US009369918B2

(12) **United States Patent**
**Grandhi et al.**

(10) **Patent No.: US 9,369,918 B2**
(45) **Date of Patent: Jun. 14, 2016**

(54) **METHOD AND APPARATUS FOR SUPPORTING WIDEBAND AND MULTIPLE BANDWIDTH TRANSMISSION PROTOCOLS**

(75) Inventors: **Sudheer A. Grandhi**, Pleasanton, CA (US); **Bhaskar M. Anepu**, Hummelstown, PA (US); **Xiaofei Wang**, Cedar Grove, NJ (US)

(73) Assignee: **INTERDIGITAL PATENT HOLDINGS, INC.**, Wilmington, DE (US)

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

(21) Appl. No.: **13/529,651**

(22) Filed: **Jun. 21, 2012**

(65) **Prior Publication Data**

US 2012/0327870 A1 Dec. 27, 2012

**Related U.S. Application Data**

(60) Provisional application No. 61/500,788, filed on Jun. 24, 2011, provisional application No. 61/508,524, filed on Jul. 15, 2011, provisional application No. 61/607,352, filed on Mar. 6, 2012, provisional application No. 61/642,048, filed on May 3, 2012.

(51) **Int. Cl.**
***H04W 74/08*** (2009.01)
***H04W 28/06*** (2009.01)
(Continued)

(52) **U.S. Cl.**
CPC ..... ***H04W 28/06*** (2013.01); ***H04W 74/06*** (2013.01); ***H04W 74/0808*** (2013.01); *H04W 74/004* (2013.01); *H04W 74/006* (2013.01); *H04W 74/04* (2013.01); *H04W 88/08* (2013.01)

(58) **Field of Classification Search**
CPC ... H04W 28/06; H04W 74/004; H04W 88/08; H04W 74/04; H04W 74/006; H04W 84/12; H04W 74/0816; H04W 28/04; H04W 28/044; H04W 74/06; H04W 74/0808
USPC ..... 370/252, 312, 328, 329, 331, 447, 468, 370/445, 449–457, 462, 437
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

7,885,287 B2 * 2/2011 Bachrach et al. ..... 370/447
2002/0181425 A1 * 12/2002 Sherman ..... 370/338

(Continued)

FOREIGN PATENT DOCUMENTS

WO 2007/078073 7/2007

OTHER PUBLICATIONS

"Channelization and Bandwidth Modes for 802.11 ah"; doc.: IEEE 802.11-11/1238r0, Sep. 18, 2011, 6 Pages.*

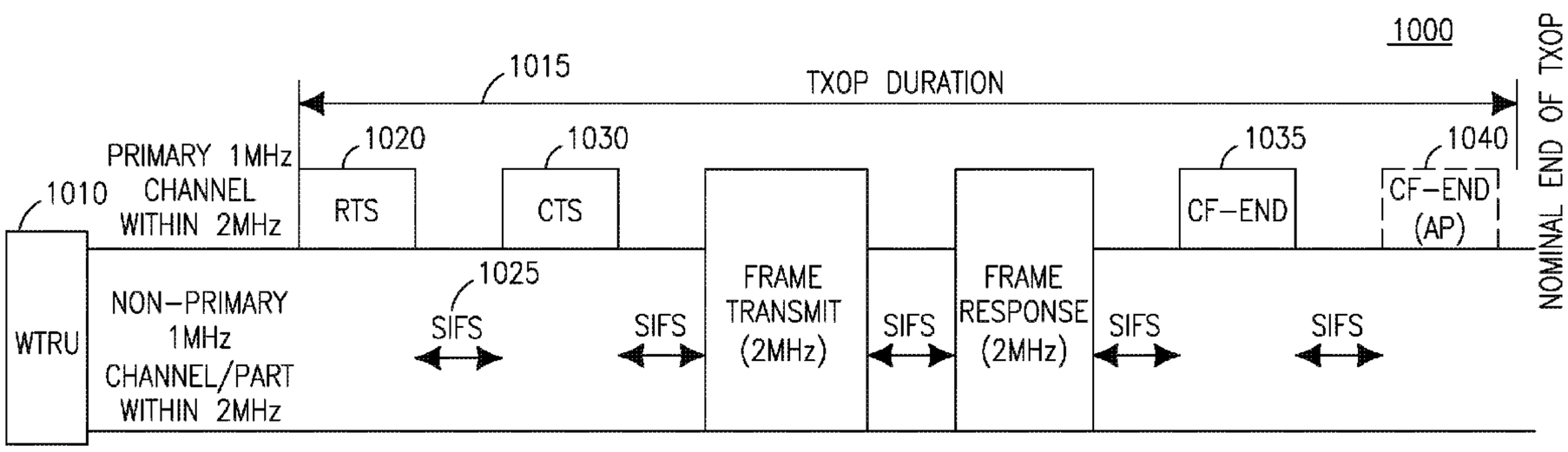
(Continued)

*Primary Examiner* — Edan Orgad
*Assistant Examiner* — Ivan O Latorre
(74) *Attorney, Agent, or Firm* — Volpe and Koenig, P.C.

(57) **ABSTRACT**

Enhanced protocols and devices may be used to alleviate loss of spectrum efficiency in wideband transmission. The protocols may implement a wideband transmission opportunity (TXOP) truncation where one or more of the channels involved in communication over the wideband are released. In one scenario, a wireless transmit/receive unit (WTRU) may obtain a TXOP for a 2 MHz bandwidth mode frame transmission with another device capable of operating in a 2 MHz bandwidth mode and a 1 MHz bandwidth mode. The WTRU may conduct a request-to-send (RTS)/clear-to-send (CTS) frame exchange in the second bandwidth mode, and truncate the TXOP by transmitting a contention free (CF)-End frame in the first and second bandwidth modes. In another scenario, an AP may obtain a TXOP for a 2 MHz bandwidth mode frame transmission with a WTRU capable of both 2 MHz and 1 MHz bandwidth modes.

**12 Claims, 14 Drawing Sheets**



(51) **Int. Cl.**

| | |
|---|---|
| ***H04W 74/06*** | (2009.01) |
| *H04W 74/00* | (2009.01) |
| *H04W 74/04* | (2009.01) |
| *H04W 88/08* | (2009.01) |

(56) **References Cited**

U.S. PATENT DOCUMENTS

| | | | | |
|---|---|---|---|---|
| 2003/0123405 | A1* | 7/2003 | Del Prado et al. | 370/331 |
| 2007/0115882 | A1* | 5/2007 | Wentink | 370/329 |
| 2007/0171858 | A1* | 7/2007 | Grandhi et al. | 370/328 |
| 2007/0217352 | A1* | 9/2007 | Kwon | 370/312 |
| 2007/0248117 | A1* | 10/2007 | Zuniga et al. | 370/468 |
| 2008/0112351 | A1* | 5/2008 | Surineni et al. | 370/312 |
| 2010/0135268 | A1* | 6/2010 | Seok | 370/338 |
| 2011/0305288 | A1* | 12/2011 | Liu et al. | 375/260 |
| 2012/0106426 | A1* | 5/2012 | Hart et al. | 370/312 |
| 2012/0134324 | A1* | 5/2012 | Chu et al. | 370/329 |
| 2012/0207036 | A1* | 8/2012 | Ong et al. | 370/252 |
| 2012/0250617 | A1* | 10/2012 | Wentink | 370/328 |

OTHER PUBLICATIONS

"IEEE P802.11 Wireless LANs Proposed TGAC Draft Amendment", doc.: IEEE802.11-10/1361r3 Jan. 2011, 92 Pages.*

"Multi-Channel Transmsisions", doc.: IEEE802.11-09/1022r0 Oct. 2009, 13 Pages.*

"80MHz/160Mhz Protection", doc.: IEEE802.11-10/1096r4 Sep. 2010, 13 Pages.*

"Channel Selection and Mangaement for 11 ac", doc.: IEEE802.11-10/0593r1, May 2010, 21 Pages.*

Gast, Matthew , "802.11 Wireless Networks: The Definitive Guide, 2nd Edition", Apr. 25, 2005, O'Reilly Media, Inc., 2nd Edition, p. 218-223.*

IEEE Standards Association, "Use of the IEEE assigned Organizationally Unique Identifier with ANSI/IEEE Std 802-2001 Local and Metropolitan Area Networks", Nov. 2, 2001, ANSI/IEEE STD 802-2001 Local and Metropoication Area Networks Tutorial Rev.Nov. 2002, 3 Pages.*

Cheong, "TGah Functional Requirements and Evaluation Methodology Rev. 5," IEEE 802.11-11/0905r5, Jan. 19, 2012.

Institute of Electrical and Electronics Engineers, "Draft Standard for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks—Specific Requirements—Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications—Amendment 5: Enhancements for Very High Throughput for Operation in Bands Below 6 GHz," IEEE P802.11ac/D1.0, May 2011.

Institute of Electrical and Electronics Engineers, "IEEE Standard for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks—Specific Requirements—Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications," IEEE Std 802.11-2007, Jun. 2007.

Institute of Electrical and Electronics Engineers, "IEEE Standard for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks—Specific Requirememnts—Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications," IEEE Std 802.11-2012, Mar. 2012.

Institute of Electrical and Electronics Engineers, "IEEE Standard for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks—Specific Requirememnts—Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications—Amendment 5: Enhancements for Higher Throughput," IEEE Std 802.11n-2009, Sep. 2009.

* cited by examiner

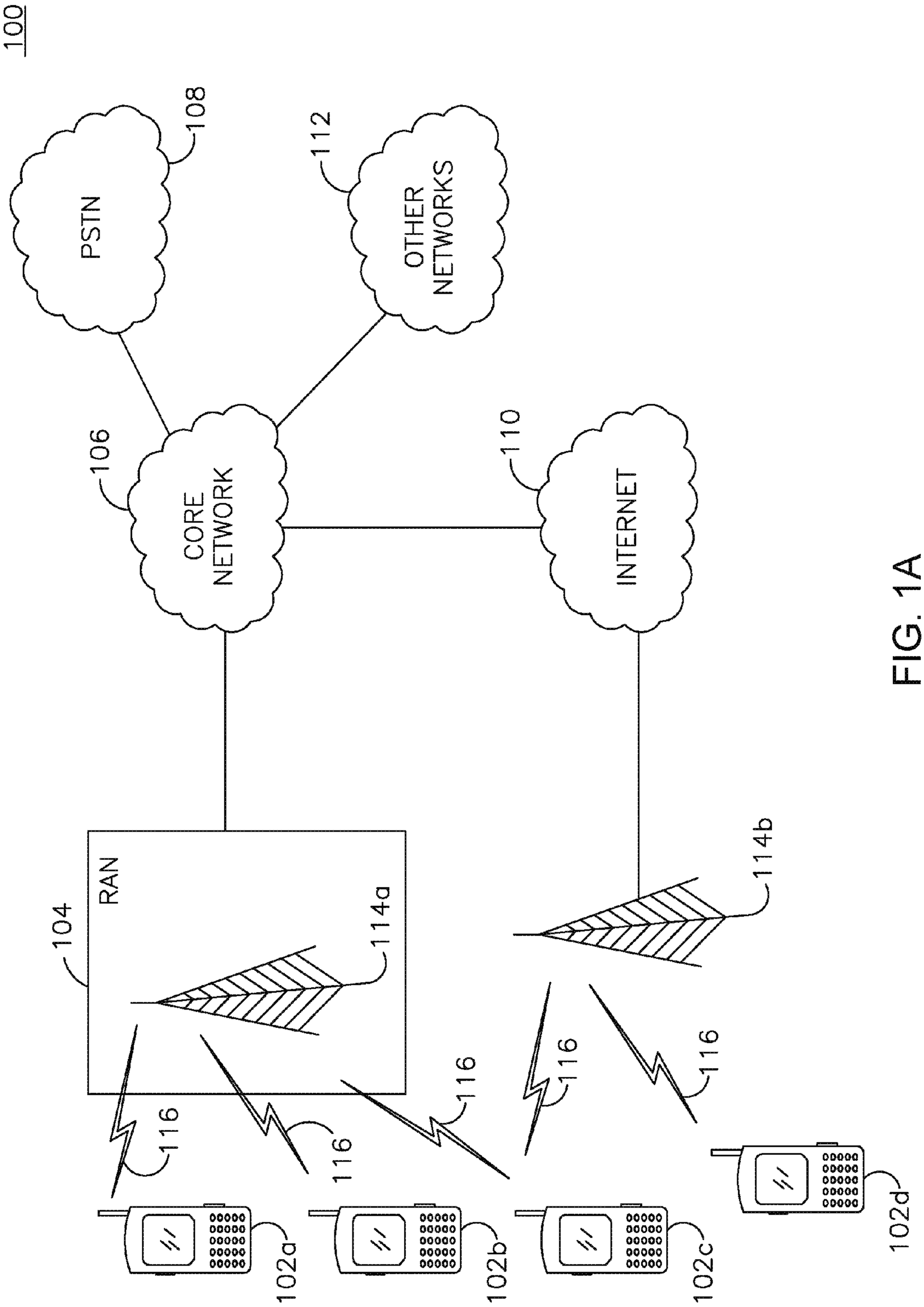

100
PSTN
108
OTHER NETWORKS
112
CORE NETWORK
106
INTERNET
110
RAN
104
114a
114b
116
116
116
116
102a
102b
102c
102d

FIG. 1A

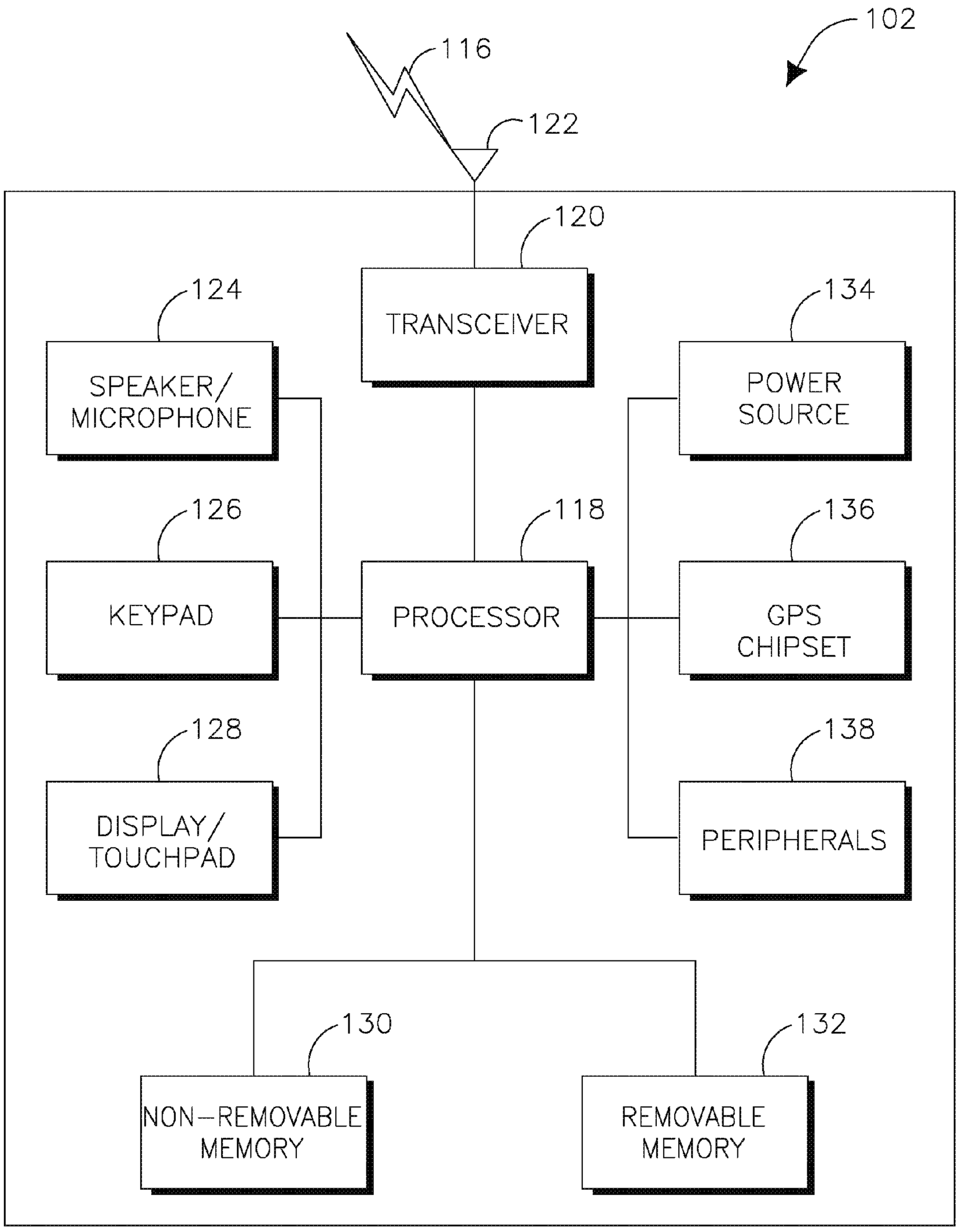

102
116
122
120
TRANSCEIVER
124
SPEAKER/
MICROPHONE
134
POWER
SOURCE
126
KEYPAD
118
PROCESSOR
136
GPS
CHIPSET
128
DISPLAY/
TOUCHPAD
138
PERIPHERALS
130
NON-REMOVABLE
MEMORY
132
REMOVABLE
MEMORY

FIG. 1B

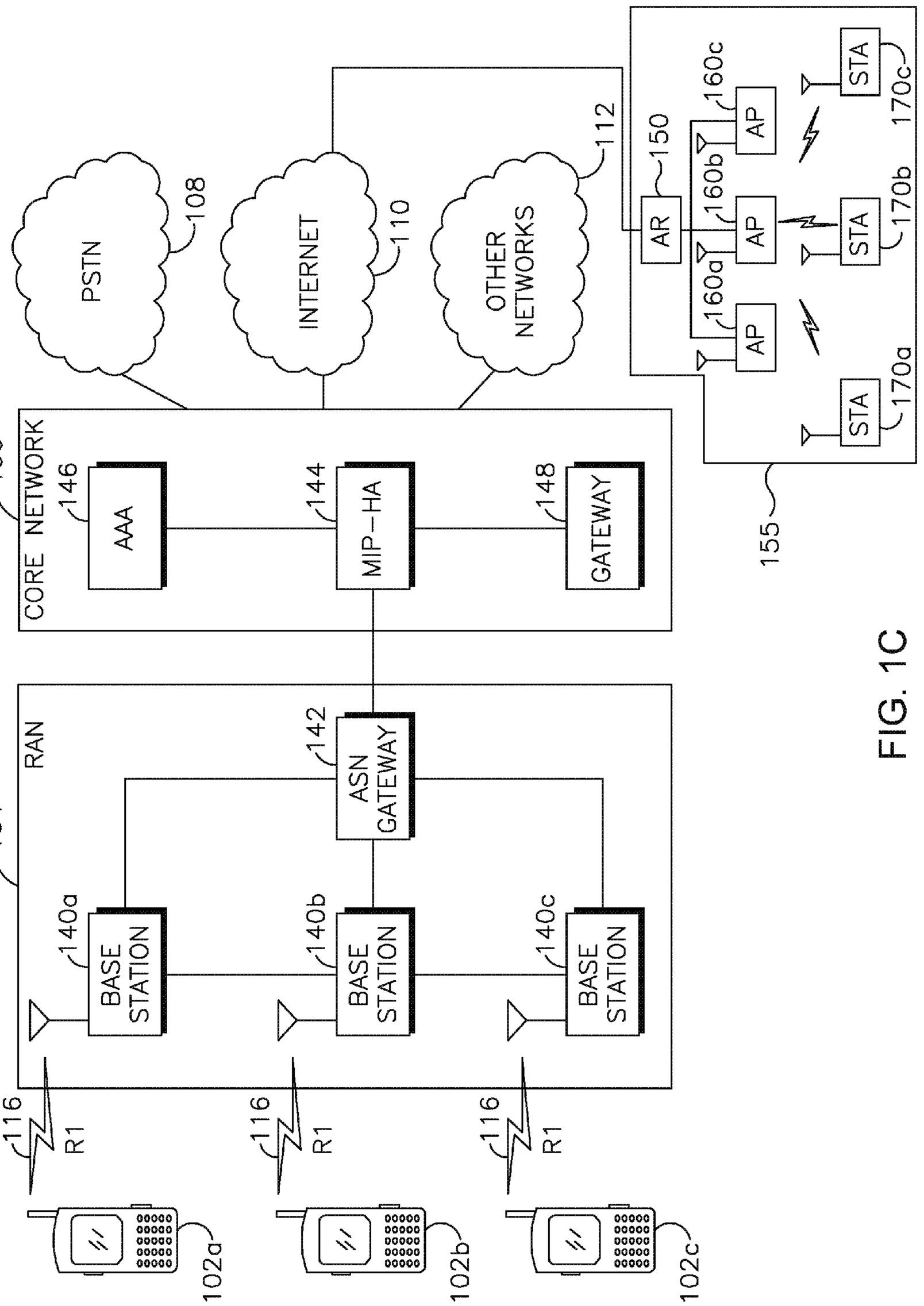

PSTN
108
INTERNET
110
OTHER NETWORKS
112
AR
150
160a
160b
160c
AP
AP
AP
STA
170a
STA
170b
STA
170c
155
CORE NETWORK
106
AAA
146
MIP–HA
144
GATEWAY
148
RAN
104
ASN GATEWAY
142
BASE STATION
140a
BASE STATION
140b
BASE STATION
140c
116
R1
116
R1
116
R1
102a
102b
102c

FIG. 1C

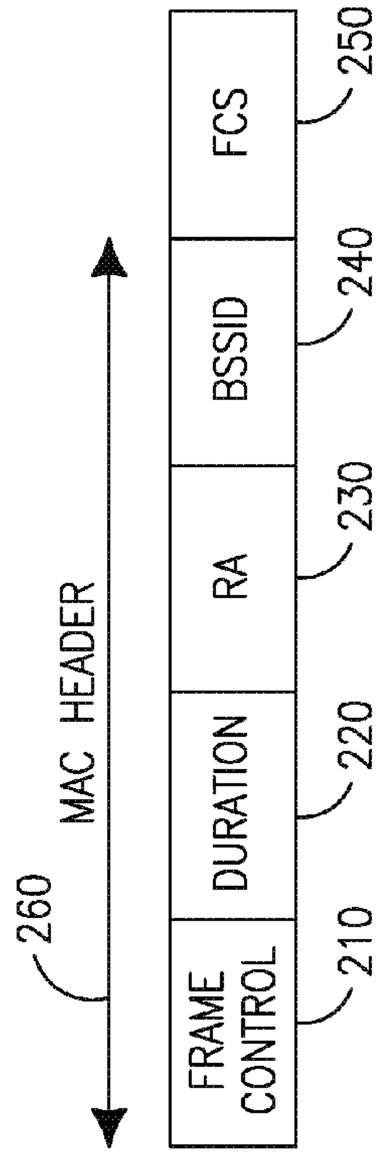

200
260
MAC HEADER
FRAME CONTROL
DURATION
RA
BSSID
FCS
210
220
230
240
250

FIG. 2

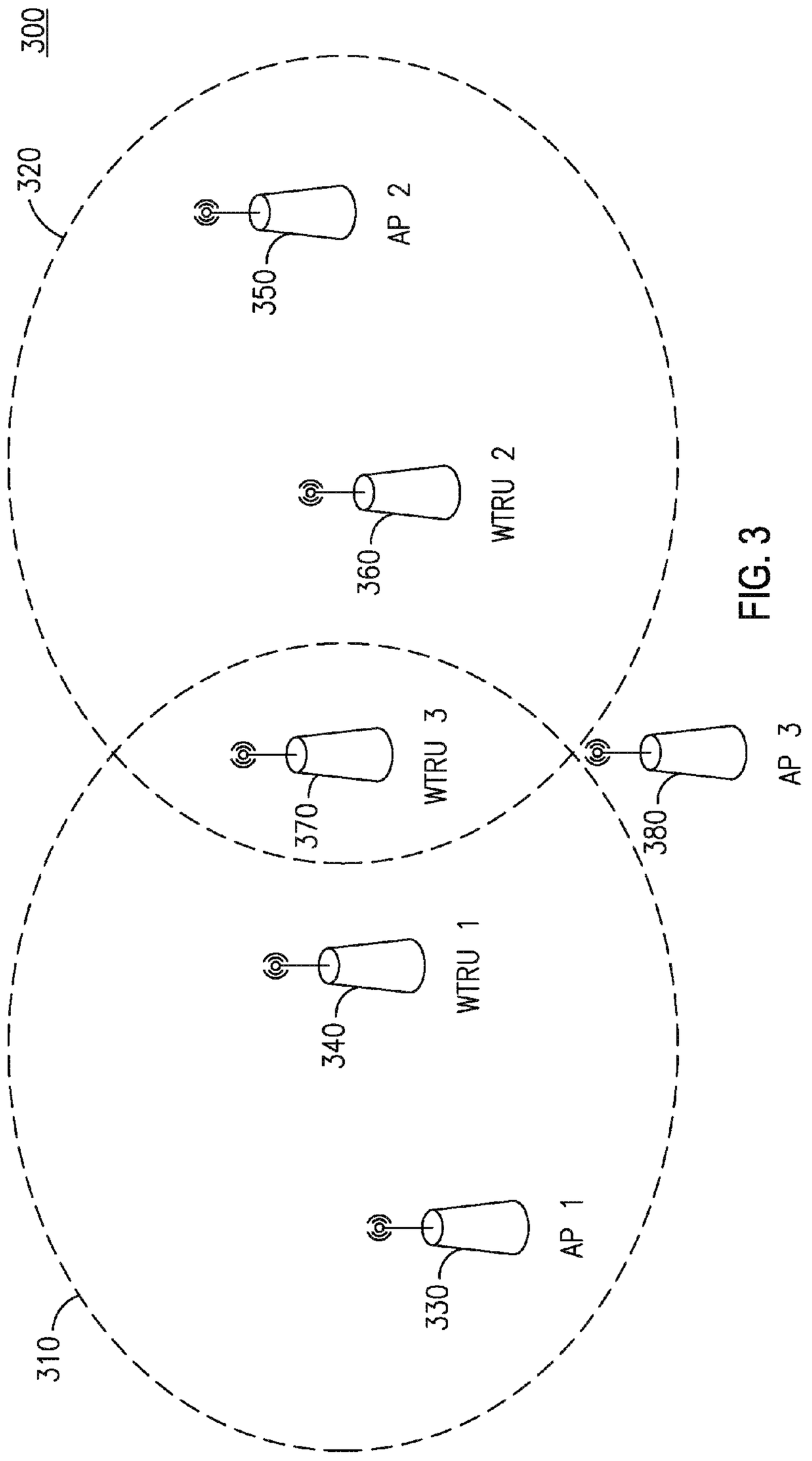

300
320
AP 2
350
WTRU 2
360
WTRU 3
370
WTRU 1
340
AP 3
380
AP 1
330
310

FIG. 3

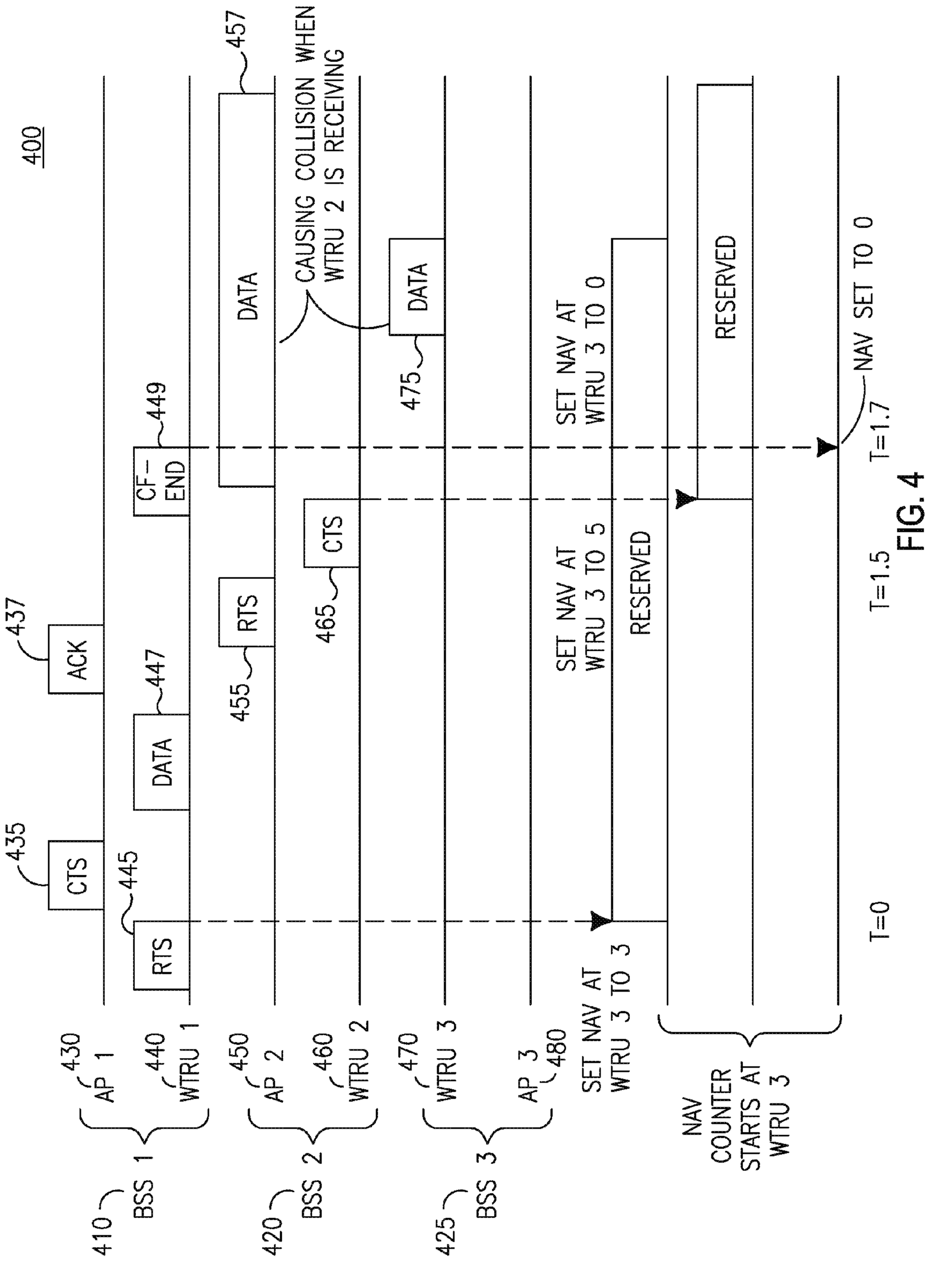

400
410
BSS 1
420
BSS 2
425
BSS 3
430
AP 1
440
WTRU 1
450
AP 2
460
WTRU 2
470
WTRU 3
480
AP 3
435
CTS
445
RTS
437
ACK
447
DATA
455
RTS
465
CTS
449
CF-END
457
DATA
CAUSING COLLISION WHEN WTRU 2 IS RECEIVING
475
DATA
SET NAV AT WTRU 3 TO 3
SET NAV AT WTRU 3 TO 5
RESERVED
SET NAV AT WTRU 3 TO 0
RESERVED
NAV SET TO 0
NAV COUNTER STARTS AT WTRU 3
T=0
T=1.5
T=1.7

FIG. 4

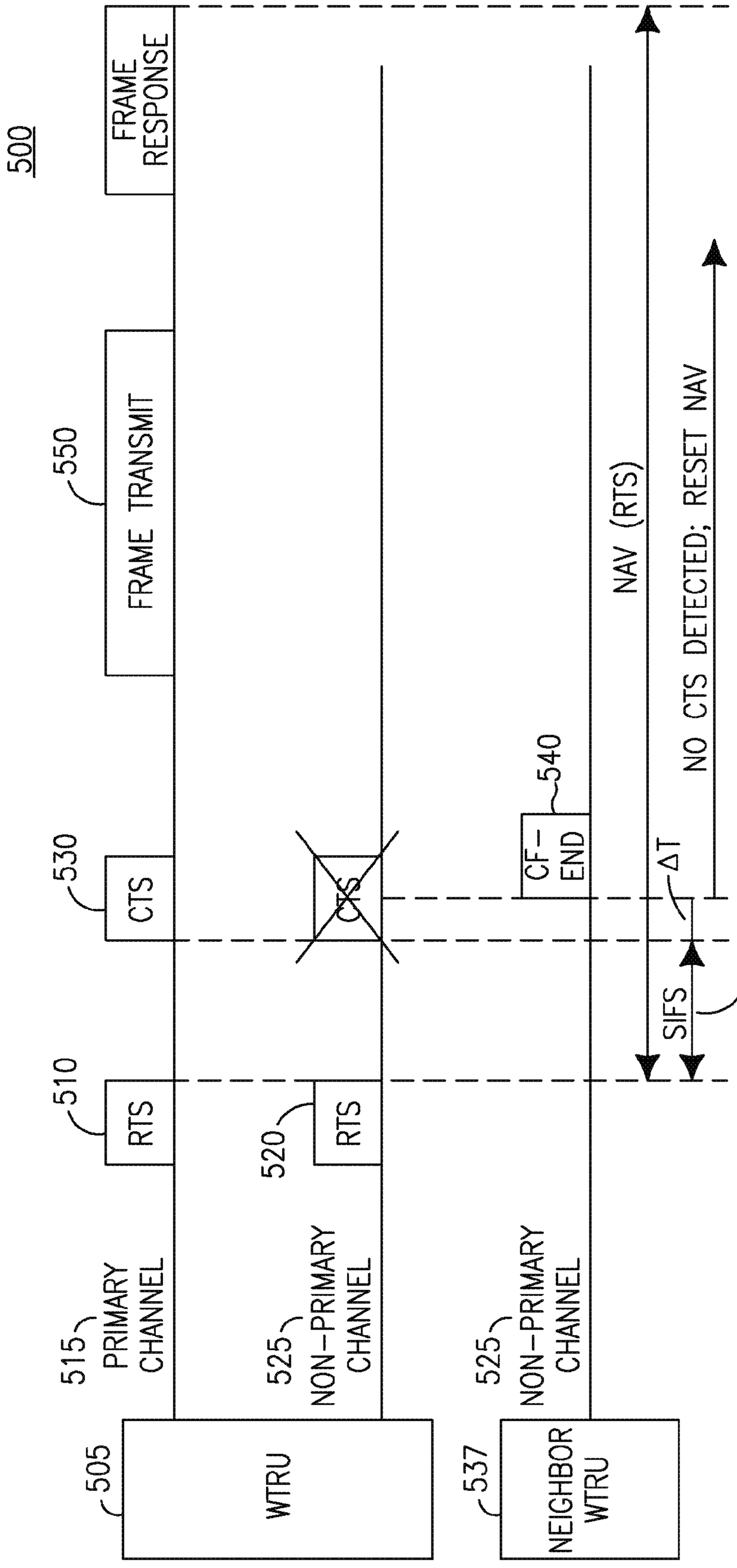

500
FRAME RESPONSE
550
FRAME TRANSMIT
530
CTS
CTS
540
CF-END
NAV (RTS)
ΔT
NO CTS DETECTED; RESET NAV
SIFS
535
510
RTS
520
RTS
515
PRIMARY CHANNEL
525
NON-PRIMARY CHANNEL
525
NON-PRIMARY CHANNEL
505
WTRU
537
NEIGHBOR WTRU

FIG. 5

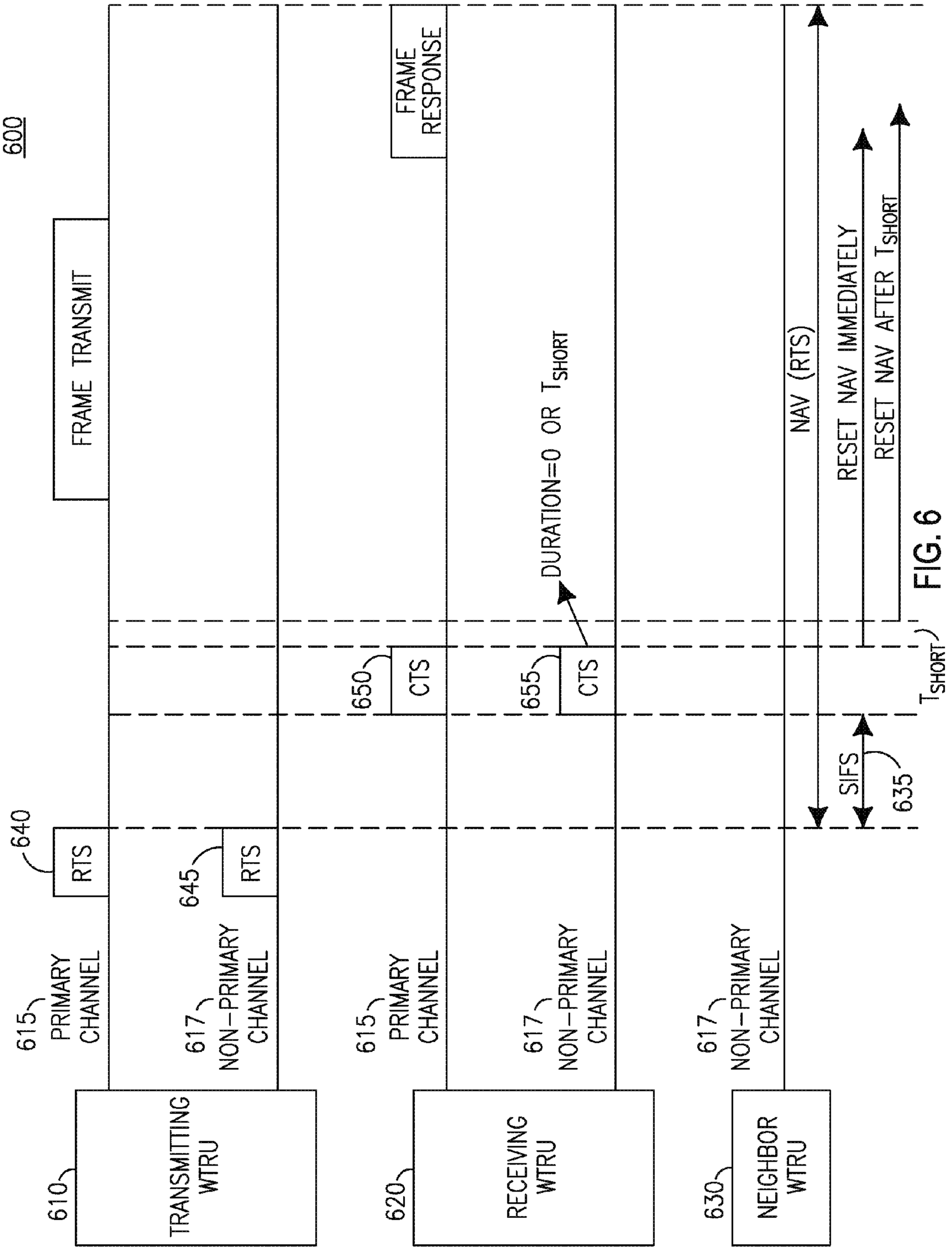

600
FRAME TRANSMIT
FRAME RESPONSE
640
RTS
645
RTS
650
CTS
655
CTS
DURATION=0 OR $T_{SHORT}$
NAV (RTS)
RESET NAV IMMEDIATELY
RESET NAV AFTER $T_{SHORT}$
$T_{SHORT}$
SIFS
635
615
PRIMARY CHANNEL
617
NON-PRIMARY CHANNEL
610
TRANSMITTING WTRU
620
RECEIVING WTRU
630
NEIGHBOR WTRU

FIG. 6

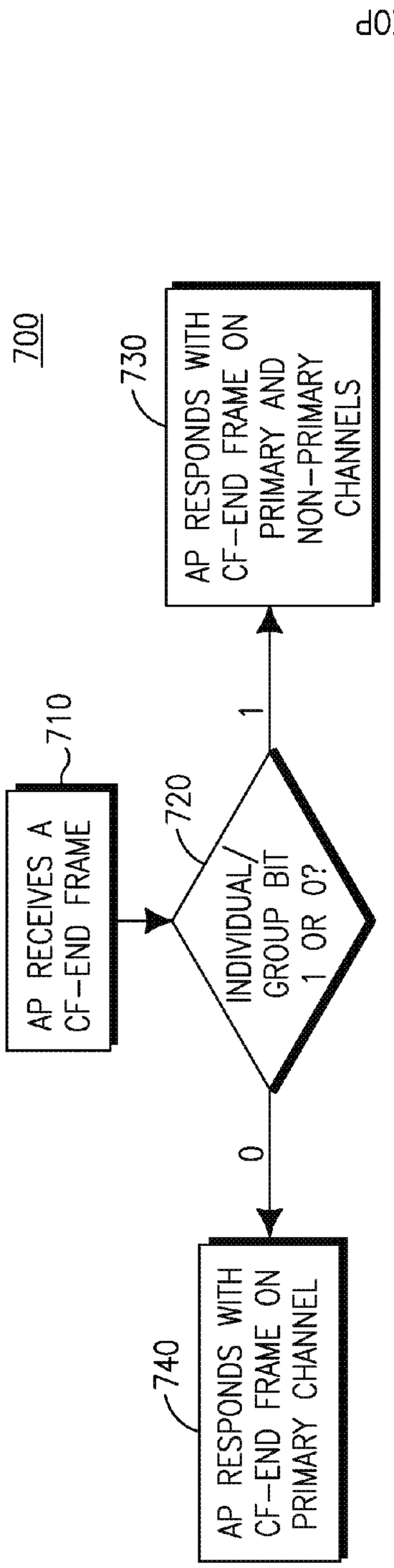

700
AP RECEIVES A CF-END FRAME
710
INDIVIDUAL/ GROUP BIT 1 OR 0?
720
1
0
AP RESPONDS WITH CF-END FRAME ON PRIMARY AND NON-PRIMARY CHANNELS
730
AP RESPONDS WITH CF-END FRAME ON PRIMARY CHANNEL
740

FIG. 7

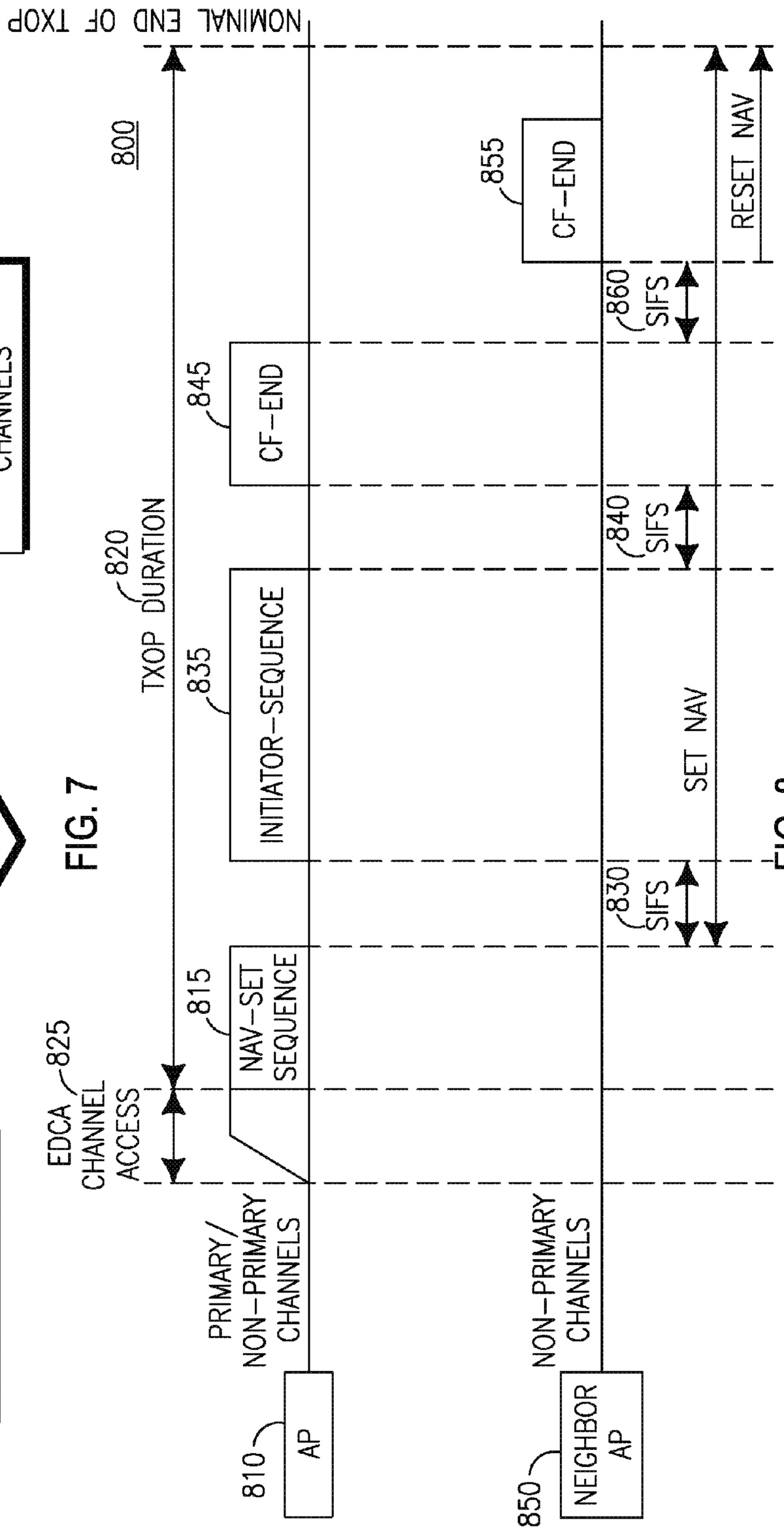

NOMINAL END OF TXOP
800
RESET NAV
855
CF-END
860
SIFS
TXOP DURATION
820
CF-END
845
INITIATOR-SEQUENCE
835
840
SIFS
815
NAV-SET SEQUENCE
SET NAV
830
SIFS
EDCA CHANNEL ACCESS
825
PRIMARY/ NON-PRIMARY CHANNELS
NON-PRIMARY CHANNELS
AP
810
NEIGHBOR AP
850

FIG. 8

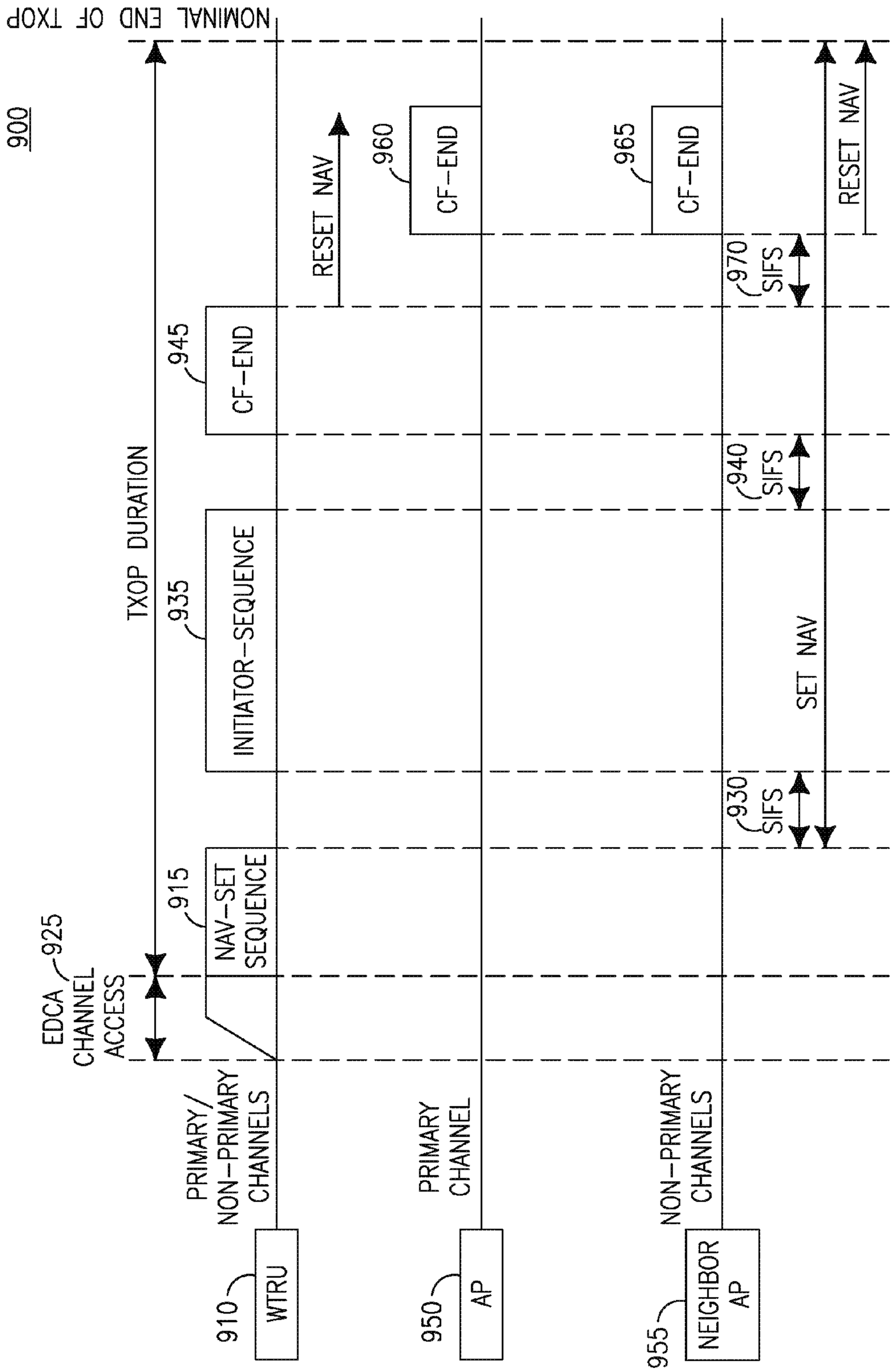

900
NOMINAL END OF TXOP
TXOP DURATION
EDCA CHANNEL ACCESS
925
PRIMARY/ NON-PRIMARY CHANNELS
PRIMARY CHANNEL
NON-PRIMARY CHANNELS
910
WTRU
950
AP
955
NEIGHBOR AP
915
NAV-SET SEQUENCE
935
INITIATOR-SEQUENCE
945
CF-END
960
CF-END
965
CF-END
RESET NAV
RESET NAV
930
SIFS
940
SIFS
970
SIFS
SET NAV

FIG. 9

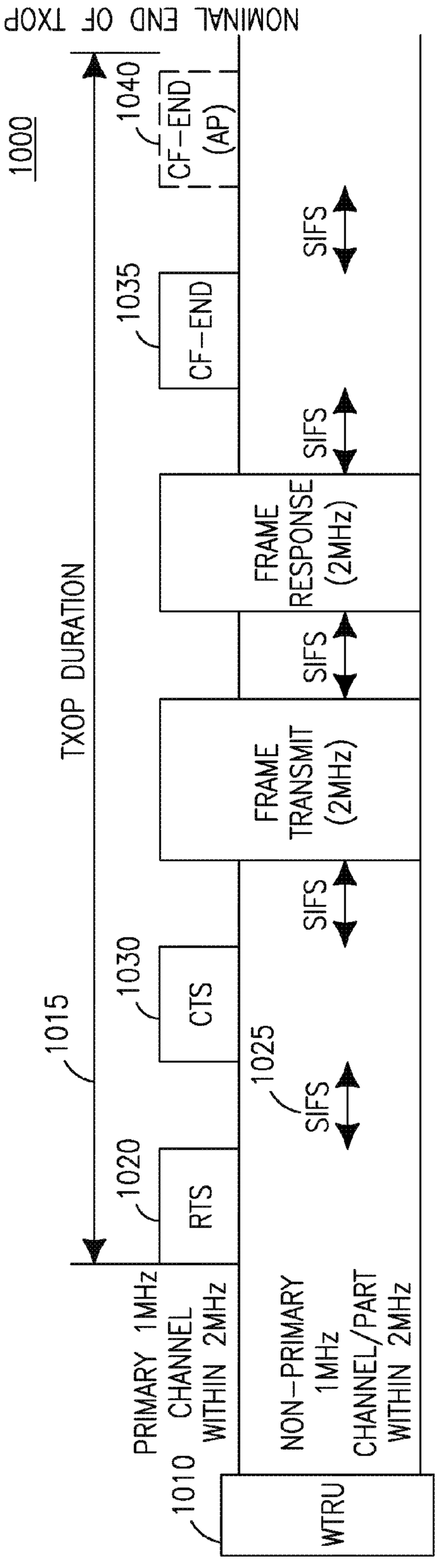

1000
NOMINAL END OF TXOP
1040
CF-END (AP)
1035
CF-END
SIFS
SIFS
1015
TXOP DURATION
1030
CTS
SIFS
FRAME TRANSMIT (2MHz)
SIFS
FRAME RESPONSE (2MHz)
1025
SIFS
1020
RTS
PRIMARY 1MHz CHANNEL WITHIN 2MHz
NON-PRIMARY 1MHz CHANNEL/PART WITHIN 2MHz
1010
WTRU

FIG. 10

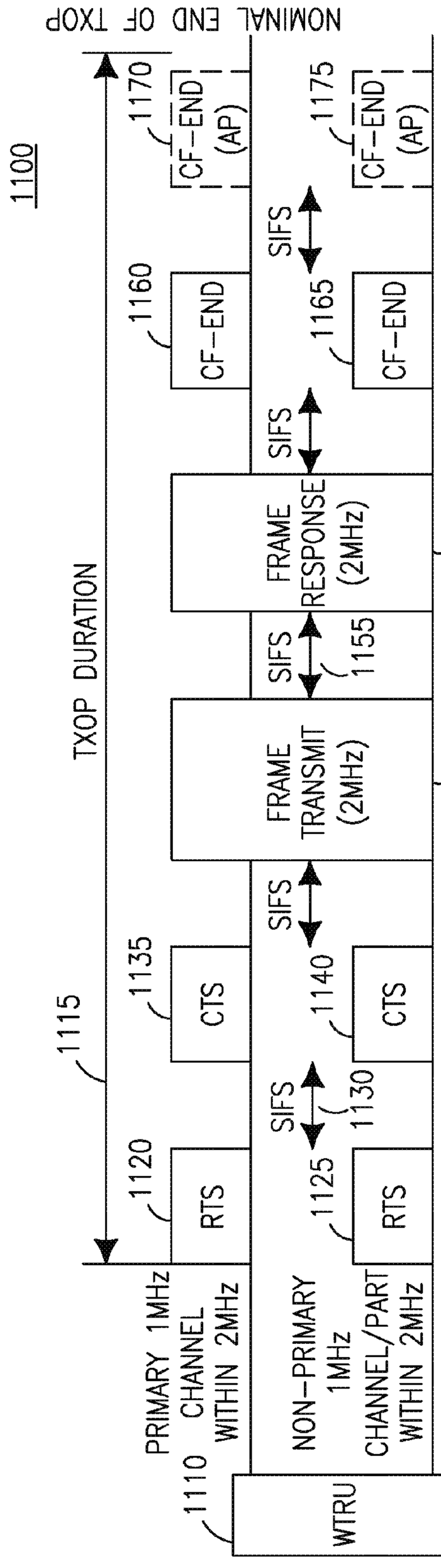

1100
NOMINAL END OF TXOP
1170
CF-END (AP)
1160
CF-END
SIFS
1175
CF-END (AP)
1165
CF-END
SIFS
1115
TXOP DURATION
1135
CTS
SIFS
FRAME TRANSMIT (2MHz)
SIFS
FRAME RESPONSE (2MHz)
1150
1140
CTS
1130
SIFS
1155
1145
1120
RTS
PRIMARY 1MHz CHANNEL WITHIN 2MHz
NON-PRIMARY 1MHz CHANNEL/PART WITHIN 2MHz
1125
RTS
1110
WTRU

FIG. 11

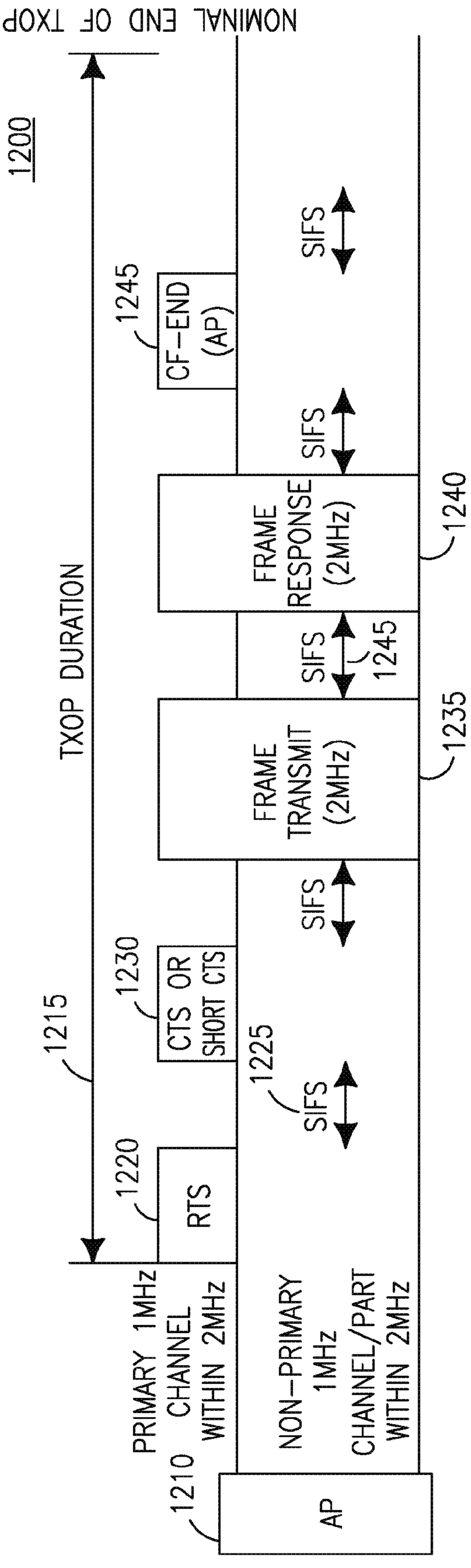

NOMINAL END OF TXOP
1200
TXOP DURATION
1215
AP
PRIMARY 1MHz CHANNEL WITHIN 2MHz
NON-PRIMARY 1MHz CHANNEL/PART WITHIN 2MHz
1210
RTS
1220
CTS OR SHORT CTS
1230
SIFS
1225
FRAME TRANSMIT (2MHz)
1235
SIFS
1245
FRAME RESPONSE (2MHz)
1240
SIFS
1245
CF-END (AP)
SIFS

FIG. 12A

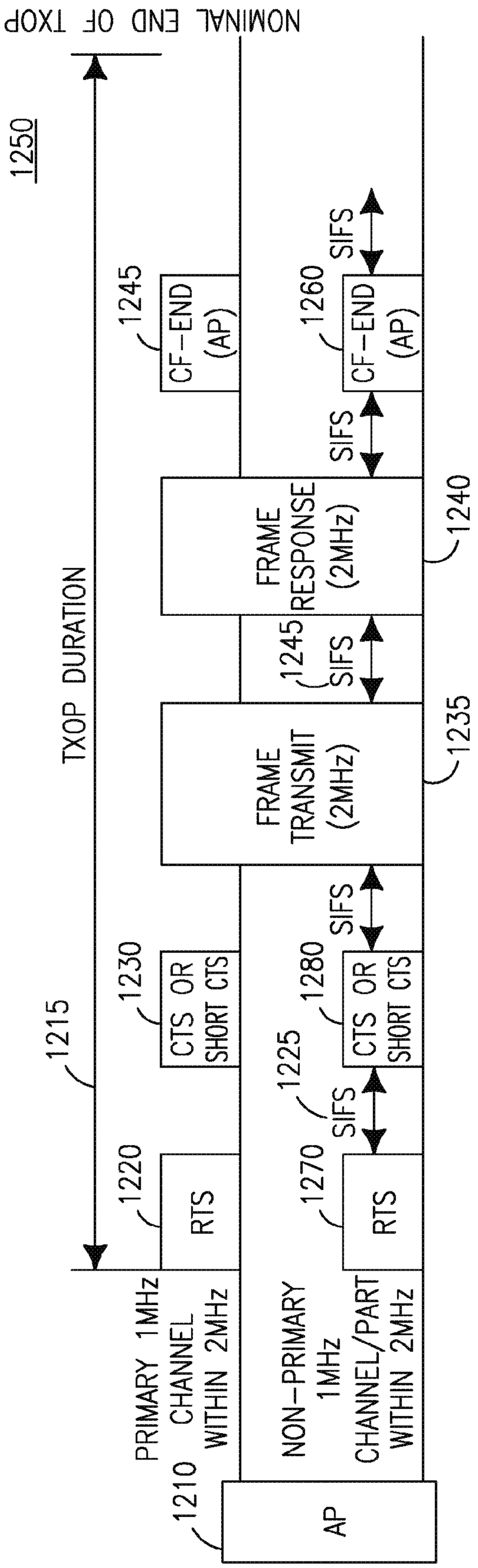

NOMINAL END OF TXOP
1250
TXOP DURATION
1215
1245
CF-END (AP)
1260
CF-END (AP)
SIFS
SIFS
FRAME RESPONSE (2MHz)
1240
1245
SIFS
FRAME TRANSMIT (2MHz)
1235
1230
CTS OR SHORT CTS
SIFS
1280
CTS OR SHORT CTS
1225
SIFS
1220
RTS
1270
RTS
PRIMARY 1MHz CHANNEL WITHIN 2MHz
NON-PRIMARY 1MHz CHANNEL/PART WITHIN 2MHz
1210
AP

FIG. 12B

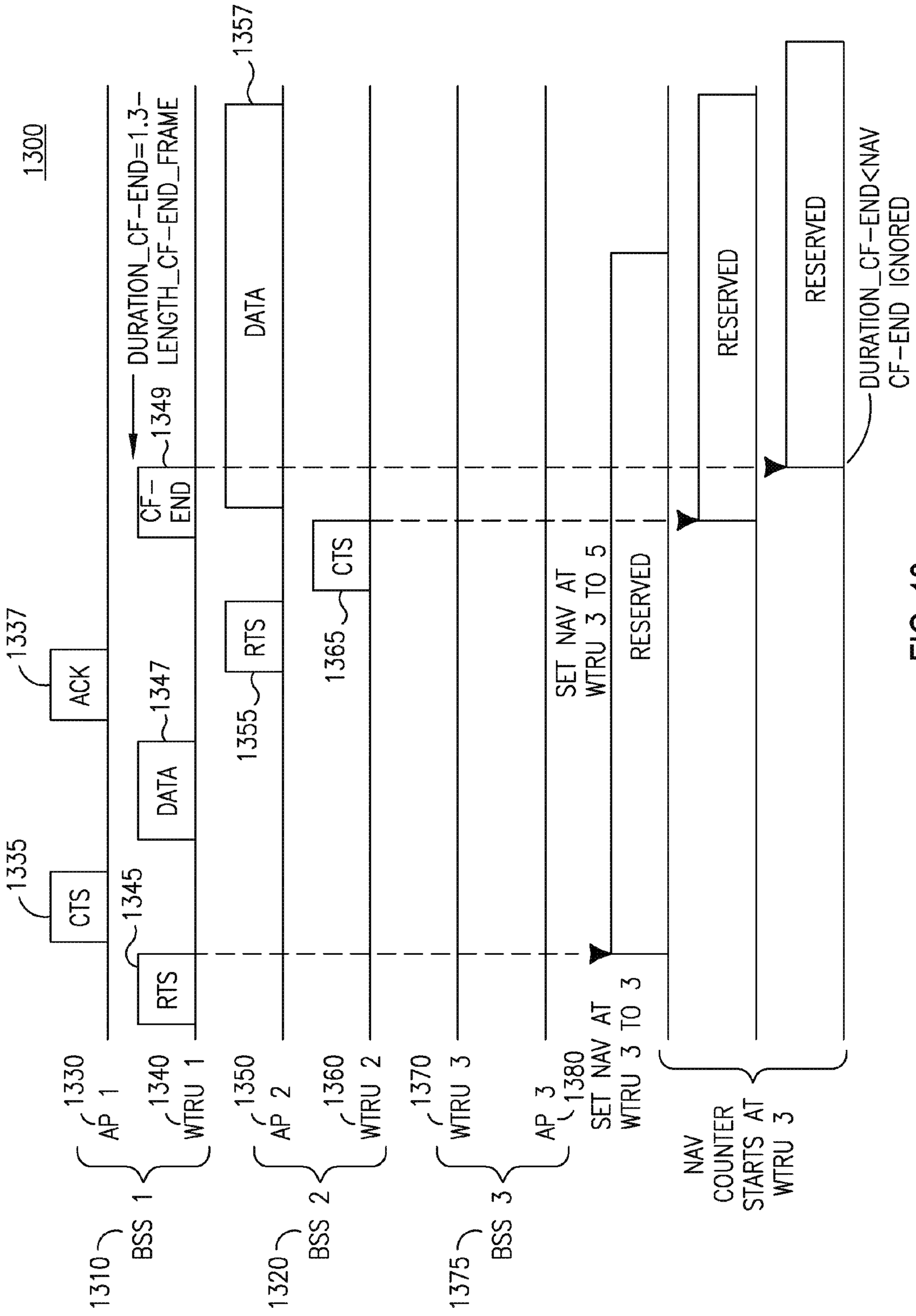

1300
1310
BSS 1
1320
BSS 2
1375
BSS 3
1330
AP 1
1340
WTRU 1
1350
AP 2
1360
WTRU 2
1370
WTRU 3
1380
AP 3
1335
CTS
1337
ACK
1345
RTS
1347
DATA
1355
RTS
1365
CTS
1357
DATA
1349
CF-END
SET NAV AT WTRU 3 TO 3
NAV COUNTER STARTS AT WTRU 3
RESERVED
SET NAV AT WTRU 3 TO 5
RESERVED
RESERVED
DURATION_CF-END<NAV
CF-END IGNORED
DURATION_CF-END=1.3-
LENGTH_CF-END_FRAME

FIG. 13

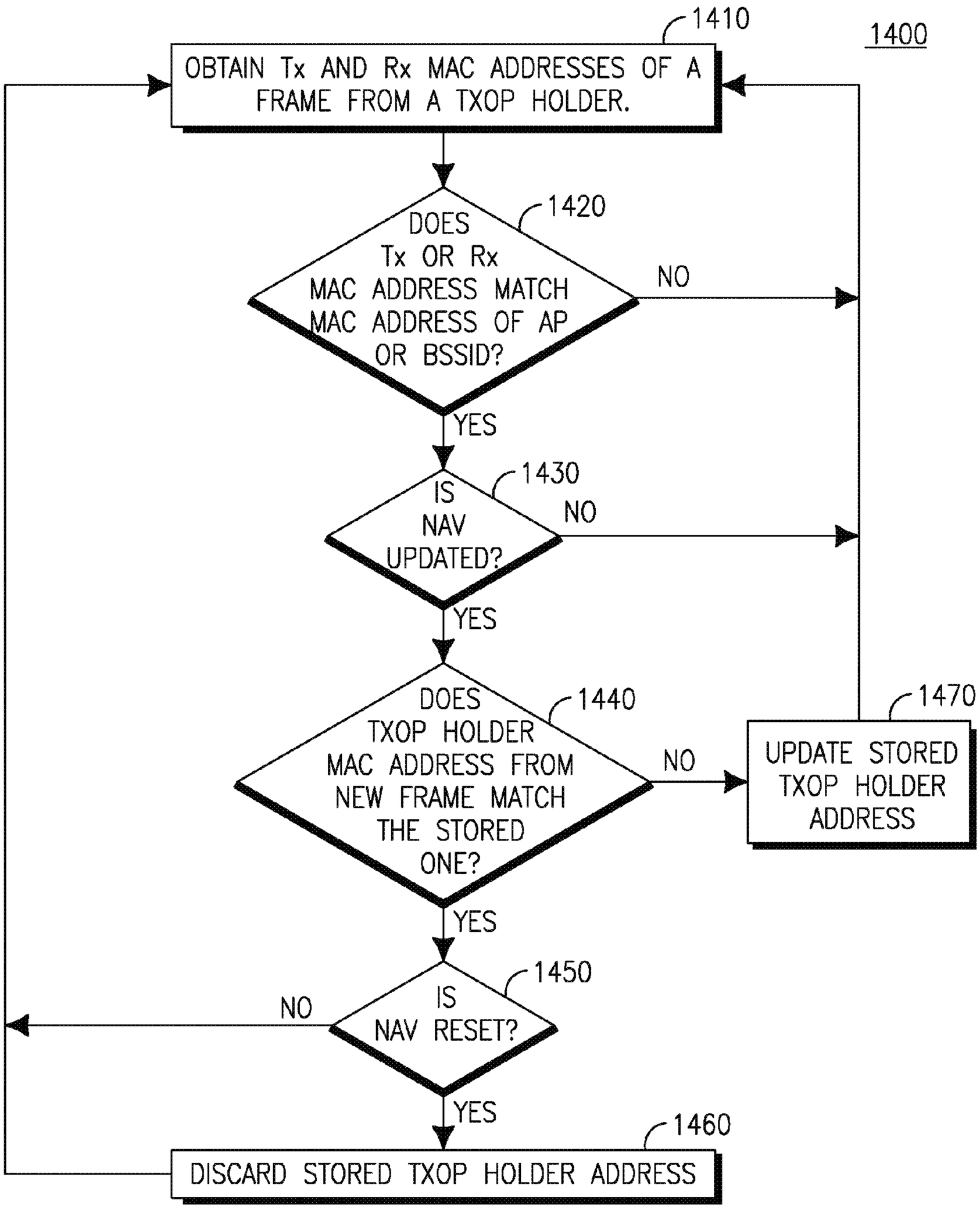

1400
1410
OBTAIN Tx AND Rx MAC ADDRESSES OF A FRAME FROM A TXOP HOLDER.
1420
DOES Tx OR Rx MAC ADDRESS MATCH MAC ADDRESS OF AP OR BSSID?
NO
YES
1430
IS NAV UPDATED?
NO
YES
1440
DOES TXOP HOLDER MAC ADDRESS FROM NEW FRAME MATCH THE STORED ONE?
NO
1470
UPDATE STORED TXOP HOLDER ADDRESS
YES
1450
IS NAV RESET?
NO
YES
1460
DISCARD STORED TXOP HOLDER ADDRESS

FIG. 14

# METHOD AND APPARATUS FOR SUPPORTING WIDEBAND AND MULTIPLE BANDWIDTH TRANSMISSION PROTOCOLS

## CROSS REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Application No. 61/500,788 filed on Jun. 24, 2011, U.S. Provisional Application No. 61/508,524 filed on Jul. 15, 2011, U.S. Provisional Application No. 61/607,352 filed on Mar. 6, 2012, and U.S. Provisional Application No. 61/642,048 filed on May 3, 2012, the contents of which are hereby incorporated by reference.

## BACKGROUND

A wireless local area network (WLAN) in an infrastructure basic service set (BSS) mode may include an access point (AP) for the BSS and one or more wireless transmit/receive units (WTRUs) associated with the AP. The AP may access or interface with a distribution system (DS) or another type of wired or wireless network that carries traffic in and out of the BSS. Traffic to WTRUs that originates from outside the BSS may arrive through the AP and may be delivered to the WTRUs. Traffic originating from WTRUs to destinations outside the BSS may be transmitted to the AP to be delivered to the respective destinations.

Traffic between WTRUs within the BSS may also be transmitted through the AP where the source WTRU transmits traffic to the AP, and the AP delivers the traffic to the destination WTRU. Such traffic between WTRUs within a BSS may be peer-to-peer traffic. Such peer-to-peer traffic may also be transmitted directly between the source and destination WTRUs with a direct link setup (DLS) using an IEEE 802.11e DLS or an IEEE 802.11z tunneled DLS (TDLS). A WLAN in an independent BSS mode may not have APs and WTRUs that communicate directly with each other.

New spectrum is being allocated in various countries around the world for wireless communication systems such as WLANs. Such spectrum may be limited in the size and also in the bandwidth of the channels it comprises. Given the limitations of such spectrum, WLANs may only be able to support smaller bandwidths and lower data rates, as compared to high throughput (HT) and very high throughput (VHT) WLANs, such as IEEE 802.11n and current draft IEEE 802.11ac based WLANs, respectively. For example, such is the case in spectrum allocated below 1 GHz in various countries with bandwidths of 1, 2, 4, 8 and 16 MHz. Another example is the television white space (TVWS) spectrum. In addition, more than one primary bandwidth mode may be supported because sometimes only some bandwidth modes are reliable or feasible for communication because of poor wireless link conditions and also because only some bandwidth modes allow a longer range in communication. Higher bandwidth transmissions may be supported as an aggregation of multiple primary bandwidth mode channels. One such example is in the sub 1 GHz spectrum where there may be BSSs supporting and allowing operation of 2 MHz and 1 MHz bandwidth modes as the primary bandwidth modes. Higher bandwidth transmissions, (e.g., 4 MHz, 8 MHz, 16 MHz), may be supported over multiples of 2 MHz/1 MHz bandwidths.

The WTRUs may support an increased communication range with a robust low rate modulation and coding set with repetition in a 1 MHz mode. Also, the WTRUs may be capable of receiving in 2 MHz and 1 MHz modes.



## SUMMARY

Enhanced protocols may be used to alleviate loss of spectrum efficiency in wideband transmission. The protocols may implement wideband transmission opportunity (TXOP) truncation where all of the channels involved in communication over the wideband may be released. In one scenario, a wireless transmit/receive unit (WTRU) may obtain a TXOP, (i.e., reserve a medium), for a 2 MHz bandwidth mode frame transmission with another device, (e.g., another WTRU or an access point (AP)), capable of the 2 MHz bandwidth mode and a 1 MHz bandwidth mode. The WTRU may conduct a request-to-send (RTS)/clear-to-send (CTS) frame exchange in the second bandwidth mode, and truncate the TXOP with a contention free (CF)-End frame in the first and second bandwidth modes. In another scenario, an AP may obtain a TXOP for a 2 MHz bandwidth mode frame transmission with a WTRU capable of both 2 MHz and 1 MHz bandwidth modes.

An AP may receive a first CF-End frame and transmit a second CF-End frame in response to the first CF-End frame. The first CF-End frame may include a bit that indicates whether a bandwidth value is set. The second CF-End frame may be transmitted on a primary channel and/or on one or more non-primary channels based on whether the bandwidth value is set. The bit may indicate that a scrambling sequence is included in the first CF-End frame, and may indicate that the scrambling sequence includes bandwidth information. The first CF-End frame may indicate a truncation of a wideband TXOP.

A WTRU may maintain a first and second network allocation vector (NAV) counter and receive a CF-End frame from another WTRU. The CF-End frame may indicate a truncation of a TXOP of the other WTRU. The WTRU may update the first and second NAV counters based on the received CF-End frame. Based on the updated first and second NAV counters, the WTRU may determine whether to attempt to access the medium.

A WTRU may maintain a TXOP holder MAC address and receive a CF-End frame from another WTRU. The CF-End frame may indicate a truncation of a TXOP of the other WTRU. The WTRU may reset the NAV counter of the WTRU based on a BSSID field in the received CF-End frame.

## BRIEF DESCRIPTION OF THE DRAWINGS

A more detailed understanding may be had from the following description, given by way of example in conjunction with the accompanying drawings wherein:

FIG. **1**A is a diagram of an example communications system in which one or more disclosed embodiments may be implemented;

FIG. **1**B is a diagram of an example wireless transmit/receive unit (WTRU) that may be used within the communications system shown in FIG. **1**A;

FIG. **1**C is a diagram of an example radio access network and an example core network that may be used within the communications system shown in FIG. **1**A;

FIG. **2** is a diagram of an example format of an IEEE 802.11 contention free (CF)-End frame;

FIG. **3** is a diagram of an example network in which a CF-End frame may lead to premature cancellation of a network allocation vector (NAV);

FIG. **4** is a diagram of example of packet exchanges of the network of FIG. **3**;

FIG. **5** is a diagram of an example CF-End frame transmission by a neighbor AP/WTRU;

FIG. **6** is a diagram of an example NAV reset by a receiving WTRU;

FIG. **7** is a diagram of an example method for transmitting a CF-End frame with a parameter set to truncate a transmit opportunity (TXOP);

FIG. **8** is a diagram of an example wideband TXOP protocol;

FIG. **9** is a diagram of an example wideband TXOP protocol;

FIG. **10** is a diagram of an example method for a WTRU to obtain a TXOP;

FIG. **11** is a diagram of an example method for a WTRU to obtain a TXOP;

FIG. **12**A is a diagram of an example method for an AP to obtain a TXOP;

FIG. **12**B is a diagram of another example method for an AP to obtain a TXOP;

FIG. **13** is a diagram of an example packet exchange sequence; and

FIG. **14** is a diagram of an example method for a WTRU/AP storing or saving the TXOP holder MAC address for the BSS in which it belongs or is associated.

## DETAILED DESCRIPTION

FIG. **1**A shows an example communications system **100** in which one or more disclosed embodiments may be implemented. The communications system **100** may be a multiple access system that provides content, such as voice, data, video, messaging, broadcast, and the like, to multiple wireless users. The communications system **100** may enable multiple wireless users to access such content through the sharing of system resources, including wireless bandwidth. For example, the communications systems **100** may employ one or more channel access methods, such as code division multiple access (CDMA), time division multiple access (TDMA), frequency division multiple access (FDMA), orthogonal FDMA (OFDMA), single-carrier FDMA (SC-FDMA), and the like.

As shown in FIG. **1**A, the communications system **100** may include WTRUs **102***a*, **102***b*, **102***c*, **102***d*, a radio access network (RAN) **104**, a core network **106**, a public switched telephone network (PSTN) **108**, the Internet **110**, and other networks **112**, though it will be appreciated that the disclosed embodiments contemplate any number of WTRUs, base stations, networks, and/or network elements. Each of the WTRUs **102***a*, **102***b*, **102***c*, **102***d* may be any type of device configured to operate and/or communicate in a wireless environment. By way of example, the WTRUs **102***a*, **102***b*, **102***c*, **102***d* may be configured to transmit and/or receive wireless signals and may include user equipment (UE), a mobile station, a fixed or mobile subscriber unit, a pager, a cellular telephone, a personal digital assistant (PDA), a smartphone, a laptop, a netbook, a personal computer, a wireless sensor, consumer electronics, and the like.

The communications systems **100** may also include a base station **114***a* and a base station **114***b*. Each of the base stations **114***a*, **114***b* may be any type of device configured to wirelessly interface with at least one of the WTRUs **102***a*, **102***b*, **102***c*, **102***d* to facilitate access to one or more communication networks, such as the core network **106**, the Internet **110**, and/or the other networks **112**. By way of example, the base stations **114***a*, **114***b* may be a base transceiver station (BTS), a Node-B, an evolved Node-B (eNB), a Home Node-B (HNB), a Home eNB (HeNB), a site controller, an access point (AP), a wireless router, and the like. While the base stations **114***a*, **114***b* are each depicted as a single element, it will be appreciated that the base stations **114***a*, **114***b* may include any number of interconnected base stations and/or network elements.

The base station **114***a* may be part of the RAN **104**, which may also include other base stations and/or network elements (not shown), such as a base station controller (BSC), a radio network controller (RNC), relay nodes, and the like. The base station **114***a* and/or the base station **114***b* may be configured to transmit and/or receive wireless signals within a particular geographic region, which may be referred to as a cell (not shown). The cell may further be divided into cell sectors. For example, the cell associated with the base station **114***a* may be divided into three sectors. Thus, in one embodiment, the base station **114***a* may include three transceivers, i.e., one for each sector of the cell. In another embodiment, the base station **114***a* may employ multiple-input multiple-output (MIMO) technology and, therefore, may utilize multiple transceivers for each sector of the cell.

The base stations **114***a*, **114***b* may communicate with one or more of the WTRUs **102***a*, **102***b*, **102***c*, **102***d* over an air interface **116**, which may be any suitable wireless communication link, (e.g., radio frequency (RF), microwave, infrared (IR), ultraviolet (UV), visible light, and the like). The air interface **116** may be established using any suitable radio access technology (RAT).

More specifically, as noted above, the communications system **100** may be a multiple access system and may employ one or more channel access schemes, such as CDMA, TDMA, FDMA, OFDMA, SC-FDMA, and the like. For example, the base station **114***a* in the RAN **104** and the WTRUs **102***a*, **102***b*, **102***c* may implement a radio technology such as universal mobile telecommunications system (UMTS) terrestrial radio access (UTRA), which may establish the air interface **116** using wideband CDMA (WCDMA). WCDMA may include communication protocols such as high-speed packet access (HSPA) and/or evolved HSPA (HSPA+). HSPA may include high-speed downlink packet access (HSDPA) and/or high-speed uplink packet access (HSUPA).

In another embodiment, the base station **114***a* and the WTRUs **102***a*, **102***b*, **102***c* may implement a radio technology such as evolved UTRA (E-UTRA), which may establish the air interface **116** using long term evolution (LTE) and/or LTE-Advanced (LTE-A).

In other embodiments, the base station **114***a* and the WTRUs **102***a*, **102***b*, **102***c* may implement radio technologies such as IEEE 802.16 (i.e., worldwide interoperability for microwave access (WiMAX)), CDMA2000, CDMA2000 1X, CDMA2000 evolution-data optimized (EV-DO), Interim Standard 2000 (IS-2000), Interim Standard 95 (IS-95), Interim Standard 856 (IS-856), global system for mobile communications (GSM), enhanced data rates for GSM evolution (EDGE), GSM/EDGE RAN (GERAN), and the like.

The base station **114***b* in FIG. **1**A may be a wireless router, HNB, HeNB, or AP, for example, and may utilize any suitable RAT for facilitating wireless connectivity in a localized area, such as a place of business, a home, a vehicle, a campus, and the like. In one embodiment, the base station **114***b* and the WTRUs **102***c*, **102***d* may implement a radio technology such as IEEE 802.11 to establish a wireless local area network (WLAN). In another embodiment, the base station **114***b* and the WTRUs **102***c*, **102***d* may implement a radio technology such as IEEE 802.15 to establish a wireless personal area network (WPAN). In yet another embodiment, the base station **114***b* and the WTRUs **102***c*, **102***d* may utilize a cellular-

based RAT, (e.g., WCDMA, CDMA2000, GSM, LTE, LTE-A, and the like), to establish a picocell or femtocell. As shown in FIG. **1**A, the base station **114***b* may have a direct connection to the Internet **110**. Thus, the base station **114***b* may not be required to access the Internet **110** via the core network **106**.

The RAN **104** may be in communication with the core network **106**, which may be any type of network configured to provide voice, data, applications, and/or voice over Internet protocol (VoIP) services to one or more of the WTRUs **102***a*, **102***b*, **102***c*, **102***d*. For example, the core network **106** may provide call control, billing services, mobile location-based services, pre-paid calling, Internet connectivity, video distribution, and the like, and/or perform high-level security functions, such as user authentication. Although not shown in FIG. **1**A, it will be appreciated that the RAN **104** and/or the core network **106** may be in direct or indirect communication with other RANs that employ the same RAT as the RAN **104** or a different RAT. For example, in addition to being connected to the RAN **104**, which may be utilizing an E-UTRA radio technology, the core network **106** may also be in communication with another RAN (not shown) employing a GSM radio technology.

The core network **106** may also serve as a gateway for the WTRUs **102***a*, **102***b*, **102***c*, **102***d* to access the PSTN **108**, the Internet **110**, and/or other networks **112**. The PSTN **108** may include circuit-switched telephone networks that provide plain old telephone service (POTS). The Internet **110** may include a global system of interconnected computer networks and devices that use common communication protocols, such as the transmission control protocol (TCP), user datagram protocol (UDP) and the Internet protocol (IP) in the TCP/IP suite. The networks **112** may include wired or wireless communications networks owned and/or operated by other service providers. For example, the networks **112** may include another core network connected to one or more RANs, which may employ the same RAT as the RAN **104** or a different RAT.

Some or all of the WTRUs **102***a*, **102***b*, **102***c*, **102***d* in the communications system **100** may include multi-mode capabilities, i.e., the WTRUs **102***a*, **102***b*, **102***c*, **102***d* may include multiple transceivers for communicating with different wireless networks over different wireless links. For example, the WTRU **102***c* shown in FIG. **1**A may be configured to communicate with the base station **114***a*, which may employ a cellular-based radio technology, and with the base station **114***b*, which may employ an IEEE 802 radio technology.

FIG. **1**B shows an example WTRU **102** that may be used within the communications system **100** shown in FIG. **1**A. As shown in FIG. **1**B, the WTRU **102** may include a processor **118**, a transceiver **120**, a transmit/receive element, (e.g., an antenna), **122**, a speaker/microphone **124**, a keypad **126**, a display/touchpad **128**, a non-removable memory **130**, a removable memory **132**, a power source **134**, a global positioning system (GPS) chipset **136**, and peripherals **138**. It will be appreciated that the WTRU **102** may include any sub-combination of the foregoing elements while remaining consistent with an embodiment.

The processor **118** may be a general purpose processor, a special purpose processor, a conventional processor, a digital signal processor (DSP), a microprocessor, one or more microprocessors in association with a DSP core, a controller, a microcontroller, an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) circuit, an integrated circuit (IC), a state machine, and the like. The processor **118** may perform signal coding, data processing, power control, input/output processing, and/or any other functionality that enables the WTRU **102** to operate in a wireless environment. The processor **118** may be coupled to the transceiver **120**, which may be coupled to the transmit/receive element **122**. While FIG. **1**B depicts the processor **118** and the transceiver **120** as separate components, the processor **118** and the transceiver **120** may be integrated together in an electronic package or chip.

The transmit/receive element **122** may be configured to transmit signals to, or receive signals from, a base station (e.g., the base station **114***a*) over the air interface **116**. For example, in one embodiment, the transmit/receive element **122** may be an antenna configured to transmit and/or receive RF signals. In another embodiment, the transmit/receive element **122** may be an emitter/detector configured to transmit and/or receive IR, UV, or visible light signals, for example. In yet another embodiment, the transmit/receive element **122** may be configured to transmit and receive both RF and light signals. The transmit/receive element **122** may be configured to transmit and/or receive any combination of wireless signals.

In addition, although the transmit/receive element **122** is depicted in FIG. **1**B as a single element, the WTRU **102** may include any number of transmit/receive elements **122**. More specifically, the WTRU **102** may employ MIMO technology. Thus, in one embodiment, the WTRU **102** may include two or more transmit/receive elements **122**, (e.g., multiple antennas), for transmitting and receiving wireless signals over the air interface **116**.

The transceiver **120** may be configured to modulate the signals that are to be transmitted by the transmit/receive element **122** and to demodulate the signals that are received by the transmit/receive element **122**. As noted above, the WTRU **102** may have multi-mode capabilities. Thus, the transceiver **120** may include multiple transceivers for enabling the WTRU **102** to communicate via multiple RATs, such as UTRA and IEEE 802.11, for example.

The processor **118** of the WTRU **102** may be coupled to, and may receive user input data from, the speaker/microphone **124**, the keypad **126**, and/or the display/touchpad **128** (e.g., a liquid crystal display (LCD) display unit or organic light-emitting diode (OLED) display unit). The processor **118** may also output user data to the speaker/microphone **124**, the keypad **126**, and/or the display/touchpad **128**. In addition, the processor **118** may access information from, and store data in, any type of suitable memory, such as the non-removable memory **130** and/or the removable memory **132**. The non-removable memory **130** may include random-access memory (RAM), read-only memory (ROM), a hard disk, or any other type of memory storage device. The removable memory **132** may include a subscriber identity module (SIM) card, a memory stick, a secure digital (SD) memory card, and the like. In other embodiments, the processor **118** may access information from, and store data in, memory that is not physically located on the WTRU **102**, such as on a server or a home computer (not shown).

The processor **118** may receive power from the power source **134**, and may be configured to distribute and/or control the power to the other components in the WTRU **102**. The power source **134** may be any suitable device for powering the WTRU **102**. For example, the power source **134** may include one or more dry cell batteries (e.g., nickel-cadmium (NiCd), nickel-zinc (NiZn), nickel metal hydride (NiMH), lithium-ion (Li-ion), and the like), solar cells, fuel cells, and the like.

The processor **118** may also be coupled to the GPS chipset **136**, which may be configured to provide location information (e.g., longitude and latitude) regarding the current loca-

tion of the WTRU **102**. In addition to, or in lieu of, the information from the GPS chipset **136**, the WTRU **102** may receive location information over the air interface **116** from a base station, (e.g., base stations **114***a*, **114***b*), and/or determine its location based on the timing of the signals being received from two or more nearby base stations. The WTRU **102** may acquire location information by way of any suitable location-determination method while remaining consistent with an embodiment.

The processor **118** may further be coupled to other peripherals **138**, which may include one or more software and/or hardware modules that provide additional features, functionality and/or wired or wireless connectivity. For example, the peripherals **138** may include an accelerometer, an e-compass, a satellite transceiver, a digital camera (for photographs or video), a universal serial bus (USB) port, a vibration device, a television transceiver, a hands free headset, a Bluetooth® module, a frequency modulated (FM) radio unit, a digital music player, a media player, a video game player module, an Internet browser, and the like.

FIG. **1**C is a system diagram of the RAN **104** and the core network **106** according to an embodiment. As noted above, the RAN **104** may employ an E-UTRA radio technology to communicate with the WTRUs **102***a*, **102***b*, **102***c* over the air interface **116**. The RAN **104** may also be in communication with the core network **106**.

The RAN **104** may include eNode-Bs **140***a*, **140***b*, **140***c*, though it will be appreciated that the RAN **104** may include any number of eNode-Bs while remaining consistent with an embodiment. The eNode-Bs **140***a*, **140***b*, **140***c* may each include one or more transceivers for communicating with the WTRUs **102***a*, **102***b*, **102***c* over the air interface **116**. In one embodiment, the eNode-Bs **140***a*, **140***b*, **140***c* may implement MIMO technology. Thus, the eNode-B **140***a*, for example, may use multiple antennas to transmit wireless signals to, and receive wireless signals from, the WTRU **102***a*.

Each of the eNode-Bs **140***a*, **140***b*, **140***c* may be associated with a particular cell (not shown) and may be configured to handle radio resource management decisions, handover decisions, scheduling of users in the uplink and/or downlink, and the like. As shown in FIG. **1**C, the eNode-Bs **140***a*, **140***b*, **140***c* may communicate with one another over an X2 interface.

The core network **106** shown in FIG. **1**C may include a mobility management gateway (MME) **142**, a serving gateway **144**, and a packet data network (PDN) gateway **146**. While each of the foregoing elements are depicted as part of the core network **106**, it will be appreciated that any one of these elements may be owned and/or operated by an entity other than the core network operator.

The MME **142** may be connected to each of the eNode-Bs **142***a*, **142***b*, **142***c* in the RAN **104** via an S1 interface and may serve as a control node. For example, the MME **142** may be responsible for authenticating users of the WTRUs **102***a*, **102***b*, **102***c*, bearer activation/deactivation, selecting a particular serving gateway during an initial attach of the WTRUs **102***a*, **102***b*, **102***c*, and the like. The MME **142** may also provide a control plane function for switching between the RAN **104** and other RANs (not shown) that employ other radio technologies, such as GSM or WCDMA.

The serving gateway **144** may be connected to each of the eNode Bs **140***a*, **140***b*, **140***c* in the RAN **104** via the S1 interface. The serving gateway **144** may generally route and forward user data packets to/from the WTRUs **102***a*, **102***b*, **102***c*. The serving gateway **144** may also perform other functions, such as anchoring user planes during inter-eNode B handovers, triggering paging when downlink data is available for the WTRUs **102***a*, **102***b*, **102***c*, managing and storing contexts of the WTRUs **102***a*, **102***b*, **102***c*, and the like.

The serving gateway **144** may also be connected to the PDN gateway **146**, which may provide the WTRUs **102***a*, **102***b*, **102***c* with access to packet-switched networks, such as the Internet **110**, to facilitate communications between the WTRUs **102***a*, **102***b*, **102***c* and IP-enabled devices. An access router (AR) **150** of a wireless local area network (WLAN) **155** may be in communication with the Internet **110**. The AR **150** may facilitate communications between APs **160***a*, **160***b*, and **160***c*. The APs **160***a*, **160***b*, and **160***c* may be in communication with STAs **170***a*, **170***b*, and **170***c*.

The core network **106** may facilitate communications with other networks. For example, the core network **106** may provide the WTRUs **102***a*, **102***b*, **102***c* with access to circuit-switched networks, such as the PSTN **108**, to facilitate communications between the WTRUs **102***a*, **102***b*, **102***c* and traditional land-line communications devices. For example, the core network **106** may include, or may communicate with, an IP gateway (e.g., an IP multimedia subsystem (IMS) server) that serves as an interface between the core network **106** and the PSTN **108**. In addition, the core network **106** may provide the WTRUs **102***a*, **102***b*, **102***c* with access to the networks **112**, which may include other wired or wireless networks that are owned and/or operated by other service providers.

Herein, the terminology "WTRU" may include but is not limited to a station (STA), a user equipment (UE), a mobile station, a fixed or mobile subscriber unit, a pager, a cellular telephone, a personal digital assistant (PDA), a computer, a mobile internet device (MID) or any other type of user device capable of operating in a wireless environment. When referred to herein, the terminology "AP" may include but is not limited to a base station, a Node-B, a site controller, or any other type of interfacing device capable of operating in a wireless environment.

A network allocation vector (NAV) protection mechanism may be used at the medium access control (MAC) layer to protect packet transmissions on the wireless medium. For the embodiments described herein, the terms device, node, or device/node may refer to, for example, a WTRU, an AP, or any other node. A NAV may be an indicator maintained by each device/node, of a time period when transmission on the wireless medium may not be initiated by the device/node. Each frame may contain a duration field that is set to a time period as defined by the MAC layer protocol. The duration field may be set to a time period corresponding to the transmission of any subsequent frames along with inter-frame spacing as required by the frame exchange sequences defined in the MAC layer protocol. A device that receives a valid frame not addressed to it, may update its NAV using the information in the duration field of the received frame if the update results in a new NAV value that may be greater than the current NAV value.

In a BSS, packet collisions may occur because of a hidden node. To mitigate the hidden node problem, a request-to-send (RTS) and a clear-to-send (CTS) frame exchange may be used to set the NAV appropriately in the neighborhoods of the devices engaged in a frame exchange. To obtain a transmit opportunity (TXOP) and reserve the medium, a device may transmit an RTS frame addressed to a recipient device as the first frame of a frame exchange sequence. The recipient device may respond with a CTS frame addressed to the device that transmitted the RTS frame. In this way the NAV may be set for other WTRUs in the neighborhoods of the devices to

support the frame exchange sequence. The duration fields in the RTS and CTS frames may be set to protect the desired frame exchange sequence.

Alternatively, a CTS-to-self frame may be transmitted before a transmission requiring protection. A device may first transmit a CTS frame addressed to itself and with a duration value that protects the subsequent transmissions. This alternative may involve less overhead than other protection mechanisms.

WLANs with very high throughput (VHT) of greater than 100 Mbps on top of the MAC layer, for example in accordance with current draft IEEE 802.11ac, may be used to enhance system performance and achieve high data rates. VHT WLANs may include features such as wideband transmissions by aggregating channels. For example, for IEEE 802.11, a channel may be 20 MHz wide. In another example, four (4) 20 MHz channels may be aggregated for an 80 MHz wideband transmission.

A BSS may operate with a 20 MHz channel as a primary channel on which the devices of the BSS may camp or be associated with. In order for a device to perform a wideband transmission, it may aggregate one or more non-primary 20 MHz channels with the primary 20 MHz channel to create a desired bandwidth to support the wideband transmission. Any channel that is not a primary channel may be referred to as a secondary channel or a non-primary channel. In addition, the device may set the NAV of other devices on the non-primary channels of the aggregated channel for the wideband transmission. To set the NAV of the devices on the non-primary channels, the initiating device of the wideband transmission may conduct an RTS-CTS frame exchange on the non-primary channels with the receiving/responding device of the wideband transmission. The receiving/responding device may respond to the RTS frame from the initiating device on the one or more non-primary channels with a CTS frame if it determines that the non-primary channel is clear/idle/not-busy. For example, the receiving/responding device may respond with a CTS frame when there is no potentially interfering signal, energy, or transmission.

If the receiving/responding device on the one or more non-primary channels responds with a CTS frame, then the initiating device may assume that the non-primary channels are available for use and may aggregate the channels into the bandwidth for wideband transmission. If the receiving/responding device does not respond with a CTS frame on the one or more non-primary channels, or there is a failure in the reception of the CTS frame, the initiating device may assume that the one or more non-primary channels is not available for use and may not aggregate the channels into the bandwidth for wideband transmission. However, the RTS frame transmitted by the initiating device may set the NAV so that the devices in its neighborhood may not reset the NAV until a CTS timeout interval. The CTS timeout interval may include the duration from the reception of RTS from the initiating device to the start of the reception of a packet following the RTS from the initiating device. The NAV in the neighboring devices may be set as:

$$(2\times SIFS)+(CTS\ Time)+Receiver\ Start\ Delay+(2\times Slot\ Time), \quad \text{Equation (1)}$$

where the short inter-frame spacing (SIFS) and Slot Time may be system parameters.

Two cases may be considered with respect to the deployment of overlapping BSS (OBSS) in the neighborhood: an OBSS case and a non-OBSS case. The OBSS case may include a scenario where the communication between the transmitting and receiving devices may interfere with a neighboring BSS, and may impact performance.

In a non-OBSS case, if the neighbor devices that have their NAV set by the RTS frame are in the same BSS as the initiating device that transmitted the RTS, the neighbor devices may not be able to use those channels for an off-channel DLS/TDLS operation until a CTS timeout interval. This may lead to an inefficient usage of the spectrum. In an OBSS case, if the neighbor devices that have their NAV set by the RTS frame are in an OBSS, the neighbor devices may not be able to use those channels for the duration of a CTS timeout interval, which may lead to an inefficient usage of the spectrum.

The inefficiency in usage of spectrum for the OBSS devices may affect basic BSS operation, for example, communication between an AP and one or more WTRUs, and their respective DLS/TDLS operation. OBSS interference may occur in dense urban deployments with the proliferation of wireless devices. This problem may be aggravated if the non-primary channel for the BSS in question is a primary channel for the OBSS. An enhanced protocol may be designed to alleviate this loss of spectrum efficiency for the devices in the OBSS.

In both example cases above, any WTRU that sets its NAV based on the duration field of the RTS frame may consider the medium to be busy for a CTS timeout interval, regardless of whether the medium was actually reserved with an acknowledging CTS frame.

In another example, a WTRU may successfully reserve the medium on a primary channel and one or more non-primary channels for a pre-determined duration of time, which may be referred to as a wideband TXOP duration. The wideband TXOP may be a TXOP for the initiating WTRU over a wideband that includes a primary channel and one or more non-primary channels. One way of reserving the medium may be performing a successful RTS-CTS frame exchange on the requested channels. The WTRUs that receive either the RTS frame, the CTS frame, or both, may set their NAVs based on a duration field contained in these frames. The medium may be reserved and the NAV may be set by any other allowed MAC protocol. The allowed MAC protocol may not include RTS-CTS. Though the medium may have been successfully reserved by the initiating WTRU for a pre-determined duration, for example, for a wideband TXOP duration, the data transmission may not last for the total wideband TXOP duration for which the medium has been reserved. In this situation, the device that may hold the TXOP, or may have reserved the medium for the wideband TXOP duration, may initiate a procedure to truncate the wideband TXOP so that the medium may be released to other devices, including those in an OBSS, on channels aggregated in the wideband transmission.

FIG. **2** is a diagram of an example format of an IEEE 802.11 CF-End frame **200**. The CF-End frame may include a frame control field **210**, a duration field **220**, an RA field **230**, a basic service set identifier (BSSID) field **240**, and an FCS field **250**. The frame control field **210**, the duration field **220**, the RA field **230**, and the BSSID field **240** may be included in a MAC header **260**. The BSSID may be included a timing advance (TA) field. In the CF-End frame **200**, the duration field **220** may be set to **0** and the RA field **230** may include the broadcast group address.

Each BSS may be uniquely identified by a BSSID. The CF-End frame may have a BSSID field **240**, and it may be, for example, a TA field that contains the BSSID of the WTRU transmitting it. Any WTRU that receives a CF-End frame may reset its NAV. This procedure for truncation of TXOP may be inadequate for truncation of wideband TXOP in VHT WLANs, since the medium may be released to all WTRUs,

including those in an OBSS, on all channels in the wideband spectrum. A wideband TXOP truncation procedure to solve this problem is described herein. TXOP reservation and truncation mechanisms are described herein for multiple primary bandwidth modes as well.

Mechanisms for bandwidth and static/dynamic indications in the spectrum where legacy devices operate, for example, as in IEEE 802.11ac, may have to adopt signaling and protocol methods that may be constrained to support legacy compatibility. Such indications may be used in control frames, for example, in an RTS/CTS exchange for wideband TXOP reservation. In certain spectrums allocated for WLAN, for example, below 1 GHz, there may be no requirement of compatibility with legacy devices. This lack of compatibility may be exploited in designing new methods in signaling and protocol for bandwidth and static/dynamic indications.

The basic IEEE 802.11 CF-End mechanisms that truncate TXOP reservation may have some deficiencies. A WTRU may interpret the reception of a CF-End frame as a NAV reset, and it may reset its NAV timer to 0 at the end of the PPDU containing this frame, irrespective of whether the NAV has been set in the WTRU that transmitted the CF-End frame. This may lead to a premature cancellation of the NAV, and decreased performance due to a packet collision that may be caused by such premature NAV cancellations.

FIG. **3** is a diagram of an example network **300** in which the design of a CF-End frame may lead to premature cancellation of a NAV. FIG. **3** shows a first BSS (BSS**1**) **310** and a second BSS (BSS**2**) **320**. As shown in FIG. **3**, AP**1** **330** and WTRU**1** **340** belong to BSS**1** **310**; AP**2** **350** and WTRU**2** **360** belong to BSS**2** **320**; and WTRU**3** **370** may belong to BSS**1** **310** or it may belong to another overlapping BSS (OBSS) BSS**3** (not shown) started by AP**3** **380**. WTRU**3** **370** may be within radio range of WTRU**1** **340**, WTRU**2** **360** and AP**3** **380**; AP**1** **330**, AP**2** **350** and AP**3** **380** may not be able to hear each other; WTRU**1** **340** may be within range of AP**1** **330** and WTRU**3** **370**, while WTRU**2** **360** may be within range of AP**2** **350** and WTRU**3** **370**.

FIG. **4** is a diagram of example of packet exchanges **400** of the network of FIG. **3**, which may lead to premature cancellation of NAV at WTRU**3** due to the current design of truncation of TXOP by using CF-End frames. FIG. **4** shows a first BSS (BSS**1**) **410** and a second BSS (BSS**2**) **420**. As shown in FIG. **4**, AP**1** **430** and WTRU**1** **440** belong to BSS**1** **410**; AP**2** **450** and WTRU**2** **460** belong to BSS**2** **420**; and WTRU**3** **470** may belong to BSS**1** **410** or it may belong to another overlapping BSS (OBSS) BSS**3** **475** started by AP**3** **480**.

As shown in FIG. **4**, at T=0 ms, WTRU**1** **440** may transmit an RTS frame **445** to reserve the medium for 3 ms, and set the NAV counter at WTRU**3** **480** to be 3 ms. AP**1** **430** may respond with a CTS frame **435**, after which the WTRU**1** **440** may start to transmit its data frame **447** to AP**1** **430**. AP**1** **430** may subsequently transmit an acknowledgement (ACK) **437** of the reception of the data packet. At time T=1.5 ms, AP**2** **450**, without being able to hear the ACK **437** transmitted by AP**1** **430**, may transmit an RTS frame **455** to WTRU**2** **460**. When WTRU**2** **460** receives the RTS frame **455** from AP**2** **450**, it may respond with a CTS frame **465** to reserve the medium for 5 ms, and may update the NAV counter at WTRU**3** **470** to be 5 ms. AP**2** **450**, after receiving the CTS frame **465** from WTRU**2** **460**, may start transmitting its data packet **457** for WTRU**2** **460**. At T=1.7 ms, WTRU**1** **440**, which may have finished all of its transmissions, may transmit a CF-End frame **449** to indicate truncation of its TXOP. WTRU**3** **470** may set its NAV=0 after receiving the CF-End frame **449** from WTRU**1** **440** though the current NAV at WTRU**3** **470** is set by WTRU**2** **460**, which may currently be receiving a data packet **475** after a correct medium reservation. WTRU**3** **470** may decide to compete for medium access, since its NAV=0 and WTRU**3** **470** may not sense any activity using clear channel assessment (CCA). This may lead to a collision at WTRU**2** **460**. WTRU**2** **460** may fail to receive its packets from AP**2** **450**, and may lead to a breakdown of the medium reservation mechanism and decreased system performance.

The problem of premature cancellation of NAV is expected to be more prevalent in the current and future generations of WLAN systems due to increased WLAN coverage ranges. In IEEE 802.11ah systems, for example, a WTRU may be required to have a coverage range of up to 1 km. This may lead to a much greater number of overlapping BSSs in the same area. The chance of hearing a CF-End frame that erroneously cancels NAV counters may increase with the number of OBSSs.

The problem of premature cancellation of a NAV may also be more prevalent in the current and future generations of WLAN systems due to lower data rates. In IEEE 802.11ah systems, for example, a WTRU may have a data rate as low as 100 kbps. Transmissions using a low data rate may lead to a longer transmission time, which may require more frequent application of a medium reservation mechanism, which in turn may lead to more frequent truncation of TXOPs and more frequent premature cancellations of NAVs at WTRUs.

The problem of premature cancellation of a NAV may also be more prevalent in the current and future generations of WLAN systems due to multiple operating bandwidths in OBSS. For example, in IEEE 802.11ac, 802.11af and 802.11ah systems, there may be multiple operating modes with variable, and sometimes dynamic, operating bandwidths. More frequent application of medium reservation mechanisms may provide protection of different and/or dynamic operating modes with variable bandwidths in OBSSs, which in turn may lead to more frequent truncation of TXOPs and more frequent premature cancellations of NAVs at WTRUs.

A method and apparatus may be used to alleviate the loss of spectrum efficiency in wideband transmission. For example, when a medium reservation is conducted by a device in a BSS over a wideband that it may not be able to use in its entirety, the method and apparatus may release unusable bandwidth. The released bandwidth may be used by devices in the same BSS for DLS/TDLS mode. Additionally, a method and apparatus may be used to alleviate spectrum usage inefficiency in an OBSS environment. The method and apparatus may be used to address the issue of wideband TXOP truncation where the channels involved in communication over the wideband may be released for WTRUs of both the current BSS and any OBSS.

In addition, a method and apparatus may be used for TXOP reservation and truncation for multiple primary bandwidth modes. The methods may include signaling and protocol enhancements for bandwidth and static/dynamic indications when legacy compatibility may not be a requirement or constraint. The methods may also include signaling and protocol enhancements to remedy deficiencies in the basic CF-End mechanism in IEEE 802.11 to truncate a TXOP.

Although the embodiments described hereafter consider the method of reserving the medium using an RTS-CTS frame exchange, it should be understood that the embodiments are not limited to these specific examples, and may be applied to any other type of frame exchange or in a different way, for example, any other MAC protocol for medium reservation and NAV setting. It should also be understood that

the drawings are for illustration purposes only and may not be considered as limiting the scope of the embodiments.

A transmitting WTRU may be an IEEE 802.11 WTRU that initiates communication with another IEEE 802.11 WTRU. The communication may be triggered by an RTS frame or any other MAC protocol to reserve the medium and set the NAV. A receiving WTRU may be an IEEE 802.11 WTRU that is the recipient of the data being transmitted by the transmitting WTRU. A neighboring BSS may be a BSS neighboring (overlapping with or interfering with) the BSS to which the transmitting and the receiving WTRUs belong. A neighbor AP/WTRU may be an IEEE 802.11 AP/WTRU that may be a member of the neighboring BSS. The neighbor AP/WTRU may refer to an AP or any WTRU in the neighboring BSS.

A NAV reset may be performed by a neighbor AP/WTRU. The neighbor AP/WTRU may monitor the channels on which an RTS frame was transmitted by the transmitting WTRU. The monitored channels may include a primary channel and/or one or more non-primary channels. If the neighbor AP/WTRU does not detect any activity in the medium on any or all of those channels following the RTS frame, the neighbor AP/WTRU may free the medium for its BSS.

In one embodiment, the neighbor AP/WTRU may monitor these channels for a certain predefined period of time for any activity in order to determine if the medium is being used for communication on those channels. For example, the neighbor AP/WTRU may monitor the primary channel of its BSS, (i.e., the neighboring BSS), which may be a non-primary channel for the BSS of the transmitting WTRU. The neighbor AP/WTRU may monitor this channel for a CTS frame from a receiving WTRU following an RTS frame transmission from the transmitting WTRU. Alternatively, the neighbor AP/WTRU may monitor the channels on which the RTS frame was transmitted by the transmitting WTRU.

The neighbor AP/WTRU may or may not receive the CTS frame transmitted by the receiving WTRU in response to the RTS frame from the transmitting WTRU due to any of the following reasons. The neighbor AP/WTRU may be a hidden node to the receiving WTRU, and hence the CTS frame transmitted by the receiving WTRU may be heard by the transmitting WTRU but not the neighbor WTRU. The CTS frame of the receiving WTRU may be lost due to interference or collision. The receiving WTRU may not have responded to the RTS frame of the transmitting WTRU.

If a CTS frame corresponding to the RTS frame of the transmitting WTRU is not heard after a short inter-frame spacing (SIFS) duration of time, the neighbor AP/WTRU may further monitor the medium for a predetermined additional amount of time to determine if the medium is being used. For example, the neighbor AP/WTRU may monitor the medium for a duration of (SIFS+ΔT) from the reception of an RTS frame. Alternatively, the neighbor AP/WTRU may monitor the medium for an additional (SIFS+ΔT) time duration following the time when the CTS frame was expected. ΔT may be a predefined value or a configurable parameter.

If the medium is found to be idle at the end of a (SIFS+ΔT) duration from the transmission time of the RTS frame, or at the end of a (SIFS+ΔT) duration from the time a CTS frame is expected, the neighbor AP/WTRU may release the medium by resetting the NAV in any or all of the following ways. For example, the neighbor AP/WTRU may transmit a specific frame, for example a contention free (CF)-End frame with the BSS identity (BSSID) field set to its BSSID and the receiver address (RA) field set to the broadcast group address.

FIG. **5** is a diagram of an example CF-End frame transmission **500** by a neighbor WTRU. In the example shown in FIG. **5**, a WTRU **505** may transmit an RTS frame **510** on a primary channel **515**, and an RTS frame **520** on a non-primary channel **525**. In this example, the WTRU **505** may receive a CTS frame **530** on the primary channel **515** after a SIFS duration **535**. If the neighbor WTRU **537** does not receive a CTS frame on the non-primary channel **525** after a (SIFS+ΔT) duration, the neighbor WTRU **537** may transmit a CF-End frame **540** on the non-primary channel **525** to reset the NAV on the non-primary channel. The WTRU may transmit a data frame **550** on the primary channel **515** if the CTS frame **530** was received.

In another example, a new action frame may be defined or any other existing action frame may be modified to reset the NAV. At the end of a monitoring period, if the medium is found to be idle, the neighbor WTRU may transmit the new action frame, or modified existing action frame, that lets other WTRUs in its BSS reset their NAVs.

A NAV reset may be performed by the receiving WTRU. For example, the receiving WTRU may respond to the RTS on the channels where communication may not be possible, in such a way that the WTRUs that set their NAV based on the RTS may reset their NAVs for future communication.

In one example, the receiving WTRU, after receiving an RTS from the transmitting WTRU on the channels that the transmitting WTRU intends to aggregate for wideband transmission, may respond with a CTS frame on those channels where communication is possible and may respond in an alternative manner on the channels where communication may not be possible. The channels where communication may not be possible may be referred to as "non-usable channels" hereafter.

One alternative manner in which the receiving WTRU may respond may be by transmitting a CTS frame even on the non-usable channels. When responding on a non-usable channel, the receiving WTRU may set the Duration field to 0. Any WTRU other than the transmitting WTRU that receives a CTS frame with this Duration value may reset its NAV. Alternatively, the receiving WTRU may set the Duration field in the CTS transmitted on non-usable channels to a value that may be a short duration of time, for example $T_{short}$. $T_{short}$ may be a fixed value or a configurable parameter. Since any WTRU that receives a CTS may set its NAV to the value indicated in the Duration field of the CTS frame, the WTRUs/APs receiving this CTS may backoff for a short duration of time and may be able to access the medium after that. This example may apply to legacy and IEEE 802.11ac WTRUs alike.

In both examples described above, the transmitting WTRU may consider the channel(s) on which a CTS with a duration set to a value other than what is expected for successful communication is received as non-usable. For example, if the Duration field in the CTS frame contains a value other than (Duration field value in the RTS frame—SIFS Time—time required to transmit the CTS frame), the transmitting WTRU may consider the channel(s) on which this CTS frame was received as not available for communication.

In another example, a new action frame may be introduced or an existing action frame may be modified to achieve this purpose. For example, after receiving an RTS from the transmitting WTRU, the receiving WTRU may respond with a CTS on the channels where communication is possible and with the new or modified action frame on the non-usable channels. The WTRUs that receive this new or modified action frame may consider the channel(s) on which this frame was received to be free and available for communication and may reset their NAVs. The transmitting WTRU on reception of this new or modified existing action frame may consider the corresponding channel(s) as unusable.

FIG. **6** is a diagram of an example NAV reset **600** performed by the receiving WTRU in non-usable channels using a CTS frame with the duration field set to 0 or $T_{short}$. FIG. **6** shows a transmitting WTRU **610**, a receiving WTRU **620**, and a neighbor WTRU **630**. The transmitting WTRU **610** may be configured to communicate on a primary channel **615** and a non-primary channel **617**. The receiving WTRU **620** may be configured to communicate on the primary channel **615** and the non-primary channel **617**. The neighbor WTRU may be configured to communicate on the non-primary channel **617**. The transmitting WTRU **610** may transmit an RTS frame **640** on the primary channel **615**, and an RTS frame **645** on the non-primary channel **617**. The receiving WTRU **620**, in response to the RTS frame **640**, may transmit a CTS frame **650** on the primary channel **615** after a SIFS duration **635**. In response to the RTS frame **645**, the receiving WTRU may transmit a CTS frame **655** on the non-primary channel **617** after a SIFS duration **635**. The CTS frame **655** may include a Duration field set to 0 or $T_{short}$. The neighbor WTRU **630** may receive the CTS frame **655** on the non-primary channel **617** and reset its NAV immediately or after $T_{short}$, based on the duration indicated by the Duration field.

A wideband TXOP truncation may be performed. A wideband TXOP may be a TXOP for a medium reservation over one or more channels, for example on a primary channel and one or more non-primary channels. In a wideband TXOP truncation example, all or some of the channels involved in communication may be released when the communication terminates before the end of the wideband TXOP duration. A wideband TXOP truncation may allow other WTRUs/APs, including those in an OBSS, to use the medium on any of the channels of the wideband transmission.

The NAV may be set on the primary and non-primary channels by a device to reserve the medium for a wideband TXOP to transmit packet data. The NAV may be set using any allowed mechanism, for example, RTS and CTS frame exchange, transmitting CTS-to-self frames on the primary and non-primary channels, or by any other method such as transmitting IEEE 802.11n based non-HT duplicate packet formats where the same packet may be transmitted simultaneously on primary and non-primary channels. The device may truncate the TXOP with a CF-End frame if it has no more packet data to transmit. The CF-End frame transmitted by a device may include the BSSID of the BSS to which the device belongs or is associated with. The device may transmit a CF-End frame on each of the channels, for example the primary channel and non-primary channels. If the device transmits on a primary channel and non-primary channels, the device may use the non-HT duplicate mode where the CF-End frame may be transmitted simultaneously on the channels. Alternatively, the CF-End frame on a channel may be transmitted with a BSSID that matches the BSSID of the BSS for which the given channel is a primary channel.

The CF-End frame may be transmitted in a wideband packet format by a WTRU truncating its wideband TXOP where the CF-End frame may span the entire bandwidth of the primary and non-primary channels. In this example, the AP of the BSS to which the WTRU belongs may transmit a CF-End frame after an inter-frame duration, for example a SIFS, in response to the CF-End frame from the WTRU in one or more of the following ways. In a first example, the AP may transmit a CF-End frame with its BSSID on the primary channel. In a second example, the AP may transmit a CF-End frame with its BSSID on the primary and non-primary channels, for example in a non-HT duplicate format. In a third example, the AP may transmit a CF-End frame with its BSSID on the primary channel and a CF-End frame on a non-primary channel with the BSSID of the BSS for which the non-primary channel may be the primary channel.

An AP/WTRU may obtain neighbor AP BSSID information. In one example, all APs in the same neighborhood may obtain neighbor AP information explicitly via a wired backbone or control signaling over the wireless interface. The neighborhood may include the same geographical area, and the APs may belong to the same subnet, for example. In another example, the APs may obtain its neighbor AP information implicitly by monitoring different channels.

When an AP receives a CF-End frame from a device in a neighbor BSS on the primary channel of the AP, where the BSSID in the received CF-End frame does not match the BSSID of the AP, the AP may respond by transmitting a CF-End frame after an inter-frame duration, for example, a SIFS duration, with its own BSSID on the primary channel of the AP.

When an AP receives a CF-End frame from a device in the same BSS on the primary channel of the AP, where the BSSID in the received CF-End frame matches the BSSID of the AP, the AP may respond by transmitting a CF-End frame after an inter-frame duration, for example, a SIFS duration, with its own BSSID on the primary channel of the AP.

A CF-End frame with specific parameters may be set to truncate the TXOP on both primary and non-primary channels. For example, one or more parameters of the CF-End frame may be set so that the TXOP may be truncated both on the primary and the non-primary channels efficiently and may result in better usage of the available bandwidth in both the current and the neighbor BSS.

FIG. **7** is a diagram of an example method **700** for transmitting a CF-End frame with a parameter set to truncate the TXOP on both the primary and non-primary channels. If a non-AP WTRU of the BSS under consideration is the TXOP holder, the non-AP WTRU may transmit one of the following to truncate its TXOP: (1) a CF-End frame with the individual/group bit in a timing advance (TA) field set to '0' on the primary channel or on all primary and non-primary channels, or (2) a CF-End frame with the individual/group bit in the TA field set to '1', on the primary channel or on all primary and non-primary channels. Referring to FIG. **7**, the AP may receive a CF-End frame **710**. The AP may determine **720** whether an individual/group bit in the TA field of the CF-End frame is set to '1'. A CF-End frame with an individual/group bit that is set to '1' may, for example, indicate truncation of the TXOP to all devices, including the OBSS devices, and/or it may indicate a bandwidth in which to transmit the CF-End frame response. If the AP determines that the individual/group bit is set to '1', the AP may respond by transmitting a CF-End frame on the primary and non-primary channels **730**. For example, if the individual/group bit is set to '1', the AP may respond on the same channels that the AP received the CF-End frames or on the bandwidth indicated by the received CF-End frame. When the individual/group bit is set to '1', it may indicate that a bandwidth value is set, and/or that a scrambling sequence is included in the frame which signals the bandwidth value. If the AP determines that the individual/group bit is set to '0', the AP may respond by transmitting a CF-End frame on the primary channel **740**.

In this example, the AP of the BSS to which the WTRU belongs may transmit a CF-End frame after an inter-frame duration, for example a SIFS, in response to the CF-End frame from the WTRU. Alternatively, if the AP itself is a TXOP holder, it may directly transmit a CF-End frame truncating the TXOP. In both the above cases, the AP may set one or more parameters of the CF-End frame in any or all of the

following ways. The AP may transmit the CF-End frame on the primary channel and also the non-primary channels if needed.

The following mechanisms may be adopted independently or in any combination. For example, the AP may set the individual/group bit of the TA field in the CF-End frame to '0' on the primary channel and to '1' on all non-primary channels that may be released, the AP may set the individual/group bit of the TA field in the CF-End frame to '0' on the primary channel, the AP may set the individual/group bit of the TA field in the CF-End frame to '0' on the primary channel and to '0' on all non-primary channels that may be released, the AP may set the individual/group bit of the TA field in the CF-End frame to '1' on all the channels that may be released, (both primary and non-primary channels), and/or the AP may set the duration field of the CF-End frame to a non-zero value.

A WTRU/AP may store the TXOP holder MAC address for the BSS in which it belongs or is associated with. This MAC address may be obtained, for example, from the MAC address included in the frame that initiated a frame exchange sequence or TXOP reservation. The WTRU/AP may determine that the TXOP holder is associated with or belongs to its BSS if either the transmitter or receiver address in the frame, received or transmitted by the TXOP holder, matches the MAC address of the AP of its BSS or BSSID. The WTRU/AP may discard the stored TXOP holder MAC address for its BSS when the NAV timer is zero or is reset. The WTRU/AP may change or update the stored TXOP holder MAC address for its BSS when the NAV timer is set or updated with a new value.

When a non-AP WTRU or AP receives a CF-End frame from a neighbor device on the primary channel of the WTRU, where the BSSID in the received CF-End frame does not match the BSSID of the WTRU, and the individual/group bit in the TA field is set to '1', the WTRU may reset its NAV and consider the medium available for communication. In a variation of this embodiment, the NAV reset may also be conditional upon whether the current NAV was not set by a TXOP holder that belongs to or is associated with its BSS.

When a non-AP WTRU or AP receives a CF-End frame from a neighbor device on the primary channel of the WTRU where the BSSID in the received CF-End frame does not match the BSSID of the WTRU, and the individual/group bit in the TA field is set to '0', the WTRU may reset its NAV and consider the medium available for communication. In a variation of this embodiment the NAV reset may also be conditional upon whether the current NAV was not set by a TXOP holder that belongs to or associated with its BSS.

When an AP receives a CF-End frame from a neighbor device on the primary channel of the AP, where the BSSID in the received CF-End frame does not match the BSSID of the AP but the individual/group bit in the TA field is set to '1', the AP may respond by transmitting a CF-End frame after an inter-frame duration, for example, a SIFS duration, with its own BSSID on the primary channel of the AP. In a variation of this embodiment, the AP response with a CF-End frame may also be conditional upon whether its current NAV was not set by a TXOP holder that belongs to or associated with its BSS. The AP may transmit the CF-End frame after a predetermined duration such as a SIFS, a PIFS, or any other inter-frame duration.

When an AP receives a CF-End frame from a neighbor device on the primary channel of the AP, where the BSSID in the received CF-End frame does not match the BSSID of the AP, and the individual/group bit in the TA field is set to '0', the AP may respond by transmitting a CF-End frame after an inter-frame duration, for example, a SIFS duration, with its own BSSID on the primary channel of the AP. In a variation of this embodiment, the AP response with a CF-End frame may also be conditional upon whether its current NAV was not set by a TXOP holder that belongs to (is associated with) its BSS. The AP may transmit the CF-End frame after predetermined duration such as a SIFS, a PIFS, or any other inter-frame duration.

In the above CF-End frames or CF-End frame sequences, there may be a decision process in the devices that determines if the above CF-End frames or CF-End frame sequences may be accommodated in the remaining duration of the wideband TXOP. The transmission of the CF-End frames or CF-End frame sequences may be conditional on that determination of whether they may be accommodated. For example, the CF-End frames or CF-End frame sequences may not be transmitted if they cannot be accommodated within the initially reserved TXOP duration.

FIG. **8** is a diagram of an example method **800** for wideband TXOP truncation in an OBSS case where an AP **810** may be the TXOP holder. The AP **810** may begin a NAV-set sequence **815** on its primary channel and/or one or more non-primary channels to initiate a TXOP duration **820**. The NAV-set sequence **815** may begin after an EDCA channel access period **825**. After a SIFS duration **830**, the AP **810** may begin an initiator sequence **835**. After a SIFS duration **840**, the AP **810** may transmit a CF-End frame **845** on its primary channel and/or one or more non-primary channels to indicate truncation of the TXOP. The neighbor AP **850** may transmit a CF-End frame **855** to its BSS WTRUs, on its primary channel after a SIFS duration **860** following the reception of a CF-End frame **845** from the AP **810**. The primary channel of the neighbor AP **850** may be a communicating BSS non-primary channel of the AP **810**. The CF-End frame **855** may include the BSSID of the neighbor AP **850**. This method may aid the WTRUs on previously busy channels in both BSSs to reset their NAVs and release the medium for communication.

FIG. **9** is a diagram of an example method **900** for wideband TXOP truncation in an OBSS case where a WTRU **910** may be the TXOP holder. The WTRU **910** may begin a NAV-set sequence **915** on its primary channel and/or one or more non-primary channels to initiate a TXOP duration **820**. The NAV-set sequence **915** may begin after an EDCA channel access period **925**. After a SIFS duration **930**, the WTRU **910** may begin an initiator sequence **935**. After a SIFS duration **940**, the TXOP holding WTRU **910** may transmit a CF-End frame **945** on its primary channel and/or one or more non-primary channels to indicate truncation of the TXOP. The AP **950** of the BSS of this WTRU and the neighbor AP **955** may each transmit a CF-End frame **960**, **965** after a SIFS duration **970** following the WTRU **910** CF-End frame transmission. The CF-End frame **960** and the CF-End frame **965** may each include their corresponding BSSID in the frame. This method may aid the WTRUs on previously busy channels in both BSSs to reset their NAVs and release the medium for communication.

A No CF-End frame method may be implemented. In this example, a VHT device, for example, a WTRU or an AP, that does not have any data to transmit before the end of the initially reserved TXOP may not transmit any CF-End frame to truncate the TXOP. This rule may be applied for VHT devices in one or more of the following scenarios in wideband transmission, or all transmissions regardless of whether they may be wideband or not. This example method may be used to achieve fairness in the medium where all the WTRUs and/or APs that set their NAVs at the beginning of the TXOP may continue to back off until the end of the actual TXOP. In this example, since a CF-End frame is not transmitted, the

TXOP is not truncated and the remaining TXOP duration after data transmission may be wasted. However since no device may access the channel, a level of fairness may be achieved for all devices.

TXOP protection and truncation in multiple primary bandwidth modes are described below. Some WLAN systems may support multiple primary bandwidth modes of transmission. The multiple bandwidth modes may be supported because sometimes only some bandwidth modes are reliable or feasible for communication because of poor wireless link conditions. The IEEE 802.11ah standard operating in the sub 1 GHz spectrum may have BSSs that support operation of multiple primary bandwidth modes namely, 2 MHz and 1 MHz bandwidth modes. The 1 MHz bandwidth mode may be more reliable for communication and offers a longer range than the 2 MHz bandwidth mode. The devices may support an increased communication range with a robust low rate modulation and coding set with repetition, for example, MCS0-rep2, only in 1 MHz mode. It may be required that all devices are capable of receiving in 2 MHz and 1 MHz modes. Higher transmission bandwidths of 4, 8 and 16 MHz may also be supported in IEEE 802.11ah. TXOP truncation mechanisms for multiple primary bandwidth modes using the 2 MHz and 1 MHz primary bandwidth modes are described as an example for convenience. These mechanisms may apply to a general case of multiple primary bandwidth modes.

In a BSS supporting 2 MHz and 1 MHz primary bandwidth modes, there may be WTRUs that may only transmit or receive using the 1 MHz bandwidth mode. This may be because the WTRUs may be capable of only 1 MHz primary bandwidth mode operation, or the WTRUs may be capable of both 2 MHz and 1 MHz primary bandwidth modes of operation, but have a poor channel link with the other device they are communicating with. In this example, only 1 MHz bandwidth mode operation may be feasible for communication and 2 MHz bandwidth mode transmissions may not be received successfully. Note that the other WTRUs in the BSS may be able to communicate using both 2 MHz and 1 MHz primary bandwidth modes.

FIG. **10** is a diagram of an example method **1000** for a WTRU **1010** to obtain a TXOP and reserve the medium for a 2 MHz bandwidth mode frame transmission using an RTS/CTS exchange in a 1 MHz bandwidth mode and truncating the TXOP with a CF-End frame in a 1 MHz bandwidth mode. In FIG. **10**, a WTRU **1010** may reserve the medium **1015** for a 2 MHz bandwidth mode frame transmission with another device that may be capable of both 2 MHz and 1 MHz bandwidth modes. To obtain a TXOP for a 2 MHz bandwidth mode frame transmission, the WTRU **1010** may conduct an RTS-CTS exchange in the 1 MHz bandwidth mode so that WTRUs that transmit or receive using the 1 MHz bandwidth mode may set their NAV in addition to other WTRUs. The RTS-CTS exchange may include the WTRU **1010** transmitting an RTS frame **1020** on a primary 1 MHz channel within the 2 MHz bandwidth, and receiving, after a SIFS duration **1025**, a CTS frame **1030** on the primary 1 MHz channel within the 2 MHz bandwidth in response to the RTS frame **1020**. In this example, when the WTRU **1010** has no more data to transmit, the WTRU **1010** may truncate the TXOP with a CF-End frame **1035** transmission in the 1 MHz bandwidth mode so that WTRUs that transmit or receive using the 1 MHz bandwidth mode may reset their NAV in addition to other WTRUs. In response to such a CF-End frame transmission in the 1 MHz bandwidth mode, an AP (not shown) in a BSS may transmit a CF-End frame **1040** in the 1 MHz bandwidth mode so that all WTRUs in the BSS may reset their NAV and thus may mitigate hidden node problems.

Alternatively, the WTRU may truncate the TXOP with a CF-End frame transmission in the 2 MHz bandwidth mode so that the WTRUs that transmit or receive using the 2 MHz bandwidth mode may reset their NAV in addition to other WTRUs. In response to such a CF-End frame transmission in the 2 MHz bandwidth mode, an AP in a BSS may transmit a CF-End frame in the 1 MHz bandwidth mode so that all WTRUs in the BSS may reset their NAV and thus may mitigate hidden node problems.

FIG. **11** is a diagram of an example method **1100** for a WTRU **1110** to obtain a TXOP and reserve the medium for a 2 MHz bandwidth mode frame transmission using RTS/CTS exchange in both 1 MHz parts of the 2 MHz bandwidth and truncating the TXOP with a CF-End frame in both 1 MHz parts of the 2 MHz bandwidth. A neighbor AP or OBSS may camp on or operate on the non-primary 1 MHz part of the 2 MHz primary channel of the given BSS, using the non-primary 1 MHz part as its primary 1 MHz channel.

Referring to FIG. **11**, a WTRU **1110** may reserve the medium **1115** for a 2 MHz bandwidth mode frame transmission with another device that may be capable of both 2 MHz and 1 MHz bandwidth modes. To obtain a TXOP for a 2 MHz bandwidth mode frame transmission the WTRU **1110** may conduct an RTS-CTS exchange in both 1 MHz parts of the 2 MHz bandwidth so that WTRUs that transmit or receive using the 1 MHz bandwidth mode may set their NAV in addition to other WTRUs, in its BSS and the OBSS.

The RTS-CTS exchange may include the WTRU **1110** transmitting an RTS frame **1120** on the primary 1 MHz channel within the 2 MHz bandwidth, and transmitting an RTS frame **1125** on the non-primary 1 MHz channel within the 2 MHz bandwidth. After a SIFS duration, **1130**, the WTRU **1110** may receive a CTS frame **1135** on the primary 1 MHz channel within the 2 MHz bandwidth, and receive a CTS frame **1140** on the non-primary 1 MHz channel within the 2 MHz bandwidth.

The WTRU **1110** may then transmit its data **1145** on the 2 MHz bandwidth, and receive a response **1150** on the 2 MHz bandwidth after a SIFS duration **1155**. When the WTRU **1110** has no more data to transmit, the WTRU **1110** may truncate the TXOP with a CF-End frame transmission **1160**, **1165** in both 1 MHz parts of the 2 MHz bandwidth or at least in the primary 1 MHz channel within the 2 MHz bandwidth, so that WTRUs that transmit or receive using the 1 MHz bandwidth mode may reset their NAV in addition to other WTRUs, in its BSS and the OBSS, or in the 2 MHz bandwidth mode. In response to such a CF-End frame transmission an AP (not shown) in a BSS may transmit a CF-End frame **1170**, **1175** in both 1 MHz parts of the 2 MHz bandwidth so that all WTRUs in its BSS and OBSS may reset their NAV and thus may mitigate hidden node problems.

FIG. **12**A is a diagram of an example method **1200** for an AP **1210** to obtain a TXOP **1215** and reserve the medium for a 2 MHz bandwidth mode frame transmission using an RTS/CTS exchange in a 1 MHz bandwidth mode and truncating the TXOP with a CF-End frame in the 1 MHz bandwidth mode. In FIG. **12**A, the AP **1210** may reserve the medium for a 2 MHz bandwidth mode frame transmission with a WTRU (not shown) that may be capable of both 2 MHz and 1 MHz bandwidth modes. To obtain a TXOP **1215** for a 2 MHz bandwidth mode frame transmission, the AP may conduct an RTS-CTS exchange in the 1 MHz bandwidth mode so that WTRUs that transmit or receive using the 1 MHz bandwidth mode may set their NAV in addition to other WTRUs. The RTS-CTS exchange may include the AP **1210** transmitting an RTS frame **1220** on a primary 1 MHz channel within the 2 MHz bandwidth, and receiving, after a SIFS duration **1225**, a

CTS frame **1230** on the primary 1 MHz channel within the 2 MHz bandwidth in response to the RTS frame **1220**. The CTS frame **1230** may be a short CTS frame. A short CTS frame may be a shortened version of the CTS frame. The short CTS frame may only include a PHY preamble, and may not include MAC layer fields. The frame format of the short CTS may comprise a short training field (STF), a long training field (LTF) and a signal (SIG) field in that order. The SIG field of the short CTS frame may include an indication that the frame is a short CTS frame. The short CTS frame may include other indications or signaling requirements for the short CTS frame such as CTS ID to indicate the intended receiver of the CTS, a bandwidth when the CTS may need to indicate the available bandwidth at the receiver side within the bandwidth indicated by RTS, and a duration for NAV setting.

The AP **1210** may then transmit its data **1235** on the 2 MHz bandwidth, and receive a response **1240** on the 2 MHz bandwidth after a SIFS duration **1245**. When the AP **1210** has no more data to transmit, the AP **1210** may truncate the TXOP **1215** with a CF-End frame **1245** in the 1 MHz bandwidth mode so that WTRUs that transmit or receive using the 1 MHz bandwidth mode may reset their NAV in addition to other WTRUs.

FIG. **12**B is a diagram of an example scenario **1250** where a neighbor AP or OBSS may camp on or operate on the non-primary 1 MHz part of the 2 MHz primary channel of the given BSS, using non-primary 1 MHz part as its primary 1 MHz channel. In this example, an AP may reserve the medium for a 2 MHz bandwidth mode frame transmission with an RTS/CTS exchange in both 1 MHz parts of the 2 MHz bandwidth and truncate the TXOP with a CF-End frame in both 1 MHz parts of the 2 MHz bandwidth. To handle such a scenario, the AP **1210** may transmit another CF-End frame **1260** simultaneously on the non-primary 1 MHz channel/part within the 2 MHz to reset the NAV for WTRUs in a neighbor BSS or OBSS. In addition, to obtain a TXOP **1215** for a 2 MHz bandwidth mode frame transmission, the AP **1210** may conduct an RTS-CTS exchange in both 1 MHz parts of the 2 MHz bandwidth so that WTRUs that transmit or receive using the 1 MHz bandwidth mode may set their NAV in addition to other WTRUs, in its BSS and the OBSS. For example, the AP **1210** may transmit an RTS frame **1270** on the non-primary 1 MHz part within the 2 MHz bandwidth, and receive a CTS frame **1280** after a SIFS duration **1225**. The CTS frame **1280** may be a short CTS frame.

In the above embodiments, the RTS and CTS frames transmitted in the 1 MHz bandwidth mode may include one or more indicators that indicate the transmission bandwidth mode for which TXOP or medium reservation is requested. The one or more indicators may indicate a 2 MHz or a 1 MHz bandwidth mode for which a TXOP is requested. Such indicators may be included in any part of the frame, for example, in the signal (SIG) field of the physical layer (PHY) preamble, the MAC header, or scrambling sequence used in the frame. This may be useful in scenarios where unused bandwidth may be reused.

In the above embodiments, the CF-End frames transmitted in the 1 MHz bandwidth mode may include one or more indicators that indicate that the TXOP being truncated is for a given bandwidth mode. The one or more indicators may indicate a 2 MHz or a 1 MHz bandwidth mode for which a TXOP is being truncated. Such indicators may be included in any part of the frame, for example, in the SIG field of a PHY preamble, the MAC header, or scrambling sequence used in the frame. This may be useful in scenarios where unused bandwidth may be reused.

In one embodiment of signaling bandwidth information in frames which may be used for RTS, CTS and CF-End frames, a device may set the individual/group bit in the TA field of a frame to '0' to indicate a 1 MHz bandwidth. Alternatively, the device may set the individual/group bit in the TA field of a frame to '1' to indicate a 2 MHz or higher bandwidth, for example 4 MHz, 8 MHz, or 16 MHz, where the actual bandwidth may be signaled in combination with other indications. An example indication may include a scrambling sequence used in the frame. In such an example, 1 bit may be used to indicate static and dynamic bandwidth and 2 bits may be used to indicate 2 MHz, 4 MHz, 8 MHz, and/or 16 MHz.

In the above embodiments, the CF-End frames may have the individual/group bit in the TA field of the CF-End frame be set appropriately according to the mechanisms discussed earlier.

The RTS-CTS exchange mechanism examples in the above embodiments, when applied to wideband transmissions, for example, 4 MHz, 8 MHz, or 16 MHz, may be repeated. These wideband transmissions may be repeated using the non-HT duplicate format in each primary mode bandwidth, for example, two 2 MHz bandwidths within a 4 MHz wideband.

In a variation of the embodiments above, the RTS-CTS frame exchange sequence may be replaced by any other valid NAV setting frame sequence exchange such as a CTS-to-self, a short CTS-to-self frame, an initial frame, or a data packet. An initial frame may be an initiating frame such as a PSMP frame or a Null Data Packet Announcement frame for channel sounding purposes. In order to obtain a TXOP for a 2 MHz bandwidth mode frame transmission, a WTRU may transmit a CTS-to-self frame in the 1 MHz bandwidth mode so that WTRUs that only transmit or receive using the 1 MHz bandwidth mode may set their NAVs in addition to other WTRUs. In the above embodiments the RTS-CTS frame exchange may be also be replaced by an RTS-short CTS frame exchange.

Even though the above embodiments have been described with the 2 MHz and 1 MHz primary bandwidth modes as an example for convenience, they may be applicable to the general case of multiple primary bandwidth modes. The 1 MHz primary bandwidth mode may represent more reliable primary bandwidth modes or the most reliable primary bandwidth mode, for example, MCS0-Rep2 PHY transmission mode of 1 MHz in IEEE 802.11ah, and the 2 MHz primary bandwidth mode may represent higher primary bandwidth modes that may be less reliable for communication. An MCS02-Rep2 transmission may use BPSK modulation with ½ code rate and two times repetition. In this example, the RTS-CTS frames and the CF-End frames may be signaled in the more reliable primary bandwidth modes or in the most reliable primary bandwidth mode, for example, MCS0-Rep2 PHY transmission mode of 1 MHz in IEEE 802.11ah.

An 802.11ah BSS may support both 1 MHz and 2 MHz primary modes of operation. Therefore it may need some channel selection methods for the BSS. The AP may follow one or more of the following methods to establish an 802.11ah BSS. These methods may aid in the coexistence of two or more BSSs in the same neighborhood. In one example, the primary 1 MHz, 2 MHz, 4 MHz or 8 MHz channel for an 802.11ah AP may be the channel within the operating channel width of the BSS that is used to transmit 1 MHz, 2 MHz, 4 MHz or 8 MHz frames/packets, respectively.

A secondary 1 MHz channel for an 802.11ah AP with a 2 MHz operating channel width may be a 1 MHz channel in its operating channel width that does not overlap with its primary 1 MHz channel. A secondary 2 MHz channel in an 802.11ah BSS may be a 2 MHz subchannel adjacent to the primary 2 MHz channel that together form the primary 4 MHz channel.

A secondary 4 MHz channel in an 802.11ah BSS may be a 4 MHz subchannel adjacent to the primary 4 MHz channel that together form the primary 8 MHz channel. A secondary 8 MHz channel in an 802.11ah BSS may be an 8 MHz subchannel adjacent to the primary 8 MHz channel that together form the primary 16 MHz channel.

An AP may scan a set of channels that are potentially affected by 802.11ah BSS operation for existing BSSs before starting an 802.11ah BSS. The AP may scan a channel for a specific duration and more than once if needed. If an AP starts an 802.11ah BSS that occupies some or all channels of any existing BSSs, the AP may select a primary channel of the new 802.11ah BSS such that a primary 2 MHz channel may be identical to the 2 MHz primary channel of any one of the existing BSSs or a primary 1 MHz channel may be identical to the 1 MHz primary channel of any one of the existing BSSs.

In a BSS with a 4 MHz, 8 MHz, or 16 MHz operating channel width, the selected 2 MHz primary channel, from among the channels on which no beacons are detected during scanning, may not be identical to the secondary 2 MHz channel of any existing BSSs with a 4 MHz, 8 MHz or 16 MHz operating channel width and/or may not overlap with the secondary 4 MHz channel of any existing BSSs with a 16 MHz operating channel width. In a BSS with a 2 MHz operating channel width, the selected 2 MHz primary channel, from among the channels on which no beacons are detected during scanning, may not be identical to the secondary 2 MHz channel of any existing BSSs with a 4 MHz, 8 MHz or 16 MHz operating channel width and/or may not overlap with the secondary 4 MHz channel of any existing BSSs with a 16 MHz operating channel width. In a BSS with a 1 MHz operating channel width, the selected 1 MHz primary channel, from among the channels on which no beacons are detected during scanning, may not overlap with the secondary 2 MHz channel of any existing BSSs with a 4 MHz, 8 MHz or 16 MHz operating channel width and/or may not overlap with the secondary 4 MHz channel of any existing BSSs with a 16 MHz operating channel width.

An AP operating in an 802.11ah BSS with a 4 MHz, 8 MHz or 16 MHz operating channel width, in response to detecting a BSS in the neighborhood whose primary channel is the secondary 2 MHz channel of the AP, may switch to 2 MHz operating channel width and/or move to a different channel set. An AP operating in an 802.11ah BSS with a 2 MHz, 4 MHz, 8 MHz or 16 MHz operating channel width, in response to detecting a BSS in the neighborhood whose primary channel is the secondary 1 MHz channel of the AP, may switch to 1 MHz operating channel width and/or move to a different channel set.

In a spectrum where legacy devices operate, for example, as in IEEE 802.11ac devices operating in a 5 GHz bandwidth with legacy IEEE 802.11n devices, the bandwidth and static/dynamic indications may support compatibility with legacy devices. The bandwidth and static/dynamic indications may be used in control frames, for example, in RTS and CTS exchanges for wideband TXOP reservation. Because of the constraint for legacy support, the bandwidth and static/dynamic indications for IEEE 802.11ac were designed so that the last three bits within the first 7 bits of the scrambling sequence used in a frame may be used for bandwidth and static/dynamic indications. One bit may be used for a static/dynamic indication, and two bits may be used for a bandwidth indication of 20 MHZ, 40 MHz, 80 MHz or 160 MHz/80 MHZ+80 MHz. To indicate that the first 7 scrambled bits are modified the individual/group bit in the TA field of the control frame, for example, an RTS frame, may be set to 1.

Using the three bits in the scrambling sequence for signaling may reduce the effectiveness of the scrambling function. This problem may be eliminated by exploiting the fact that in the new spectrum being allocated for a WLAN, for example, below 1 GHz as in IEEE 802.11ah, there is no requirement of compatibility with legacy devices. Two bits in the SIG field of the PHY preamble may be used for a bandwidth indication of 2 MHz, 4 MHz, 8 MHz or 16 MHz/8 MHZ+8 MHz. Note that the bandwidths of IEEE 802.11ah may be obtained from IEEE 802.11ac by scaling down with a factor of 10. To indicate whether the bandwidth is Static/Dynamic an individual/group bit may be included in the TA field of the control frame, for example, the bit may be set to 1 to indicate a dynamic bandwidth and 0 to indicate a static bandwidth.

In another method of signaling bandwidth information for 1 MHz, 2 MHz, 4 MHz, 8 MHz, and 16 MHz, a device may set the individual/group bit in the TA field of a frame to '0' to indicate a 1 MHz bandwidth. Alternatively, the device may set the individual/group bit in the TA field of a frame to '1' to indicate a 2 MHz or higher bandwidth, for example, 4 MHz, 8 MHz, or 16 MHz, where the actual bandwidth may be signaled in combination with other indications, for example, in a scrambling sequence used in the frame. In this example, 1 bit may be used to indicate static and dynamic bandwidth and 2 bits may be used to indicate 2 MHz, 4 MHz, 8 MHz, and 16 MHz.

The WTRU/AP behavior for this solution is as follows. A WTRU/AP may set the individual/group bit in the TA field of a control frame to indicate static/dynamic bandwidth, for example, the bit may be set to 1 to indicate dynamic bandwidth and 0 to indicate static bandwidth. A WTRU/AP may set the two bits for a bandwidth indication of 2 MHz, 4 MHz, 8 MHz or 16 MHz/8 MHZ+8 MHz in the SIG field of the PHY preamble of a control frame. Thus, in a wideband TXOP reservation protocol exchange, a WTRU/AP may transmit an RTS with three bits set as described above to indicate the desired bandwidth and whether it is static/dynamic. In response to this in the static case, a WTRU/AP may transmit a CTS frame including a bandwidth indication, if all of the bandwidth is available as requested in the RTS. In the dynamic case, a WTRU/AP may respond by transmitting a CTS frame including a bandwidth indication on the available channels in the bandwidth requested/indicated in the RTS frame.

Even though the above embodiments have been described with the 2 MHz primary bandwidth mode as an example for convenience, the embodiments may be applicable to the general case of any primary bandwidth mode.

Solutions are described herein that may provide a remedy for the deficiencies in the basic truncation of TXOP mechanism using CF-End frames.

As described in FIG. **4**, the NAV counter at WTRU**3** may be prematurely cancelled when it receives a CF-End frame from a first WTRU, although the most recent value of the NAV counter at the first WTRU may have been updated by a medium reservation frame from another WTRU that may be out of the radio range of the first WTRU. FIG. **13** is a diagram of an example packet exchange sequence **1300** similar to the one illustrated in FIG. **4**, however, with the enhancement such that the NAV counter at the other WTRU may no longer be cancelled prematurely due to the extra check on the duration field of the CF-End frame by the receiving WTRUs of the CF-End frame.

FIG. **13** shows a first BSS (BSS**1**) **1310** and a second BSS (BSS**2**) **1320**. As shown in FIG. **13**, AP**1** **1330** and WTRU**1** **1340** may belong to BSS**1** **1310**; AP**2** **1350** and WTRU**2** **1360** may belong to BSS**2** **1320**; and WTRU**3** **1370** may belong to

BSS1 **1310** or it may belong to another overlapping BSS (OBSS) BSS3 **1375** started by AP3 **1380**.

As shown in FIG. **13**, at T=0 ms, WTRU1 **1340** may transmit an RTS frame **1345** to reserve the medium for 3 ms, and set the NAV counter at WTRU3 **1380** to be 3 ms. AP1 **1330** may respond with a CTS frame **1335**, after which the WTRU1 **1340** may start to transmit its data frame **1347** to AP1 **1330**. AP1 **1330** may subsequently transmit an acknowledgement (ACK) **1337** of the reception of the data packet **1347**. At time T=1.5 ms, AP2 **1350**, without being able to hear the ACK **1337** transmitted by AP1 **1330**, may transmit an RTS frame **1355** to WTRU2 **1360**. When WTRU2 **1360** receives the RTS frame **1355** from AP2 **1350**, it may respond with a CTS frame **1365** to reserve the medium for 5 ms, and may update the NAV counter at WTRU3 **1370** to be 5 ms. AP2 **1350**, after receiving the CTS frame **1365** from WTRU2 **1360**, may start transmitting its data packet **1357** for WTRU2 **1360**. At T=1.7 ms, WTRU1 **1340**, which may have finished all of its transmissions, may transmit a CF-End frame **1349** to indicate truncation of its TXOP. In this example method, a value may be included in the duration field of the CF-End frame **1349**, which may be currently set to "0". When WTRU1 **1340** completes all transmissions and still has a TXOP remaining, it may transmit the CF-End frame **1349** with its duration field set as follows:

$$\text{Duration_CF-End} = \text{Remainder_TXOP} - \text{Length_CF-End_Frame}, \quad \text{Equation (2)}$$

where Remainder_TXOP is the time remaining in the TXOP of which the holder is the transmitting WTRU of the CF-End frame, and Length_CF-End_Frame is the length in time of the CF-End frame.

WTRU3 **1370** may receive CF-End frame **1349** and compare its NAV counter value to the duration value contained in the CF-End frame **1349**. If NAV≤Duration_CF-End, NAV is set to 0. Alternatively, NAV is set to 0 if NAV=Duration_CF-End. Otherwise, the received CF-End frame may be ignored. Note that an AP may transmit a CF-End frame with its duration field set as Duration_CF-End=Remainder_TXOP−Length_CF-End_Frame to indicate truncation of its TXOP.

In a second example, an additional NAV counter referred to as Previous NAV value (P_NAV) may be used in the MAC Layer of WTRUs, where P_NAV may be used to set the duration field of the CF-End frame to "Remainder_TXOP−Length_CF-End_Frame". The P_NAV counter may be used to record previous NAV counter values which may in turn be used to prevent premature cancellation of medium reservations. By definition, P_NAV≤NAV. The P_NAV counter, if its value is non-zero, may follow the same count-down process as the NAV counter.

The AP/WTRU behavior may be as follows. When an AP/WTRU receives a packet P that contains medium reservation time T, it may compare its P_NAV, NAV values to the value of T. For example, for NAV>T, if P_NAV>T, ignore P. Otherwise, set P_NAV=T. In another example, for NAV=T, if P_NAV<T, set P_NAV=T. Otherwise, ignore P. In yet another example, for NAV<T, set P_NAV=NAV, and set NAV=T. These examples may include an adjustment for timing inaccuracies, propagation delays and clock drifts, and the like.

When a WTRU or AP completes all transmissions and still has TXOP left, it may transmit a CF-End frame with its Duration Field set to the value Duration_CF-End=Remainder_TXOP−Length_CF-End_Frame. When a WTRU receives a CF-End frame, it may compare its P_NAV, NAV counter values to the duration value included in the CF-End frame.

In a NAV<Duration_CF-End example, the received CF-End frame may be ignored. For NAV=Duration_CF-End, if P_NAV#0, the WTRU may set NAV=P_NAV and set P_NAV=0. If P_NAV=0, the WTRU may set NAV=0.

In a NAV>Duration_CF-End example, if P_NAV>Duration_CF-End, the received CF-End frame may be ignored. If P_NAV=Duration_CF-End, the WTRU may set P_NAV=0. If P_NAV<Duration_CF-End, the received CF-End frame may be ignored. These examples may include an adjustment for timing inaccuracies, propagation delays and clock drifts, and the like.

FIG. **14** is a diagram of an example method **1400** for a WTRU/AP storing or saving the TXOP holder MAC address for the BSS in which it belongs or is associated. Referring to FIG. **14**, the WTRU/AP may obtain **1410** a transmit (Tx) and receive (Rx) MAC address of a frame from a TXOP holder. This MAC address may be obtained for example from the MAC address included in the frame that initiated a frame exchange sequence or TXOP reservation. The WTRU/AP may determine **1420** whether the TXOP holder is associated with or belongs to its BSS if either the Tx or Rx MAC address in the frame received or transmitted by the TXOP holder matches the MAC address of the AP of its BSS or BSSID.

The WTRU/AP may determine **1430** whether the NAV is updated if the Tx or Rx MAC address matches the MAC address of the AP or BSSID. If the NAV is updated, the WTRU/AP may determine **1440** whether the TXOP holder MAC address from the frame matches a stored MAC address. If the TXOP holder MAC address matches a stored MAC address, the WTRU/AP may determine **1450** whether the NAV timer has been reset. If the NAV timer is zero or has been reset, the WTRU/AP may discard **1460** the TXOP holder MAC address. If the TXOP holder MAC address does not match a stored MAC address, the WTRU/AP may change or update **1470** the stored TXOP holder MAC address for its BSS when the NAV timer is set or updated with a new value.

In an example variation of this embodiment, a WTRU/AP may also store/save and maintain the TXOP holder MAC address when the TXOP holder does not belong to its BSS. This may be separate from the saved or stored TXOP holder MAC address for its BSS. The WTRU/AP may determine that the TXOP holder is not associated with, or does not belong to, its BSS if neither the transmitter nor receiver address in the frame received or transmitted by the TXOP holder matches the MAC address of the AP of its BSS or BSSID.

In this example, the WTRU/AP may maintain a BSS NAV and a Non-BSS NAV. The BSS NAV may be set or updated when the TXOP holder is associated with the same BSS as the WTRU/AP. The non-BSS NAV may be set or updated when the TXOP holder is not associated with the same BSS as the WTRU/AP. The WTRU/AP may attempt to initiate medium access procedure only if both of its NAVs, BSS NAV and Non-BSS NAV timers are zero or reset.

The WTRU/AP behavior for this solution is described below. If a WTRU/AP receives a CF-End frame with a BSSID that does not match its own then it may not reset its BSS NAV and may reset its non-BSS NAV. If a WTRU/AP receives a CF-End frame with a BSSID that does match its own, then it may reset its BSS NAV and may not reset its non-BSS NAV.

In another example variation of this embodiment, if a WTRU receives a CF-End frame with a BSSID that does match its own, then it may reset its BSS NAV, and may reset its non-BSS NAV. This behavior may be implemented as part of the system design or made configurable as part of deployment or operation that is configurable by AP for the entire BSS, or configurable by WTRU/AP autonomously. Essen-

tially, this variation of the embodiment may allow aggressive operation of devices by ignoring neighbor BSS transmissions.

In another example, if a WTRU/AP receives a CF-End frame with a BSSID that does not match its own, then it may not reset its NAV if the NAV was set by a TXOP holder that does belong to the same BSS. Moreover, the WTRU/AP may reset the NAV if the NAV was not set by a TXOP holder in the same BSS. Note that a WTRU/AP may store the TXOP holder address for the BSS, and therefore may know whether the current NAV was set by a TXOP holder that belongs to its BSS or not.

If a WTRU/AP receives a CF-End frame with a BSSID that does match its own, then it may reset the NAV if the NAV was set by a TXOP holder in the same BSS. Moreover, the WTRU/AP may not reset its NAV if the NAV was not set by a TXOP holder that belongs to the same BSS. Note that a WTRU/AP may store the TXOP holder address for the BSS and therefore may know whether the current NAV was set by a TXOP holder that belongs to its BSS or not.

In a variation of this embodiment, if a WTRU receives a CF-End frame with a BSSID that does match its own, then it may reset the NAV if the NAV was set by a TXOP holder in the same BSS. Moreover, the WTRU may reset its NAV if the NAV was not set by a TXOP holder that belongs to the same BSS. This behavior may be implemented as part of the system design or made configurable as part of deployment or operation that is configurable by AP for the entire BSS, or configurable by a WTRU/AP autonomously. This variation of the embodiment may allow aggressive operation of devices by ignoring neighbor BSS transmissions.

In all of the above proposed embodiments, a device may transmit a CF-End frame if there is sufficient time left in the TXOP duration to accommodate the CF-End frame duration and associated SIFS duration. There may be a decision process in the devices that determines if the above CF-End frames or CF-End frame sequences may be accommodated in the remaining duration of the wideband TXOP. The transmission of the CF-End frames or CF-End frame sequences may be conditional on that determination of whether they may be accommodated. For example, the CF-End frames may not be transmitted if they cannot be accommodated within the initially reserved TXOP duration.

In all of the above proposed mechanisms/embodiments, when a WTRU/AP receives a CF-End with a non-matching BSSID, may take further action to clear its NAV based on a check that its NAV was not set by a device in its own BSS. In all the above proposed embodiments, when an AP receives a CF-End frame with a non-matching BSSID, the AP may take further action to transmit a subsequent CF-End frame with its own BSSID based on a check that NAV was not set by a device in its own BSS.

In all of the above proposed embodiments, when a WTRU/AP receives a CF-End frame with a non-matching BSSID and with the individual/group bit of the TA field in the CF-End frame set to a value (0 or 1), the WTRU/AP may take further action to clear its NAV based on a check that its NAV was not set based on a transmission by a device in its own BSS. In all the above proposed embodiments, when an AP receives a CF-End frame with a non-matching BSSID and with the individual/group bit of the TA field in the CF-End frame set to a value (0 or 1), the AP may take further action by transmitting a subsequent CF-End frame with its own BSSID based on a check that its NAV was not set based on transmission by a device in its own BSS.

As an alternative in all the above proposed embodiments, a WTRU or AP may transmit a CF-End frame with the BSSID field that may include its own MAC address indicating the identity of the transmitter of the CF-End frame. In such an alternative, a device, may check to see if the MAC address of the transmitter of the CF-End frame matches the TXOP holder address stored in the device. If there is a match then the device receiving the CF-End frame may reset its NAV.

Although features and elements are described above in particular combinations, one of ordinary skill in the art will appreciate that each feature or element may be used alone or in combination with any of the other features and elements. In addition, the embodiments described herein may be implemented in a computer program, software, or firmware incorporated in a computer-readable medium for execution by a computer or processor. Examples of computer-readable media include electronic signals, (transmitted over wired or wireless connections), and computer-readable storage media. Examples of computer-readable storage media include, but are not limited to, a read only memory (ROM), a random access memory (RAM), a register, a cache memory, a semiconductor memory device, a magnetic media, (e.g., an internal hard disc or a removable disc), a magneto-optical media, and an optical media such as a compact disc (CD) or a digital versatile disc (DVD). A processor in association with software may be used to implement a radio frequency transceiver for use in a WTRU, UE, terminal, base station, Node-B, eNB, HNB, HeNB, AP, RNC, wireless router or any host computer.

What is claimed is:

**1**. A method for use in a first wireless transmit/receive unit (WTRU), the method comprising:

maintaining a network allocation vector (NAV);

receiving a contention free (CF)-End frame from a second WTRU, wherein the CF-End frame includes a duration field and a basic service set identifier (BSSID) field indicating a medium access control (MAC) address associated with an access point (AP), wherein the BSSID field includes an individual/group bit; and

on a condition that the individual/group bit of the BSSID field has a value of one (1), determining that a scrambling sequence of the CF-End frame indicates a bandwidth associated with a transmit opportunity (TXOP) being truncated by the second WTRU and resetting the NAV.

**2**. The method of claim **1** further comprising:

updating the NAV of the first WTRU based on a value set in the duration field of the received CF-End frame.

**3**. The method of claim **1** further comprising:

maintaining a TXOP holder MAC address for a basic service set (BSS) based on a transmitter address in a received frame from the TXOP holder.

**4**. The method of claim **1** further comprising:

maintaining a TXOP holder MAC address for a basic service set (BSS) based on a receiver address in a received frame from the TXOP holder.

**5**. The method of claim **1** further comprising:

maintaining a TXOP holder MAC address for a basic service set (BSS) based on the duration field in a received frame from the TXOP holder.

**6**. The method of claim **1** further comprising:

receiving a second CF-END frame from the AP; and

determining whether to attempt to access a wireless medium based on the NAV.

**7**. A first wireless transmit/receive unit (WTRU) comprising:

a processor configured to maintain a network allocation vector (NAV);

a receiver configured to receive a contention free (CF)-End frame from a second WTRU, wherein the CF-End frame includes a duration field and a basic service set identifier (BSSID) field that indicates a medium access control (MAC) address associated with an access point (AP), wherein the BSSID field includes an individual/group bit;

wherein on a condition that the individual/group bit of the BSSID field has a value of one (1), the processor is further configured to determine that a scrambling sequence of the CF-End frame indicates a bandwidth associated with a transmit opportunity (TXOP) being truncated by the second WTRU and reset the NAV.

**8**. The first WTRU of claim **7**, wherein the processor is further configured to update the NAV of the first WTRU based on a value set in the duration field of the received CF-End frame.

**9**. The first WTRU of claim **7**, wherein the processor is further configured to maintain a TXOP holder MAC address for a basic service set (BSS) based on a transmitter address in a received frame from the TXOP holder.

**10**. The first WTRU of claim **7**, wherein the processor is further configured to maintain a TXOP holder MAC address for a basic service set (BSS) based on a receiver address in a received frame from the TXOP holder.

**11**. The first WTRU of claim **7**, wherein the processor is further configured to maintain a TXOP holder MAC address for a basic service set (BSS) based on the duration field in a received frame from the TXOP holder.

**12**. The first WTRU of claim **7**, wherein the receiver is further configured to receive a second CF-END frame from the AP, and wherein the processor is further configured to determine whether to attempt to access a wireless medium based on the individual/group bit of the BSSID field.

* * * * *