** and **2606** may be associated with AP **2602**. The second BSS may include an AP **2612** and a plurality of STAs **2614** and **2616**. STAs **2614** and **2616** may be associated with AP **2612**. In an example, AP **2602** and AP **2612** may form a multi-AP group. AP **2602** may be the master AP and AP **2612** may be a slave AP of the multi-AP group. AP **2602** and AP **2612** may exchange frames to set up a multi-AP transmission and form a coordinated AP set. The coordinated AP set corresponds to the set of APs that participate in the multi-AP transmission. The coordinated AP set may be a part of the multi-AP group. In an embodiment, during a multi-AP setup phase, AP **2602** and AP **2612** may exchange frames to exchange capability information. In an example, AP **2602** may transmit to AP **2612** a first indication of support by AP **2602** of two or more multi-AP transmission schemes. In another example, AP **2602** may transmit to AP **2612** a second indication of support by AP **2602** of two or more multi-AP transmission schemes. In an embodiment, AP **2602** may transmit to AP **2612** a third indication of support by AP **2602** of a multi-AP transmission scheme selection capability. In another embodiment, AP **2612** may transmit to AP **2602** a fourth indication of support by AP **2612** of the multi-AP transmission scheme selection capability. It is assumed in example **2600** that both AP **2602** and AP **2612** support the multi-AP transmission scheme selection capability.

[0222] In an embodiment, AP **2602** receives a third frame in period **2624** within less than a TXOP duration, for example, 2526, after receiving a first frame in period **2622**. The first frame includes the indication of the first multi-AP transmission scheme for use in the coordinated AP set, and the third frame includes the indication of the third multi-AP transmission scheme for the coordinated AP set.

[0223] In an example, during period **2622**, after the transmission of a beacon frame, a multi-AP information exchange phase **2642** and a multi-AP sounding phase **2644** take place. Phases **2642** and **2644** are similar to phases **1544** and **1546** described above. In an embodiment, during period **2622**, frame exchanges including the receiving of the first

frame in multi-AP coordination update phase **2646** or multi-AP selection phase **2648** may take place. Frame exchanges for phase **2646** and **2648** may be similar to the procedures regarding frames **2142**, **2144**, and **2146** in example **2100** of FIG. **21**. In an example, AP **2612** is designated in example **2600**, APs **2602** and **2612** may perform a multi-AP data sharing phase **2650** (which may be required for JT) followed by a multi-AP data transmission phase **2652** using JT with associated STAs **2604**, **2606**, **2614**. In an example, AP **2602** may transmit a second frame to announce a second multi-AP transmission scheme for the coordinated AP set in period **2622**. In an example, the second frame may be transmitted by AP **2602** in multi-AP selection phase **2648**, (e.g., the second frame may be similar to frame **1246** of example **1200**). In an example, the second frame may be transmitted by AP **2602** in multi-AP data sharing phase **2650**, (e.g., the second frame may be similar to frame **1342** of example **1300**). In another example, the second frame may be transmitted by AP **2602** in multi-AP data transmission phase **2652**, (e.g., the second frame may be similar to frame **1442** of example **1400**). In an example, after the frame exchanges in phase **2652**, a multi-AP information exchange phase **2654** and an optional multi-AP sounding phase **2656** take place. Phases **2654** and **2656** are similar to phases **1544** and **1546** described above. Similarly, during period **2624**, frame exchanges including the receiving of the third frame in multi-AP coordination update phase **2658** or multi-AP selection phase **2660** may take place. Frame exchanges for phase **2658** and **2660** may be similar to the procedures regarding frames **2142**, **2144**, and **2146** in example **2100** of FIG. **21**. In an embodiment, frame exchanges in phases **2646**, **2648**, **2658** and **2660** of example **2600** may be similar to the frame exchanges in phases **2546**, **2548**, **2558** and **2560** of example **2500** described above. In example **2600**, during period **2624**, AP **2602** adopts CSR as the fourth multi-AP transmission scheme, without changing the slave AP **2612**. Therefore, a multi-AP data sharing phase **2662** may be optional. In example **2600**, the fourth multi-AP transmission scheme is CSR serving STAs **2604**, **2406**, **2614** and **2616** in a multi-AP data transmission phase **2664**, as indicated by marker **2630**.

[0224] As would be understood by a person of skill in the art based on the teachings herein, the embodiments as described above in examples **2200**, **2300**, **2400**, **2500**, and **2600** may be readily extended to cases including more than two APs (e.g., three APs as illustrated in example **1700** of FIG. **17**). As in the case involving two APs, the third frame may be received by the master AP at various durations after receiving the first frame, e.g., at least a beacon interval, less than a beacon interval, at least a TXOP, or less than a TXOP, after receiving the first frame.

[0225] FIG. **27** illustrates an example process **2700** according to an embodiment. Example process **2700** is provided for the purpose of illustration only and is not limiting of embodiments. Process **2700** may be performed by a first AP. The first AP may be a master AP of a coordinated AP set.

[0226] As shown in FIG. **27**, process **2700** begins in step **2702**, which includes receiving, by a first AP from a second AP, a first frame comprising an indication of a first multi-AP transmission scheme for use in a coordinated AP set comprising the first AP and the second AP.

[0227] In an embodiment, the first multi-AP transmission scheme corresponds to a preferred multi-AP transmission scheme for the second AP for use in the coordinated AP set. In an embodiment, the first AP and the second AP belong to different BSSs.

[0228] In an embodiment, the first frame comprises a management frame. In an embodiment, the management frame comprises a beacon frame. In an embodiment, the management frame comprises an action frame. In an embodiment, the management frame comprises an operations element comprising the indication of the first multi-AP transmission scheme. In an embodiment, the action frame comprises BSS information comprising the indication of the first multi-AP transmission scheme. In an embodiment, the action frame is communicated in a multi-AP information exchange phase. In an embodiment, the action frame comprises a multi-AP information update request frame or a multi-AP information update response frame. In an embodiment, the multi-AP information update request frame or the multi-AP information update response frame comprises a preferred scheme field comprising the indication of the first multi-AP transmission scheme. In an embodiment, the multi-AP information update request frame or the multi-AP information update response frame is communicated in a multi-AP information update phase.

[0229] In an embodiment, the first frame comprises a data frame. In an embodiment, the data frame comprises a feedback frame to a multi-AP trigger frame. In an embodiment, the multi-AP trigger frame comprises a multi-AP selection trigger frame, and wherein the multi-AP trigger frame is communicated in a multi-AP selection phase. In an embodiment, the multi-AP trigger frame is communicated in a multi-AP coordination update phase. In an embodiment, the multi-AP trigger frame is communicated in a multi-AP data transmission phase. In an embodiment, the feedback frame comprises a QoS control field comprising the indication of the first multi-AP transmission scheme. In an embodiment, the feedback frame comprises an HT control field comprising the indication of the first multi-AP transmission scheme. In an embodiment, the feedback frame is communicated in a multi-AP selection phase. In an embodiment, the feedback frame is communicated in a multi-AP coordination update phase.

[0230] In an embodiment, before step **2702**, process **2700** may further include transmitting, by the first AP, a fifth frame comprising an indication of a fifth multi-AP transmission scheme for the coordinated set comprising the first AP and the second AP. In an embodiment, the fifth frame is transmitted before the receiving of the first frame. In an embodiment, the fifth multi-AP transmission scheme corresponds to a preferred multi-AP transmission scheme for the first AP for use in the coordinated AP set. In an embodiment, the fifth frame further comprises a request for the second AP to use the fifth multi-AP transmission scheme for the coordinated set. In an embodiment, the first frame further comprises a rejection in response to the fifth frame.

[0231] As shown in FIG. **27**, in step **2704**, process **2700** includes transmitting, by the first AP, a second frame announcing a second multi-AP transmission scheme determined based on the first multi-AP transmission scheme indicated in the first frame.

[0232] In an embodiment, the second frame comprises a control frame. In an embodiment, the second frame is communicated in a multi-AP selection phase, a multi-AP coordination update phase, a multi-AP data sharing phase, or a multi-AP data transmission phase.

[0233] In an embodiment, the second multi-AP transmission scheme is the same as or different than the first multi-AP transmission scheme.

[0234] In an embodiment, after step **2704**, process **2700** may further include receiving, by the first AP from the second AP, a third frame comprising an indication of a third multi-AP transmission scheme for the coordinated AP set. In an embodiment, the third frame is received at least a beacon interval after the receiving of the first frame. In an embodiment, the first frame and the third frame comprise a beacon frame, an action frame, etc. In an embodiment, the third frame is received less than a beacon interval after the receiving of the first frame. In an embodiment, the first frame and the third frame comprise an action frame, a multi-AP information update request frame, or a multi-AP information update response frame. In an embodiment, the third frame is received at least a TXOP duration after the receiving of the first frame. In an embodiment, the third frame is received less than a TXOP duration after the receiving of the first frame. In an embodiment, the first frame and the third frame comprise a feedback frame to a multi-AP trigger frame. In an embodiment, the third multi-AP transmission scheme is an update of the first multi-AP transmission scheme for the second AP. In an embodiment, the third multi-AP transmission scheme is different from the first multi-AP transmission scheme or the second multi-AP transmission scheme.

[0235] In an embodiment, after step **2704**, process **2700** may further include transmitting, by the first AP, a fourth frame announcing a fourth multi-AP transmission scheme determined based on the second multi-AP transmission scheme and the third multi-AP transmission scheme.

[0236] In an embodiment, after step **2704**, process **2700** may further include receiving, by the first AP from a third AP, a third frame comprising an indication of a third multi-AP transmission scheme for the coordinated AP set comprising the first AP, the second AP, and the third AP. In an embodiment, the third multi-AP transmission scheme corresponds to a preferred multi-AP transmission scheme for the third AP for the coordinated AP set. In an embodiment, the third frame is received before the transmitting of the second frame. In an embodiment, the third frame is received less than a TXOP duration after the receiving of the first frame. In an embodiment, the first frame and the third frame comprise: a beacon frame, an action frame, a data frame, a multi-AP information update request frame, or a multi-AP information update response frame, a feedback frame to a multi-AP trigger frame, etc.

[0237] In an embodiment, after step **2704**, process **2700** may further include determining, by the first AP, a fourth multi-AP transmission scheme for the coordinated AP set based on the first multi-AP transmission scheme and the third multi-AP transmission scheme. In an embodiment, process **2700** may further include transmitting, by the first AP, a fourth frame announcing the fourth multi-AP transmission scheme. In an embodiment, the fourth frame is the second frame. In an embodiment, the fourth multi-AP transmission scheme is the same as the first multi-AP transmission scheme or the third multi-AP transmission scheme or different than the first multi-AP transmission scheme and the third multi-AP transmission scheme.

[0238] In an embodiment, after step **2704**, process **2700** may further include receiving, by the first AP from a third AP, a third frame comprising an indication of a third multi-AP transmission scheme for the coordinated AP set comprising the first AP, the second AP, and the third AP. In an embodiment, the third frame is received after the transmitting of the second frame. In an embodiment, the third frame is received less than a beacon interval after the receiving of the first frame. In an embodiment, the third frame is received at least a TXOP duration after the receiving of the first frame. In an embodiment, the third frame is received less than a TXOP duration after the receiving of the first frame. In an embodiment, the first frame and the third frame comprise: a beacon frame, an action frame, a data frame, a multi-AP information update request frame, or a multi-AP information update response frame, a feedback frame to a multi-AP trigger frame, etc.

[0239] In an embodiment, after step **2704**, process **2700** may further include determining, by the first AP, a fourth multi-AP transmission scheme for the coordinated AP set based on the second multi-AP transmission scheme and the third multi-AP transmission scheme. In an embodiment, process **2700** may further include transmitting, by the first AP, a fourth frame announcing the fourth multi-AP transmission scheme. In an embodiment, the fourth multi-AP transmission scheme is the same as the second multi-AP transmission scheme or the third multi-AP transmission scheme or different from the second multi-AP transmission scheme and the third multi-AP transmission scheme.

[0240] In an embodiment, the receiving of the first frame occurs during a setup phase of the coordinated AP set. In an embodiment, the receiving of the first frame occurs after a setup phase of the coordinated AP set.

[0241] In an embodiment, the indication of the first multi-AP transmission scheme indicates no preference for a multi-AP transmission scheme. In an embodiment, the indication of the preferred multi-AP transmission scheme indicates coordinated spatial reuse (CSR), coordinated transmission opportunity (C-TXOP), coordinated time-division multiple-access (C-TDMA), coordinated frequency-division multiple-access (C-FDMA), coordinated beamforming (CBF), joint transmission (JT), or joint reception (JR), etc.

[0242] FIG. **28** illustrates an example process **2800** according to an embodiment. Example process **2800** is provided for the purpose of illustration only and is not limiting of embodiments. Process **2800** may be performed by a first AP. The first AP may be a slave AP of a coordinated AP set.

[0243] As shown in FIG. **28**, process **2800** begins in step **2802**, which includes transmitting, by a first AP from a second AP, a first frame comprising an indication of a first multi-AP transmission scheme for use in a coordinated AP set comprising the first AP and the second AP.

[0244] In an embodiment, the first multi-AP transmission scheme corresponds to a preferred multi-AP transmission scheme for the first AP for use in the coordinated AP set. In an embodiment, the first AP and the second AP belong to different BSSs.

[0245] In an embodiment, the first frame comprises a management frame. In an embodiment, the management frame comprises a beacon frame. In an embodiment, the management frame comprises an action frame. In an embodiment, the management frame comprises an operations element comprising the indication of the first multi-AP transmission scheme. In an embodiment, the action frame comprises BSS information comprising the indication of the first multi-AP transmission scheme. In an embodiment, the

action frame is communicated in a multi-AP information exchange phase. In an embodiment, the action frame comprises a multi-AP information update request frame or a multi-AP information update response frame. In an embodiment, the multi-AP information update request frame or the multi-AP information update response frame comprises a preferred scheme field comprising the indication of the first multi-AP transmission scheme. In an embodiment, the multi-AP information update request frame or the multi-AP information update response frame is communicated in a multi-AP information update phase.

[0246] In an embodiment, the first frame comprises a data frame. In an embodiment, the data frame comprises a feedback frame to a multi-AP trigger frame. In an embodiment, the multi-AP trigger frame comprises a multi-AP selection trigger frame, and wherein the multi-AP trigger frame is communicated in a multi-AP selection phase. In an embodiment, the multi-AP trigger frame is communicated in a multi-AP coordination update phase. In an embodiment, the multi-AP trigger frame is communicated in a multi-AP data transmission phase. In an embodiment, the feedback frame comprises a QoS control field comprising the indication of the first multi-AP transmission scheme. In an embodiment, the feedback frame comprises an HT control field comprising the indication of the first multi-AP transmission scheme. In an embodiment, the feedback frame is communicated in a multi-AP selection phase. In an embodiment, the feedback frame is communicated in a multi-AP coordination update phase.

[0247] In an embodiment, before step **2802**, process **2800** may further include receiving, by the first AP from the second AP, a fifth frame comprising an indication of a fifth multi-AP transmission scheme for the coordinated set comprising the first AP and the second AP. In an embodiment, the fifth frame is received before the transmitting of the first frame. In an embodiment, the fifth multi-AP transmission scheme corresponds to a preferred multi-AP transmission scheme for the second AP for use in the coordinated AP set. In an embodiment, the fifth frame further comprises a request for the first AP to use the fifth multi-AP transmission scheme for the coordinated set. In an embodiment, the first frame further comprises a rejection in response to the fifth frame.

[0248] As shown in FIG. **28**, in step **2804**, process **2800** includes receiving, by the first AP from the second AP, a second frame announcing a second multi-AP transmission scheme determined based on the first multi-AP transmission scheme indicated in the first frame.

[0249] In an embodiment, the second frame comprises a control frame. In an embodiment, the second frame is communicated in a multi-AP selection phase, a multi-AP coordination update phase, a multi-AP data sharing phase, or a multi-AP data transmission phase.

[0250] In an embodiment, the second multi-AP transmission scheme is the same as or different than the first multi-AP transmission scheme.

[0251] In an embodiment, after step **2804**, process **2800** may further include transmitting, by the first AP to the second AP, a third frame comprising an indication of a third multi-AP transmission scheme for the coordinated AP set. In an embodiment, the third frame is transmitted at least a beacon interval after the transmitting of the first frame. In an embodiment, the first frame and the third frame comprise a beacon frame, an action frame, etc. In an embodiment, the third frame is transmitted less than a beacon interval after the transmitting of the first frame. In an embodiment, the first frame and the third frame comprise an action frame, a multi-AP information update request frame, or a multi-AP information update response frame. In an embodiment, the third frame is transmitted at least a TXOP duration after the transmitting of the first frame. In an embodiment, the third frame is transmitted less than a TXOP duration after the transmitting of the first frame. In an embodiment, the first frame and the third frame comprise a feedback frame to a multi-AP triggerframe. In an embodiment, the third multi-AP transmission scheme is an update of the first multi-AP transmission scheme for the first AP. In an embodiment, the third multi-AP transmission scheme is different from the first multi-AP transmission scheme or the second multi-AP transmission scheme.

[0252] In an embodiment, after step **2804**, process **2800** may further include receiving, by the first AP from the second AP, a fourth frame announcing a fourth multi-AP transmission scheme determined based on the second multi-AP transmission scheme and the third multi-AP transmission scheme.

[0253] In an embodiment, after step **2804**, process **2800** may further include transmitting, by the first AP to a third AP, a third frame comprising an indication of a third multi-AP transmission scheme for the coordinated AP set comprising the first AP, the second AP, and the third AP. In an embodiment, the third multi-AP transmission scheme corresponds to a preferred multi-AP transmission scheme for the third AP for the coordinated AP set. In an embodiment, the third frame is transmitted before the receiving of the second frame. In an embodiment, the third frame is transmitting less than a TXOP duration after the transmitting of the first frame. In an embodiment, the first frame and the third frame comprise: a beacon frame, an action frame, a data frame, a multi-AP information update request frame, or a multi-AP information update response frame, a feedback frame to a multi-AP trigger frame, etc.

[0254] In an embodiment, after step **2804**, process **2800** may further include receiving, by the first AP, a fourth frame announcing the fourth multi-AP transmission scheme for the coordinated AP set determined based on the first multi-AP transmission scheme and the third multi-AP transmission scheme. In an embodiment, the fourth frame is the second frame. In an embodiment, the fourth multi-AP transmission scheme is the same as the first multi-AP transmission scheme or the third multi-AP transmission scheme or different than the first multi-AP transmission scheme and the third multi-AP transmission scheme.

[0255] In an embodiment, after step **2804**, process **2800** may further include transmitting, by the first AP from a third AP, a third frame comprising an indication of a third multi-AP transmission scheme for the coordinated AP set comprising the first AP, the second AP, and the third AP. In an embodiment, the third frame is transmitted after the receiving of the second frame. In an embodiment, the third frame is transmitted less than a beacon interval after the transmitting of the first frame. In an embodiment, the third frame is transmitted at least a TXOP duration after the transmitting of the first frame. In an embodiment, the third frame is transmitted less than a TXOP duration after the transmitting of the first frame. In an embodiment, the first frame and the third frame comprise: a beacon frame, an action frame, a data frame, a multi-AP information update

request frame, or a multi-AP information update response frame, a feedback frame to a multi-AP trigger frame, etc.

[0256] In an embodiment, after step **2804**, process **2800** may further include receiving, by the first AP, a fourth frame announcing the fourth multi-AP transmission scheme for the coordinated AP set determined based on the second multi-AP transmission scheme and the third multi-AP transmission scheme. In an embodiment, the fourth multi-AP transmission scheme is the same as the second multi-AP transmission scheme or the third multi-AP transmission scheme or different from the second multi-AP transmission scheme and the third multi-AP transmission scheme.

[0257] In an embodiment, the transmitting of the first frame occurs during a setup phase of the coordinated AP set. In an embodiment, the transmitting of the first frame occurs after a setup phase of the coordinated AP set.

[0258] In an embodiment, the indication of the first multi-AP transmission scheme indicates no preference for a multi-AP transmission scheme. In an embodiment, the indication of the preferred multi-AP transmission scheme indicates coordinated spatial reuse (CSR), coordinated transmission opportunity (C-TXOP), coordinated time-division multiple-access (C-TDMA), coordinated frequency-division multiple-access (C-FDMA), coordinated beamforming (CBF), joint transmission (JT), or joint reception (JR), etc.

What is claimed is:

1. A first access point (AP) comprising:
one or more processors; and
memory storing instructions that, when executed by the one or more processors, cause the first AP to:
receive, from a second AP, a first frame comprising an indication of a first multi-AP transmission scheme for use in a coordinated AP set comprising the first AP and the second AP; and
transmit a second frame announcing a second multi-AP transmission scheme determined based on the first multi-AP transmission scheme indicated in the first frame.

2. The first AP of claim **1**, wherein the first multi-AP transmission scheme corresponds to a preferred multi-AP transmission scheme for the second AP for use in the coordinated AP set.

3. The first AP of claim **1**, wherein the second multi-AP transmission scheme is the same as the first multi-AP transmission scheme.

4. The first AP of claim **1**, wherein the second multi-AP transmission scheme is different from the first multi-AP transmission scheme.

5. The first AP of claim **1**, wherein the instructions, when executed by the one or more processors, further cause the first AP to:
receive, from the second AP, a third frame comprising an indication of a third multi-AP transmission scheme for the coordinated AP set; and
transmit a fourth frame announcing a fourth multi-AP transmission scheme determined based on the second multi-AP transmission scheme and the third multi-AP transmission scheme.

6. The first AP of claim **5**, wherein the third multi-AP transmission scheme is an update of the first multi-AP transmission scheme for the second AP.

7. The first AP of claim **1**, wherein the instructions, when executed by the one or more processors, further cause the first AP to:
receive, from a third AP, a third frame comprising:
an indication of a third multi-AP transmission scheme for the coordinated AP set comprising the first AP, the second AP, and the third AP;
determine a fourth multi-AP transmission scheme for the coordinated AP set based on the first multi-AP transmission scheme and the third multi-AP transmission scheme; and
transmit a fourth frame announcing the fourth multi-AP transmission scheme.

8. The first AP of claim **7**, wherein the fourth frame is the second frame.

9. The first AP of claim **7**, wherein the third frame is received after the transmitting of the second frame.

10. The first AP of claim **7**, wherein the third frame is received less than a beacon interval after the receiving of the first frame.

11. A first access point (AP) comprising:
one or more processors; and
memory storing instructions that, when executed by the one or more processors, cause the first AP to:
transmit, to a second AP, a first frame comprising:
an indication of a first multi-AP transmission scheme for use in a coordinated AP set comprising the first AP and the second AP; and
receive, from the second AP, a second frame announcing a second multi-AP transmission scheme for the coordinated AP set determined based on the first multi-AP transmission scheme indicated in the first frame.

12. The first AP of claim **11**, wherein the instructions, when executed by the one or more processors, further cause the first AP to:
transmit, to the second AP, a third frame comprising:
an indication of a third multi-AP transmission scheme for the coordinated AP set; and
receive, from the second AP, a fourth frame announcing a fourth multi-AP transmission scheme for the coordinated AP set determined based on the second multi-AP transmission scheme and the third multi-AP transmission scheme.

13. The first AP of claim **12**, wherein the third frame is transmitted at least a beacon interval after the transmitting of the first frame.

14. The first AP of claim **12**, wherein the first frame and the third frame comprise a beacon frame or an action frame.

15. The first AP of claim **12**, wherein the third frame is transmitted less than a beacon interval after the transmitting of the first frame.

16. A non-transitory computer-readable medium comprising instructions that, when executed by one or more processors of a first access point (AP), cause the first AP to:
receive, from a second AP, a first frame comprising an indication of a first multi-AP transmission scheme for use in a coordinated AP set comprising the first AP and the second AP; and
transmit a second frame announcing a second multi-AP transmission scheme determined based on the first multi-AP transmission scheme indicated in the first frame.

17. The non-transitory computer-readable medium of claim **16**, wherein the first multi-AP transmission scheme corresponds to a preferred multi-AP transmission scheme for the second AP for use in the coordinated AP set.

18. The non-transitory computer-readable medium of claim **16**, wherein the instructions further cause the first AP to:

receive, from a third AP, a third frame comprising:

an indication of a third multi-AP transmission scheme for the coordinated AP set comprising the first AP, the second AP, and the third AP;

determine a fourth multi-AP transmission scheme for the coordinated AP set based on the first multi-AP transmission scheme and the third multi-AP transmission scheme; and

transmit a fourth frame announcing the fourth multi-AP transmission scheme.

19. The non-transitory computer-readable medium of claim **18**, wherein the fourth frame is the second frame.

20. The non-transitory computer-readable medium of claim **18**, wherein the third frame is received after the transmitting of the second frame.

* * * * *