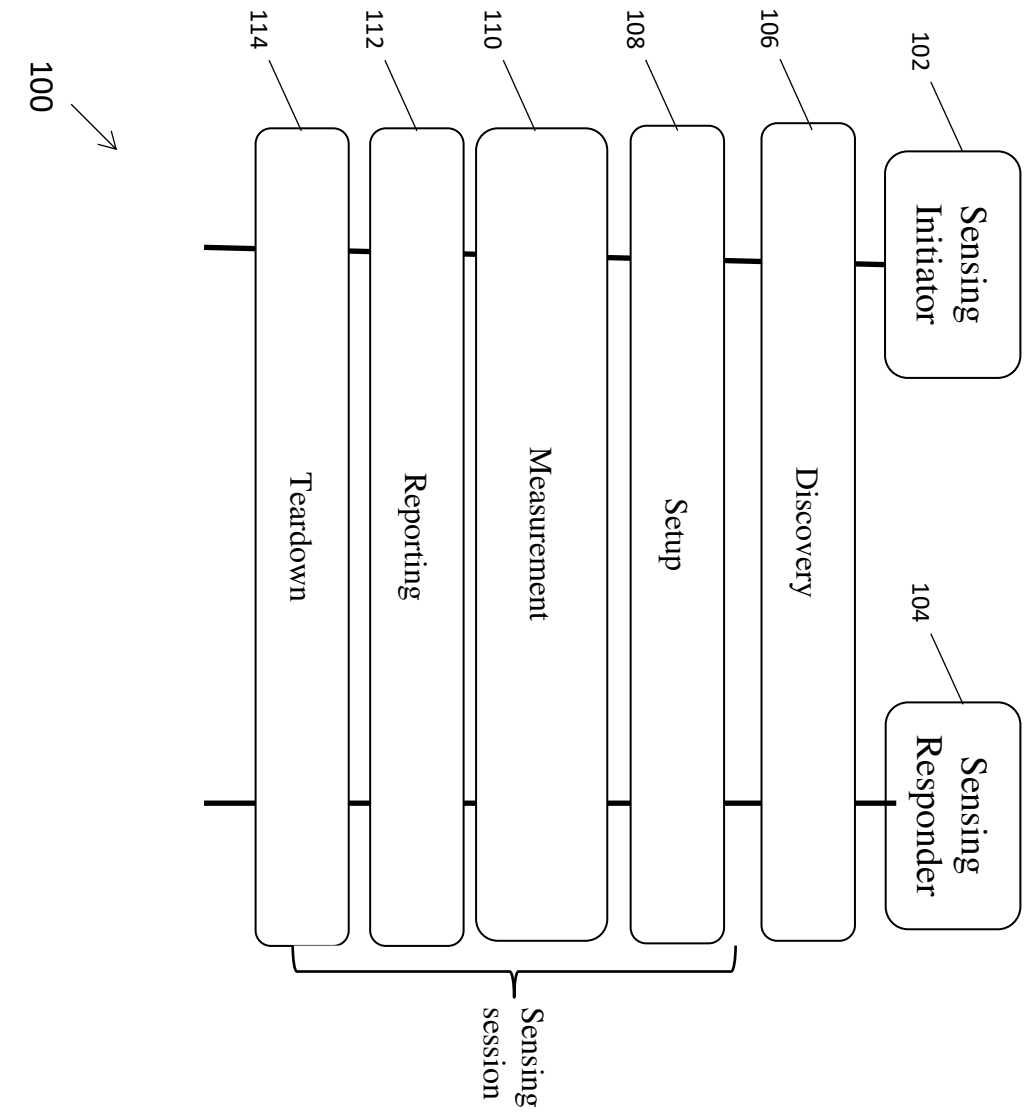

100
102
Sensing Initiator
104
Sensing Responder
106
Discovery
108
Setup
110
Measurement
112
Reporting
114
Teardown
Sensing session

Figure 1

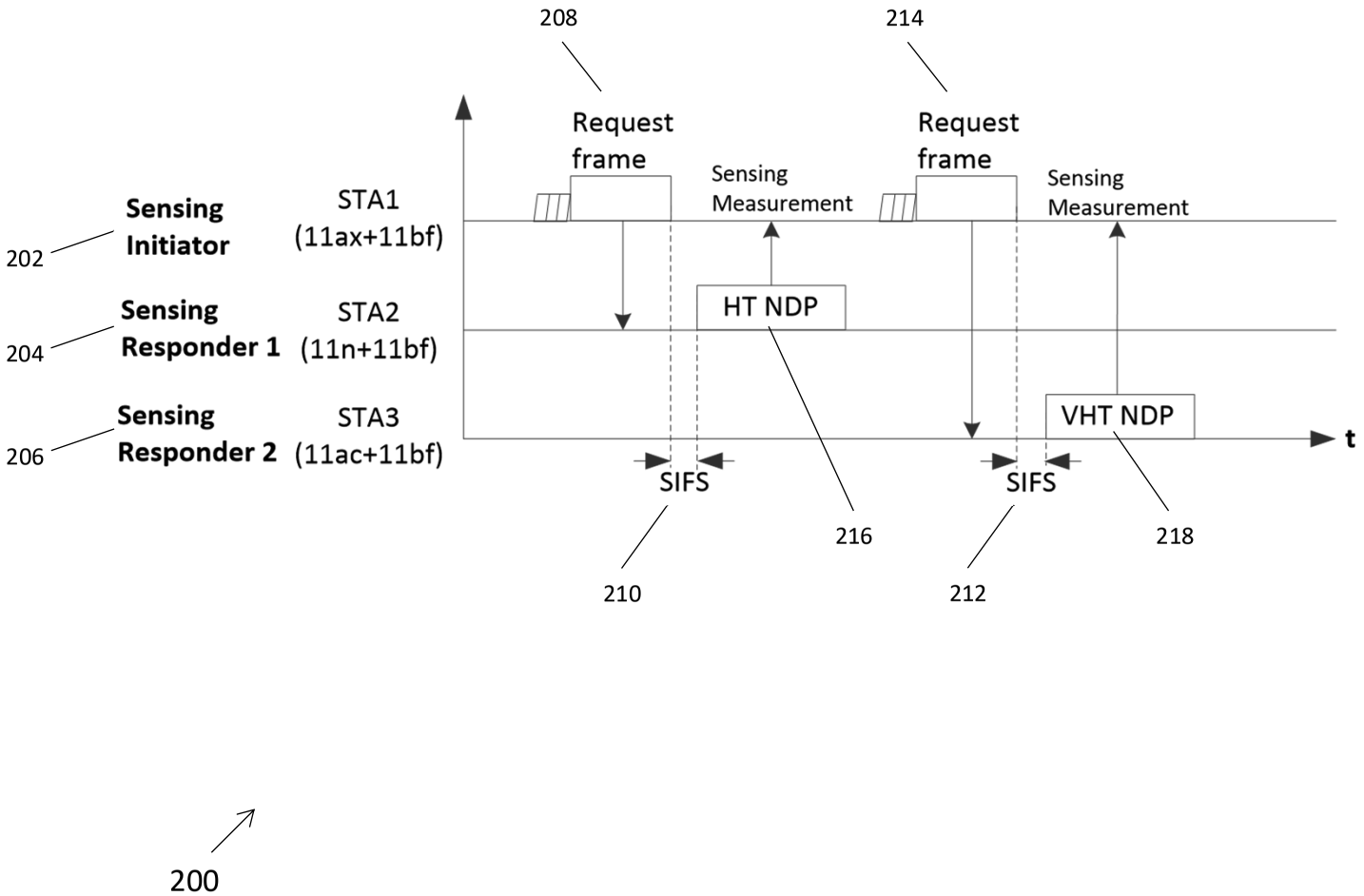

208
214
Request frame
Request frame
Sensing Measurement
Sensing Measurement
Sensing Initiator
STA1 (11ax+11bf)
202
Sensing Responder 1
STA2 (11n+11bf)
204
HT NDP
Sensing Responder 2
STA3 (11ac+11bf)
206
VHT NDP
t
SIFS
SIFS
216
218
210
212
200

Figure 2

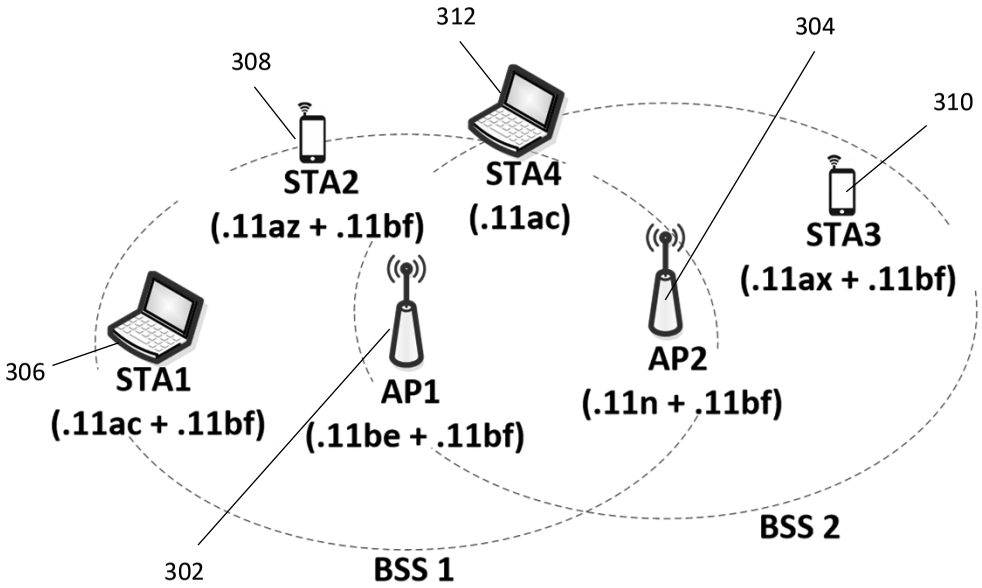
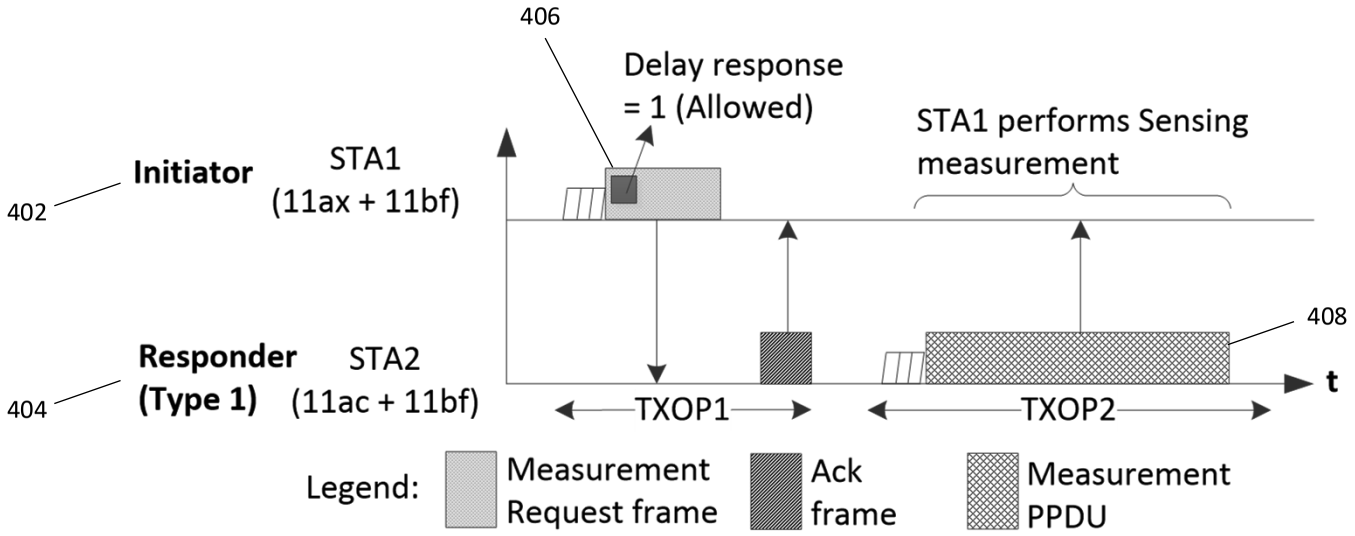

312
304
308
310
STA2
(.11az + .11bf)
STA4
(.11ac)
STA3
(.11ax + .11bf)
306
STA1
(.11ac + .11bf)
AP1
(.11be + .11bf)
AP2
(.11n + .11bf)
BSS 2
302
BSS 1
300

Figure 3


406
Delay response
= 1 (Allowed)
STA1 performs Sensing
measurement
Initiator
STA1
(11ax + 11bf)
402
Responder
(Type 1)
STA2
(11ac + 11bf)
404
408
t
TXOP1
TXOP2
Legend:
Measurement
Request frame
Ack
frame
Measurement
PPDU

400

Figure 4

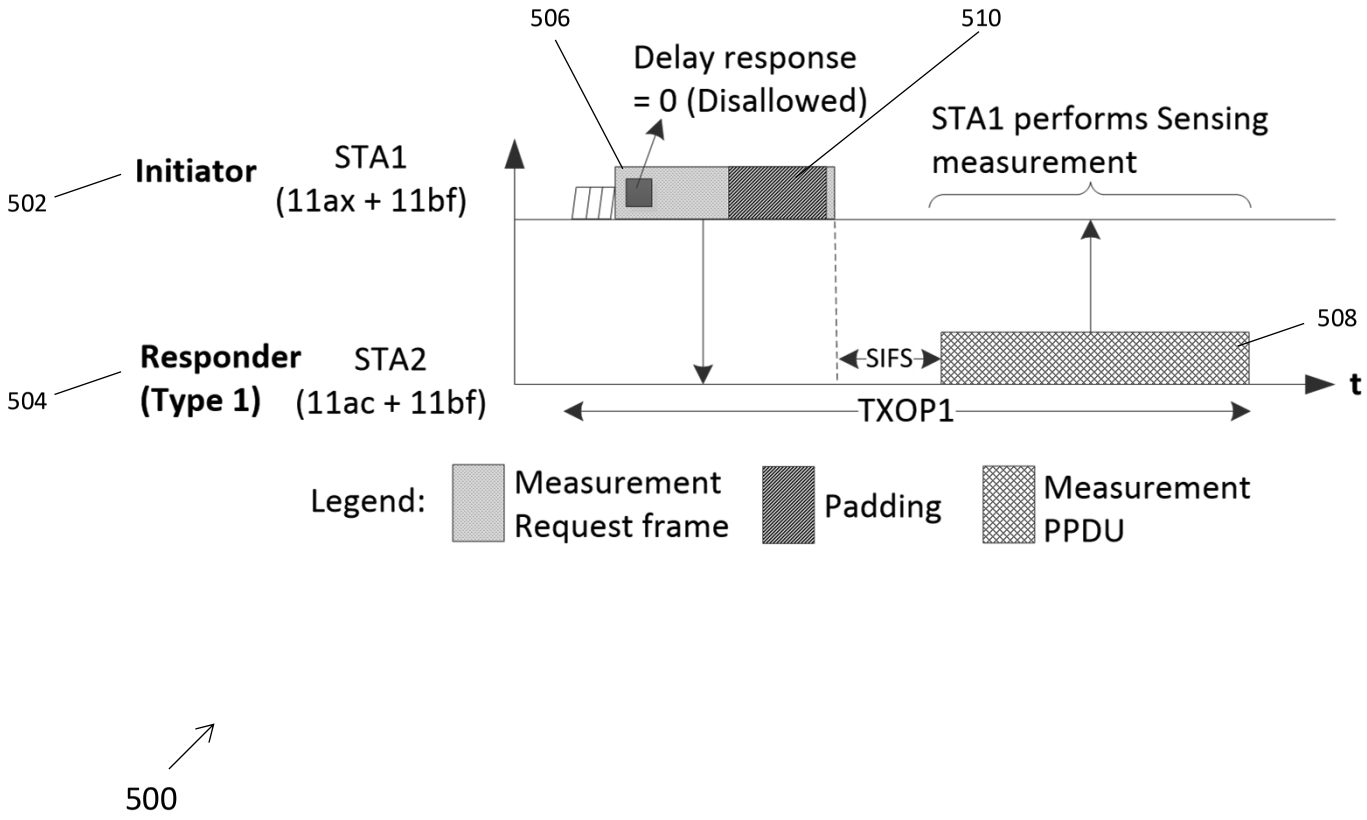

506
510
Delay response
= 0 (Disallowed)
STA1 performs Sensing
measurement
502
Initiator
STA1
(11ax + 11bf)
508
504
Responder
(Type 1)
STA2
(11ac + 11bf)
SIFS
t
TXOP1
Legend:
Measurement
Request frame
Padding
Measurement
PPDU
500

Figure 5

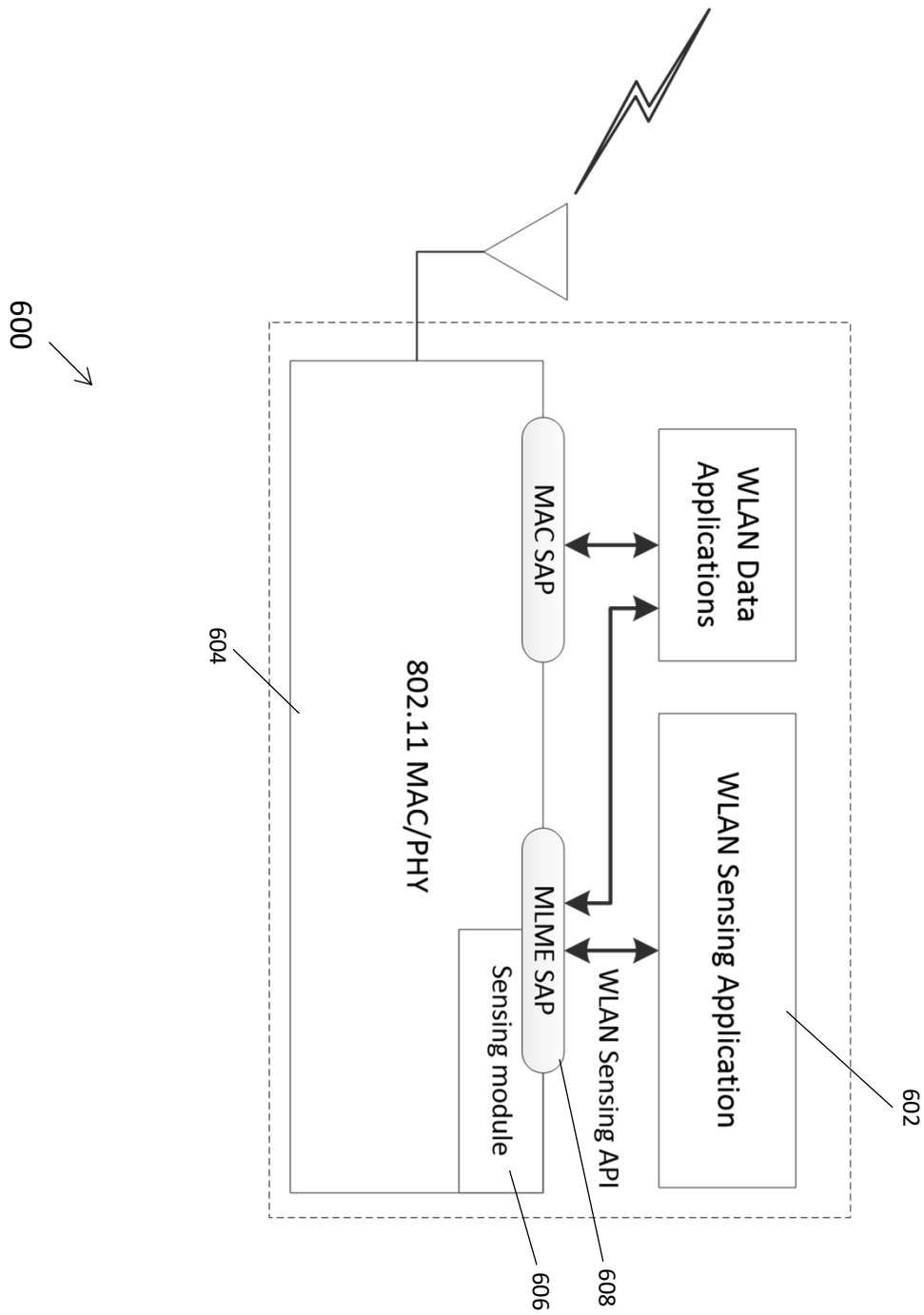
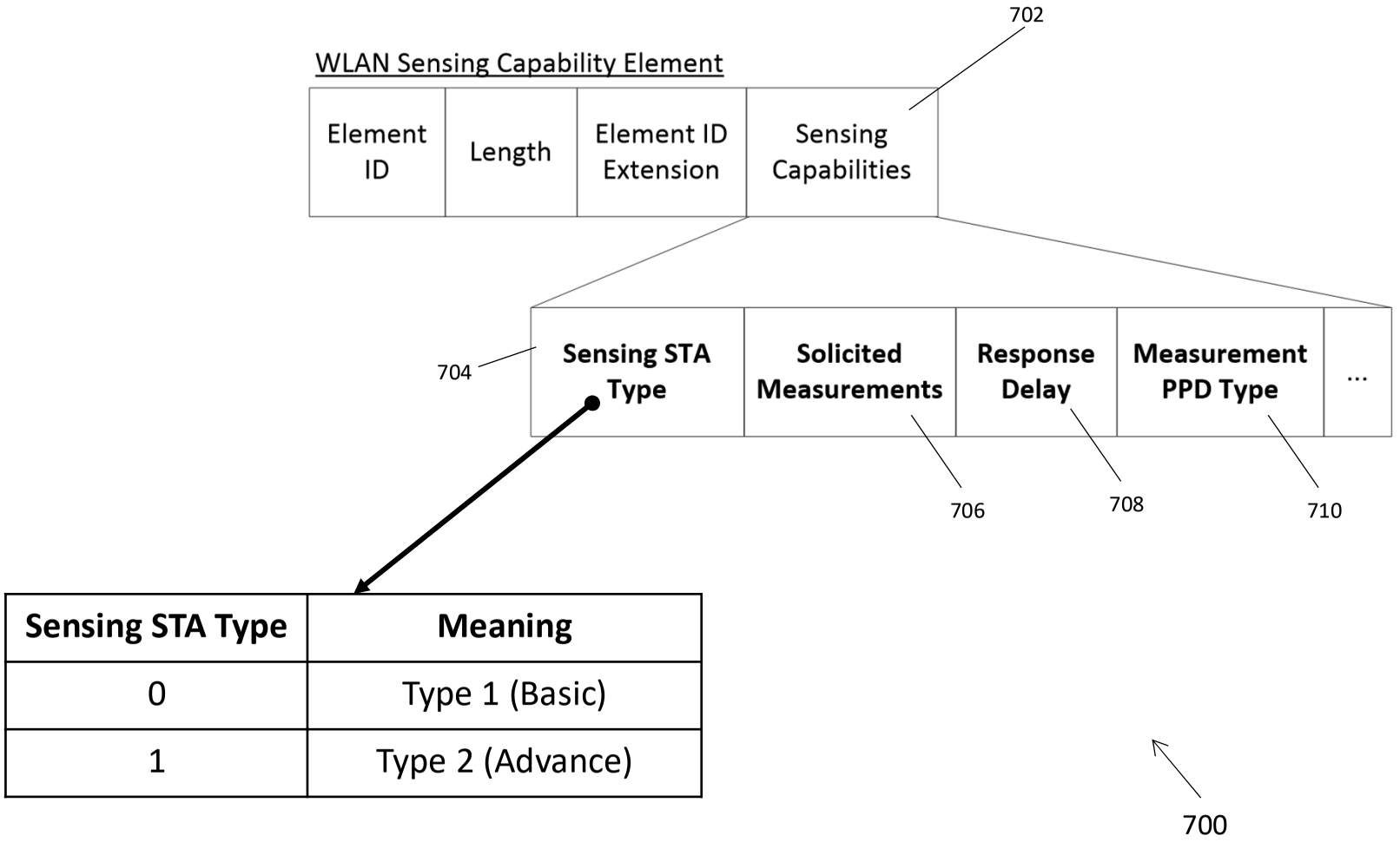

600
WLAN Data Applications
WLAN Sensing Application
602
MAC SAP
MLME SAP
WLAN Sensing API
608
802.11 MAC/PHY
604
Sensing module
606

Figure 6



Sensing STA Type	Meaning
0	Type 1 (Basic)
1	Type 2 (Advance)

Figure 7

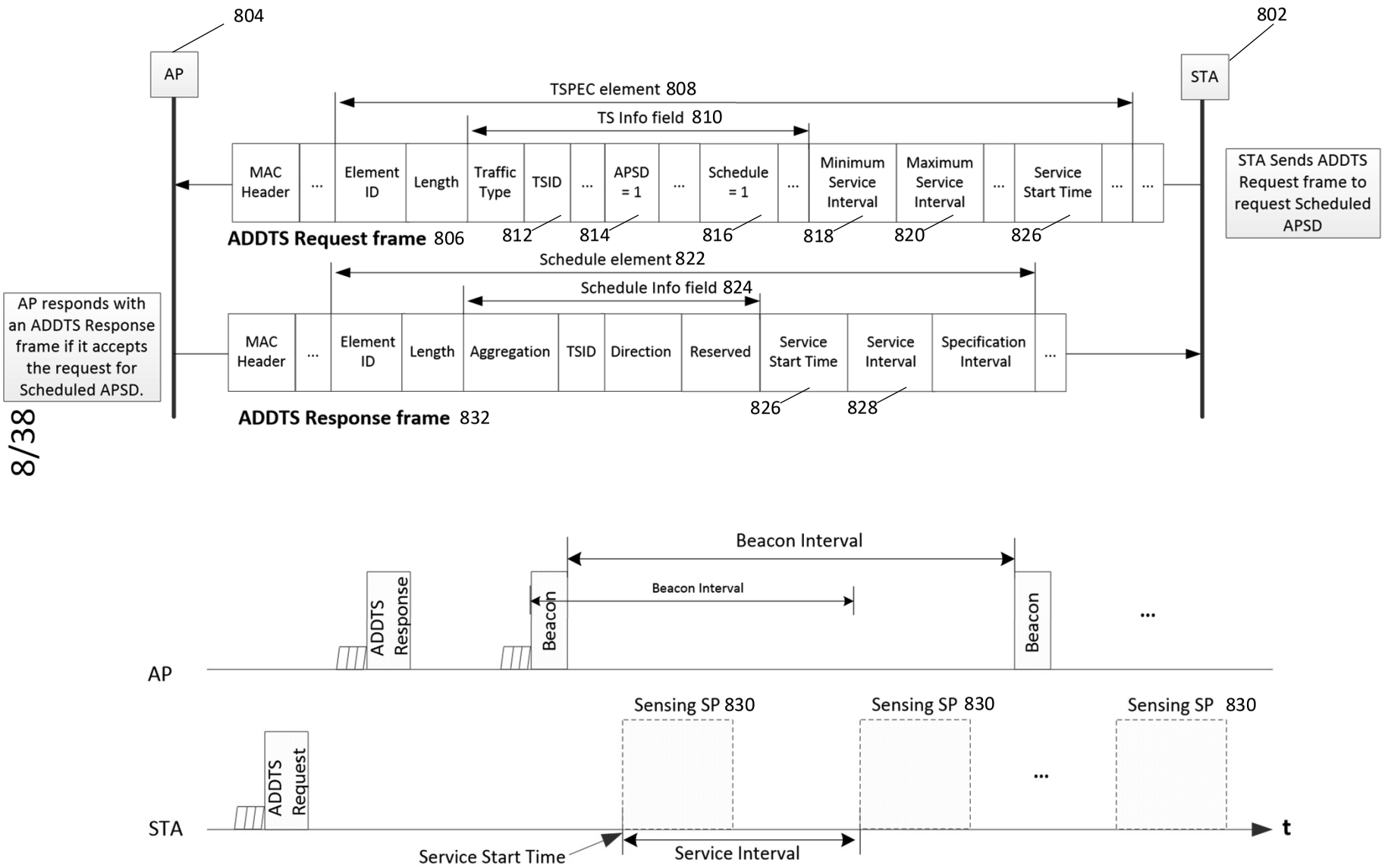

804
AP
802
STA
TSPEC element 808
TS Info field 810
MAC Header
Element ID
Length
Traffic Type
TSID
APSD = 1
Schedule = 1
Minimum Service Interval
Maximum Service Interval
Service Start Time
ADDTS Request frame 806
812
814
816
818
820
826
STA Sends ADDTS Request frame to request Scheduled APSD
AP responds with an ADDTS Response frame if it accepts the request for Scheduled APSD.
Schedule element 822
Schedule Info field 824
Aggregation
Direction
Reserved
Service Interval
Specification Interval
ADDTS Response frame 832
826
828
Beacon Interval
ADDTS Response
Beacon
AP
Sensing SP 830
ADDTS Request
STA
t
Service Start Time
Service Interval

Figure 8

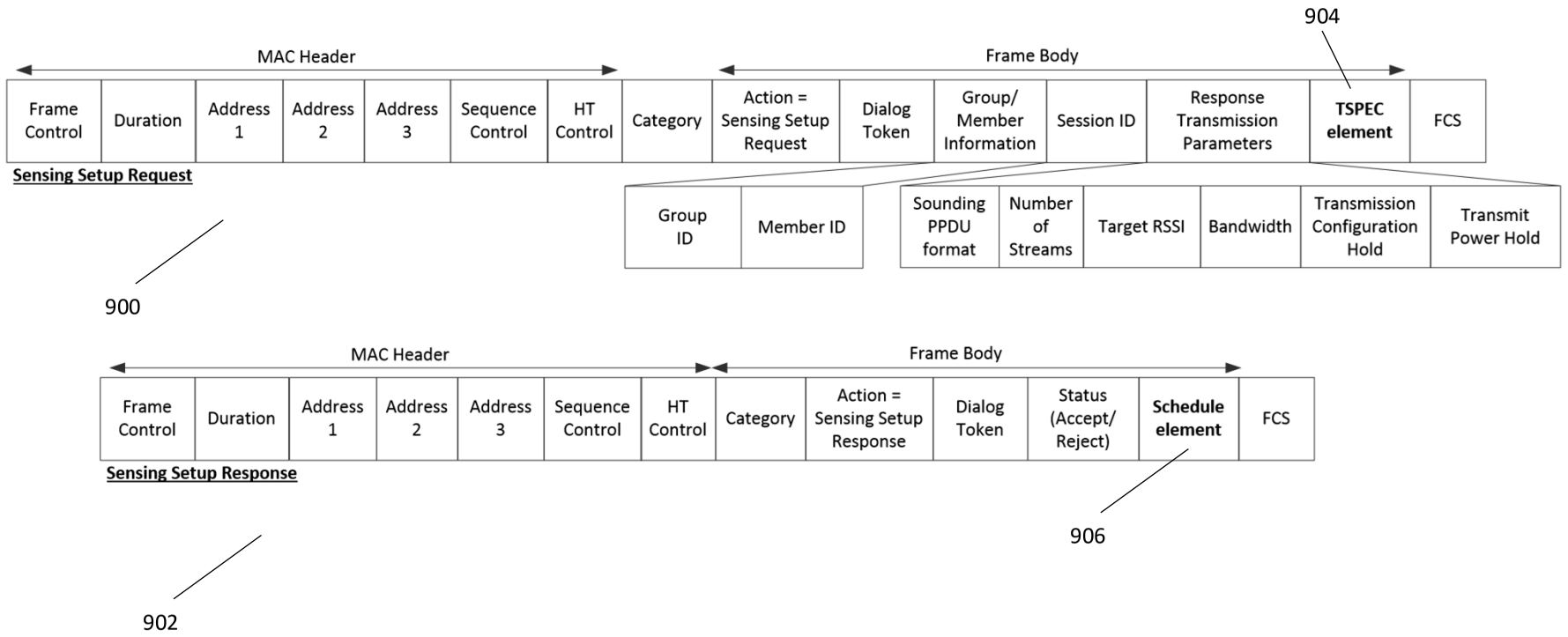

MAC Header
Frame Body
904
Frame Control
Duration
Address 1
Address 2
Address 3
Sequence Control
HT Control
Category
Action = Sensing Setup Request
Dialog Token
Group/ Member Information
Session ID
Response Transmission Parameters
TSPEC element
FCS
Sensing Setup Request
Group ID
Member ID
Sounding PPDU format
Number of Streams
Target RSSI
Bandwidth
Transmission Configuration Hold
Transmit Power Hold
900
MAC Header
Frame Body
Frame Control
Duration
Address 1
Address 2
Address 3
Sequence Control
HT Control
Category
Action = Sensing Setup Response
Dialog Token
Status (Accept/ Reject)
Schedule element
FCS
Sensing Setup Response
906
902

Figure 9

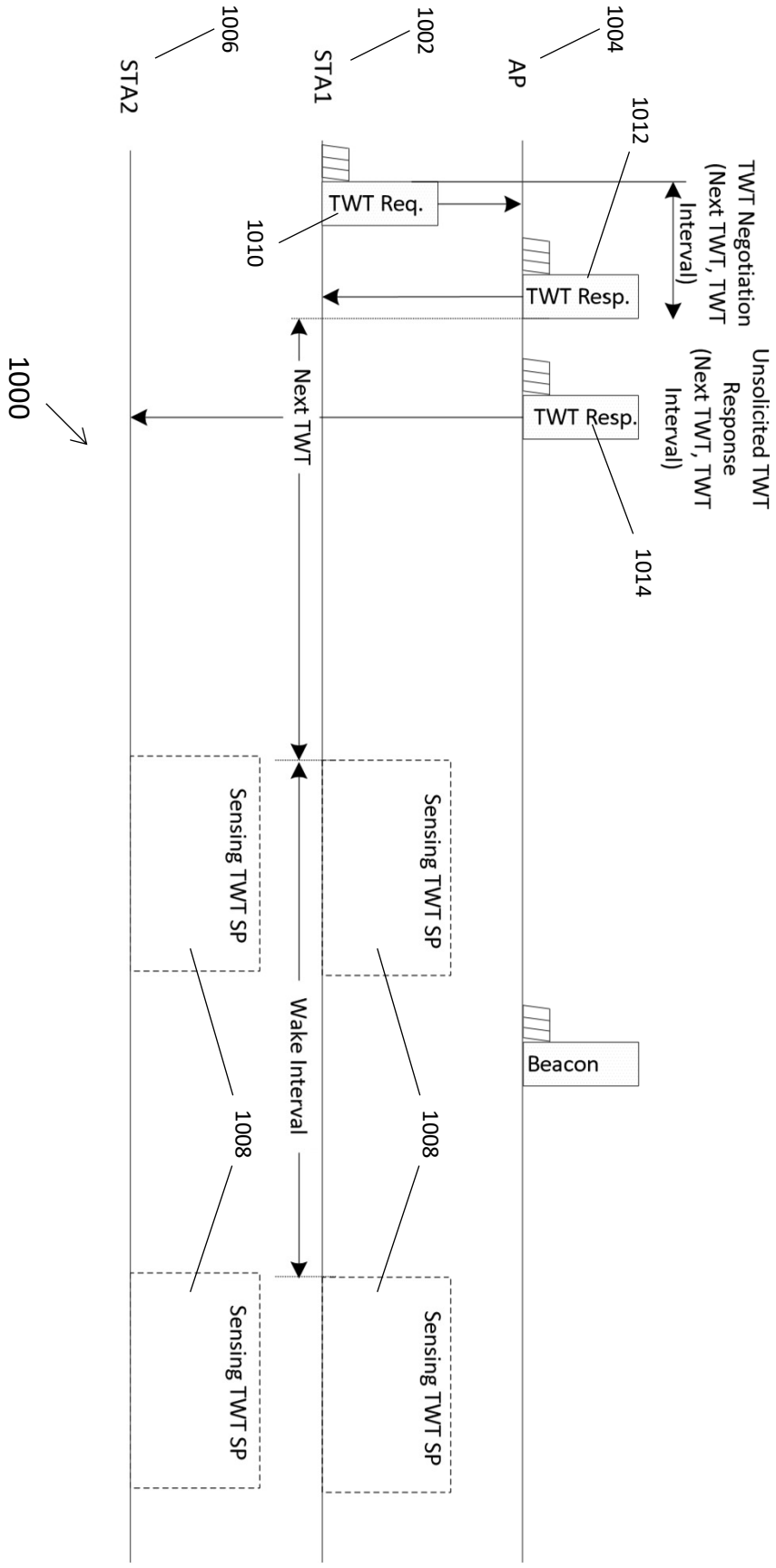

1000
1002
STA1
1004
AP
1006
STA2
1008
1010
1012
1014
TWT Negotiation (Next TWT, TWT Interval)
TWT Req.
TWT Resp.
Unsolicited TWT Response (Next TWT, TWT Interval)
TWT Resp.
Next TWT
Beacon
Wake Interval
Sensing TWT SP
Sensing TWT SP
Sensing TWT SP
Sensing TWT SP

Figure 10

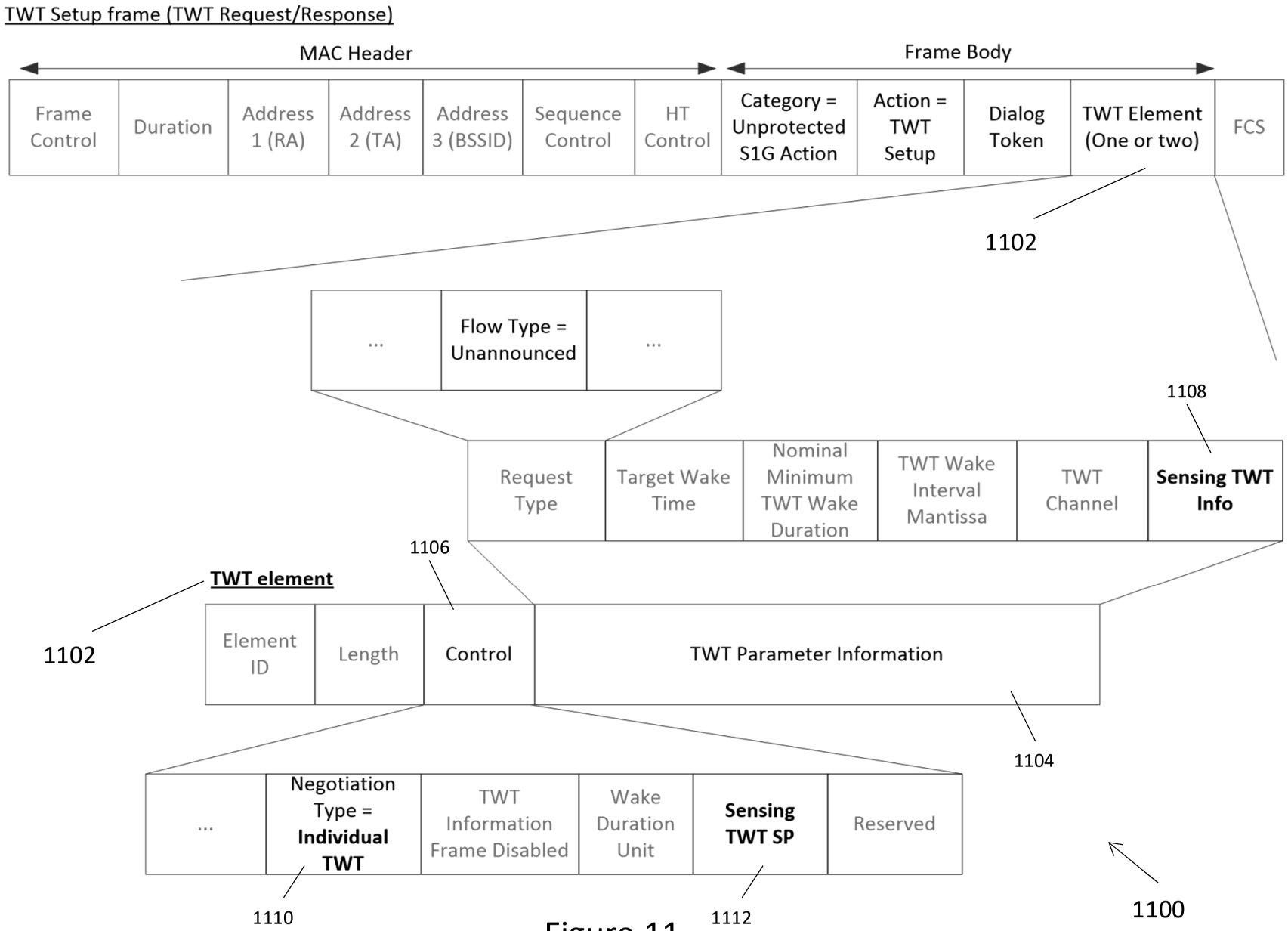

TWT Setup frame (TWT Request/Response)
MAC Header
Frame Body
Frame Control
Duration
Address 1 (RA)
Address 2 (TA)
Address 3 (BSSID)
Sequence Control
HT Control
Category = Unprotected S1G Action
Action = TWT Setup
Dialog Token
TWT Element (One or two)
FCS
1102
...
Flow Type = Unannounced
...
1108
Request Type
Target Wake Time
Nominal Minimum TWT Wake Duration
TWT Wake Interval Mantissa
TWT Channel
Sensing TWT Info
1106
TWT element
1102
Element ID
Length
Control
TWT Parameter Information
1104
...
Negotiation Type = Individual TWT
TWT Information Frame Disabled
Wake Duration Unit
Sensing TWT SP
Reserved
1110
1112
1100

Figure 11

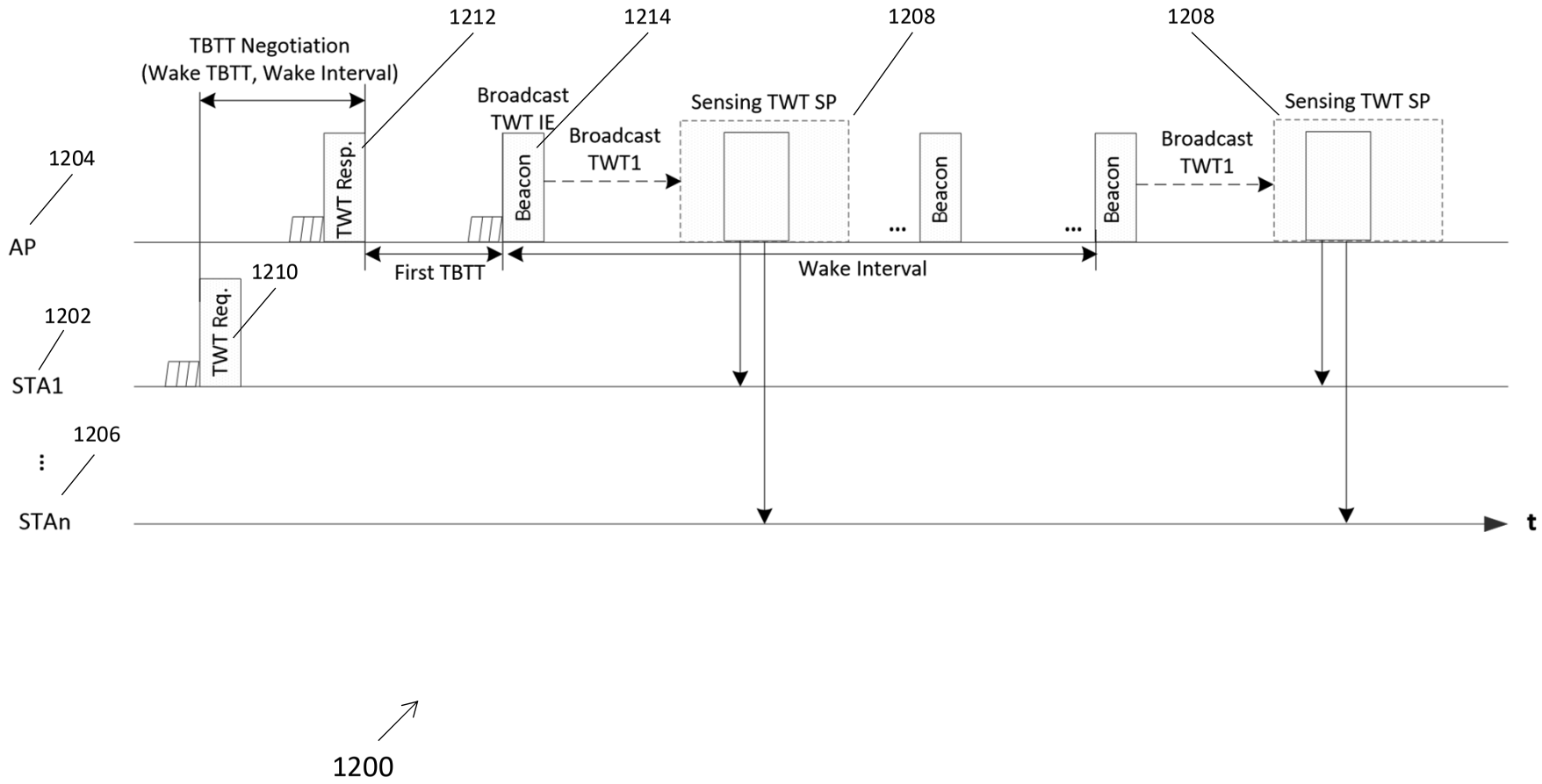

TBTT Negotiation
(Wake TBTT, Wake Interval)
1212
1214
1208
1208
Broadcast
TWT IE
Sensing TWT SP
Sensing TWT SP
Broadcast
TWT1
Broadcast
TWT1
1204
AP
TWT Resp.
Beacon
Beacon
Beacon
First TBTT
Wake Interval
1210
TWT Req.
1202
STA1
1206
STAn
t
1200

Figure 12

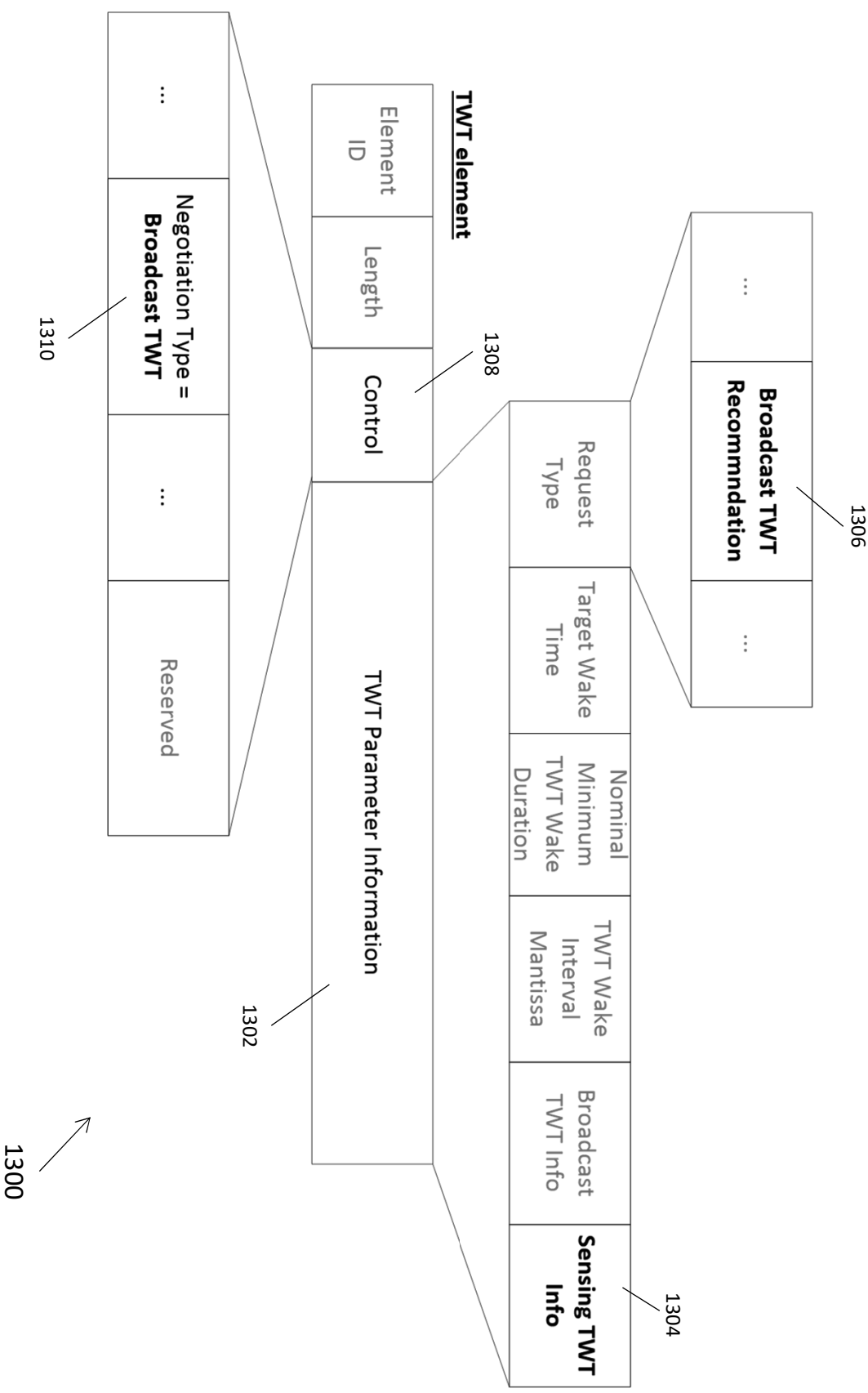

TWT element
Element ID
Length
Control
TWT Parameter Information
Negotiation Type = Broadcast TWT
Reserved
...
...
Request Type
Target Wake Time
Nominal Minimum TWT Wake Duration
TWT Wake Interval Mantissa
Broadcast TWT Info
Sensing TWT Info
Broadcast TWT Recommndation
...
...
1300
1302
1304
1306
1308
1310

Figure 13

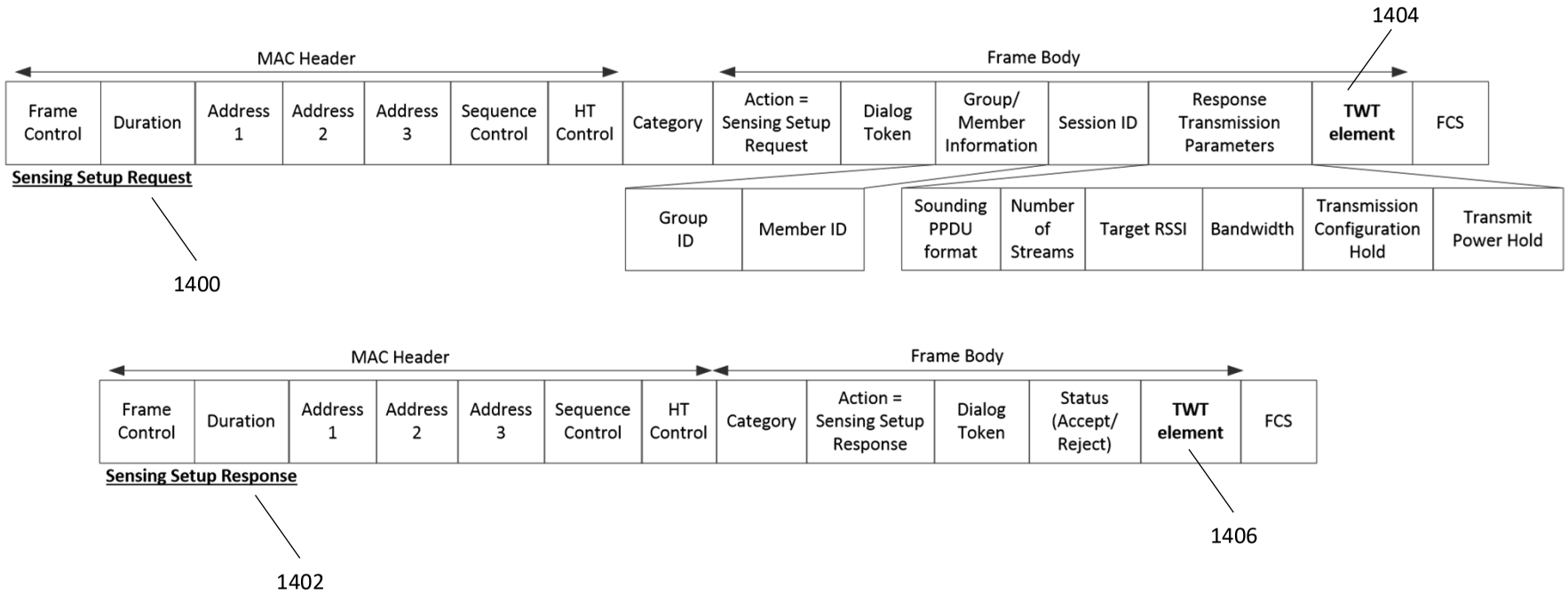

1404
MAC Header
Frame Body
Frame Control
Duration
Address 1
Address 2
Address 3
Sequence Control
HT Control
Category
Action = Sensing Setup Request
Dialog Token
Group/ Member Information
Session ID
Response Transmission Parameters
TWT element
FCS
Sensing Setup Request
1400
Group ID
Member ID
Sounding PPDU format
Number of Streams
Target RSSI
Bandwidth
Transmission Configuration Hold
Transmit Power Hold
MAC Header
Frame Body
Frame Control
Duration
Address 1
Address 2
Address 3
Sequence Control
HT Control
Category
Action = Sensing Setup Response
Dialog Token
Status (Accept/ Reject)
TWT element
FCS
Sensing Setup Response
1402
1406

Figure 14

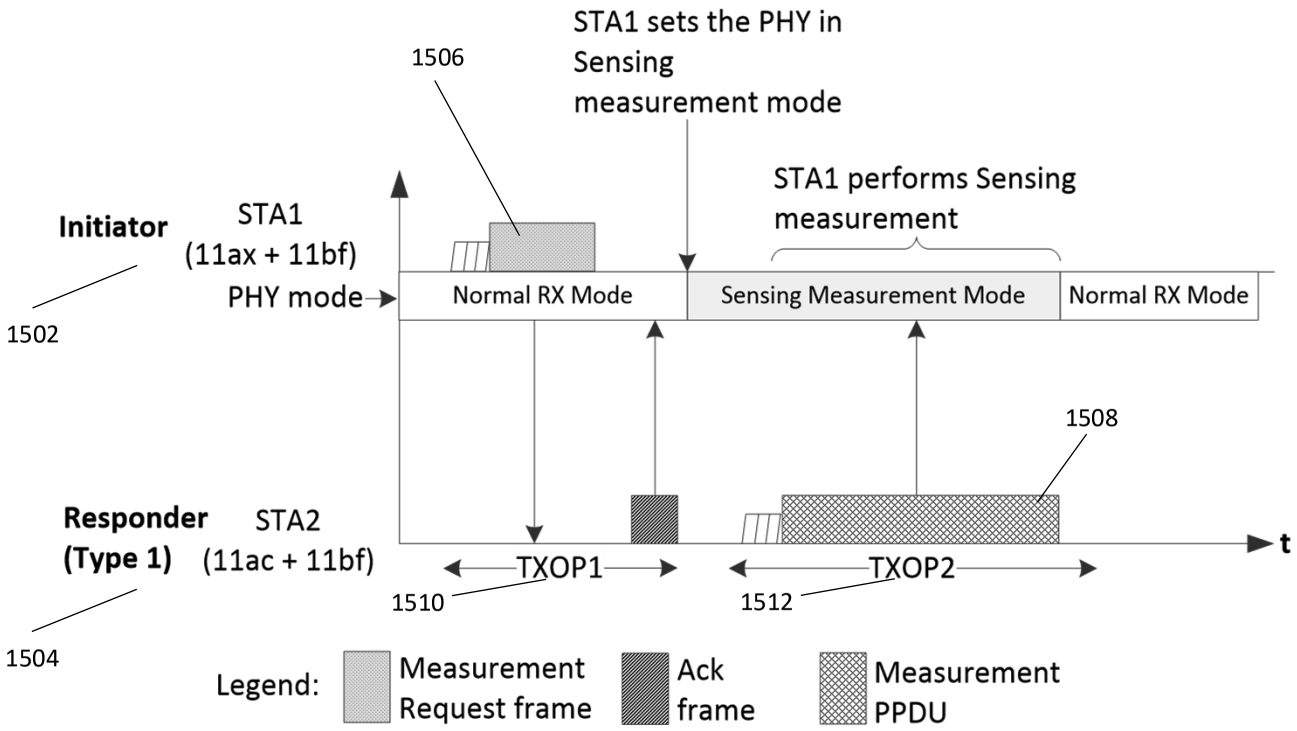
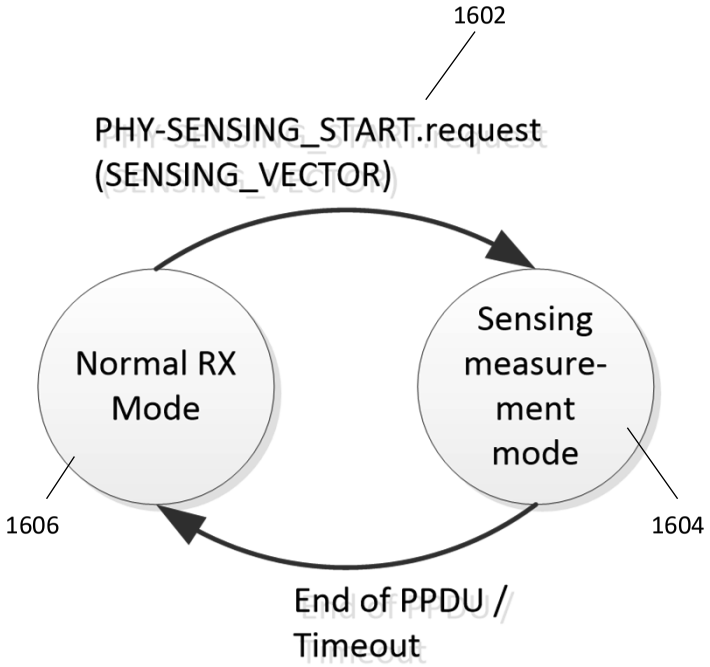

STA1 sets the PHY in Sensing measurement mode
1506
STA1 performs Sensing measurement
Initiator
STA1
(11ax + 11bf)
PHY mode
Normal RX Mode
Sensing Measurement Mode
Normal RX Mode
1502
1508
Responder
(Type 1)
STA2
(11ac + 11bf)
t
TXOP1
TXOP2
1510
1512
1504
Legend:
Measurement Request frame
Ack frame
Measurement PPDU
1500

Figure 15



PHY RX modes

Figure 16

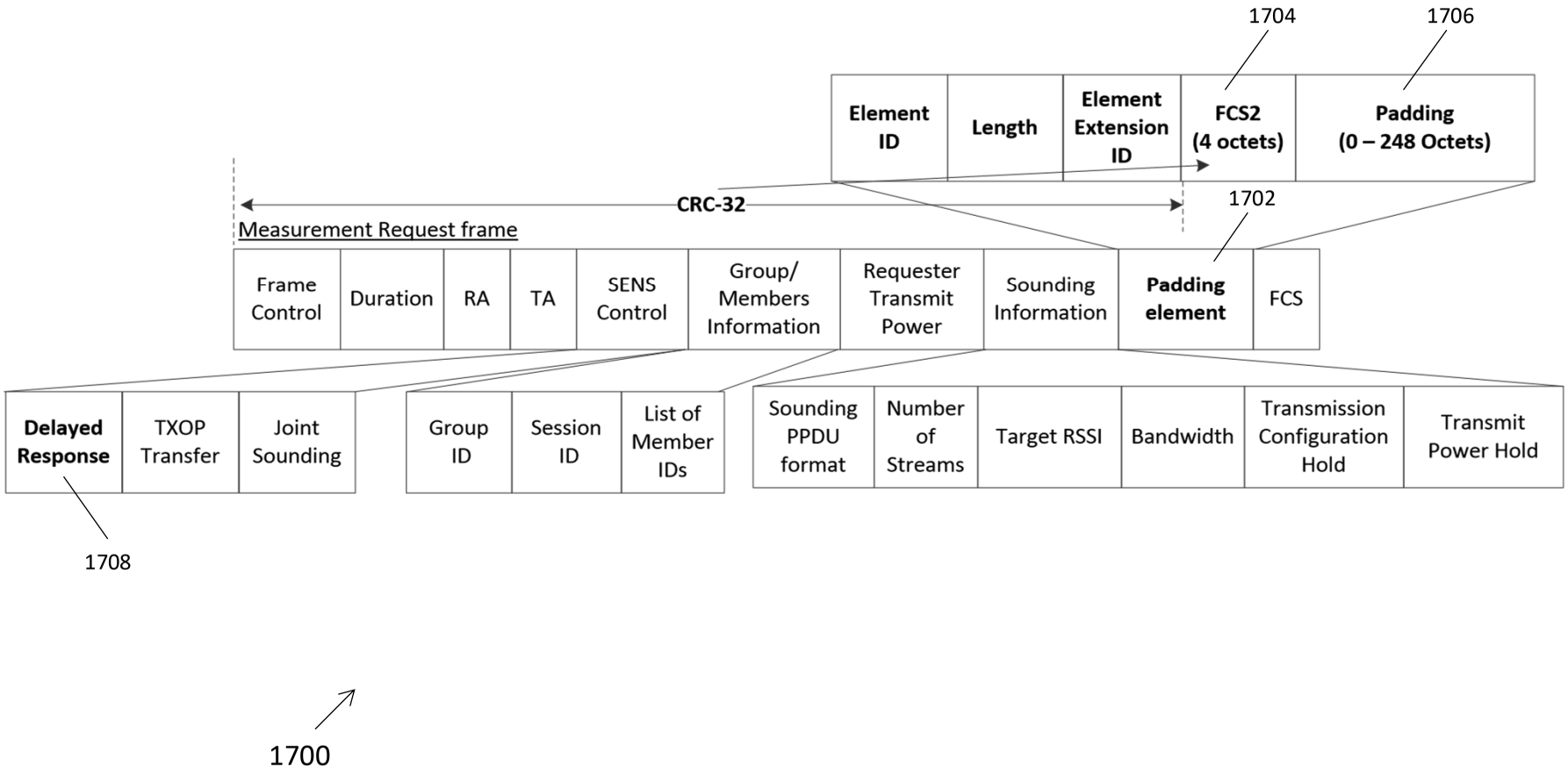

1704
1706
Element ID
Length
Element Extension ID
FCS2 (4 octets)
Padding (0 – 248 Octets)
CRC-32
1702
Measurement Request frame
Frame Control
Duration
RA
TA
SENS Control
Group/ Members Information
Requester Transmit Power
Sounding Information
Padding element
FCS
Delayed Response
TXOP Transfer
Joint Sounding
Group ID
Session ID
List of Member IDs
Sounding PPDU format
Number of Streams
Target RSSI
Bandwidth
Transmission Configuration Hold
Transmit Power Hold
1708
1700

Figure 17

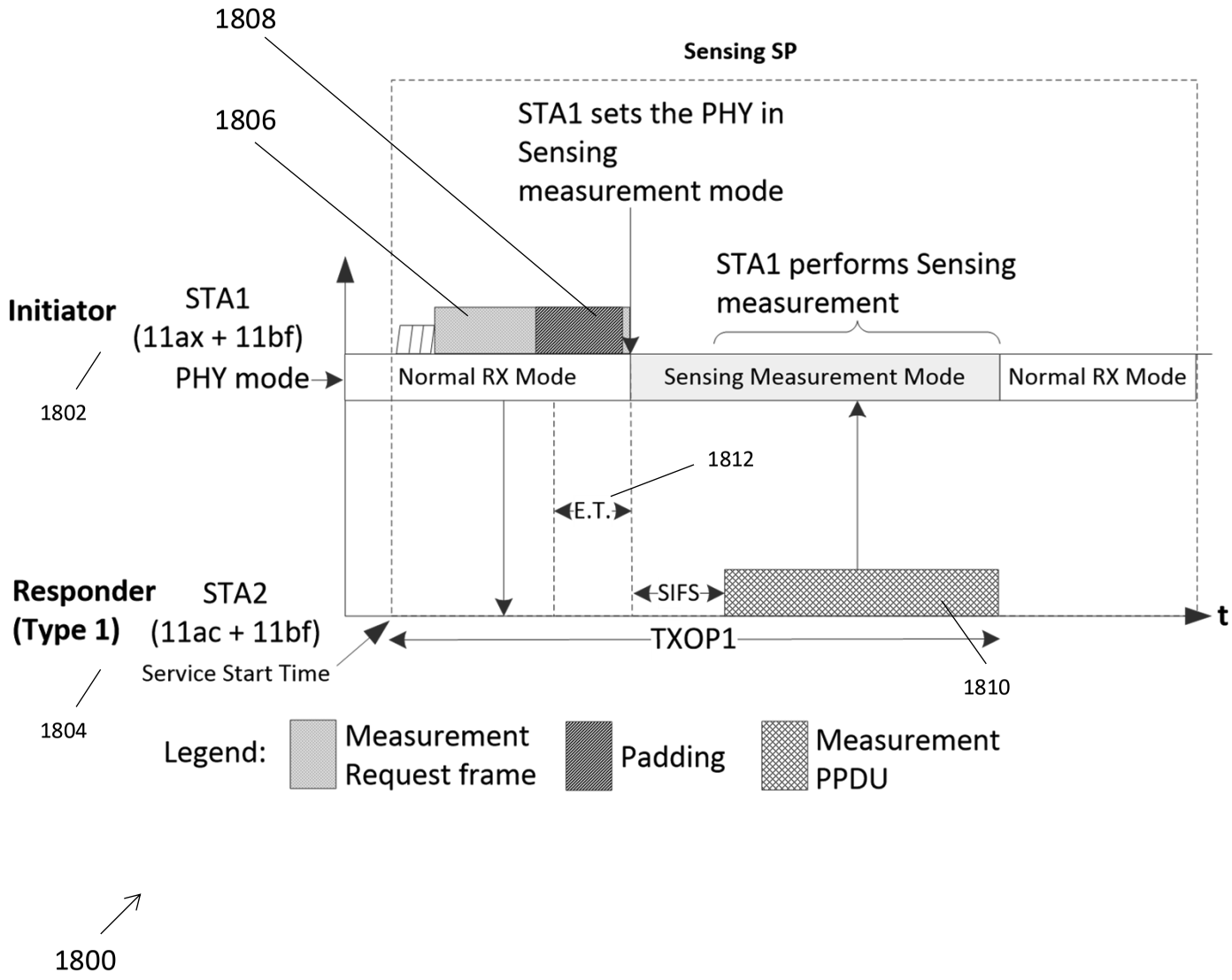

1808
1806
Sensing SP
STA1 sets the PHY in Sensing measurement mode
STA1 performs Sensing measurement
Initiator
STA1
(11ax + 11bf)
PHY mode
Normal RX Mode
Sensing Measurement Mode
Normal RX Mode
1802
1812
E.T.
SIFS
Responder
(Type 1)
STA2
(11ac + 11bf)
Service Start Time
TXOP1
t
1810
1804
Legend:
Measurement Request frame
Padding
Measurement PPDU
1800

Figure 18

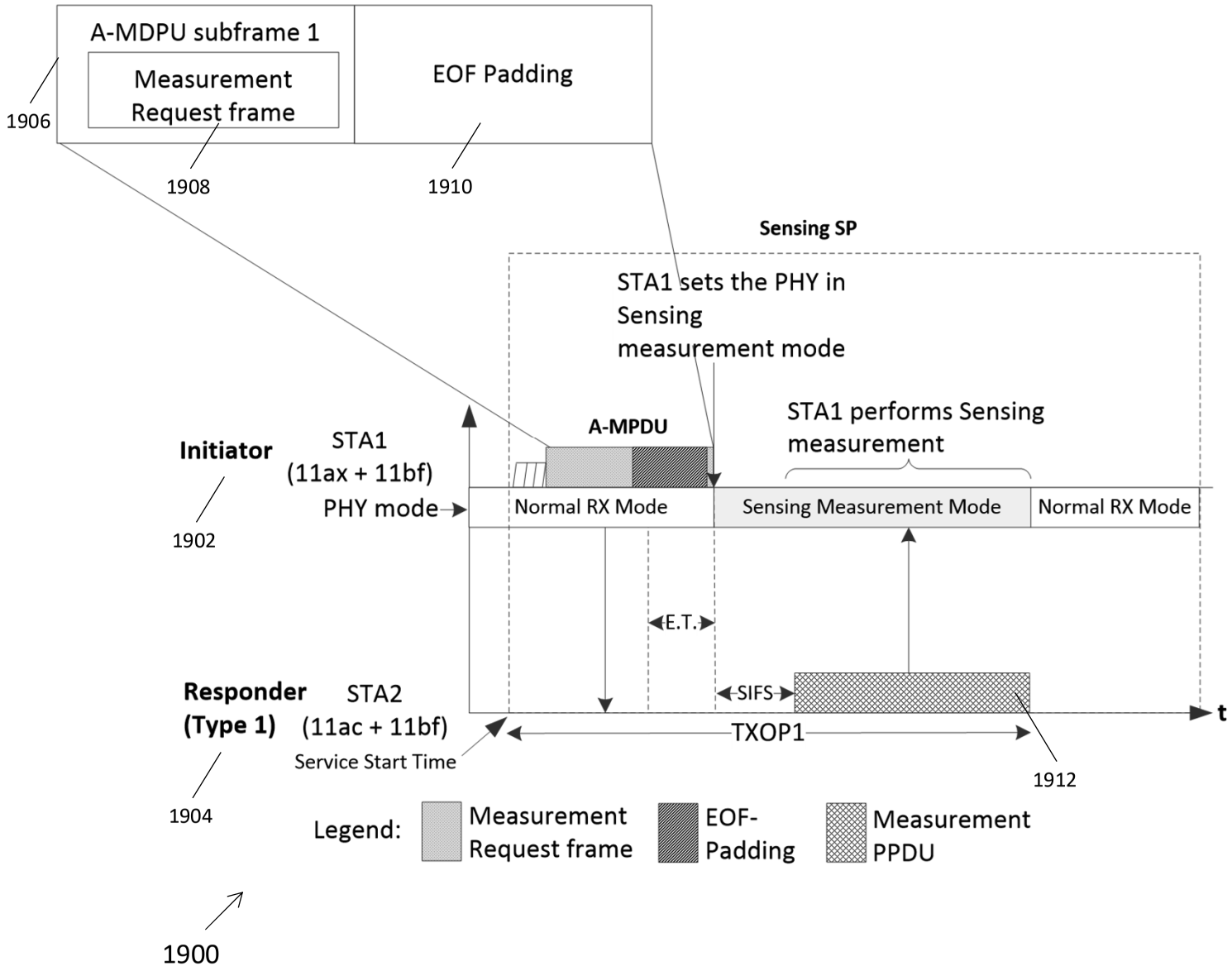

A-MDPU subframe 1
Measurement Request frame
EOF Padding
1906
1908
1910
Sensing SP
STA1 sets the PHY in Sensing measurement mode
STA1 performs Sensing measurement
A-MPDU
Initiator
STA1
(11ax + 11bf)
PHY mode
Normal RX Mode
Sensing Measurement Mode
Normal RX Mode
1902
E.T.
SIFS
t
Responder
(Type 1)
STA2
(11ac + 11bf)
Service Start Time
TXOP1
1912
1904
Legend:
Measurement Request frame
EOF-Padding
Measurement PPDU
1900

Figure 19

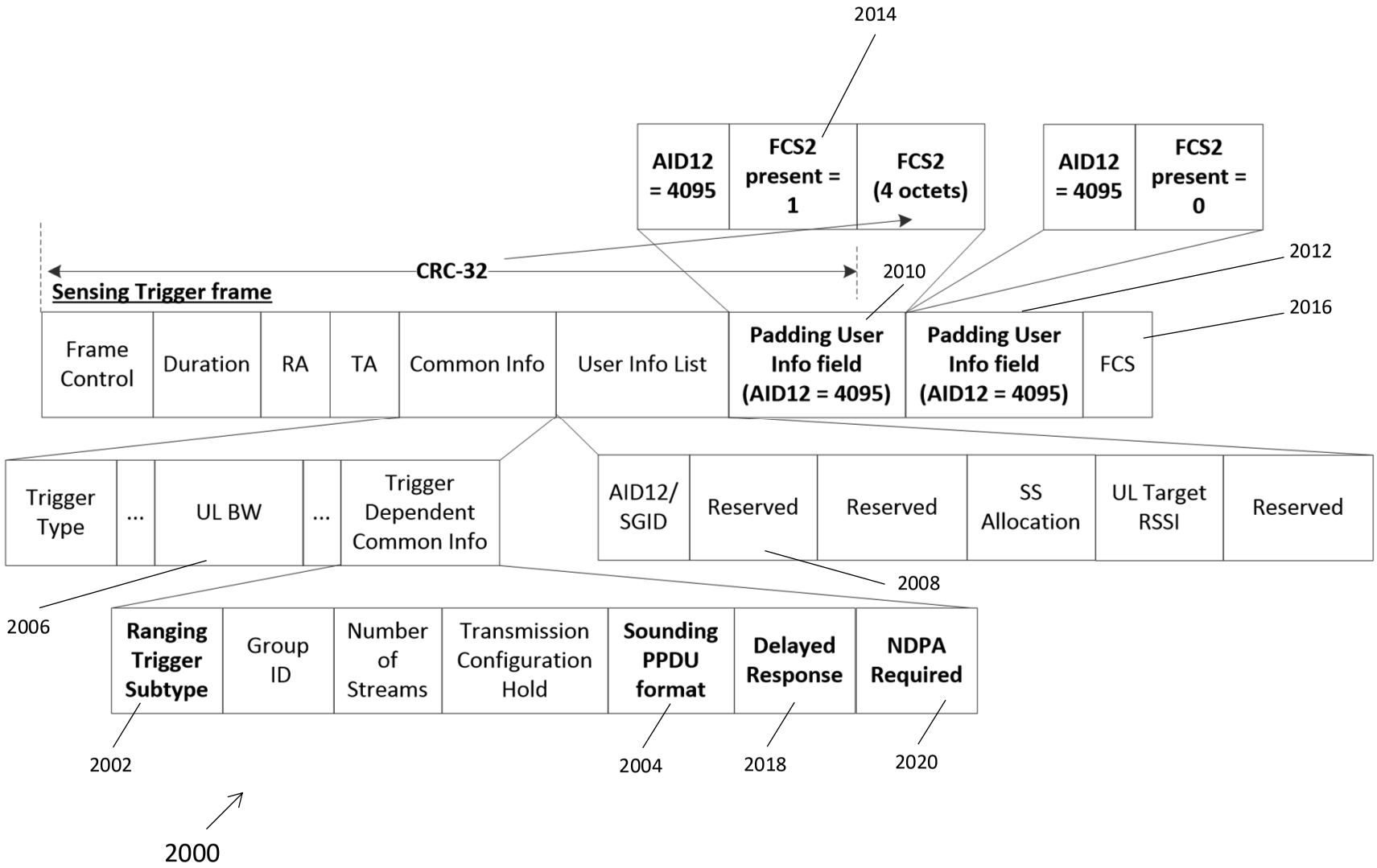

2014
AID12 = 4095
FCS2 present = 1
FCS2 (4 octets)
AID12 = 4095
FCS2 present = 0
CRC-32
2012
2010
2016
Sensing Trigger frame
Frame Control
Duration
RA
TA
Common Info
User Info List
Padding User Info field (AID12 = 4095)
Padding User Info field (AID12 = 4095)
FCS
Trigger Type
...
UL BW
...
Trigger Dependent Common Info
AID12/ SGID
Reserved
Reserved
SS Allocation
UL Target RSSI
Reserved
2008
2006
Ranging Trigger Subtype
Group ID
Number of Streams
Transmission Configuration Hold
Sounding PPDU format
Delayed Response
NDPA Required
2002
2004
2018
2020
2000

Figure 20

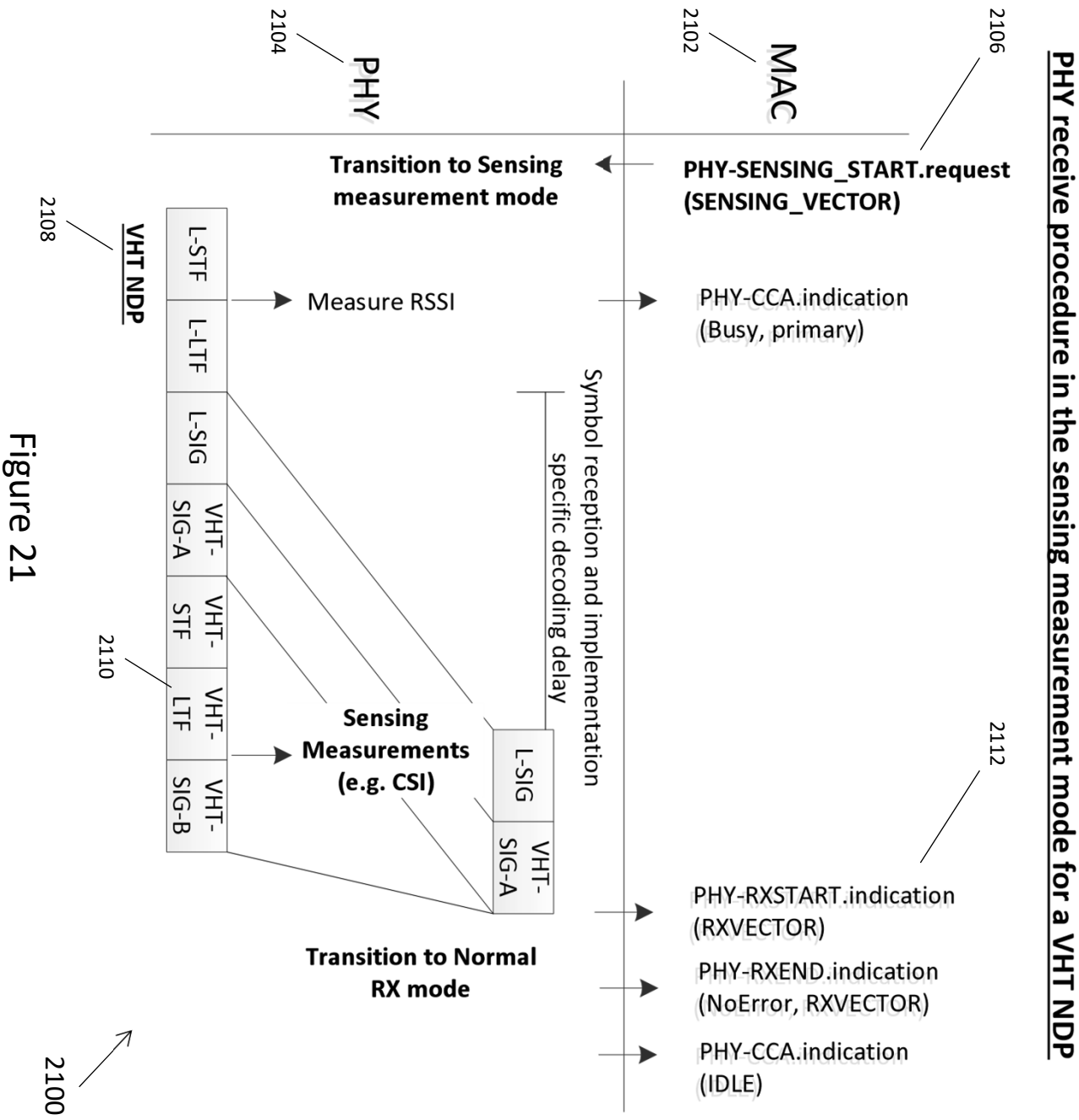
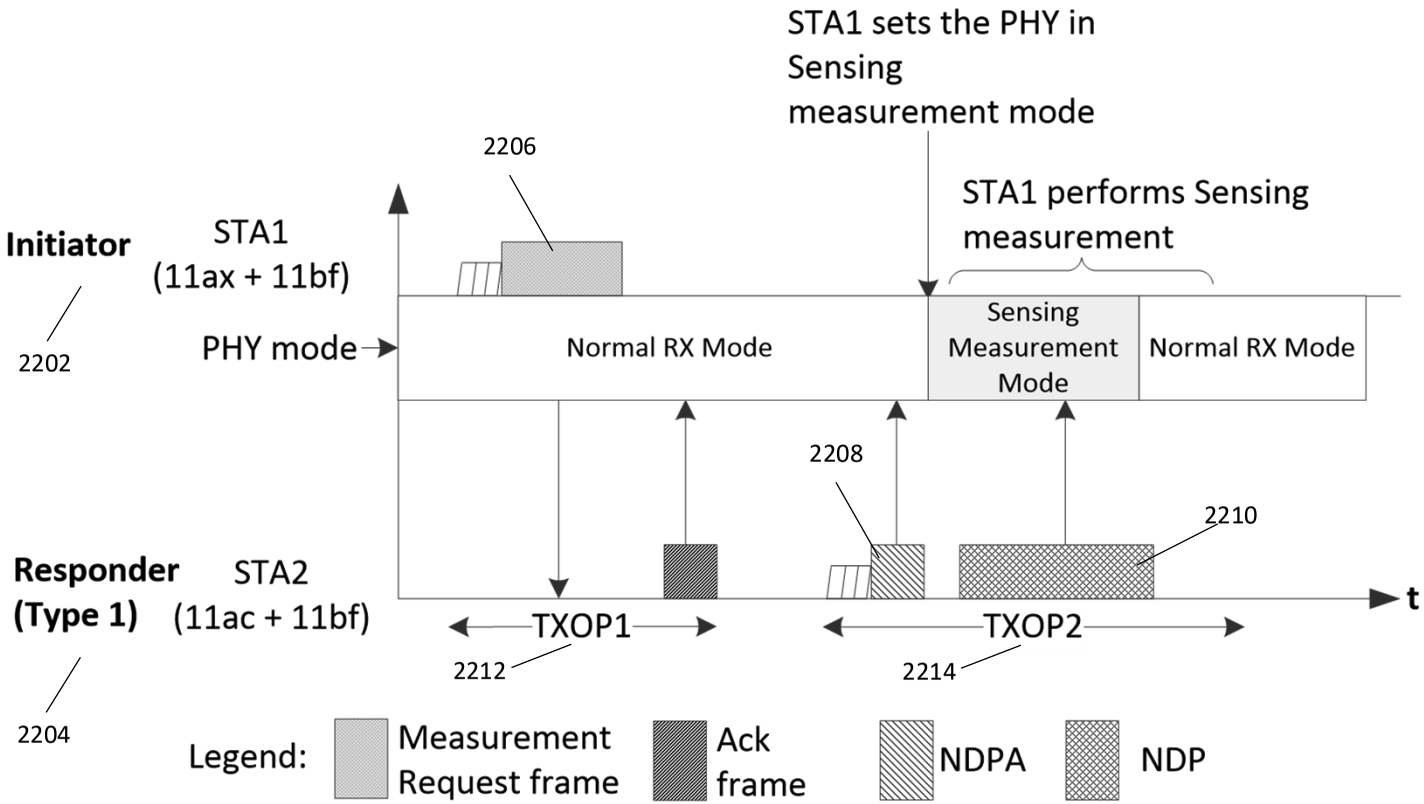

PHY receive procedure in the sensing measurement mode for a VHT NDP
2100
2102
MAC
2104
PHY
2106
PHY-SENSING_START.request
(SENSING_VECTOR)
Transition to Sensing
measurement mode
2108
VHT NDP
L-STF
L-LTF
L-SIG
VHT-SIG-A
VHT-STF
VHT-LTF
VHT-SIG-B
Measure RSSI
PHY-CCA.indication
(Busy, primary)
Symbol reception and implementation
specific decoding delay
2110
Sensing
Measurements
(e.g. CSI)
L-SIG
VHT-SIG-A
2112
PHY-RXSTART.indication
(RXVECTOR)
Transition to Normal
RX mode
PHY-RXEND.indication
(NoError, RXVECTOR)
PHY-CCA.indication
(IDLE)

Figure 21



2200

Figure 22

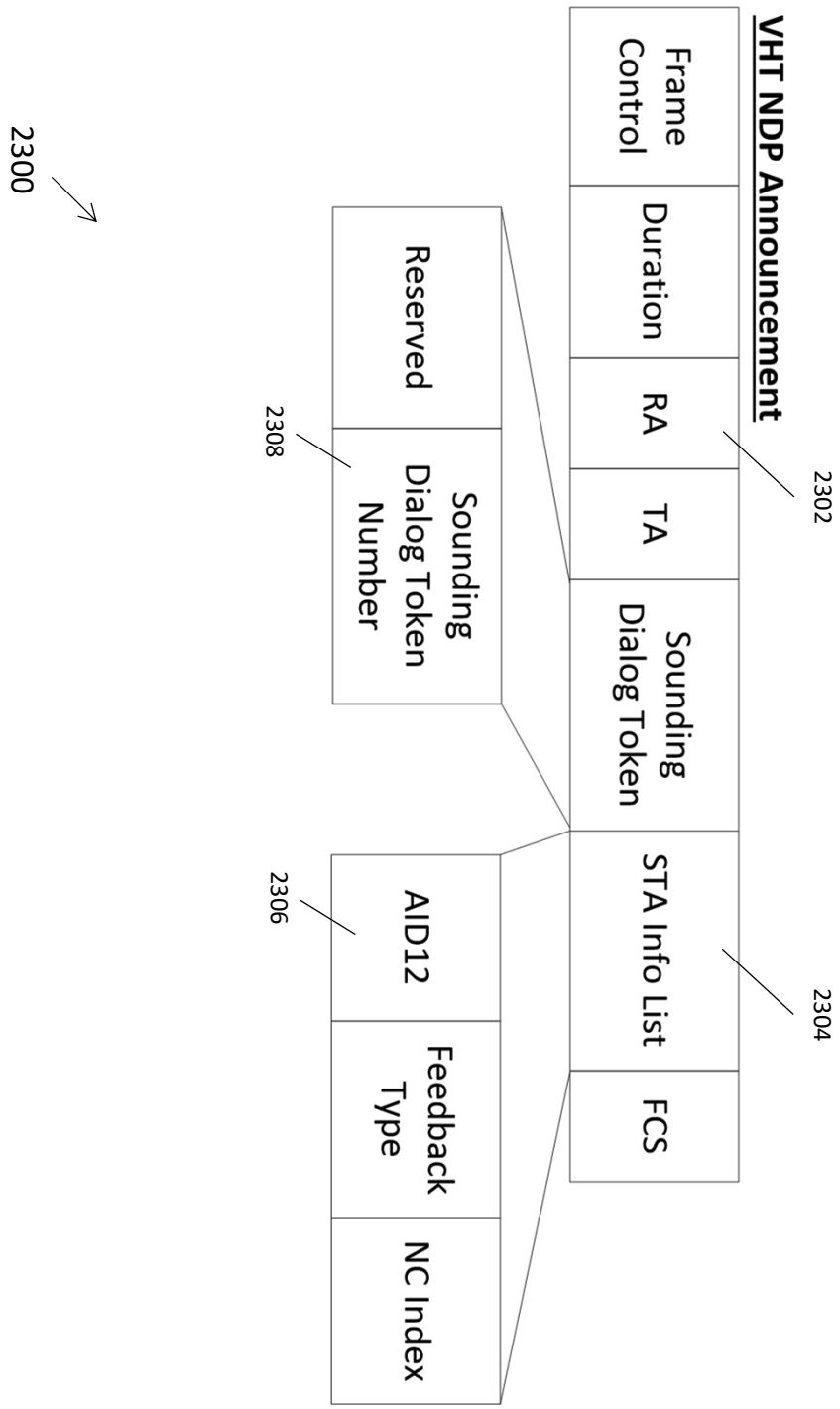
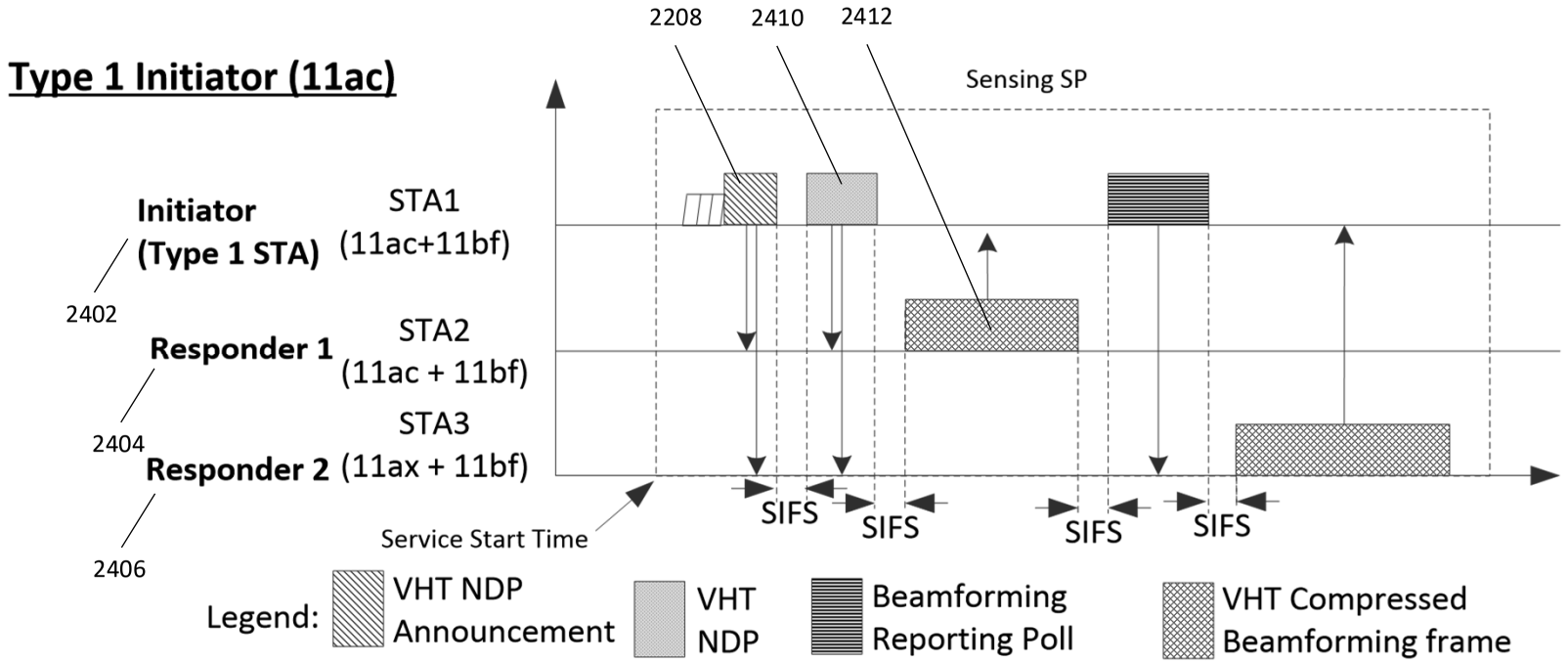

2300
VHT NDP Announcement
Frame Control
Duration
RA
TA
Sounding Dialog Token
STA Info List
FCS
2302
2304
Reserved
Sounding Dialog Token Number
2308
AID12
Feedback Type
NC Index
2306

Figure 23



2400

Figure 24

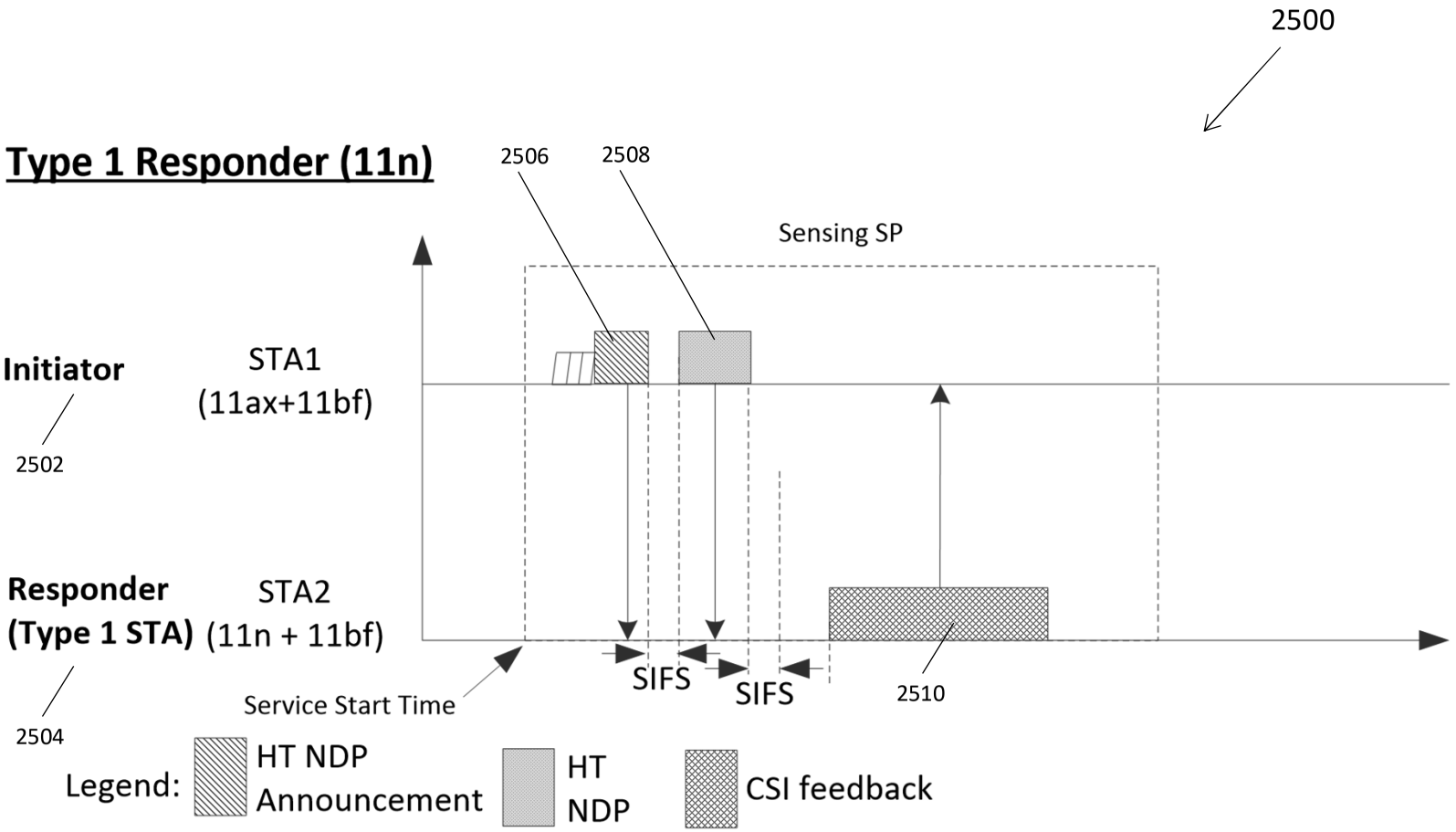

2500
Type 1 Responder (11n)
2506
2508
Sensing SP
Initiator
STA1
(11ax+11bf)
2502
Responder
(Type 1 STA)
STA2
(11n + 11bf)
2504
Service Start Time
SIFS
SIFS
2510
Legend:
HT NDP
Announcement
HT
NDP
CSI feedback

Figure 25

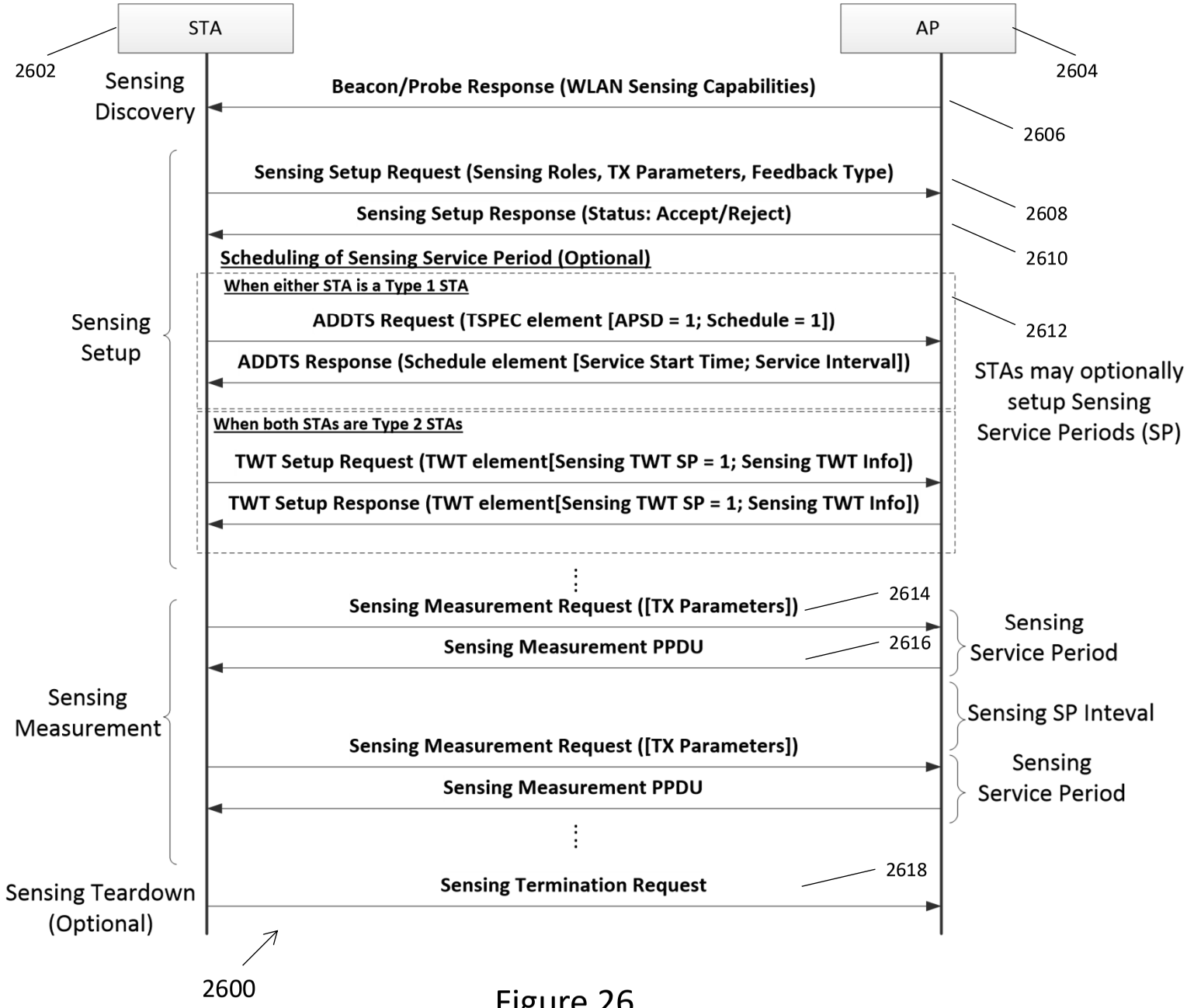

STA
AP
2602
2604
Sensing Discovery
Beacon/Probe Response (WLAN Sensing Capabilities)
2606
Sensing Setup Request (Sensing Roles, TX Parameters, Feedback Type)
Sensing Setup Response (Status: Accept/Reject)
2608
2610
Scheduling of Sensing Service Period (Optional)
When either STA is a Type 1 STA
Sensing Setup
ADDTS Request (TSPEC element [APSD = 1; Schedule = 1])
2612
ADDTS Response (Schedule element [Service Start Time; Service Interval])
STAs may optionally setup Sensing Service Periods (SP)
When both STAs are Type 2 STAs
TWT Setup Request (TWT element[Sensing TWT SP = 1; Sensing TWT Info])
TWT Setup Response (TWT element[Sensing TWT SP = 1; Sensing TWT Info])
Sensing Measurement Request ([TX Parameters])
2614
Sensing Measurement PPDU
2616
Sensing Service Period
Sensing Measurement
Sensing SP Inteval
Sensing Measurement Request ([TX Parameters])
Sensing Measurement PPDU
Sensing Service Period
Sensing Termination Request
2618
Sensing Teardown (Optional)
2600

Figure 26

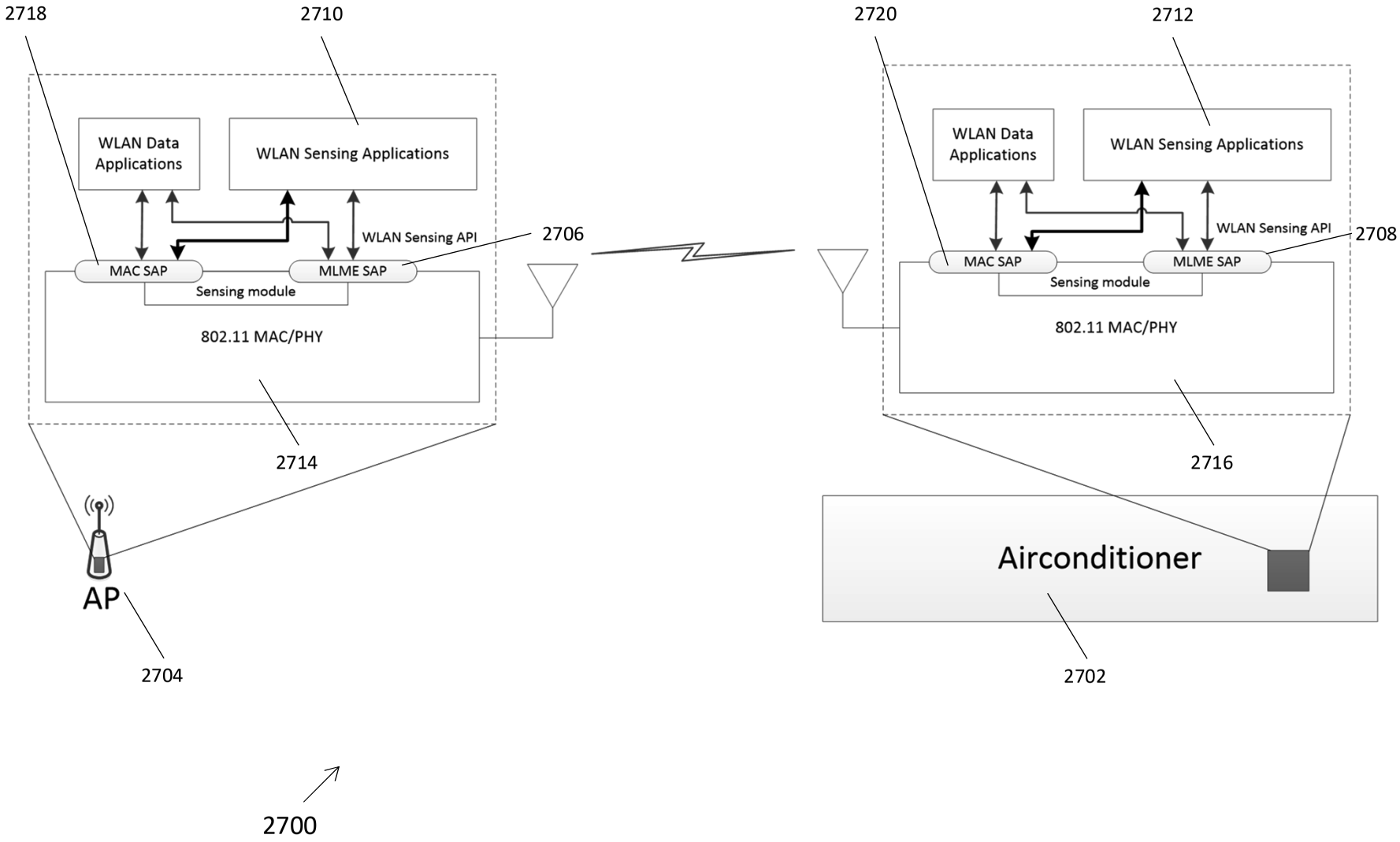

2718
2710
2720
2712
WLAN Data Applications
WLAN Sensing Applications
WLAN Data Applications
WLAN Sensing Applications
WLAN Sensing API
2706
WLAN Sensing API
2708
MAC SAP
MLME SAP
MAC SAP
MLME SAP
Sensing module
Sensing module
802.11 MAC/PHY
802.11 MAC/PHY
2714
2716
AP
Airconditioner
2704
2702
2700

Figure 27

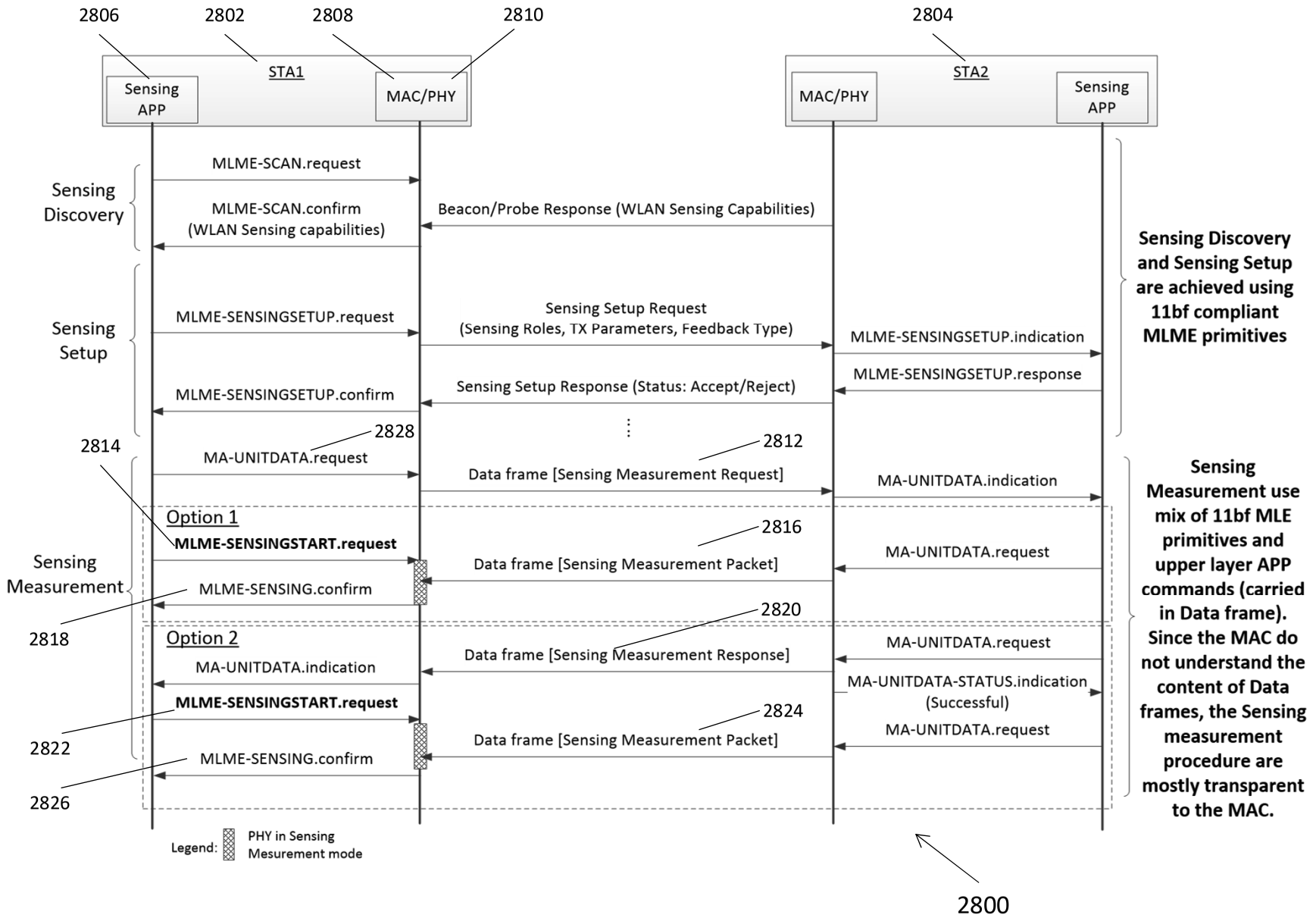
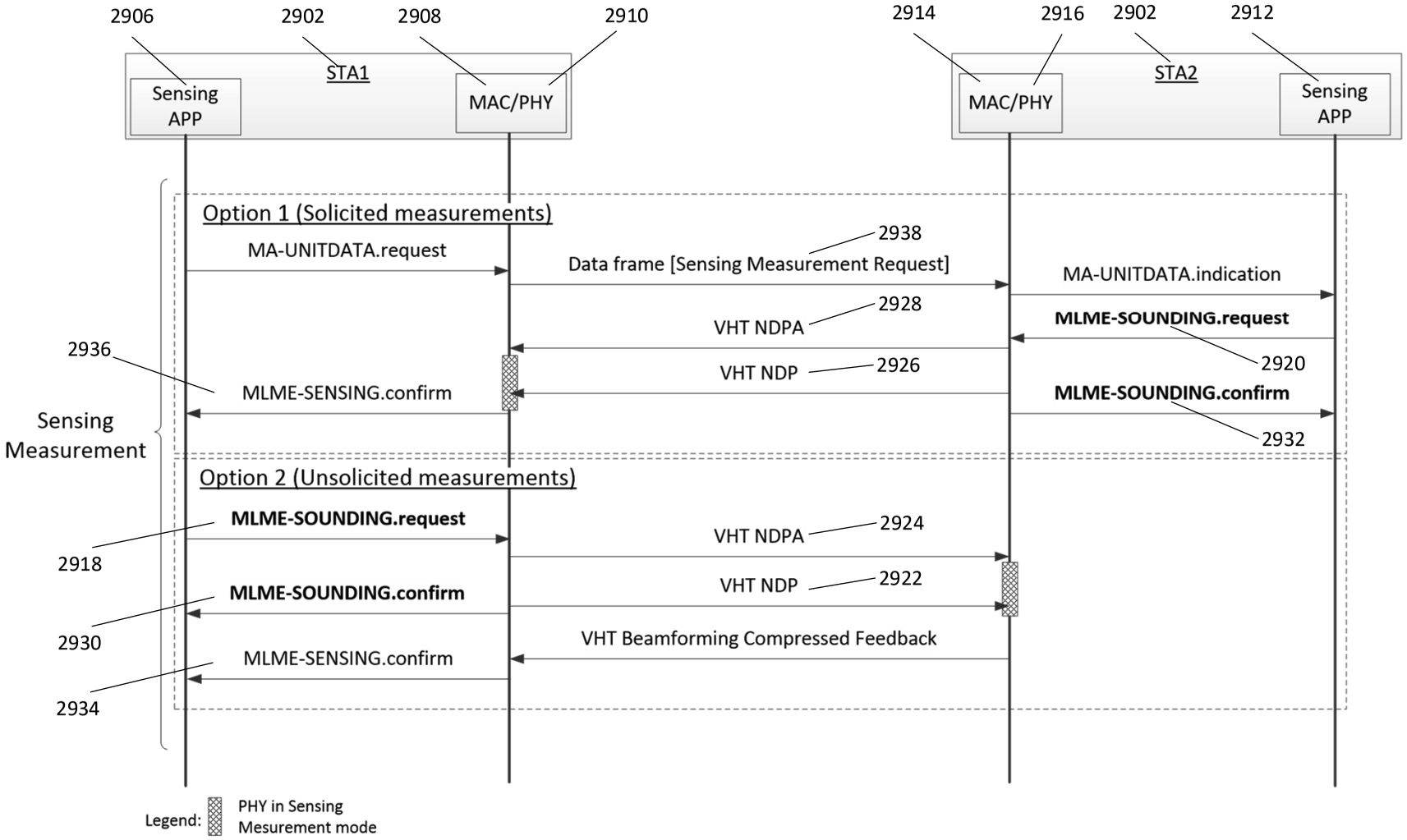

2806
2802
2808
2810
2804
STA1
Sensing APP
MAC/PHY
STA2
MAC/PHY
Sensing APP
MLME-SCAN.request
Sensing Discovery
MLME-SCAN.confirm (WLAN Sensing capabilities)
Beacon/Probe Response (WLAN Sensing Capabilities)
Sensing Discovery and Sensing Setup are achieved using 11bf compliant MLME primitives
Sensing Setup
MLME-SENSINGSETUP.request
Sensing Setup Request (Sensing Roles, TX Parameters, Feedback Type)
MLME-SENSINGSETUP.indication
MLME-SENSINGSETUP.response
MLME-SENSINGSETUP.confirm
Sensing Setup Response (Status: Accept/Reject)
2828
2812
2814
MA-UNITDATA.request
Data frame [Sensing Measurement Request]
MA-UNITDATA.indication
Option 1
2816
MLME-SENSINGSTART.request
Data frame [Sensing Measurement Packet]
MA-UNITDATA.request
Sensing Measurement
MLME-SENSING.confirm
2818
2820
Option 2
Data frame [Sensing Measurement Response]
MA-UNITDATA.request
MA-UNITDATA.indication
MA-UNITDATA-STATUS.indication (Successful)
MLME-SENSINGSTART.request
2824
2822
Data frame [Sensing Measurement Packet]
MA-UNITDATA.request
MLME-SENSING.confirm
2826
Sensing Measurement use mix of 11bf MLE primitives and upper layer APP commands (carried in Data frame). Since the MAC do not understand the content of Data frames, the Sensing measurement procedure are mostly transparent to the MAC.
Legend:
PHY in Sensing Mesurement mode
2800

Figure 28



2900

Figure 29

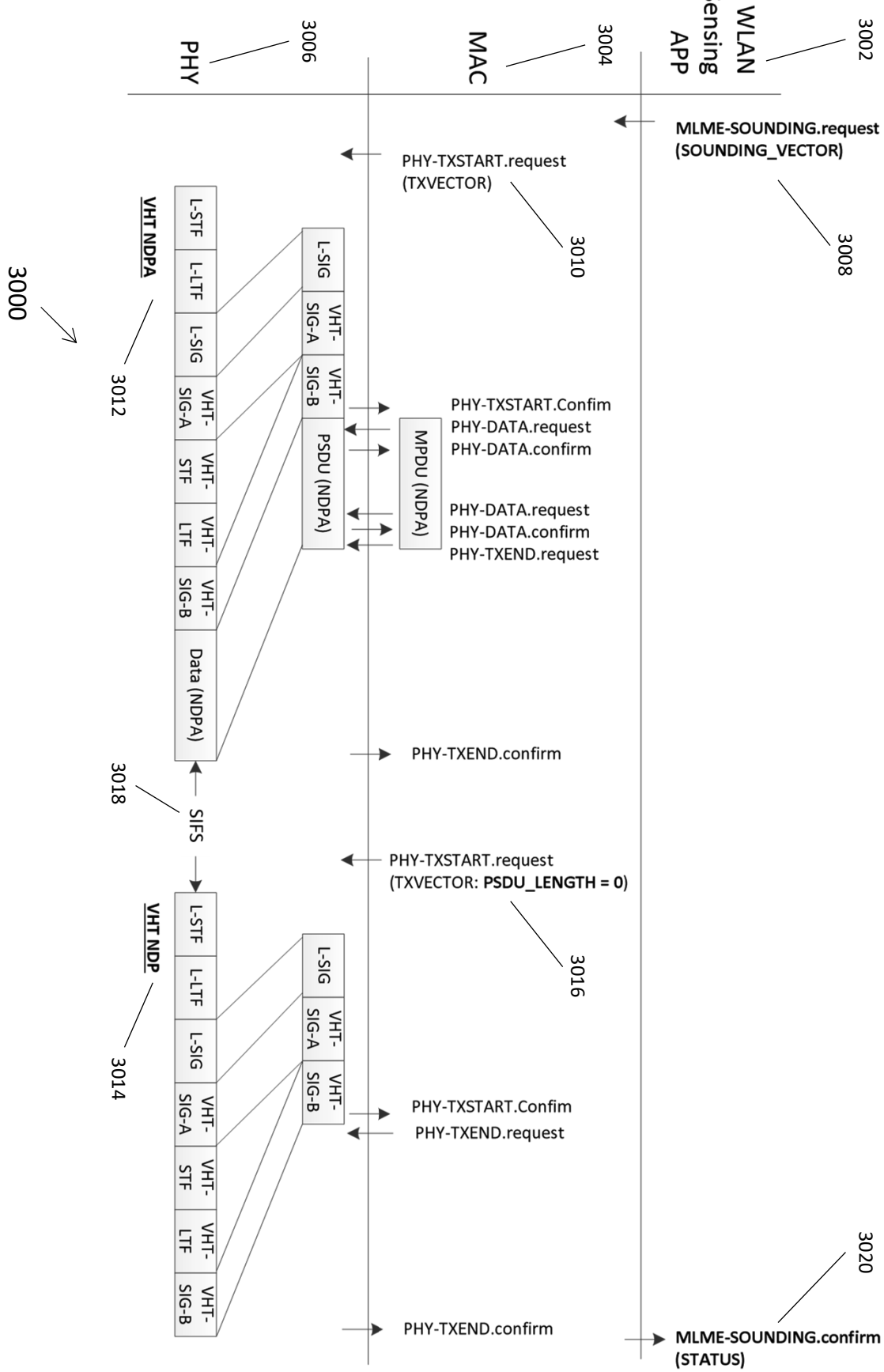

3000
WLAN Sensing APP
3002
MAC
3004
PHY
3006
MLME-SOUNDING.request
(SOUNDING_VECTOR)
3008
PHY-TXSTART.request
(TXVECTOR)
3010
VHT NDPA
3012
L-STF
L-LTF
L-SIG
VHT-SIG-A
VHT-SIG-B
VHT-STF
VHT-LTF
VHT-SIG-B
Data (NDPA)
PSDU (NDPA)
MPDU (NDPA)
PHY-TXSTART.Confim
PHY-DATA.request
PHY-DATA.confirm
PHY-DATA.request
PHY-DATA.confirm
PHY-TXEND.request
PHY-TXEND.confirm
3018
SIFS
PHY-TXSTART.request
(TXVECTOR: PSDU_LENGTH = 0)
3016
VHT NDP
3014
PHY-TXSTART.Confim
PHY-TXEND.request
PHY-TXEND.confirm
3020
MLME-SOUNDING.confirm
(STATUS)

Figure 30

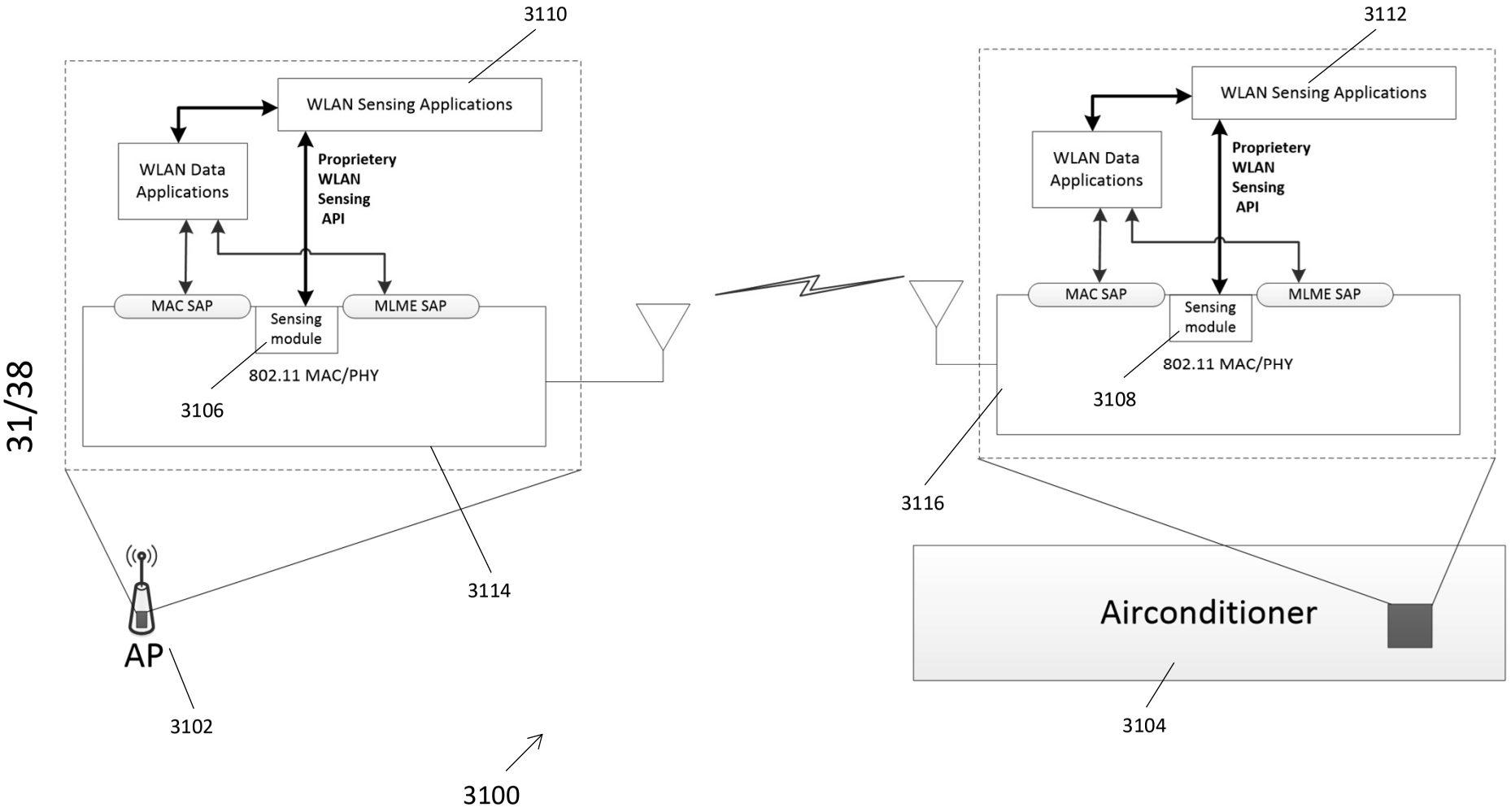

3110
WLAN Sensing Applications
WLAN Data Applications
Proprietery WLAN Sensing API
MAC SAP
Sensing module
MLME SAP
802.11 MAC/PHY
3106
3112
WLAN Sensing Applications
WLAN Data Applications
Proprietery WLAN Sensing API
MAC SAP
Sensing module
MLME SAP
802.11 MAC/PHY
3108
3116
3114
AP
3102
Airconditioner
3104
3100

Figure 31

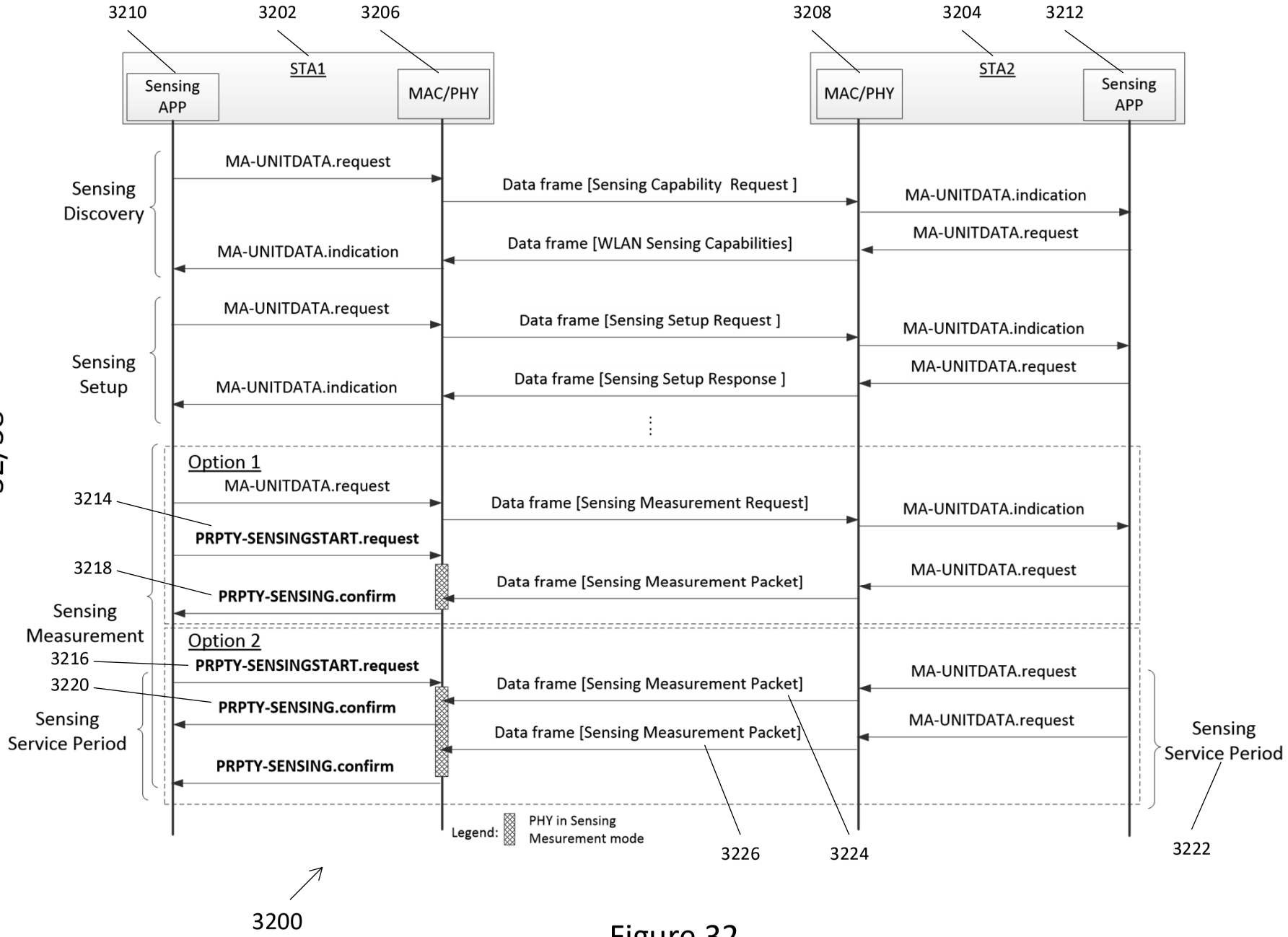

3210
3202
3206
3208
3204
3212
STA1
STA2
Sensing APP
MAC/PHY
MAC/PHY
Sensing APP
Sensing Discovery
MA-UNITDATA.request
Data frame [Sensing Capability Request]
MA-UNITDATA.indication
MA-UNITDATA.request
Data frame [WLAN Sensing Capabilities]
MA-UNITDATA.indication
Sensing Setup
MA-UNITDATA.request
Data frame [Sensing Setup Request]
MA-UNITDATA.indication
MA-UNITDATA.request
Data frame [Sensing Setup Response]
MA-UNITDATA.indication
Option 1
MA-UNITDATA.request
Data frame [Sensing Measurement Request]
MA-UNITDATA.indication
3214
PRPTY-SENSINGSTART.request
3218
PRPTY-SENSING.confirm
Data frame [Sensing Measurement Packet]
MA-UNITDATA.request
Sensing Measurement
Option 2
3216
PRPTY-SENSINGSTART.request
MA-UNITDATA.request
3220
PRPTY-SENSING.confirm
Data frame [Sensing Measurement Packet]
Sensing Service Period
MA-UNITDATA.request
Data frame [Sensing Measurement Packet]
Sensing Service Period
PRPTY-SENSING.confirm
Legend:
PHY in Sensing Mesurement mode
3226
3224
3222
3200

Figure 32

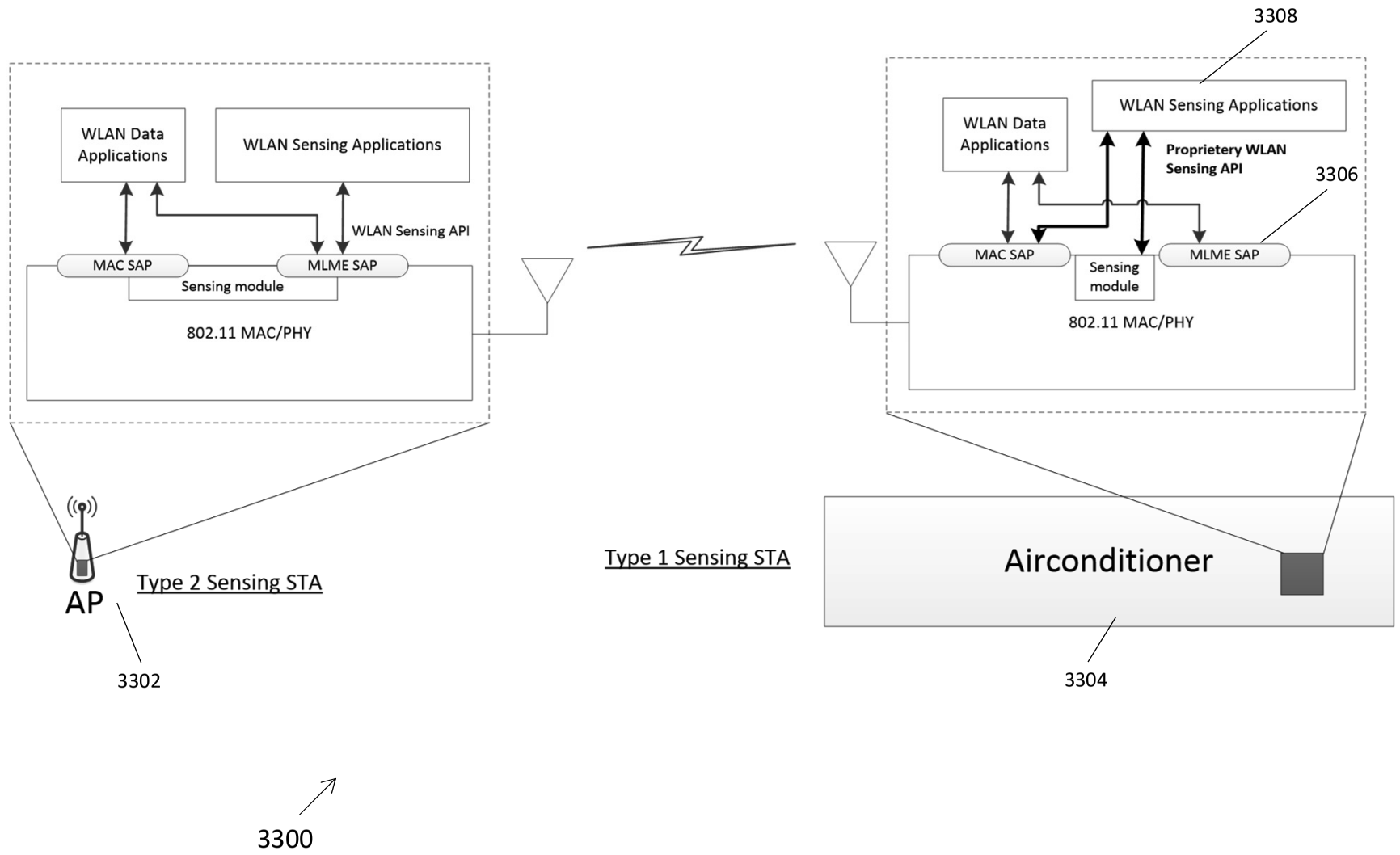

3308
WLAN Data Applications
WLAN Sensing Applications
WLAN Sensing API
MAC SAP
MLME SAP
Sensing module
802.11 MAC/PHY
WLAN Data Applications
WLAN Sensing Applications
Proprietery WLAN Sensing API
3306
MAC SAP
Sensing module
MLME SAP
802.11 MAC/PHY
AP
Type 2 Sensing STA
Type 1 Sensing STA
Airconditioner
3302
3304
3300

Figure 33

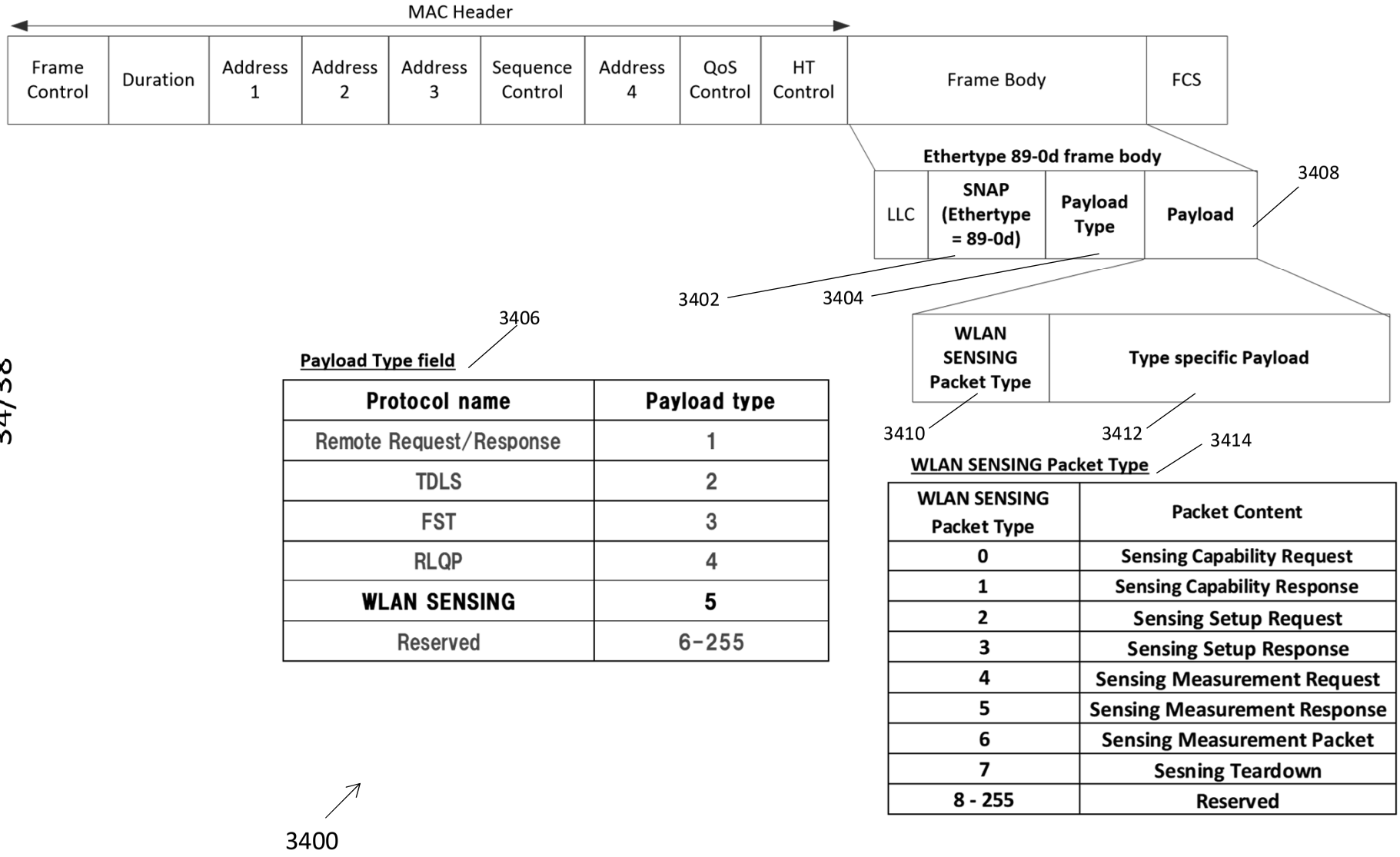

MAC Header
Frame Control
Duration
Address 1
Address 2
Address 3
Sequence Control
Address 4
QoS Control
HT Control
Frame Body
FCS
Ethertype 89-0d frame body
LLC
SNAP (Ethertype = 89-0d)
Payload Type
Payload
3408
3402
3404
3406
Payload Type field
Protocol name
Payload type
Remote Request/Response
1
TDLS
2
FST
3
RLQP
4
WLAN SENSING
5
Reserved
6-255
WLAN SENSING Packet Type
Type specific Payload
3410
3412
3414
WLAN SENSING Packet Type
Packet Content
0
Sensing Capability Request
1
Sensing Capability Response
2
Sensing Setup Request
3
Sensing Setup Response
4
Sensing Measurement Request
5
Sensing Measurement Response
6
Sensing Measurement Packet
7
Sesning Teardown
8 - 255
Reserved
3400

Figure 34

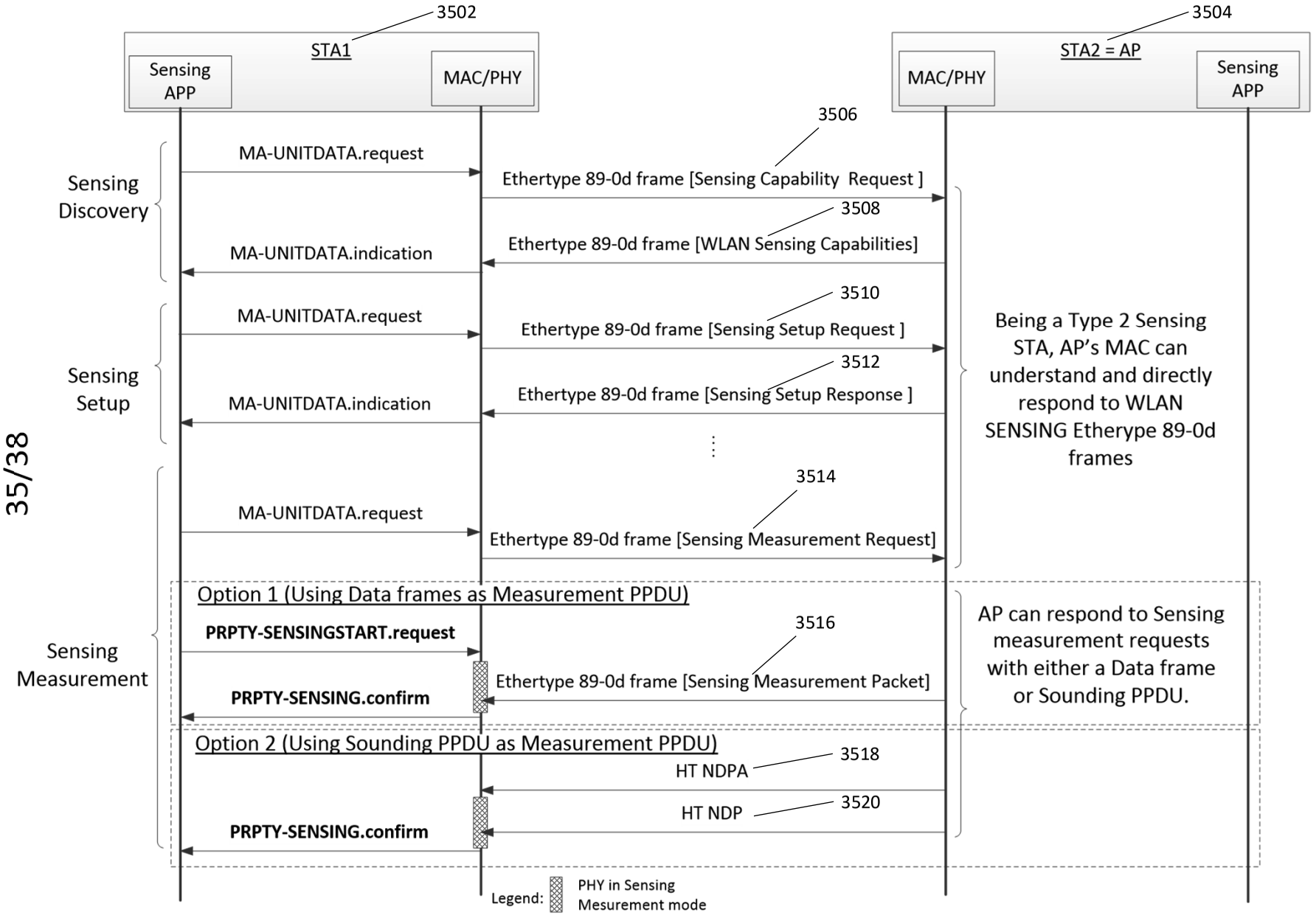


Figure 35

3500

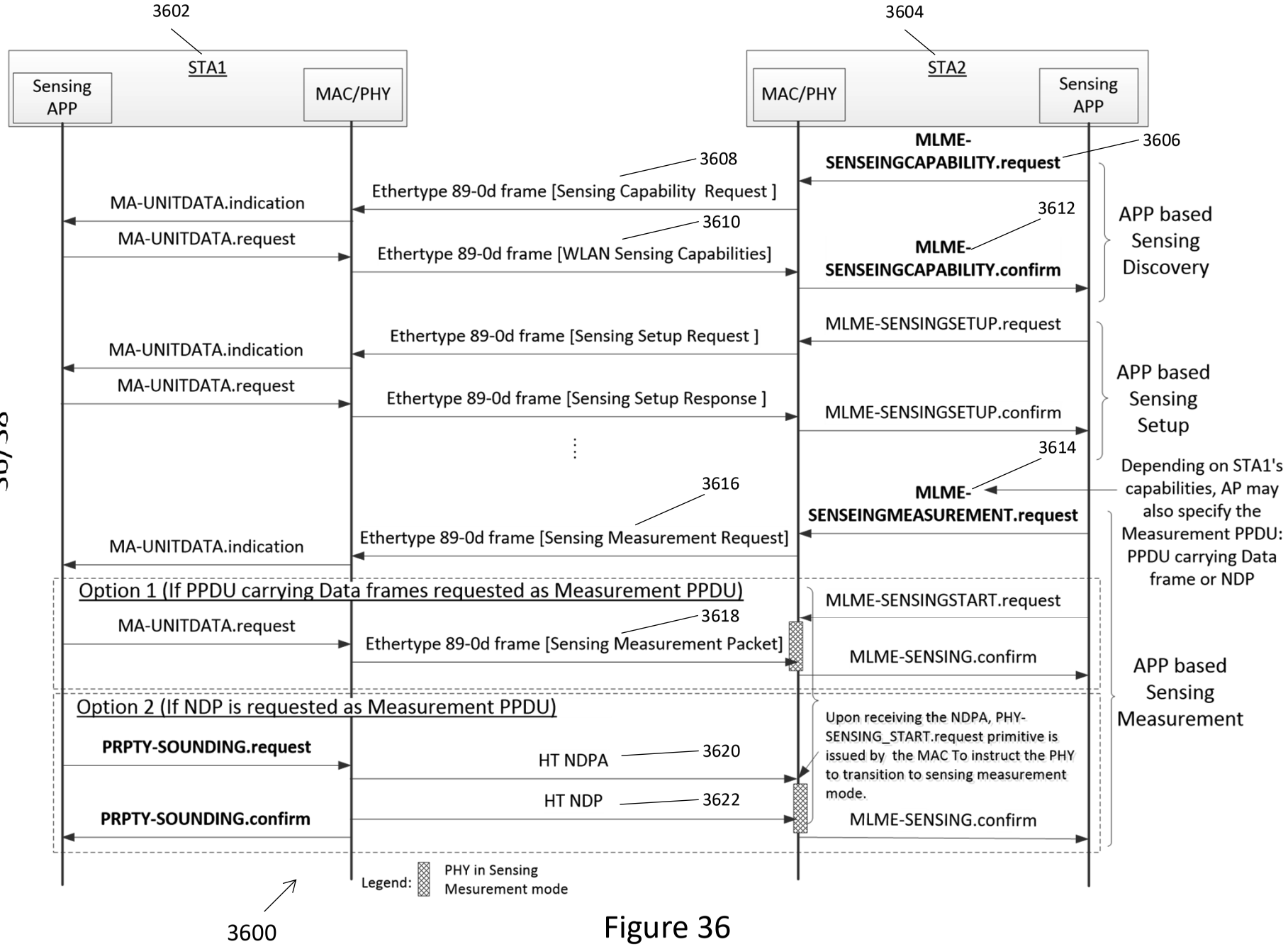

3602
STA1
Sensing APP
MAC/PHY
3604
STA2
MAC/PHY
Sensing APP
MLME-SENSEINGCAPABILITY.request
3606
3608
Ethertype 89-0d frame [Sensing Capability Request]
MA-UNITDATA.indication
MA-UNITDATA.request
3610
Ethertype 89-0d frame [WLAN Sensing Capabilities]
3612
MLME-SENSEINGCAPABILITY.confirm
APP based Sensing Discovery
MLME-SENSINGSETUP.request
Ethertype 89-0d frame [Sensing Setup Request]
MA-UNITDATA.indication
MA-UNITDATA.request
Ethertype 89-0d frame [Sensing Setup Response]
MLME-SENSINGSETUP.confirm
APP based Sensing Setup
3614
Depending on STA1's capabilities, AP may also specify the Measurement PPDU: PPDU carrying Data frame or NDP
MLME-SENSEINGMEASUREMENT.request
3616
Ethertype 89-0d frame [Sensing Measurement Request]
MA-UNITDATA.indication
Option 1 (If PPDU carrying Data frames requested as Measurement PPDU)
MLME-SENSINGSTART.request
MA-UNITDATA.request
3618
Ethertype 89-0d frame [Sensing Measurement Packet]
MLME-SENSING.confirm
APP based Sensing Measurement
Option 2 (If NDP is requested as Measurement PPDU)
Upon receiving the NDPA, PHY-SENSING_START.request primitive is issued by the MAC To instruct the PHY to transition to sensing measurement mode.
PRPTY-SOUNDING.request
HT NDPA
3620
HT NDP
3622
PRPTY-SOUNDING.confirm
MLME-SENSING.confirm
Legend:
PHY in Sensing Mesurement mode
3600

Figure 36

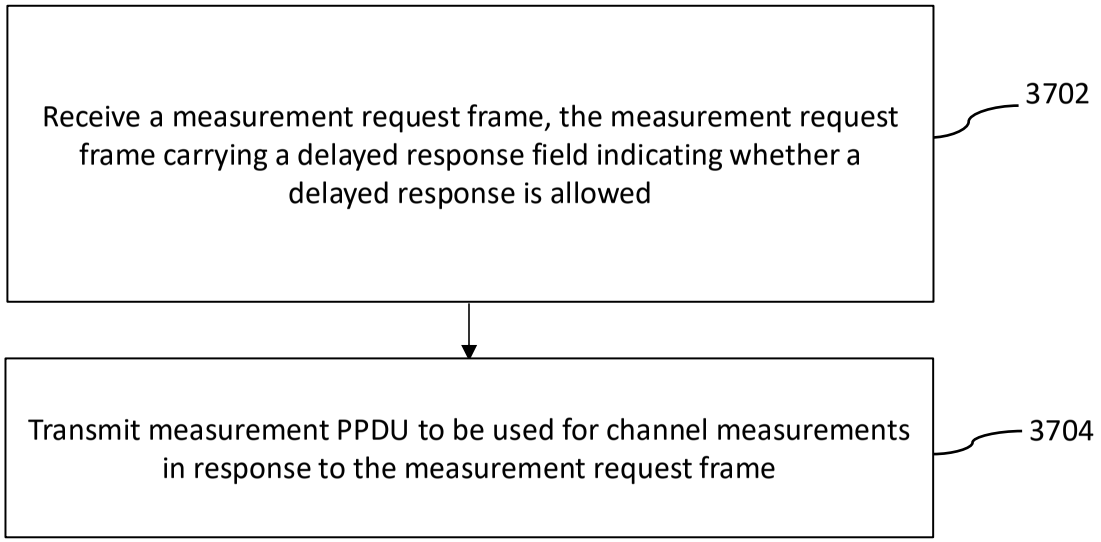

Receive a measurement request frame, the measurement request frame carrying a delayed response field indicating whether a delayed response is allowed
3702
Transmit measurement PPDU to be used for channel measurements in response to the measurement request frame
3704
3700

Figure 37

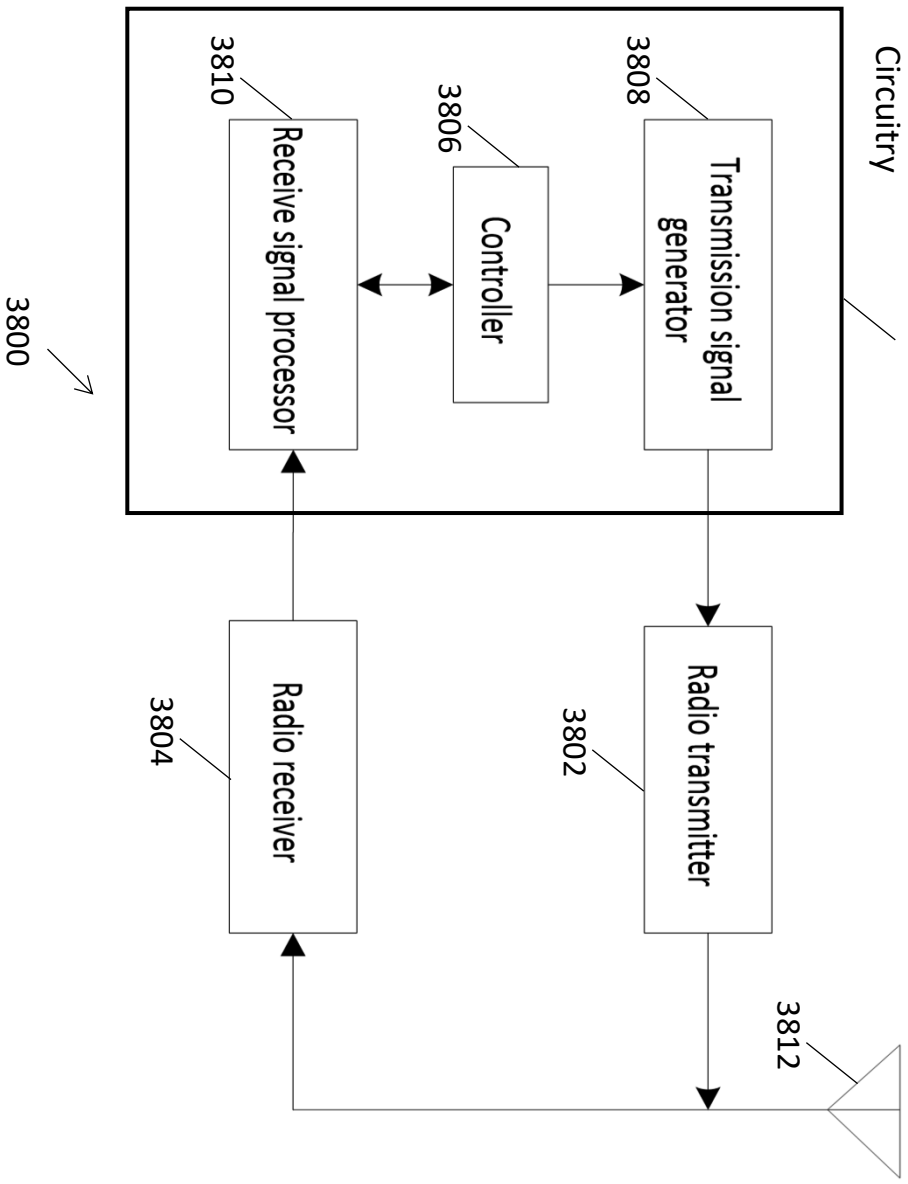

Circuitry
3814
3808
Transmission signal generator
3806
Controller
3810
Receive signal processor
3800
Radio transmitter
3802
Radio receiver
3804
3812

Figure 38