Radiocommunication Study Groups

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Specification of the EUHT-5G[1] radio interface technology

[1] Developed by [Nufront] as [EUHT-5G].

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1 System Aspects (including network architecture, system architecture, Layer 2 protocols, Physical layer, signaling details)

1.1 Scope

This specification specifies the media access control and physical layer for Enhanced Ultra High Throughput Fifth-generation (EUHT-5G) technology, including system reference model, structure, frame format and function of media access control layer, physical layer, etc.

1.2 Terms and definitions

The following terms and definitions apply to this specification.

1.2.1 Medium access control protocol data unit

A data unit exchanged between two peer MAC entities using PHY layer services.

1.2.2 MAC management protocol data unit

A data unit exchanged between two peer MAC entities for implementing a MAC management protocol.

1.2.3 MAC service data unit

Information delivered as a unit between MAC service access points.

1.2.4 central access point

An entity to provide access service to the station for access.

1.2.5 station

A terminal device that has a MAC and PHY function interface and can communicate with the CAP.

1.2.6 modulation and coding scheme

A combination of specific modulation schemes and coding rates employed on the spatial stream.

1.2.7 beam forming

A technique for pre-processing transmitted data in accordance with known channel conditions.

1.2.8 spatial stream

A data stream that is spatially transmitted in parallel.

1.2.9 spatial time stream

A spatial-time encoded stream after space-time coding of the spatial stream.

1.2.10 group acknowledgement

The way to feedback acknowledgement information in batch.

1.2.11 short preamble sequence

Training sequence for automatic gain control and coarse synchronization.

1.2.12 long preamble sequence

Training sequence for fine synchronization and channel estimation. It also called common reference signal (CRS).

1.2.13 system information channel

A physical channel containing system information such as frame structure allocation.

1.2.14 control channel

A physical channel containing user's uplink and downlink transmission scheduling information.

1.2.15 downlink sounding channel

A physical channel used to transmit downlink sounding signals and complete downlink channel measurements.

1.2.16 uplink sounding channel

A physical channel used to transmit uplink sounding signals and complete uplink channel measurements.

1.2.17 uplink scheduling request channel

A physical channel used to transmit uplink scheduling request signals.

1.2.18 uplink random access channel

The physical channel used to transmit uplink random access signals.

1.2.19 downlink traffic channel

A physical channel used to transmit user's downlink service data and control information.

1.2.20 uplink traffic channel

A physical channel used to transmit user's uplink service data and feedback information.

1.2.21 downlink guard interval

A guard interval in the physical layer frame structure for downlink to uplink conversion.

1.2.22 uplink guard interval

A guard interval in the physical layer frame structure for uplink to downlink conversion.

1.2.23 resource unit

A resource unit contains 16 data subcarriers, which is the minimum allocable unit for each STA in frequency domain.

1.3 System reference model

The system reference model is shown in Figure 1. The main functions of each layer are as follows:

a) The MAC layer includes the adaptation sublayer and MAC sublayer:

- Adaptation sublayer: It mainly provides the function of mapping and conversion between external network data and MAC layer service data unit (MSDU) in this part;

– MAC sublayer: In addition to acting as the Media Access Control, it also includes management and control functions of the system and supports specific functions of the PHY.

The MAC layer can support multiple sub-channel and multiple channels (component carriers).

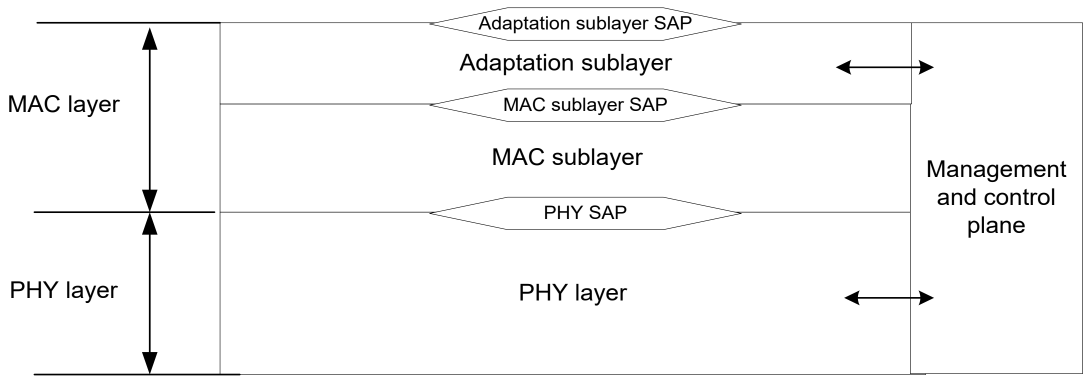
b) The PHY layer mainly provides a PHY transmission mechanism that maps the MAC Protocol Data Unit (MPDU) to the corresponding physical channel, using Orthogonal Frequency Division Multiplexing (OFDM) and Multiple Input Multiple Output (MIMO) technologies.

EUHT-5G system uses working bandwidth 1 as the basic channel bandwidth(sub-channel), and supports working bandwidth 2 and working bandwidth 3 in one component carrier, which is indicated in control channel (section 1.7.4.2). Each channel (component carrier) can contain up to 4 sub-channels. The bandwidth of sub-channel is no more than the bandwidth of one channel. The bandwidth of each sub-channel is working bandwidth 1 in the working bandwidth set.

EUHT-5G system supports carrier aggregation (CA). In CA mode, one component carrier (CC) is one channel, the channel bandwidth of each CC is stated in Broadcast Control Frame (BCF).

Figure 1

System reference model



1.4 Media Access Control layer

1.4.1 General

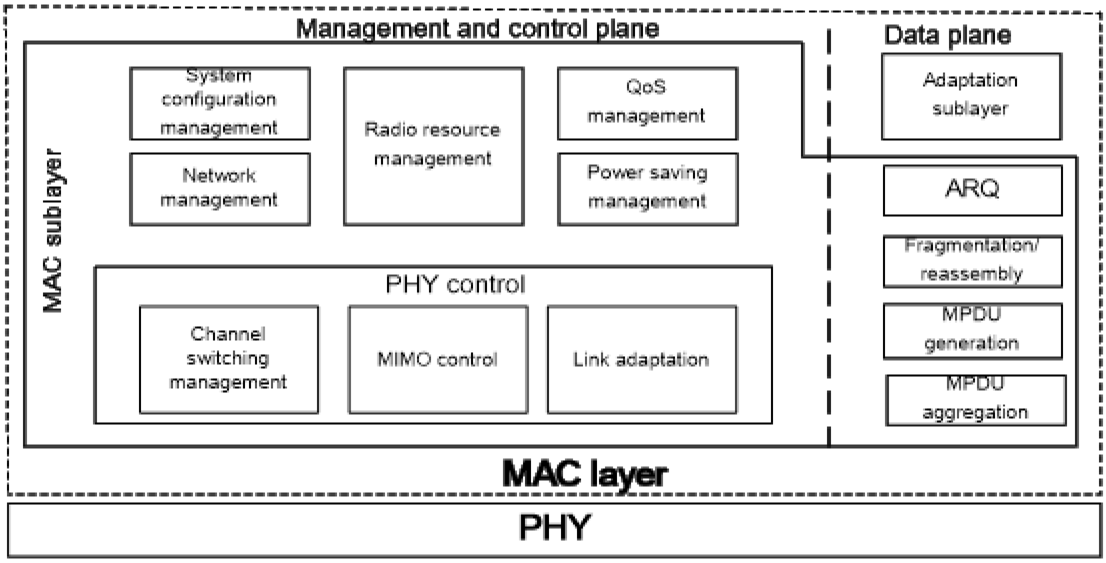
The MAC layer is used to manage and control the allocation and sharing of Physical Layer transmission resources among multiple users. The functional composition is shown in Figure 2. The MAC layer defined in this specification has the following characteristics:

– The system uses centralized control architecture for multi-user scheduling;

– The system MAC layer provides connection-oriented services for initial access process.

FIGURE 2

Functions of MAC layer



As indicated in Figure 2, there is one unique MAC layer entity in CAP or STA to implement the functions of both management/control and data plane.

1.4.2 Adaptation sublayer

The MAC layer is divided into the adaptation sublayer and the MAC sublayer, and the former uses the services provided by the latter. The adaptation sublayer completes the functions as follows:

- receive Service Data Unit (SDU) from the upper layer;
- QoS classification of the received upper SDUs;
- For the service data unit whose QoS classification is completed, the header can be compressed as needed; when the service stream information is established, the header compression function can be switched on or off in the form of dynamic modification;
- Data encryption and decryption of the SDU;
- For services with low time delay and high reliability, in addition to improve reliability by the multi-connection service replication and arbitration mechanism at the adaptation layer, service identification can also be carried out in the adaptation sublayer and the multi-connection transmission mode can be constructed therein. The multi-connection mode can be activated or deactivated by dynamic modification of the service flow information in section 1.6.5. If the multi-connection mode is enabled for the special type of service identified above and specific dual-conncetion signalling is completed, multiple copies of the message can be created by the message copy mode in the adaptation sublayer then the copied message will be assigned the same MAC sequence number (SN). In MAC sublayer, and it is possible to schedule multiple copies of the same message in different physical resources (different sub-channels, or different component carriers (CCs) of same or different CAPs) to improve transmission reliability, and repeat message detection in the MAC sublayer of the receiver to avoid duplicate message delivery. If the multi-connection mode is not enabled, SDU will be sent to MAC sublayer to generate MAC PDU with different MAC sequence number (SN), which can be sent in different physical resources (different sub-channels, or different CCs of same or different CAPs)

– Send the PDU of the adaptation sublayer generated by this layer to the MAC sublayer;

– Receive the SDU of the adaptation sublayer in the peer entity.

1.4.3 MAC sublayer

The basic functions of the MAC sublayer are distinguished in the management control plane and the data plane.

The management control plane has the following functions:

a) System configuration: it manages system configuration and exchange system configuration information with the station.

b) Radio resource management: it mainly performs the service scheduling function to allocate resources based on service parameters and channel conditions, and has functions such as load balancing and access control.

The RRM also includes CA management. The CA in this specification has following features.

1) One cell (CAP) can support multiple CCs. In EUHT specification, there is no concept about primary and secondary CC and all the CCs are independent. STA will access the network through one of the CCs belong to the candidate CAP, as indicated in section 1.6.4.

2) Each CC has its own control channel to carry L1/L2 control signaling. Each CC contains complete frame structure (preamble, SICH, CCH and TCH).

3) If dual-connection signalling is completed, MAC sublayer will negotiate with the adaptation sublayer to active the multi-connection function.

c) Mobility management: Mobility management of the idle and connected state of the STA.

d) Network access and security management: responsible for initializing and accessing processes, generating the information required for the access process, including access code selection, capability negotiation, and so on. Assist the MME entity to realize two-way authentication between the mobile station and the network;

e) QoS management: it manages the QoS parameters of the service and maintains the establishment, modification and deletion of each service stream.

f) Power saving management: it manages STAs without service to enter the sleep state, and return from the sleep state to the active state.

g) PHY control, mainly including the following sub-functions:

1) Channel management: including channel switching, management spectrum measurement and message reporting;

2) Transmission mode management: channel sounding mechanism, and MIMO working mode selection;

3) Link adaptation:

– CQI measurement and feedback;

– MCS selection and feedback;

– Power control and management.

The data plane has the following functions:

- Instant frame acknowledgement (IACK)): The instant frame acknowledgement mechanism between the uplink and downlink scheduling periods of adjacent physical frames is an important measure to reduce the time delay, and complete acknowledgement and re-transmission operations for the MPDU of the MAC layer or for the fragmented/ aggregated MPDU, see section 1.6.9;
- Fragmentation / reassembly: according to the scheduling result, the upper layer service data unit is fragmented and sent to the next processing module, and multiple fragments are reassembled and restored at the receiving end;
- MPDU generation: it encapsulates the upper layer service units into the basic MAC frames, and then sends to the next processing module;
- MPDU aggregation: the sender aggregates the upper layer service data unit according to the scheduling result.

1.4.4 Status of STA

See Figure 3 for the basic state transition of the STA in this system. In the state transition diagram, the STA has four states, i.e. initial state, access state, connection state, and idle state, see below:

- Initial state: After the STA is powered on, search for the physical frame pilot to get system synchronization;
- Access state: The STA needs to get synchronization, and then access the process randomly or by capability negotiation. It includes three sub-states:
    a) State of waiting for resource allocation requested by random access: after the STA sends the random access code, it transits to the state of waiting for resource allocation requested by random access, and waits for the CAP side to allocate the CCH for sending the subsequent random access request;
    b) State of waiting for random access response: the STA uses the resources allocated by the CAP to send a random access request frame and transits to the state of waiting for random access response;
    c) State of waiting for capability negotiation response: after the STA receives the random access response information and the allocated CCH, the STA sends the capability negotiation request frame and transits to the state of waiting for capability negotiation response.
- Connecting state (MAC_CONNECTED): service running state, in which, reserved resources are allocated to users to apply for resources by taking uplink ACK resources in downlink services; service stream management: modification and deletion; STA can enter sleep state (MAC_INACTIVE) after receiving the sleep request; the user can quit the network after receiving the quit network frame and return to the initial state.
- Idle state(MAC_IDLE): when the STA is not accessed to any connection, it enters the idle state; at this time, it can enter sleep state (MAC_INACTIVE), and it has the ability to be woke up immediately;

State transition conditions see Table 1.

TABLE 1

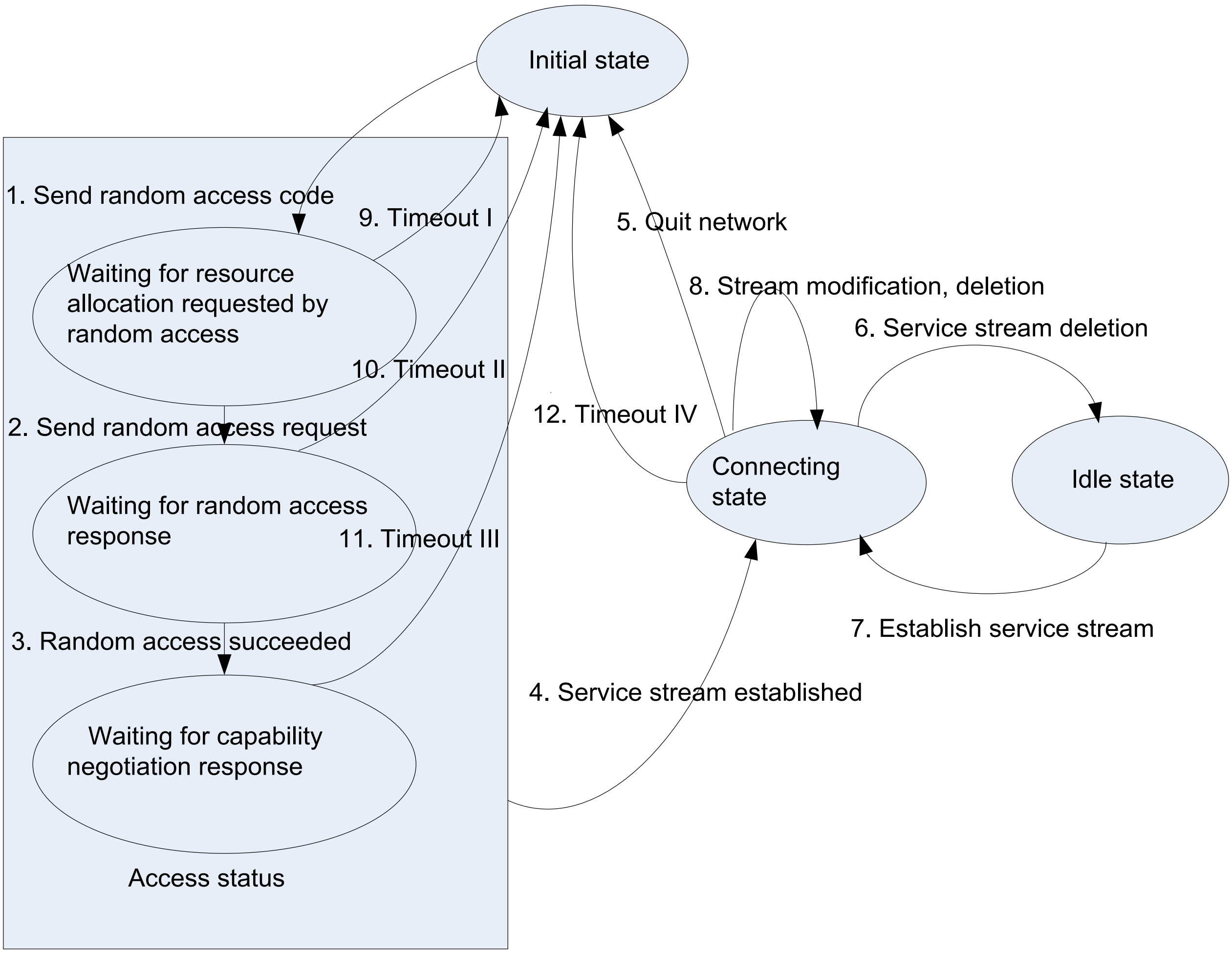
State transition conditions

No.	Transition	State before transition	State after transition	Transition condition description
1	Send random access code	Initial state	Waiting for resource allocation requested by random access	STA sends random access code
2	Send random access request	Waiting for resource allocation requested by random access	Waiting for random access response	STA receives the CCH allocated by the random access request resource, and sends random access request.
3	Random access succeeded	Waiting for random access response	Waiting for capability negotiation response	STA receives the random access response frame sent by the CAP.
4	Service stream is completed for construction	Waiting for capability negotiation response	Connecting state	CAP responses to the stream establishing request of the STA to establish a service stream for the user and allocate reserved resources for the user.
5	Quit the network	Connecting state	Initial state	The CAP receives the quit network request, responses the user, and deletes the user.
6	Service stream deletion	Connecting state	Idle state	After all the service connections of the STA are deleted, the STA transits to idle state.
7	Establishment of service stream	Idle state	Connecting state	If the STA in idle state establishes a service stream, it transits to the connecting state.
8	Stream modification, deletion	Connecting state	Connecting state	service stream management operation requested by the STA
9	Timeout I	Waiting for allocation requested by random access	Initial state	Timeout after sending random access request for resource allocation
10	Timeout II	Waiting for random access response	Initial state	Timeout of random access response
11	Timeout III	Waiting for capability negotiation response	Initial state	Timeout of capability negotiation response
12	Timeout IV	Connecting	Initial state	Timeout of stream establishment

The STA state transition is shown in Figure 3.

FIGURE 3

STA state transition − media access control frame format



The establishment of EUHT-5G's radio resource connection is done through MAC layer signaling. The radio resource link is defined as a MAC service flow in this specification. After entering MAC_CONNCETED (connecting state), the service flow will be established. The service flow will be suspended during sleep state when there is no service and resumed when STA is awakened. Service flows can also be deleted and modified.

DRX is a discontinuous reception mode. The main purpose is to reduce energy consumption to achieve power saving. EUHT-5G STAs can support flexible sleep cycles. During a sleep cycle, only the information of the listening window is listened. STA is monitoring the downlink control channel and whether there is a corresponding DTF-IND. Therefore, DRX is the concept of sleep cycle for EUHT-5G system.

For STAs in the MAC_INACTIVE (sleep state) state, if there is a cell-change mobility process that needs to be triggered, the STA will be woken up from the sleep state to the normal MAC_CONNCETED (connecting state) connection state, and then start performing related mobility process. The specific wake-up process is defined in Section 1.6.16, and the signaling involved in wake-up is same as paging signaling.

More information of power saving mechanism can be seen in section 1.6.16.

1.5 MAC frame format

1.5.1 General MAC frame format

1.5.1.1 Overview of the general MAC frame format

The frame format of the MAC Protocol Data Unit (MPDU) is shown in Figure 4. Each MPDU can be divided into three parts: part one is a fixed-length general MAC header; part two is the payload carried by the MPDU; and part three is the frame check sequence (FCS) information. In carrier aggregation mode, CAP/STA can decide which CCs are used to send these MAC PDUs, unless otherwise stated.

Bits involved in all field of the MAC frame are numbered in a sequence from low to high and sent to the Physical Layer in this sequence. The bits in one byte are transmitted to the Physical Layer in the order from the least significant bit (LSB) to the most significant bit (MSB). The bits contained in the same byte correspond to decimal numbers in order from low to high, for example, b9~b11=000, corresponding to 0; b9~b11=001, corresponding to 4. Padding bits should be appended to the frame body to make it byte aligned.

FIGURE 4

General MAC frame format

MAC header (6 bytes)						0 - 4095 bytes	4 bytes
Frame control	Fragment Sequence Number	Seq. Nr.	Reserved	Fragment indication	Length	Frame body	FCS
Bit : 16	4	12	3	1	12		

1.5.1.2 Frame control field

1.5.1.2.1 Frame control field overview

The frame control field contains the following: protocol version, frame type, subtype, Flow ID (FID), re-transmission indication and reservation. The specific format is shown in Figure 5. All MAC frames contain the frame control field.

FIGURE 5

Frame control field

Frame control (2 bytes)					
Protocol version	Frame type	Subtype	Flow ID	re-transmission indication	Reserved
Bit : 2	1	5	4	1	3

1.5.1.2.2 Protocol version field

The protocol version field is 2 bits long and always has the same length and position in all revisions of this specification. For this specification, the protocol version value is 0 and all other values are reserved.

1.5.1.2.3 Frame type and subtype fields

The frame type field has a length of 1 bit, and the subtype field has a length of 5 bits. Both fields collectively identify the function of the frame. There are two frame types: management control type and data type. Each frame type is subdivided into several subtypes. Table 2 defines various valid combinations of types and subtypes.

TABLE 2

Combinations of valid types and subtypes

Type b2	Type description	Subtype b7 b6 b5 b4 b3	Subtype description
0	Management/ control	00000	Broadcasting control frame (BCF)
		00001	Random access request frame (RA-REQ)
		00010	Random access response frame (RA-RSP)
		00011	STA basic capability request frame (SBC-REQ)
		00100	STA basic capability response frame (SBC-RSP)
		00101	Dynamic service addition request frame (DSA-REQ)
		00110	Dynamic service addition response frame (DSA- RSP)
		00111	Dynamic service change request frame (DSC-R EQ)
		01000	Dynamic service change response frame (DSC-RSP)
		01001	Dynamic service delete request frame (DSD-REQ)
		01010	Dynamic service delete response frame (DSD-RSP)
		01011	Independent resource request frame (RES-REQ)
		01100	Multiple input multiple output feedback frame based on channel state information (CSI-MIMO)
		01101	Channel quality information feedback frame (CQI-FB)
		01110	Reserved
		01111	Reserved
		10000	Acknowledgement frame (ACK)
		10001	Group acknowledgement request frame (Group AckReq)
		10010	Group acknowledgement frame (Group Ack)
		10011	Quit network frame (Quit)
		10100	Channel switching information frame (CSW - INF)
		10101	Sleep request frame (SLP-REQ)

		10110	Sleep response frame (SLP-RSP)
		10111	Downlink traffic indication frame (DTF-IND)
		11000	Measuring request frame(CM-REQ)
		11001	Measuring response frame(CM-RSP)
		11010	Measurement report frame(CM-REP)
		11011	Handover request frame(HO-REQ)
		11100	Handover command frame(HO-CMD)
		11101	Custom frame(TLV, Type-Length-Value structure)
		11110～11111	Reserved
1	Data	00000	Data frame (DATA)
		00001	Data padding frame (PAD DATA)
		00010～11111	Reserved

1.5.1.2.4 Flow ID (FID) field

The length of the FID field is 4 bits. 0000 is used for management control stream, and 0001~1111 is for the data streams.

1.5.1.2.5 Re-transmission indication field

The re-transmission indication field is 1 bit in length. If the current frame is a re-transmission frame of the previous frame, the field is set to 1; otherwise, it is set to 0.

1.5.1.2.6 Reserved field

The reserved field is 3 bits, default of 0.

1.5.1.2.7 Fragment sequence number field

The fragment sequence number field is 4 bits long and used to indicate the number of each fragment of the MSDU/MMPDU. The value ranges from 0 to 15. When the MSDU/MMPDU has only one fragment, the FSN is 0; when the MSDU/MMPDU has multiple fragments, the first FSN is 0. The FSN of different fragments of the same MSDU/MMPDU is incremented by 1. In the instant acknowledgement mode, the fragment sequence number can be wrap-around, that is, after the FSN 15 is acknowledged, it counts from 0 subsequently.

1.5.1.2.8 Sequence number field

The sequence number field is 12 bits long and has a value range of 0 to 4095 to indicate the sequence number of the MSDU/MMPDU. All transmitted MSDU/MMPDUs in an FID stream are assigned a sequence number. The first MSDU/MMPDU sequence number is 0, and the sequence number of different MSDU/MIVIPDUs in the same FID is incremented by 1.

1.5.1.2.9 Reserved

The reserved field is 3 bits, default of 0.

1.5.1.3 Fragment indication field

The fragment indication field is 1 bit in length. In all data frames or management control frames with sequence numbers, if the current MSDU/MMPDU still has any fragment after the current frame, the field is set to 1; otherwise, the field is set to 0.

1.5.1.4 Length field

The length field is 12 bits, which indicates the total byte length of all fields between the MAC header field and FCS field.

1.5.1.5 Frame body field

The length of the frame body field is variable, the minimum frame body length is 0 byte, and the maximum frame body length is 4095 bytes.

1.5.1.6 Frame check sequence field

The FCS field is 32 bits, containing a 32-bit CRC. The FCS is calculated from the MAC header and the entire field of the frame body.

The FCS is calculated using the standard polynomial of degree 32. See Equation 1:

$$G(x) = x^{32} + x^{26} + x^{23} + x^{22} + x^{16} + x^{12} + x^{11} + x^{10} + x^{8} + x^{7} + x^{5} + x^{4} + x^{2} + x + 1$$

Equation 1

The initial state of the register is 0xFFFFFFFF, and the register state is inverted as the FCS field output after the end of the operation. The FCS field transmits in the order from high order to low.

1.5.2 Data frame

1.5.2.1 Data frame format

The format of the data frame is shown in Figure 6.

FIGURE 6

Data frame format

MAC header (6 bytes)								0 - 4095 bytes	4 bytes
Frame control	Fragment Sequence Number	Seq. Nr	Reserved	Channel-associated request indication	Instant/ delayed acknowledgment	Fragment indication	Length	Frame body	FCS
Bit: 16	4	12	1	1	1	1	12		

1.5.2.2 Reserved field

The field is 1 bit long, and default of 0.

1.5.2.3 Channel-associated request indication field

The channel-associated request indication field is 1 bit in length. If the field is 1, it indicates that a channel-associated resource request field will be added at the forefront of the frame body; if the segment is 0, it indicates that there is no channel-associated resource request field.

1.5.2.4 Instant / delayed acknowledgement field

Instant /delayed acknowledgement field is 1bit long. If the field is 1, it indicates that the sender notifies the receiver to immediately acknowledge all data frames that are not acknowledged when receiving the frame. If the field is 0, it indicates that the sender allows the receiver to delay the acknowledgement of the frame when receiving it.

1.5.2.5 Data padding frame

When the frame type is 1, and the subtype is 00001, it indicates that this is a data padding frame. At this time, the frame body is invalid data, and only used as a placeholder.

1.5.3 Management control frame

1.5.3.1 General

The management control frame is divided into the management control frames with and without the sequence number.

The management control frame without sequence number includes: random access request frame, random access response frame, STA basic capability request frame, STA basic capability response frame, dynamic service addition request frame, dynamic service addition response frame, dynamic service change request frame, dynamic service change response frame, dynamic service delete request frame, dynamic service delete response frame, independent resource request frame, ACK frame, Group AckReq frame, Group Ack frame, quit network frame, channel switching information frame, sleep request frame, sleep response frame, downlink traffic indication frame, CM-REQ, CM-RSP, HO-REQ, HO-CMD and extensible TLV frame.

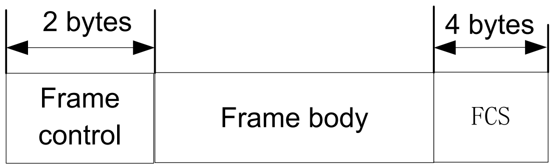
The management control frame with sequence number includes the BCF frame, CSI-MIMO frame, CQI-FB frame, and CM-REP frame.

1.5.3.2 General frame format of management control frame without sequence number

General frame format of management control frame without sequence number is shown in Figure 7.

FIGURE 7

General frame format of management control frame without sequence number

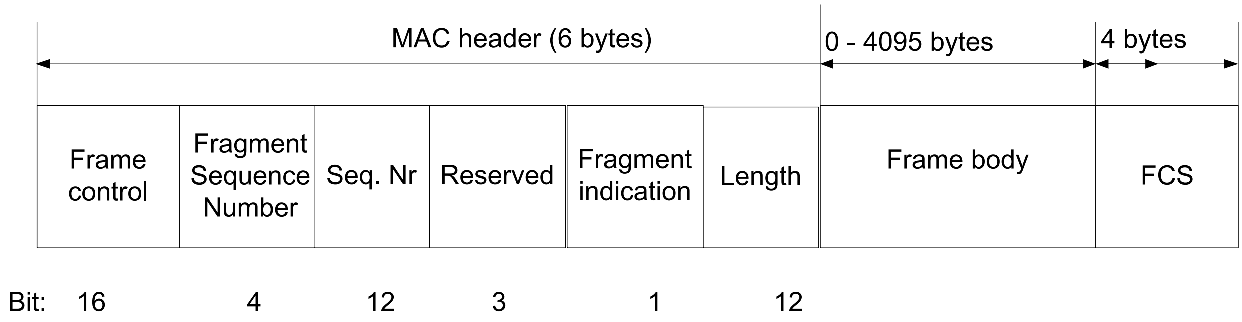


1.5.3.3 General frame format of management control frame with sequence number

General frame format of management control frame with sequence number is shown in Figure 8.

FIGURE 8

General frame format of management control frame with sequence number



1.5.3.4 Management control frame definition

1.5.3.4.1 Broadcast control frame

BCF is used for CAP to broadcast its capabilities and informations.

The BCF frame body contains fixed and extensible parts. See Table 3 for information of the fixed part. The extensible part can be in a TLV structure and appended to the fixed part, as indicated in section 1.5.3.4.23. STA can know whether there is extensible part by checking if the length field in BCF MAC header is larger than the length of fixed part.

TABLE 3

Fixed part of BCF frame body

Information	Length/ bit	Remarks
CAP-MAC address	48	Unique identifier of the CAP
Working channel number	8	The minimum channel number occupied by the CAP
work bandwidth	2	Working bandwidths for broadcasting CAP: 0: working bandwidth 1 in working bandwidth mode; 1: working bandwidth 2 in working bandwidth mode; 2: working bandwidth 3 in working bandwidth mode; 3: Reserved
CAP antenna configuration	3	Indicates the antenna configuration on the CAP side, 0:1 antenna; 1:2 antennas; 2:4 antennas; 3:6 antennas; 4:8 antennas; 5:16 antennas; 6~7: reserved
Network identifier length	8	The valid length of the network identifier field. The value ranges from 1 to 31, in bytes.
Network identifier	248	A string started with a letter or number, with the maximum length of 31 bytes.

Time stamp	64	Provides a public clock within the CAP for system synchronization during STA initialization, unit: μs
BCF interval	16	Indicates the time cycle in which the BCF frame appears, unit: ms
The minimum backoff window for Random Access	4	Used for the control of the backoff window for Random Access, and the value of the minimum backoff window（ranges within $0\sim2^n-1$, n=4).
The minimum backoff window for scheduling request	4	Used to control the backoff window of the collision-based resource request, and the minimum window value (ranges within $0\sim2^n-1$, n=4).

1 TABLE 3 (CONTINUED)

Information	**Length/ bit**	**Remarks**
The maximum backoff window for Random Access	8	Used for the control of the backoff window for Random Access, and the value of the maximum backoff window (ranges within $0\sim2^n-1$, n=8).
The maximum backoff window for scheduling request	8	Used to control the backoff window of the collision-based resource request, and the maximum window value (ranges within $0\sim2^n-1$, n=8).
CAP transmit power	8	Indicates the current transmit power of the CAP, The signed decimal number of the field is *n*, *n* = -128~127 (the negative part is represented in the complement form): the transmit power of CAP is *n* dBm
RSSI_DL_DROP	8	Indicates the threshold value for RSSI, the signed decimal number of this field is n, n = -128~127 (the negative part is represented in the complement form): the RSSI threshold by the current serving CAP is n dBm.
Position of the downlink sounding channel	8	Indicates the position of the downlink sounding channel in the DL-TCH. The field corresponds to a decimal number of *n* and *n*=0-255. The downlink sounding channel divides the DL-TCH into the front and rear parts, and the latter part has *n* OFDM symbols. The DL TCH length indicated in SICH does not include the length of downlink sounding channel.
Demodulation reference signal time domain interval 0	7	Number of OFDM symbols for adjacent demodulation reference signal time domain intervals (configured with short interval)
Demodulation reference signal time domain interval 1	9	Number of OFDM symbols for adjacent demodulation reference signal time domain intervals (configured with long interval)
DGI	2	Downlink-uplink conversion time, 0: The guard interval is 2 OFDM symbol periods; 1: The guard interval is 4 OFDM symbol periods; 2: The guard interval is 1 OFDM symbol periods; 3: Reserved;
UGI	2	Uplink-downlink conversion time, 0: The guard interval is 2 OFDM symbol periods; 1: The guard interval is 4 OFDM symbol periods 2: The guard interval is 1 OFDM symbol periods;

		3: Reserved;
UL-RACH format	2	00: Random access format 1; 01: Random access format 2; 10: Random access format 3; 11: Random access format 1 with 8 repetition
LDPC support mode	1	0: support LDPC 448/1344/2688 code length 1: support LDPC 1344/2688/5376 code length
Reserved	12	Default of 0

In low-error mode, the fixed part of BCF frame body is shown in Table 4:

TABLE 4

Fixed part of BCF frame body in low-error mode

Information	**Length/ bit**	**Remarks**
CAP-MAC address	48	Unique identifier of the CAP
Working channel number	8	The minimum channel number occupied by the CAP
CAP Working bandwidth set	3	000: 5/10/20M working bandwidth mode 001: 10/20/40M working bandwidth mode 010: 15/30/60M working bandwidth mode 011: 20/40/80M working bandwidth mode 100: 25/50/100M working bandwidth mode
work bandwidth	2	Working bandwidths for broadcasting CAP: 0: working bandwidth 1 in working bandwidth mode; 1: working bandwidth 2 in working bandwidth mode; 2: working bandwidth 3 in working bandwidth mode; 3: Reserved
CAP antenna configuration	3	Indicates the antenna configuration on the CAP side, 0:1 antenna; 1:2 antennas; 2:4 antennas; 3:6 antennas; 4:8 antennas; 5:16 antennas; 6~7: reserved
BCF interval	16	Indicates the time cycle in which the BCF frame appears, unit: ms
The minimum backoff window for Random Access	4	Used for the control of the backoff window for Random Access, and the value of the minimum backoff window (ranges within $0\sim2^n-1$, n=4).
The minimum backoff window for scheduling request	4	Used to control the backoff window of the collision-based resource request, and the minimum window value (ranges within $0\sim2^n-1$, n=4).
Reserved	4	Default of 0

TABLE 4 (CONTINUED)

Information	Length/ bit	Remarks
The maximum backoff window for Random Access	8	Used for the control of the backoff window for Random Access, and the value of the maximum backoff window (ranges within $0\sim2^n-1$, n=8).
The maximum backoff window for scheduling request	8	Used to control the backoff window of the collision-based resource request, and the maximum window value (ranges within $0\sim2^n-1$, n=8).
CAP transmit power	8	Indicates the current transmit power of the CAP, The signed decimal number of the field is *n*, *n* = -128~127 (the negative part is represented in the complement form): the transmit power of CAP is *n* dBm
RSSI_DL_DROP	8	Indicates the threshold value for RSSI, the signed decimal number of this field is n, n = -128~127 (the negative part is represented in the complement form): the RSSI threshold by the current serving CAP is n dBm.
UL-RACH format	2	00: Random access format 1; 01: Random access format 2; 10: Random access format 3; 11: Reserved;
Reserved	25	Default of 0

It should be noted that the extensible part is located in the frame body of BCF, which means it is part of BCF frame although it uses the structure of TLV. The subtype of the frame is 00000 (BCF) while the custom frame has its own frame subtype (11101).

In the extensible part of BCF, TLV_type=0 is defined for starting frequency of component carriers in aggregation, as indicated in Table 5. STA can determine the number of component carriers by checking the TLV length field.

TABLE 5

The extensible part of BCF with TLV_type = 0

Field	TLV_type	TLV length	Data
Bit	8	16	Customized
Value	0	32*N, N<=16	Customized

The Data field in the extensible part of BCF with TLV_type=0 is defined in Table 6.

TABLE 6

Data field with TLV_type=0 of the extensible part of BCF

Name	Length/ bit	Value
starting frequency of component carrier #1	19	Indicates starting frequency of component carrier (CC) #1, i.e frequency when channel number=0.

		Refer to Table E.1-3 for EUHT-ARFCN
Bandwidth of component carrier #1	4	0000 ~ 1101: 5/10/15/20/25/30/40/50/60/80/100/200/400/1000MHz
Reserved	1	Reserved
CAP transmit power of component carrier #1	8	Indicates the current transmit power of the CAP in component carrier #1, The signed decimal number of the field is *n*, *n* = -128~127 (the negative part is represented in the complement form): the transmit power of CAP is *n* dBm
…	…	…
starting frequency of component carrier #N	19	Indicates starting frequency of component carrier #N, i.e frequency when channel number=0. Refer to Table E.1-3 for EUHT-ARFCN
Bandwidth of component carrier #N	4	0000 ~ 1101: 5/10/15/20/25/30/40/50/60/80/100/200/400/1000MHz
Reserved	1	Reserved
CAP transmit power of component carrier #N	8	Indicates the current transmit power of the CAP in component carrier #N, The signed decimal number of the field is *n*, *n* = -128~127 (the negative part is represented in the complement form): the transmit power of CAP is *n* dBm

Based on the starting frequency of each CC (F_start_{cc}), working channel number (WCN) and Working bandwidth of CC (Working_BW_{cc}), the center frequency value (F_center_{cc}) of each component carrier (CC) can be calculated as Equation 2

$$\text{F\_center}_{cc} = \text{F\_start}_{cc} + (\text{WCN} + 0.5) * \text{Working\_BW}_{cc}$$

Equation 2

In the extensible part of BCF, TLV_type=5 is defined for uplink open loop power control parameters for each component carrier, as indicated in Table 7.

TABLE 7

The extensible part of BCF with TLV_type = 5

Field	TLV_type	TLV length	Data
Bit	8	16	Customized
Value	5	If Para_ind = 1, TLV length = 38*N+5, N<= 16 If Para_ind = 0, TLV length = 43;	Customized

The Data field in the extensible part of BCF with TLV_type=5 is defined in Table 8.

TABLE 8

The Data field with TLV_type=5 of the extensible part of BCF

Name	Length/ bit	Value
Para_ind	1/b_0	0: All component carriers have same power control parameters as component carrier #1; 1: Each component carrier has different power control parameters
Carrier_Num	4/ b_4 b_3 b_2 b_1	The number of component carrier N with configured power control parameters, value range（1~16）； 0: N = 1; … 15: N = 16
$P_{STAmax,1}$	8/ b_{12}~b_5	The maximum output power on component carrier #1(unit: dBm); the signed decimal number of the field is *n*, *n* = -128~127, b_{20} is the sign bit (0: positive, 1:negative);
$P_{0,1}$	8/b_{20}~b_{13}	The target received power of STA is *n* dBm on component carrier 1, and the signed decimal number of the field is *n*, *n* = -128~127, b_{20} is the sign bit (0: positive, 1:negative);
$Alpha_1$	3/b_{23}~b_{21}	the compensation factor α_{cc} on component carrier 1: {0, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1}；
$P_{0\_SRS,1}$	8/b_{31}~b_{24}	The target received power of STA is *n* dBm for UL SRS transmission on component carrier 1, and the signed decimal number of the field is *n*, *n* = -128~127 , b_{31} is the sign bit (0: positive, 1:negative);
$Alpha_{SRS,1}$	3/b_{34}~b_{32}	the compensation factor α_{cc} for UL SRS transmission on component carrier 1: {0, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1};
$P_{0\_prach,1}$	8/b_{42}~b_{35}	The target received power of STA is *n* dBm for UL PRACH transmission on component carrier 1, and the signed decimal number of the field is *n*, *n* = -128~127, b_{42} is the sign bit (0: positive, 1:negative);
…….		
$P_{STAmax,N}$	8/$b_{(N-1)*38+12}$~$b_{(N-1)*38+5}$	The maximum output power on component carrier N(unit: dBm); the signed decimal number of the field is *n*, *n* = -128~127, b_{20} is the sign bit (0: positive, 1:negative);
$P_{0,N}$	8/$b_{(N-1)*38+20}$~$b_{(N-1)*38+13}$	The target received power of STA is *n* dBm on component carrier N, and the signed decimal number of the field is *n*, *n* = -128~127, $b_{(N-1)*38+20}$ is the sign bit (0: positive, 1:negative);
$Alpha_N$	3/$b_{(N-1)*38+23}$~$b_{(N-1)*38+21}$	the compensation factor α_{cc} on component carrier N: {0, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1}；
$P_{0\_SRS,N}$	8/$b_{(N-1)*38+31}$~$b_{(N-1)*38+24}$	The target received power of STA is *n* dBm for UL SRS transmission on component carrier N, and the signed decimal number of the field is *n*, *n* = -128~127, $b_{(N-1)*38+31}$ is the sign bit (0: positive, 1:negative);
$Alpha_{SRS,N}$	3/b(N-1)*38+34~b(N-1)*38+32	the compensation factor α_{cc} for UL SRS transmission on component carrier N: {0, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1};

$P_{0\_prach,N}$	$8/b_{(N-1)*38+42}$~$b_{(N-1)*38+35}$	The target received power of STA is n dBm for UL PRACH transmission on component carrier N, and the signed decimal number of the field is n, n = -128~127, $b_{(N-1)*38+42}$ is the sign bit (0: positive, 1:negative);

In the extensible part of BCF, TLV_type=6 is defined for received signal strength indication (RSSI) threshold for handover, as indicated in Table 9.

TABLE 9

The extensible part of BCF with TLV_type = 6

Field	**TLV_type**	**TLV length**	**Data**
Bit	8	16	Customized
Value	6	If Para_ind = 1, TLV length = 8*N+5, N<= 16 If Para_ind = 0, TLV length = 13;	Customized

The Data field with TLV_type=6 of BCF_TLV frame is defined in Table 10.

TABLE 10

The Data field with TLV_type=6 of BCF_TLV frame

Name	Length/ bit	Value
Para_ind	1	0: All component carriers have same RSSI threshold parameters as component carrier #1; 1: Each component carrier has different RSSI threshold parameters
Carrier_Num	4	The number of component carrier N with configured RSSI threshold parameters, value range（1~16）； 0: N = 1; … 15: N = 16
RSSI_DL_DROP_1	8	Indicates the threshold value for RSSI on component carrier #1, the signed decimal number of this field is *n*, *n* = -128~127 (the negative part is represented in the complement form): the RSSI threshold by the current serving CAP is *n* dBm.
…	…	…
RSSI_DL_DROP_N	8	Indicates the threshold value for RSSI on component carrier #N, the signed decimal number of this field is *n*,

		n = -128~127 (the negative part is represented in the complement form): the RSSI threshold by the current serving CAP is *n* dBm.

1.5.3.4.2 Random access request frame

The random access request frame is shown in Figure 9, which is used by the STA to initiate the random access request to the CAP.

FIGURE 9

Random access request frame

Bit:	16	48	48	8	8	32	32
	Frame control	STA-MAC	CAP-MAC	Power adjustment margin	STA transmit power	Reserved	FCS

The contents of the random access request frame body are shown in Table 11.

TABLE 11

Random access request frame body

Name	Length/ bit	Value
STA-MAC address	48	MAC address of the STA
CAP-MAC address	48	MAC address of the CAP requested for access
Power adjustment margin	8	STA transmit power adjustment margin. The signed decimal number of the field is *n*, *n* = -128~127 (the negative part is represented in the complement form): the transmit power margin is *n* dBm
STA transmit power	8	The current transmit power of the STA. The signed decimal number of the field is *n*, *n* = -128~127 (the negative part is represented in the complement form): the STA transmit power is *n* dBm
Reserved	32	Default of 0

1.5.3.4.3 Random access response frame

The random access response frame is shown in Figure 10, which is used by the CAP to respond to the received random access request.

FIGURE 10

Random access response frame

Bit:	16	8	2	6	48	12	36	32
	Frame control	Power	Access status	Reserved	STA-MAC	TSTAID	Reserved	FCS

The contents of the random access response frame body are shown in Table 12.

TABLE 12

Random access response frame body

Name	Length/ bit	Value
Power adjustment	8	Transmit power adjustment value of the STA. The signed decimal number of the field is *n*, *n* = -128~127 (the negative part is expressed in complement form): the transmit power adjustment value is *n* dBm
Access status	2	0: reserved; 1: Give up 2: Success; 3: Re-access
Reserved	6	Default of 0
STA's MAC address	48	MAC address of the STA
TSTAID	12	Temporary identifier for identifying the user
Reserved	36	Default of 0

1.5.3.4.4 STA basic capability request frame

The STA basic capability request frame is used by the STA to notify the CAP of its basic capabilities. The information contained in the frame body is shown in Table 13.

TABLE 13

STA basic capability request frame body

Name	Length/ bit	Value
Number of STA antenna	3	Indicates the number of antennas on the STA side, 0:1 antenna; 1:2 antennas; 2:4 antennas; 3:6 antennas; 4:8 antennas; 5:16 antennas; 6~7: reserved
Reserved	2	Default of 0
STA supporting carrier aggregation	16	Indicates which component carriers broadcasted in BCF are supported by this STA. "1" in the b_n (LSB is b0): Component carrier #n+1 is supported. "0" in the b_n (LSB is b0): Component carrier #n+1 is not supported.
Reserved	1	Default of 0
STA working sub-channel mapping	4	0001: Sub-channel 0;

		0010: Sub-channel 1; 0100: Sub-channel 2; 1000: Sub-channel 3; By bitmap “OR” operation, it can indicate working bandwidth 2 and working bandwidth 3 stations operating on multiple working bandwidth 1 subchannels
STA version number	4	Default of 0
Maximum number of STA transmit spatial streams	3	0: the number of spatial streams is 1; 1: the number of spatial streams is 2; 2: The number of spatial streams is 3; 3: The number of spatial streams is 4; 4: The number of spatial streams is 5; 5: The number of spatial streams is 6; 6: The number of spatial streams is 7; 7: The number of spatial streams is 8
Maximum number of spatial streams that STA receives	3	0: The number of spatial streams is 1; 1: The number of spatial streams is 2; 2: The number of spatial streams is 3; 3: The number of spatial streams is 4; 4: The number of spatial streams is 5; 5: The number of spatial streams is 6; 6: The number of spatial streams is 7; 7: The number of spatial streams is 8
Reserved	3	Default of 0
Indication of Tx STBC capability of the STA	1	0: Not supported; 1: Support
Indication of Rx STBC Capability of the STA	1	0: Not supported; 1: Support
Reserved	9	Default of 0
STA DGI demand indication	2	0: 2 guard intervals between OFDM symbols are required; 1: 4 guard intervals between OFDM symbols are required; 2: 1 guard intervals between OFDM symbols are required; 3: reserved;
STA UGI demand indication	2	0: 2 guard intervals between OFDM symbols are required; 1: 4 guard intervals between OFDM symbols are required; 2: 1 guard intervals between OFDM symbols are required; 3: reserved;
Authentication access mode	2	0: Authentication is not supported; 1: Support authentication, local security context is available 2: Support authentication, no local security context 3: Reserved
STA support changing working bandwidth	4	Please refer to STA support working bandwidth mode. b2..b0 = 000: not support changing working bandwidth b0=1: support changing working bandwidth 3 b0=0: not support changing working bandwidth 3

		b1=1: support changing working bandwidth 2 b1=0: not support changing working bandwidth 2 b2=1: support changing working bandwidth 1 b2=0: not support changing working bandwidth 1 b3: reserved
Reserved	3	Default of 0
STA support LDPC code length	4	b3..b0: b0： 0: not support LDPC 448 code length 1: support LDPC 448 code length b1： 0: not support LDPC 1344 code length 1: support LDPC 1344 code length b2： 0: not support LDPC 2688 code length 1: support LDPC 2688 code length b3： 0: not support LDPC 5376 code length 1: support LDPC 5376 code length
Supported bandwidth of STA	16	Indicates which bandwidths are supported by this STA. “1” in the b_n (LSB is b0): Bandwidth #n+1 is supported. “0” in the b_n (LSB is b0): Bandwidth #n+1 is not supported. Bandwidth #1 ~ #16 is as follows, 5/10/15/20/25/30/40/50(sub-6GHz)/60/80/100MHz(sub-6GHz)/50(mmWave band)/100(mmWave band)/200/400/1000MHz
Reserved	21	Default of 0

1.5.3.4.5 STA basic capability response frame

The STA basic capability response frame is used by the CAP to notify the STA working parameters. The information contained in the frame body is shown in Table 14.

TABLE 14

STA basic capability response frame body

Name	Length/ bit	Value
STA ID	12	Used to identify users
Working subchannel mapping	4	0001: Sub-channel 0; 0010: Sub-channel 1; 0100: Sub-channel 2; 1000: Sub-channel 3; By bitmap “OR” operation, it can indicate working bandwidth 2 and working bandwidth 3 stations operating on multiple working bandwidth 1 subchannels
Carrier aggregation indication	16	CAP notifies which component carriers broadcasted in BCF are used by the STA based on the capability request frame sent by STA. “1” in the b_n (LSB is b0): Component carrier #n+1 is used.

		"0" in the b_n (LSB is b0): Component carrier #n+1 is not used.
Reserved	4	Default of 0
Tx STBC	1	0: Not supported; 1: Support
Rx STBC	1	0: Not supported; 1: Support
Maximum number of STA transmit spatial streams	3	0: The number of spatial streams is 1; 1: The number of spatial streams is 2; 2: The number of spatial streams is 3; 3: The number of spatial streams is 4; 4: The number of spatial streams is 5; 5: The number of spatial streams is 6; 6: The number of spatial streams is 7; 7: The number of spatial streams is 8
Maximum number of spatial streams that STA receives	3	0: The number of spatial streams is 1; 1: The number of spatial streams is 2; 2: The number of spatial streams is 3; 3: The number of spatial streams is 4; 4: The number of spatial streams is 5; 5: The number of spatial streams is 6; 6: The number of spatial streams is 7; 7: The number of spatial streams is 8
Reserved	10	Default 0
STA DGI demand	2	0: 2 guard intervals between OFDM symbols are required; 1: 4 guard intervals between OFDM symbols are required; 2: 1 guard intervals between OFDM symbols are required; 3: reserved;
STA UGI demand	2	0: 2 guard intervals between OFDM symbols are required; 1: 4 guard intervals between OFDM symbols are required; 2: 1 guard intervals between OFDM symbols are required; 3: reserved;
Authentication instruction	2	0: Authentication is not supported; 1: Support authentication, security context is available. 2: Support authentication, no security context. 3: Reserved
STA working bandwidth	4	Indicates the working bandwidth of STA, 0~15 represents bandwidth #1~#16 Bandwidth #1 ~ #16 is as follows, 5/10/15/20/25/30/40/50(sub-6GHz)/60/80/100MHz(sub-6GHz)/50(mmWave band)/100(mmWave band)/200/400/1000MHz
Indication of changed working bandwidth and sub-channel	4	b2…b0: 000: not change current sub-channel。 001: change to sub-channel 1 in working bandwidth 1 010: change to sub-channel 2 in working bandwidth 1

		011: change to sub-channel 3 in working bandwidth 1 100: change to sub-channel 4 in working bandwidth 1 101: change to upper sideband in working bandwidth 2 110: change to lower sideband in working bandwidth 2 111: change to working bandwidth 3 b3: reserved
STA support LDPC code length mode	1	0: support LDPC448/1344/2688 code length 1: support LDPC 1344/2688/5376 code length
Reserved	43	Default 0

1.5.3.4.6 Service stream management

The dynamic service addition request frame is shown in Figure 11. It is used for the request for adding service streams between the CAP and the STA.

FIGURE 11

Dynamic service addition request frame

Bit:	16	4	3	1	32	48	36	4	32
	Frame control	FID	Service type	Direction	Service guarantee rate	Target MAC address	Reserved	FID Max Buffer Size (MaxBufferSize)	FCS

The dynamic service addition response frame is shown in Figure 12, which is used to response on the dynamic service addition request initiated by the CAP to the STA.

FIGURE 12

Dynamic service addition response frame

Bit:	16	4	3	1	32	32	36	4	32
	Frame control	FID	Service type	Reserved	Service guarantee rate	Maximum service rate	Reserved	FID Max Buffer Size (MaxBufferSize)	FCS

The dynamic service change request frame is shown in Figure 13, which is used for the request to change the QoS parameters of the service stream initiated by the CAP and the STA.

FIGURE 13

Dynamic service change request frame

Bit:	16	4	3	1	32	48	36	4	32
	Frame control	FID	Service type	Direction	Service guarantee rate	Target MAC address	Reserved	FID Max Buffer Size (MaxBufferSize)	FCS

The dynamic service change response frame is shown in Figure 14, which is used to response on the request for the dynamic service change initiated by the CAP to the STA.

FIGURE 14

Dynamic service change response frame

Bit:	16	4	3	1	32	32	36	4	32
	Frame control	FID	Service type	Reserved	Service guarantee rate	Maximum service rate	Reserved	FID Max Buffer Size (MaxBufferSize)	FCS

The dynamic service delete request frame is shown in Figure 15, which is used to request to delete the service stream initiated by the CAP and STA.

FIGURE 15

Dynamic service delete request frame

Bit:	16	4	11	1	32
	Frame control	FID	Reserved	Direction	FCS

The dynamic service delete response frame is shown in Figure 16, which is used to response to the request initiated by the CAP to the STA for deleting the dynamic service stream.

FIGURE 16

Dynamic service delete response frame

Bit:	16	A	11	1	32
	Frame control	FID	Reserved	Direction	FCS

See Table 15 for the definition of contents of dynamic service addition request/ response frame, dynamic/ service change request/ response frame bodies.

TABLE 15

Frame body field for service stream management

Field	Length/ bit	Description
FID	4	Flow ID
Service type	3	Specific service type (see Table 40)
Direction	1	0: downlink, 1: uplink
Indication of reserved field extension function	2	00: No function extension; 01: Extension of the multi-connection function; 10: Extension of header compression; 11: Extension of header compression and multi-connection functions;
Reserved		Default of 0
Service guarantee rate	32	Unit: bit/s, value: within 0~232

Maximum service rate	32	Unit: bit/s, value: within 0~232
Target MAC address	48	48-bit MAC address
FID maximum buffer size (MaxBufferSize)	4	0: Buffer up to 8 MPDUs; 1: Buffer up to 16 MPDUs; 2: Buffer up to 32 MPDUs; 3: Buffer up to 64 MPDUs; 4: Buffer up to 128 MPDUs; 5: Buffer up to 256 MPDUs; 6: Buffer up to 512 MPDUs; 7 - 15: Reserved

1.5.3.4.7 Resource request frame

The resource request has two manners:

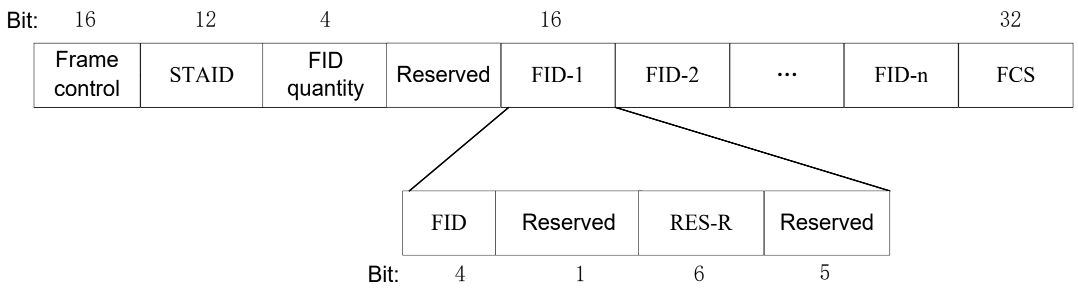
a) Independently send the resource request;

b) Carry the channel-associated resource request when sending data.

The independent resource request frame is used by the STA service stream to request bandwidth from CAP, as shown in Figure 17.

FIGURE 17

Independent resource request frame



The contents of the frame body of the independent resource request frame are shown in Table 16.

TABLE 16

Independent resource request frame body

Field	**Length/ bit**	**Description**
STAID	12	Uniquely identifies a STA
FID quantity	4	Indicates the number of service streams of the resource request.
Reserved	16	Default of 0
FID	4	Indicates that the STA performs the resource request for the service stream FID.
Reserved	4	Default of 0
Resource index	7	Indicates the index of the requested resource size in the resource table

Reserved	1	Default of 0

The resource table is shown in Table 17.

TABLE 17

Resource table

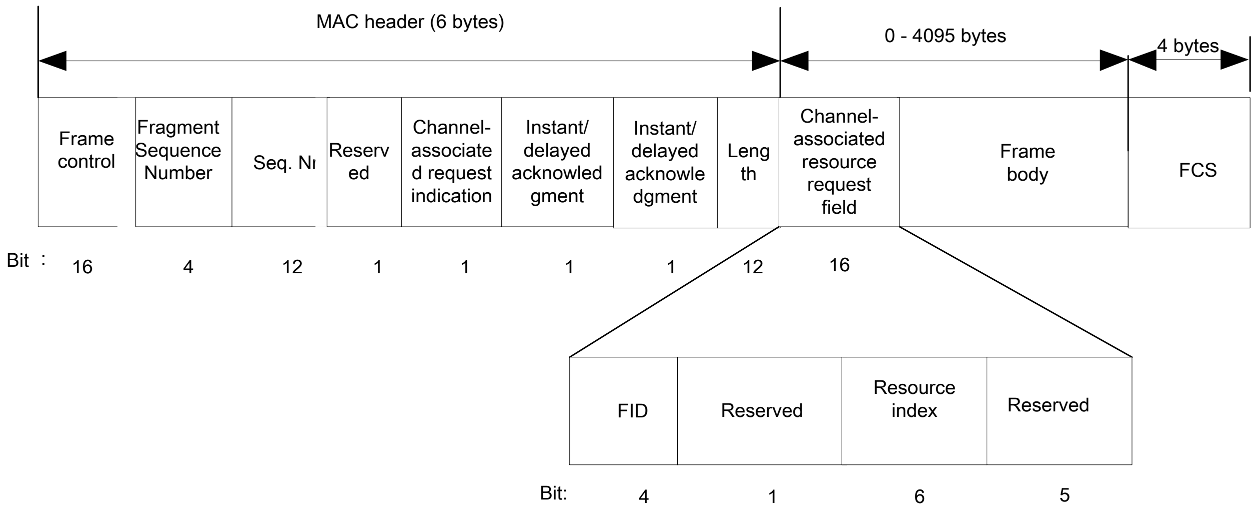
Index	**Resource size / byte**	**Index**	**Resource size / byte**
0	BS=0	23	337<BS≤364
1	1<BS≤14	24	365<BS≤392
2	15<BS≤28	25	393<BS≤420
3	29<BS≤42	26	421<BS≤448
4	43< BS≤56	27	449<I3S<476
5	57<BS≤70	28	477<BS≤504
6	71<BS≤84	29	505<BS≤532
7	85<BS≤98	30	533<BS≤560
8	99<BS≤112	31	561<BS≤588
9	113<BS≤126	32	589<BS≤616
10	127<BS≤140	33	617<BS≤644
11	141<BS≤154	34	645<BS≤672
12	155<BS≤168	35	673<BS≤700
13	169<BS≤182	36	701<BS≤728
14	183<BS≤196	37	729<BS≤784
15	197<BS≤210	38	785<BS≤840
16	211<BS≤224	39	841<BS≤896
17	225<BS≤238	40	897<BS≤952
18	239<BS≤252	41	953<BS≤1008
19	253<BS≤266	42	1009<BS≤1064
20	267<BS≤280	43	1065<BS≤1120
21	281<BS≤308	44	1121<BS≤1176
22	309<BS≤336	45	1177<BS≤1232
46	1233<BS≤1288	80	5825<BS≤6272
47	1289< BS≤1344	81	6273 <BS≤6720
48	1345<BS≤1400	82	6721<BS≤7168
49	1401<BS≤1456	83	7169<BS≤7616
50	1457<BS≤1512	84	7617<BS≤8064
51	1513<BS≤1568	85	8065<BS≤8512

52	1569<BS≤1624	86	8513<BS≤8960
53	1625<BS≤1680	87	8961<BS≤9408
54	1681<BS≤1736	88	9409<BS≤9856
55	1737<BS≤1792	89	9857<BS≤10304
56	1793<BS≤1904	90	10305<BS≤10752
57	1905<BS≤2016	91	10753<BS≤11648
58	20I7<BS≤2128	92	11649<BS≤12544
59	2129<BS≤2240	93	12545<BS≤13440
60	2241<BS≤2352	94	13441<BS≤14336
61	2353<BS≤2464	95	14337<BS≤15232
62	2465<BS≤2576	96	15233<BS≤16128
63	2577<BS≤2688	97	16129<BS≤17920
64	2689<BS≤2800	98	17921<BS≤19712
65	2801<BS≤2912	99	19713<BS≤21504
66	2913<BS≤3024	100	21505<BS≤23296
67	3025<BS≤3136	101	23297<BS≤25088
68	3137<BS≤3360	102	25089<BS≤28672
69	3361<BS≤3584	103	28673<BS≤32256
70	3585<BS≤3808	104	32257<BS≤35840
71	3809<BS≤4032	105	35841<BS≤39424
72	4033<BS≤4256	106	39425<BS≤43008
73	4257<BS≤4480	107	43009<BS≤50176
74	4481<BS≤4704	108	50177<BS≤57344
75	4705<BS≤4928	109	57345<BS≤64512
76	4929<BS≤5152	110	64513<BS≤71680
77	5153<13S<5376	111	71681<BS≤86016
78	5377<BS≤5600	112	86017<BS≤100352
79	5601<BS≤5824	113	100353<BS≤114688
114	114689<BS≤129024	121	286721<BS≤344064
115	129025<BS≤143360	122	344065<BS≤458752
116	143361<BS≤172032	123	458753<BS≤573440
117	172033<BS≤200704	124	573441<BS≤802816
118	200705<BS≤229376	125	802817<BS≤1835008
119	229377<BS≤258048	126	1835009<BS≤3500000
120	258049<BS≤286720	127	BS>3500000

When the channel-associated request indicates that the field is 1, a channel-associated resource request field is added to the front of the frame body, as shown in Figure 18.

FIGURE 18

Data frame with channel-associated resource request



The FID and resource index definitions are shown in Table 16 and Table 17.

1.5.3.4.8 MIMO feedback frame

1.5.3.4.8.1 CSI matrix feedback frame body

The frame body of CSI matrix feedback frame is shown in Figure 19.

When the bytes of the MAC frame body involved in this clause are not aligned, it is necessary to add 1~7 bits after the frame body to maintain byte alignment. In carrier aggregation mode, the CSI information of one component carrier should be fed back on the same component carrier.

FIGURE 19

CSI matrix feedback (CSI-MIMO) frame body

MIMO feedback control information	CSI matrix report

1.5.3.4.8.2 MIMO feedback control information

The MIMO feedback control information field is defined in Table 18.

TABLE 18

MIMO feedback control information field

Field	Length/ bit	Description
Subchannel mapping indication	4	Indicates the channel bandwidth fed back by the MIMO and specific subchannels

Quantitative mode	2	For CSI feedback, 00: Nb= 6; 01: Nb=8; 10,11: Reserved Refer to Attachment 4 for Nb.
Subcarrier grouping (Ns)	3	Indicates the number of subcarriers in the frame: 0: 1 subcarrier is included in the group (not grouped) (FPI=1); 1: 2 subcarriers are included in the group (FPI = 2); 2: 4 subcarriers are included in the group (FPI = 4); 3: 8 subcarriers are included in the group (FPI = 8); 4: 16 subcarriers are included in the group (FPI = 16); 5 - 7: Reserved
Number of rows of CSI matrix	3	Number of rows of CSI matrix (Nr), 1~8 (000~111)
Number of columns of CSI matrix	4	Number of column of CSI matrix (Nc) , 1~16 (0000~1111)
Reserved	8	Default value: 0

1.5.3.4.8.3 Channel state information matrix report field

The CSI-MIMO feedback frame is shown in Table 19.

Among them, Nr is the number of rows of the CSI matrix of the feedback request (see Table 19).

The CQI information in Table 19 is represented by SINR, and the SINR is encoded as 8 bits. The decimal number of the 8-bit is n, valuing from 0 to 255, indicating that the linear average of the SINR of all the subcarriers is (-20 + 0.25*n) dB.

The quantization of elements in CSI matrix is shown in Attachment 4. The elements in CSI matrix are transmitted row by row. Each element contains real and imaginary part, in which the real part is transmitted first.

TABLE 19

CSI report field in full-bandwidth scheme in normal mode

Field	Description
Receive CQI on antenna 1	8 bit, Receive average SINR on antenna 1
……	
Receive CQI on antenna Nr	8 bit, Receive average SINR on antenna Nr
$M_H(k)$ value of subcarrier-(N_{FFT}/2-13)	See Attachment 4 for $M_H(k)$
……	
$M_H(k)$ value of subcarrier-1 -FPI*2	
$M_H(k)$ value of subcarrier-1 -FPI	
$M_H(k)$ value of subcarrier-1	
$M_H(k)$ value of subcarrier1	
$M_H(k)$ value of subcarrier 1+ FPI	

$M_H(k)$ value of subcarrier 1+ FPI*2	
……	
$M_H(k)$ value of subcarrier (N_{FFT}/2-13)	
CSI matrix of subcarrier-(N_{FFT}/2-13)	CSI matrix
……	
CSI matrix of subcarrier-1 -FPI*2	CSI matrix
CSI matrix of subcarrier-1 -FPI	CSI matrix
CSI matrix of subcarrier-1	CSI matrix
CSI matrix of subcarrier1	CSI matrix
CSI matrix of subcarrier 1+ FPI	CSI matrix
CSI matrix of subcarrier 1+ FPI*2	CSI matrix
……	
CSI matrix of subcarrier (N_{FFT}/2-13)	CSI matrix

The CQI information in Table 20 is represented by SINR, and the SINR is encoded as 8 bits. The decimal number of the 8-bit is n, valuing from 0 to 255, indicating that the linear average of the SINR of all the allocated RU is (-20 + 0.25*n) dB.

TABLE 20

CSI report field in OFDMA scheme

Field	Description
RU Allocation Bitmap	160 bits, indicates the RU allocation information The "1" in the bitmap indicates the relative RU is allocated
Receive CQI on antenna 1	8 bits, Receive average SINR on antenna 1
……	
Receive CQI on antenna Nr	8 bit, Receive average SINR on antenna Nr
$M_H(k)$ value of 1st allocated RU	See Attachment 4 for $M_H(k)$
$M_H(k)$ value of 2nd allocated RU	
……	
$M_H(k)$ value of last allocated RU	
CSI matrix of 1st allocated RU	CSI matrix
CSI matrix of 2nd allocated RU	CSI matrix
……	
CSI matrix of last allocated RU	CSI matrix

1.5.3.4.9 Channel quality feedback frame

The channel quality feedback frame is shown in Figure 20. The CQI information part of the frame body includes subchannel mapping, MCS1 and MCS2, coding type and SINR. See Table 21 for the definition of the frame body in full-bandwidth scheme and See Table 22 for the definition of the frame body in OFDMA scheme. In carrier aggregation mode, the CQI information of one component carrier should be fed back on the same component carrier.

When the bytes of the MAC frame body involved in this clause are not aligned, it is necessary to add 1~7 bits after the frame body to maintain byte alignment.

FIGURE 20

CQI information section

	Subchannel mapping	**MCS1**	**MCS2**	**Coding type**	**SINR**
Bit:	4	7	7	2	…

TABLE 21

CQI information section in full-bandwidth scheme

Field	**Length/ bit**	**Description**
Subchannel mapping	4	Indicates this frame contains the CQI information for selected subchannels. The "1" in the bitmap indicates the relative subchannel is selected. For example, 0001 indicates the CQI of subchannel #0 is contained in this frame. Multiple frames can be transmitted to convey different CQI information for different subchannels.
MCS1	7	Suggested MCS of codeword 1
MCS2	7	Suggested MCS of codeword 2
Coding type	2	Indicates the encoding method recommended by the STA. 0: BCC; 1: LDPC code length 1; 2: LDPC code length 2; 3: LDPC code length 3
Number of spatial stream (Ns)	3	1~8 (000 ~ 111)
SINR0	8	The average SINR on the first spatial stream of the request channel. The corresponding decimal number of the field is n, and the value ranges from 0 to 255. The SINR is expressed as -20+ 0.25 n dB. The default value of n is 0.
SINR1	8	The average SINR on second spatial stream of the request channel. The corresponding decimal number of the field is n, and the value ranges from 0 to 255. The SINR is expressed as -20+ 0.25 n dB. The default value of n is 0.

…	…	…
SINR Ns-1	8	The average SINR on Ns-th spatial stream of the request channel. The corresponding decimal number of the field is *n*, and the value ranges from 0 to 255. The SINR is expressed as -20+ 0.25 *n* dB. The default value of n is 0.
Subcarrier SINR enable	1	0: no subcarrier SINR present 1: subcarrier SINR present
Number of subcarrier SINR streams (Nsts)	3	Indicates number of streams for subcarrier SINR feedback
Subcarrier grouping (Ns)	3	Indicates the number of subcarriers in the frame: 0: 1 subcarrier is included in the group (not grouped) (FPI=1); 1: 2 subcarriers are included in the group (FPI = 2); 2: 4 subcarriers are included in the group (FPI = 4); 3: 8 subcarriers are included in the group (FPI = 8); 4: 16 subcarriers are included in the group (FPI = 16); 5 - 7: Reserved
1st stream SINR of subcarrier-(N_{FFT}/2-13)	8	The average SINR on first spatial stream of the request channel. The corresponding decimal number of the field is *n*, and the value ranges from 0 to 255. The SINR is expressed as -20+ 0.25 *n* dB. The default value of n is 0.
…	…	…
1st stream SINR of subcarrier-1 -FPI*2	8	Same as above
1st stream SINR of subcarrier-1 -FPI	8	
1st stream SINR of subcarrier-1	8	
1st stream SINR of subcarrier1	8	
1st stream SINR of subcarrier 1+ FPI	8	
1st stream SINR of subcarrier 1+ FPI*2	8	
…		
1st stream SINR of subcarrier (N_{FFT}/2-13)	8	
2nd stream SINR of subcarrier-(N_{FFT}/2-13)	8	The average SINR on first spatial stream of the request channel. The corresponding decimal number of the field is *n*, and the value ranges from 0 to 255. The SINR is expressed as -20+ 0.25 *n* dB. The default value of n is 0.
…	…	…
2nd stream SINR of subcarrier-1 -FPI*2	8	Same as above

2nd stream SINR of subcarrier-1 -FPI	8	
2nd stream SINR of subcarrier-1	8	
2nd stream SINR of subcarrier1	8	
2nd stream SINR of subcarrier 1+ FPI	8	
2nd stream SINR of subcarrier 1+ FPI*2	8	
……		
2nd stream SINR of subcarrier (N_{FFT}/2-13)	8	
…	…	
Beamforming Matrix Index Feedback Enable	1	0: Beamforming Matrix Index no present 1: Beamforming Matrix Index present
Number of spatial stream (Ns_BF)	3	1~8 (000 ~ 111)
Index of the 1st spatial stream	Log2(Ncpc)	The index of the beamforming vector for 1st spatial stream selected from codebook matrix, as defined in 1.5.3.4.23
Index of the 2nd spatial stream)	Log2(Ncpc)	The index of the beamforming vector for 2nd spatial stream selected from codebook matrix, as defined in 1.5.3.4.23
…	…	…
Index of the Ns_BFth spatial stream	Log2(Ncpc)	The index of the beamforming vector for Ns_BFth spatial stream selected from codebook matrix, as defined in 1.5.3.4.23

TABLE 22

CQI information section in OFDMA scheme

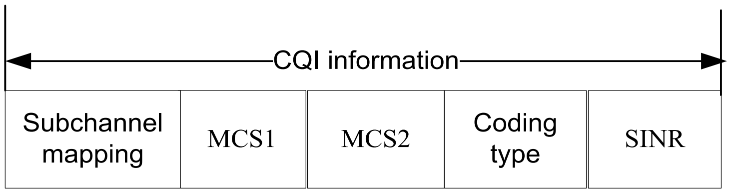
Field	Length/ bit	Description
Subchannel mapping	4	Indicates this frame contains the CQI information for selected subchannels. The “1” in the bitmap indicates the relative subchannel is selected. For example, 0001 indicates the CQI of subchannel #0 is contained in this frame. Multiple frames can be transmitted to convey different CQI information for different subchannels.
RU Allocation Bitmap	14	indicates the RU allocation information The “1” in the bitmap indicates the relative RU is allocated
MCS1	7	MCS of request channel codeword 1
MCS2	7	MCS of request channel codeword 2

Coding type	2	Indicates the encoding method recommended by the STA. 0: BCC; 1: LDPC code length 1; 2: LDPC code length 2; 3: LDPC code length 3
SINR0	8	The average SINR on the first spatial stream of the request channel. The corresponding decimal number of the field is *n*, and the value ranges from 0 to 255. The SINR is expressed as -20+ 0.25 *n* dB. The default value of n is 0.
SINR1	8	The average SINR on second spatial stream of the request channel. The corresponding decimal number of the field is *n*, and the value ranges from 0 to 255. The SINR is expressed as -20+ 0.25 *n* dB. The default value of n is 0.
…	…	…
SINR7	8	The average SINR on 8th spatial stream of the request channel. The corresponding decimal number of the field is *n*, and the value ranges from 0 to 255. The SINR is expressed as -20+ 0.25 *n* dB. The default value of n is 0.
RU SINR enable	1	0: no RU SINR present 1: RU SINR present
1st stream SINR of 1st allocated RU	8	The average SINR on first spatial stream of the request channel. The corresponding decimal number of the field is *n*, and the value ranges from 0 to 255. The SINR is expressed as -20+ 0.25 *n* dB. The default value of n is 0.
1st stream SINR of 2nd allocated RU	8	Same as above
…	…	…
1st stream SINR of last allocated RU		
2nd stream SINR of 1st allocated RU		
2nd stream SINR of 2nd allocated RU		
…		
2nd stream SINR of last allocated RU		
…		

When the system is operating at working bandwidth 1, the CQI-FB frame body is as shown in Figure 21.

FIGURE 21

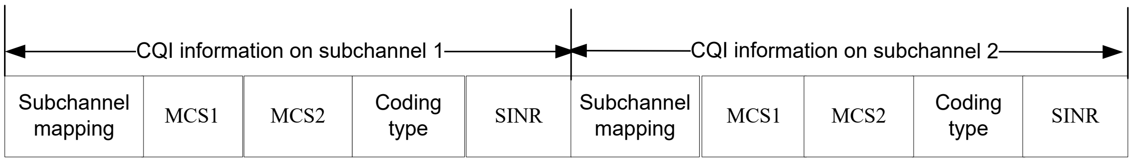
CQI-FB frame body in working bandwidth 1



When the system is operating in working bandwidth 2 aggregation mode, the CQI-FB frame body is as shown in Figure 22.

FIGURE 22

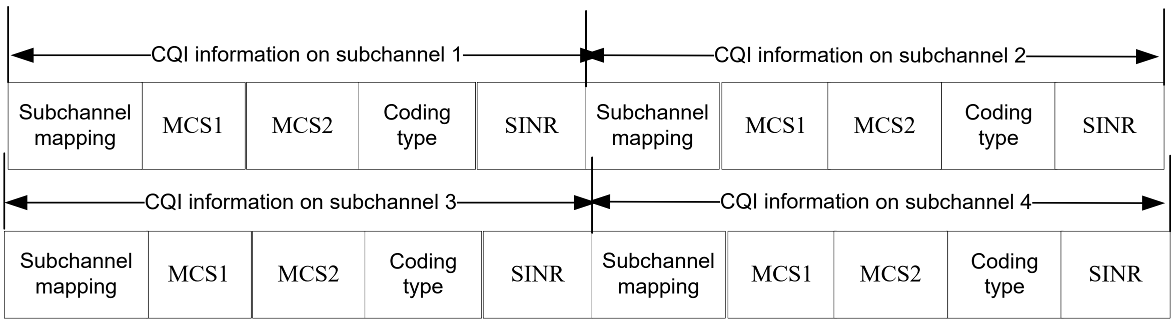
CQI-FB frame body in working bandwidth 2 mode



When the system is operating in working bandwidth 3 mode, the CQI-FB frame body is as shown in Figure 23.

FIGURE 23

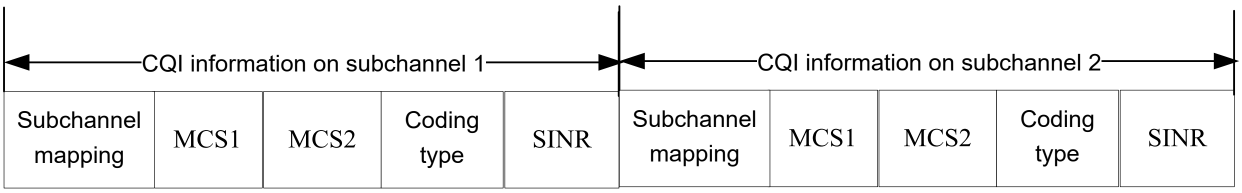
CQI-FB frame body in working bandwidth 3 mode



When the working bandwidth 3 system is operating at continuous working bandwidth 2, the CQI-FB frame body is as shown in Figure 24.

FIGURE 24

CQI-FB frame body part when the working bandwidth 3 system operating at working bandwidth 2



1.5.3.4.10 Acknowledgement frame

The acknowledgement frame field is defined as shown in Figure 25.

FIGURE 25

ACK frame

Bit:	**16**	**4**	**4**	**4**	**12**	**32**
	Frame control	Reserved	FID	FSN	SN	FCS

The contents of the frame body of the ACK frame are shown in Table 23.

TABLE 23

ACK frame body

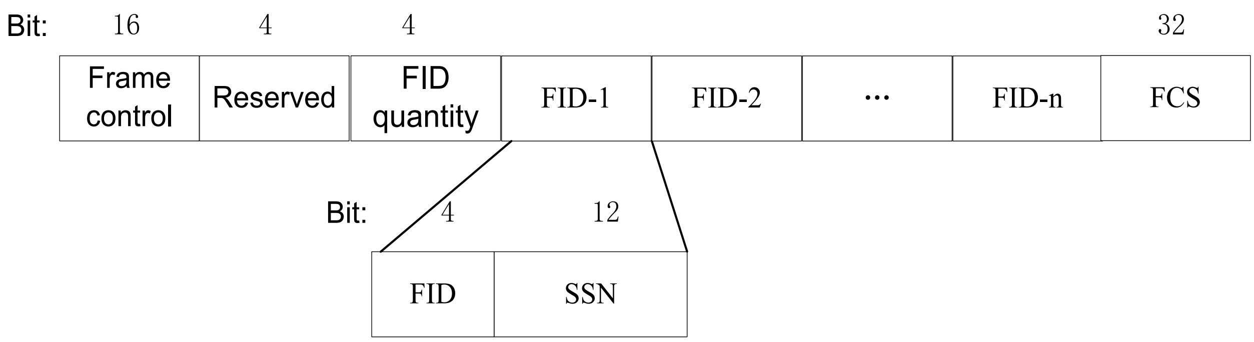
Field	**Length/ bit**	**Description**
Reserved	4	Default of 0
FID	4	Flow ID
FSN	4	Indicates that the acknowledgement is acknowledgement for the frame with the Fragment Sequence Number of FSN. If no fragmentation is used, this field is set to 0.
SN	12	Indicates that the acknowledgement is acknowledgement for the MPDU with the Sequence Number of SN. If the frame needs to be acknowledged is a management control frame without sequence number, the SN is set to 0.

1.5.3.4.11 Group acknowledgement request frame

The group acknowledgement request frame field is defined as shown in Figure 26.

FIGURE 26

Group acknowledgement request frame



See Table 24 for the contents of the frame body.

TABLE 24

Group acknowledgement request frame body

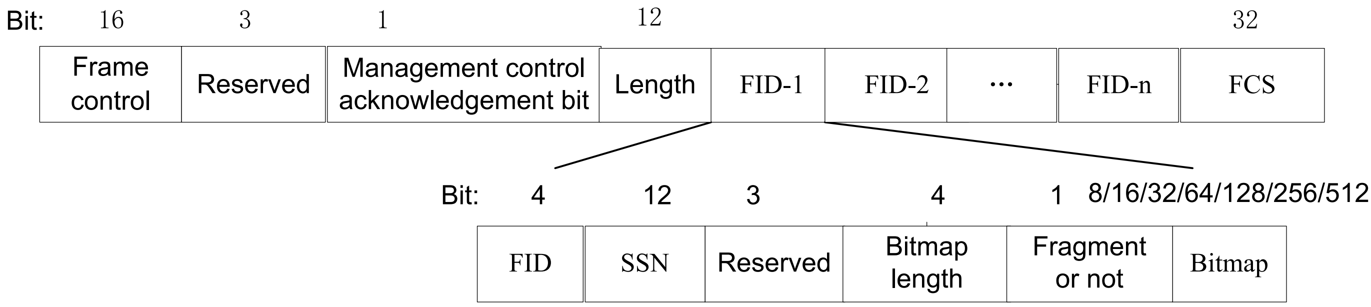
Field	Length/ bit	Description
Reserved	4	Default of 0
FID number	4	Indicates the number of FID information blocks included between the field and the FCS. The format of each FID information block is the same
FID	4	Require the receiver to perform Group Ack on the FID service stream.
SSN	12	When the receiver is notified of the Group Ack, this value is used as the starting sequence number of the Bitmap.

1.5.3.4.12 Group acknowledgement frame

The group acknowledgement frame field is defined as shown in Figure 27.

FIGURE 27

Group acknowledgement frame



The contents of the frame body of the group acknowledgement frame are as shown in Table 25.

TABLE 25

Group acknowledgement frame body

Field	Length/ bit	Description
Reserved	3	Default of 0.
Management control frame acknowledgement bit	1	Indicates that acknowledgement is received for receiving a management control frame without sequence number.
Length	12	Indicates the total byte length of all fields between the length field and FCS field
FID	4	Notifies the sender that the FID information block is the Group Ack for a certain FID service stream
SSN	12	Notifies the sender of the Starting Sequence Number of the Bitmap for the FID information block
Bitmap Length	4	Indicates the length of the Bitmap for each FID information block. 0: 8 bits; 1: 16 bits;

		2: 32 bits; 3: 64 bits; 4: 128 bits; 5: 256 bits; 6: 512 bits; 7 - 15: Reserved
Reserved	3	Default of 0
Fragment or not	1	If the value is 1, it indicates the acknowledgement is for the fragmented data frame. At this point, each bit in the Bitmap is the acknowledgement for one fragment in the frame. If the value is 0, it indicates that the acknowledgement is for the unfragmented data frame. At this point, each bit in the Bitmap is the acknowledgement for a frame.
Bitmap	8/16/32/64/128/256/512	A bit in the Bitmap indicates whether a certain MPDU/fragment is successfully received. If received successfully, it is set to 1, otherwise it is set to 0. MPDU Sequence Number/Fragment Sequence Number is calculated based on the SSN and the offset.

1.5.3.4.13 Quit network frame

The quit network frame is shown in Figure 28, which is used by the STA to quit the network.

FIGURE 28

Quit network frame

Bit	16	4	12	32
	Frame control	Reserved	STAID	FCS

The frame body of the quit network frame is defined in Table 26.

TABLE 26

Description of the frame body of the quit network frame

Field	Length/ bit	Description
Reserved	4	Default of 0
STAID	12	Used to identify users

1.5.3.4.14 Channel switching information frame

The channel switching information frame is used by the CAP to fastly notify the STA of a set of CCs’ channel switching. In CA mode, this message is also used to activate / deactivate some carriers, and the field is defined as shown in Figure 29.

FIGURE 29

Channel switching information frame

Bit:	16	16	16	8	**2**	**4**	**1**	**12**	**5**	**8**	**8**
	Frame control	CC ACTIVE indication	CC switching indication	CAP/STA starting channel number	CAP/STA work bandwidth	Working subchannel mapping	Channel switching indication	STAID	Reserved	Channel switching mode	Chann switchi counte

The frame body content of the channel switching information frame is as shown in Table 27.

TABLE 27

Channel switching and CC activation information frame body

Field	Length/ bit	Description
Channel switching indication	1	0：CAP channel switching, the information below is defined for CAP 1：STA channel switching, the information below is defined for STA
CC ACTIVE indication	16	Activate or Deactivate the CCs of CAP/STA "1" in the b_n (LSB is b_0): activate the component carrier #n+1 "0" in the b_n (LSB is b_0): deactivate the component carrier #n+1
CC switching indication	16	Indicate the CCs should perform the following switching operation. "1" in the b_n (LSB is b_0): the following switching operation is defined for the component carrier #n+1 "0" in the b_n (LSB is b_0): the following switching operation is not defined for the component carrier #n+1
CAP/STA working channel number	8	The working channel number (WCN) corresponding to the new channel to be switched by the CAP/STA, in the unit of working bandwidth ($Working\_BW_{cc}$, defined below) of selected CC (indicated above). The target center frequency value is calculated as $F\_center_{cc} = F\_start_{cc} + (WCN + 0.5) * Working\_BW_{cc}$ in which F_start_{cc} is starting frequency value define in BCF.
CAP/STA working bandwidth	2	Indicates the working bandwidth of the CAP/STA 0: working bandwidth 1; 1: working bandwidth 2; 2: working bandwidth 3; 3: Reserved
Reserved	4	Default of 0
STAID	12	STAID: only for speicific STAID BSTAID(0x000): stand for all the STAID should perform the channel switching operation.
Reserved	5	Default of 0
Channel switching mode	8	Indicates the limit on transmission during channel switching. 1: indicates that the CAP requires the STA to stop data transmission before channel switching; Other values indicate to be reserved

Channel switching counter	8	Indicates the elapsed time from sending the channel switching information frame to the new channel is switched, in units of physical frame.

1.5.3.4.15 Sleep request frame

The sleep request frame is used for the switching request sent by the STA to the CAP for switching from the active mode to the sleep mode. The request field is defined as shown in Figure 30.

FIGURE 30

Sleep request frame

Bit:	16	4	4	16	16	16	32
	Frame control	Reserved	Subsequent sleep window changes	Sleep start time	Sleep start window	listening window size	FCS

The contents of the frame body of the sleep request frame are as shown in Table 28.

TABLE 28

Sleep request frame body

Field	Length/ bit	Description
Reserved	4	Default of 0
Subsequent sleep window changes	4	Indicates the change from the initial sleep window requested by the STA, 0: Unchanged; 1: Multiplication; Other values indicate to be reserved
Sleep start time	16	Indicates the start time of the first sleep window requested by the STA, which is expressed in frame number
Sleep start window	16	Indicates the size of the first sleep window requested by the STA, in time unit of a physical frame
listening window size	16	Indicates the size of the listening window requested by the STA, in time unit of a physical frame

1.5.3.4.16 Sleep response frame

The sleep response frame is used for the CAP to actively send the message to notice the STA for sleep, or for the response to the sleep request frame. The frame body field is defined as shown in Figure 31.

FIGURE 31

Sleep response frame

Bit:	**16**	**4**	**4**	**16**	**16**	**16**	**32**
	Frame control	Reserved	Subsequent sleep window changes	Sleep start time	Sleep start window	listening window size	FCS

The contents of the frame body of the sleep request frame are as shown in Table 29.

TABLE 29

Description of the frame body of the sleep response frame

Field	**Length/ bit**	**Description**
Reserved	4	Default of 0.
Subsequent changes in the sleep window	4	Indicates the change relative to the initial sleep window allowed by the CAP, 0: Unchanged; 1: Multiplication; Other values indicate to be reserved
Sleep start time	16	Indicates the start time of the first sleep window allowed by the CAP, which is expressed in frame number
Sleep start window	16	Indicates the size of the first sleep window allowed by the CAP, in time unit of a physical frame
listening window size	16	Indicates the size of the listening window allowed by the CAP, in time unit of a physical frame

1.5.3.4.17 Downlink traffic indication frame

The downlink traffic indication (DTF-IND) frame is used by the CAP to inform the sleeping STA of the downlink traffic information, and the frame body field is defined as shown in Figure 32.

FIGURE 32

Downlink traffic indication frame

Bit	**16**	**12**	**4**	**32**
	Frame control	Reserved	TI indication	FCS

The frame body content of the downlink traffic indication frame is as shown in Table 30.

TABLE 30

Downlink traffic indication frame body field

Field	**Length/ bit**	**Description**
Reserved	12	Default of 0
TI indication	4	Indicates whether there is downlink data of the STA on the CAP side.

		0: indicates that there is no data of the STA; 1: indicates that there is data of the STA; Other values indicate to be reserved

1.5.3.4.18 Measuring request frame

The STA can decide to actively send a CM-REQ message to the current CAP if the measured RSSI of the current cell is lower than RSSI threshold values defined in BCF, to request for measuring the time and the information list of neighbor cells. See Table 31 for the parameters carried by the CM-REQ.

TABLE 31

Message Parameters of measuring request frame

Field	Length (bit)	Description
Allocation of measuring time	8	Indicates the requested measuring time, in unit of physical layer frames.
Average signal quality	8	Indicates the average RSSI received by STA from the serving CAP. If STA is in CA mode and uses multiple CCs, the RSSI value should be averaged over all CCs it uses. The signed decimal number of this field is *n*, *n* = -128~127 (the negative part is represented in the complement form): the average RSSI is *n* dBm.
Reserved	64	Default of 0

1.5.3.4.19 Measurement response frame

The CM-RSP can be used to response CM-REQ message, and can also be proactively sent by the CAP to control the measurement of the STA. Parameters carried by CM-RSP can be found in Table 32.

TABLE 32

Message parameters of measuring response frame

Field	Length (bit)	Description
Allocation of measuring time	8	Indicates the allocated measuring time, in unit of physical layer frames. If set to 0, it indicates the measurement is rejected
Start time for measuring	8	Indicates the time duration from when the measuring response message is received by the STA to the start of the measurement, in unit of physical layer frames.
Measurement result reporting mode	2	Indicates the measurement result reporting mode 0: Report triggered by event 1: Periodic report 2 - 3: Reserved
Measurement type	2	Indicates the type of measurement: 0: Indicates that only the SICH is detected; 1: Indicates that the BCF needs to be received;

		2: Indicates that TA needs to be measured 3: Reserved
Reserved	4	Default of 0
Measurement interval	8	in unit of physical layer frames.
Number of measurements	8	Indicates the number of times the measurement result is reported
Measurement result reporting period	8	If the measurement result reporting mode is 1, this field indicates the measurement result reporting period, in unit of physical layer frames.
Candidate CAP1 identifier	8	Indicates the lower 8 bits of the candidate CAP1's MAC address
Candidate CAP1 channel identifier	8	Indicates the channel number of the working channel of candidate CAP1
Candidate CAP2 identifier	8	Indicates the lower 8 bits of the candidate CAP2's MAC address
Candidate CAP2 channel identifier	8	Indicates the channel number of the working channel of candidate CAP2
Candidate CAP1 working bandwidth	4	0000 ~ 1101: 5/10/15/20/25/30/40/50/60/80/100/200/400/1000MHz
Candidate CAP2 working bandwidth	4	0000 ~ 1101: 5/10/15/20/25/30/40/50/60/80/100/200/400/1000MHz
Reserved	56	Default of 0

1.5.3.4.20 Measurement report frame

The STA reports the measurement results according to the indication information of the measurement report in the received CM-RSP message. See Table 33 for the parameters carried in the CM-REP message.

TABLE 33

Message parameters of measurement report frame

Field	Length (bit)	Description
Measurement result report mode	2	Indicates the reporting mode of the measurement result, 0: Report triggered by event 1: Periodic report 2 - 3: Reserved
Reserved	6	Default: 0
Average RSSI of the current cell	8	Indicates the average RSSI received by STA from the serving CAP. If STA is in CA mode and uses multiple CCs, the RSSI value should be averaged over all CCs it uses. The signed decimal number of this field is n, n = -128~127 (the negative part is represented in the complement form): the average RSSI is n dBm.
Candidate CAP1 identifier	8	Indicates the lower 8 bits of the candidate CAP1's MAC address.
Candidate CAP1 channel number	8	Indicates the channel number of the candidate CAP1, which should be the same as the channel number specified in CM-RSP.
Average RSSI of candidate CAP1	8	Indicates the average RSSI received by STA from the candidate CAP1 on the channel specified in the row above. The signed

		decimal number of this field is *n*, *n* = -128~127 (the negative part is represented in the complement form): the average RSSI is *n* dBm.
Candidate CAP2 identifier	8	Indicates the lower 8 bits of the MAC address of the candidate CAP2
Channel number of candidate CAP2	8	Indicates the channel number of the candidate CAP2, which should be the same as the channel number specified in CM-RSP
Average RSSI of candidate CAP2	8	Indicates the average RSSI received by STA from the candidate CAP2 on the channel specified in the row above. The signed decimal number of the field is *n*, *n* = -128~127 (the negative part is represented in the complement form): the average RSSI of candidate CAP2 is *n* dBm.

1.5.3.4.21 Handover request frame

For STA-triggered handover, the STA can send a HO-REQ message to the currently serving CAP (CAP-S) to trigger the handover procedure. See Table 34 for the parameters carried by HO-REQ.

TABLE 34

Message parameters of handover request frame

Field	Length (bit)	Description
Candidate CAP1 identifier	8	Indicates the lower 8 bits of the candidate CAP1's MAC address
Candidate CAP1 channel number	8	Indicates the channel number of the working channel of candidate CAP1, which should be the same as the channel number specified in CM-RSP
Channel quality of candidate CAP1	8	Indicates the average RSSI received by STA from the candidate CAP1 on the channel specified in the row above. The signed decimal number of this field is *n*, *n* = -128~127 (the negative part is represented in the complement form): the average RSSI is *n* dBm.
Candidate CAP 2 identifier	8	Indicates the lower 8 bits of the candidate CAP2's MAC address
Candidate CAP2 channel number	8	Indicates the channel number of the working channel of candidate CAP2, which should be the same as the channel number specified in CM-RSP
Channel quality of candidate CAP 2	8	Indicates the average RSSI strength of the candidate CAP2 on the channel specified in the row above, the signed decimal number of the field is *n*, *n* = -128~127 (the negative part is represented in the complement form): the channel quality (RSSI) of candidate CAP2 is *n* dBm.
Reserved	64	

1.5.3.4.22 Handover command frame

After received HO-REQ message sent by the STA, CAP can send handover command (HO-CMD) frame to notify STA to start the handover execution process. CAP can also proactively send HO-CMD to STA to trigger the handover execution process even if STA does not send HO-REQ. See Table 35 for the message parameters carried by HO-CMD.

TABLE 35

Message parameters of handover command frame

Field	Length (bit)	Description
Handover indication	2	Indicates whether to receive the handover initiated by the STA. 0: reject the handover; 1: accept the handover; 2~ 3: reserved
Handover type	2	Indicates the type of handover 0: Re-access type; 1: Competitive access type 2: Competition-free access type; 3: reserved
Dual connection	2	0: invalid 1: enter dual connection 2: leave dual connection 3: reserved
Reserved	2	Default: 0
CC Activatioin/deactivation indication	16	Activate or Deactivate the CCs of STA "1" in the b_n (LSB is b_0): activate the component carrier #n+1 "0" in the b_n (LSB is b_0): deactivate the component carrier #n+1
Target CAP identifier	8	Indicates the lower 8 bits of the target CAP's MAC address
Target CAP's channel number	8	Indicates the channel number of the working channel of target CAP, which should be the same as the channel number specified in HO-REQ for corresponding CAP.
TSTAID	12	If the handover type is 2, it indicates that the target CAP (CAP-D) pre-allocates for the STA for the temporary STAID during the handover time. If the handover type is in other values, this field is reserved
Effective time	4	Indicates the effective time of the TSTAID, in frames.
TA information	8	If the handover type is 2, this field indicates the TA information estimated by the CAP-D for the STA. If the handover type is in other values, this field is reserved
AK information	64	If the handover type is 2, this field indicates the authentication information in CAP-D If the handover type is in other values, this field is reserved
Reserved	48	Default: 0

1.5.3.4.23 Custom frame (TLV structure)

TABLE 36

TLV frame definition

Field	TLV type	TLV length	Data
Bit	8	16	Customized

Custom frames are management frames, which can be used to extend management frames to transmit other specific high-priority information. The frame body of custom frames are TLV frame which length is variable. The SICH and CCH information can be transmitted not only by SICH and CCH channel, but also by custom frames for further assurance.

The subtype of custom frames is: 11101, which is indicated in section 1.5.1.2.3.

The related TLV types are defined in Table 37:

TABLE 37

THE RELATED TLV TYPES OF CUSTOM FRAMES

TLV type	Type description
0	The frequencies of component carriers
1	Auth_ul_info
2	Auth_dl_info
3	SICH_info
4	CCH_info
5	Uplink power control
6	RSSI threshold for handover
7	Codebook information

The details of “Auth_ul_info” with TLV_type=1 can be referred to 6.3.1.1 and 6.3.1.4 of Attachment 6.

The details of “Auth_dl_info” with TLV_type=2 can be referred to 6.3.1.2 and 6.3.1.3 of Attachment 6.

If the TLV_type is 3 or 4, the complete bits of SICH or CCH defined in section 1.7.4.1 and 1.7.4.2 will be included in the “Data” field in custom frames. The different types of SICH can be distinguished by TLV length. The different types of CCH can be distinguished by TLV length.

The extensible parts of BCF frame defined in section 1.5.3.4.1 can also be transmitted in custom frame. The MAC header with the subtype (11101) defined in section 1.5.1.3.2 will be added before the TLV structure to generate custom frame.

TLV frame with TLV_type=7 is defined for codebook information, the TLV frame definition with TLV_type = 7 is indicated in Table 38.

TABLE 38

TLV frame with TLV_type = 7

Field	TLV_type	TLV length	Data
Bit	8	16	Customized
Value	7	32+Nrc*Ncpc*16	Customized

The Data field in the TLV frame with TLV_type=7 is defined in Table 39.

TABLE 39

Data field with TLV_type=7 of TLV frame

Name	Length/ bit	Value
Ncc_ind	10	indicates the number of columns of total codebook matrix (Ncc) Ncc = Ncc_ind+1
Nrc_ind	4	indicates the number of rows of total codebook matrix (Nrc) Nrc = 2*(Nrc_ind+1) Number of rows of partial codebook matrix transmitted in current frame is Nrc , too.
Ncc_start_ind	10	indicates the start column index (starting from 1) of partial codebook matrix transmitted in current frame (Ncc_start) Ncc_start = Ncc_start_ind +1
Ncpc_ind	8	indicates the number of columns of partial codebook matrix transmitted in current frame (Ncpc) Ncpc = Ncpc_ind +1 The column index of this partial codebook matrix is [Ncc_start, Ncc_start+1, …, Ncc_start+Ncpc-1],
$Qbr_{1,1}$	8	Quantization bits of the real part of the first column and the first row element in the partial codebook matrix.
$Qbi_{1,1}$	8	Quantization bits of the imaginary part of the first column and the first row element in the partial codebook matrix.
$Qbr_{2,1}$	8	Quantization bits of the real part of the first column and the second row element in the partial codebook matrix.
$Qbi_{2,1}$	8	Quantization bits of the imaginary part of the first column and the second row element in the partial codebook matrix.
…	…	…
$Qbr_{Nrc,1}$	8	Quantization bits of the real part of the first column and the last row element in the partial codebook matrix.
$Qbi_{Nrc,1}$	8	Quantization bits of the imaginary part of the first column and the last row element in the partial codebook matrix.
$Qbr_{1,2}$	8	Quantization bits of the real part of the second column and the first row element in the partial codebook matrix.
$Qbi_{1,2}$	8	Quantization bits of the imaginary part of the second column and the first row element in the partial codebook matrix.
…	…	…
$Qbr_{Nrc,2}$	8	Quantization bits of the real part of the second column and the last row element in the partial codebook matrix.
$Qbi_{Nrc,2}$	8	Quantization bits of the imaginary part of the second column and the last row element in the partial codebook matrix.
…	…	…
$Qbr_{Nrc,Ncpc}$	8	Quantization bits of the real part of the last column and the last row element in the partial codebook matrix.
$Qbi_{Nrc,Ncpc}$	8	Quantization bits of the imaginary part of the last column and the last row element in the partial codebook matrix.

1.5.4 Group MAC protocol data unit

The G-MPDU consists of a series of G-MPDU subframes, see Figure 33.

FIGURE 33

G-MPDU format

G-MPDU subframe 1	G-MPDU subframe 2	…	G-MPDU subframe n
Byte: changeable	Changeable		Changeable

The G-MPDU subframe includes a G-MPDU delimiter, an MPDU, and possible padding bytes. In addition to the last G-MPDU subframe, each G-MPDU subframe needs to be added with 0 to 1 padding bytes, so that the length of each G-MPDU subframe is an integer multiple of 2 bytes. The G-MPDU subframe format is as shown in Figure 34.

FIGURE 34

G-MPDU subframe format

G - MPDU delimiter	MPDU	Padding
Bytes: 2	Changeable	0~1

The delimiter of G-MPDU is 2 bytes long and is used to locate the MPDU of the G-MPDU. The format of the delimiter is as shown in Figure 35.

FIGURE 35

G-MPDU delimiter

Delimiter identifier	CRC
8bit	8bit

The value of the delimiter identifier is fixed at 0x46. The CRC is obtained by removing the remaining length of the FCS from the MPDU. Using an 8-bit CRC, the CRC is generated using a standard polynomial, see Equation 3:

$$G(x) = x^8 + x^2 + x + 1$$

Equation 3

The initial state of the register is 0xFF, and the register state is inverted as the CRC sequence output after the end of the operation. The CRC bits are transmitted in byte order from high order to low.

All MPDUs transmitted on the service transmission channel are transmitted by means of G-MPDU.

1.6 Media access control layer function

1.6.1 Adaptation sublayer

The function of the adaptation sublayer is to classify data of IP layer and to identify a service stream with an FID.

Within STA/CAP, the adaptation layer divides IP packets into multiple service streams, each of which belongs to an individual type of service and uses an FID identifier. The FID ranges from 1 to 15, and each FID service stream corresponds to a set of QoS parameters.

A maximum of 15 service streams can be established in each STA to occupy UL-TCH for data communication with CAP at the same time. Similarly, the CAP allows to establish 15 simultaneous service streams for each STA at the maximum to occupy DL-TCH for data communication with STA. Various management control frames occupy the data communication connections with the FID of 0 and it is default of being established successfully.

1.6.2 MAC sublayer

1.6.2.1 Addressing and connection

Both the STA and the CAP have a 48-bit globally unique MAC address as the identity. This address is used to acknowledge with each other and to forward intra-network packets during the network access phase. If the STA successfully accesses the network, the CAP assigns a 12-bit STA identifier (STAID) to the STA to uniquely identify it.

The MAC layer can provide connection-oriented services for applications. Up to 16 connections can be maintained between the CAP and each STA. Each connection is internally identified with a 4-bit FID.

1.6.2.2 Media access control address

Both the STA and the CAP use the globally unique 48-bit MAC address as the identifier.

1.6.2.3 Broadcast identification

The BSTAID is 12 bits long with the range of 0x000 ,0x001…0x007 to broadcast to all STAs in the CAP range. 0x001 can be used for the transmission of uplink unscheduled broadcast type.

1.6.2.4 STA identification

The STAID has a length of 12 bits with the range from 0x100 to 0xFFF.

After the STA completes the capability negotiation, the CAP allocates a unique identifier (STAID) within the scope of the CAP for each STA.

In the process of receiving and parsing CCH information, the STA needs to process the control information carried by the BSTAID in addition to the control information matching the STAID.

1.6.2.5 Temporary STA identification

The TSTAID is 12 bits in length and ranges from 0x008 to 0x0FF to temporarily identify an STA before assigning the STAID. The CAP assigns a TSTAID value to the STA through the random access response frame. The CAP assigns a TSTAID value to the STA through the random access response frame.

During the capability negotiation process between the STA and CAP, the STA uses the TSTAID to match the STAID carried in the CCH and parses out its own control information. Once the STA acquires the STAID, the original TSTAID is invalid.

1.6.2.6 Flow ID (FID)

The FID is 4 bits long and is used to identify an uplink or downlink service stream. The FID number is managed by the sender, and those of the uplink and downlink are independent of each other.

1.6.3 CAP detects idle channel

The flow of the CAP to detect the idle channel is shown in Figure 36. The steps are as follows:

a) The CAP determines the list of channels to be detected.

b) Select an undetected channel number from the channel list one by one in sequence.

c) The CAP starts detecting the wireless signal energy on the selected channel and activates the detecting cycle timer.

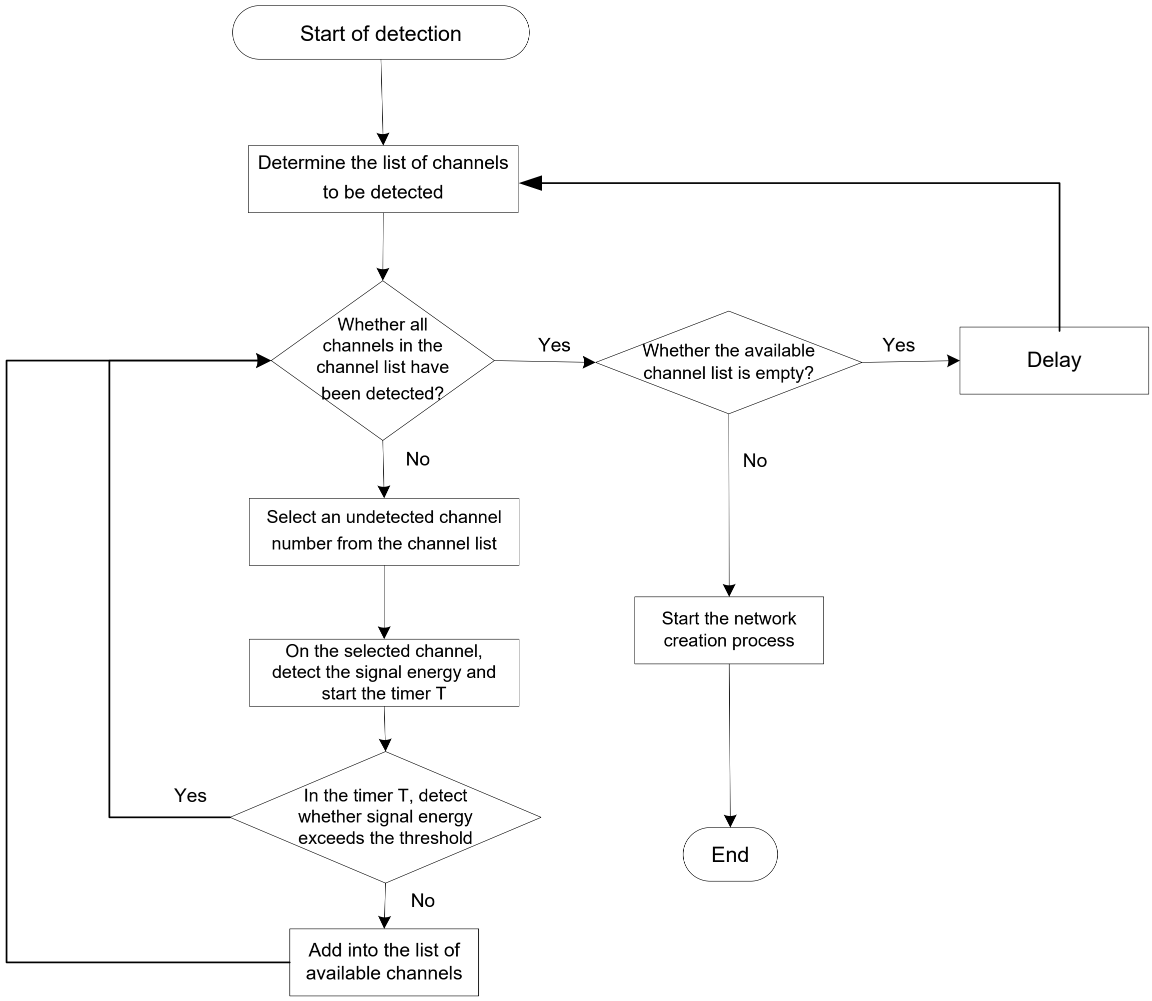
   – During the detection period, if the detected signal energy is lower than the preset threshold, add the channel to the available channel list, and detect other undetected channels without interruption until all the channels in the channel list are detected.

   – During the detection period, if the detected signal energy exceeds the preset threshold, continue to scan other channels that have not been detected until all channels in the channel list are detected.

d) After all the channels in the channel list are detected, if the available channel list is not empty, the network creation process is started. Otherwise, restart the detection after a period of delay.

FIGURE 36

Flow of detecting idle channels



1.6.4 STA network join process

1.6.4.1 General

The network join process refers to the process in which the STA discovers the network and establishes a connection with the CAP. Network join includes the following steps:

a) Get system synchronization;

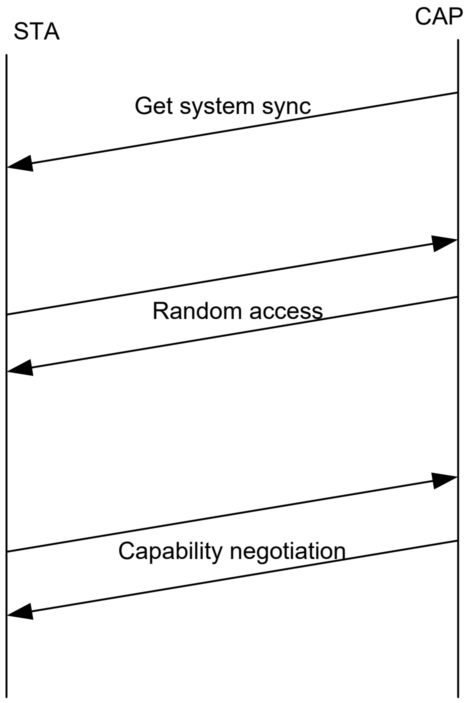
b) Random Access;

c) Capability negotiation.

The network join process is as shown in Figure 37.

FIGURE 37

Network join process



The network join process is defined in the following sections in non-CA mode. In the CA mode, the process is similar with the non-CA mode. The detail procedure in CA mode is defined below.

1) STA starts-up and tries to get system synchronization by receiving the BCF from one of the CC of the CAP.
2) When STA successfully decodes BCF, STA will get necessary information of all the CCs. Then the STA can choose one of the CCs to start random access procedure. The detailed random access procedure on one CC is defined in 1.6.4.3.
3) The capability negotiation procedure will be performed on the chosen CC. The detailed capability negotiation procedure on one CC is defined in section 1.6.4.4. It should be noted that STA shall report which CCs broadcasted in BCF can be supported by this STA, as defined in STA Basic Capability Request frame.
   After received the STA Basic Capability Request frame, CAP will decide which CCs broadcasted in BCF will be used for the STA and send STA Basic Capability Response frame back to the STA. STA shall monitor all the CCs it uses by receiving and decoding SICH and CCH on the CCs.
4) CAP or STA can decide which CCs are used to initiate the follow-up network join signaling procedures.
5) When the network join process is finished, the CAP can schedule the signaling and traffic of STA in multiple CCs the STA used.

After STA joins the network, CAP can activate or de-activate CCs as defined in section 1.6.15.

More details about network access procedure in dual-connection condition in CA mode can refer to section "1.6.19.2 Handover management".

1.6.4.2 System synchronization

The STA system synchronization process is as shown in Figure 38.

The main operation processes are as follows:

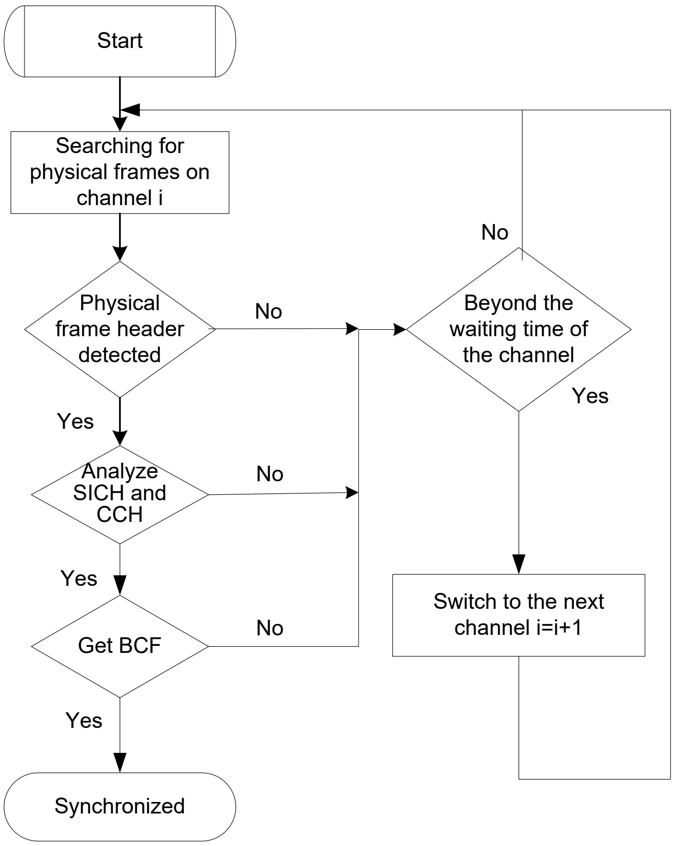
a) Scan physical signals on a channel;

b) If the STA can correctly detect the physical frame header, it considers that there is a physical frame on the channel. Otherwise, repeat the detection until time out, and then switch to the next channel and repeat the above operation;

c) If the STA can correctly parse the SICH and BCF information and successfully acquire the system information, the initial system synchronization is succeeded. Otherwise, after the waiting time is exceeded, switch to the next channel and repeat the above operation.

FIGURE 38

STA system synchronization

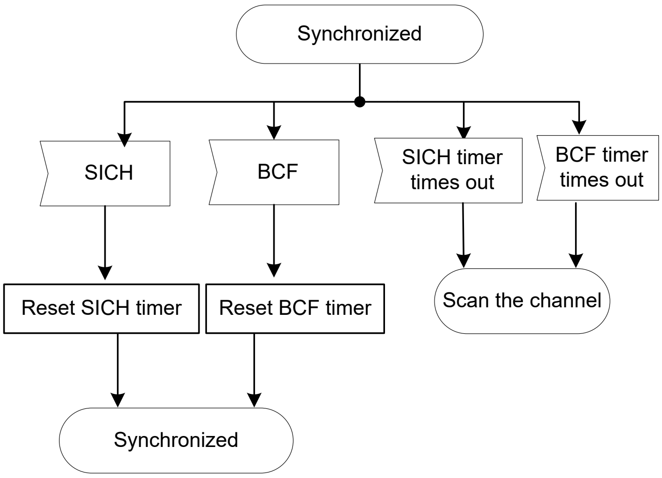


After the STA is initially synchronized, the synchronization is maintained thereafter.

If the SICH timer or the BCF timer expires, the STA needs to re-establish the initial synchronization, and proceeds to the flow of Figure 38. The process of maintaining synchronization is as shown in Figure 39.

FIGURE 39

Keep synchronized

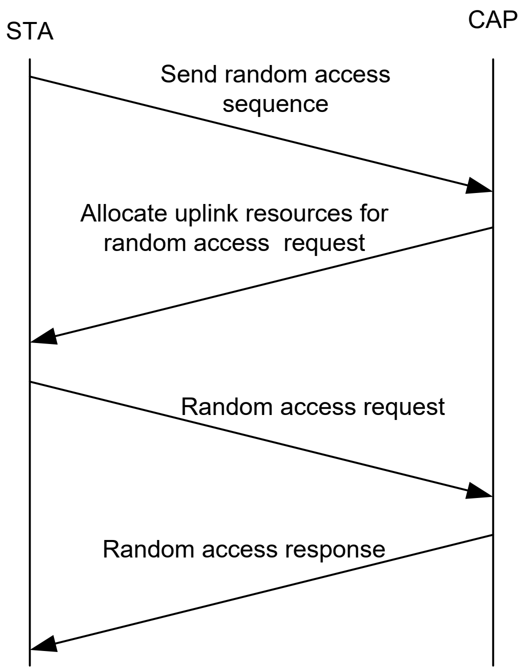


1.6.4.3 Random access

The random access process is as shown in Figure 40.

FIGURE 40

Random access flow

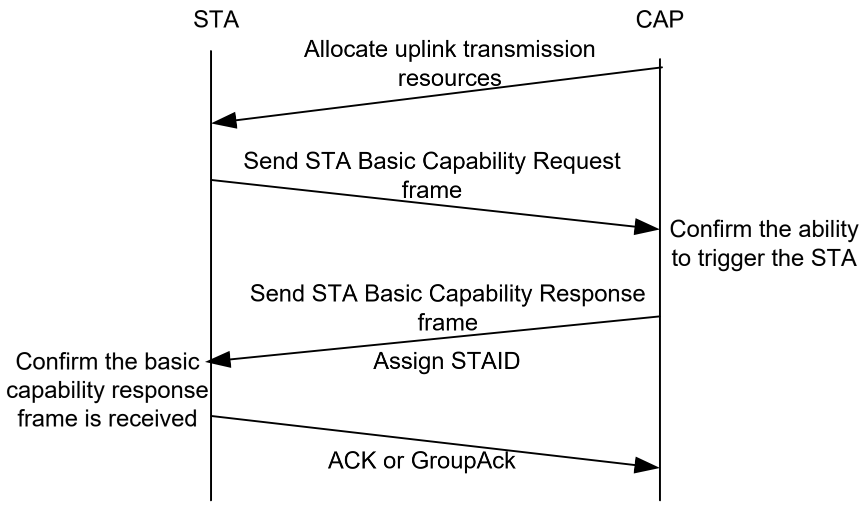


1.6.4.4 Capability negotiation

The capability negotiation process is as shown in Figure 41. The STA notifies the CAP of its basic capability by sending an STA Basic Capability Request frame (SBC-REQ). After the CAP receives the SBC-REQ, it compares the capability parameters. The capability parameters supported by both parties, as well as the carrier aggregation information for the STA, are all included in the STA basic capability response frame (SBC-RSP) to notify the STA.

FIGURE 41

Capability negotiation



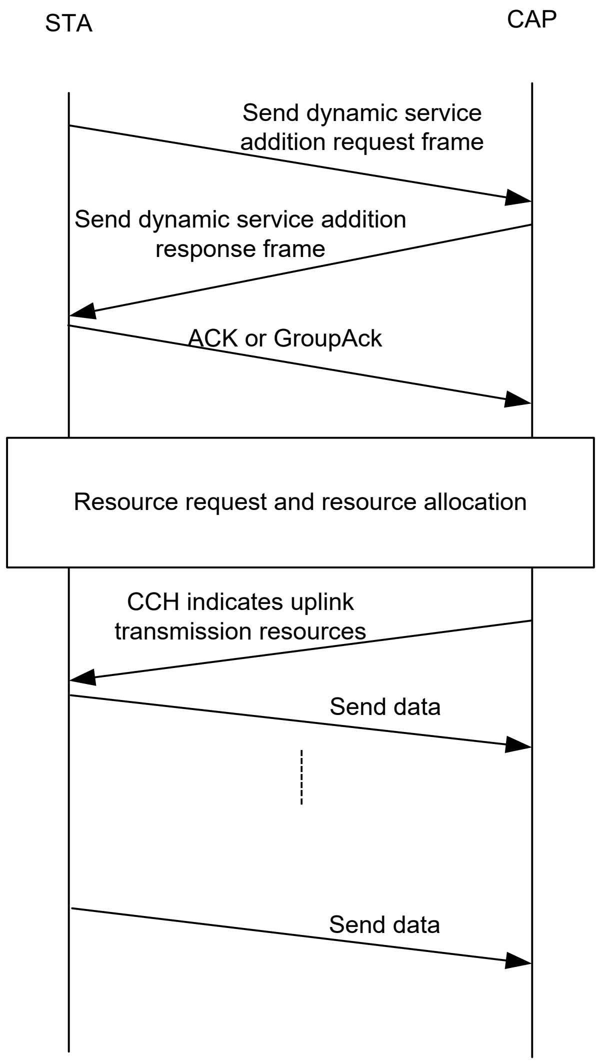
1.6.5 Managing service stream

1.6.5.1 Establishing service stream and data transmission

The establishment of uplink service stream and data transmission process are as shown in Figure 42.

FIGURE 42

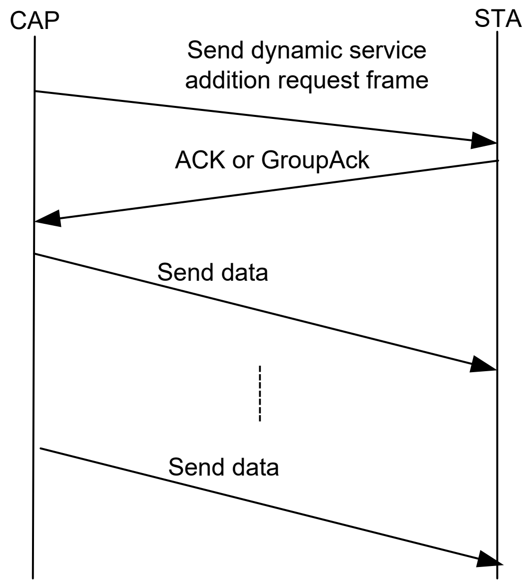
Uplink service stream establishment and data transmission process



The downlink service stream establishment and data transmission process is as shown in Figure 43.

FIGURE 43

Downlink service stream establishment and data transmission process

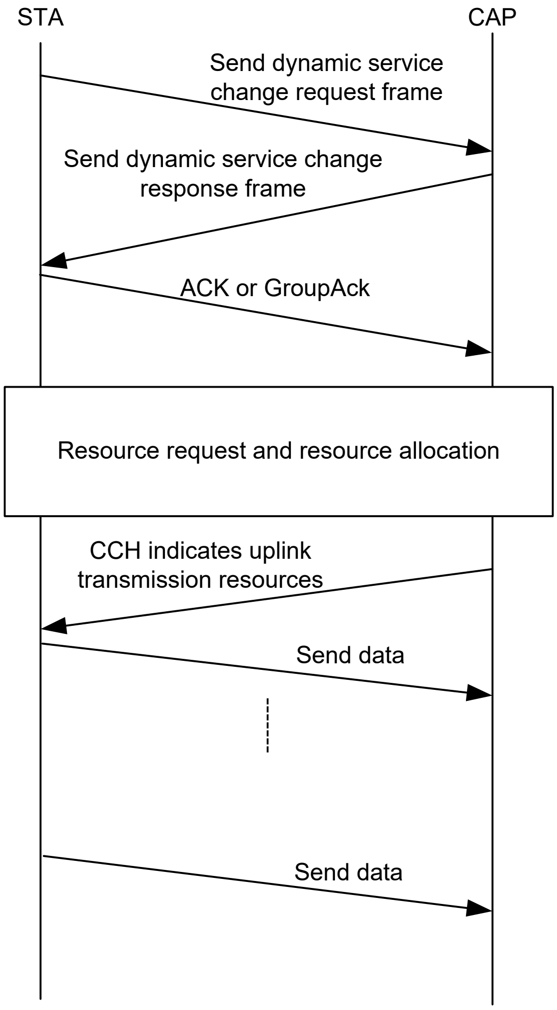


1.6.5.2 Changing the service stream

The process of changing the uplink service stream and data transmission is as shown in Figure 44.

FIGURE 44

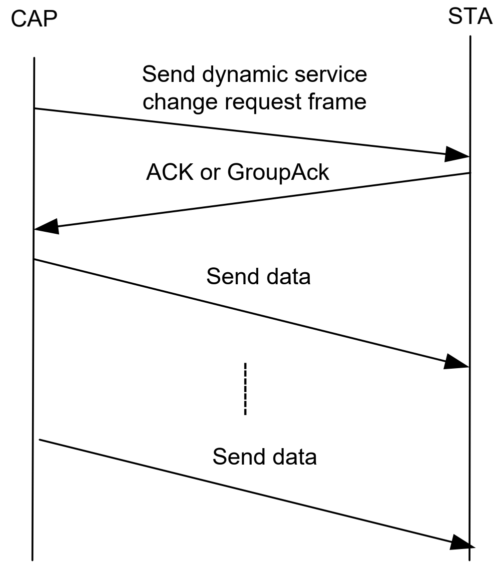
Uplink service stream change and data transmission process



The downlink service stream modification and data transmission process is as shown in Figure 45.

FIGURE 45

Downlink service stream change and data transmission process



1.6.5.3 Deleting the service stream

After the service transmission ends, the STA initiates the Dynamic Service Delete process, as shown in Figure 46.

After the service transmission ends, the CAP initiates the Dynamic Service Delete process, as shown in Figure 47. Wherein, The CAP can delete the uplink service stream by setting the direction field of the Dynamic Service Delete Request frame.

FIGURE 46

Uplink service stream deletion process

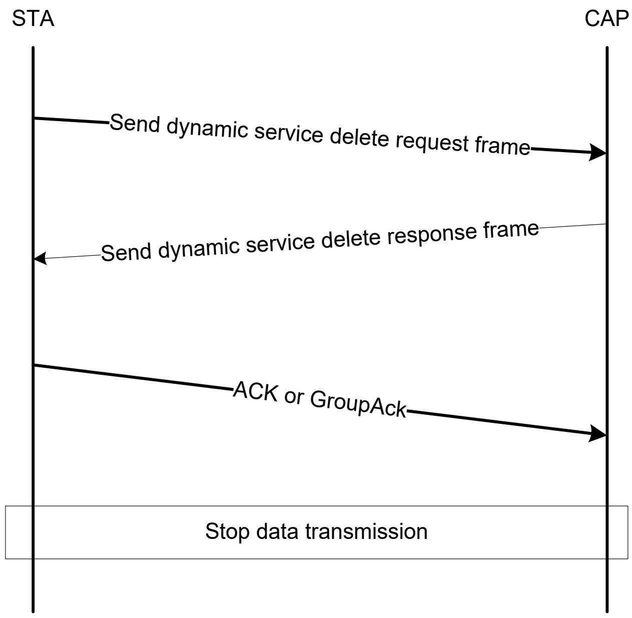
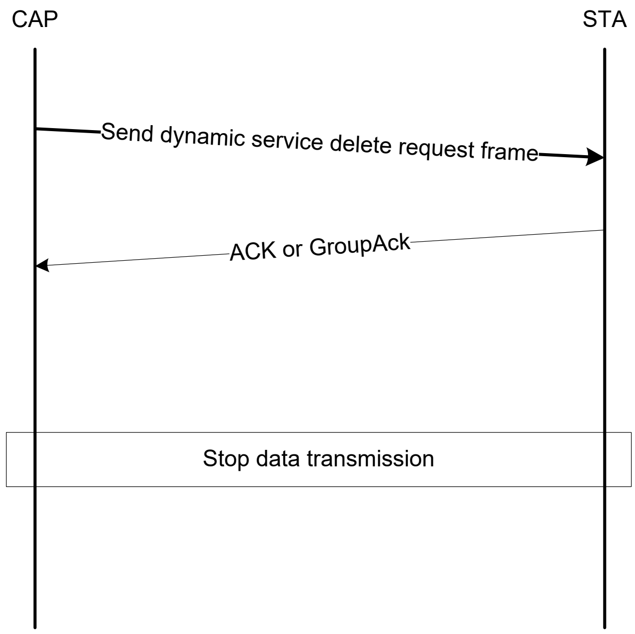


FIGURE 47

Downlink/Uplink service stream delete process



1.6.6 Resource request and resource allocation

1.6.6.1 Resource request

1.6.6.1.1 Resource request overview

The resource request manners supported by this standard system are as follows:

a) Collision-based resource request: The STA transmits the scheduling request sequence (SR PN) on the scheduling request channel;

b) Polling: The STA issues a resource request frame within the uplink bandwidth allocated by the CAP in polling manner;

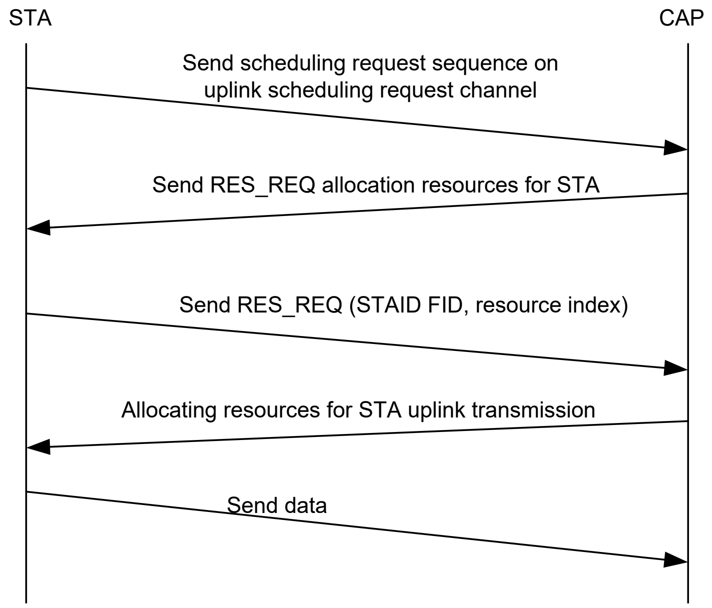
c) Channel-associated resource request: The STA sends the resource request through the channel-associated field when it has the uplink resource.

1.6.6.1.2 Collision-based resources request

When the STA needs uplink transmission resources, the STA transmits the scheduling request sequence on the uplink scheduling request channel to request resources. The resource request process is as shown in Figure 48.

FIGURE 48

Collision-based resources request



1.6.6.1.3 Polling

If the CAP has sufficient bandwidth resources, it can perform unicast polling on the STA. The CAP maintains a timer for each STA. When the timer expires, the CAP allocates resources to the STA for uplink service transmission and resets the timer.

The polling process is as shown in Figure 49.

The flowchart of polling is described as following:

a) Check if the CAP has enough bandwidth for polling.

b) If no, the process ends.

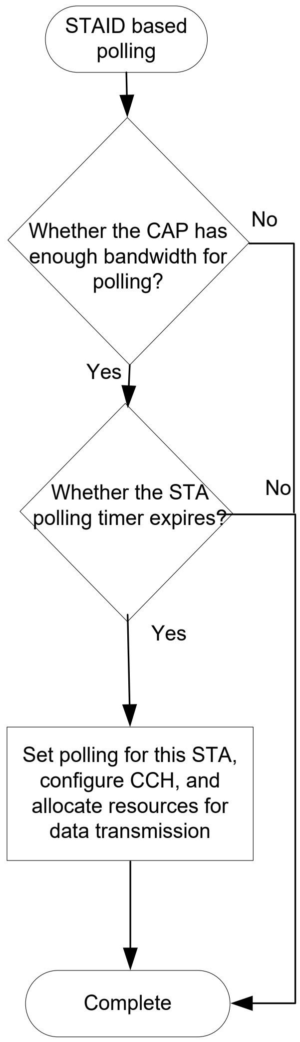
c) If yes, check if the STA's polling timer expires.

d) If yes, allocate resources for data transmission to the STA and reset the polling timer.

e) If no, the process ends.

FIGURE 49

Polling flow chart



1.6.6.1.4 Uplink unscheduled transmission

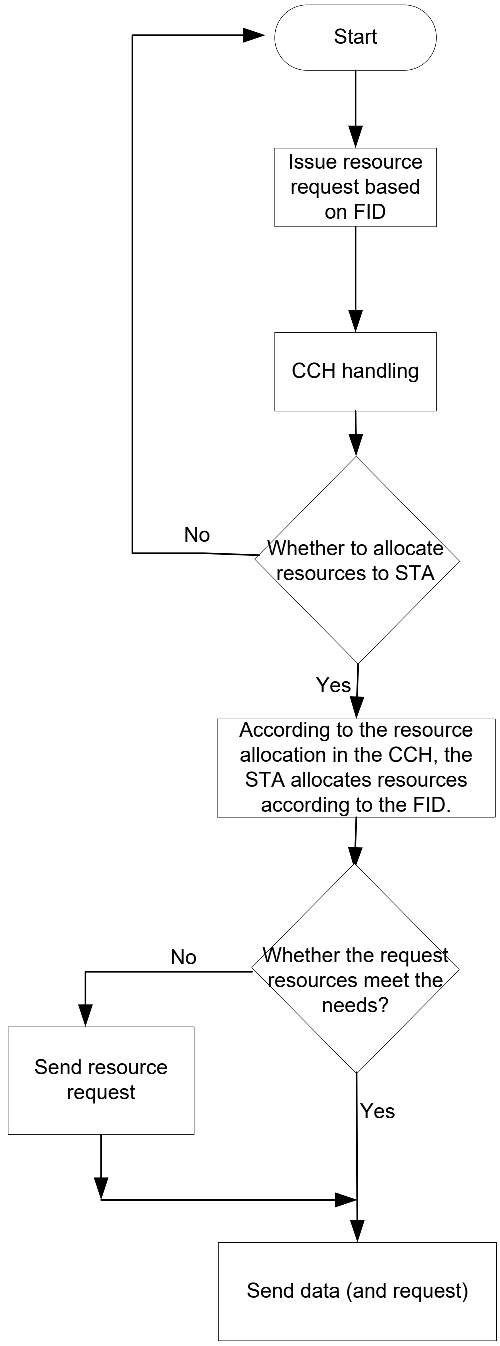
In some emergent scenarios where the time delay is tightened, the CAP supports the uplink unscheduled transmission. It can be achieved by the resources reserved in the uplink UL-TCH and using the BSTAID to allocate broadcast resources to the uplink, to provide the STA with a schedule-free information reporting channel. In this case, the uplink broadcast CCH can be formed by using the BSTAID to scramble the unicast signaling of the UL defined in section 1.7.4.2. The uplink of the same physical frame can be configured with multiple uplink broadcast CCH broadcast resources. The users compete for broadcast resources by the pre-negotiated mechanism.

1.6.6.2 Resource allocation

The STA requests for resources according to the FID service stream, and the CAP allocates the resources to the STA through the CCH. The resource allocation between all FID streams of the STA is completed by the STA internal scheduling. The resource request and the distribution process are as shown in Figure 50.

FIGURE 50

Resource request/ assignment process



1.6.7 Service type and QoS

1.6.7.1 QoS

The QoS parameters of the service stream are as follows:

– Service type: This parameter identifies the unique type of the service.

– Service priority: This parameter specifies the priority assigned to a service stream.

– Service guarantee rate: This parameter defines the basic rate that guarantees the service, in bits per second, which matches the SDU rate entered by the IP Adaptation Layer. This parameter does not cover the rate occupied by the MAC.

– Maximum service rate: This parameter describes the maximum service rate that the system provides to the service for rate shaping. Additional data beyond this rate will be discarded. The unit is bit per second. And it matches the SDU rate entered by the IP Adaptation Layer. This parameter does not cover the rate occupied by the MAC.

1.6.7.2 Service type

According to the QoS parameters of the service, eight types of services are defined at the MAC layer, and are classified into reserved resources and non-reserved resources. The service type 0 to 4 belong to the reserved resource class, and the system reserves the transmission bit rate for the corresponding services; the service type 5 to 7 belong to the unreserved resource class, and the system does not guarantee the transmission bit rate for the corresponding services.

The service type and parameter requirements are as shown in Table 40.

TABLE 40

Application categories and main QoS parameters of eight services

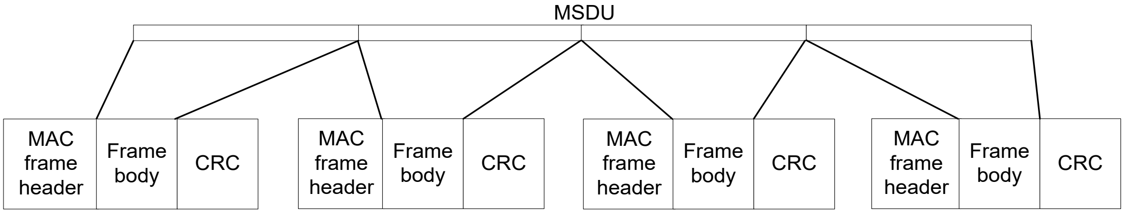
Service type	Resource Type	Priority	Delay budget	Packet loss rate budget	Service example
0	Reserved resources	1	50 ms	10^{-3}	Emergency safety service
1		2	100 ms	10^{-2}	Voice session
2		4	150 ms	10^{-3}	Video session (real time streaming service)
3		3	50 ms	10^{-3}	Real-time game
4		5	300 ms	10^{-6}	Non-session video (cache stream service)
5	No resources reserved	6	100 ms	10^{-3}	Interactive game
6		7	300 ms	10^{-6}	Video (cache streaming service), TCP-based services (for example, WWW, FTP, P2P file sharing, etc.)
7		8	1000 ms	10^{-6}	Background E-mail reception, file download and file printing with low transmission time requirements

1.6.8 Fragmentation and reassembly

The process of dividing an MSDU/ MMPDU into a smaller set of MAC frames is called fragmentation, as shown in Figure 51. Fragmentation is done by the sender. The process of multiple fragments be reassembled together at the receiving end is reassembly.

FIGURE 51

MAC frame fragmentation



In the instant acknowledgement mode, when the remaining resources of the physical frame are insufficient to send an entire data packet, a part of the data may be transmitted first by the fragment according to the remaining resource size, thereby occupying the entire channel so as to improve the utilization of the channel resource. The fragment transmission condition can be judged by the instant acknowledgement. When the fragment transmission succeeds, the next physical frame continues to transmit the remaining portion, and the remaining portion can be fragmented again according to the channel resource condition. When fragment transmission fails, it can be re-fragmented according to the channel resources. The fragment size is not required to be the same as the last fragment length, but it needs to meet the requirement that each physical frame can only transmit the same fragment in the data package with the same sequence number. In multi-connection mode, multiple copies of one package with one sequence number in one physical frame must be consistent. The receiver reassembles according to the sequence number of the package, fragment sequence number and fragmentation instructions. When receiving multiple pieces of data with the same sequence number and fragment sequence number, the last received data shall prevail.

1.6.9 Instant acknowledgement (IACK) and re-transmission mechanism

All non-broadcast management control frames in this specification, except random access request response frame and independent resource request frame, need to send acknowledgement frame or implied acknowledgement. The implicit acknowledgement means that the response frame for the unicast management control frame can be regarded as the acknowledgement frame. The non-broadcast management control frame does not need to be immediately acknowledged, and the response frame is allowed to respond within the maximum permitted number of physical frames. If the response frame sent by the CAP does not receive the acknowledgement frame of the STA, the response frame can be re-transmitted until the "maximum number of re-transmissions of the MPDU" is reached. When it exceeds the maximum number of re-transmissions of the MPDU, the sender will discard the frame.

This specification adopts the frame structure of the self-contained frame, which can be reasonably scheduled and complete group acknowledgement on the data of the last time period in the next time period quickly and efficiently. The time period mentioned here is one of the downlink period or the uplink period of the physical frame. The sender determines the data frame to be acknowledged immediately or in a delayed manner. By default, the instant acknowledgement is used to reduce the system delay. The group acknowledgement frame (Group ACK) of the instant acknowledgement type transmits in the short signaling channel of the next time period in a highly reliable manner, enabling an efficient group acknowledgement. The receiver determines whether the acknowledgement is needed immediately according to the immediate/delayed acknowledgement field of the MAC header. If the acknowledgement frame is not received in the next time period, the data frame can be re-transmitted before the maximum number of MPDU re-transmissions is reached. After it exceeds the maximum number of MPDU re-transmissions, the sender will discard the frame. The next time period mentioned here may be from an uplink physical frame period to a downlink physical frame period, or vice versa. When the MPDU is re-transmitted, the Sequence Number and Fragment Sequence Number remain unchanged.

For the service message with low time delay and high reliability, multiple copies are created in the adaptation sublayer by means of message copying. The above-mentioned messages are detected in the adaptation sublayer on the receiving end to avoid duplicate message delivery. If the physical frame receives a copy of any message, it instantly acknowledges and there is no need to re-transmit. Otherwise, it can be fast re-transmitted in the next time period. The re-transmission also uses the message copying manner to improve reliability.

1.6.10 Frame acknowledgement

In this specification, ACK frame or Group Ack frame are used for acknowledgement.

For the management control frame, the unicast management control frame without corresponding response frame needs to use ACK or Group Ack for acknowledgement. Otherwise, the corresponding response frame is used directly for acknowledgement, and the corresponding response frame list is as shown in Table 41.

TABLE 41

Corresponding response frame list

Request frame	Corresponding response frame
Random access request frame (RA-REQ)	Random access response frame (RA-RSP)
STA basic capability request (SBC-REQ)	STA basic capability response (SBC-RSP)
Uplink dynamic service addition request (DSA-REQ)	Dynamic service addition response (DSA-RSP)
Uplink dynamic service change request (DSC-REQ)	Dynamic service change response (DSC-RSP)
Uplink dynamic service delete request (DSD-REQ)	Dynamic service delete response (DSD-RSP)
Group acknowledgement request frame (Group AckReq)	Group acknowledgement frame (Group Ack)
Sleep request frame (SLP-REQ)	Sleep response frame (SLP-RSP)

The ACK frame and the Group Ack frame no longer require other frames for the acknowledgement.

According to the fragment acknowledgement indication field in the DSA-REQ/DSA-RSP or DSC-REQ/DSC-RSP messages, if the field is 0, it indicates that the fragment /assembly acknowledgement mechanism is adopted. The sender sends multiple fragments in sequence, and the receiver does not acknowledge for the individual fragment. After the receiver correctly receives all the data fragments, the entire data frame is acknowledged. After the sender sends all the fragments, if the acknowledgement is not received, the entire data frame needs to be re-transmitted instead of re-transmitting the fragments of the data frame.

For fragmented and unfragmented data frames, either ACK or Group Ack mode can be used for acknowledgement.

The waiting interval of the instant frame acknowledgement is a time period. While the waiting interval of the delayed frame acknowledgement is determined by the sender.

The receiver will send the MSDU to the next MAC processing flow in ascending order of SN. Any MSDU sent to the next MAC processing flow will be removed from the cache.

1.6.11 Link adaptation

1.6.11.1 Downlink adaptation

1.6.11.1.1 Downlink adaptation overview

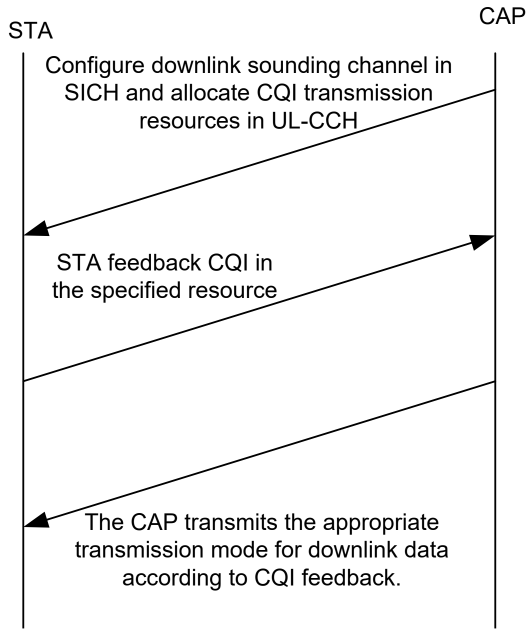
The CAP adaptively selects different physical layer transmission modes for the STA according to the channel quality information (CQI), service type, packet loss rate fed back by the STA, including the MIMO working mode, coding type, and MCS etc.

1.6.11.1.2 Request-response based feedback mechanism

The request-response based feedback mechanism means that the CAP actively sends CQI feedback request, as shown in Figure 52.

FIGURE 52

Request-response based downlink adaptation



1.6.11.1.3 Active feedback

The STA can actively send a CQI to the CAP. The feedback of the required resources can be acquired by the following means:

a) CQI feedback is directly aggregated with the data and transmitted using the allocated uplink data resources;

b) The STA carries the resource request reported by the corresponding CQI in the uplink data frame, and then the CAP allocates resources;

c) The STA sends the resource request by sending a scheduling request sequence, and feeds the request resource allocation back to the CQI.

In the case of active feedback, the CQI information is encapsulated into CQI-FB frame.

1.6.11.2 Uplink adaptation

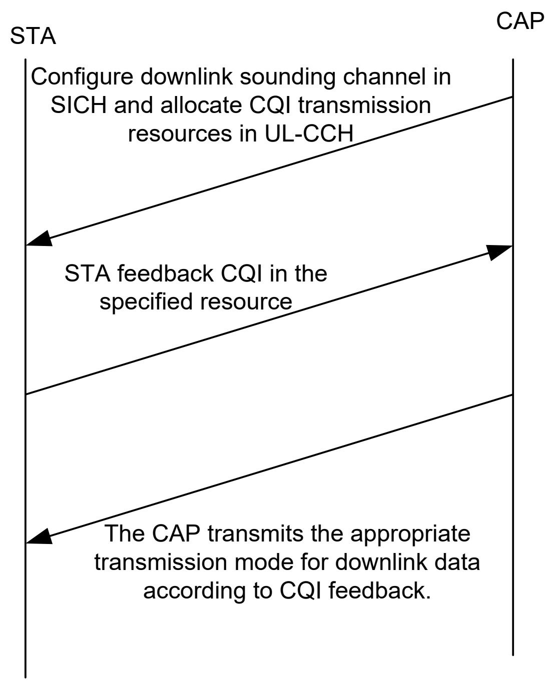
The CAP can adaptively adjust the Physical Layer transmission mode for the STA according to information such as the uplink quality, service type, uplink power and packet loss rate of the STA.

1.6.11.3 Closed-loop MIMO mode

Closed-loop MIMO operating modes include SU-MIMO and MU-MIMO. Among them, SU-MIMO can be used as a special case of MU-MIMO to be processed by a unified MAC layer processing flow, as shown in Figure 53.

FIGURE 53

Downlink closed-loop MIMO working mode flow



1.6.12 Quit network process

When the STA wants to quit the network, it actively sends a quit network frame to the CAP, and after receiving the ACK feedback from the CAP, it can exit the network. The downlink CAP may send a quit network frame to the STA, requesting the STA to exit the network, as shown in Figure 54 and Figure 55.

FIGURE 54

Uplink quit network process

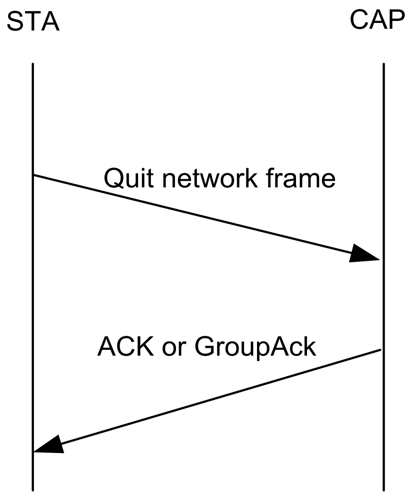
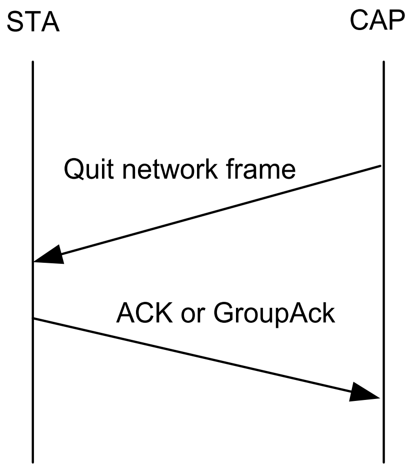


FIGURE 55

Downlink quit network process



1.6.13 Random backoff

A binary exponential backoff algorithm is used to handle collisions. The sizes of the minimum and maximum back-off windows of the binary exponential backoff algorithm are controlled by the CAP and broadcast in BCF frames (see Table 3).

The random backoff steps are as follows:

a) Step 1: When the STA sends the random access sequence or the scheduling request sequence, first set its internal backoff window equal to the minimum backoff window $CW_{\min}$ in the BCF frame;

b) Step 2: The STA sends a random access sequence on the random access channel or a scheduling request sequence on the scheduling request channel.

c) Step 3: The STA waits for resource allocation information for the random access request or the resource request in the subsequent CCH;

d) Step 4: If the STA receives the resource allocation information, the processing ends;

e) Step 5: If the resource allocation information for the random access request or the resource request is not detected in the CCH within the "Random Access Maximum Waiting Frame Interval" or the "Scheduling Request Maximum Waiting Frame Interval", the STA regards this as conflict;

f) Step 6: The STA will randomly select the backoff value within [0 $2^{m-1} \cdot CW_{min}$] (the backoff window is not greater than the maximum backoff window), and the backoff unit is one frame, where *m* represents the number of re-transmissions;

g) Step 7: After the backoff counter counts to 0, the STA sends the random access sequence or scheduling request sequence again. Then, repeat steps 4, 5, 6, and 7 until the "maximum number of attempts for random access" is reached.

1.6.14 Exception handling

1.6.14.1 Exception handling overview

Exception handling is divided into two types, i.e. exception caused by conflicts and exception caused by unexpected situations.

1.6.14.2 Exception handling caused by conflicts

1.6.14.2.1 Random access sequence conflict

After the STA sends the random access sequence, if the resource allocation information of the CAP is not obtained after the “Random Access Maximum Waiting Frame Interval” is expired, it is regarded as the random access fails and the random access process needs to be restarted.

After the STA sends the random access request frame, if the random access response frame is not received after the “Random Access Maximum Waiting Frame Interval” is expired, it is regarded as the random access fails and the random access process needs to be restarted.

1.6.14.2.2 Scheduling request sequence conflict

After the STA sends the scheduling request sequence, if the resource allocation information of the CAP is not obtained after the “Scheduling Request Maximum Waiting Frame Interval” is expired, it is regarded as the resource request fails and needs to be request again.

After the STA sends the independent resource request frame, if the resource allocation information of the CAP is not obtained after the “Resource Request Maximum Waiting Frame Interval” is expired, it is regarded as the resource request fails and needs to be request again.

1.6.14.3 Exception handling caused by unexpected conditions

1.6.14.3.1 STA out of sync

If the STA does not receive the BCF frame until the BCF timer expires, it is considered that the STA has lost synchronization with the CAP and needs to re-access the network.

1.6.14.3.2 Successive transmission failures of central access point

After the CAP sends an MPDU/G-MPDU to the STA, if it does not receive the correct acknowledgement from any MPDU, it is considered that the transmission fails and starts the counter to count the number of transmission failures. If it fails to transmit the subsequent of MPDU/G-MPDU to the STA successively, the number of transmission failures is accumulated. If the correct acknowledgement of any MPDU is received, the accumulated counter will be reset. If the accumulated value exceeds the “maximum number of consecutive transmission failures allowed by the CAP to the STA", the CAP considers that the STA is abnormal and deletes it from the active STA list.

1.6.14.3.3 Random access phase anomaly

After the STA sends the random access sequence and waits until the "Random Access Maximum Waiting Frame Interval" expires, if it does not receive the resource indication of the random access request frame sent by the CAP, the random access sequence shall be resent. After receiving the STA random access sequence and waiting until the "Random Access Maximum Waiting Frame Interval" expires, if the CAP does not receive the random access request frame from the STA, it deletes all the information of the corresponding STA. After the STA sends the random access request frame and waits until the "Random Access Response Maximum Waiting Frame Interval" expires, if it does not receive the random access response frame from the CAP, it re-sends the random access sequence. The STA detects the MAC address of the STA in the received random access response frame. If the address does not match the STA's own address, the random access sequence will be resent.

1.6.14.3.4 Capability negotiation phase anomaly

After the STA receives the random access response frame of the CAP and waits until the "STA Basic Capability Request Frame's Maximum Waiting Frame Interval" expires, if it does not receive the resource indication of the STA basic capability request frame, it is considered that the capability negotiation fails and the random access process is restarted.

After the STA sends the STA basic capability request frame and waits until the "STA Basic Capability Response Frame's Maximum Waiting Frame Interval" expires, if it does not receive the STA basic capability response frame, it is considered that the capability negotiation fails and the random access process is restarted.

After the CAP sends the STA basic capability response frame and waits until the "STA Basic Capability Response Frame Acknowledgment's Maximum Waiting Frame Interval" expires, if it does not receive the acknowledgement of the STA basic capability response frame from the STA, it is considered that the capability negotiation fails. Before the maximum waiting frame interval for the STA basic capability negotiation response frame acknowledgement expires, the CAP can re-transmit the STA basic capability response frame.

1.6.14.3.5 Dynamic service stream management phase anomaly

In the uplink service stream management process, the STA sends the service stream management request. If the "maximum waiting frame interval of the service stream response frame" expires, it is considered that the service stream management process fails. After the CAP sends the the service stream response frame, if the "maximum waiting frame interval of the acknowledgement of the service stream response frame" expires, it is considered that the service stream management process fails.

After the CAP sends the service stream management request frame, if the "maximum waiting frame interval of the acknowledgement of the downlink service stream request frame" expires, it is considered that the service stream management process fails.

After the re-transmission times of the CAP sending service stream management request response frame exceed the limit, the CAP actively initiates the process of deleting the service stream. During the downlink service stream management process, after the re-transmission times of the CAP sending service stream management request exceed the limit, the CAP actively initiates the process of deleting the service stream. In the above two processes, after the accumulated re-transmission times of the CAP exceed the "maximum times of consecutive CAP re-transmission", the CAP considers that the STA is abnormal and actively removes it from the active STA list.

1.6.15 Carrier aggregation management

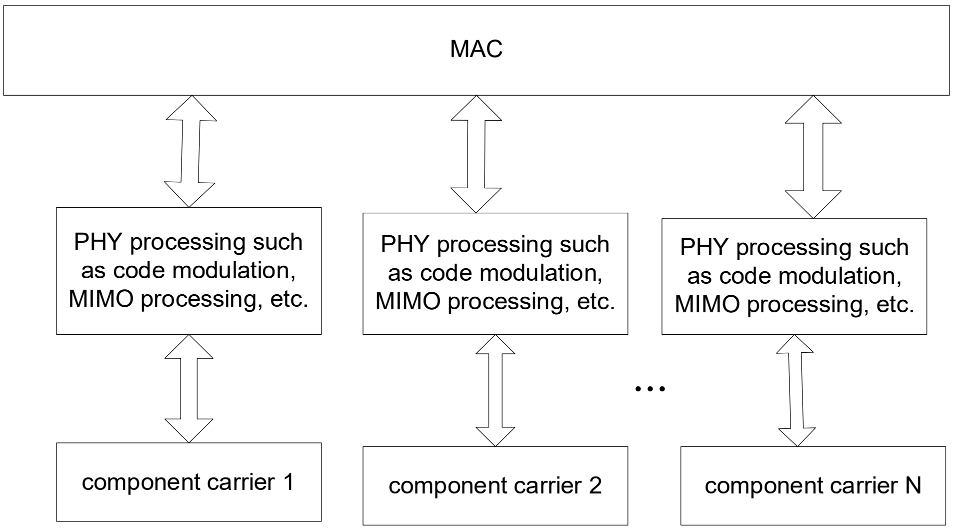
1.6.15.1 General

The system supports CAP and STA networking with different bandwidth capabilities and communicates with each other. The EUHT-5G system uses working bandwidth 1 as the basic channel bandwidth, and supports working bandwidth 2 and working bandwidth 3 in one component carrier, and support continuous or discontinuous larger bandwidths by carrier aggregation, as indicated in section 1.7.11.

In the EUHT-5G system, the MAC layer entity uniformly manages and controls multiple component carriers. The CAP determines the bandwidth mode to be adopted by the STA for each transmission at the PHY layer according to the currently available bandwidth, the bandwidth capability of the STA, and the scheduling result. The multi-carrier working mode supported by the EUHT-5G system is shown in Figure 56.

FIGURE 56

Multi-carrier working mode of EUHT-5G system



1.6.15.2 Carrier aggregation management

The CA associated signalling and procedure at CAP and STA is described as below.

1）CAP Broadcasts CA related information.

As described in Section 1.5.3.4.1, if CAP wants to support CA, it will transmit BCF containing fixed part and extensible part (CA related information). The extensible part will be appended to fixed part. One CAP can support multiple CCs. The number of CCs for different CAP (cell) can be different.

CAP will decide to transmit BCF on which CC(s) since BCF contains information of all CCs. To speed up the network join process, the better practice is to transmit BCF on ALL CCs. BCF related CCH is defined in section 1.7.5.6.4.

Each CC has complete frame structure including independent CCH, which means the relative processing (for example, resource allocation, MCS selection, channel coding/decoding, etc.) is independent for each CC. The overhead of multiple CCs is similar as single CC, since each CC has similar overhead including Preamble, SICH, CCH, etc. The frame structure and system parameters in each CC is defined in section 1.7.11, and CCH and TCH in each component carrier can be different.

2）STA performs system synchronization and obtain the CA information from BCF.

As stated in "STA network join process" in section 1.6.4, STA will perform channel scan before joining network. If STA cannot find the preambles and successfully decode SICH/CCH/BCF, it will move to next channel. The scan step is decided by STA.

If STA successfully receives a MAC frame, it will

a) Check the frame type and subtype in MAC header. If the frame type is 0 and subtype is 00000, the STA will know that it is BCF frame.
b) STA will further check the length field in MAC header. If the value indicated in "length" field is larger than the length of BCF fixed part, STA will know that there is extensible part after the BCF fixed part.
c) Since the extensible part uses the TLV structure, the STA will check the TLV type. If it is 0, STA will know the extensible part carries the CA related information.

If STA obtains BCF at some CC, it will have the information of all CCs supported by current CAP, including the starting frequency, bandwidth, transmit power, etc. The calculation of center frequency of each CC is defined in section 1.5.3.4.1.

3）STA joins the CAP.

As defined in section 1.6.4, if STA decides to join the CAP, STA will perform random access and capability negotiation procedure at one CC of the CAP.

4） Handover behavior in CA mode.

The handover related signaling can be exchanged on CC(s) according to the decision of CAP/STA. The CA handover is similar as single carrier handover procedure as stated in section 1.6.19.2. More information about dual-connection in CA mode can be seen in section 1.6.19.2.4. More specifically, the handover procedure in CA mode is as follows;

a) STA will monitor the RSSI of CCs it uses. If the RSSI of one or more CCs are below the threshold (RSSI_DL_DROP_N) defined in section 1.5.3.4.1, STA can decide to send CM-REQ frame to serving CAP on one of the CC it uses to request for channel measurement. STA can decide whether and when to send CM-REQ. STA can also decide to send CM-REQ frame on which CC. The average RSSI over all the CCs the STA uses will be reported to serving CAP.

b) CAP sends CM-RSP back to STA to control the channel measurement of STA. In CA mode, CAP will decide which CC used by STA to send CM-RSP frame. Since STA shall monitor all the CCs it uses, it can correctly receive the CM-RSP frame.

c) STA measures the average RSSI of serving CAP and candidate CAPs, then sends CM-REP to report the values to serving CAP. In CA mode, the RSSI of serving CAP should be averaged over all CCs the STA uses. The RSSI value of candidate CAPs is obtained from the working channel specified in CM-RSP. STA will decide the CC to carry CM-REP.

d) STA can trigger the handover process by sending HO-REQ frame to serving CAP. CAP can send HO-CMD back to STA to start the handover execution process. CAP can also proactive ly sent HO-CMD to STA to start the handover execution process. The information of CAP-D is provided in HO-CMD. In CA mode, STA/CAP can decide which CC will be used to transmit the messages. Serving CAP may activate/deactivate some CCs as indicated in HO-CMD.

e) In handover execution phase, STA will join CAP-D on the working channel specified in HO-CMD, the detailed process is defined in section 1.6.19.2. If the CAP-D supports CA, STA can work in CA mode in the target cell after capability negotiation.

f) EUHT-5G can accomplish 0ms mobility interruption time during handover by using dual connection. More details are stated in section 1.6.19.2.4.

5) Activation/Deactivation of CCs in CA mode.

CAP can dynamically activate or deactivate some component carriers for CAP or STA as defined in section 1.5.3.4.22. CAP can also activate or deactivate some CCs of STA by sending HO-CMD. If some CCs are activated, STA shall monitor those CCs by decoding SICH and CCH on the CCs. If some CCs are deactivated, STA can stop monitoring those CCs.

1.6.15.3 Channel switching management

CAP can decide to switch the working channel, working bandwidth of one or more CCs for CAP or STA by sending the channel switching information frame to the STA to notify the STA, as defined in section 1.5.3.4.14. The relative information in BCF should be updated after the channel switching.

1.6.16 Power saving management

1.6.16.1 General

The STA has two power states:

– Active state: that is, the STA is in a normal communication mode with full power;

– Sleep state: the STA is in a low power state mode and cannot send and receive data.

The transition between these two states is determined by the power management modes of the STA. The management modes are as follows:

– Active mode (AM) means that the STA is active and can receive frames at any time.

– Sleep Mode (SM) means that the STA is in a lowest power state within a certain period, thereby saving power and air interface resources.

In sleep mode, the sleep cycle includes a sleep window and a listening window. In the sleep window, the STA cannot communicate with the CAP. At this time, one or more hardware devices can be turned off in one or more physical frames to save power. There will be a listening window at the end of each sleep window. Within the listening window, the CAP indicates the STA whether there is data arriving through the DTF-IND frame. After the listening window ends, if the STA receives the data arrival indication, it exits the sleep mode and is ready to receive data. Otherwise, it maintains the sleep mode and returns to the sleep window.

In CA mode, STA can decide which CC is used to send SLP-REQ frame. CAP can decide which CC is used to send SLP-RSP back to STA. During sleep window, STA shall sleep on all CCs it uses. During listening window, STA will moniter the DTF-IND frame on the CC where SLP-RSP was received. If DTF-IND frame is received and TI indication field in DTF MAC frame is 1, STA will exit sleep mode on all CCs it uses.

1.6.16.2 Power saving mechanism

1.6.16.2.1 Overview of power saving mechanism

The sleep mode applies to both STA and CAP. The sleep mode of STA can be triggered by the STA or CAP. The sleep parameter can be negotiated between the STA and the CAP through MAC layer signaling. The sleep mode of CAP is triggered by CAP.

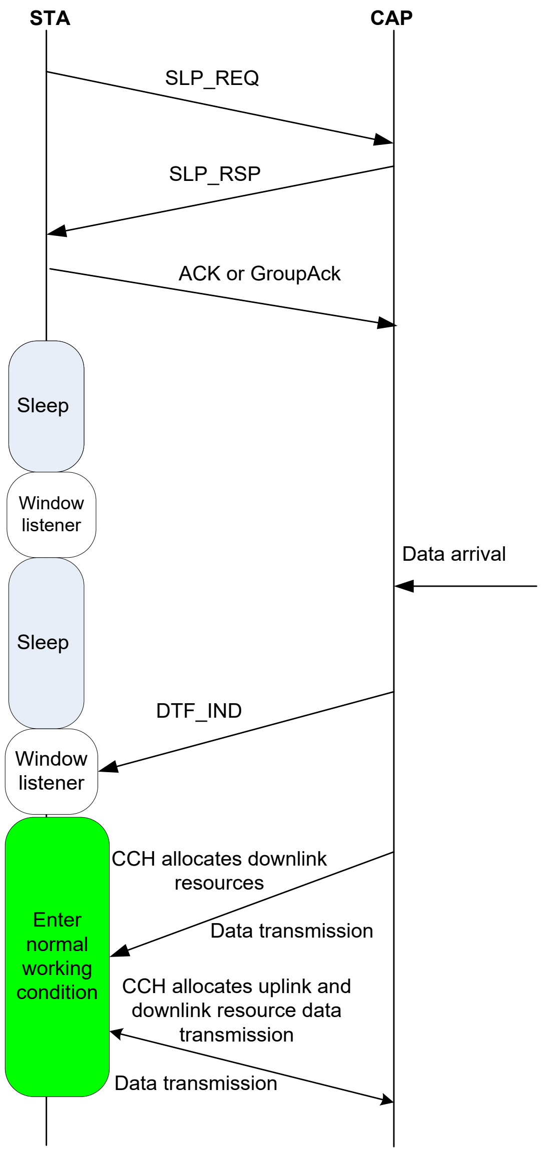
1.6.16.2.2 Sleep triggered by STA

When the STA does not transmit uplink data for a certain period of time, it can trigger the corresponding sleep operation, and negotiate the parameters such as the sleep period and the sleep start time with the CAP through the corresponding management control frame interaction (SLP-REQ/SLP-RSP). For details, see 1.5.3.4.15 and 1.5.3.4.16.

The CAP caches the downlink data for the STA in the sleep mode. When the cached data reaches a certain threshold, the CAP sends a DTF-IND frame in the listening window to activate the sleeping STA. The specific process is shown in Figure 57.

FIGURE 57

Example -- sleep triggered by STA, waked up by CAP



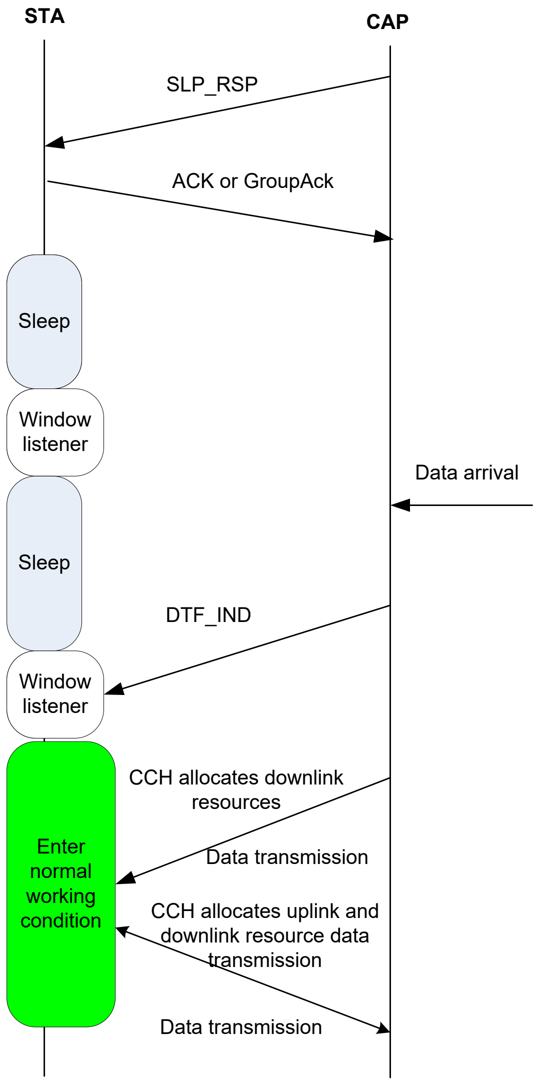
1.6.16.2.3 Sleep triggered by CAP

The CAP notifies the STA to enter the sleep state through the SLP-RSP frame according to the working state of the STA, and carries the sleep parameters of the STA in the SLP-RSP frame.

During the STA sleep period, the CAP caches the downlink data of the STA. When the cached data reaches a certain threshold, the CAP sends a DTF-IND frame in the listening window to activate the sleeping STA. The specific process is shown in Figure 58.

FIGURE 58

Process -- sleep triggered by CAP and waked up by CAP

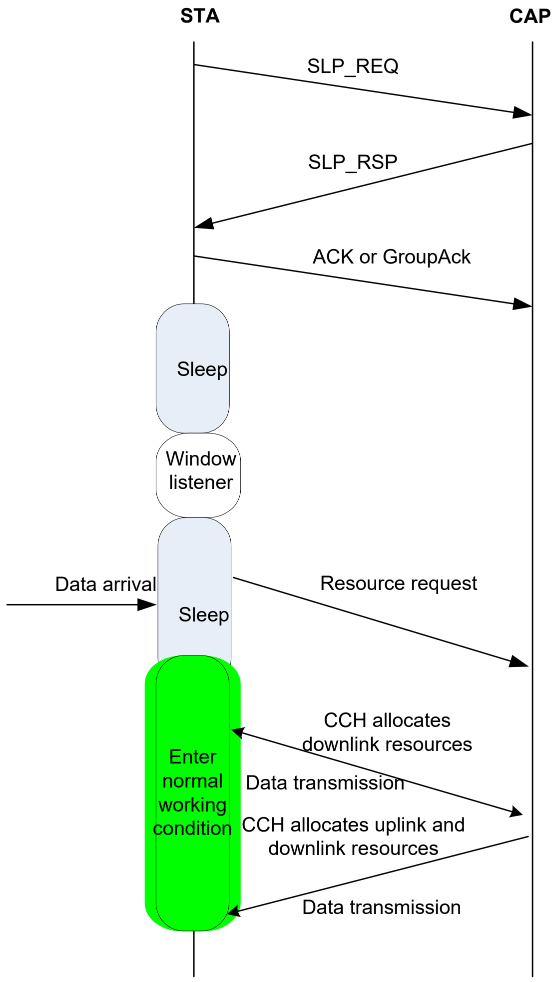


1.6.16.2.4 Wake-up by STA

If the sleeping STA has uplink data to be transmitted, the STA can actively terminate the sleep and enter the active state. The specific process is shown in Figure 59.

FIGURE 59

Process of wake-up by STA



1.6.16.2.5 Wake-up by CAP

CAP caches downlink data of STA in STA sleep period. When cached data reach a certain threshold, CAP sends DTF-IND frame in monitoring window to active sleep STA. In this case, the sleeping STA terminates sleep mode when the TI indication field in DTF MAC frame is 1.

1.6.16.2.6 Power Saving for CAP

The BCF frame will be transmitted periodically by CAP. The BCF frame is used for STA to detect the CAP and obtain the basic information on the CAP. The BCF interval can be configured through the network. The BCF interval range is up to 65535ms. The higher value of BCF interval will increase the energy efficiency of CAP. If there is no data to transfer in the network, CAP may enter hibernation mode after sending one physical frame which contains BCF to allow terminal to join the network or request to access network. Also, the hibernating CAP is ready to receive RA PN in RACH in the frame. In CA mode, CAP will send BCF on all CCs it supports.

1.6.17 System configuration parameters

System configuration parameters are shown in Table 42.

TABLE 42

System configuration parameter settings table

Parameter name	Defaults	Description
Random access maximum waiting frame interval	4	The maximum number of waiting frames that can be allowed after the STA sending the random access sequence.
Random access response maximum waiting frame interval	4	The maximum number of waiting frames that can be allowed after the STA sending the random access request frame.
STA Basic Capability Request Maximum Waiting Frame Interval	4	The maximum number of frames that the STA waits for the CAP to allocate resources to it after receiving the random access request response frame.
Maximum frame interval of STA basic capability response frames	4	The maximum number of waiting frames that can be allowed after the STA sending the STA basic capability request frame.
STA Basic Capability Response Frame Acknowledgment's Maximum Waiting Frame Interval	4	The maximum number of waiting frames that can be allowed after the CAP sending the STA basic capability request frame
Maximum waiting frame interval of traffic stream response frame	4	The maximum number of waiting frames that can be allowed after the STA sending the service stream request frame.
Maximum waiting frame interval of the acknowledgement frame of the downlink service stream request	4	The maximum number of waiting frames that can be allowed after the CAP sending the service stream request frame
Maximum waiting frame interval of the acknowledgement of the service stream response frame	4	The maximum number of waiting frames that can be allowed after the CAP sending the service stream response frame
Scheduling Request Maximum Waiting Frame Interval	4	The maximum number of waiting frames that can be allowed after the STA sending the scheduling request sequence
Resource Request Maximum Waiting Frame Interval	4	The maximum number of waiting frames that can be allowed after the STA sending the independent resource request frame.
Maximum number of consecutive failed transmissions allowed by the CAP to the STA	20	The number of consecutive transmission failures that the CAP can tolerate for a certain STA
MPDU maximum re-transmission times	5	The maximum number of attempts to re-transmit an MPDU
Maximum number of attempts for random access	10	The maximum number of times the STA can try the Random Access
Max Buffer Size of the connection in which FID is 0	16	The connection with FID of 0 can buffer 16 MPDU at maximum

1.6.18 Identification and confidentiality

The identification and confidential mechanism of EUHT-5G is completed by the cooperation between the STA on the mobile station side and the network side. The security mechanism of the "identification and authentication generated by negotiation with keys" is adopted to achieve the two-way identification and authentication between the network and the mobile station so as to ensure authorized access of the legitimate users. And the encryption and decryption keys for secure data transmission are generated during the identification and authentication process to ensure the security of data transmission.

In order to enhance security, the root key is not transmitted in the air interface and network path, but only local to the STA and network side.

The two-way authentication between the mobile station and the network is possible, that is, the network can identify the mobile station and the mobile station can also identify the network. Isolation of encryption and decryption keys on data plane is possible: each STA encrypts and decrypts with a different and individual key on each CAP. The encrypted and decrypted data plane messages can be securely transmitted. The security of control signaling is critical to the security of radio communication systems. The system can enter the secure transmission mode after being authenticated. It encrypts and decrypts the control signaling through the encryption and decryption algorithm to ensure the secure transmission of key signaling in the control layer. At the same time, the system has a CRC checking mechanism in the MAC layer to ensure that the integrity of the control signaling is not falsified.

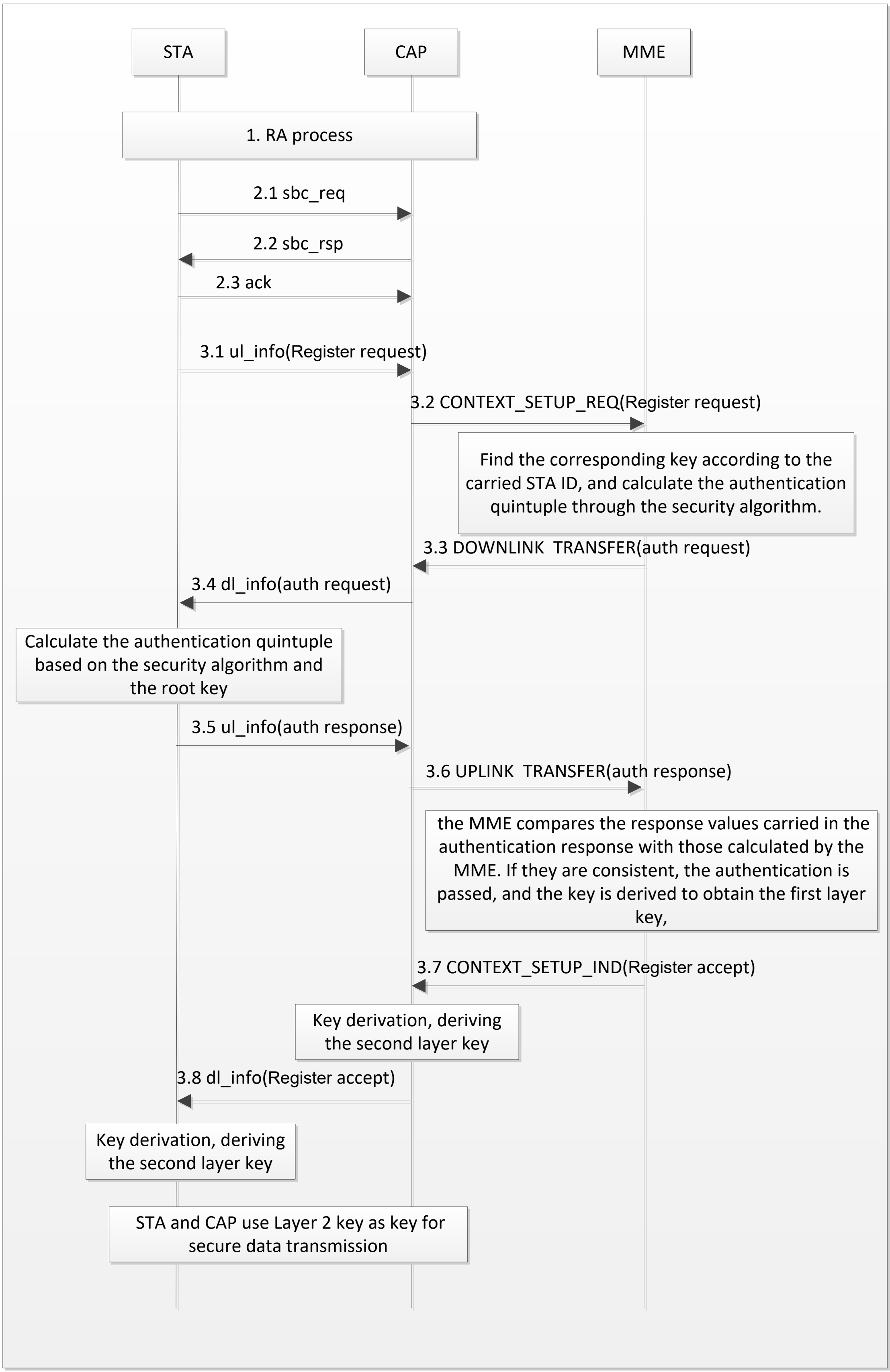
The AES encryption and decryption algorithm can be used to encrypt and decrypt data packets, ensuring the secure transmission.

1.6.18.1 Authentication flow

The MME (Mobility Management Entity) network element is introduced into the system to implement the authentication function of the Authentication Server. A peer-to-peer control protocol flow is added between the STA and the MME to realize the function. A peer-to-peer control protocol flow is added between the CAP and the MME to support the implementation of the function. The specific authentication process supported by this system is as Figure 60.

FIGURE 60

Authentication flow



1. RA process

2. In the SBC process, the STA carries the initial network access in the SBC_REQ signaling, and the CAP informs the STA in the SBC_RSP signaling that the upper layer authentication process needs to be initiated.

3. Specific authentication process is described as follows:

3.1 The STA sends an uplink message ul_info (which carries the up layer signaling "Register Request, which carries the STA ID information").

3.2 After receiving the message, the CAP sends a context establishment request (in which the up layer signaling "Register Request" is carried).

3.3 After receiving the message, the MME finds the corresponding root key according to the carried STA ID, and calculates a set of authentication vectors by using a security algorithm, where the response value is used for subsequent authentication of the STA. And a downlink message, which carries the up layer signaling "authentication request, carrying specific authentication vectors such as RAND, AUTN etc.", is sent, expecting the STA to use the authentication vectors to calculate an response value to report to the network.

3.4 After receiving the message, the CAP sends a downlink message dl_info (which carries the up layer signaling "authentication request, carrying specific authentication vectors such as RAND, AUTN, etc.").

3.5 After receiving the message, the STA calculates a set of authentication vectors according to the root key by the security algorithm, and puts the calculated response value into the up layer signaling "Authentication Response" and sends it to the CAP.

3.6 The CAP sends the received message to the MME through an uplink message ("Authentication Response, carrying the specific response value calculated by the STA").

3.7 After receiving the authentication response message, the MME compares the response values carried in the authentication response with those calculated by the MME. If they are consistent, the authentication is passed, and the key is derived to obtain the first layer key, which is sent to the CAP. At the same time, a downlink message is sent, which carries the up layer signaling "registration success".

3.8 After receiving the message, the CAP derives the second layer key for subsequent encryption and decryption. Simultaneously, a downlink message, which carries the up layer signaling "registration success", is sent. After receiving the message, the STA learns that the network authentication has been passed, and uses the root key to derive the second layer key. The STA and the CAP use the second layer key as the key for encrypting and decrypting the data message.

In CA mode, STA can decide which CC is used to send authentication related frames. CAP can decide which CC is used to send authentication related frames back to STA.

(Note: If the Response value calculated by the MME is not consistent with the MME's own calculation, the MME considers it to be an illegal user and will reject the registration process. The STA will not be allowed to perform service transmission in the following).

1.6.19 Mobility management

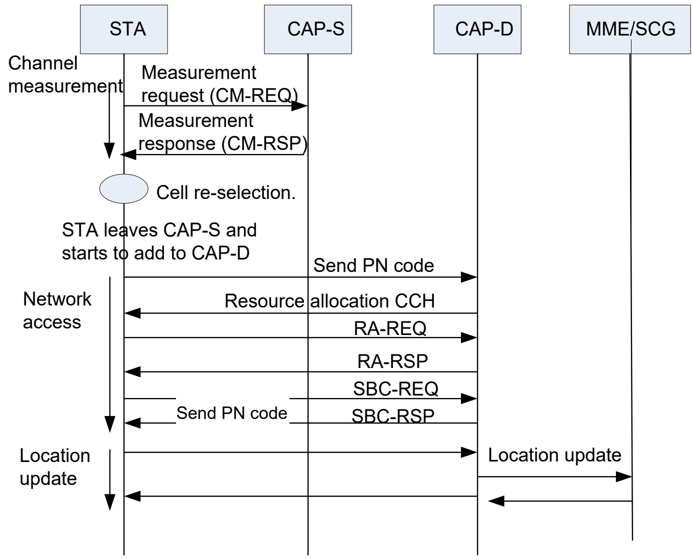
Mobility management is mainly divided into two categories based on the state of the STA, i.e. mobility management in idle state and in connection state. The mobility management in the idle state is mainly performed through the cell reselection process, and that in the connection state through the handover process.

1.6.19.1 Cell re-select process

In idle mode, cell reselection is triggered during monitoring the channel quality measurements of the serving cell and neighboring cells. The serving cell may indicate and configure the STA to search and measure information of neighboring cells by measuring the response message. The criteria for cell reselection relate to measurements of serving cells and neighboring cells. The STA determines whether to initiate the cell reselection process according to the reselection decision criterion based on the current channel quality measurement result and the configured threshold value at the network side. Once it is determined to reselect the target cell, the STA initiates a network access procedure with the target cell. After the target cell completes the network access procedure, the STA may stay in the local cell and send a location update message to the core network. The process is as shown in Figure 61.

FIGURE 61

Cell re-select process



1.6.19.2 Handover management

1.6.19.2.1 Basic handover procedure

When the STA is in the service connection state, its mobility management can be performed through the handover process. The handover procedure covers the channel measurement handover triggering, the handover decision and preparation, and the handover execution. The basic handover procedure is shown in Figure 62.

– Channel measurement:

To assist the handover decision, the CAP may allocate a corresponding time interval for the STA to perform channel scan measurement, and report channel measurement results of the serving cell and the neighboring cells, in preparation for subsequent channel switching and cell handover.

The measurement steps are as follows:

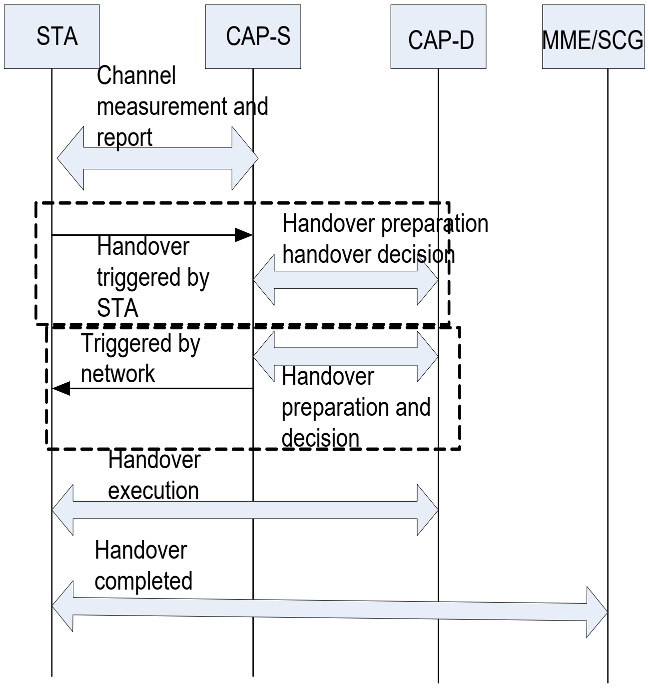
Step 1: the STA measures the average Received Signal Strength Indication (RSSI) of the working channel of the current cell.

Step 2: the average RSSI measurement value of the working channel of the current cell is compared with the set threshold value RSSI_DL_DROP. When the measured value is less than the threshold value RSSI_DL_DROP, the timer starts counting.

Step 3: If the measured value of the average RSSI of the current cell in the set lag time T_1 is less than the threshold RSSI_DL_DROP, send a measurement request message to the CAP-S.

FIGURE 62

Basic process of handover



Step 4: According to the measurement response message returned by the CAP-S, which carries the allocated measurement time and candidate cell list information, measurement of the candidate cell starts, and the RSSI of the working channel of the candidate cell is measured.

Step 5: If the candidate cell meets the handover condition, a handover request containing the average RSSI measurement value of the working channel of the candidate cell is sent to the CAP-S.

The CAP-S makes a handover decision according to the handover request sent by the STA and executes the subsequent handover procedure.

− Handover triggering

The handover may be triggered by the STA according to the channel change; for the STA-triggered handover, the STA sends a HO-REQ message to the CAP-S to trigger the handover procedure, and then starts the signaling interaction prepared by the handover between the CAP-S and the CAP-D.

The network side can also initiate handover according to the purpose of load balancing. For the handover triggered by the network side, the network side sends a HO-CMD message to the STA to trigger the handover by the CAP-S, and the handover preparation interaction procedure between the CAP-S and the CAP-D is completed before the handover triggering, as shown in Figure 62.

− Handover decision and preparation

For the STA-triggered handover, the CAP-S may send a handover preparation message to one or more candidate CAPs according to the recommended one or more candidate CAP information carried by the HO-REQ message, and query parameters such as available resources to determine the CAP-D for the STA. The STA is notified by the HO-CMD message.

For the handover triggered by the network side, the network side selects the target CAP for the STA according to the previous handover preparation interaction, and carries the target CAP-D information through the HO-CMD message. Once the CAP-D is determined, the CAP-S can send STA capability information, service context and other information to the CAP-D through the backbone network before handover to optimize the handover performance.

In this phase, the CAP-D can pre-allocate the temporary STAID parameters, send them to the STA through the CAP-S and by the HO-CMD message. After receiving the HO-CMD command, the STA shall update the information according to the parameters carried by the HO-CMD, including the TSTAID that shall be assigned to the CAP-D by the STAID. And the authentication message shall be the authentication and other messages used by the CAP-D. If the CAP-D has assigned TSTAID to the STA during the handover process, then the FID used by the STA does not need to be updated during the handover process.

− Handover execution

Upon receiving the HO-CMD message, the STA begins executing the CAP-D network access procedure within the specified handover time. If the HO-CMD message carries the TSTAID parameter assigned by the CAP-D, during the validity period of the temporary STAID parameter, the STA shall use the TSTAID parameter to complete the access procedure that is not conflict with the CAP-D. That is, the STA waits for the resource indication allocated by the TSTAID to proceed with the competition-free access, wherein the station can implement seamless frame handover between the same frequency or different frequency points with the lowest delay in the handover execution, and achieve fast synchronization and seamless acquisition of main control signaling. If the temporary STAID expires, the STA shall randomly select the PN code to compete for the random access in the RACH channel. After receiving the ranging code, the CAP-D will send the ranging CCH and allocate the uplink bandwidth of the RA-REQ. After the STA receives the RA-RSP, the STA successfully accesses the CAP-D, that is, the STA can communicate normally.

− Handover completed

After the STA and the CAP-D can communicate normally, the CAP-D sends an update routing message to the MME/SCG to update the background routing.

1.6.19.2.2 Handover process

Since the handover process is a complex process that spans multiple network entities across multiple layers of protocols, the following describes the most basic handover process of the air interface in this system.

The handover process triggered by the STA as an example is shown in Figure 63. The dotted line portion is an optional step, and the handover process is determined according to the indication type of the handover command.

The handover steps are as follows:

a) When the signal quality (average RSSI) of the current cell has been lower than the measurement threshold for a certain period of time, the STA can decide to send a measurement request message to the current serving cell (CAP-S).

b) The CAP-S returns the measurement response message, and allocates channel measurement time to the STA and carries candidate list information.

c) The STA judges the handover condition based on the channel measurement result. If the received signal quality (average RSSI) exceeds the handover threshold for a period of time, the handover request is sent to the CAP-S to trigger the handover.

d) The CAP-S performs a handover decision according to the recommended candidate CAP carried in the handover request, and determines the target CAP-D.

e) The CAP-S sends a CAP request handover message to the target CAP-D to reserve the handover resource.

f) The CAP-S sends a handover command message to the STA. The handover command message carries a handover type indication.

g) After receiving the handover command, the STA initiates a handover process to the CAP-D according to the relevant parameters carried in the handover command. According to the handover type carried in the handover command message, the STA enters different handover processes. If the handover type is Re-Access Type, the STA will initiate an access process on the CAP-D, which is the same as the network access process. If the handover type is competitive access, it is accessed following steps h) to k), and the capability negotiation process is omitted. If the switch type is competition-free access, it is handed over following step 1).

h) The STA transmits the PN code on the RACH channel of the CAP-D, and adopts the competitive access mode in the same manner as the new STA.

i) After receiving the PN code, the CAP-D sends the uplink resource allocation CCH that transmits the RA-REQ and carries power and uplink TA information.

j) The STA sends an RA-REQ on the allocated resource, and carries the STA MAC address.

k) After receiving the RA-REQ, the CAP-D sends the RA-RSP and assigns a unique STAID.

l) In the competition-free access mode, the CAP-D needs to assign the STAID to the user in advance, and informs the STA in the handover command of the temporary STAID and other information allocated by the CAP-D; the STA completes the synchronization and obtains the control signaling of the new base station with the minimum delay so as to achieve seamless frame handover.

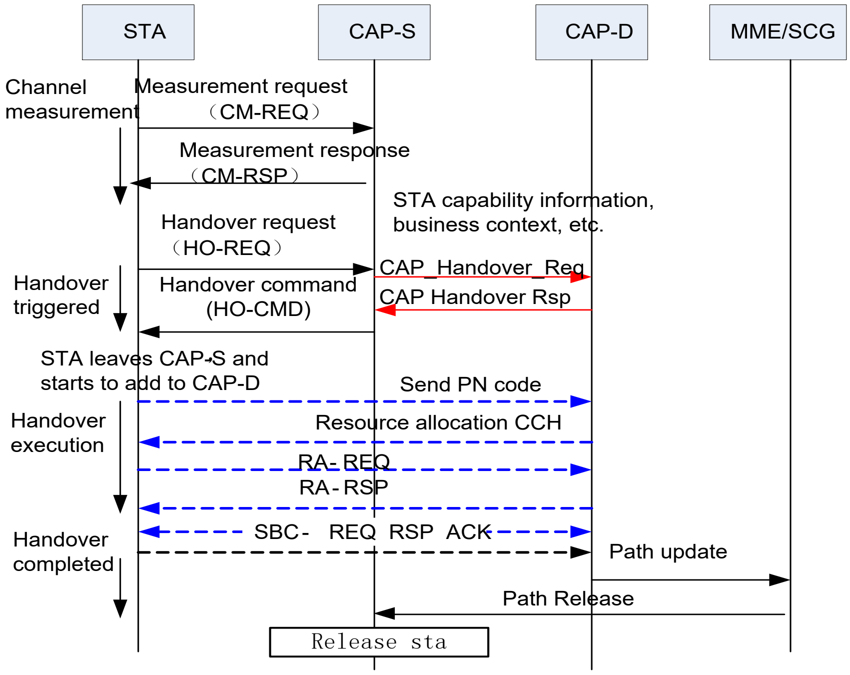
m) The CAP-D sends a path update message to the core network device MME/SCG to recover the downlink service transmission.

n) So far, the STA completes the uplink and downlink service handover through the CAP-D, and the CAP-S releases the resources.

The handover process in CA mode follows the above procedure. More CA realted details is stated in section section 1.6.15.2.

FIGURE 63

Example of air interface handover process triggered by STA



1.6.19.2.3 Lossless Handover

EUHT-5G system supports mobility by using the network control and STA-assisted handover mechanism.

The network provides measurement configuration information to STA. According to the network configuration information, when the STA detects that the condition of handover is satisfied, the STA send “handover request” message to the network.

In the handover process, the serving CAP decides whether to initiate the handover procedure based on the measured results reported by the STA. The serving CAP initiates a handover procedure and sends a "CAP Handover Request" message to the target CAP when the serving CAP judges that the handover condition is satisfied. The message carries service flow info, security info, etc. The info helps the target CAP establish Radio Bearer and restore Air Interface data transmission.

The target CAP provides some information to help the STA have access to the target CAP. The target CAP sends the information to the serving CAP through the "CAP Handover Response" message. Then the serving CAP sends the information that can be used in the target CAP to the STA by sending the "Handover Command" message through the air interface so as to help the STA access the target CAP when it hands over.

In the lossless handover process, the CAP-S will forward the the data packets to the CAP-D, including the data packets received from core network but have not been sent to STA, and the data packets that have been sent to the STA by CAP-S but CAP-S have not received ACK from the STA.

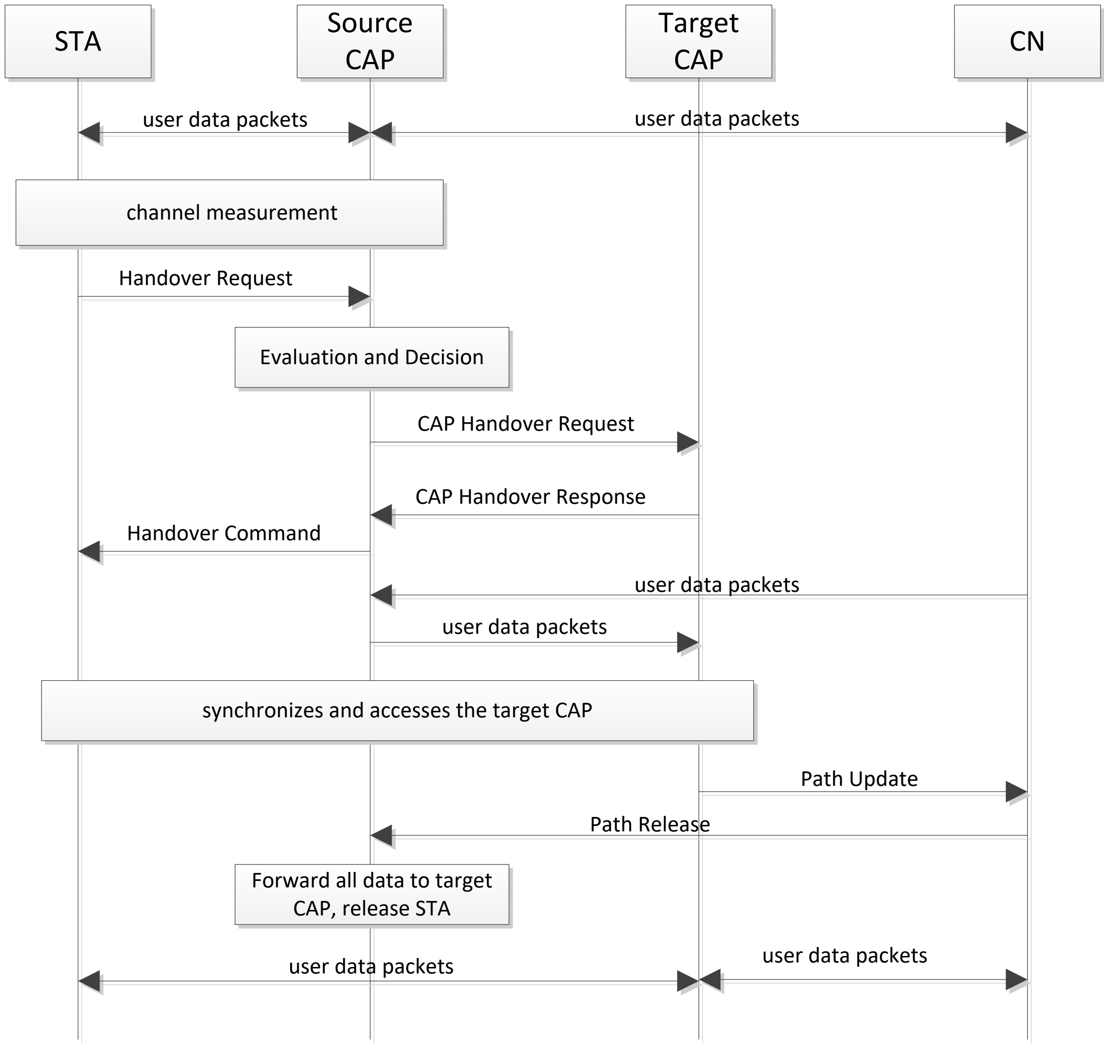
The STA synchronizes and accesses the CAP-D according to the information received from the CAP-S in the "Handover Command" message.

The target CAP sends a “Path Update" message to the CN (Core Network) to notify the path of the change. The serving CAP receives a “Path Release” message from the network and releases the STA information.

Through the above control plane and user plane procedure, the STA completes the handover procedure and establishes a new radio connection with the target CAP for data transmission.

FIGURE 64

Lossless handover flow



In carrier aggregation mode, CAP/STA considers all component carriers of one CAP as a whole in the handover process and follow the procedure in Figure 62, Figure 63 and Figure 64.

1.6.19.2.4 0ms Mobility interruption time

Carrier aggregation (CA) can be used for STA to connect with both CAP-S and CAP-D during handover to implement dual connection. In CA mode, CAP-S and CAP-D need to communicate to decide which CCs of CAP-S and CAP-D can be used by the STA during handover. The indication of CCs of CAP-S to STA is defined in HO-CMD. If the total number of CCs STA used in CAP-S already reaches the maximum capability of STA, CAP-S may need to de-activate some CCs used by STA to release the RF channels for the connection with CAP-D. The indication of CCs STA used to connect with CAP-D is defined in the basic capability response frame sent by CAP-D, see section 1.5.3.4.5.

RACH-less is used in EUHT-5G, the CAP-D can pre-allocate resources for STA to reduce handover latency.

EUHT-5G can accomplish 0ms interrupt handover by entering / leaving dual connection mode. 0ms Interruption handover procedure consists of three phases:

Phase 1: Handover preparation

Handover preparation completes the signaling procedure of the initiation phase of the handover. In this phase, STA is connected to the CAP-S. In CA mode, STA can use multiple CCs for data transmission. The unique sequence number (SN) in MAC header will be used by the MAC layer entity in CAP-S/STA to correctly re-assemble MAC data unit (MPDU) in all CCs.

Phase 2: Handover execution

CAP-S send HO-CMD frame in which the “dual connection” field is 1 to notify STA enters dual connection mode. In this mode, STA will join CAP-D while keeping the connection with CAP-S. After the network join process, STA can connect with both serving CAP and CAP-D at the same time. In the dual connection mode, the CAP-S acts as an anchor to interact with the core network (CN). In downlink transmission, data packets can be forwarded from CAP-S to CAP-D. In uplink transmission, data packets can be forwarded from CAP-D to CAP-S.

After the dual-connection is established, the data packets from CN arrives at the CAP-S’s MAC layer entity and the CAP-S MAC layer is responsible for generating the MAC PDU with unique MAC SN in MAC header. While CAP-S is transmiting downlink MAC-PDUs to STA, the CAP-S can also decide to forward part of downlink MAC PDUs to the CAP-D to increase throughput, or forward duplicated downlink MAC PDUs to CAP-D to increase reliability. From STA’s perspective, if the MAC PDUs received from different CCs and different CAPs have different unique sequence number, then STA’s MAC entity can reorder MAC PDUs from different CCs and different CAPs based on sequence number. If the MAC PDUs received from different CCs and different CAPs have the same unique sequence number (due to the duplication), then STA’s MAC entity can detect and discard the extra duplicated MAC PDUs.

For the uplink case, there is one MAC entity in STA which uniformly manage all the CCs, even those CCs belong to different CAPs. The STA can decide to send the duplicated uplink MAC PDUs (with the same MAC SN) to both CAP-S and CAP-D for increasing reliability. On the other hand, STA can also decide to send the different uplink MAC PDUs (with different MAC SN) to both CAP-S and CAP-D for increasing throughput. Similarly, STA can decide to send the duplicated uplink MAC PDUs (with the same MAC SN) on multiple CCs for increasing reliability. On the other hand, STA can also decide to send the different uplink MAC PDUs (with different MAC SN) on multiple CCs for increasing throughput.

At the CAP’s side, data packets received by CAP-D will be forwarded to CAP-S. CAP-S’s MAC layer entity is responsible for reassembling MAC PDUs from the CAP-S and CAP-D, similar with downlink.

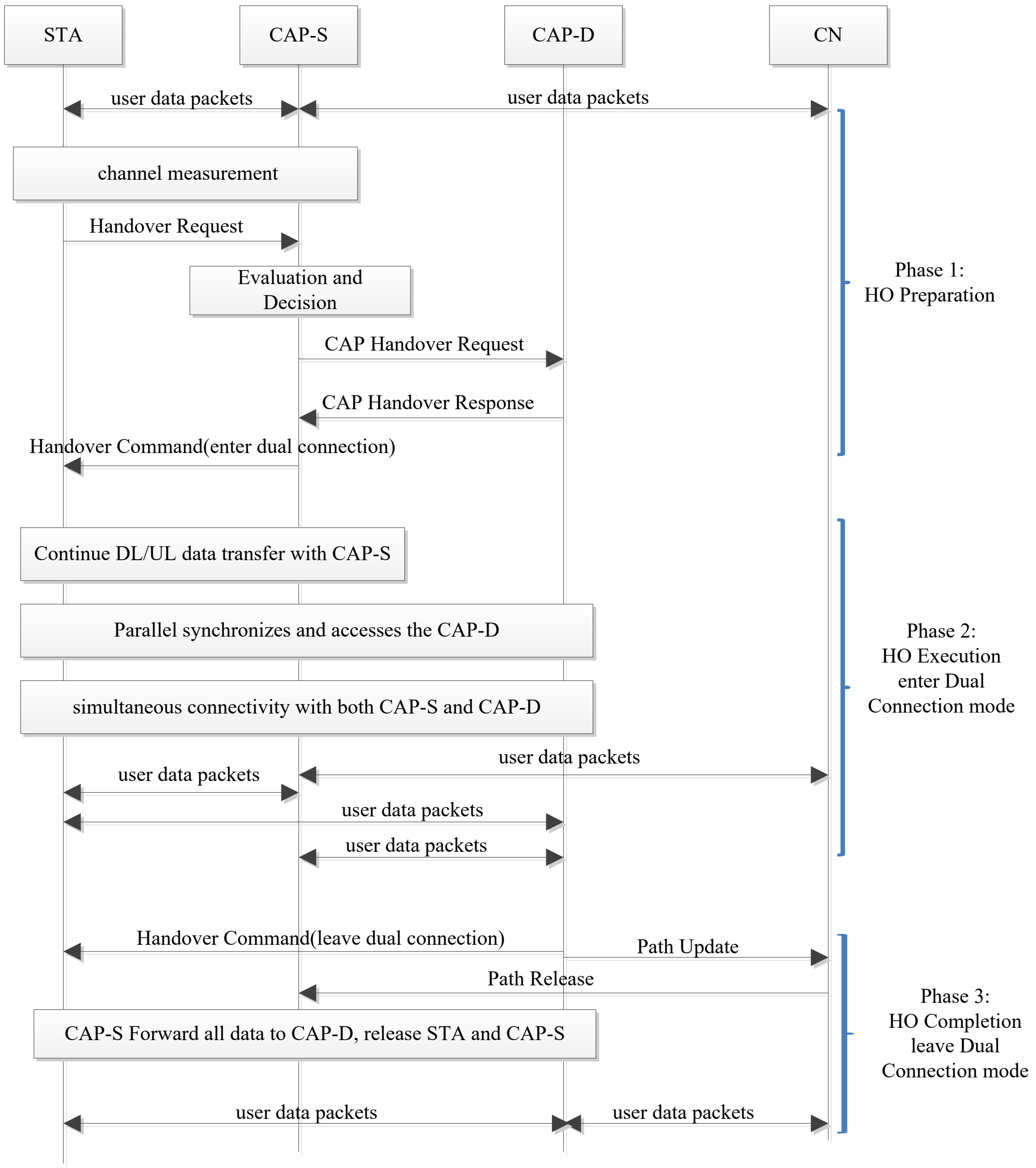
Phase 3: Exit dual connection and handover completion

CAP-D sends HO-CMD frame in which the “dual connection” field is 2 to notify STA exits dual connection mode. After STA leaves the dual connection mode, the connection between STA and the CAP-S is released. The path between CAP-S/D and CN is updated so that CN will exchange downlink/uplink data packets with STA through CAP-D, which completes the handover process.

The 0ms interruption time procedure can be showed as Figure 65.

FIGURE 65

The 0ms interruption time procedure



1.6.19.3 Interworking with other systems

EUHT-5G support interwork with the 3GPP-LTE/5G system (legacy IMT system). EUHT-5G system can support interwork with other wireless communication systems by using dual-mode terminal.

A dual-mode terminal that integrates 3GPP-LTE/5G functions to achieve interworking with 3GPP system. A radio adaptation layer is added in the dual-mode terminal on top of both 3GPP and EUHT protocol stack, which can dynamically select and activate the specific radio access technology.

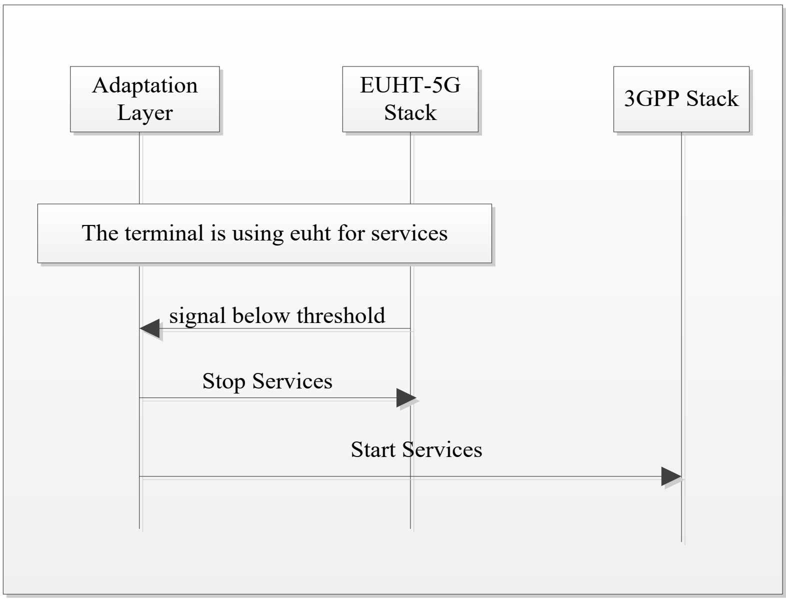
Procedure of the dual-mode STA can be shown as Figure 66:

1) The dual-mode STA monitors the radio qualities and the traffic load of the two radio networks, and selects the better radio access network to carry out services according to an appropriate criterion.

2) when the STA is using the EUHT access network for services, if the signal quality of the EUHT-5G network becomes worse and the signal quality of the 3GPP network is better, the STA 's adaptation layer will choose to use the LTE network for services and vice versa.

FIGURE 66

dual-mode STA Procedure



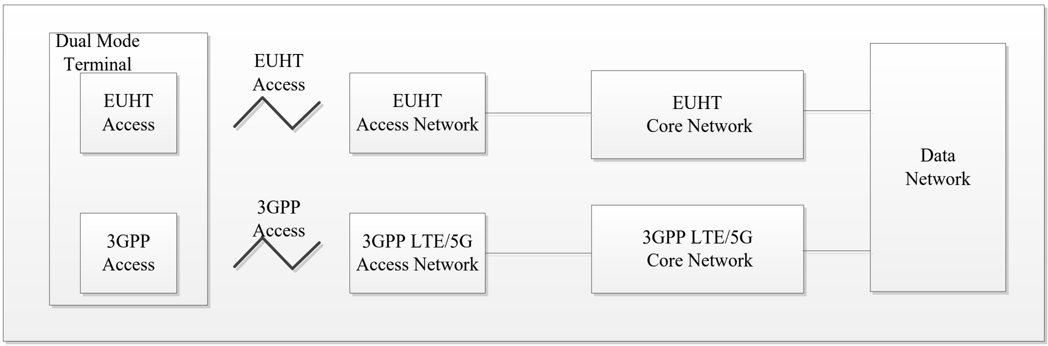
There are two modes: Independent Core Network Mode, Access to 3GPP Core Network Mode.

1.6.19.3.1 Independent Core Network Mode

In the independent core network mode shown in Figure 67, EUHT-5G and 3GPP LTE / 5G have their own independent core networks. This mode does not need to modify the existing network, and has no impact on the existing network. All the interworking control and protocol in the dual-mode STA is implemention ralated.

FIGURE 67

Independent Core Network Mode



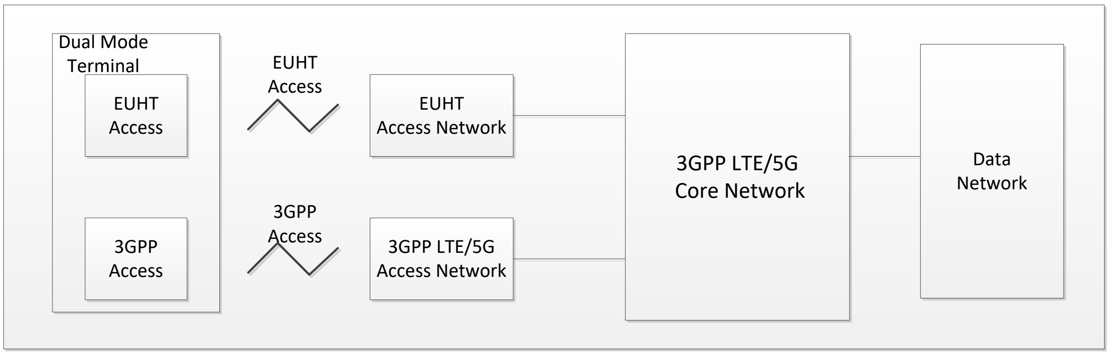
1.6.19.3.2 Access to 3GPP Core Network Mode

In Access to 3GPP Core Network Mode, EUHT-5G can acts as the role of non-3GPP radio access system to access to 3GPP Core Network to realize the interworking between the two systems, shown in Figure 68.

3GPP standard defines the architecture of interwork between non-3GPP access technology and 3GPP LTE/5G system, as well as related standard interfaces. EUHT-5G can complete the relevant functions according to the interface standard as a non-3GPP access technology defined in the standard, and then realize the interworking with 3GPP LTE/5G.

FIGURE 68

Access to 3GPP Core Network Mode



1.7 Physical Layer

1.7.1 Frame structure and basic parameters

1.7.1.1 Frame structure

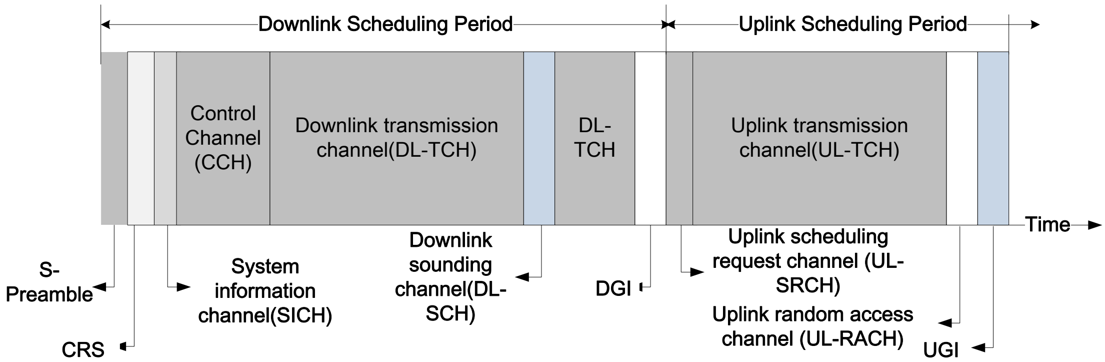
The general physical layer frame structure is shown in Figure 69. The frame structure is self-contained, in which the system information channel (SICH) broadcasts information of the frame structure. The content of SICH and the types of sub-fields can be controlled and distributed to

CAPs by network management entity to coordinate multiple CAPs based on actual service conditions. Resources can be adaptively allocated to uplink and downlink traffic channels and short signalling resources in one frame (see 1.7.5.6). The granularity of resource allocation is one OFDM symbol.

Combined with the adaptation sublayer's multi-connection function, service layer’s service replication and arbitration functions, and carrier aggregation function (see 1.7.11), system-level multi-connection and multichannel processing transmission can be flexibly implemented to further improve service reliability.

FIGURE 69

General Frame Structure of physical layer



See Table 43 for the definition of each sub-field in the frame structure. The generation procedure of each sub-field is described in 1.7.2 and can be classified into three working mode: normal mode, low-error mode and mmWave mode. Both normal mode and low-error mode are used for sub 6 GHz band, in which the low-error mode is used to achieve high reliability. mmWave mode is used in millimeter wave band (above 24GHz, etc.). The mode detection algorithm of the current frame in STA is implementation related. For example, the normal mode and low-error mode can be distinguished by preamble sequence. Moreover, the decoding results of SICH/CCH can also help the mode detection.

The length of UGI can be adjusted in unit of samples to align the frame with timing source (GPS, etc.) and achieve time synchronization between multiple CAPs.

TABLE 43

Sub-Field definition in frame structure

Name of Sub-Field	Function
Short preamble sequence (S-Preamble)	System coarse synchronization
Long preamble sequence (L-Preamble)	System fine synchronization and channel estimation
System information channel (SICH)	Broadcast frame structure configuration
Transmission control channel (CCH)	Uplink traffic channel resource scheduling Downlink traffic channel resource scheduling
Downlink sounding channel (DL-SCH)	Downlink channel measurement

Uplink sounding channel (UL-SCH)	Uplink channel measurement
Uplink scheduling request channel (UL-SRCH)	Uplink scheduling request
Uplink random access channel (UL-RACH)	STA initial access
Downlink traffic channel (DL-TCH)	Downlink data transmission Downlink signaling transmission
Uplink traffic channel (UL-TCH)	Uplink data transmission Uplink feedback transmission
Downlink guard interval (DGI)	Downlink to uplink transceiving guard interval
Uplink guard interval (UGI)	Uplink to downlink transceiving guard interval

1.7.1.2 Basic parameters of orthogonal frequency division multiplexing

In Sub-6GHz band, there are three types of subcarrier spacing parameter, 19.53KHz, 39.0625KHz and 78.125KHz. In mmWave mode, 50MHz, 100MHz, 200 MHz,400MHz and 1GHz bandwidths are supported. When the bandwidth in mmWave mode is less than 1GHz, the sub-carrier spacing is 390.625KHz. The sub-carrier spacing is 976.5625 KHz when the bandwidth in mmWave mode is 1GHz.

With each type of subcarrier spacing parameter, different bandwidths are supported. This clause describes the parameters of OFDM with different subcarrier spacing and bandwidth settings.

The basic parameters of OFDM are shown in Table 44 to Table 51. It should be noted that the N_{FFT} values in those tables are the number of subcarriers which occupy the whole bandwidth. It is implementation related to choose different number of points of FFT operation.

Two cyclic prefix (CP) lengths are supported: normal CP and short CP. The cyclic prefix is generated by copying the last Nfft/4 (normal CP) or Nfft/8 (short CP) sample points from each OFDM symbol after IDFT.

TABLE 44

OFDM parameters with 19.53125 kHz subcarrier spacing

System bandwidth	BW(n) = 5/10/15/20/25/30/40/50 MHz, n=1:8
Subcarrier spacing	19.53125kHz
FFT sample points	N_{FFT}= 256/512/768/1024/1280/1536/2048/2560, n=1:8
CP sample points	N_{FFT}/8 (Short CP), N_{FFT} /4 (Normal CP)
Number of data subcarriers	224/448/672/896/1120/1344/1792/2240
Number of phase tracking pilot subcarriers	6/12/18/24/30/36/48/60 For OFDMA scheme, 16/32/48/64/80/96/128/160
Phase tracking pilot index	For each bandwidth mode index n, the phase tracking pilot set is given below: Define basic phase tracking pilot index set: Pb = [-99, -66, -33, 33, 66, 99] For OFDMA scheme, Pb = [-120, -103, -86, -69, -52, -35, -18, -1, 1, 18, 35, 52, 69, 86, 103, 120] If BW(n)/5 is odd: k = [0, …, (BW(n)/5-1)/2],

	{ Pb-k*256, Pb-(k-1)*256, ..., Pb, ..., Pb+(k-1)*256, Pb+k*256 } if BW(n)/5 is even: k = [0, …, BW(n)/10-1], { Pb-128-k*256, Pb-128-(k-1)*256, ..., Pb-128, Pb+128, ..., Pb+128+(k-1)*256, Pb+128+(k-1)*256 }
Number of virtual subcarriers	26/52/78/104/130/156/208/260 For OFDMA scheme, 16/32/48/64/80/96/128/160
Virtual subcarrier index	For each bandwidth mode index n, the virtual subcarrier set is given below: Define basic virtual sbucarrier index set: Vb = [-128, ..., -116, 0, 116, ... ,127] For OFDMA scheme, Vb = [-128, ..., -121, 0, 121, ..., 127] If BW(n)/5 is odd: k = [0, …, (BW(n)/5-1)/2], { Vb-k*256, Vb-(k-1)*256, ..., Vb, ..., Vb+(k-1)*256, Vb+k*256} If BW(n)/5 is even: k = [0, …, BW(n)/10-1], { Vb-128-k*256, Vb-128-(k-1)*256, ..., Vb-128, Vb+128, ..., Vb+128+(k-1)*256, Vb+128+(k-1)*256 }
FFT time window	51.2 µs
Cyclic Prefix	6.4µs (Short CP) , 12.8µs (Normal CP)
OFDM symbol period	57.6µs (Short CP) , 64µs (Normal CP)

TABLE 45

OFDM parameters with 39.0625 kHz subcarrier spacing

System bandwidth	BW(n) = 5/10/15/20/25/30/40/50/60/80/100 MHz, n=1:11
Subcarrier spacing	39.0625kHz
FFT sample points	N_{FFT} = 128/256/384/512/640/768/1024/1280/1536/2048/2560, n=1:11
CP sample points	N_{FFT}/8 (Short CP), N_{FFT}/4 (Normal CP)
Number of data subcarriers	112/224/336/448/560/672/896/1120/1344/1792/2240
Number of phase tracking pilot subcarriers	4/6/12/12/20/18/24/30/36/48/60 For OFDMA scheme, 8/16/24/32/40/48/64/80/96/128/160

Phase tracking pilot index	For each bandwidth mode index n, the phase tracking pilot index set is given below:
	1) n=1,3,5: Pb = [-44, -22, 22, 44] ; for OFDMA scheme, Pb = [-60, -43, -26, -9, 9, 26, 43, 60]
	n=1, { Pb }
	n=3, { Pb-128, Pb, Pb+128 }
	n=5, { Pb-256, Pb-128, Pb, Pb+128, Pb+256 }
	
	2) n=2,4,6,7,8,9,10,11: Pb = [-99, -66, -33, 33, 66, 99] ; for OFDMA scheme, Pb = [-120, -103, -86, -69, -52, -35, -18, -1, 1, 18, 35, 52, 69, 86, 103, 120]
	if BW(n)/10 is odd: k = [0, …, (BW(n)/10-1)/2]:
	{ Pb-k*256, Pb-(k-1)*256, ..., Pb, ..., Pb+(k-1)*256, Pb+k*256 }
	if BW(n)/10 is even: k = [0, …, BW(n)/20-1]:
	{ Pb-128-k*256, Pb-128-(k-1)*256, ..., Pb-128, Pb+128, ..., Pb+128+(k-1)*256, Pb+128+(k-1)*256 }

Virtual subcarrier index	For each bandwidth mode index n, the virtual subcarrier index set set is given below:
	1) n=1,3,5: Vb = [-64, …, -59, 0, 59, …, 63] ; for OFDMA scheme, Vb = [-64, ..., -61, 0, 61, 63]
	n=1, { Vb }
	n=3, { Vb-128, Vb, Vb+128 }
	n=5, { Vb-256, Vb-128, Vb, Vb+128, Vb+256 }
	
	2) n=2,4,6,7,8,9,10,11: Vb = [-128, …, -116, 0, 116, …, 127]; for OFDMA scheme, Vb = [-128, …, -121, 0, 121, …, 127]
	if BW(n)/10 is odd: k = [0, …, (BW(n)/10-1)/2]:
	{ Vb-k*256, Vb-(k-1)*256, ..., Vb, ..., Vb+(k-1)*256, Vb+k*256 }
	if BW(n)/10 is even: k = [0, …, BW(n)/20-1]:
	{ Vb-128-k*256, Vb-128-(k-1)*256, ..., Vb-128, Vb+128, ..., Vb+128+(k-1)*256, Vb+128+(k-1)*256 }

FFT time window	25.6 μs
Cyclic Prefix	3.2μs (Short CP), 6.4μs (Normal CP)
OFDM symbol period	28.8μs (Short CP), 32μs (Normal CP)

TABLE 46

OFDM parameters with 78.125 kHz subcarrier spacing

System bandwidth	BW(n) = 5/10/15/20/25/30/40/50/60/80/100 MHz, n=1:11
Subcarrier spacing	78.125 kHz
FFT sample points	N_{FFT}= 64/128/196/256/320/384/512/640/768/1024/1280, n=1:11
CP sample points	N_{FFT}/8(Short CP), N_{FFT}/4 (Normal CP)
Number of data subcarriers	56/112/168/224/280/336/448/560/672/896/1120 For OFDMA scheme, 48/112/144/224/240/336/448/560/672/896/1120
Number of phase tracking pilot subcarriers	2/4/6/6/10/12/12/20/18/24/30 For OFDMA scheme, 4/8/12/16/20/24/32/40/48/64/80
Phase tracking pilot index	For each bandwidth mode index n, the different phase tracking pilot set is given below: n=1,3,5: Pb = [-22, 22] ; for OFDMA scheme, Pb = [-26, -9, 9, 26] n=1, { Pb } n=3, { Pb-64, Pb, Pb+64} n=5, { Pb-128, Pb-64, Pb, Pb+64, Pb+128} n=2,6,8: Pb = [-44, -22, 22, 44] ; for OFDMA scheme, Pb = [-60, -43, -26, -9, 9, 26, 43, 60] n=2, { Pb } n=6, { Pb-128, Pb, Pb+128 } n=8, { Pb-256, Pb-128, Pb, Pb+128, Pb+256 } n=4,7,9,10,11: Pb = [-99, -66, -33, 33, 66, 99] ; for OFDMA scheme, Pb = [-120, -103, -86, -69, -52, -35, -18, -1, 1, 18, 35, 52, 69, 86, 103, 120] if BW(n)/20 is odd: k = [0, …, (BW(n)/20-1)/2]:

	{ Pb-k*256, Pb-(k-1)*256, ..., Pb, ..., Pb+(k-1)*256, Pb+k*256 } if BW(n)/20 is even: k = [0, …, BW(n)/40-1]: { Pb-128-k*256, Pb-128-(k-1)*256, ..., Pb-128, Pb+128, ..., Pb+128+(k-1)*256, Pb+128+(k-1)*256 }

Virtual subcarrier index	For each bandwidth mode index n, the virtual subcarrier set is given below:
	n=1,3,5: Vb = [-32, -31, -30, 0, 30, 31] ; for OFDMA scheme, Vb = [-32, ..., -27, 0, 27, ..., 31]
	n=1, { Vb }
	n=3, { Vb-64, Vb, Vb+64}
	n=5, { Vb-128, Vb-64, Vb, Vb+64, Vb+128}
	
	n=2,6,8: Vb = [-64, …, -59, 0, 59, …, 63] ; for OFDMA scheme, Vb = [-64, ..., -61, 0, 61, 63]
	n=2, { Vb }
	n=6, { Vb-128, Vb, Vb+128 }
	n=8, { Vb-256, Vb-128, Vb, Vb+128, Vb+256 }
	
	n=4,7,9,10,11: Vb = [-128, …, -116, 0, 116, …, 127]; for OFDMA scheme, Vb = [-128, …, -121, 0, 121, …, 127]
	if BW(n)/20 is odd: k = [0, …, (BW(n)/20-1)/2]:
	{ Vb-k*256, Vb-(k-1)*256, ..., Vb, ..., Vb+(k-1)*256, Vb+k*256 }
	if BW(n)/20 is even: k = [0, …, BW(n)/40-1]:
	{ Vb-128-k*256, Vb-128-(k-1)*256, ..., Vb-128, Vb+128, ..., Vb+128+(k-1)*256, Vb+128+(k-1)*256 }

FFT time window	12.8 μs
Cyclic Prefix	1.6μs (Short CP), 3.2μs (Normal CP)
OFDM symbol period	14.4μs (Short CP), 16μs (Normal CP)

TABLE 47

OFDM basic parameters with 50 MHz Bandwidth in mmWave mode

System bandwidth	50 MHz
Subcarrier spacing in frequency domain	390.625 kHz
FFT sample points	128
CP sample points	16(Short CP)/32(Normal CP)
Number of data subcarriers	112
Data subcarrier index	[-58 ...-50][-48...-33][-31...-1] [+58 ...+50][+48...+33][+31...+1]
Number of phase tracking pilot subcarriers	4
Phase tracking pilot index	[-49 -32 32 49]
Number of virtual subcarriers	12
FFT time window	2.56μs
Cyclic Prefix	0.32us(Short CP)/0.64us(Normal CP)
OFDM symbol period	2.88us(Short CP)/3.20us(Normal CP)

TABLE 48

OFDM basic parameters with 100 MHz Bandwidth in mmWave mode

System bandwidth	100 MHz
Subcarrier spacing in frequency domain	390.625 kHz
FFT sample points	256
CP sample points	32(Short CP)/64(Normal CP)
Number of data subcarriers	224
Data subcarrier index	[-115…-100][-98…-67][-65…-34][-32…-1] [+115…+ 100][+98…+ 67][+ 65…+ 34][+ 32…+1]
Number of phase tracking pilot subcarriers	6
Phase tracking pilot index	[-99 -66 -33 +33 +66 +99]
Number of virtual subcarriers	26
FFT time window	2.56μs
Cyclic Prefix	0.32us(Short CP)/0.64us(Normal CP)
OFDM symbol period	2.88us(Short CP)/3.20us(Normal CP)

TABLE 49

OFDM basic parameters with 200 MHz Bandwidth in mmWave mode

System bandwidth	200 MHz
Subcarrier spacing in frequency domain	390.625 kHz
FFT sample points	512
CP sample points	64(Short CP)/128(Normal CP)
Number of data subcarriers	448
Data subcarrier index	[-243…-228][-226…-195][-193…-162][-160…-129] [-127...-96][-94...-63][-61...-30][-28...-13] [+243…+228][+226…+195][+ 193…+162][+160…+129] [+127...+96][+94...+63][+61...+30][+28...+13]
Number of phase tracking pilot subcarriers	12
Phase tracking pilot index	[-227 -194 -161 -95 -62 -29 29 62 95 161 194 227]
Number of virtual subcarriers	52
FFT time window	2.56μs
Cyclic Prefix	0.32us(Short CP)/0.64us(Normal CP)
OFDM symbol period	2.88us(Short CP)/3.20us(Normal CP)

TABLE 50

OFDM basic parameters with 400 MHz Bandwidth in mmWave mode

System bandwidth	400 MHz
Subcarrier spacing in frequency domain	390.625 kHz
Baseband sampling clock	400MHz
FFT sample points	1024
CP sample points	128(Short CP)/256(Normal CP)
Number of data subcarriers	896
Data subcarrier index	[-499...-484][-482...-451][-449...-418][-416...-385] [-383...-352][-350...-319][-317...-286][-284...-269] [-243…-228][-226…-195][-193…-162][-160…-129] [-127...-96][-94...-63][-61...-30][-28...-13] [+499...+484][+482...+451][+449...+418][+416...+385] [+383...+352][+350...+319][+317...+286][+284...+269] [+243…+228][+226…+195][+193…+162][+160…+129] [+127...+96][+94...+63][+61...+30][+28...+13]
Number of phase tracking pilot subcarriers	24
Phase tracking pilot index	[-483 -450 -417 -351 -318 -285 -227 -194 -161 -95 -62 -29 29 62 95 161 194 227 285 318 351 417 450 483]
Number of virtual subcarriers	104
FFT time window	2.56μs
Cyclic Prefix	0.32us(Short CP)/0.64us(Normal CP)
OFDM symbol period	2.88us(Short CP)/3.20us(Normal CP)

TABLE 51

Table42 OFDM basic parameters with 1 GHz Bandwidth in mmWave mode

System bandwidth	1GHz
Subcarrier spacing in frequency domain	976.5625kHz
Baseband sampling clock	1GHz
FFT sample points	1024
CP sample points	128(Short CP)/256(Normal CP)
Number of data subcarriers	896
Data subcarrier index	[-499...-484][-482...-451][-449...-418][-416...-385] [-383...-352][-350...-319][-317...-286][-284...-269] [-243…-228][-226…-195][-193…-162][-160…-129] [-127...-96][-94...-63][-61...-30][-28...-13] [+499...+484][+482...+451][+449...+418][+416...+385] [+383...+352][+350...+319][+317...+286][+284...+269]

	[+243…+228][+226…+195][+193…+162][+160…+129] [+127...+96][+94...+63][+61...+30][+28...+13]
Number of phase tracking pilot subcarriers	24
Phase tracking pilot index	[-483 -450 -417 -351 -318 -285 -227 -194 -161 -95 -62 -29 29 62 95 161 194 227 285 318 351 417 450 483]
Number of virtual subcarriers	104
FFT time window	1.024μs
Cyclic Prefix	0.128us(Short CP)/0.256us(Normal CP)
OFDM symbol period	1.152us(Short CP)/1.28us(Normal CP)

The EUHT-5G system uses working bandwidth sets to facilitate implementation. Please refer to section 1.5.3.4.4, 1.5.3.4.5 and 1.7.4.1 for the working bandwidth sets details.

1.7.1.3 Physical layer symbol

The definition of the Physical layer symbols associated with this specification is shown in Table 52.

TABLE 52

Physical layer symbol definition

Symbol	Definition
N_{ID}^{CAP}	CAP MAC: the lowest 7 bits of the address
N_{ID}^{STA}	STA MAC: the lowest 12 bits of the address
N_{Frame}	Frame Number
N_{FFT}	Number of FFT sample points
N_{cp}	Number of CP sample points
N_{sr}	The highest useful subcarrier index
N_{su}	Number of useful subcarriers
N_{sd}	Number of data subcarriers
$\triangle_f$	Subcarrier spacing
N_{sympss}	Number of OFDM symbols per spatial stream
N_{scpsym}	Number of data subcarriers per OFDM symbol
N_{cbpsym}	Number of encoded bits carried per OFDM symbol
N_{cbpsc}	Number of encoded bits carried per subcarrier
N_{ss}	Number of paralleled spatial streams
N_{sts}	Number of paralleled spatial time streams
N_{Tx}	Number of transmitting antennas

DPI_F	Demodulation reference signal frequency domain internal (subcarrier spacing)
DPI_T	Demodulation reference signal time domain internal (OFDM symbol interval)
DPI_{num}	Number of OFDM symbols occupied by demodulation reference signal
SPI_F	Sounding pilot frequency domain internal (subcarrier spacing)
SPI_{num}	Number of OFDM symbols occupied by the sounding pilot
SC_{dp}^{sti}	The stith space-time stream demodulation reference signal subcarrier set index
SC_{sp}^{ti}	The Ith transmit antenna detection pilot subcarrier aggregation index
si	Spatial stream index
sti	Space time stream index
ti	Transmitting antenna index

In OFDMA scheme, N_{scpsym} and N_{cbpsym} of a STA is number of subcarriers and coded bits of the total resource units allocated to the STA in one OFDM symbol.

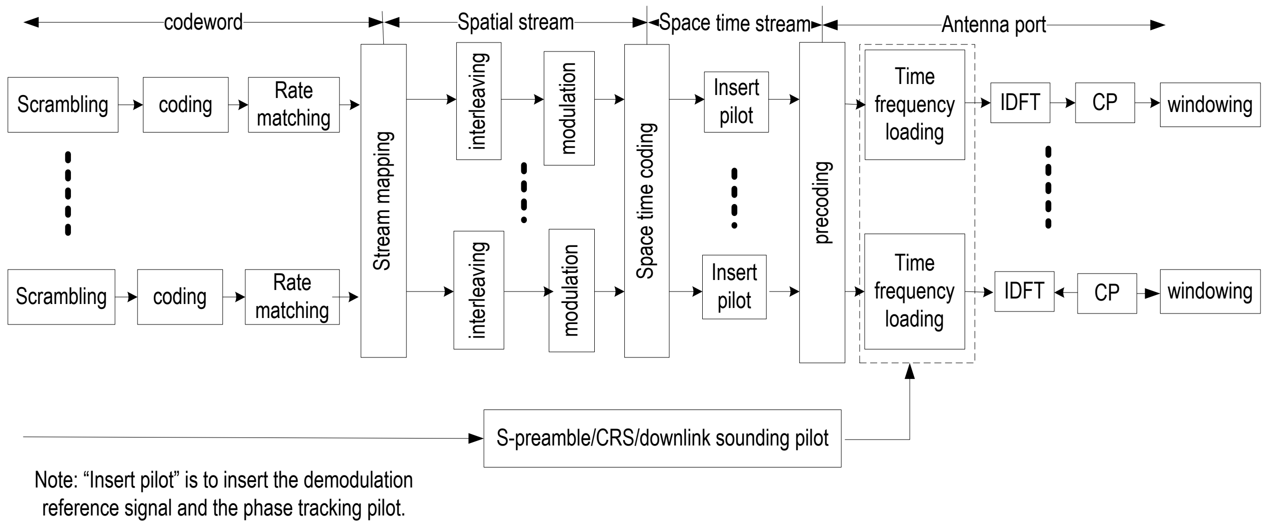
1.7.2 Transmitter block diagram and signal processing flow

1.7.2.1 Transmitter block diagram

The transmitter block diagram at the CAP side is shown in Figure 70.

FIGURE 70

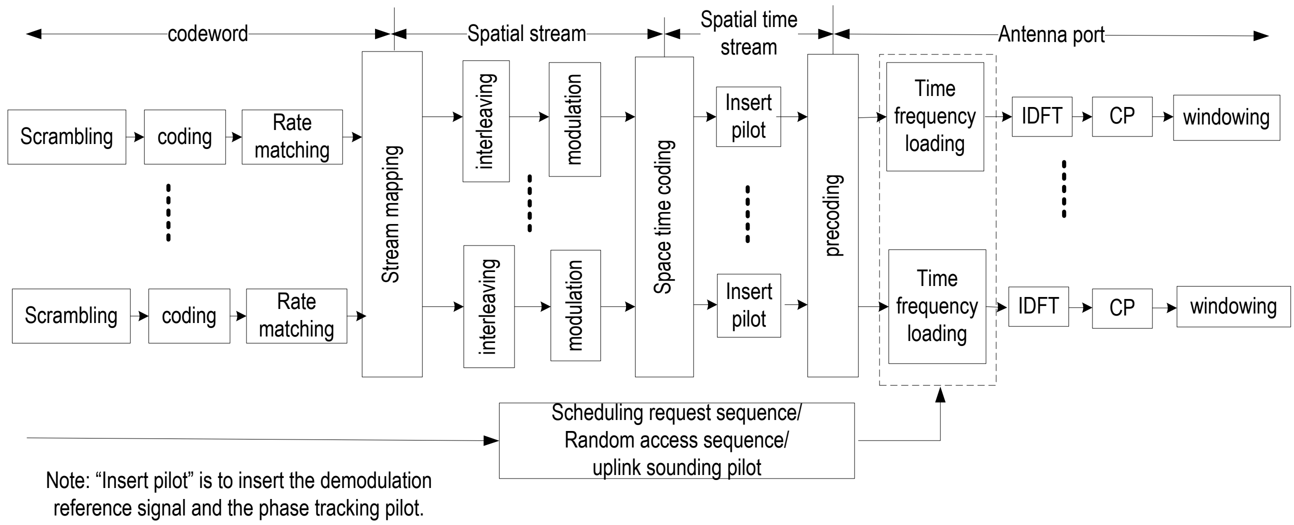
Transmitter block diagram at CAP side



The transmitter block diagram at the STA side is shown in Figure 71.

FIGURE 71

transmitter block diagram at STA



One codeword supports up to 4 streams. Up to two codewords is supported. The detailed signal generation for physical frame can be found in 1.7.5.4.

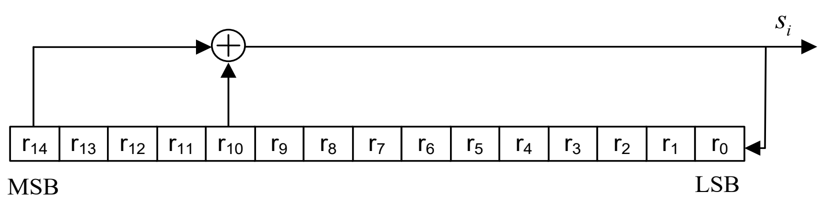
The cyclic shift diversity (CSD) can be added for each transmit chain and space-time stream, which can be implemented in time-domain or frequency-domain. The values of cyclic shift are implementation related.

1.7.2.2 Scrambling

The output binary sequence [$s_0 s_1 \cdots s_{\text{len-bit-1}}$] of the maximum-length linear feedback shift register with a polynomial of $1+X^{11}+X^{15}$ is generated as the scrambling code sequence to scramble the data bit sequence [$b_0 b_1 \cdots b_{\text{len-bit-1}}$]. Each code block in the system is scrambled and reset once. The block diagram of the generation of scrambling code sequence is shown in Figure 72.

FIGURE 72

Block diagram of the generation of scrambling code sequence



For the system information channel, and control channel in low error mode, the initial value of the register$r_{init} = [101010001110110]_b$, MSB on the left, and LSB on the right; for other uplink and downlink control channels and traffic channels, the initial value of the register $r_{init} =$ $[0\ 0\ 1\ 0\ 1\ 0\ 1\ 1\ N_{ID}^{CAP}]$, where N_{ID}^{CAP} are the lowest 7 bits of the CAP MAC address, and indicated in the system information channel.

The data bit sequence and the scrambling code sequence are XORed bit by bit according to Equation 4, and the bit sequence $[\tilde{b}_0\tilde{b}_1 \cdots \tilde{b}_{Len_bit-1}]$of the scrambled output can be obtained

$$\tilde{b}_i = (b_i + s_i)\, mod\, 2\, , i = 0,1, \ldots Len\_bit - 1$$

Equation 4

1.7.2.3 Channel coding

1.7.2.3.1 General

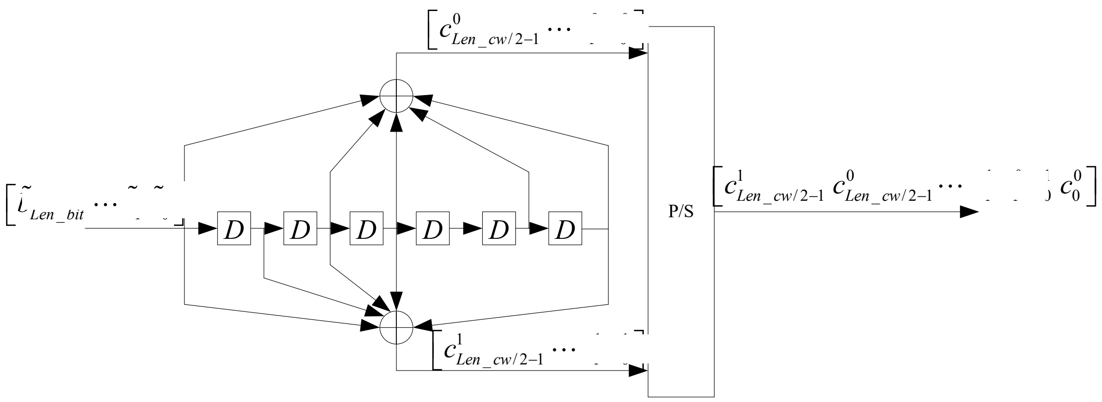
The channel coding module performs FEC protection on the data bit sequence $[\tilde{b}_0\ \tilde{b}_1\ \cdots\ \tilde{b}_{Len_bit-1}]$of the scrambled output. This specification supports two forward error correction codes, i.e. convolutional code and LDPC code.

1.7.2.3.2 Convolutional coding

The convolutional code structure in this specification is [133 171], see Figure 73. The convolutional code output is $[c_0c_1 \cdots c_{len\_cw-1}]$.

FIGURE 73

Convolutional encoder structure



In the figure, $C_{2l} = C_l^0, C_{2l+1} = C_l^1, l = 0,1, \ldots Len\_cw / 2 - 1$.

Zero tailed convolutional code and tail-biting convolutional code (TBCC) are used in this specification.

When a zero tailed convolutional code is used, the initial state of the six registers of the encoder is all zeros, and six zero bits need to be padded after the bit sequence$[\tilde{b}_0\ \tilde{b}_1\ \cdots\ \tilde{b}_{Len_bit-1}]$. The encoded bit length is:

$$Len\_cw = 2 \times (Len\_bit + 6)$$

Equation 5

When a tail-biting convolutional code (TBCC) is used, the initial state of the six registers of the encoder is the last 6 bits of the data bit sequence, that is $[\tilde{b}_{Len\_bit-1}\ \tilde{b}_{Len\_bit-2}\ \tilde{b}_{Len\_bit-3}\ \tilde{b}_{Len\_bit-4}\ \tilde{b}_{Len\_bit-5}\ \tilde{b}_{Len\_bit-6}]$, and zero bits are not required to be padded after the data bit sequence. The encoded bit length is:

$$Len\_cw = 2 \times Len\_bit$$

Equation 6

1.7.2.3.3 Low density parity check coding

1.7.2.3.3.1 Low-density parity check matrix and generator matrix

The check matrix H of LDPC can be expressed as follows, see Equation 7:

$$\boldsymbol{H} = \begin{bmatrix} \boldsymbol{A}_{0,0} & \boldsymbol{A}_{0,1} & \cdots & \boldsymbol{A}_{0,c-1} \\ \boldsymbol{A}_{1,0} & \boldsymbol{A}_{1,1} & \cdots & \boldsymbol{A}_{1,c-1} \\ \vdots & \vdots & \ddots & \vdots \\ \boldsymbol{A}_{\rho-1,0} & \boldsymbol{A}_{\rho-1,1} & \cdots & \boldsymbol{A}_{\rho-1,c-1} \end{bmatrix}$$

Equation 7

Where, $A_{i,j}$ is a t×t cyclic matrix with a row weight of 0 or 1. Each row of the matrix is rotated one bit to the right by one line, where the first row is the right shift of the last row. The codeword represented by the matrix H is called (N, K) LDPC code, where N is the code length, K represents the length of the information bits, and its code rate is R=K/N. The first line of $A_i=[A_{i,0}, A_{i,1} \cdots, A_{i,c-1}]$, i = 0, 1, ..., ρ-1 is called the $(i + 1)^{th}$ row generator of H , then H has a total of ρ row generators.

The check matrix H can be converted into the form of the system check matrix H_{sys} by row-based modulo 2 operation and permutation operation. H_{sys} can be expressed as:

$$\mathbf{Hsys} = \left[\mathbf{P}^T \mid \mathbf{I}_{N-K} \right]$$

Equation 8

Where I_{N-K} is the identity matrix of (N-K) x (N-K) and $\mathbf{P}^T$ is the matrix of (N-K) x K.

The generator matrix G corresponding to the system check matrix H_{sys} can be expressed as:

$$\boldsymbol{G} = [\boldsymbol{I}_K | \boldsymbol{P}]$$

Equation 9

Where I_K is the unit matrix of K x K, P is the transposed matrix of P^T, and P can be expressed as:

$$\boldsymbol{P} = \begin{bmatrix} \boldsymbol{P}_{0,0} & \boldsymbol{P}_{0,1} & \cdots & \boldsymbol{P}_{0,\rho-1} \\ \boldsymbol{P}_{1,0} & \boldsymbol{P}_{1,1} & \cdots & \boldsymbol{P}_{1,\rho-1} \\ \vdots & \vdots & \ddots & \vdots \\ \boldsymbol{P}_{c-\rho-1,0} & \boldsymbol{P}_{c-\rho-1,1} & \cdots & \boldsymbol{P}_{c-\rho-1,\rho-1} \end{bmatrix}$$

Equation 10

Where $P_{i,j}$ is a t×t cyclic matrix, and each column of the matrix is obtained by shifting one column of the previous column downwards, wherein the first column is the cyclic shift of the last column. The first column of $Pj=[P_{0,,j},P_{1,,j},\cdots P_{c-\rho-1,j}]^T$, j=0,1,⋯ρ-1 is call the $(j+1)^{th}$ column generator of the matrix G, then G has a total of ρ column generators.

1.7.2.3.3.2 Low density parity encoding

The information bit length K is obtained based on the selected LDPC code length and code rate. The data bit sequence $[\tilde{b}_0 \ \tilde{b}_1 \ \cdots \ \tilde{b}_{Len\_bit-1}]$ is sequentially divided into N_{SB} sub-block. The first R_{SB} sub-blocks, each sub-block carries $\lfloor Len\_bit/N_{SB} \rfloor + 1$ data bits; the following $N_{SB} - R_{SB}$ sub-blocks, each sub-block carries $\lfloor Len\_bit/N_{SB} \rfloor$ data bits. Among them:

$$N_{SB} = \lceil \text{Len\_bit} / K \rceil$$

Equation 11

$$R_{SB} = mod(Len\_bit, N_{SB})$$

Equation 12

When the number of bits carried by the sub-block is less than *K*, the data bit sequence in the sub-block is used for cyclic padding to ensure that the number of bits of the sub-block after padding is equal to *K*.

The LDPC code encoding process of each sub-block can be expressed as Equation 13:

$$x = u \cdot G$$

Equation 13

Where $u = (u_0, u_1, ..., u_{K-1})$ indicates K coded information bits, $x = (u_0, u_1, \cdots u_{k-1}, v_0, v_1, \cdots v_{N-K-1})$ stands for the codeword with a length of N, $v=(v_0, . . . , v_{N-K-1})$ is $N - K$ check bits, and the coded code words satisfy the check equation $H \cdot x^T = 0$.

The LDPC code length, code rate, information bit length, and size of the cyclic submatrix are as shown in Table 53. See Attachment 3 for the LDPC check matrix.

TABLE 53

LDPC coding parameters

N	K	R	t
448	96	3/14	16
448	224	1/2	28
448	256	4/7	32
1344	672	1/2	56
1344	840	5/8	56
1344	1008	3/4	56
1344	1176	7/8	42
2688	1344	1/2	112
2688	1680	5/8	112
2688	2016	3/4	112
2688	2240	5/6	112
5376	2688	1/2	112
5376	3360	5/8	112
5376	4032	3/4	112
5376	4704	7/8	112

After the LDPC encoding, the N_{SB} LDPC codewords are generated, and the bits of these LDPC codewords are sequentially combined into a bit sequence $[c_0 c_1 c_2 ... c_{Len\_cw-1}]$, where $Len\_cw = N_{SB} \times N$.

It should be noted that (448,96) LDPC code is generated from (480,96) LDPC by puncture.

After (480,96) LDPC encoding, puncture the first 32 bits of the check bits output by (480,96) encoding output to obtain (448, 96) LDPC code.

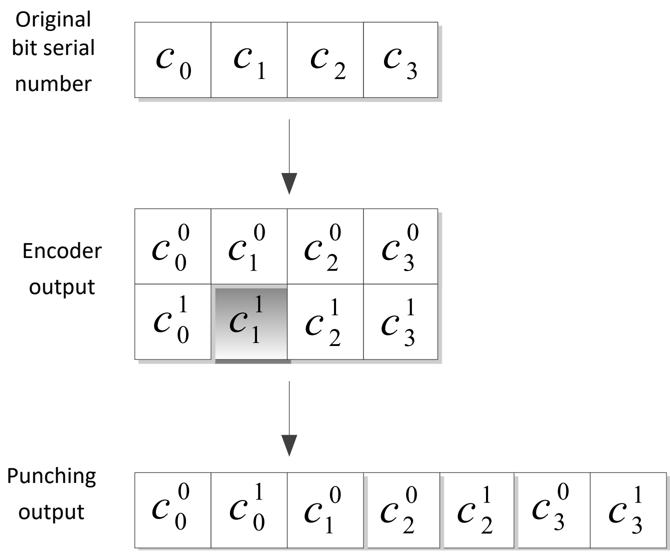
1.7.2.4 Rate matching

If the channel is coded in the manner of convolutional code, the encoder output code rate is 1/2. Other code rates (4/7, 5/8, 2/3, 3/4, 5/6 and 7/8) are obtained by puncture. The puncture pattern is shown in Figure 74 to Figure 79.

a) 4/7 code rate

FIGURE 74

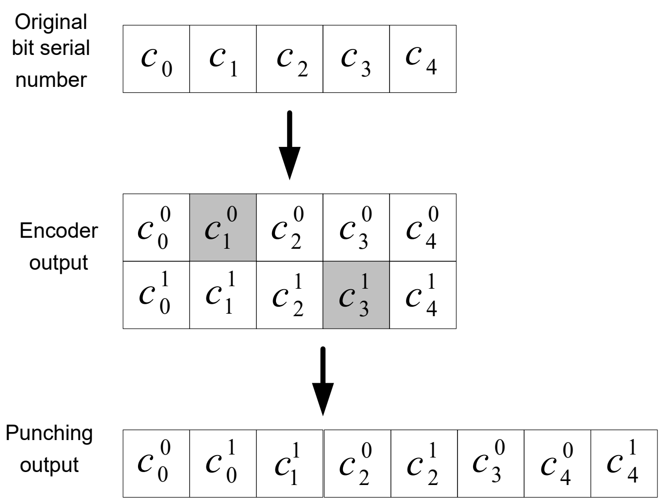
4/7 Puncture Pattern



b) 5/8 code rate

FIGURE 75

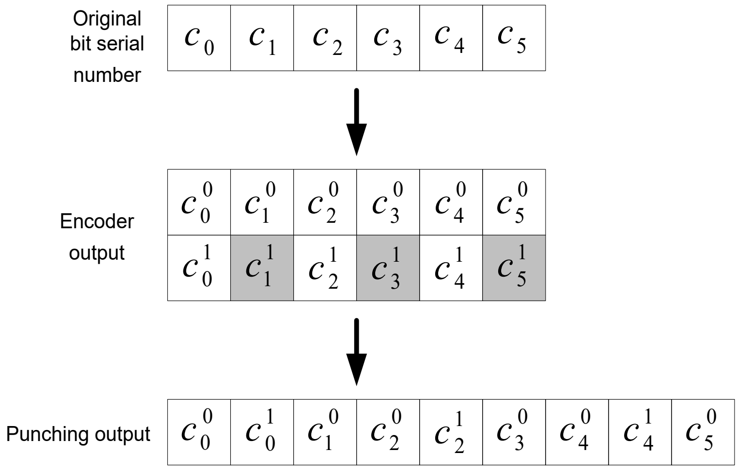
5/8 Puncture Pattern



c) 2/3 code rate

FIGURE 76

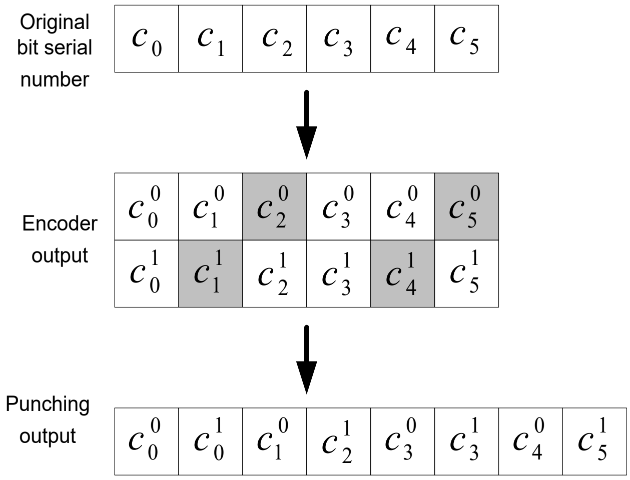
2/3 Puncture Pattern



d) 3/4 code rate

FIGURE 77

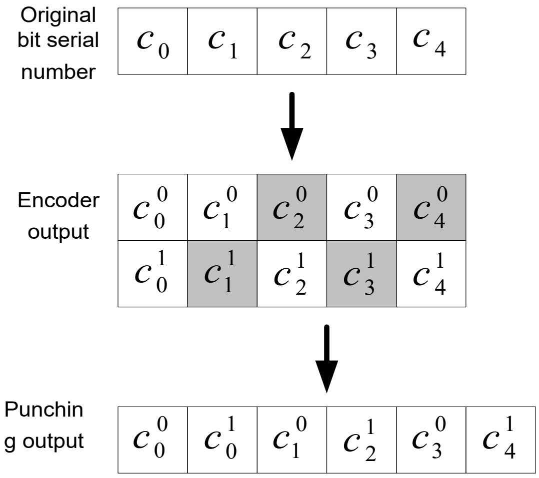
3/4 Puncture Pattern



e) 5/6 code rate

FIGURE 78

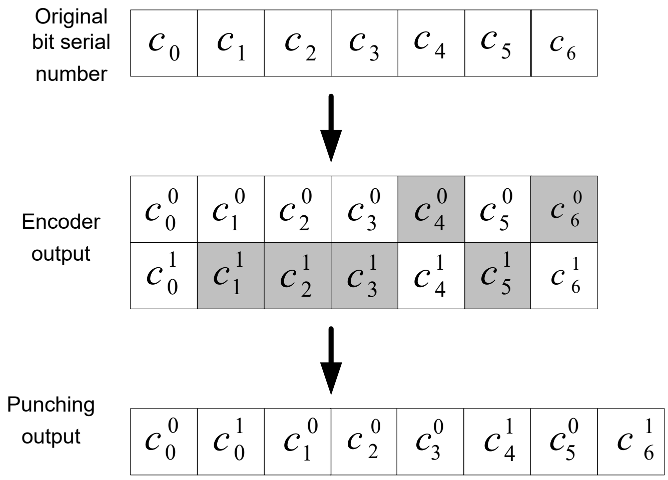
5/6 Puncture Pattern



f) 7/8 code rate

FIGURE 79

7/8 Puncture Pattern



The puncture output bits are $\left[\tilde{c}_0 \ \tilde{c}_1 \ \cdots \ \tilde{c}_{Len\_punc\_ini-1}\right]$.

If the channel is coded in the manner of LDPC, the above puncturing process is not required, $\tilde{c}_i = c_i, (i = 0,1\ldots Len_{cw})$, where $Len_{cw} = Len\_punc\_ini$.

After convolutional coding or LDPC coding, padding bits will be added to make sure there are integer number of OFDM symbols. In normal mode, padding bits will be used to fill up all the OFDM symbols left. In low-error mode, padding bits will be used to fill up the valid data OFDM symbols after frequency repetition, and other OFDM symbols left will be filled up by CRS in normal mode.

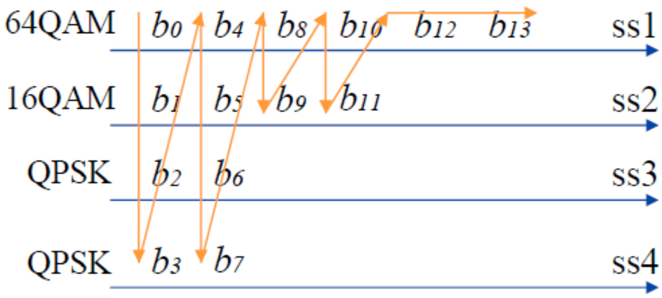
1.7.2.5 Stream mapping

The coded bits are mapped to multiple streams as follows.

The coded bits are split into groups. The number of bits in each group (N_{cbpsc_total}) is the total number of bits in one subcarrier summing over all spatial streams. Coded bits in a group are round-robin mapped to spatial streams. If sith spatial stream is already allocated with $N_{cbpsc}(si)$ bits, sith spatial stream will be skipped, as illustrated in Figure 80. The mapping operation above is repeated group by group until all the coded bits are mapped.

FIGURE 80

Example of stream mapping



When the spatial streams are transmitted in parallel, it is indicated in the control channel how each codeword is mapped to the spatial stream (see Section 1.7.4.2).

Code bits q_l^{si} mapped to each spatial stream perform the following cyclic shift within each OFDM symbol, see Equation 14,

$$r = \left[l + si \cdot N_{cbpsc}(si) \cdot 37\right] mod\left[N_{scpsym} \cdot N_{cbpsc}(si)\right]$$
$$l = 0,1,2,\cdots,N_{scpsym} \cdot N_{cbpsc}(si) - 1$$

Equation 14

After the cyclic shift, each spatial stream outputs a bit sequence $q_{r(l)}^{si} \quad l = 0,1,\cdots,N_{scpsym} \cdot N_{cbpsc}(si) - 1$ to the bit interleaver.

1.7.2.6 Bit interleaving

If the channel is coded in the manner of LDPC, bit interleaving processing is optional; if in the manner of convolutional code, the following bit interleaving process is employed. The interleaving depth of each spatial stream is shown in Equation 15:

$$N_{cbpsym}(si) = N_{cbpsc}(si) \cdot N_{scpsym}$$

Equation 15

The following two permutation processes were employed.

For the first permutation, see Equation 16:

$$i = \left(N_{cbpsym}(si)/16\right) \cdot mod(k,16) + \lfloor k/16 \rfloor \qquad i,k = 0,1,\cdots N_{cbpsym} - 1$$

Equation 16

For the second permutation, see Equation 17:

$$j = \tilde{Q}(si) \times \lfloor i/\tilde{Q}(si) \rfloor + mod\{[i + N_{cbpsym}(si) - \lfloor 16 \times i/N_{cbpsym}(si) \rfloor], \tilde{Q}(si)\}$$

Equation 17

In which,

$$\tilde{Q}(si) = max\left(\frac{N_{cbpsc}(si)}{2},\ 1\right)$$

After the above interleaving process, each stream outputs a bit sequence as $[\tilde{q}_0^{si}\ \tilde{q}_1^{si}\ \cdots\ \tilde{q}_{Len\_cw(si)-1}^{si}]$.

The deinterleaving process is as follows. For the first permutation, see Equation 18:

$$i = \tilde{Q}(si) \times \lfloor j/\tilde{Q}(si) \rfloor + mod\{[j + \lfloor 16 \times j/N_{cbpsym}(si) \rfloor], \tilde{Q}(si)\}$$

Equation 18

where $j = 0,1, \cdots N_{cbpsym} - 1$

For the second permutation, see Equation 19:

$$k = 16 \cdot i - (N_{cbpsym}(si) - 1) \times \lfloor 16 \times i/N_{cbpsym}(si) \rfloor$$

Equation 19

1.7.2.7 Constellation mapping

Each subcarrier can support BPSK, QPSK, 16-QAM, 64-QAM, 256-QAM and 1024-QAM modulation. Each subcarrier modulation outputs symbol as shown in Equation 20.

$$d = (I + jQ) \times K_{MOD}$$

Equation 20

K_{MOD} is the normalized parameter for different modulation modes. See Table 54.

TABLE 54

Normalized parameters of different modulation modes

Modulation	K_{MOD}
BPSK	1
QPSK	$1/\sqrt{2}$
16-QAM	$1/\sqrt{10}$
64-QAM	$1/\sqrt{42}$
256-QAM	$1/\sqrt{170}$
1024-QAM	$1/\sqrt{682}$

The bit mapping relationship of different modulation modes is shown in the following tables.

TABLE 55

BPSK constellation mapping

Input bit (b_0)	**Output of channel *I***	**Output of channel *Q***
0	-1	0
1	1	0

TABLE 56

QPSK constellation mapping

Input bit (b_0)	**Output of channel *I***	**Input bit (b_1)**	**Output of channel *Q***
0	-1	0	-1
1	1	1	1

TABLE 57

16 - QAM constellation mapping

Input bit (b_0b_1)	**Output of channel *I***	**Input bit (b_2b_3)**	**Output of channel *Q***
00	-3	00	-3
01	-1	01	-1
11	1	11	1
10	3	10	3

TABLE 58

64 - QAM constellation mapping

Input bit ($b_0b_1b_2$)	**Output of channel *I***	**Input bit (b_3 b_4b_5)**	**Output of channel *Q***
000	-7	000	-7
001	-5	001	-5
011	-3	011	-3
010	-1	010	-1
110	1	110	1
111	3	111	3
101	5	101	5
100	7	100	7

TABLE 59

256 - QAM constellation mapping

Input bit ($b_0b_1b_2b_3$)	**Output of channel *I***	**Input bit ($b_4b_5b_6b_7$)**	**Output of channel *Q***
0000	-15	0000	-15
0001	-13	0001	-13
0011	-11	0011	-11
0010	-9	0010	-9
0110	-7	0110	-7
0111	-5	0111	-5
0101	-3	0101	-3
0100	-1	0100	-1
1100	1	1100	1
1101	3	1101	3
1111	5	1111	5
1110	7	1110	7
1010	9	1010	9
1011	11	1011	11
1001	13	1001	13
1000	15	1000	15

TABLE 60

1024 - QAM constellation mapping

Input bit ($b_0b_1b_2b_3b_4$)	**Output of channel *I***	**Input bit ($b_5b_6b_7b_8b_9$)**	**Output of channel Q**
00000	-31	00000	-31
00001	-29	00001	-29
00011	-27	00011	-27
00010	-25	00010	-25
00110	-23	00110	-23
00111	-21	00111	-21
00101	-19	00101	-19
00100	-17	00100	-17
01100	-15	01100	-15
01101	-13	01101	-13
01111	-11	01111	-11
01110	-9	01110	-9
01010	-7	01010	-7
01011	-5	01011	-5
01001	-3	01001	-3
01000	-1	01000	-1
11000	1	11000	1
11001	3	11001	3
11011	5	11011	5
11010	7	11010	7
11110	9	11110	9
11111	11	11111	11
11101	13	11101	13
11100	15	11100	15
10100	17	10100	17
10101	19	10101	19
10111	21	10111	21
10110	23	10110	23
10010	25	10010	25
10011	27	10011	27

10001	29	10001	29
10000	31	10000	31

After the above modulation mapping, each spatial stream outputs a modulation symbol stream as $\left[d_0^{si}\ d_1^{si}\ \cdots\ d_{Len\_mod(si)-1}^{si}\right]$, see Equation 21.

$$Len\_mod(si) = N_{sympss} \cdot N_{scpsym}$$

Equation 21

1.7.2.8 Space time coding

The system defined in this specification supports the space-time coding for one, two, three and four parallel modulation symbol streams, expanding the spatial streams to two, four, six, eight, sixteen space time streams, so that the system obtains the transmit diversity gain. If the space-time coding is used in the transmission, b_{55} in Table 67

is set to 1, otherwise it is set to 0.

Modulation output symbol is $d_{k,i,n}; k = 0 \ldots N_{scpsym} - 1; i = 0 \ldots N_{ss} - 1; n = 0 \ldots N_{sympss} - 1$, after encoded by STBC, outputs as $\tilde{d}_{k,i,n}; k = 0 \ldots N_{scpsym} - 1; i = 0 \ldots N_{sts} - 1; n = 0 \ldots N_{sympss} - 1$. The mapping relationship between STBC output symbols and input symbols is shown in Table 61.

TABLE 61

Space time coding

N_{sts}	N_{ss}	i_{STS}	$\tilde{d}_{k,i,2m}$	$\tilde{d}_{k,i,2m+1}$
2	1	1	$d_{k,1,2m}$	$d_{k,1,2m+1}$
		2	$-d_{k,1,2m+1}^{*}$	$d_{k,1,2m}^{*}$
4	2	1	$d_{k,1,2m}$	$d_{k,1,2m+1}$
		2	$-d_{k,1,2m+1}^{*}$	$d_{k,1,2m}^{*}$
		3	$d_{k,2,2m}$	$d_{k,2,2m+1}$
		4	$-d_{k,2,2m+1}^{*}$	$d_{k,2,2m}^{*}$
6	3	1	$d_{k,1,2m}$	$d_{k,1,2m+1}$
		2	$-d_{k,1,2m+1}^{*}$	$d_{k,1,2m}^{*}$
		3	$d_{k,2,2m}$	$d_{k,2,2m+1}$
		4	$-d_{k,2,2m+1}^{*}$	$d_{k,2,2m}^{*}$
		5	$d_{k,3,2m}$	$d_{k,3,2m+1}$
		6	$-d_{k,3,2m+1}^{*}$	$d_{k,3,2m}^{*}$
8	4	1	$d_{k,1,2m}$	$d_{k,1,2m+1}$

N_{sts}	N_{ss}	i_{STS}	$\tilde{d}_{k,i,2m}$	$\tilde{d}_{k,i,2m+1}$
		2	$-d^*_{k,1,2m+1}$	$d^*_{k,1,2m}$
		3	$d_{k,2,2m}$	$d_{k,2,2m+1}$
		4	$-d^*_{k,2,2m+1}$	$d^*_{k,2,2m}$
		5	$d_{k,3,2m}$	$d_{k,3,2m+1}$
		6	$-d^*_{k,3,2m+1}$	$d^*_{k,3,2m}$
		7	$d_{k,4,2m}$	$d_{k,4,2m+1}$
		8	$-d^*_{k,4,2m+1}$	$d^*_{k,4,2m}$
16	8	1	$d_{k,1,2m}$	$d_{k,1,2m+1}$
		2	$-d^*_{k,1,2m+1}$	$d^*_{k,1,2m}$
		3	$d_{k,2,2m}$	$d_{k,2,2m+1}$
		4	$-d^*_{k,2,2m+1}$	$d^*_{k,2,2m}$
		5	$d_{k,3,2m}$	$d_{k,3,2m+1}$
		6	$-d^*_{k,3,2m+1}$	$d^*_{k,3,2m}$
		7	$d_{k,4,2m}$	$d_{k,4,2m+1}$
		8	$-d^*_{k,4,2m+1}$	$d^*_{k,4,2m}$
		9	$d_{k,5,2m}$	$d_{k,5,2m+1}$
		10	$-d^*_{k,5,2m+1}$	$d^*_{k,5,2m}$
		11	$d_{k,6,2m}$	$d_{k,6,2m+1}$
		12	$-d^*_{k,6,2m+1}$	$d^*_{k,6,2m}$
		13	$d_{k,7,2m}$	$d_{k,7,2m+1}$
		14	$-d^*_{k,7,2m+1}$	$d^*_{k,7,2m}$
		15	$d_{k,8,2m}$	$d_{k,8,2m+1}$
		16	$-d^*_{k,8,2m+1}$	$d^*_{k,8,2m}$

1.7.2.9 Insert pilot

The transmission symbols of the phase tracking pilots are repeated sequence of [1 0] with the sequence length equals to the number of phase tracking pilots. Then the repeated sequence are loaded into the phase tracking pilot subcarrier after BPSK modulation. Please refer to section 1.7.1.2 for detailed information about the number and subcarrier index of phase tracking pilot.

The demodulation reference signal (DRS) are inserted before precoding. The generation and pattern of DRS is described in section 1.7.5.3.

1.7.2.10 Precoding

The optional precoding can be performed before time-frequency loading as descried in section 1.7.5.4.

1.7.2.11 Time-frequency loading

For the tith antenna port, the transmitted symbol stream is $\left[\tilde{x}_0^{ti}\ \tilde{x}_1^{ti}\ \cdots\ \tilde{x}_{Len\_precode-1}^{ti}\right]$, see Equation 22:

$$Len\_precode = N_{sympss} + Len\_dp$$

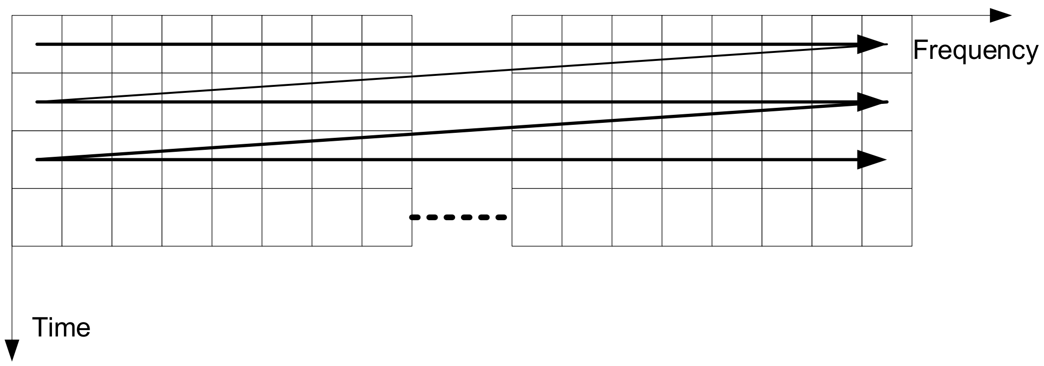
Equation 22

Where: *Len-dp* is the number of the demodulation reference signal symbols. According to the demodulation reference signal pattern indicated by the scheduling signaling (see 1.7.5.3), the number of OFDM symbols occupied by the demodulation reference signal can be calculated.

The time-frequency loading sequence is shown in Figure 81. The frequency domain is loaded first and then the time domain.

FIGURE 81

Time-frequency loading sequence for precoding output symbols stream



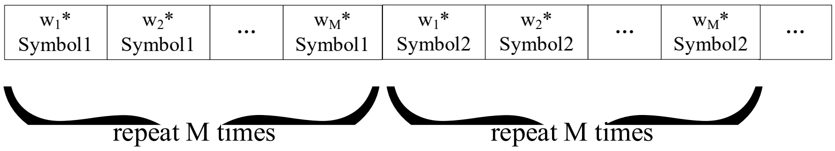
The repetition in frequency domain and time domain can be used. Assume the number of total allocated data sub-carriers is K. The input modulation symbols is $S_0S_1\ldots S_{K/N}$ which will be repeated N times to become $[S_0S_1\ldots S_{K/N}, S_0S_1\ldots S_{K/N}, \ldots, S_0S_1\ldots S_{K/N}]$. The total number of modulation symbols after repetition is K. The K modulation symbols after repetition will be mapped onto allocated data subcarriers, from lower frequency to higher frequency.

The repetition in time domain repeats baseband OFDM symbols (including CP) M times. Please refer to section 1.7.4 for the indication of repetition number N and M for SICH, CCH and TCH. The repetition number M for TCH is indicated by MCS in normal mode.

The OFDM symbol repetition pattern in time-domain is shown in Figure 82:

FIGURE 82

The OFDM symbol repetition pattern in time-domain



The weighted vector **w** = [w_1 w_2 … w_M] is selected from row vectors in matrix $\mathbf{W_M}$ with dimension of M*M .

$\mathbf{W_1}$ = {1}

$\mathbf{W_2}$ = {1 1; 1 -1}

$\mathbf{W_3}$ = {1 -1 1; 1 0.5+0.866i -0.5+0.866i; 1 0.5-0.866i -0.5-0.866i}

$\mathbf{W_4}$ = {1 -1 1 1;1 1 -1 1;1 1 1 -1; -1 1 1 1}

$\mathbf{W_6}$ = {1 -1 1 1 1 -1; 1 -0.5+0.866i -0.5-0.866i -1 -0.5+0.866i -0.5-0.866i; 1 0.5+0.866i -0.5+0.866i 1 -0.5-0.866i 0.5-0.866i; 1 1 1 -1 1 1; 1 0.5-0.866i -0.5-0.866i 1 -0.5+0.866i 0.5+0.866i; 1 -0.5-0.866i -0.5+0.866i -1 -0.5-0.866i -0.5+0.866i}.

In normal mode and mmWave mode, the row index (starting from 0) selected to generate weighted vector **w** is determined by S-Preamble ID as indicated in section 1.7.3. More specifically, the row index is the remainder after S-Preamble ID is divided by M (mod(S-Preamble ID, M)).

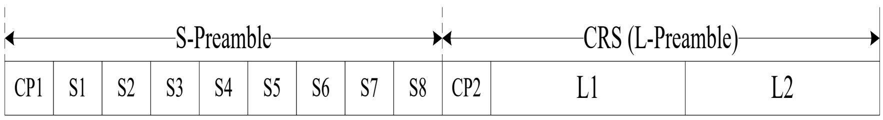
In low error mode, the row index (starting from 0) selected to generate weighted vector **w** is determined by PN_ID as indicated in section 1.7.3. More specifically, the row index is the remainder after PN_ID is divided by M (mod(PN_ID, M)).

1.7.3 Preamble sequence

In normal mode, the Physical layer preamble sequence consists of short preamble sequence and long preamble sequence (also known as common reference signal, CRS) as shown in Figure 83.

FIGURE 83

Physical layer preamble sequence with Type-I long preamble



There are three different basic types for both short preamble and long preambles: P1, P2 and P3, which correspond to different number of subcarriers (224/112/56) respectively. The bandwidth which one basic preamble occupies is the basic bandwidth. If the bandwidth of the component carrier is larger than basic bandwidth, the basic preambles can be duplicated in the component carrier. The duplication is in frequency domain in unit of basic bandwidth with rotation factors as shown in Table 62.

The preamble, system information channel and control channel use the same subcarrier spacing. System information channel is also duplicated in the component carrier in the same way as preamble. The same rotation factors are applied to system information channel and control channel. Traffic channel can use different subcarrier spacing.

TABLE 62

Preamble duplication in different Subcarrier spacing and **bandwidth modes**

Subcarrier spacing (kHz)	**5 MHz**	**10 MHz**	**15 MHz**	**20 MHz**	**25 MHz**	**30 MHz**	**40 MHz**	**50 MHz**	**60 MHz**	**80 MHz**	**100 MHz**
	Nsd	**Nsd**	**Nsd**	**Nsd**	**Nsd**	**Nsd**	**Nsd**	**Nsd**	**Nsd**	**Nsd**	**Nsd**
19.53125	224	448	672	896	1120	1344	1792	2240	N/A	N/A	N/A
Duplication number (Basic Preamble type)	1 (P1)	2 (P1)	3 (P1)	4 (P1)	5 (P1)	6 (P1)	8 (P1)	10 (P1)	N/A	N/A	N/A
39.0625	112	224	336	448	560	672	896	1120	1344	1792	2240
N (Basic Preamble Mode)	1 (P2)	1 (P1)	3 (P2)	2 (P1)	5 (P2)	3 (P1)	4 (P1)	5 (P1)	6 (P1)	8 (P1)	10 (P1)
78.125	56	112	168	224	280	336	448	560	672	896	1120
N (Basic Preamble Mode)	1 (P3)	1 (P2)	3 (P3)	1 (P1)	5 (P3)	3 (P2)	2 (P1)	5 (P2)	3 (P1)	4 (P1)	5 (P1)

The generation procedure of basic preamble is given below.

The basic short preamble sequence is generated by modulating elements of a Length-N of Zadoff-Chu sequence.

The ZC sequences are generated according to the Equation 22:

$$Z(n) = e^{j\pi\frac{\mathrm{rn}^2}{N}},\ \ n = 0,1,\ldots N-1;$$

Equation 23

Three different Zadoff-Chu sequences with different sequence root index values can be used for different short preamble ID shown in Table 63.

TABLE 63

Parameters of Different Short Preamble Types

Parameters	**Short Preamble type P1**	**Short Preamble type P2**	**Short Preamble type P3**
Sequence length: N	28	14	6
ZC Root index r for different S-Preamble ID {1,2,3,4}	{27, 1, 26, 2}	{13, 1, 12, 10}	{5, 1, 4, 6}
N_e	-112	-56	-24

The short preamble sequence is mapped to N frequency domain subcarriers by the following method.

The set of subcarriers to be filled is: $\{k_n | k_n = Ne + 8 \cdot m,\ m = 0,1,2 \cdots N,\ \ k_n \neq 0\ \}$

Short CP is applied to short preamble to generate CP1.

The CRS sequence(L-Preamble) occupies N subcarriers in the frequency domain. A pseudo-random sequence $\{C_n, \cdot n = 0, 1, ..., N\text{-}1\}$ with a length of N is BPSK-modulated and then according to the configuration of the current cell. The different value of N for 3 long preamble types is shown in Table 64.

TABLE 64

Parameters of Different Long Preamble Types

Parameters	Long Preamble type P1	Long Preamble type P2	Long Preamble type P3
Sequence length: N	114	58	28
N_e	-114	-58	-28

The BPSK-modulated sequence is mapped onto subcarriers by one of the following methods.

The set of subcarriers to be filled is: $\{\mathrm{Kn}\ |\mathrm{kn} = \mathrm{Ne} + 2 \bullet \mathrm{m}, \mathrm{m} = 0,1,2 \ldots\ \mathrm{N}, \mathrm{Kn} \neq 0\ \}$ or $\{\mathrm{Kn}\ |\mathrm{kn} = \mathrm{Ne} + 2 \bullet \mathrm{m} + 1, \mathrm{m} = 0,1,2 \ldots\ \mathrm{N} - 1, \mathrm{Kn} \neq 0\ \}$

. For the long preamble type P1, the BPSK-modulated sequence (LP) is {-1,-1,1,1,1,-1,1,1,-1,-1,1,-1,1,1,-1,-1,-1,1,1,-1,1,-1,-1,-1,-1,-1,1,-1,1,-1,1,-1,1,-1,1,1,-1,-1,-1,1,-1,1,1,1,-1,1,1,-1,1,1,1,1,-1,-1,1,-1,1,1,-1,1,1,1,-1,-1,-1,1,-1,-1,1,-1,1,1,-1,1,-1,-1,-1,1,-1,-1,1,-1,1,1,1,1,1,-1,1,1,-1,-1,1,1,-1,1,1,-1,1,-1,1,1,-1,-1,-1,-1,1,1,1,-1,-1,-1,1,-1,1,-1}

For the long preamble type P2, the BPSK-modulated sequence (LP) is {-1,-1,1,1,1,-1,1,1,-1,-1,1,-1,1,1,-1,-1,-1,1,1,-1,1,-1,-1,-1,-1,-1,1,-1,1,-1,1,-1,1,-1,1,1,-1,-1,-1,1,-1,1,1,1,-1,1,1,-1,1,1,1,1,-1,-1,1,-1,1,1,1,-1}

For the long preamble type P3, the BPSK-modulated sequence (LP) is {-1,-1,1,1,1,-1,1,1,-1,-1,1,-1,1,1,-1,-1,-1,1,1,-1,1,-1,-1,-1,-1,-1,1,-1}.

The P1/P2/P3 long preamble sequence should be multiplied by mask sequence. There are two types of mask sequence. If the S-Preamble ID is 1 or 2, the pattern of the mask sequence is [1 1 1 1 …1 1]. If the S-Preamble ID is 3 or 4, the pattern of the mask sequence is [1 -1 1 -1 …1 -1].

The long preamble transmitted from different CAP should be added phase shift $\varphi_{i,k}$ after mapping to subcarriers, according to Equation 24:

$$\varphi_{i,k} = e^{-j\frac{2\pi k \delta^i}{N_{FFT}}}$$

Equation 24

in which i is the phase shift index for different CAP, $\delta^i = \{0,\ \frac{N_{FFT}}{8},\ \frac{N_{FFT}}{4},\ N_{FFT} \times \frac{3}{8},\ \frac{N_{FFT}}{2},\ N_{FFT} \times \frac{5}{8},\ N_{FFT} \times \frac{3}{4},\ N_{FFT} \times \frac{7}{8}\}$. After transformed into time domain, normal CP (CP2) is applied to generate Type-I long preamble. The Type-II long preamble is the two times repetition of Type-I long preamble in time domain as [w_1* Long preamble, w_2* Long preamble]. If the S-Preamble ID is 1 or 3, the [w_1 w_2] is [1 1]. If the S-Preamble ID is 2 or 4, the [w_1 w_2] is [1 -1].

In Low-error mode, short preamble(S-Preamble) is 5 identical PN sequences and each PN sequence has 255 points. The 255-point PN sequence is:

S255={ 1,1,1,1,1,1,1,-1,1,-1,-1,1,1,1,-1,-1,-1,-1,1,-1,1,1,1,1,-1,-1,-1,-1,-1,-1,-1,1,1,-1,1,1,1,1,-
1,1,-1,1,1,-1,-1,-1,-1,-1,1,-1,1,-1,1,-1,1,-1,-1,-1,1,1,1,1,1,-1,-1,1,1,1,-1,1,-1,1,-1,-1,1,1,-1,-1,1,1,-
1,1,-1,-1,-1,-1,-1,-1,1,-1,-1,-1,-1,1,1,-1,-1,1,-1,-1,-1,1,-1,-1,-1,1,1,-1,1,-1,1,-1,1,1,-1,1,-1,1,1,1,-
1,1,1,-1,1,-1,-1,1,-1,1,1,1,-1,-1,1,1,-1,-1,-1,1,1,-1,-1,-1,-1,1,1,1,-1,-1,1,-1,-1,1,1,1,1,-1,1,1,1,-1,1,-1,-
1,-1,1,-1,1,-1,-1,-1,-1,1,-1,-1,1,-1,-1,-1,-1,-1,1,1,1,1,-1,-1,1,-1,1,1,-1,-1,1,-1,1,-1,-1,1,-1,-1,1,-1,1,-
1,1,1,1,1,1,-1,1,1,-1,-1,-1,1,-1,-1,1,1,-1,1,1,-1,1,1,-1,-1,1,1,1,1,1,1,-1-1,-1,1,-1,1,1,-1,1,1,1,-1,-1,-
1,1,1,1,-1};

Based on the above PN sequences, different CAP adopt PN sequences with different PN_ID (starting from 0). The PN_ID is the index of the set PN_SET = {0, 32, 64, 96, 128, 160, 192, 224}, which can determine the value of Ki = PN_SET{ PN_ID}. The generation method is as follows：

SP255(k) = S255(Ki+k), k=0,   1,   ...,254-Ki

SP255(k) = S255(k-255+Ki), k=255-Ki, 255-Ki+1, ..., 254

In low-error mode, long preamble consists of 511-point PN sequence, and two 64 PN sequences as CP before (PN64_CP1) and after it (PN64_CP2), which is showed in Figure 84.

FIGURE 84

Long preamble of low-error mode

PN64_CP1	511 PN sequence	PN64_CP2

The 511-point PN sequence is:

S511={1,1,1,1,1,1,1,1,-1,1,1,1,-1,1,1,1,-1,-1,1,1,-1,1,1,1,-1,-1,-1,1,-1,1,-1,1,-1,-1,1,-1,-1,1,1,1,-1,-
1,-1,1,1,1,-1,1,1,-1,1,-1,1,-1,1,1,1,-1,-1,1,-1,-1,1,1,-1,-1,-1,-1,-1,1,1,-1,-1,-1,-1,1,1,1,-1,1,-1,-1,1,-1,-
1,-1,1,1,-1,1,-1,1,1,-1,1,1,1,1,1,-1,1,1,-1,-1,1,1,-1,-1,-1,1,-1,1,1,1,-1,-1,-1,-1,-1,1,-1,-1,-1,-
1,1,1,1,1,1,-1,-1,-1,-1,-1,-1,-1,-1,-1,1,1,1,1,-1,-1,-1,-1,1,-1,-1,-1,1,1,1,1,-1,1,-1,-1,1,1,-1,-1,1,-1,-
1,1,-1,-1,-1,-1,1,-1,1,1,1,1,-1,-1,-1,1,1,-1,-1,1,1,1,1,-1,1,1,-1,1,1,1,-1,1,-1,1,-1,-1,-1,1,-1,1,-1,-1,-1,-
1,1,1,-1,1,1,-1,1,-1,-1,-1,1,1,-1,-1,-1,1,1,1,1,1,1,-1,-1,-1,1,-1,-1,-1,1,-1,1,1,-1,-1,-1,-1,1,-1,1,-1,1,1,-
1,1,-1,1,1,1,1,1,1,-1,1,-1,1,-1,1,-1,1,-1,-1,-1,-1,-1,1,-1,1,-1,-1,1,-1,1,1,1,1,1,-1,-1,1,-1,-1,-1,1,-1,-
1,1,-1,-1,1,-1,1,-1,-1,1,1,1,1,1,-1,1,-1,-1,-1,1,-1,-1,-1,-1,-1,1,1,1,-1,-1,-1,-1,1,1,-1,-1,1,-1,1,1,-1,-
1,1,-1,1,-1,-1,-1,1,1,1,-1,-1,1,-1,1,1,1,-1,1,-1,-1,-1,-1,-1,-1,-1,1,-1,1,1,-1,1,-1,-1,1,1,1,-1,1,-1,1,1,-1,-
1,1,1,1,-1,-1,1,1,1,1,1,1,1,-1,-1,1,1,-1,-1,1,1,-1,1,-1,1,-1,-1,1,1,-1,1,1,-1,-1,-1,-1,-1,1,-1,-1,1,-
1,1,1,-1,1,1,-1,1,1,-1,-1,1,-1,-1,-1,-1,-1,1,1,-1,1,-1,-1,1,-1,1,-1,1,1,1,1,-1,1,-1,1,1,1,-1,1,1,-1,-1,-
1,1,-1,-1,1,1,-1,1,-1,-1,-1,-1,1,-1,-1,1,1,1,1,-1,-1,1,-1,1,-1,1,-1,1,1,-1,-1,-1,1,1,-1,1,1,1,1,-1,-1,1,1,1,-
1,1,1,1,1,-1}

Based on the above PN sequences, different CAP can adopt PN sequences with different L_PN_ID (starting from 0). The value of L_PN_ID for long preamble is same as PN_ID for short preamble. The set L_PN_SET = {0, 64, 128, 192, 256, 320, 384, 448}, which can determine the value of Ki = L_PN_SET{ L_PN_ID}. The generation method is as follows：

LP511(k) = S511(K_i+k), k=0,   1,   ..., 510-K_i

LP511(k) = S511(k-511+K_i), k=511-K_i, 511-K_i+1, ..., 510

PN64_CP1(k) = LP511(447+k), k=0, 1, ... 63

PN64_CP2(k) = LP511(k), k=0, 1, ... 63

In Low-error mode, the short preamble and long preamble should be filtered to meet the requirements of spectrum mask.

In mmWave mode, the Physical layer preamble sequence consists of short preamble sequence and long preamble (CRS sequence) and occupies two OFDM symbols. Same as the normal mode, the long preamble should be added phase shift $\varphi_{i,k}$ after mapping to subcarriers, according to Equation 24.

For 50MHz bandwidth, the preamble generation procedure is same as the procedure in normal mode based on basic preamble type P2.

For 100MHz bandwidth, the preamble generation procedure is same as the procedure in normal mode based on basic preamble type P1.

For 200MHz/400MHz bandwidth, the short preamble and CRS shall be duplicated with rotation factors in frequency domain in the unit of 100 MHz. For 1GHz bandwidth, the preambles generation procedure follows the same method in 400MHz bandwidth.

In normal mode and mmWave mode, the preamble, system information channel and control channel use the same subcarrier spacing. System information channel is also duplicated inside one component carrier in the same way as preamble. The SICH, CCH and TCH of each component carrier are independent with that of other component carriers. The same rotation factors are applied to system information channel and control channel.

1.7.4 System information channel and control channel

1.7.4.1 System information channel field definition

There are two types of SICH: Type-I SICH and Type II SICH. Type-I and Type-II SICH can be used in normal mode while Type-I SICH can be used in mmWave mode.

Type-I SICH uses MCS0 with normal CP. Convolutional coding is applied. Type-I SICH shall be repeated 4 times in frequency domain and 2 times in time domain in mmWave mode as specified in section 1.7.2.11. There is no repetition for Type-I SICH in normal mode. The system information field in Type-I SICH is defined in Table 65.

TABLE 65

System Information field definition in Type-I SICH

Bit	Definition	Notes
$b_7b_6\ldots b_0$	The lowest 8 bits of this CAP MAC address	CAP identifier and scrambling code seed
$b_{10}b_9b_8$	CAP Working bandwidth set	For sub-6GHz band: 000: 5/10/20MHz working bandwidth mode 001: 10/20/40MHz working bandwidth mode 010: 15/30/60MHz working bandwidth mode 011: 20/40/80MHz working bandwidth mode 100: 25/50/100MHz working bandwidth mode For mmWave mode, 000: 50MHz working bandwidth mode

		001: 100MHz working bandwidth mode 010: 200MHz working bandwidth mode 011: 400MHz working bandwidth mode 100: 1GHz working bandwidth mode Others: reserved
$b_{12}b_{11}$	Subcarrier spacing indication for TCH	For sub-6GHz band: 00: 19.53125KHz 01: 39.0625KHz 10: 78.125KHz 11: reserved For mmWave mode, 00: 390.625KHz 01: 976.5625KHz 10: reserved 11: reserved
$b_{19}\ldots b_{13}$	Reserved	Reserved
b_{20}	Cyclic Prefix Type for CCH and TCH	0: Normal CP; 1: Short CP
$b_{23}b_{22}\ldots b_{21}$	CAP antenna configuration	0:1 antenna; 1:2 antennas; 2:4 antennas; 3:6 antennas; 4:8 antennas; 5:16 antennas; 6~7: reserved
$b_{29}b_{28}\ldots b_{24}$	Control channel length indication	Control channel length, ≤63 OFDM symbols.
b_{30}	DRS Mode in MU-MIMO	0: DRS for different STAs are allocated to different OFDM symbols 1: DRS for different STAs are allocated to the same OFDM symbols
b_{31}	Interleaving with LDPC	0: No bit interleaving if LDPC is used 1: Bit interleaving if LDPC is used
$b_{42}b_{39}\ldots b_{32}$	Downlink traffic channel length indication	Number of OFDM symbols in downlink traffic channel For normal mode, $b_{40}b_{39}\ldots b_{32}$ is used, $b_{42}b_{41}$ is reserved. For mmWave mode, $b_{42}b_{41}\ldots b_{32}$ is used.
$b_{45}b_{44}b_{43}$	Reserved	Reserved
$b_{56}b_{55}\ldots b_{46}$	Uplink traffic channel length indication	Number of OFDM symbols in uplink traffic channel For normal mode, $b_{54}b_{53}\ldots b_{46}$ is used, $b_{56}b_{55}$ is reserved. For mmWave mode, $b_{56}b_{55}\ldots b_{46}$ is used.
$b_{63}b_{62}\ldots b_{57}$	Indication of DGI and UGI configuration in long distance ranging	b_{63}=1, ranging mode b_{63}=0, non-ranging mode

		$b_{62}\ldots b_{57}$: OFDM symbol number of UGI in ranging mode(b63=1), and DGI in both ranging mode and non-ranging mode.
b_{64}	Downlink sounding channel configuration	0: No downlink sounding channel
		1: With downlink sounding channel.
b_{65}	The subcarrier offset indication of DRS/ Sounding Pilot	Indicates the subcarrier offset of DRS/Sounding Pilot. DRS and Sounding Pilot use the same setting. 0: without subcarrier offset 1: with subcarrier offset
b_{66}	Reserved	Reserved
b_{67}	Uplink sounding channel configuration	0: No uplink sounding channel; 1: With uplink sounding channel.
b_{68}	indication of Full-bandwidth or OFDMA scheme	0: Full-bandwidth 1: OFDMA
$b_{70}b_{69}$	Uplink scheduling request channel	00: No scheduling request channel
		01: Scheduling request channel is configured with 1 OFDM symbol;
		10: Scheduling request channel is configured with 2 OFDM symbols;
		11: Scheduling request channel is configured with 4 OFDM symbols;
b_{71}	Uplink random access channel configuration	0: No uplink random access channel;
		1: With uplink random access channel
b_{72}	Indication of RACH and ranging	b_{72}=0, RACH b_{72}=1, ranging
$b_{75}b_{74}b_{73}$	Reserved	Reserved
$b_{87}b_{86}\ldots b_{76}$	Frame number	0~4095, frame number counter
$b_{103}b_{102}\ldots b_{88}$	16-bit CRC	CRC protection
$b_{111}b_{110}\ldots b_{104}$	Convolutional encoder zero bit	Return the end state of the convolutional code to zero
Note: The system information channel adopts the 16-bit CRC, and the CRC generator polynomial is $g(D)=D^{16}+D^{12}+D^{5}+1$. The initial state of the register is 0xFF, and the register state is inverted as the CRC sequence output after the end of the operation. The high-order register output corresponds to the high bit (b_{103}) and the low-order register output corresponds to the low bit (b_{88}).		

Type-II SICH uses QPSK with LDPC 3/14 coding rate. Bit interleaving is applied for type-II SICH. Only normal CP is supported for Type-II SICH. The system information field in Type-II SICH is defined in Table 66. Type-II SICH shall be repeated 2 times in time domain as indicated in section 1.7.2.11.

TABLE 66

System Information field definition in Type-II SICH

Bit	Definition	Notes
$b_7b_6 \ldots b_0$	The lowest 8 bits of this CAP MAC address	CAP identifier and scrambling code seed
$b_{10}b_9b_8$	CAP Working bandwidth set	For sub-6GHz band: 000: 5/10/20M working bandwidth mode 001: 10/20/40M working bandwidth mode 010: 15/30/60M working bandwidth mode 011: 20/40/80M working bandwidth mode 100: 25/50/100M working bandwidth mode Others: reserved
$b_{12}b_{11}$	Subcarrier spacing indication for TCH in normal mode	00: 19.53125KHz 01: 39.0625KHz 10: 78.125KHz 11: reserved
b_{13}	Cyclic Prefix Type for CCH and TCH	0: Normal CP; 1: Short CP
$b_{19}b_{18} \ldots b_{14}$	Control channel length indication	Control channel length, ≤63 OFDM symbols.
b_{20}	DRS Mode in MU-MIMO	0: DRS for different STAs are allocated to different OFDM symbols 1: DRS for different STAs are allocated to the same OFDM symbols
b_{21}	Interleaving with LDPC	0: No bit interleaving if LDPC is used 1: Bit interleaving if LDPC is used
$b_{30} \ldots b_{22}$	Downlink traffic channel length indication	Number of OFDM symbols in downlink traffic channel
$b_{39} \ldots b_{31}$	Uplink traffic channel length indication	Number of OFDM symbols in uplink traffic channel
$b_{46}b_{45} \ldots b_{40}$	Indication of DGI and UGI configuration in long distance ranging	b_{46}=1, ranging mode b_{46}=0, non-ranging mode $b_{45} \ldots b_{40}$: OFDM symbol number of UGI in ranging mode(b_{46}=1), and DGI in both ranging mode and non-ranging mode.
b_{47}	Downlink sounding channel configuration	0: No downlink sounding channel 1: With downlink sounding channel
b_{48}	The subcarrier offset indication of DRS/ Sounding Pilot	Indicates the subcarrier offset of DRS/Sounding Pilot. DRS and Sounding Pilot use the same setting. 0: without subcarrier offset 1: with subcarrier offset
b_{49}	Uplink sounding channel configuration	0: No uplink sounding channel; 1: With uplink sounding channel

b_{50}	indication of Full-bandwidth or OFDMA scheme	0: Full-bandwidth 1: OFDMA
$b_{52}b_{51}$	Uplink scheduling request channel	00: No scheduling request channel
		01: Scheduling request channel is configured with 1 OFDM symbol;
		10: Scheduling request channel is configured with 2 OFDM symbols;
		11: Scheduling request channel is configured with 4 OFDM symbols;
b_{53}	Uplink random access channel configuration	0: No uplink random access channel;
		1: With uplink random access channel
b_{54}	Indication of RACH and ranging	b_{72}=0, RACH b_{72}=1, ranging
$b_{66}b_{65}\ldots b_{55}$	Frame number	0~4095, frame number counter
$b_{72}\ldots b_{67}$	Index of starting OFDM symbol for Type-II CCH	0~62: Index of starting OFDM symbol for Type-II CCH. 63: No Type-II CCH in CCH sub-field Note: The index of the first OFDM symbol in CCH is 0.
$b_{78}b_{77}\ldots b_{73}$	Index of starting OFDM symbol for Type-III CCH	0~62: Index of starting OFDM symbol for Type-III CCH. 63: No Type-III CCH in CCH sub-field Note: The index of the first OFDM symbol in CCH is 0.
b_{79}	Reserved	Reserved
$b_{95}b_{94}\ldots b_{80}$	16-bit CRC	CRC protection
Note: The system information channel adopts the 16-bit CRC, and the CRC generator polynomial is $g(D)=D^{16}+D^{12}+D^{5}+1$. The initial state of the register is 0xFF, and the register state is inverted as the CRC sequence output after the end of the operation. The high-order register output corresponds to the high bit (b_{103}) and the low-order register output corresponds to the low bit (b_{88}).		

In low-error mode, the system information channel and control channel are integrated to reduce the overhead.

1.7.4.2 Control channel field

The control channel consists of multiple unicast and broadcast scheduling signaling. There are three types of CCH in normal mode: Type-I CCH, Type-II CCH and Type-III CCH. CAP can decide which types of CCH are used. If there are different types of CCH in the CCH sub-field, the OFDM symbols which contain the same type of CCHs should be put together. The order in time domain should be [Type-I CCH (if exists), Type-II CCH (if exists), Type III CCH (if exists)]. The index of starting OFDM symbol of Type-II CCH and Type-III CCH is indicated in SICH.

Type-I CCH uses MCS101with LDPC coding. The uplink and downlink TCH scheduling signaling field in Type-I CCH is shown in Table 67.

TABLE 67

Definition of control channel field in Type-I CCH

Bit	**Definition**	
	DL	**UL**
b_0	b_0=1, downlink scheduling; b_0=0, uplink scheduling	
b_1	b_1=0, SU-MIMO transmission; b_1=1, MU-MIMO transmission or uplink sounding signal configuration	
b_5 b_4... b_2	[$b_5b_4...b_2$], Bit Map indicates the effective subchannel position of the scheduling signaling, the bandwidth of each subchannel is working bandwidth 1 in the working bandwidth set.	
b_6	Indicates the current transmission mode: 0: Open loop transmission; 1: Closed loop transmission (dedicated demodulation reference signal mode);	
b_7	Bit Map indicates the index of resource unit (RU) in OFDMA scheme with $b_{68}\ b_{67} \cdots b_{56}$together. Each bit indicates the corresponding index RU is occupied. ($b_{68}\ b_{67} \cdots b_{56} b_7$)	
b_{16} b_{15}... b_8	User resource group starting OFDM symbol index, field value: 0~510. User resource group includes DRS symbols. Each user resource group begins with DRS symbols.	
b_{23} b_{22}... b_{17}	MCS of codeword I indication (see Attachment 1)	
b_{32} b_{31}... b_{24}	Number of consecutive OFDM symbols in the user resource group, field value: 0 to 511	
b_{42} b_{41}... b_{33}	If b_1=0, $b_{39}...b_{33}$: indicates th MCS of codeword II; if $b_{39}...b_{33}$=[1111111], this transmission uses only one codeword b_{42} b_{41} b_{40} : reserved If b_1=1, $b_{36}...b_{33}$: The total number of spatial streams in MU-MIMO is [$b_{36}...b_{33}$]+2 $b_{36}...b_{33}$ = 0000, this transmission is a 2-stream MU-MIMO … $b_{36}...b_{33}$ = 1110, this transmission is a 16-stream MU-MIMO $b_{40}...b_{37}$: indicates the index (starting from 0) of starting spatial stream of this STA is [$b_{40}...b_{37}$] b_{42} b_{41}: reserved	When$b_{42}b_{41} \neq 11$, b_{36}... b_{33}, Bitmap indicates CQI or CSI, feedback subchannel b_{40}=1, request CQI feedback $b_{42}b_{41}$=01, request CSI feedback; $b_{42}b_{41}$=11, MCS of codeword II is indicated by b_{39} b_{38}... b_{33}
$b_{44}b_{43}$	00: BCC code; 01: LDPC code length is 1 (determined by capability response frame);	

<table>
<tr><td></td><td colspan="2">10: LDPC code length is 2 (determined by capability response frame);
11: LDPC code length is 3 (determined by capability response frame)</td></tr>
<tr><td>b_{45}</td><td colspan="2">0: Time domain demodulation reference signal interval 0 (short demodulation reference signal interval, see Table 3);
1: Time domain demodulation reference signal interval 1 (long demodulation reference signal interval, see Table)</td></tr>
<tr><td>$b_{47}b_{46}$</td><td colspan="2">00: frequency domain demodulation reference signal interval pattern 1 ($DPI_F = 1$);
01: frequency domain demodulation reference signal interval pattern 2 ($DPI_F = 2$);
10: frequency domain demodulation reference signal interval pattern 3 ($DPI_F = 4$);
11: Reserved</td></tr>
<tr><td>b_{48}</td><td colspan="2">Indicates the uplink sounding signal configuration</td></tr>
<tr><td rowspan="2">b_{54} b_{53}... b_{49}</td><td colspan="2">$if\ b_1 = 0$(SU-MIMO transmission),
$b_{54} \cdots b_{49}$indicates the resources used for signaling and feedback transmission in the user resource group, the field value is 0~63;</td></tr>
<tr><td>$if\ b_1 = 1$(downlink MU-MIMO transmission),
b54…b49: reserved</td><td>$if\ b_1 = 1$ and $b_{48} = 0$, indicates the total number of uplink MU-MIMO streams and spatial stream starting position index
b54..b52,
001, this transmission includes a 2-stream MU-MIMO;
010, this transmission includes a 3-stream MU-MIMO;
011, this transmission includes a 4-stream MU-MIMO;
100, this transmission includes a 5-stream MU-MIMO;
101, this transmission includes a 6-stream MU-MIMO;
110, this transmission includes a 7-stream MU-MIMO;
111, this transmission includes an 8-stream MU-MIMO;
b51..b49,
Spatial stream starting position index, field value 0~7.

$if\ b_1 = 1$ and $b_{48} = 1$, indicates the uplink sounding configuration
b54
1: uplink sounding signals exists in the current whole UL-TCH;
0: uplink sounding signals exists in the end of current STA's UL-TCH;

b53…b51

if b54 is set to '1', indicate the location of starting OFDM symbol of uplink sounding signal in the current whole UL-TCH.</td></tr>
</table>

		Assume the index of the last OFDM symbol in current whole UL-TCH is N. Then the location of starting OFDM symbol of uplink sounding signal is 000: N 001: N -1 010: N-2 … 111: N-7 if b54 is set to ‘0’, indicate the location of starting OFDM symbol of uplink sounding signal in current STA’s UL-TCH. Assume the index of the last OFDM symbol in current STA’s UL-TCH is N. Then the location of starting OFDM symbol of uplink sounding signal is 000: N 001: N -1 010: N-2 … 111: N-7 … $b_{50}b_{49}$ Indicate the SPI_F of uplink sounding signal. 00: $SPI_F = 1$ 01: $SPI_F = 2$ 10: $SPI_F = 4$ 11: reserved
b_{55}	0, STBC transmission not adopted; 1, STBC transmission adopted.	
b_{68} b_{67}... b_{56}	Bit Map indicates the index of resource unit (RU) in OFDMA scheme with b_7 together. Each bit indicates the corresponding index RU is occupied. ($b_{68}\ b_{67} \cdots b_{56} b_7$)	
b_{84} b_{83}... b_{69}	CRC protection based on STAID/BSTAID	
Note 1: b_{84} b_{83}... b_{69} is the CRC of the TCH t scheduling signaling field and the unique 12-bit ID of the cell allocated by the CAP. $[b_{84}\ b_{83} \ldots b_{69}]$ =XOR($[0000d_{11}d_{10}\ldots d_0]_{STAID/BSTAID}$, $[c_{15}c_{14}\ldots c_0]_{CRC}$) Note 2: The control channel is checked by a 16-bit CRC. The CRC generator polynomial is $g(D) = D^{16} + D^{12} + D^5 + 1$. Definition is the same as that in Table 65 . Note 3: The signaling and feedback transmission formats indicated by b_{54}...b_{49} are given in 1.7.5.6.		

Type-II CCH uses QPSK with LDPC 3/14 coding rate. The Definition of control channel field in Type-II CCH is shown in Table 68. Type-III CCH is the two times repetition of Type-II CCH in time domain.

TABLE 68

Definition of control channel field in Type-II CCH

Bit	**Definition**	
	DL	**UL**
b_0	b_0=1, downlink scheduling; b_0=0, uplink scheduling	
b_1	b_1=0, SU-MIMO transmission; b_1=1, MU-MIMO transmission or uplink sounding signal configuration	
$b_5\ b_4 \ldots\ b_2$	[$b_5 b_4 \ldots b_2$], Bit Map indicates the effective subchannel position of the scheduling signaling, the bandwidth of each subchannel is working bandwidth 1 in the working bandwidth set.	
b_6	Indicates the current transmission mode: 0: Open loop transmission; 1: Closed loop transmission (dedicated demodulation reference signal mode);	
b_7	Reserved	
$b_{16}\ b_{15} \ldots\ b_8$	User resource group starting OFDM symbol index, field value: 0~510. User resource group includes DRS symbols. Each user resource group begins with DRS symbols.	
$b_{23}\ b_{22} \ldots\ b_{17}$	MCS of codeword I indication (see Attachment 1)	
$b_{32}\ b_{31} \ldots\ b_{24}$	Number of consecutive OFDM symbols in the user resource group, field value: 0 to 511	
$b_{42}\ b_{41} \ldots\ b_{33}$	If b_1=0, $b_{39} \ldots b_{33}$: indicates th MCS of codeword II; if $b_{39} \ldots b_{33}$=[1111111], this transmission uses only one codeword $b_{42}\ b_{41}\ b_{40}$: reserved If b_1=1, $b_{36} \ldots b_{33}$: The total number of spatial streams in MU-MIMO is [$b_{36} \ldots b_{33}$]+2 $b_{36} \ldots b_{33}$ = 0000, this transmission is a 2-stream MU-MIMO … $b_{36} \ldots b_{33}$ = 1110, this transmission is a 16-stream MU-MIMO $b_{40} \ldots b_{37}$: indicates the index (starting from 0) of starting spatial stream of this STA is [$b_{40} \ldots b_{37}$] $b_{42}\ b_{41}$: reserved	When $b_{42}b_{41} \neq 11$, $b_{36} \ldots\ b_{33}$, Bitmap indicates CQI or CSI, feedback subchannel b_{40}=1, request CQI feedback $b_{42}b_{41}$=01, request CSI feedback; $b_{42}b_{41}$=11, MCS of codeword II is indicated by $b_{39}\ b_{38} \ldots\ b_{33}$
$b_{44}b_{43}$	00: BCC code; 01: LDPC code length is 1 (determined by capability response frame); 10: LDPC code length is 2 (determined by capability response frame); 11: LDPC code length is 3 (determined by capability response frame)	
b_{45}	0: Time domain demodulation reference signal interval 0 (short demodulation reference signal interval, see Table 3);	

	1: Time domain demodulation reference signal interval 1 (long demodulation reference signal interval, see Table)	
$b_{47}b_{46}$	00: frequency domain demodulation reference signal interval pattern 1 ($DPI_F = 1$); 01: frequency domain demodulation reference signal interval pattern 2 ($DPI_F = 2$); 10: frequency domain demodulation reference signal interval pattern 3 ($DPI_F = 4$); 11: Reserved	
b_{54} b_{53}... b_{48}	$if\ b_1 = 0$(SU-MIMO transmission), then $b_{54} \cdots b_{49}$indicates the resources used for signaling and feedback transmission in the user resource group, the field value is 0~63;	
	$b_1 = 1$, downlink MU-MIMO transmission, b54…b48, reserved	$if\ b_1 = 1$ and $b_{72} = 0$, indicates total number of uplink MU-MIMO streams and spatial stream starting position index b54..b52, 001, this transmission includes a 2-stream MU-MIMO; 010, this transmission includes a 3-stream MU-MIMO; 011, this transmission includes a 4-stream MU-MIMO; 100, this transmission includes a 5-stream MU-MIMO; 101, this transmission includes a 6-stream MU-MIMO; 110, this transmission includes a 7-stream MU-MIMO; 111, this transmission includes an 8-stream MU-MIMO; b51..b49, Spatial stream starting position index, field value 0~7. $if\ b_1 = 1$ and $b_{72} = 1$, indicates the uplink sounding configuration b54 1: uplink sounding signals exists in the current whole UL-TCH; 0: uplink sounding signals exists in the end of current STA's UL-TCH; b53…b50 if b54 is set to '1', indicate the location of starting OFDM symbol of uplink sounding signal in the current whole UL-TCH. Assume the index of the last OFDM symbol in current whole UL-TCH is N. Then the location of starting OFDM symbol of uplink sounding signal is 0000: N 0001: N -1 0010: N-2

		… 1111: N-15 if b54 is set to '0', indicate the location of starting OFDM symbol of uplink sounding signal in current STA's UL-TCH. Assume the index of the last OFDM symbol in current STA's UL-TCH is N. Then the location of starting OFDM symbol of uplink sounding signal is 0000: N 0001: N -1 0010: N-2 … 1111: N-15 … B49b48 Indicate the SPI_F of uplink sounding signal. 00: $SPI_F = 1$ 01: $SPI_F = 2$ 10: $SPI_F = 4$ 11: reserved
b_{55}	0, STBC transmission not adopted; 1, STBC transmission adopted.	
b_{63} b_{62}... b_{56}	Indicates the index of starting RU. The index of the first RU is 0.	
b_{71} b_{70}... b_{64}	Indicates the number of consecutive RUs	
b_{72}	Indicates the uplink sounding signal configuration	
b_{79} b_{78}... b_{73}	Reserved	
b_{95} b_{94}... b_{80}	CRC protection based on STAID/BSTAID	
Note 1: b_{84} b_{83}... b_{69} is the CRC of the TCH t scheduling signaling field and the unique 12-bit ID of the cell allocated by the CAP. $[b_{84}\ b_{83}...\ b_{69}]$ =XOR($[0000d_{11}d_{10}\ldots d_0]_{STAID/BSTAID}$, $[c_{15}c_{14}\ldots c_0]_{CRC}$) Note 2: The control channel is checked by a 16-bit CRC. The CRC generator polynomial is $g(D) = D^{16} + D^{12} + D^5 + 1$. Definition is the same as that in Table 65 . Note 3: The signaling and feedback transmission formats indicated by b_{54}...b_{49} are given in 1.7.5.6.		

In low-error mode, the control channel field is defined in Table 69. The CCH transmission uses MCS1. Convolutional coding is applied for control channel with frequency repetition number is 4 and time repetition number is 3. Normal CP is used for CCH.

TABLE 69

Control field definition in low-error mode

Bit	Definition	Notes
$b_3b_2 \ldots b_0$	The lowest 4 bits of this CAP MAC address	[0 0 0 $b_3b_2 \ldots b_0$] is used for CAP identifier and scrambling code seed
b_5 b_4	Frame length	00: 0.5ms 01: 1ms 10: 2ms 11: 4ms
$b_9b_8b_7b_6$	DL ratio : UL ratio	0000: 1:15 0001: 2:14 0010: 3:13 0011: 4:12 0100: 5:11 0101: 6:10 0110: 7:9 0111: 8:8 1000: 9:7 1001: 10:6 1010: 11:5 1011: 12:4 1100: 13:3 1101: 14:2 1110: 15:1 1111: 0:16
$b_{11}b_{10}$	DL Repetition number in time domain(M)	00: 1 01: 2 10: 3 11: 4
$b_{14}b_{13}b_{12}$	Indication of number of RUs in uplink	000: 1 RU 001: 2RUs 010: 4RUs 011: 6RUs 100: 8RUs 101: 10RUs 110: 12RUs 111: All RUs
$b_{18}b_{17}b_{16}b_{15}$	the start index of RU in uplink	0000 ~ 1101: RU #1 ~ RU #14 1110~1111: reserved
$b_{20}b_{19}$	UL Repetition number in time domain(M)	00: 2 01: 3 10: 4 11: 6
b_{21}	UL Repetition number in frequency domain(N)	0: 2 1: 4
$b_{27}b_{26} \ldots b_{22}$	Frame number	0~63, frame number counter

$b_{29}b_{28}$	Uplink scheduling request channel	00: No uplink scheduling request channel; 01: Scheduling request channel is configured with 1 OFDM symbol; 10: Scheduling request channel is configured with 2 OFDM symbols; 11: Scheduling request channel is configured with 4 OFDM symbols;
b_{30}	Uplink random access channel configuration	0: No uplink random access channel; 1: With uplink random access channel
b_{31}	Indication of Cyclic Prefix type in TCH	0: Normal CP 1: Short CP
$b_{55}b_{54}\ldots b_{32}$	24-bit CRC	CRC protection
Note 1: $b_{55}b_{54}..b_{32}$ is the CRC of the unicast or broadcast scheduling signaling field and the unique 12-bit ID of the cell allocated by the CAP. $[b_{55}\ b_{54}\ \cdots\ b_{32}] = [0\ 0\ 0\ 0\ d_{11}\ d_{10}\ \cdots\ d_0]_{STAID/BSTAID} \oplus [c_{23}\ c_{22}\ \cdots\ c_0]_{CRC}$ Note 2: The control channel is checked by a 24-bit CRC. The CRC generator polynomial is $g(D) = D^{24} + D^{23} + D^{18} + D^{17} + D^{14} + D^{11} + D^{10} + D^7 + D^6 + D^5 + D^4 + D^3 + D + 1$.. Note 3: The DL/UL symbol number with different DL/UL ratio is calculated as follows: DLTCH_symbol_number = floor(N*DL_Ratio/(DL_Ratio+UL_Ratio)) ULTCH_symbol_number = N - DLTCH_symbol_number. N represents the number of TCH OFDM symbols.		

In low-error mode, the MCS in both uplink and downlink is fixed to be QPSK, LDPC 4/7 coding rate with 448 codeword size. OFDMA scheme is used in low error mode. Downlink transmission will use all the RUs and the frequency domain repetition times is fixed to be 4.

In mmWave mode, the control channel transmits in MCS101. LDPC coding is applied for control channel with frequency repetition number is 4 and time repetition number is 4. The field of CCH is shown in Table 70.

TABLE 70

Definition of control channel field in mmWave mode

Bit	**Definition**	
	DL	**UL**
b_0	b_0=1, downlink scheduling; b_0=0, uplink scheduling	
b_1	b_1=0, SU-MIMO transmission; b_1=1, MU-MIMO transmission	
$b_5\ b_4\ldots\ b_2$	[$b_5b_4\ldots b_2$], Bit Map indicates the effective subchannel position of the scheduling signaling, the bandwidth of each subchannel is working bandwidth 1 in the working bandwidth set.	
b_6	Indicates the current transmission mode:	

<table>
<tr><td></td><td colspan="2">0: Open loop transmission;
1: Closed loop transmission (dedicated demodulation reference signal mode);</td></tr>
<tr><td>b_7</td><td colspan="2">Reserved</td></tr>
<tr><td>b_{18} ... b_8</td><td colspan="2">User resource group starting OFDM symbol index, field value: 0~2046. User resource group includes DRS symbols. Each user resource group begins with DRS symbols.</td></tr>
<tr><td>b_{20}... b_{19}</td><td colspan="2">Repetition number in time domain
00: 1
01: 2
10: 3
11: 4</td></tr>
<tr><td>b_{22}... b_{21}</td><td colspan="2">Repetition number frequency domain
00: 1
01: 2
10: 4
11: 8</td></tr>
<tr><td>b_{25}... b_{23}</td><td colspan="2">reserved</td></tr>
<tr><td>b_{32} ... b_{26}</td><td colspan="2">MCS of codeword I indication (see Attachment 1)</td></tr>
<tr><td>b_{42} b_{41}... b_{33}</td><td>If b_1=0,
b_{39}...b_{33}: indicates th MCS of codeword II;
if b_{39}...b_{33}=[1111111], this transmission uses only one codeword
b_{42} b_{41} b_{40} : reserved

If b_1=1,
b_{36}...b_{33}: The total number of spatial streams in MU-MIMO is [b_{36}...b_{33}]+2
b_{36}...b_{33} = 0000, this transmission is a 2-stream MU-MIMO
…
b_{36}...b_{33} = 1110, this transmission is a 16-stream MU-MIMO

b_{40}...b_{37}: indicates the index (starting from 0) of starting spatial stream of this STA is [b_{40}...b_{37}]

b_{42} b_{41}: reserved</td><td>When$b_{42}b_{41} \neq 11$,
b_{36}... b_{33}, Bitmap indicates CQI or CSI, feedback subchannel

b_{40}=1, request CQI feedback
$b_{42}b_{41}$=01, request CSI feedback;
$b_{42}b_{41}$=11, MCS of codeword II is indicated by b_{39} b_{38}... b_{33}</td></tr>
<tr><td>$b_{44}b_{43}$</td><td colspan="2">00: BCC code;
01: LDPC code length is 1 (determined by capability response frame);
10: LDPC code length is 2 (determined by capability response frame);
11: LDPC code length is 3 (determined by capability response frame)</td></tr>
<tr><td>b_{45}</td><td colspan="2">0: Time domain demodulation reference signal interval 0 (short demodulation reference signal interval, see Table);
1: Time domain demodulation reference signal interval 1 (long demodulation reference signal interval, see Table)</td></tr>
<tr><td>$b_{47}b_{46}$</td><td colspan="2">00: frequency domain demodulation reference signal interval pattern 1 (DPI_F = 1);
01: frequency domain demodulation reference signal interval pattern 2 (DPI_F = 2);
10: frequency domain demodulation reference signal interval pattern 3 (DPI_F = 4);
11: Reserved</td></tr>
</table>

<table>
<tr><td>b_{48}</td><td colspan="2">Indicates the uplink sounding signal configuration</td></tr>
<tr><td rowspan="2">b_{54} b_{53}... b_{49}</td><td colspan="2">$if\ b_1 = 0$(SU-MIMO transmission),
$b_{54} \cdots b_{49}$indicates the resources used for signaling and feedback transmission in the user resource group, the field value is 0~63;</td></tr>
<tr><td>$if\ b_1 = 1$(downlink MU-MIMO transmission), b54…b49: reserved</td><td>$if\ b_1 = 1$ and $b_{48} = 0$, indicates the total number of uplink MU-MIMO streams and spatial stream starting position index
b54..b52,
001, this transmission includes a 2-stream MU-MIMO;
010, this transmission includes a 3-stream MU-MIMO;
011, this transmission includes a 4-stream MU-MIMO;
100, this transmission includes a 5-stream MU-MIMO;
101, this transmission includes a 6-stream MU-MIMO;
110, this transmission includes a 7-stream MU-MIMO;
111, this transmission includes an 8-stream MU-MIMO;
b51..b49,
Spatial stream starting position index, field value 0~7.

$if\ b_1 = 1$ and $b_{48} = 1$, indicates the uplink sounding configuration
b54
1: uplink sounding signals exists in the current whole UL-TCH;
0: uplink sounding signals exists in the end of current STA’s UL-TCH;

b53…b51

if b54 is set to ‘1’, indicate the location of starting OFDM symbol of uplink sounding signal in the current whole UL-TCH.

Assume the index of the last OFDM symbol in current whole UL-TCH is N. Then the location of starting OFDM symbol of uplink sounding signal is
000: N
001: N -1
010: N-2
…
111: N-7

if b54 is set to ‘0’, indicate the location of starting OFDM symbol of uplink sounding</td></tr>
</table>

		signal in current STA's UL-TCH. Assume the index of the last OFDM symbol in current STA's UL-TCH is N. Then the location of starting OFDM symbol of uplink sounding signal is 000: N 001: N -1 010: N-2 … 111: N-7 … $b_{50}b_{49}$ Indicate the SPI_F of uplink sounding signal. 00: $SPI_F = 1$ 01: $SPI_F = 2$ 10: $SPI_F = 4$ 11: reserved
b_{55}	0, STBC transmission not adopted; 1, STBC transmission adopted.	
b_{68} b_{67}... b_{56}	Reserved	
B_{72} $b_{71}b_{70}$ b_{69} B_{76} $b_{75}b_{74}$ b_{73} B_{80} $b_{79}b_{78}$ b_{77} B_{84} $b_{83}b_{82}$ b_{81} B_{88} $b_{87}b_{86}$ b_{85} B_{92} $b_{91}b_{90}$ b_{89} B_{96} $b_{95}b_{94}$ b_{93} B_{100} $b_{99}b_{98}$ b_{97}	For each tx antenna, there are N TRN units and each TRN unit contains M TRN sequences. The M TRN sequences in one TRN unit are transmitted with the same direction. The different TRN units can be transmitted with different direction. 0000: M=1, N=4 0001: M=1, N=16 0010: M=1, N=32 0011: M=1, N=64 0100: M=4, N=1 0101: M=4, N=4 0110: M=4, N=8 0111: M=4, N=16 1000: M=16, N=1 1001: M=16, N=2 1010: M=16, N=4 1011: M=32, N=1 1100: M=32, N=2 1101: M=64, N=1 B_{72} $b_{71}b_{70}$ b_{69} is set for tx antenna1 B_{76} $b_{75}b_{74}$ b_{73} is set for tx antenna2 B_{80} $b_{79}b_{78}$ b_{77} is set for tx antenna3 B_{84} $b_{83}b_{82}$ b_{81} is set for tx antenna4 B_{88} $b_{87}b_{86}$ b_{85} is set for tx antenna5 B_{92} $b_{91}b_{90}$ b_{89} is set for tx antenna6 B_{96} $b_{95}b_{94}$ b_{93} is set for tx antenna7 B_{100} $b_{99}b_{98}$ b_{97} is set for tx antenn8	
b_{111}... b_{101}	Number of consecutive OFDM symbols in the user resource group, field value: 1 to 2047	
b_{127}... b_{112}	CRC protection and STAID/BSTAID identification	

Note 1: b_{116} b_{115}... b_{101} is the CRC of the unicast or broadcast scheduling signaling field and the unique 12-bit ID of the cell allocated by the CAP.

$[b_{116}\ b_{115}...\ b_{101}]$ =XOR($[0000d_{11}d_{10}...d_0]_{STAID/BSTAID}$, $[c_{15}c_{14}...c_0]_{CRC}$)

Note 2: The control channel is checked by a 16-bit CRC. The CRC generator polynomial is $g(D) = D^{16} + D^{12} + D^5 + 1$. Definition is the same as that in Table 65 .

Note 3: The signaling and feedback transmission formats indicated by $b_{54}...b_{49}$ are given in 1.7.5.6.

1.7.5 Downlink/Uplink traffic channel

1.7.5.1 Resource allocation type of Downlink/Uplink traffic channel

1.7.5.1.1 General

In the downlink/uplink traffic channel, this specification supports TDMA and OFDMA resource multiplexing scheduling. The time-frequency resources allocated to each STA in the uplink or downlink traffic channel are called resource groups.

1.7.5.1.2 Time division multiplexing resource allocation

In the case of time division multiplexing, the OFDM symbol index in the STA resource group starts from 0.

1.7.5.1.3 OFDMA resource allocation

In OFDMA scheme, the unit of resource allocation is one resource unit (RU). One RU is composed of 16 data subcarriers. The RUs in OFDM symbols is consecutive and non-overlapped. The phase tracking pilot subcarriers are allocated for RUs as follows: The adjacent phase tracking pilot subcarrier towards the center direction (subcarrier at DC) is allocated for the RU. The RUs at left and right edge in frequency domain contain two phase tracking pilot subcarriers. The information of RU allocation is indicated in CCH.

1.7.5.2 Resource indication of Downlink/Uplink traffic channel

1.7.5.2.1 Indication of time division multiplexing resource allocation

Control channel indicates The STA resource group starting OFDM symbol index and the number of the continuous OFDM symbols occupied by the STA resource group. The resource group allocated for the STA includes the resources occupied by the demodulation reference signal.

1.7.5.2.2 Indication of OFDMA resource allocation

The indication of OFDMA resource allocation is indicated in control channel.

1.7.5.3 Traffic channel demodulation reference signal

1.7.5.3.1 General

This specification can dynamically adjust the demodulation reference signal (DRS) pattern in normal and mmWave mode. Different time domain interval of DRS can be configured through the Control Channel field b_{45}; different frequency domain interval of DRS can be configured through the Control Channel field $b_{47}b_{46}$.

If b_6 in Control Channel field is 1, the demodulation reference signal can be precoded (i.e. dedicated demodulation reference signal); if b_6 in Control Channel field is 0, demodulation reference signal cannot be precoded (i.e. common demodulation reference signal).

In low-error mode, there is no downlink DRS. CRS is used for both CCH and DL-TCH channel estimation.

In low-error mode, the uplink DRS shall be generated in the same way as the CRS in low-error mode, and LP511 should repeat 2 times in time domain as [w1* LP511, w2* LP511]. If PN_ID is in {0, 2, 4, 8}, the [w1 w2] is [1 1]. If the PN_ID is in {1, 3, 5, 7}, the [w1 w2] is [1 -1]. It should be filtered to meet the requirements of frequency mask.

1.7.5.3.2 Demodulation reference signal pattern

The number of OFDM symbols which DRS occupies depends on the value of the subcarrier offset indication of DRS/Sounding Pilot in SICH. If there is subcarrier offset, the OFDM symbol number of DRS is N_{sts}. Otherwise, the OFDM symbol number of DRS is $\left\lceil \frac{N_{sts}}{DPI_F} \right\rceil$.

1.7.5.3.3 Demodulation reference signal interval

Different time domain intervals of DRS can be configured by control channel scheduling signaling b_{45} (see Section 1.7.4.2) to adapt to different radio propagation environments. Time domain pilot interval configuration, DPI_T, is to insert a set of demodulation reference signal in every DPI_T OFDM symbols. If b_{45}=0, it is a short DPI_T, and if b_{45}=1, it is a long DPI_T. The values of long and short DPI_T are indicated in the MAC layer BCF frame.

1.7.5.3.4 Demodulation reference signal sequence

The generator polynomial of the pilot sequence is $1+X^{11}+X^{15}$. The structure of the linear feedback shift register with the maximum length is as shown in section1.7.2.2. The generated sequence is BPSK-modulated to obtain the pilot symbol sequence {Si} i = 0, 1, ..., 32767. There are four different sequences for DRS with different initial states of the register. The initial state is $[0\ 0\ 1\ 0\ 1\ 0\ 1\ 1\ a_6\ a_5\ a_4\ a_3\ a_2\ a_1\ a_0]$.MSB is on the left, and LSB on the right, where $[a_6\ a_5\ a_4\ a_3\ a_2\ a_1\ a_0]$ is from the set { '0101100'; '0101001'; '1010111'; '1101110' }. The index (1,2,3,4) of the current initial state is same as S-Preamble ID.

In normal mode, there are 3 different basic DRS signal (D1, D2 and D3), which can be duplicated with rotation factors in frequency domain to support various bandwidths and subcarrier spacings, as shown in Table 59. The same rotation factors should be applied to relative TCH. The generation method of D1, D2 and D3 is as follows, where the value of Nsr is 115, 58 and 29 for D1, D2 and D3 in full-bandwidth scheme, respectively. In OFDMA scheme, the value of Nsr is 120, 60, 26 for D1, D2 and D3, respectively.

The bits of {Si} is BPSK-modulated to generate {Mi, i = 0, 1, ..., 32767}. Then {Mi} is mapped to the time-frequency resource start from i=0, based on the following rules, to generate $p_{k,l}^{sti}$:

$$i = 0$$

$$for\ l = 1:1:DP_{num}$$

$$for\ k = -N_{sr}:1:+N_{sr}$$

$$if\ k \in SC_{dp}^{sti}$$

$$p_{k,l}^{sti} = M_i$$

$$else$$

$$p_{k,l}^{sti} = 0$$

$$end$$
$$i = i + 1$$
$$end$$
$$end$$

Equation 25

SC_{dp}^{sti} is the set of subcarriers defined as Equation 26,

$$SC_{dp}^{sti} = [\pm(\mathrm{SC}_{\mathrm{Offset}} + 1 + sti - (l-1)\cdot DPI_F), \pm(\mathrm{SC}_{\mathrm{Offset}} + 1 + DPI_F + sti - (l-1) \cdot DPI_F), \cdots, \pm(\mathrm{SC}_{\mathrm{Offset}} + N + sti - (l-1)\cdot DPI_F)]$$

$$l = (1-m)\left\lfloor \frac{sti}{DPI_F} \right\rfloor + m \cdot sti + 1$$

$$N = 1 + DPI_F \cdot \lfloor (N_{sr} - sti + (l-1)\cdot DPI_F - 1)/DPI_F \rfloor$$
$$sti = 0 \sim 7, m \text{ is DRS pattern defined } in \text{ SICH}$$

Equation 26

D1, D2 and D3 is generated by adding zeros to $p_{k,l}^{sti}$ at positions of virtual subcarriers given by Tables 35, 36 and 37.

For cells in which the $\mathrm{DPI_F}$ is configured with 2， 0~1 subcarrier offsets ($\mathrm{SC}_{\mathrm{Offset}}$) can be add to the SC_{dp}^{sti} in DRS， the value of $\mathrm{SC}_{\mathrm{Offset}}$ is mod(S-Preamble ID – 1, 2). For cells in which the $\mathrm{DPI_F}$ is configured with 4， 0~3 subcarrier offsets ($\mathrm{SC}_{\mathrm{Offset}}$) can be add to the SC_{dp}^{sti} in DRS， the value of $\mathrm{SC}_{\mathrm{Offset}}$ is (S-Preamble ID – 1), through which demodulation pilots of different cells can be mapped onto different subcarriers.

TABLE 71

DRS duplication modes in different Subcarrier spacing and bandwidth

Subcarrier spacing (kHz)	**5 MHz**	**10 MHz**	**15 MHz**	**20 MHz**	**25 MHz**	**30 MHz**	**40 MHz**	**50 MHz**	**60 MHz**	**80 MHz**	**100 MHz**
	NFFT										
19.53125	256	512	768	1024	1280	1536	2048	2560	N/A	N/A	N/A
Duplication number (Basic DRS Signal)	1 (D1)	2 (D1)	3 (D1)	4 (D1)	5 (D1)	6 (D1)	8 (D1)	10 (D1)	N/A	N/A	N/A
39.0625	128	256	384	512	640	768	1024	1280	1536	2048	2560
Duplication number (Basic DRS Signal)	1 (D2)	1 (D1)	3 (D2)	2 (D1)	5 (D2)	3 (D1)	4 (D1)	5 (D1)	6 (D1)	8 (D1)	10 (D1)

78.125	64	128	192	256	320	384	512	640	768	1024	1280
Duplication number (Basic DRS Signal)	1 (D3)	1 (D2)	3 (D3)	1 (D1)	5 (D3)	3 (D2)	2 (D1)	5 (D2)	3 (D1)	4 (D1)	5 (D1)

DRS transmitted from different CAP should add phase shift $\varphi_{i,k}$ as follows,

$$\varphi_{i,k} = e^{-j\frac{2\pi k\delta^i}{N_{FFT}}}$$

Equation 27

in which i is the phase shift index for different CAP , $\delta^i = \left\{0,\ \frac{N_{FFT}}{8},\ \frac{N_{FFT}}{4},\ N_{FFT}\times\frac{3}{8},\ \frac{N_{FFT}}{2},\ N_{FFT}\times\frac{5}{8},\ N_{FFT}\times\frac{3}{4},\ N_{FFT}\times\frac{7}{8}\right\}$.The same phase shift index as long preamble should be used for DRS.

For uplink in OFDMA scheme, the same DRS generation procedure is applied first for the whole bandwidth, then the values of subcarriers which do not belong to current user are set to 0 before IFFT operation.

In mmWave mode, the Demodulation reference signal shall be generated as follows:

For 50MHz bandwidth, the DRS generation process is same as the normal mode based on basic DRS signal D2.

For 100MHz bandwidth, the DRS generation process is same as the normal mode based on basic DRS signal D1.

For 200 MHz/400MHz/1GHz bandwidth, the demodulation reference signal shall be duplicated with rotation factors in frequency domain in the unit of 100 MHz. The same rotation factors should be applied to relative TCH.

In mmWave mode, training sequence signals (also known as TRN) are used for channel tracking and beam tracking, this field is added ahead of the first demodulation reference signal. The structure of the training sequence signals is shown in Figure 85.

FIGURE 85

The structure of the training sequence signals

PN_CP1	PN_{511}	PN_CP2

The training sequence signals are transmitted using the sequence PN_{511}. The CP length for the training sequence signals is 127 sequence length and should be added ahead and behind the reference signals.

See Attachment 2 for the values of PN sequence.

1.7.5.4 Multi-antenna schemes for downlink traffic channel

1.7.5.4.1 General

In the multi-antenna transmission mode, the time domain baseband signal of the tith antenna port is obtained by the Equation 28:

$$r_{Field}^{(ti)}(t) = \frac{1}{\sqrt{N_{Field}^{Tone} \cdot N_{sts}}} w_T(t) \sum_{\substack{k=-N_{FFT}/2 \\ k \notin SC_V}}^{N_{FFT}/2-1} \sum_{si=1}^{N_{sts}} [Q_k]_{ti,si} \tilde{x}_k^{(si)} \, exp(j2\pi k \Delta f t)$$

Equation 28

In which,

$w_T(t)$ - time domain window function, which is implementation related;

$\tilde{x}_k^{(si)}$- the loading symbol of the k^th^ subcarrier on the si^th^ spatial stream;

SC_V – the set of virtual subcarriers;

Δf – Subcarrier spacing

$[Q_k]_{ti,si}$- Elements of the ti^th^ row and the si^th^ column of the precoding matrix Q_k, $Q_k \in C^{N_{TX} \times N_{sts}}$.

The downlink multi-antenna transmission includes:

Mode 1: Open loop SU-MIMO;

Mode 2: Closed loop SU-MIMO;

Mode 3: Closed loop MU-MIMO.

1.7.5.4.2 Mode 1: open loop SU-MIMO

Open loop SU-MIMO can support up to 8 streams. In open loop SU-MIMO, the STA can receive up to two codewords in parallel. Matrix $Q_k \in C^{N_{TX} \times N_{sts}}$ in open loop mode is a column orthogonal matrix. The value of Q_k is implementation related. The same Q_k should be applied to both DRS and data OFDM symbols for one user.

1.7.5.4.3 Mode 2: closed loop SU-MIMO

Closed loop SU-MIMO can support up to 8 streams. The same precoding is performed in each subcarrier group, which is defined as precoding group. The number of precoding groups is N_g. The number of subcarriers in the g^{th} precoding group is Ω_g.

In full−bandwidth scheme, the number of subcarriers Ω_g in the precoding group in SU-MIMO mode is determined by Equation 29, in which DPI_F is indicated in control channel field.

$$\Omega_g = \begin{cases} 1, if\ DPI_F = 1 \\ 4 \times DPI_F, else \end{cases}$$

Equation 29

The group begins from center useful subcarrier to the edge subcarriers for both positive and negative frequency until there are less than Ω_g subcarriers left at the edge. Those subcarriers left form a new precoding group.

In OFDMA scheme, the precoding group contains a resource unit and the adjacent pilot subcarrier towards the center direction (subcarrier at DC). The precoding groups at left and right edge in frequency domain contain two adjacent pilot subcarriers.

1.7.5.4.4 Mode 3: closed loop MU-MIMO

In closed loop MU-MIMO, each STA can only support one codeword. The same precoding is performed in each subcarrier group, which is defined precoding group. The number of precoding groups is N_g. The number of subcarriers in the g^{th} precoding group is Ω_g.

In full−bandwidth scheme, the number of subcarriers Ω_g in the precoding group in MU-MIMO mode is determined by Equation 30, in which DPI_F is indicated in control channel field..

$$\Omega_g = DPI_F$$

Equation 30

The group begins from center useful subcarrier to the edge subcarriers for both positive and negative frequency until there are less than Ω_g subcarriers left in the edge. Those subcarriers left form a new precoding group.

In OFDMA scheme, the precoding group contains a resource unit and the adjacent pilot subcarrier towards the center direction (subcarrier at DC). The precoding groups at left and right edge in frequency domain contain two adjacent pilot subcarriers.

1.7.5.5 Multi-antenna solution for uplink traffic channel

The uplink multi-antenna transmission supports:

Mode 1: Open loop SU-MIMO;

Mode 2: Closed-loop SU-MIMO.

Mode 3: Uplink MU-MIMO.

1.7.5.5.1 Mode 1: open loop SU-MIMO

Same as 1.7.5.4.2.

1.7.5.5.2 Mode 2: closed loop SU-MIMO

Same as 1.7.5.4.3.

1.7.5.5.3 Mode 3: Uplink MU-MIMO

For STA side, the uplink MU-MIMO transmission is same as SU-MIMO. CAP may schedule multiple STAs to form the MU-MIMO group, in which STAs can transmit simultaneously. Each STA can only support one codeword. The MIMO detection processing at CAP side is used to obtain the spatial streams from different STAs. The detailed MIMO detection and scheduling algorithms are implementation related.

1.7.5.6 Signaling/feedback transmission channel

1.7.5.6.1 General

The signaling/feedback information can be transmitted in traffic channel (grouped with other MAC frames) or signaling/feedback channel. There are two types of signaling/feedback channel. The first one is the dedicated signaling/feedback channel, which is located at the beginning of STA's resource group and uses the same transmission scheme as STA's traffic data. The second one is the common signaling/feedback channel, which is located at the beginning of the whole DL/UL TCH.

The transmission format of common signaling/feedback channel is shown in Table 72. The transmission format of dedicated signalling/feedback channel follows traffic channel.

TABLE 72

Signaling/ feedback transmission format

Coding Type	Convolutional code

Number of streams	Single stream
Modulation and Coding Rate	Indicated in CCH
Space time coding	Disable
Demodulation Reference Signal	$DPI_F = 1$
Transmission mode	Open loop MIMO

Define D ($b_{54}b_{53}...b_{49}$) as the decimal number corresponding to $b_{54}b_{53}...b_{49}$, where b_{54} is the most significant bit, and b_{49} is the least significant bit. Within the STA resource group, OFDM symbol 0 to D ($b_{54}b_{53}...b_{49}$)-1 are used for dedicated signaling or feedback transmission, and the transmission format is independent of the indication in Section 1.7.4.2.

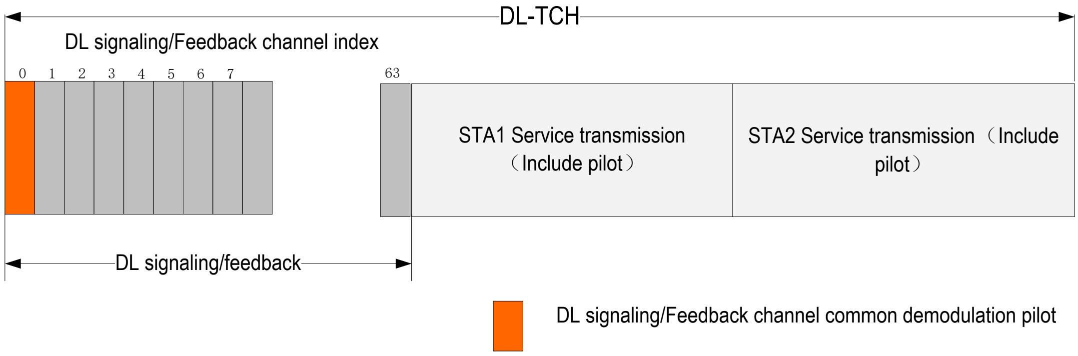
The indication of the common signaling/feedback channel is shown in the following chapters.

1.7.5.6.2 Downlink Signaling/ feedback transmission channel

The downlink signaling/ feedback transmission channel is at the beginning of the DL-TCH, as shown in Figure 86. All downlink signaling/ feedback transmission channels share a demodulation reference signal.

FIGURE 86

Downlink signaling/feedback transmission channel

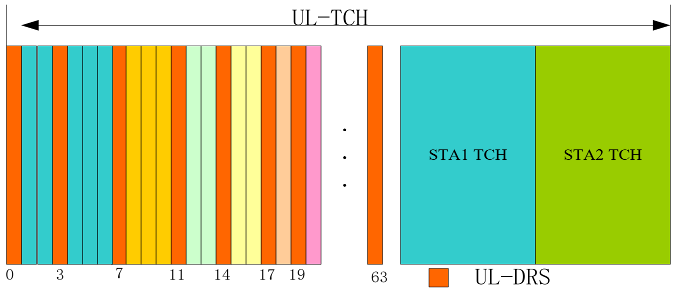


1.7.5.6.3 Uplink Signaling/ feedback transmission channel

Uplink signaling/ feedback transmission channel multiplexes the UL-TCH resources as shown in Figure 87, each STA has its own DRS.

FIGURE 87

Uplink signaling/feedback channel



1.7.5.6.4 Resource indication of Signaling/ feedback transmission channel

The information of signaling/ feedback channel is indicated by CCH with CRC scrambled with BSTAID. See Table 73 for the specific fields.

TABLE 73

Field definition of resource indication signaling of the signaling/ feedback transmission channel

<table>
<tr><th rowspan="2">Bit</th><th colspan="2">Definition</th></tr>
<tr><th>DL</th><th>UL</th></tr>
<tr><td>$b_3\ b_2\ b_1\ b_0$</td><td colspan="2">Broadcast type:
$b_3\ b_2\ b_1\ b_0$=0001 indicates the downlink signaling/feedback channel resource;
$b_3\ b_2\ b_1\ b_0$=0000 indicates the uplink signaling/feedback channel resource</td></tr>
<tr><td>$b_7\ b_6\ b_5\ b_4$</td><td colspan="2">working bandwidth 1 subchannel Bitmap, multiple subchannels can be set to the same signaling/feedback channel</td></tr>
<tr><td>$b_{16}\ b_{15} \ldots b_8$</td><td colspan="2">Signaling/ feedback channel resource group starting OFDM symbol index, field value: 0~510</td></tr>
<tr><td>$b_{22}\ b_{21} \ldots b_{17}$</td><td colspan="2">Reserved</td></tr>
<tr><td>$b_{28}\ b_{27} \ldots b_{23}$</td><td colspan="2">Number of symbols occupied by the signaling/feedback channel, field values 1 to 63</td></tr>
<tr><td>$b_{30}b_{39}$</td><td colspan="2">Reserved</td></tr>
<tr><td>b_{31}</td><td>0: The downlink broadcast channel allocation is valid;
1: The downlink broadcast channel allocation is invalid</td><td rowspan="4">Reserved</td></tr>
<tr><td>$b_{37}b_{36} \ldots b_{32}$</td><td>starting index (Starting from 1) occupied by the downlink broadcast channel in signaling/feedback channel</td></tr>
<tr><td>$b_{43} \ldots b_{38}$</td><td>Number of OFDM symbols occupied by the downlink broadcast channel</td></tr>
<tr><td>$b_{47} \ldots b_{44}$</td><td>MCS Indication for downlink broadcast channel
0000: MCS 0
0001: MCS 1
…
1101: MCS 13
1110: MCS 122
1111: MCS 123</td></tr>
</table>

$b_{68}\ b_{54} \ldots b_{48}$	Reserved
$b_{84}\ b_{70} \ldots b_{69}$	16-bit CRC is scrambled by BSTAID
Note 1: The number of OFDM symbols occupied by the downlink signaling feedback channel is D ($b_{28}\ b_{27} \ldots b_{23}$), and the OFDM symbol with index 0 is the common demodulation reference signal occupying resources. Note 2: The CRC is defined the same as in Table 65.	

1.7.5.6.5 Signaling/feedback transmission channel assignment

The CAP may assign the resources in the signaling/feedback channel to the STA through broadcasting CCH with CRC scrambled with BSTAID, as shown in Table 74.

TABLE 74

Signaling/ feedback transmission channel assignment signaling field definition

Bit	Definition	
	DL	UL
$b_3\ b_2\ b_1\ b_0$	Broadcast type: $b_3\ b_2\ b_1\ b_0$=0011, downlink signaling/feedback channel allocation; $b_3\ b_2\ b_1\ b_0$=0010, uplink signaling/feedback channel allocation	
$b_7\ b_6\ b_5\ b_4$	Subband bitmap	
$b_{19}\ b_{18} \ldots b_8$	STA ID	
$b_{24}b_{23} \ldots b_{19}$	index of starting OFDM symbol in the signaling/feedback channel. The field value ranges from 0 to 63	
$b_{30}b_{29} \ldots b_{25}$	the number of OFDM symbols occupied, field values 1 to 63; a field value of 0 indicates that the channel indication is invalid.	
$b_{44}b_{43} \ldots b_{31}$	Resource Unit bit map, “1” in each bit indicates the corresponding RU is occupied	
b_{45}	0: information is duplicated in subbands; 1: information is different in subbands	
$b_{49} \ldots b_{46}$	MCS Indication for signaling/feedback channel 0000: MCS 0 0001: MCS 1 … 1101: MCS 13 1110: MCS 122 1111: MCS 123	
$b_{68}b_{67} \ldots b_{50}$	reserved	
$b_{84}b_{83} \ldots b_{69}$	16-bit CRC is scrambled by BSTAID	

.

1.7.5.7 Directional broadcast channel

In mmWave mode, Directional broadcast channel(D-BCH) is transmitted periodically to allow STAs to received network information and perform initial access. The structure of frames following D-BCH is defined in 1.7.1.1.

Directional broadcast channel(D-BCH) are composed of Directional System information(D-SICH) and Directional STA initial access(D-RACH). The period of D-BCH can be detected by STA based on the preamble of D-BCH.

The directional system information Bits shall be converted into complex constellation points by using QPSK modulation. The constellation points shall then be spread using the sequence PN_{127}. The directional system information field is defined in Table 75.

The directional System information channel with different beam pattern can be used for completing the base station TX antenna beam training.

The directional System information channel are composed of Synchronous signals, demodulation reference signals and directional System information field.

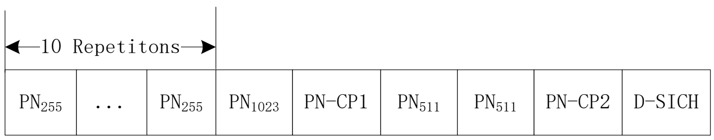
Synchronous signals are transited using the sequence PN_{255} and PN_{1023}, the sequence PN_{255} are transited with the time domain repetition number 10.

10 repetitions of PN_{255} is used for coarse synchronization and frequency offset estimation, PN_{1023} is used for fine synchronization and frequency offset estimation.

The demodulation reference signals are transited using the sequence PN_{511} with the time domain repetition number 2. The CP length for the demodulation reference signals is 127 sequence length and should be added ahead and behind the reference signals.

The structure of the directional System information channel is shown in Figure 88.

FIGURE 88



See Attachment 2 for the values of PN sequence.

TABLE 75

Directional System Information field

Bit	Definition	Notes
$b_7b_6\ldots b_0$	The lowest 8 bits of this CAP MAC address	CAP identifier and scrambling code seed
$b_{19}b_{18}\ldots b_8$	System Frame Number	0~4095,
$b_{25}b_{24}\ldots b_{20}$	Beam Num	≤ 64 Beam
$b_{31}b_{30}\ldots b_{26}$	Beam ID	≤ Beam Num, used to indicate the beam index where the current D-SICH is located, can be used to calculate time synchronization
$b_{44}b_{33}b_{32}$	bandwidth	000: 50M 001: 100M 010: 200M 011: 400M 100: 1GHz 101~111: Reserved

$b_{35}b_{34}$	RACH num	RACH number for a single Beam: 00： 1 01： 2 10： 4 11： 8
$b_{37}b_{36}$	RACH Root set	Indicates ZC sequence root set index: 00: 1 01: 2 10: 3 11: 4
$b_{41}b_{40}b_{39}b_{38}$	Cap txpower	Indicates that CAP's current transmit power in dBm: 0000: 40 0001: 29 0010: 22.4 0011: 34
b_{42}	BeamLoad	Indicates the current beam load: 0: Light load 1: Heavy load
b_{43}	D-BCH Length	0: 0.5ms 1: 1ms
b_{45}	Reserved	
b_{61} b_{60}… b_{46}	CRC	CRC protection

Directional STA initial access(D-RACH)：

– The initial channel access of D-RACH is based on a fully competitive mode, including the corresponding RACH channel resources and the preamble. The available random-access resources and preamble sets can be obtained by receiving the D-SICH.

– The initial random access process includes scanning different beams to obtain relevant D-SICH information, selecting the RACH channel corresponding to the most appropriate beam, randomly selecting a preamble in the alternative set to initiate the access and waiting to receive a random access response (DL-CCH) message which carries the initial TA, allocated uplink transmission resources, etc., and then the STA uses the allocated resources to send the first uplink message (connection establishment request) while opening a window to wait for the connection establishment response message. If the access fails, the STA can continuously try to initiate an access for several times.

The D-RACH preamble is Zadoff-Chu sequence with Length = 1023， and the sequences are generated according to the equation following:

$$Z(n) = e^{j\pi\frac{\mu n^2}{N}},\ \ n = 0,1,\ldots \mathrm{N}-1; N = 1023\ ；\mu：\text{root index}$$

Equation 31

1.7.6 Downlink/ Uplink sounding channel

1.7.6.1 Downlink sounding channel

When the system information field SICH indicates that the frame is configured with downlink sounding channel, which can be used to measure downlink channel and obtain uplink channel state information by channel reciprocity. The specific location of the downlink traffic channel and the downlink sounding channel is indicated by the MAC layer BCF frame.

The generation of downlink sounding pilot is same as DRS, as shown in 1.7.5.3.4. It should be noted that the SPI_F is fixed to be 4 and the Nsts should be replaced with N_{tx}, where N_{tx} is the number of transmit antenna of CAP. The number of OFDM symbols which sounding pilot occupies depends on the value of the subcarrier offset indication of DRS/Sounding Pilot in SICH. If there is subcarrier offset, the OFDM symbol number of sounding pilot is N_{tx}. Otherwise, the OFDM symbol number of sounding pilot is $\left\lceil \frac{N_{tx}}{SPI_F} \right\rceil$.

1.7.6.2 Uplink sounding channel

When the system information field SICH indicates that the frame is configured with uplink sounding channel, which can be used to measure uplink channel and obtain downlink channel state information by channel reciprocity. The detailed configuration of uplink sounding channel is defined in CCH.The number of OFDM symbols which sounding pilot occupies depends on the value of the subcarrier offset indication of DRS/Sounding Pilot in SICH. If there is subcarrier offset, the OFDM symbol number of sounding pilot is N_{tx}. Otherwise, the OFDM symbol number of sounding pilot is $\left\lceil \frac{N_{tx}}{SPI_F} \right\rceil$.

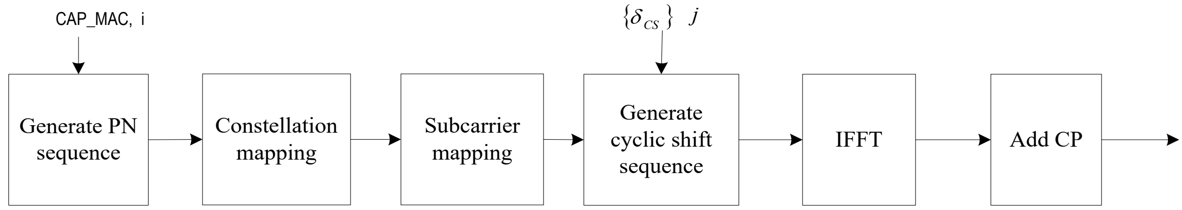
1.7.7 Uplink scheduling request channel

1.7.7.1 General

The position of the uplink scheduling request channel (UL SRCH) in the uplink frame is in Figure 66. Each STA can randomly select a subband to transmit it’s SRCH. The request signal for each subband is generated in accordance with the method shown in Figure 89.

FIGURE 89

Scheduling request signal generation method



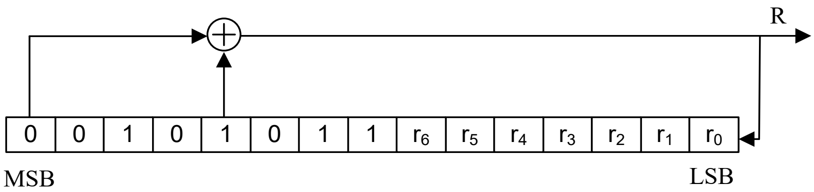
In the figure, CAP_MAC means that the lowest 7 bits of the CAP’s MAC address. i is the PN sequence index （$0 \le i < 4$）， $\{\delta_{CS}\}$ is the cyclic shift parameter set, and j is the cyclic shift parameter index (0≤j < 8). Each STA shall randomly select the value of i and j with equal probability.

1.7.7.2 Generation of PN sequences

The PN sequence adopts the linear feedback shift register sequence with the maximum length with a generator polynomial of $1+X^{11}+X^{15}$. Its block diagram is shown in Figure 90.

FIGURE 90

PN sequence generator



The initial value of the register is $r_{init} = [00101011r_6r_5r_4r_3r_2r_1r_0]_b$, MSB is on the left and the LSB on the right; where $[r_6r_5r_4r_3r_2r_1r_0]_b$ = CAP_MAC, are the lowest 7 bits of the CAP's MAC address.

The generated PN sequence {X} is divided into 16 different PN sequence $\{S_i, i = 0\sim15\}$, where S_i = X[i*1024 i*1024+1 … (i+1)*1024-1].

1.7.7.3 Modulation mapping

Sequence S_i is BPSK-modulated to obtain sequence C_i.

1.7.7.4 Subcarrier mapping

The first N_{su} modulated symols in sequence C_i is mapped to useful subcarriers to obtain sequence M_i.

1.7.7.5 Frequency domain cyclic shift

The subcarrier mapped sequence $M_i$is cyclically shifted according to Equation 32 to obtain sequence T_i.

$$T_{i,k}^{m} = M_{i,k}e^{-j\frac{2\pi k\delta_{CS}^{m}}{N_{FFT}}}$$

Equation 32

Where, N_{FFT} is the number of FFT points, $k \in [-\frac{N_{FFT}}{2}, \frac{N_{FFT}}{2} - 1]$ is index of subcarrier, and the unit is the number of sampling points. $\{\delta_{CS}^{m}\} = \left\{0, \frac{N_{FFT}}{8}, \frac{2\times N_{FFT}}{8}, \ldots, \frac{7\times N_{FFT}}{8}\right\}$, where m is the index of cyclic shift.

1.7.7.6 Resource allocation for independent resource request frame

The CAP allocates the UL-TCH resources occupied by the independent resource request frame to the STA through the signaling shown in Table 76.

TABLE 76

Source allocation for independent resource request frame

<table>
<tr><th colspan="2">Bit</th><th>Definition</th></tr>
<tr><td colspan="2">$b_3\ b_2\ b_1\ b_0$</td><td>Broadcast type:
$b_3\ b_2\ b_1\ b_0$=0110, independent resource request frame (allocation of resources for independent resource Request frame)</td></tr>
<tr><td colspan="2">$b_7\ b_6\ b_5\ b_4$</td><td>b_5b_4=00, the resource allocation of this independent resource request frame is for 3 allocations
b_5b_4=01, the resource allocation of this independent resource request frame is for 2 allocations.
b_5b_4=10, the resource allocation of this independent resource request frame is for 1 allocation
b_7b_6: reserved</td></tr>
<tr><td colspan="2" rowspan="5">$b_{23}\ b_{22}\ \ldots\ b_8$
Allocation 1</td><td>b_9b_8=00, corresponding to the scheduling request to the first OFDM symbol of UL-SRCH;
b_9b_8=01, corresponding to the scheduling request to the second OFDM symbol of UL-SRCH;
b_9b_8=10, corresponding to the scheduling request to the third OFDM symbol of UL-SRCH;
b_9b_8=11, corresponding to the scheduling request to the fourth OFDM symbol of UL-SRCH;</td></tr>
<tr><td>$b_{11}\ b_{10}$, PN sequence index, field value 0~3</td></tr>
<tr><td>$b_{14}\ b_{13}\ b_{12}$, PN sequence frequency domain circular shift index,</td></tr>
<tr><td>$b_{17}\ b_{16}\ b_{15}$, indication of the lowest 3 bits of the system frame number generated by random access</td></tr>
<tr><td>$b_{23}\ b_{22}\ldots\ b_{18}$, the starting position index of the resources allocated to the scheduling request on the signaling/feedback channel, with the field value ranging from 1 to 63, and value 0 is invalid.</td></tr>
<tr><td colspan="2" rowspan="5">$b_{39}\ b_{38}\ \ldots\ b_{24}$
Allocation 2, if b_5b_4 = 00 or 01</td><td>$b_{25}b_{24}$, defined the same as b_9b_8</td></tr>
<tr><td>$b_{27}\ b_{26}$, PN sequence index, field value 0~3</td></tr>
<tr><td>$b_{30}\ b_{29}\ b_{28}$, PN sequence frequency domain circular shift index,</td></tr>
<tr><td>$b_{33}\ b_{32}\ b_{31}$, indication of the lowest 3 bits of the system frame number generated by random access</td></tr>
<tr><td>$b_{39}\ b_{38}\ldots\ b_{34}$, the starting position index of the resources allocated to the scheduling request on the signaling/feedback channel, with the field value ranging from 1 to 63, and value 0 is invalid.</td></tr>
<tr><td rowspan="5">$b_{55}\ b_{54}\ \ldots\ b_{40}$</td><td rowspan="5">$b_5b_4$=00, allocation 3</td><td>$b_{41}b_{40}$, defined the same as b_9b_8</td></tr>
<tr><td>$b_{43}\ b_{42}$, PN sequence index, field value 0~3</td></tr>
<tr><td>$b_{46}b_{45}b_{44}$, PN sequence frequency domain circular shift index.</td></tr>
<tr><td>$b_{49}\ b_{48}\ b_{47}$, indication of the lowest 3 bits of the system frame number generated by random access</td></tr>
<tr><td>$b_{55}b_{54}\ldots b_{50}$, the starting position index of the resources allocated to the scheduling request on the signaling/feedback channel, with the field value ranging from 1 to 63, and value 0 is invalid.</td></tr>
<tr><td>$b_{55}\ b_{54}\ \ldots\ b_{40}$</td><td>$b_5b_4$ = 01</td><td>b_{40}=0: allocation 1, subband copy
b_{40}=1: allocation 1, sideband transmission
b_{41}=0: allocation 2, subband copy
b41=1: allocation 2, sideband transmission
$b_{45}\ldots b_{42}$: allocation 1 is sent on this subband (b_{40}=1 is valid)
$b_{49}\ldots b_{46}$: allocation 2 is sent on this subband (b_{41}=1 is valid)
$b_{63}\ldots b_{50}$: Reserved</td></tr>
<tr><td>$b_{55}\ b_{41}\ \ldots\ b_{24}$</td><td>$b_5b_4$ = 10 for allocation 1</td><td>b_{24}=0: allocation 1, subband copy
b_{24}=1: allocation 1, subband transmission
$b_{28}\ldots b_{25}$: subband bitmap, set to “1” if allocation 1 is sent on this subband (if b_{24}=1)</td></tr>
</table>

		$b_{42}\ldots b_{29}$: OFDMA resource unit bitmap $b_{48}\ldots b_{43}$: the number of OFDM symbols $b_{55}\ldots b_{49}$: Reserved
$b_{68}\ldots b_{56}$	$b_5b_4 = 10$	$b_{59}\ldots b_{56}$: MCS Indication for allocation 1 0000: MCS 0 0001: MCS 1 … 1101: MCS 13 1110: MCS 122 1111: MCS 123 $b_{68}\ldots b_{60}$: reserved
$b_{68}\ldots b_{56}$	$b_5b_4 = 01$	$b_{59}\ldots b_{56}$: MCS Indication for allocation 1 $b_{63}\ldots b_{60}$: MCS Indication for allocation 2 Each 4 bits of allocation 1/2, 0000: MCS 0 0001: MCS 1 … 1101: MCS 13 1110: MCS 122 1111: MCS 123 $b_{68}\ldots b_{64}$: reserved
$b_{68}\ldots b_{56}$	$b_5b_4 = 00$	$b_{59}\ldots b_{56}$: MCS Indication for allocation 1 $b_{63}\ldots b_{60}$: MCS Indication for allocation 2 $b_{67}\ldots b_{64}$: MCS Indication for allocation 2 Each 4 bits of allocation 1/2/3, 0000: MCS 0 0001: MCS 1 … 1101: MCS 13 1110: MCS 122 1111: MCS 123 b_{68}: reserved
$b_{84}\, b_{83} \ldots b_{69}$		16-bit CRC is scrambled by BSTAID

1.7.8 Uplink random access channel

1.7.8.1 Generation of random access signal

The position of the uplink random access channel (UL RACH) is at the end of the uplink frame as shown in Figure 69. Each STA can randomly select a subband to transmit it's RACH. The frequency domain RACH signal for each subband is generated in the same way as UL SRCH, as specified in 1.7.7.1~1.7.7.5, where Each STA shall randomly select the value of i and j with equal probability. It should be noted that different frequency domain cyclic shift values are used, as shown in the following sections.

The frequency domain RACH signal generated is transformed to time domain signal with the sampling points of N_{FFT}. CP and GP (Guard Period) are then added to generate the RACH channel, where there is no signal transmitting during GP.

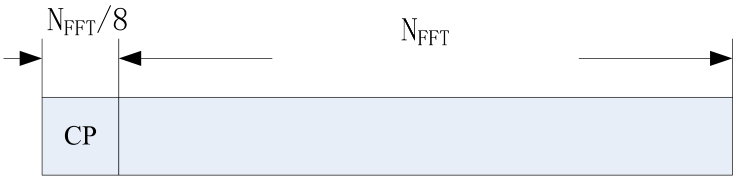
1.7.8.2 Random access channel format

There are 3 RACH formats with different configurations of CP and GP. The RACH format is indicated by BCF. The format 1 RACH can be repeated transmitted to increase the reliability as specified in BCF.

1.7.8.2.1 Format 1

FIGURE 91

The format 1 of RACH

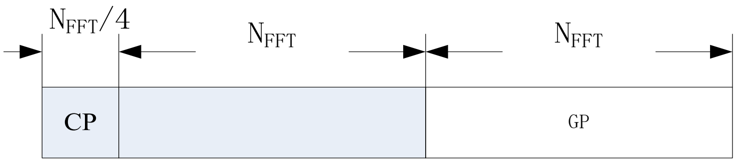


$$\{\delta_{CS}\} = \left\{0, \frac{N_{FFT}}{8}, \frac{2\times N_{FFT}}{8}, \ldots, \frac{7\times N_{FFT}}{8}\right\}.$$

1.7.8.2.2 Format 2

FIGURE 92

The format 2 of RACH

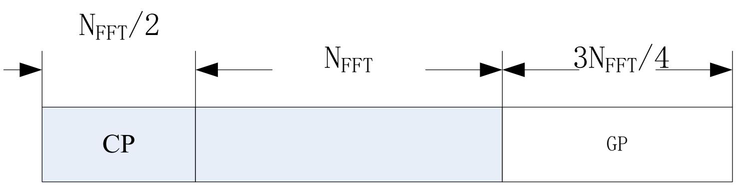


$$\{\delta_{CS}\} = \left\{0, \frac{N_{FFT}}{4}, \frac{2\times N_{FFT}}{4}, \frac{3\times N_{FFT}}{4}\right\}$$

1.7.8.2.3 Format 3

FIGURE 93

The format 3 of RACH



$$\{\delta_{CS}\} = \left\{0, \quad \frac{N_{FFT}}{2}\right\}$$

1.7.8.3 Resource allocation for random access request frame

After receiving the RACH from STA, the CAP allocates the UL signaling/feedback channel resources occupied by the random access request frame to the STA through broadcasting CCH shown in Table 77.

TABLE 77

Resource allocation for random access request frame

<table>
<tr><th colspan="2">Bit</th><th>Definition</th></tr>
<tr><td colspan="2">b_3 b_2 b_1 b_0</td><td>Broadcast type
b_3 b_2 b_1 b_0=0100, random access request (allocate resources for random access request frame)</td></tr>
<tr><td colspan="2">b_7 b_6 b_5 b_4</td><td>b_4=0, the resource allocation indication is for 2 STAs.
b_4=1, the resource allocation indication is for 1 STA.
b_7...b_5, reserved</td></tr>
<tr><td colspan="2" rowspan="5">b_{31} b_{30}… b_8
Allocation 1</td><td>b_9 b_8, PN sequence index, field value 0 - 3</td></tr>
<tr><td>b_{12} b_{11} b_{10}, PN sequence frequency domain circular shift index,</td></tr>
<tr><td>b_{15} b_{14} b_{13}, the lowest 3 bits of the system frame number generated by Random Access</td></tr>
<tr><td>b_{25} b_{24}... b_{16}, transmission timing advance</td></tr>
<tr><td>b_{31} b_{30}... b_{26}, the starting position index of the resources allocated to Random Access Request on the signaling/feedback channel, with the field value ranging from 1 to 63, and value 0 is invalid.</td></tr>
<tr><td rowspan="6">b_{55} b_{54}…
b_{32}</td><td rowspan="5">b_4=0,
allocation
2</td><td>b_{33} b_{32}, PN sequence index, field value 0 - 3</td></tr>
<tr><td>b_{36} b_{35}... b_{34}, PN sequence frequency domain circular shift index,</td></tr>
<tr><td>b_{39} b_{38} b_{37}, the lowest 3 bits of the system frame number generated by Random Access</td></tr>
<tr><td>b_{49} b_{48}... b_{40}, transmission timing advance</td></tr>
<tr><td>$b_{55}b_{54}$... b_{50}, the starting position index of the resources allocated to Random Access Request on the signaling/feedback channel, with the field value ranging from 1 to 63, and value 0 is invalid.</td></tr>
<tr><td>b_4=1</td><td>b_{38}…b_{32}, the high bits of the transmission timing advance
b_{55}...b_{39}, reserved</td></tr>
<tr><td colspan="2">b_{56}</td><td>MCS Indication for random access request frame
0: MCS 1
1: MCS 123</td></tr>
<tr><td colspan="2">b_{68} … b_{57}</td><td>reserved</td></tr>
<tr><td colspan="2">b_{84} b_{83} … b_{69}</td><td>16-bit CRC is scrambled by BSTAID</td></tr>
</table>

1.7.8.4 Resource allocation for random access response frame

The CAP indicates the DL signaling/feedback channel resources occupied by the random access response frame to the STA through the signaling shown in Table 78.

TABLE 78

Resource allocation for random access response frame

Bit	Definition
$b_3\ b_2\ b_1\ b_0$	Broadcast type $b_3\ b_2\ b_1\ b_0$=0101, Random Access Response Frame (allocate resources for Random Access Response frame)
$b_6\ b_5\ b_4$	b_4=0: allocation 1, subband copy b_4=1: allocation 1 is transmitted on corresponding subband, and no copy is performed. b_5=0: allocation 2, subband copy b_5=1: allocation 2 is transmitted on corresponding subband, and no copy is performed. b_6=0: allocation 3, subband copy b_6=1: allocation 3 is transmitted on corresponding subband, and no copy is performed.
b_7	MCS Indication for random access response frame 0: MCS 1 1: MCS 123
$b_{23}\ b_{22} \ldots b_8$ Allocation 1	$b_9\ b_8$, PN sequence index, field value 0 - 3
	$b_{12}\ b_{11}\ b_{10}$, PN sequence frequency domain circular shift index. The circular shift of 000 is 0, of 001 is32, and of 111 is 224
	$b_{15}\ b_{14}\ b_{13}$, the lowest 3 bits of the system frame number generated by Random Access
	$b_{21}\ b_{20} \ldots b_{16}$, the starting position index of the resources allocated to Random Access Request on the signaling/feedback channel, with the field value ranging from 1 to 63, and value 0 is invalid.
	$b_{23}\ b_{22}$, allocation 1 is sent in this sub-band
$b_{39}\ b_{38} \ldots b_{24}$ Allocation 2	$b_{25}\ b_{24}$, PN sequence index, field value 0 - 3
	$b_{28}\ b_{27} \ldots b_{26}$, PN sequence frequency domain circular shift index, The circular shift of 000 is 0, of 001 is32, and of 111 is 224
	$b_{31}\ b_{30}\ b_{29}$, the lowest 3 bits of the system frame number generated by Random Access
	$b_{37}\ b_{36} \ldots b_{32}$, the starting position index of the resources allocated to Random Access Response on the signaling/feedback channel, with the field value ranging from 1 to 63, and value 0 is invalid.
	$b_{39}\ b_{38}$, allocation 2 is sent in this sub-band.
$b_{55}\ b_{54} \ldots b_{40}$ Allocation 3	$b_{41}\ b_{40}$, PN sequence index, field value 0~3
	$b_{44}\ b_{43}\ b_{42}$, PN sequence frequency domain circular shift index, The circular shift of 000 is 0, of 001 is 32, and of 111 is 224
	$b_{47}\ b_{46}\ b_{45}$, the lowest 3 bits of the system frame number generated by Random Access
	$b_{53}\ b_{52} \ldots b_{48}$, the starting position index of the resources allocated to Random Access Response on the signaling/feedback channel, with the field value ranging from 1 to 63, and value 0 is invalid.
	$b_{55}\ b_{54}$, allocation 3 is sent in this sub-band.
$b_{71}\ b_{70} \ldots b_{56}$	16-bit CRC is scrambled by BSTAID

1.7.9 Uplink power and timing advance control

1.7.9.1 Open loop power control

If a STA transmits a UL-TCH on component carrier *cc*, the STA determines the UL-TCH transmission power $P_{STA,cc}$ as Equation 33:

$$P_{STA,cc} = min\{P_{STA_{MAX},cc}, \quad P_{0,\text{cc}} + \alpha_{cc} \times PL_{OL,cc} + 10 * \log10(N_{ru.cc})\}(dBm)$$

Equation 33

Where：

- $P_{STA_{MAX},cc}$: is the configured STA maximum output power on component carrier *cc* by CAP BCF TLV frame;
- $\boldsymbol{P_{0,cc}}$: is the target received power in dBm on component carrier *cc* configured by CAP BCF TLV frame and should consider different subcarrier spacing of channel;
- α_{cc}: is the compensation factor of total path loss for partial power control on component carrier *cc* configured by CAP BCF TLV frame;
- $PL_{OL,cc}$: is the transmission path loss estimated in dB on component carrier *cc*. It can be estimated according to the STA received signal power and the CAP transmit power. The CAP transmit power is indicated in the MAC layer BCF frame. In mmWave mode, the CAP transmit power is given in D-SICH.
- $N_{ru.cc}$: is the number of RUs which is allocated to STA on component carrier *cc* in current frame;

If a STA transmits SRS on component carrier *cc*, the STA can also determine the UL SRS transmission power $P_{STA\_SRS,cc}$ as Equation 33, but for SRS the value $P_{0,cc}$ and α_{cc} can be configured differently by CAP BCF TLV frame.

If a STA transmits PARCH on component carrier *cc*, the STA can also determine the initial UL PARCH transmission power $P_{STA\_PRACH,cc}$ as Equation 33, but for PRACH the value $\alpha_{cc} = 1$ and $P_{0,cc}$ is configured by CAP BCF TLV frame.

Other open power control schemes can be used to achieve better performance.

1.7.9.2 Closed loop power and timing advance control

The closed loop power control is transmitted by broadcasting CCH, shown in Table 79.

TABLE 79

Closed loop control signaling

Bit	Definition
$b_3\ b_2\ b_1\ b_0$	Broadcast type $b_3\ b_2\ b_1\ b_0$=1001, closed loop link control
$b_7\ b_6\ b_5\ b_4$	b_4=0, the closed-loop control signaling is for 100ns resolution of TA. b_4=1, the closed-loop control signaling is for 50ns resolution of TA. $b_7 ... b_5$, reserved
$b_{55}\ b_{54} ...\ b_8$	$b_{19} b_{18} ...\ b_8$, STAID

Indication	b_{29} b_{28}... b_{20}, timing advance
	$b_{31}b_{30}$, reserved
	$b_{39}b_{38}$... b_{32}, the transmit power is increased or decreased by n*0.25 dB, where n is the signed decimal number represented by $b_{39}b_{38}$... b_{32} and b_{39} is the sign bit (0: positive, 1: negative). If the value of n is positive, the transmit power is increased. If the value of n is negative, the transmit power is decreased. Each component carrier does closed loop power control independently.
	b_4=0: b_{55}...b_{40} reserved (b_{29}...b_{20} is timing advance, with resolution of 100ns) b_4=1: b_{46}..b_{40}, the high bits of the timing advance ([b_{46}..b_{40} b_{29}..b_{20}] is the timing advance, with resolution of 50ns) b_{55}...b_{47}, reserved
b_{71} … b_{56}	16-bit CRC is scrambled by BSTAID

1.7.10 Uplink distance measurement-based scheduling

The CAP can assign PN sequence index and circular shift index for STA to measure the distance. The assignment is indicated in broadcast CCH, as shown in Table 80.

TABLE 80

Indication of uplink distance measurement based scheduling

Bit	Definition
$b_3b_2b_1b_0$	Broadcast type $b_3b_2b_1b_0$=1011, measurement indication
$b_7b_6b_5b_4$	Reserved
$b_{31}b_{30}\cdots b_8$ Indication	$b_{19}b_{18}\cdots b_8$, STAID
	$b_{21}b_{20}$, PN sequence index
	$b_{23}b_{22}$, reserved
	$b_{26}b_{25}b_{24}$, circular shift index
	$b_{31}b_{30}\cdots b_{27}$, reserved
$b_{55}b_{54}\cdots b_{32}$ Indication	$b_{43}b_{42}\cdots b_{32}$, STAID
	$b_{45}b_{44}$, PN sequence index
	$b_{47}b_{46}$, reserved
	$b_{50}b_{49}b_{48}$, circular shift index
	$b_{55}b_{54}\cdots b_{51}$, reserved
b_{71} $b_{70}\cdots b_{56}$	16-bit CRC is scrambled by BSTAID

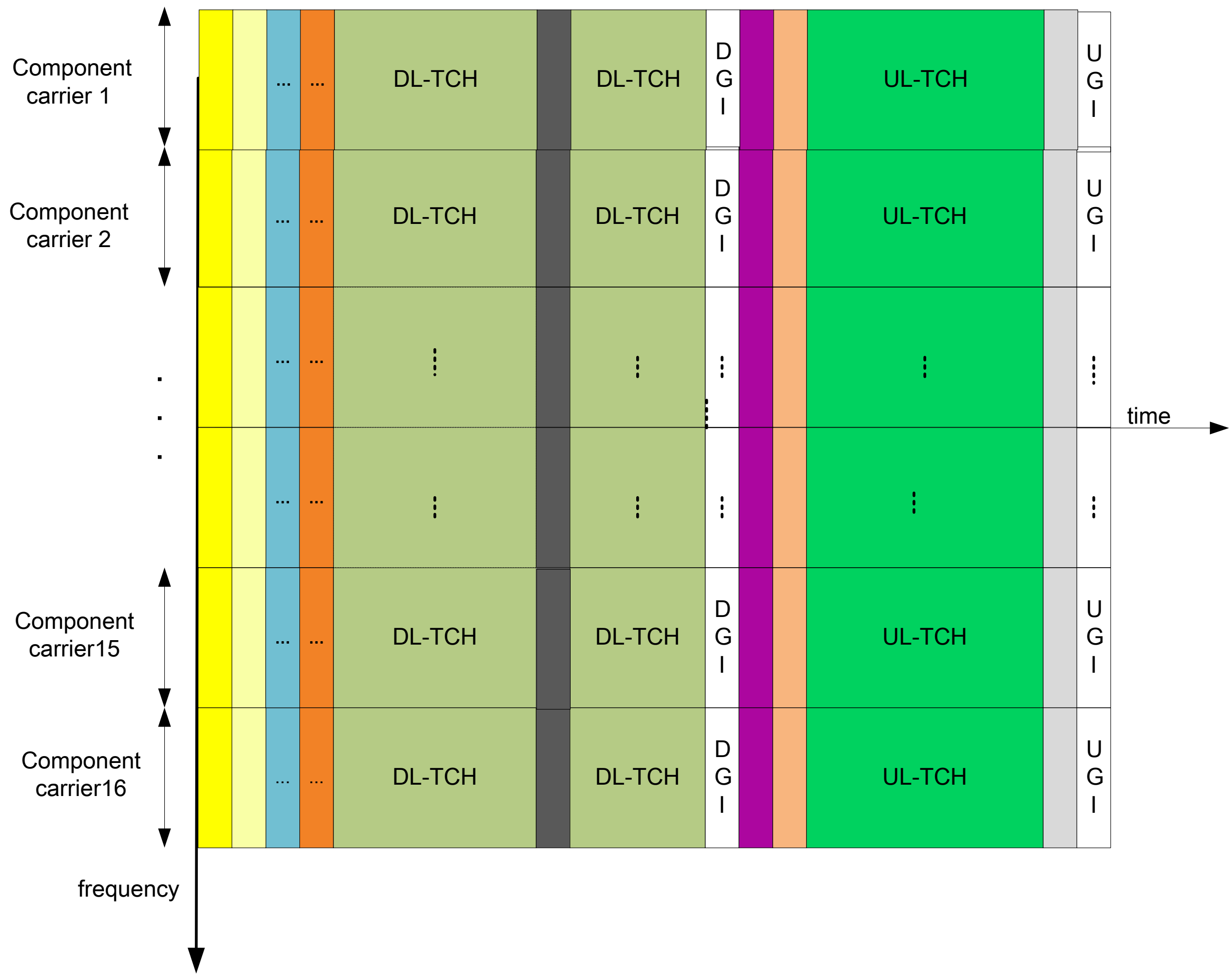
1.7.11 Carrier aggregation mode

The EUHT-5G system uses component carriers to support higher bandwidths by carrier aggregation (CA) in all modes as shown in Figure 94. The number of component carriers is up to 16. The information of component carriers is broadcasted in BCF by CAP as indicated in section 1.5.3.4.1. To avoid the interference between component carriers, the frame length of each component carrier is suggested to be same and the downlink/uplink switch timing is suggested to be aligned.

Preamble sequence and parameters for each component carrier follow the rules defined in section 1.7.3. The SICH, CCH and TCH of each component carrier are independent with that of other component carriers. Therefore, CAP or STA can decide which component carriers are used to transmit control signalling and data traffic since each component carrier has its own SICH, CCH and TCH. STA shall monitor the SICH and CCH of all CCs it used and receive the data in TCH of CCs based on the resource allocation information obtained in CCH. It should be noted that one MAC PDU will not be split into serveral parts and sent on several CCs. The unique sequence number (SN) in MAC header will be used by the MAC layer entity in CAP /STA to correctly re-assemble MAC data unit (MPDU) in all CCs.

FIGURE 94

Carrier aggregation mode



1.7.12 Transmitter and receiver specifications

The requirements in this section should be met for each component carrier in CA mode.

1.7.12.1 Transmit power

The maximum output power of CAP and STA is limited by regional regulatory requirements.

1.7.12.2 Transmission frequency and Symbol clock frequency tolerance

The transmission frequency and Symbol clock frequency tolerance is subject to the requirements specified in the relevant documents of the Radio Management Department. Different transmission link center frequencies (LO) and each transmit link symbol clock frequency shall be generated by the same reference oscillator.

1.7.12.3 Transmitter constellation error

The averaging RMS error of the transmitted constellation frame shall not exceed the value defined in Table 81.

TABLE 81

Relation between the allowable relative constellation error, constellation size and coding rate

Modulation	Coding rate	Relative constellation error / dB
BPSK	1/2	-6
BPSK	4/7	-7
QPSK	1/2	-10
QPSK	4/7	-11
QPSK	3/4	-13
16-QAM	1/2	-16
16-QAM	4/7	-17
16-QAM	5/8	-18
16-QAM	3/4	-20
16-QAM	7/8	-21
64-QAM	5/8	-24
64-QAM	3/4	-25
64-QAM	5/6	-26
64-QAM	7/8	-27
256-QAM	3/4	-30
256-QAM	5/6	-32
256-QAM	7/8	-33
1024-QAM	3/4	-35
1024-QAM	7/8	-38

1.7.12.4 Minimum input sensitivity of receiver

For a packet with a length of 1000 bytes payload, when the packet error rate is less than 10%, the minimum sensitivity of the receiver input level is shown in Table 82. The sensitivity requirements apply for both convolutional coding and LDPC. It should be noted that the table below only shows the requirement for 20MHz. The requirements for bandwidth of W MHz can be obtained by adding the values at 20MHz to 10*log10(W/20).

TABLE 82

Minimum input level sensitivity of receiver

Modulation	Coding rate R	Minimum sensitivity / dBm (20MHz bandwidth)
BPSK	1/2	-82
BPSK	4/7	-81
QPSK	1/2	-79
QPSK	4/7	-78
QPSK	3/4	-77
16-QAM	1/2	-74
16-QAM	4/7	-73
16-QAM	5/8	-72
16-QAM	3/4	-70
16-QAM	7/8	-69
64-QAM	5/8	-66
64-QAM	3/4	-65
64-QAM	5/6	-64
64-QAM	7/8	-63
256-QAM	3/4	-60
256-QAM	5/6	-58
256-QAM	7/8	-57
1024-QAM	3/4	-54
1024-QAM	7/8	-51

2 Band class information and Unwanted emission characteristics (including Spectrum Mask, spurious, ACLR)

2.1 Working frequency band and channel

The system defined in this specification can operate in the sub-6G band and millimeter wave band, or other bands that may be planned in the future. See Attachment 5 for more information.

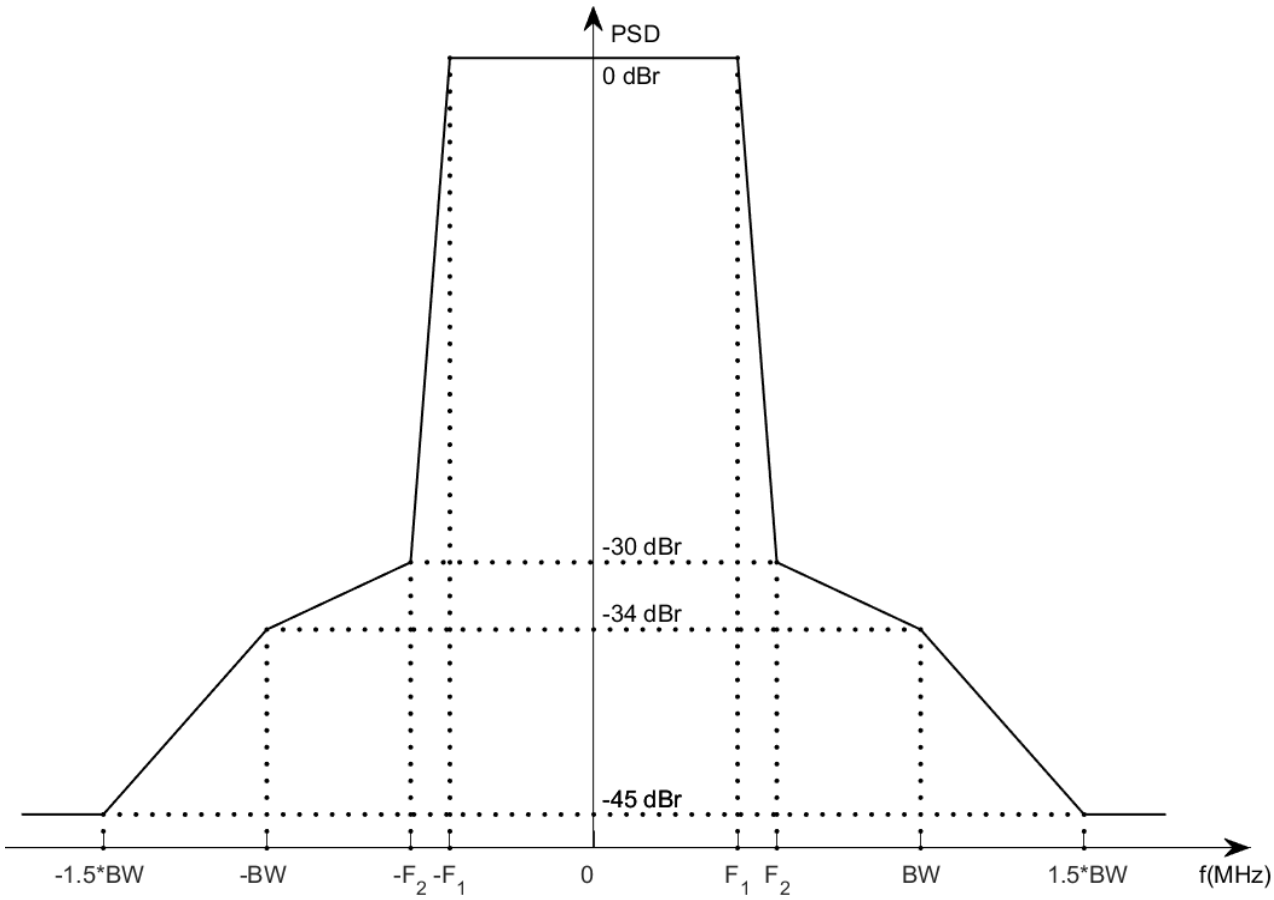
2.2 Unwanted emission characteristics (including Spectrum Mask, spurious, ACLR)

The spectrum emission template for bandwidth (BW) is shown in Figure 95, where $F_1 = \frac{BW}{2} - d_F, F_2 = \frac{BW}{2} + d_F,\ d_F = \left(\frac{N_{FFT}}{2} - N_{sr} - 1\right) \times \Delta_f$

It should be noted that the spectrum emission templates are also subject to the regional regulatory requirements.

FIGURE 95

Spectrum emission template



Adjacent Channel Leakage power Ratio is the ratio of the filtered mean power centred on the assigned channel frequency to the filtered mean power centred on an adjacent channel frequency at nominal channel spacing.

The assigned channel power and adjacent channel power are measured with rectangular filters with measurement bandwidths specified in occupied bandwidth by useful data and DC.

The ACLR should be larger than 31 dB according to spectrum emission template.

Spurious emissions are emissions which are caused by unwanted transmitter effects such as harmonics emission, parasitic emissions, intermodulation products and frequency conversion products, but exclude out of band emissions unless otherwise stated. The spurious emission limits are specified in terms of general requirements in line with Rec. ITU-R SM.329.

The requirements above should be met for each component carrier in CA mode.

Attachment 1 (Normative)
MCS Parameters

Table A. 1defines the symbols used for the MCS parameter table, and the symbols in the symbol-dependent rate table.

TABLE A. 1

Symbols used for the MCS parameter table

Symbol	Definition
R	Code rate
N_{BPSC}	The sum of the number of encoded bits of all spatial streams per subcarrier

Table Table A. 2 defines the MCS set for each spatial stream in equal-order modulation.

TABLE A. 2

MCS parameters in EQM mode

MCS index number	Modulation mode	N_{ss}	R	N BPSC
0	BPSK	1	1/2	1
1	QPSK	1	1/2	2
2	QPSK	1	3/4	2
3	16-QAM	1	1/2	4
4	16-QAM	1	5/8	4
5	16-QAM	1	3/4	4
6	16-QAM	1	7/8	4
7	64-QAM	1	5/8	6
8	64-QAM	1	3/4	6
9	64-QAM	1	5/6	6
10	64-QAM	1	7/8	6
11	256-QAM	1	3/4	8
12	256-QAM	1	5/6	8
13	256-QAM	1	7/8	8
14	BPSK	2	1/2	2
15	QPSK	2	1/2	4
16	QPSK	2	3/4	4
17	16-QAM	2	1/2	8
18	16-QAM	2	5/8	8
19	16-QAM	2	3/4	8

20	16-QAM	2	7/8	8
21	64-QAM	2	5/8	12

TABLE A.2 (CONTINUED)

MCS index number	**Modulation mode**	**N_{ss}**	**R**	**N_{BPSC}**
22	64-QAM	2	3/4	12
23	64-QAM	2	5/6	12
24	64-QAM	2	7/8	12
25	256-QAM	2	3/4	16
26	256-QAM	2	5/6	16
27	256-QAM	2	7/8	16
28	BPSK	3	1/2	3
29	QPSK	3	1/2	6
30	QPSK	3	3/4	6
31	16-QAM	3	1/2	12
32	16-QAM	3	5/8	12
33	16-QAM	3	3/4	12
34	16-QAM	3	7/8	12
35	64-QAM	3	5/8	18
36	64-QAM	3	3/4	18
37	64-QAM	3	5/6	18
38	64-QAM	3	7/8	18
39	256 QAM	3	3/4	24
40	256 QAM	3	5/6	24
41	256-QAM	3	7/8	24
42	BPSK	4	1/2	4
43	QPSK	4	1/2	8
44	QPSK	4	3/4	8
45	16-QAM	4	1/2	16
46	16-QAM	4	5/8	16
47	16-QAM	4	3/4	16
48	16-QAM	4	7/8	16
49	64-QAM	4	5/8	24
50	64-QAM	4	3/4	24

51	64-QAM	4	5/6	24
52	64-QAM	4	7/8	24
53	256-QAM	4	3/4	32
54	256-QAM	4	5/6	32
55	256-QAM	4	7/8	32

Table A. 3 defines the MCS set for 2 spatial streams in unequal modulations.

TABLE A. 3

MCS parameters of UEQM with N_{ss} = 2

MCS index number	Modulation mode		R	N_{BPSC}
	Stream 1	Stream 2		
56	16-QAM	QPSK	1/2	6
57	64-QAM	QPSK	1/2	8
58	64-QAM	16-QAM	1/2	10
59	16-QAM	QPSK	3/4	6
60	64-QAM	QPSK	3/4	8
61	64-QAM	16-QAM	3/4	10

Table A. 4 defines the MCS set for 3 spatial streams in unequal modulations.

TABLE A. 4

MCS parameters of UEQM with N_{ss} = 3

MCS index number	Modulation mode			R	N_{BPSC}
	Stream 1	Stream 2	Stream 3		
62	16-QAM	QPSK	QPSK	1/2	8
63	16-QAM	16-QAM	QPSK	1/2	10
64	64-QAM	QPSK	QPSK	1/2	10
65	64-QAM	16-QAM	QPSK	1/2	12
66	64-QAM	16-QAM	16-QAM	1/2	14
67	64-QAM	64-QAM	QPSK	1/2	14
68	64-QAM	64-QAM	16-QAM	1/2	16
69	16-QAM	QPSK	QPSK	3/4	8
70	16-QAM	16-QAM	QPSK	3/4	10
71	64-QAM	QPSK	QPSK	3/4	10
72	64-QAM	16-QAM	QPSK	3/4	12

73	64-QAM	16-QAM	16-QAM	3/4	14
74	64-QAM	64-QAM	QPSK	3/4	14
75	64-QAM	64-QAM	16-QAM	3/4	16

Table A. 5 defines the MCS set for 4 spatial streams in unequal modulations.

TABLE A. 5

MCS parameters of UEQM with $N_{ss} = 4$

MCS index number	Modulation mode				R	N_{BPSC}
	Stream 1	Stream 2	Stream 3	Stream 4		
76	16-QAM	QPSK	QPSK	QPSK	1/2	10
77	16-QAM	16-QAM	QPSK	QPSK	1/2	12
78	16-QAM	16-QAM	16-QAM	QPSK	1/2	14
79	64-QAM	QPSK	QPSK	QPSK	1/2	12
80	64-QAM	16-QAM	QPSK	QPSK	1/2	14
81	64-QAM	16-QAM	16-QAM	QPSK	1/2	16
82	64-QAM	16-QAM	16-QAM	16-QAM	1/2	18
83	64-QAM	64-QAM	QPSK	QPSK	1/2	16
84	64-QAM	64-QAM	16-QAM	QPSK	1/2	18
85	64-QAM	64-QAM	16-QAM	16-QAM	1/2	20
86	64-QAM	64-QAM	64-QAM	QPSK	1/2	20
87	64-QAM	64-QAM	64-QAM	16-QAM	1/2	22
88	16-QAM	QPSK	QPSK	QPSK	3/4	10
89	16-QAM	16-QAM	QPSK	QPSK	3/4	12
90	16-QAM	16-QAM	16-QAM	QPSK	3/4	14
91	64-QAM	QPSK	QPSK	QPSK	3/4	12
92	64-QAM	16-QAM	QPSK	QPSK	3/4	14
93	64-QAM	16-QAM	16-QAM	QPSK	3/4	16
94	64-QAM	16-QAM	16-QAM	16-QAM	3/4	18
95	64-QAM	64-QAM	QPSK	QPSK	3/4	16
96	64-QAM	64-QAM	16-QAM	QPSK	3/4	18
97	64-QAM	64-QAM	16-QAM	16-QAM	3/4	20
98	64-QAM	64-QAM	64-QAM	QPSK	3/4	20
99	64-QAM	64-QAM	64-QAM	16-QAM	3/4	22

TABLE A. 6

MCS parameters in EQM mode

MCS index number	Modulation mode	N_{ss}	R	N_{BPSC}
100	BPSK	1	4/7	1
101	QPSK	1	4/7	2
102	16QAM	1	4/7	4
103	1024-QAM	1	3/4	10
104	1024-QAM	1	7/8	10
105	1024-QAM	2	3/4	20
106	1024-QAM	2	7/8	20
107	1024-QAM	3	3/4	30
108	1024-QAM	3	7/8	30
109	1024-QAM	4	3/4	40
110	1024-QAM	4	7/8	40
121	QPSK	1	7/8	2

TABLE A. 7

MCS parameters of UEQM with higher order modulation

MCS index number	Modulation mode				R	N_{BPSC}
	Stream 1	Stream 2	Stream 3	Stream 4		
111	256-QAM	64-QAM	-	-	3/4	14
112	1024-QAM	256-QAM	-	-	3/4	18
113	256-QAM	64-QAM	64-QAM	-	3/4	20
114	1024-QAM	256-QAM	64-QAM	-	3/4	24
115	256-QAM	64-QAM	64-QAM	16-QAM	1/2	24
116	256-QAM	64-QAM	64-QAM	16-QAM	3/4	24
117	1024-QAM	256-QAM	64-QAM	16-QAM	1/2	28
118	1024-QAM	256-QAM	64-QAM	16-QAM	3/4	28
119	1024-QAM	256-QAM	64-QAM	16-QAM	7/8	28

TABLE A. 8

MCS parameters in EQM mode with repetition

MCS index number	Modulation mode	N_{ss}	R	N_{BPSC}
122	QPSK	1	4/7 * 1/3	2

123	QPSK	1	4/7 * 1/4	2

Take MCS 122 as example, it is 4/7 coding rate and QPSK modulation. The QPSK OFDM symbols generated will be repeated 3 times in time domain according to repetition scheme in section 1.7.2.11.

Attachment 2
(Normative)
PN Sequence

TABLE B 1

Values of PN Sequences

PN_{127}	{ 1, 1, 1, 1, 1, 1, -1, -1, -1, -1, -1, -1, -1, 1, -1, 1, -1, 1, -1, 1, 1, -1, -1, 1, 1, -1, -1, -1, 1, -1, -1, -1, 1, -1, 1, 1, -1, 1, -1, -1, 1, 1, 1, -1, -1, 1, -1, -1, -1, -1, 1, -1, -1, 1, -1, 1, -1, -1, 1, -1, -1, 1, 1, -1, 1, 1, -1, 1, 1, 1, -1, -1, -1, 1, 1, 1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, 1, 1, -1, 1, 1, -1, -1, -1, -1, 1, 1, 1, -1, 1, -1, 1, 1, 1, 1, -1, -1, 1, 1, 1, 1, 1, -1};
PN_{255}	{ 1, 1, 1, 1, 1, 1, 1, -1, 1, -1, -1, 1, 1, 1, -1, -1, -1, -1, 1, -1, 1, 1, 1, 1, -1, -1, -1, -1, -1, -1, -1, -1, 1, 1, -1, 1, 1, 1, 1, -1, 1, -1, 1, 1, -1, -1, -1, -1, -1, 1, -1, 1, -1, 1, -1, 1, -1, -1, -1, 1, 1, 1, 1, 1, -1, -1, 1, 1, 1, -1, 1, -1, 1, -1, -1, 1, 1, -1, -1, 1, 1, -1, 1, -1, -1, -1, -1, -1, -1, 1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, -1, -1, 1, -1, -1, -1, 1, 1, -1, 1, -1, 1, -1, 1, 1, -1, 1, -1, 1, 1, 1, -1, 1, 1, -1, 1, -1, -1, 1, -1, 1, 1, 1, -1, -1, 1, 1, -1, -1, -1, 1, 1, -1, -1, -1, -1, 1, 1, 1, -1, -1, 1, -1, -1, 1, 1, 1, 1, -1, 1, 1, 1, -1, 1, -1, -1, -1, 1, -1, 1, -1, -1, -1, -1, 1, -1, -1, 1, -1, -1, -1, -1, -1, 1, 1, 1, 1, -1, -1, 1, -1, 1, 1, -1, -1, 1, -1, 1, -1, -1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1, 1, -1, 1, 1, -1, -1, -1, 1, -1, -1, 1, 1, -1, 1, 1, -1, 1, 1, -1, -1, 1, 1, 1, 1, 1, 1, -1, -1, -1, 1, -1, 1, 1, -1, 1, 1, 1, -1, -1, -1, 1, 1, 1, -1}
PN_{511}	{ 1, 1, 1, 1, 1, 1, 1, 1, -1, 1, 1, 1, -1, 1, 1, 1, -1, -1, 1, 1, -1, 1, 1, 1, -1, -1, -1, 1, -1, 1, -1, 1, -1, -1, 1, -1, -1, 1, 1, 1, -1, -1, -1, 1, 1, 1, -1, 1, 1, -1, 1, -1, 1, -1, 1, 1, 1, -1, -1, 1, -1, -1, 1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, -1, -1, 1, 1, 1, -1, 1, -1, -1, 1, -1, -1, -1, 1, 1, -1, 1, -1, 1, 1, -1, 1, 1, 1, 1, 1, -1, 1, 1, -1, -1, 1, 1, -1, -1, -1, 1, -1, 1,

	1, 1, -1, -1, -1, -1, -1, 1, -1, -1, -1, -1, 1, 1, 1, 1, 1, -1, -1, -1, -1, -1, -1, -1, -1, -1, 1, 1, 1, 1, -1, -1, -1, -1, 1, -1, -1, -1, 1, 1, 1, 1, -1, 1, -1, -1, 1, 1, -1, -1, 1, -1, -1, 1, -1, -1, -1, -1, 1, -1, 1, 1, 1, 1, -1, -1, -1, 1, 1, -1, -1, 1, 1, 1, 1, -1, 1, 1, -1, 1, 1, 1, -1, 1, -1, 1, -1, -1, -1, 1, -1, 1, -1, -1, -1, -1, 1, 1, -1, 1, 1, -1, 1, -1, -1, -1, 1, 1, -1, -1, -1, 1, 1, 1, 1, 1, 1, -1, -1, -1, 1, -1, -1, -1, 1, -1, 1, 1, -1, -1, -1, -1, 1, -1, 1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, 1, -1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, -1, 1, -1, -1, 1, -1, 1, 1, 1, 1, 1, -1, -1, 1, -1, -1, -1, 1, -1, -1, 1, -1, -1, 1, -1, 1, -1, -1, 1, 1, 1, 1, 1, -1, 1, -1, -1, -1, 1, -1, -1, -1, -1, -1, 1, 1, 1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, 1, -1, -1, 1, -1, 1, -1, -1, -1, 1, 1, 1, -1, -1, 1, -1, 1, 1, 1, -1, 1, -1, -1, -1, -1, -1, -1, -1, 1, -1, 1, 1, -1, 1, -1, -1, 1, 1, 1, -1, 1, -1, 1, 1, -1, -1, 1, 1, 1, -1, -1, 1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, 1, 1, -1, 1, 1, -1, -1, -1, -1, -1, -1, 1, -1, -1, 1, -1, 1, 1, -1, 1, 1, -1, 1, 1, -1, -1, 1, -1, -1, -1, -1, -1, -1, 1, 1, -1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1, -1, 1, -1, 1, 1, 1, -1, 1, 1, -1, -1, -1, 1, -1, -1, 1, 1, -1, 1, -1, -1, -1, -1, 1, -1, -1, 1, 1, 1, 1, -1, -1, 1, -1, 1, -1, 1, -1, 1, 1, -1, -1, -1, 1, 1, -1, 1, 1, 1, 1, -1, -1, 1, 1, 1, -1, 1, 1, 1, 1, -1}
PN_{1023}	{ 1, 1, 1, 1, 1, 1, 1, 1, 1, -1, 1, 1, -1, 1, 1, -1, 1, 1, -1, -1, 1, -1, 1, 1, -1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, 1, 1, -1, -1, -1, -1, -1, 1, 1, -1, 1, 1, 1, -1, -1, -1, 1, -1, -1, -1, -1, -1, -1, 1, 1, 1, 1, -1, -1, -1, 1, 1, 1, 1, 1, 1, 1, -1, -1, -1, -1, -1, -1, -1, -1, -1, -1, 1, 1, 1, -1, -1, -1, 1, 1, 1, -1, 1, 1, -1, -1, -1, 1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, 1, -1, -1, -1, -1, 1, -1, 1, -1, 1, 1, 1, -1, -1, -1, -1, 1, -1, 1, 1, -1, 1, -1, 1, -1, 1, 1, 1, 1, 1, -1, 1, -1, -1, -1, -1, -1, -1, -1, -1, 1, -1, 1, -1, 1, -1, 1, -1, 1, -1, -1, -1, -1, 1, -1, 1, 1, 1, 1, -1, -1, -1, 1, -1, 1, 1, -1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, -1, 1, -1, 1, -1, -1, 1, 1, -1, -1, -1, -1, 1, -1, 1, -1, -1, 1, 1, 1, -1, -1, 1, 1, -1, -1, -1, -1, -1, -1, 1, 1, -1, 1,

	-1, 1, -1, 1, -1, 1, 1, -1, -1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, -1, -1, -1, -1, -1, 1, -1, 1, 1, -1, -1, -1, 1, 1, 1, 1, -1, 1, 1, 1, -1, -1, 1, -1, -1, 1, 1, -1, 1, 1, 1, -1, 1, -1, 1, 1, -1, -1, 1, -1, -1, -1, -1, 1, -1, -1, -1, 1, -1, 1, -1, 1, -1, -1, -1, 1, 1, -1, -1, 1, 1, -1, -1, -1, 1, -1, -1, -1, 1, -1, -1, -1, 1, 1, -1, -1, -1, 1, -1, 1, -1, 1, 1, -1, -1, -1, 1, -1, 1, 1, 1, 1, 1, -1, -1, -1, -1, 1, -1, -1, 1, -1, -1, -1, 1, 1, 1, 1, -1, -1, 1, 1, 1, -1, 1, 1, -1, 1, -1, 1, 1, -1, 1, -1, -1, 1, 1, -1, -1, 1, -1, 1, 1, 1, -1, 1, 1, 1, -1, 1, -1, -1, 1, -1, 1, 1, -1, 1, -1, -1, -1, 1, -1, 1, 1, -1, -1, 1, 1, 1, -1, 1, -1, -1, 1, 1, 1, 1, 1, 1, -1, 1, -1, 1, 1, -1, 1, 1, -1, 1, -1, -1, -1, -1, -1, 1, -1, -1, -1, -1, 1, 1, 1, -1, -1, 1, 1, 1, -1, -1, 1, -1, -1, -1, 1, -1, -1, 1, 1, 1, 1, -1, -1, -1, -1, 1, 1, -1, 1, 1, -1, -1, -1, 1, 1, -1, 1, -1, -1, 1, 1, 1, -1, 1, 1, 1, 1, -1, -1, 1, -1, -1, -1, -1, -1, -1, -1, 1, 1, -1, -1, -1, 1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, -1, 1, 1, 1, 1, -1, 1, 1, -1, 1, -1, -1, 1, -1, -1, -1, -1, -1, 1, -1, 1, -1, -1, -1, 1, 1, 1, -1, 1, -1, -1, -1, 1, 1, -1, 1, 1, 1, 1, -1, -1, -1, -1, -1, 1, -1, -1, 1, -1, 1, -1, 1, -1, 1, 1, 1, -1, 1, -1, -1, -1, -1, 1, -1, -1, 1, 1, -1, -1, -1, 1, 1, -1, -1, -1, -1, -1, 1, 1, 1, 1, 1, -1, -1, -1, 1, 1, -1, 1, 1, -1, 1, -1, 1, -1, -1, 1, 1, -1, 1, -1, -1, -1, -1, 1, 1, -1, 1, -1, -1, -1, 1, 1, 1, 1, 1, -1, 1, -1, 1, -1, -1, 1, -1, -1, 1, 1, -1, -1, 1, 1, 1, 1, -1, -1, 1, -1, 1, -1, -1, 1, -1, -1, -1, 1, -1, 1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, -1, 1, -1, 1, 1, 1, -1, -1, -1, 1, 1, -1, -1, 1, -1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, -1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, 1, -1, 1, 1, 1, -1, 1, 1, 1, 1, 1, -1, 1, 1, -1, -1, 1, -1, -1, 1, -1, 1, 1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, -1, -1, 1, 1, 1, 1, -1, 1, -1, -1, -1, 1, -1, -1, 1, -1, 1, 1, 1, -1, -1, 1, 1, 1, 1, -1, 1, 1, -1, -1, -1, -1, -1, -1, -1, 1, -1, -1, -1, 1, 1, 1, -1, -1, -1, -1, 1, 1, 1, 1, 1, 1, -1, -1, -1, 1, -1, -1, 1, -1, -1, 1, 1, 1, -1, 1, -1, 1, 1, 1, -1, 1, 1, -1, -1, 1, 1, -1, 1, 1, 1, 1, 1,

	-1, -1, 1, -1, 1, 1, -1, 1, 1, -1, -1, -1, -1, 1, -1, -1, -1, -1, -1, 1, 1, 1, -1, 1, -1, 1, -1, 1, -1, -1, 1, -1, 1, 1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, 1, -1, 1, -1, -1, 1, -1, -1, 1, -1, -1, -1, -1, 1, 1, -1, -1, -1, -1, 1, 1, 1, -1, 1, 1, 1, -1, -1, -1, -1, -1, -1, 1, -1, -1, 1, 1, 1, -1, -1, -1, 1, -1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1, -1, -1, 1, 1, -1, -1, 1, -1, -1, 1, 1, 1, 1, 1, -1, -1, 1, 1, 1, 1, 1, 1, 1, 1, -1, -1, 1, -1, -1, 1, -1, -1, 1, -1, 1, -1, -1, -1, 1, -1, 1, -1, -1, -1, -1, 1, 1, 1, 1, -1, 1, -1, 1, -1, 1, 1, -1, 1, 1, 1, 1, -1, 1, -1, -1, 1, 1, -1, 1, 1, -1, -1, 1, 1, 1, 1, 1, -1, 1, 1, 1, -1, 1, 1, -1, 1, 1, 1, 1, 1, 1, -1}
PN-CP1	{ 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, 1, 1, -1, 1, 1, -1, -1, -1, -1, -1, -1, 1, -1, -1, 1, -1, 1, 1, -1, 1, 1, -1, 1, 1, -1, -1, 1, -1, -1, -1, -1, -1, -1, 1, 1, -1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1, -1, 1, -1, 1, 1, 1, -1, 1, 1, -1, -1, -1, 1, -1, -1, 1, 1, -1, 1, -1, -1, -1, -1, 1, -1, -1, 1, 1, 1, 1, -1, -1, 1, -1, 1, -1, 1, -1, 1, 1, -1, -1, -1, 1, 1, -1, 1, 1, 1, 1, -1, -1, 1, 1, 1, -1, 1, 1, 1, 1, -1}
PN-CP2	{ 1, 1, 1, 1, 1, 1, 1, 1, -1, 1, 1, 1, -1, 1, 1, 1, -1, -1, 1, 1, -1, 1, 1, 1, -1, -1, -1, 1, -1, 1, -1, 1, -1, -1, 1, -1, -1, 1, 1, 1, -1, -1, -1, 1, 1, 1, -1, 1, 1, -1, 1, -1, 1, -1, 1, 1, 1, -1, -1, 1, -1, -1, 1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, -1, -1, 1, 1, 1, -1, 1, -1, -1, 1, -1, -1, -1, 1, 1, -1, 1, -1, 1, 1, -1, 1, 1, 1, 1, 1, -1, 1, 1, -1, -1, 1, 1, -1, -1, -1, 1, -1, 1, 1, 1, -1, -1, -1, -1, -1, 1, -1, -1, -1, -1, 1, 1, 1}

Attachment 3
(Normative)
LDPC Matrix

The check matrix H of the (N, K) LDPC code is generated by cyclically shifting its row generator, and each row generator is represented by the index of columns (range: 0 to N-1) in which the element 1 is located.

Table C. 1 shows the row generator of the (480, 96) LDPC check matrix, where the $(i + 1)^{th}$ row corresponds to the $(i + 1)^{th}$ row generator ($0 \le i < 8$).

TABLE C. 1

24 row generators for the (480, 96) LDPC check matrix

43 58 73 84 127 156
11 26 51 68 97 136
10 23 53 82 109 120 144
12 47 93 100 114 141
75 101 119 136 160
67 125 129 153 176
24 74 125 131 192
105 125 137 208
71 106 140 224
28 108 117 240
82 121 134 256
11 115 139 272
96 125 152 288
121 137 155 304
89 108 136 320
27 120 143 336
84 101 118 352
48 114 135 368
8 74 106 384
111 119 400
108 158 416
98 153 432
44 120 448
101 464

After (480,96) LDPC encoding, puncture the first 32 bits of the check bits output by (480,96) encoding output to obtain (448, 96) LDPC code.

Table C. 2 shows the row generator of the (448, 224) LDPC check matrix, where the $(i + 1)^{th}$ row corresponds to the $(i + 1)^{th}$ row generator ($0 \le i < 8$).

TABLE C. 2

8 row generators for the (448, 224) LDPC check matrix

62 139 216 302 371 405
90 167 168 330 357 433
19 149 195 272 358 427
47 122 223 224 386 413
53 87 174 251 328 441
10 81 202 279 280 395
38 109 131 230 308 384
2 66 159 258 289 336

Table C. 3 shows the row generator of the (448, 256) LDPC check matrix, where the (i + 1)th row corresponds to the (i + 1)th row generator ($0 \le i < 6$).

TABLE C. 3

6 row generators for the (448, 256) LDPC check matrix

4	46	77	133	181	239	299	391
33	79	98	166	228	256	331	424
9	66	110	131	199	261	301	364
42	106	143	164	302	326	397	421
6	75	138	197	236	333	359	430
15	39	99	212	269	366	392	420

Table C. 4 shows the row generator of the (1344, 672) LDPC check matrix, where the $(i + 1)^{th}$ row corresponds to the $(i + 1)^{th}$ row generator ($0 \le i < 12$).

TABLE C. 4

12 row generators for the (1344, 672) LDPC check matrix

177 411 505 975 1030 1190
234 468 562 844 1075 1247
291 358 619 901 1132 1304
82 348 636 728 1085 1289
139 405 513 786 1142 1187
8 462 570 696 1024 1244
10 295 523 751 903 1178
65 195 586 800 972 1256

122 224 643 684 857 1313
68 179 339 741 976 1069
125 236 396 806 867 1126
26 293 453 697 896 1028

Table C. 5 shows the row generator of the (1344, 840) LDPC check matrix, where the (i + 1)th row corresponds to the (i + 1)th row generator ($0 \le i < 9$).

TABLE C. 5

9 row generators for the (1344, 840) LDPC check matrix

188 234 410 639 752 848 1071 1197 1251
119 301 346 566 696 809 1020 1128 1308
20 236 403 462 676 866 902 1144 1311
77 284 354 523 733 810 959 1201 1242
61 118 394 451 568 853 967 1024 1252
13 186 341 508 626 790 897 1076 1299
25 172 299 468 565 746 896 1009 1198
82 127 240 522 622 694 953 1066 1130
8 139 342 520 751 860 908 1123 1247

Table C. 6 shows the row generator of the (1344, 1008) LDPC check matrix, where the (i + 1)th row corresponds to the (i + 1)th row generator ($0 \le i < 6$).

TABLE C. 6

6 row generators for the (1344, 1008) LDPC check matrix

10	80 1081	245 344 1146 1196	415	475	585	694	795	844	902	957
67	137 1138	281 401 1253 1312	470	504	642	751	852	901	1014	1078
25	124 1016	194 338 1071 1195	468	527	561	627	699	808	909	958
82	181 1015	251 290 1128 1252	395	525	584	618	684	728	865	966
139	238 1185	300 347 1249 1292	448	582	675	741	785	922	970	1072
5	168 1187	288 357 1242 1295	404	505	639	732	798	842	1027	1129

Table C. 7 shows the row generator of the (1344, 1176) LDPC check matrix, where the (i + 1)th row corresponds to the (i + 1)th row generator ($0 \le i < 4$).

TABLE C. 7

4 row generators for the (1344, 1176) LDPC check matrix

55 85 167 198 212 274 334 368 384 429 486 512 550 617 666 689 752 779 874 885 940 973 1047 1064 1103 1149 1253 1265
20 69 97 127 209 240 254 316 376 410 426 471 528 554 592 659 708 731 794 821 873 927 982 1015 1089 1145 1191 1307
15 61 111 139 169 251 282 296 358 418 452 468 513 570 596 634 701 750 773 836 863 915 969 1131 1148 1187 1238 1260
11 52 103 153 181 211 293 324 338 400 460 494 510 555 612 638 676 743 792 815 905 957 1011 1066 1099 1190 1233 1302

Table C. 8 shows the row generator of the (2688, 1344) LDPC check matrix, where the $(i + 1)^{th}$ row corresponds to the $(i + 1)^{th}$ row generator $(0 \leq i < 12)$.

TABLE C. 8

12 row generators for the (2688, 1344) LDPC check matrix

417 582 1113 1518 2328 2388 2544
112 343 529 607 844 1405 1861
61 176 302 393 455 641 2054
259 414 505 753 918 1706 2166
248 371 526 943 1030 1257 1680
91 328 483 729 1292 1792 2390
440 595 841 1561 1613 1904 2502
265 434 552 707 1279 1547 2302
22 273 377 546 1127 1659 2645
134 283 489 808 931 1949 2077
256 497 770 888 920 1198 1351
278 368 1032 1155 1401 2173 2602

Table C. 9 shows the row generator of the (2688, 1680) LDPC check matrix, where the $(i + 1)^{th}$ row corresponds to the $(i + 1)^{th}$ row generator $(0 \leq i < 9)$.

TABLE C. 9

9 row generators for the (2688, 1680) LDPC check matrix

7 193 271 358 508 941 1069 1232 1830 2544
57 119 305 383 470 875 1482 1630 1710 1861
78 169 231 417 582 732 987 1456 1594 2427
35 190 281 343 529 607 1099 1405 1520 2085
24 147 302 393 641 806 1211 1680 2197 2278
104 136 259 414 1145 1323 1449 1744 2309 2646

98 216 248 371 526 943 1257 1904 2190 2502
41 210 328 360 729 1055 1142 1673 2382 2614
49 153 322 440 595 750 841 1404 1965 2080

Table C. 10 shows the row generator of the (2688, 2016) LDPC check matrix, where the (i + 1)th row corresponds to the (i + 1)th row generator ($0 \leq i < 6$).

TABLE C. 10

6 row generators for the (2688, 2016) LDPC check matrix

62 293 374 514 679 865 943 1030 1180 1257 1435 1613 1904 2203 2388
26 626 729 791 977 1055 1142 1292 1369 1547 1725 1853 1968 2016 2500
138 598 750 841 903 1089 1167 1404 1659 1785 1837 1965 2080 2310 2552
112 398 707 862 953 1015 1201 1279 1366 1516 1593 1897 1949 2306 2664
61 176 224 362 510 590 696 819 974 1065 1127 1478 1628 1705 2197
288 474 776 808 931 1086 1177 1239 1503 1740 1817 2121 2158 2390 2646

Table C. 11 shows the row generator of the (2688, 2240) LDPC check matrix, where the (i + 1)th row corresponds to the (i + 1)th row generator ($0 \leq i < 4$).

TABLE C. 11

4 row generators for the (2688, 2240) LDPC check matrix

7 193 271 358 508 585 763 889 941 1069 1184 1232 1370 1518 1598 1749 1830 1970 2086 2203 2544
57 119 305 383 470 620 697 875 1001 1053 1181 1296 1344 1482 1630 1861 1942 2198 2315 2440 2500
78 169 231 417 495 582 732 809 987 1113 1165 1293 1408 1456 1594 1742 1822 2054 2194 2310 2612
35 190 281 343 529 607 694 844 921 1099 1225 1277 1405 1520 1568 1706 1934 2085 2306 2422 2664

Table C. 12 shows the row generator of the (5376, 2688) LDPC check matrix, where the (i + 1)th row corresponds to the (i + 1)th row generator ($0 \leq i < 24$).

TABLE C. 12

24 row generators for the (5376, 2688) LDPC check matrix

147 281 1109 1381 2089 4658 5232
98 607 826 1108 1813 2024 4398
1220 1333 1605 2406 3031 4661 4998
248 526 1445 1906 2238 2248 4854

880 968 1092 1162 1557 2149 3494
322 718 827 992 1080 1274 4317
434 1316 1668 3048 3214 3305 5109
377 765 815 1216 2354 3417 3743
1163 1610 1686 1892 2005 2466 3591
658 1039 1166 1275 2117 2808 3967
1101 1151 2501 2682 2985 4079 4571
796 1019 1213 2341 2613 3083 3865
502 706 908 1325 1776 2802 4795
37 818 991 1020 1487 2933 5213
614 930 1300 1835 3682 4764 5325
357 558 946 1244 2394 2676 4953
751 886 1356 1773 1823 2059 2949
100 764 1468 2336 3321 4168 4537
213 876 975 1378 1580 2730 3433
688 835 988 1692 2159 2560 2772
783 1199 1334 2760 3750 4081 4472
912 1311 1504 1916 2884 3952 4193
699 1024 1171 1999 2196 5097 5345
184 771 3221 3474 3816 4315 4840

Table C. 13 shows the row generator of the (5376, 3360) LDPC check matrix, where the (i + 1)th row corresponds to the (i + 1)th row generator ($0 \leq i < 18$).

TABLE C. 13

18 row generators for the (5376, 3360) LDPC check matrix

60 773 981 1045 1226 1234 1576 1846 2969 4437
22 566 772 1093 2048 2289 3329 3984 4318 5344
315 408 532 678 1977 2070 2505 2792 3494 4742
432 520 714 790 996 1570 2936 3214 3305 3367
826 1221 1429 1493 1674 2024 2201 3016 4654 5222
382 491 744 868 938 1786 2313 4137 4189 4997
119 367 603 1126 1445 1470 2238 2747 3395 4301
479 715 968 1444 1557 1765 2350 3234 3830 4413
347 1080 1204 1877 1941 2130 2472 2832 4653 4816
459 653 703 830 939 1462 3662 3703 4585 4765
302 571 942 1216 1428 1918 3056 3195 3815 5040
431 628 877 1054 1163 1328 1686 2458 3307 5290
210 370 543 572 740 1039 1166 2389 2570 4973

153 386 655 907 1101 2682 2821 3998 4907 5085
498 796 1213 1263 1664 2613 3531 3625 4110 4527
438 879 908 1076 1864 2453 2661 3045 4222 5257
550 608 818 1020 1188 1243 2773 2837 3368 3526
8 527 662 720 834 930 1103 3130 3616 3745

Table C. 14 shows the row generator of the (5376, 4032) LDPC check matrix, where the (i + 1)th row corresponds to the (i + 1)th row generator ($0 \leq i < 12$).

TABLE C. 14

12 row generators for the (5376, 4032) LDPC check matrix

0 181 342 661 686 869 933 1963 2919 3105 3183 3270 4398 4518 5076
64 308 378 660 773 1365 2177 2450 2568 2723 2878 3532 4144 4770 5344
296 490 566 772 885 1477 1678 1688 2562 2680 3721 4077 4256 4661 5240
320 532 602 884 997 1022 1450 1458 1589 1790 1800 3193 4011 4205 4854
267 432 644 714 790 1134 1317 1381 1562 1902 2089 3367 3868 4506 4966
379 544 632 826 902 1246 1674 1682 2014 2294 2729 2898 3016 3048 4846
382 491 656 744 868 1014 2126 2136 2313 2406 2496 3438 3942 4361 4730
60 157 317 367 494 768 856 1050 1126 1906 2608 3641 3889 4054 4990
235 429 479 606 715 1162 1238 1444 1557 1582 1765 3352 3507 3662 5102
292 347 541 827 1080 1204 1274 2742 2832 3464 3774 3927 4316 5214 5294
236 459 703 939 1806 2053 2234 2242 3083 3185 3576 3608 3886 4428 4697
319 348 516 571 765 815 1893 1918 2354 2686 2966 3297 3720 4089 4225

Table C. 15 shows the row generator of the (5376, 4704) LDPC check matrix, where the (i + 1)th row corresponds to the (i + 1)th row generator ($0 \leq i < 6$).

TABLE C. 15

6 row generators for the (5376, 4704) LDPC check matrix

70 154 230 436 549 574 757 821 1002 1010 1141 1342 1352 1953 2226 2499 2745 2807 2993 3071 3308 3563 3869 4398 4549 4770 4891 5232

196	266	342	548	661	686	869	1122	1253	1464	1824	1963
	2065	2338	2456	2611	2766	2857	3105				
3183	3675	3801	3981	4096	4430	4510	4661	5003			
184	308	378	454	660	773	798	981	1226	1753	1846	1936
	2075	2450	2568	2878	2969	3217	3295				
3382	3532	3609	3787	4093	4208	4542	4773	4882			
208	296	420	490	566	772	885	910	1093	1157	1346	1477
	1678	1688	1865	2187	2680	2990	3081				
3494	4077	4320	4368	4654	4734	4994	5110	5352			
30	155	320	408	532	602	678	884	1022	1269	1450	1458
	1589	2160	2299	2792	3193	3255	3441				
3756	3833	4011	4189	4317	4618	4885	4966	5106			
62	158	267	432	520	644	714	790	996	1109	1317	1381
	1570	1701	2089	2272	2411	2513	2617				
3367	3631	3868	3945	4249	4301	5078	5218	5334			

1

2

3

Attachment 4
(Normative)
Quantization of Channel State Information Matrix

The process of performing quantization coding on the channel state information matrix $H_{eff}(k)$ is defined as follows.

Calculate the maximum value of the real and imaginary parts of each element in the subcarrier matrix $m_H(k)$：

$$m_H(k) = max\left\{max\left\{\left|Re\left(H_{eff(m,l)}(k)\right)\right|_{m=1,l=1}^{m=N_r,l=N_c}\right\}, max\left\{\left|Im\left(H_{eff(m,l)}(k)\right)\right|_{m=1,l=1}^{m=N_r,l=N_c}\right\}\right\}$$

Equation 34

Where $H_{eff(m,l)}(k)$ represents the element in $H_{eff}(k)$, $Re\left(H_{eff(m,l)}(k)\right)$ represents the real part of $H_{eff(m,l)}(k)$, $Im\left(H_{eff(m,l)}(k)\right)$ represents the imaginary part of $H_{eff(m,l)}(k)$; m is the row position parameter, l is the column position parameter, Nr is the maximum number of rows, Nc is the maximum number of columns, $1 \le m \le Nr$, $1 \le l \le Nc$, $Nr \ge 1$, $Nc \ge 1$, m、l、Nr and Nc are positive integer; k is a positional parameter of a subcarrier, and can be a numbered form;

Calculate the scaling according to and perform Mbits quantization to get MH(k), and calculate the linear part $M_H^{lin}(k)$:

$$M_H(k) = min\{2^M - 1, \lceil max(0, a \cdot log_b(m_H(k)))\rceil\}$$

Equation 35

Where M represents the number of quantization bits, and the value is M=3

$\lceil x \rceil$ represents the largest integer not less than x.

a represents the optimization factor, with a value $a = 4.11, b = 2$.

Linear part $M_H^{lin}(k)$ calculation formula:

$$M_H^{lin}(k) = b^{M_H(k)/a}$$

N_b-bit quantization is performed for each element of the real and imaginary parts of the $H_{eff}^q(k)$ matrix:

$$H_{eff(m,l)}^{q(R)} = sign(H_{eff(m,l)}(k)) * min(\,2^{N_b-1} - 1, round\left(\frac{\left|Re\left(H_{eff(m,l)}(k)\right)\right|}{M_H^{lin}(k)}(2^{N_b-1} - 1)\right))$$

$$H_{eff(m,l)}^{q(I)} = sign(H_{eff(m,l)}(k)) * min(\,2^{N_b-1} - 1, round\left(\frac{\left|Im\left(H_{eff(m,l)}(k)\right)\right|}{M_H^{lin}(k)}(2^{N_b-1} - 1)\right))$$

Equation 36

Where $H_{eff(m,l)}(k)$ represents the element in $H_{eff}(k)$, $H_{eff(m,l)}^{q(R)}$represents the real part after $H_{eff(m,l)}(k)$ quantization, $H_{eff(m,l)}^{q(I)}(k)$ represents the imagery part after $H_{eff(m,l)}(k)$ quantization,

m is the row position parameter, l is the column position parameter, $sign(H_{eff(m,l)}(k))$ means taking the symbol polarity of $H_{eff(m,l)}(k)$, "｜ ｜" means taking absolute value.

The receiver restores the CSI matrix as follows:

The amplitude value $r(k)$ is restored according to $M_H(k)$:

Specifically, reverse processing is performed according to the method of $M_H(k)$ quantization to recover $r(k)$.

$$r(k) = b^{M_H(k)/a}$$

Equation 37

Then, the real part $H_{eff(m,l)}^{q(R)}$ and the imaginary part $H_{eff(m,l)}^{q(I)}(k)$ of each element $H_{eff(m,l)}^{q}(k)$ in $H_{eff}^{q}(k)$ are scaled according to $r(k)$ to recover the channel matrix $\widetilde{H}_{eff}(k)$ of the subcarrier.

Specifically, the following formula can be used:

$$Re\left(\widetilde{H}_{eff(m,l)}(k)\right) = \frac{r(k)H_{eff(m,l)}^{q(R)}(k)}{(2^{N_b-1}-1)}$$

$$Im\left(\widetilde{H}_{eff(m,l)}(k)\right) = \frac{r(k)H_{eff(m,l)}^{q(I)}(k)}{(2^{N_b-1}-1)}$$

Equation 38

Attachment 5
(Informative)
EUHT-5G Frequency Bands

The frequency bands and channel numbering are constrained by the spectrum regulator. The EUHT-5G operating bands are defined in Table E. 1 and Table E. 2for information. The EUHT_ARFCN is defined in Table E. 3 for information.

TABLE E. 1

EUHT operating bands in Sub-6GHz bands

Uplink (UL) and Downlink (DL)operating band	**Duplex Mode**
450 - 470 MHz	TDD
470 - 698 MHz	TDD
694/698 - 960 MHz	TDD
1427 - 1518 MHz	TDD
1710 - 2025 MHz	TDD
2110 - 2200 MHz	TDD
2300 - 2400 MHz	TDD
2500 - 2690 MHz	TDD
3300 - 3400 MHz	TDD
3400 - 3600 MHz	TDD
3600 - 3700 MHz	TDD
4800 - 4990 MHz	TDD

TABLE E. 2

EUHT-5G operating bands in mmWave bands

Uplink (UL) and Downlink (DL) operating band	**Duplex Mode**
26500 MHz – 29500 MHz	TDD
24250 MHz – 27500 MHz	TDD
37000 MHz – 40000 MHz	TDD
27500 MHz – 28350 MHz	TDD

TABLE E. 3

EUHT_ARFCN

Frequency range	ΔF **(KHz)**	F_{Offs} **（MHz）**	$N_{chn\text{-}Offs}$	**Range of** N_{chn}
0 - 6000（MHz）	78.125	0	0	0-76799
6 000-24 250(MHz)	78.125	6 000	76 800	76 800-310 399

24 250-100 000(MHz)	390.625	24 250	310 400	310 400-504 319

The frequency is calculated by Equation 39:

$$F = F_{Offs} + \Delta F * (N_{chn} - N_{chn\text{-}Offs}) \qquad \text{Equation 39}$$

Attachment 6
(Informative)
Definitions of Relative Upper layer messages in Core Network

F.1 Abbreviation

CN: Core Network

HO: Handover

MM: Mobility Management

MME: Mobility Management Entity

NM: Network Management

NME: Network Management Entity

SCG: Service Control Gateway

STA: Station (Terminal)

F.2 EUHT-5G Core network architecture

The EUHT-5G system uses a flat, all-IP network architecture. The core network includes the control plane and user plane entities according to the principle of separation of control and data planes. The user plane entity includes a service control gateway (SCG), the control plane entity includes NME and MME. NME is responsible for the management of the network, including the distribution of network parameters. MME can complete the functions of authentication and mobility management.

The EUHT-5G standard defines the basic functions of the core network and the main functions of the core network elements. The most important user authentication, and mobility management related processes of the core network have been defined in the EUHT-5G protocol specifications.

The EUHT-5G protocol is applicable to different application scenarios, so the interaction information related to the core network is closely related to the requirements of specific application scenarios. As a supplement, Attachment 6 defines the private message body involved in the communication between the STA and the core network, the CAP and the CAP, and the interaction between the CAP and the core network functional entity, in order to further improve the core network function.

The network management entity can complete the parameter configuration management function of network equipment

F.2.1 Basic functions of the core network

EUHT-5G specification defines Mobility Management Entity (MME) , Service Control Gateway （SCG） and Network Management Entity (NME), etc,which are the EUHT-5G core network entities. These entities are involved in the authentication procedure, mobility management procedure, user plane data transfer procedure, network management and configuration.

－ MME(Mobility Management Entity).

MME is responsible for mobility management of control plane, user context and mobile state management, and can perform authentication processes. The control plane transactions of the core network are controlled by MME.

− SCG（Service Control Gateway）

SCG is a user plane entity. which is mainly responsible for the forwarding and transmission of user data packet, the update of data transmission path and other user plane functions. SCG also serves as the gateway function of the EUHT-5G core network and connects with the external data network.

− NME (Network Management Entity).

NME is responsible for network management and configuration, including distributing relative parameters to CAPs.

F.2.2 Procedure

The procedures completed by the EUHT-5G CN mainly include authentication and mobility management.

− Authentication Procedure

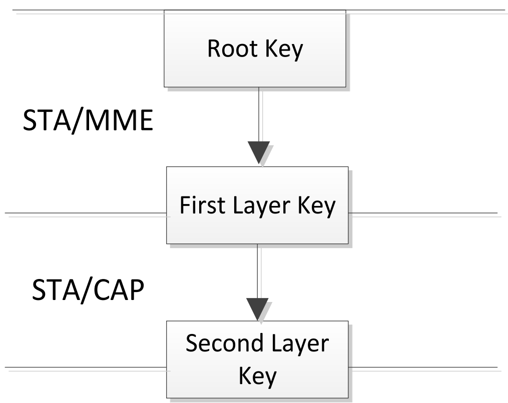
STA uses this procedure to register with the network. It is necessary to pass authentication and register to the network.

− Key Derive Function

Table F. 1 shows Key derivation based on SHA256 algorithm. STA and MME derive the first layer key, STA and CAP derive the second layer key. The second layer key is used to encrypt and decrypt radio interface data.

TABLE F. 1

Key derivation



− Mobility Management Procedure

Through the location update procedure, the core network can always get the CAP information for the current STA service and complete the location management function.

In the procedure of mobility, when the handover inter-CAP is involved, SCG is used as the handover anchor point, and a new data path between new CAP->SCG is reestablished to complete the handover.

F.3 Message

F.3.1 STA-CN

F.3.1.1 Register request

The message is from STA to CN in Table F. 2. The STA uses this message to initiate a registration request to the network.

TABLE F. 2

Register request message body

IE	Presence	Description
Protocol Id	M	IE Length：1Byte 0: MM layer other: reserved
Message Type	M	IE Length：1Byte BIT: 0 1 0 0 0 0 1 1
Register type	M	IE Length：1/2Byte 0: normal 1:periodic
Key Index	M	IE Length：1/2Byte 0000-1111
STA ID	M	IE Length：6Byte

F.3.1.2 Register accept

The message is from CN to STA in Table F. 3.The network uses this message to accept the registration request of the STA.

TABLE F. 3

Register accept message body

IE	Presence	Description
Protocol Id	M	IE Length：1Byte 0: MM layer other: reserved
Message Type	M	IE Length：1Byte BIT: 0 1 0 0 0 0 1 0
RegisterResult	M	IE Length：1/2Byte 1: normal success other: reserved
Key Index	M	IE Length：1/2Byte 0000-1111
STA ID	M	IE Length：6Byte

F.3.1.3 Authentication request

The message is from CN to STA in Table F. 4 .The network uses this message to send authentication request to the STA, which carries authentication request information.

TABLE F. 4

Authentication request message body

IE	Presence	Description
Protocol Id	M	IE Length：1Byte 0: MM layer other: reserved
Message Type	M	IE Length：1Byte BIT: 0 1 0 1 0 0 1 0
Key Index	M	IE Length：1/2Byte 0000-1111
Spare half octet	M	IE Length：1/2Byte
Authentication parameter	M	IE Length：32Byte

F.3.1.4 Authentication response

The message is from STA to CN in Table F.5. The STA uses the message to send the authentication response to the network, and the message carries the authentication response value calculated by the STA.

TABLE F.5

Authentication response message body

IE	Presence	Description
Protocol Id	M	IE Length：1Byte 0: MM layer other: reserved
Message Type	M	IE Length：1Byte BIT: 0 1 0 1 0 0 1 1
Key Index	M	IE Length：1/2Byte 0000-1111
Spare half octet	M	IE Length：1/2Byte
Authentication response	M	IE Length：16Byte

F.3.2 Messages between CAPs

F.3.2.1 CAP_HANDOVER_REQUEST

The serving CAP uses this message to send a handover request to the CAP-D shown in Table F. 6.

TABLE F. 6

CAP_HANDOVER_REQUEST message body

IE	Presence	Description
Protocol Id	M	IE Length：1Byte BIT: 10000001
Message Type	M	IE Length：1Byte BIT: 00000001
CAP-S ID	M	IE Length：6Byte
STA ID	M	IE Length：6Byte
CAP-D ID	M	IE Length：6Byte
CA Information	M	IE Length: 64 Byte Contains the CA related information of CAP-S, as defined in Table 6, the total number of component carriers is up to 16. The information of unused component carriers is set to zero.
Active CC indication	M	IE Length：2 Byte Indicate the the currently used CCs by this STA “1” in the bn (LSB is b0): the component carrier #n+1 is used by STA “0” in the bn (LSB is b0): the component carrier #n+1 is not used by STA.
HO Count	M	IE Length：2Byte It indicates HO count
HO TYPE	M	IE Length：1Byte It indicates HO Type 1: normal ho 2: no signaling access other: reserved
Dual Connection	M	IE Length：1Byte It indicates Dual Connection mode 0: invalid (normal mode, not dual connection mode) 1: enter dual connection mode 2: leave dual connection mode other: reserved
Security Info	M	IE Type：LV L: 0-255 V: Security Info
Flow Info	M	IE Type：LV L: 0-255 V: Flow Info
STA INFO	M	IE Type：LV L: 0-255 V: STA INFO

F.3.2.2 CAP_HANDOVER_RESPONSE

The message is from CAP to CAP in Table F. 7. This message is used as a response message to the handover request,The CAP-D provides some information to the Serving CAP.The serving CAP will carry the necessary information to STA for STA access to the CAP-D.

TABLE F. 7

CAP_HANDOVER_RESPONSE message body

IE	Presence	Description
Protocol Id	M	IE Length：1Byte BIT: 10000001
Message Type	M	IE Length：1Byte BIT: 00000010
SRC CAP ID	M	IE Length：6Byte
STA ID	M	IE Length：6Byte
DST CAP ID	M	IE Length：6Byte
CA Information	M	IE Length: 64 Byte Contains the CA related information of CAP-D, as defined in Table 6, the total number of component carriers is up to 16. The information of unused component carriers is set to zero.
Available CC indication	M	IE Length：2Byte Indicates which CCs are available for STA “1” in the bn (LSB is b0): the component carrier #n+1 is available “0” in the bn (LSB is b0): the component carrier #n+1 is not available
HO TYPE	M	IE Length：1Byte It indicates HO Type 1: normal ho 2: no signaling access other: reserved
Dual Connection	M	IE Length：1Byte It indicates Dual Connection mode 0: invalid (normal mode, not dual connection mode) 1: enter dual connection mode 2: leave dual connection mode other: reserved
ALLOCATE STA ID	M	IE Length：2Byte It indicates STA ID allocate sta id Used in access to the CAP-D
TA	M	IE Length：2Byte Used in access to the CAP-D
VLD_TIME	M	IE Length：2Byte No signaling access process timer Unit:ms

F.3.2.3 CAP_DATA_FORWARD_IND

The message is from CAP to CAP Table F. 8.Forwarding user data packet through this message between different CAPS.This message carries the user data packet: EUHT-5G MAC PDU.

TABLE F. 8

CAP_DATA_FORWARD_IND message body

IE	Presence	Description
Protocol Id	M	IE Length：1Byte BIT: 10000001
Message Type	M	IE Length：1Byte BIT: 00001000
SRC CAP ID	M	IE Length：6Byte
STA ID	M	IE Length：6Byte
DST CAP ID	M	IE Length：6Byte
Direction	M	IE Length：1Byte 0: downlink 1: uplink other: reserved
Qos flow ID	M	IE Length：1Byte Flow id
PDU SN	M	IE Length：4Byte PDU counter
PDU Priority	M	IE Length：1Byte Transmission priority of User data packet
PDU DATA	M	User data packet: EUHT-5G MAC PDU

F.3.3 CAP-CN

F.3.3.1 CONTEXT SETUP REQUEST

The message is from CAP to CN in Table F. 9.The CAP uses this message to initiate a user context establishment request to the CN,The message carries the upper signaling.

TABLE F. 9

CONTEXT SETUP REQUEST message body

IE	Presence	Description
Protocol Id	M	IE Length：1Byte BIT: 10000010
Message Type	M	IE Length：1Byte BIT: 00000000
CAP ID	M	IE Length：6Byte
STA ID	M	IE Length：6Byte
INFO-PDU	O	Upper signaling

F.3.3.2 CONTEXT SETUP IND

The message is from CN to CAP Table F. 10. CN uses this message to accept the user context establishment request of CAP, which carries the upper layer signaling.

TABLE F. 10

CONTEXT SETUP IND message body

IE	Presence	Description
Protocol Id	M	IE Length：1Byte BIT: 10000010
Message Type	M	IE Length：1Byte BIT: 00000001
CAP ID	M	IE Length：6Byte
STA ID	M	IE Length：6Byte
INFO-PDU	O	Upper signaling

F.3.3.3 UPLINK TRANSFER

The message is from CAP to CN in Table F. 11. The CAP uses this message to carry the upper signaling of the uplink direction to the CN.

TABLE F. 11

UPLINK TRANSFER message body

IE	Presence	Description
Protocol Id	M	IE Length：1Byte BIT: 10000010
Message Type	M	IE Length：1Byte BIT: 00000010
CAP ID	M	IE Length：6Byte
STA ID	M	IE Length：6Byte
INFO-PDU	M	Upper signaling

F.3.3.4 DOWNLINK TRANSFER

The message is from CN to CAP in Table F. 12. CN uses this message to carry the upper signaling of the downlink direction to the CAP.

TABLE F. 12

DOWNLINK TRANSFER message body

IE	Presence	Description
Protocol Id	M	IE Length：1Byte BIT: 10000010
Message Type	M	IE Length：1Byte BIT: 00000011
CAP ID	M	IE Length：6Byte
STA ID	M	IE Length：6Byte
INFO-PDU	M	Upper signaling

F.3.3.5 PATH UPDATE IND

The message is from CAP to CN Table F. 13.The CAP uses this message to inform the network that the STA path update.In the Handover process, when sta successfully handover to the CAP-D, the CAP-D uses the message to inform CN.

TABLE F. 13

PATH UPDATE IND message body

IE	Presence	Description
Protocol Id	M	IE Length：1Byte BIT: 10000010
Message Type	M	IE Length：1Byte BIT: 00000100
CAP ID	M	IE Length：6Byte
STA ID	M	IE Length：6Byte

F.3.3.6 PATH RELEASE IND

The message is from CN to CAP Table F. 14.In the Handover process, when the CN receives the path update message of the CAP-D, the CN will send the message to the serving CAP.The serving CAP releases the STA information.

TABLE F. 14

PATH RELEASE IND message body

IE	Presence	Description
Protocol Id	M	IE Length：1Byte BIT: 10000010
Message Type	M	IE Length：1Byte BIT: 00000101
CAP ID	M	IE Length：6Byte
STA ID	M	IE Length：6Byte

F.3.3.7 CAP PARAM CONFIG IND

The message is from NME (Network Management Entity) to CAP in Table F. 15. CN uses this message to send some necessary configuration information to CAP.

TABLE F. 15

CAP PARAM CONFIG IND message body

IE	Presence	Description
Protocol Id	M	IE Length：1Byte BIT: 10000010
Message Type	M	IE Length：1Byte BIT: 00000110
Message Length	M	IE Length：2Byte The length of message body in bytes, excludes Protocol Id**,** Message Type and Message Length
CAP MAC Address	M	IE Length：6Byte The MAC address of CAP-D
Frame length	M	IE Length：2Byte It indicates system frame length(unit: ofdm symbol number)
ul length	M	IE Length：2Byte It indicates ul length (unit: ofdm symbol number)
dl length	M	IE Length：2Byte It indicates dl length(unit: ofdm symbol number)
CP	M	IE Length：1 bit 0: Normal CP 1: Short CP
Short Preamble ID	M	IE Length：2 bit The index of Short Preamble ID 00: S-Preamble ID is 1 01: S-Preamble ID is 2 10: S-Preamble ID is 3 11: S-Preamble ID is 4
PN_ID	M	IE Length：3 bit The index of PN_ID, starting from 0.
Phase Shift Index	M	IE Length：3 bit The index of Phase shift, starting from 0.
Radio param	M	IE Length: 128Byte reserved
Custom Frames	O	IE Length：varible Multiple TLV frames defined in section 1.5.3.4.23 (without MAC header) can be carried in this field.