EUHT-5G Introduction

Nufront

Feb 2022

START

Outline

1. EUHT-5G Technology
2. Major Changes

Part 01

EUHT-5G Technology

System Parameters

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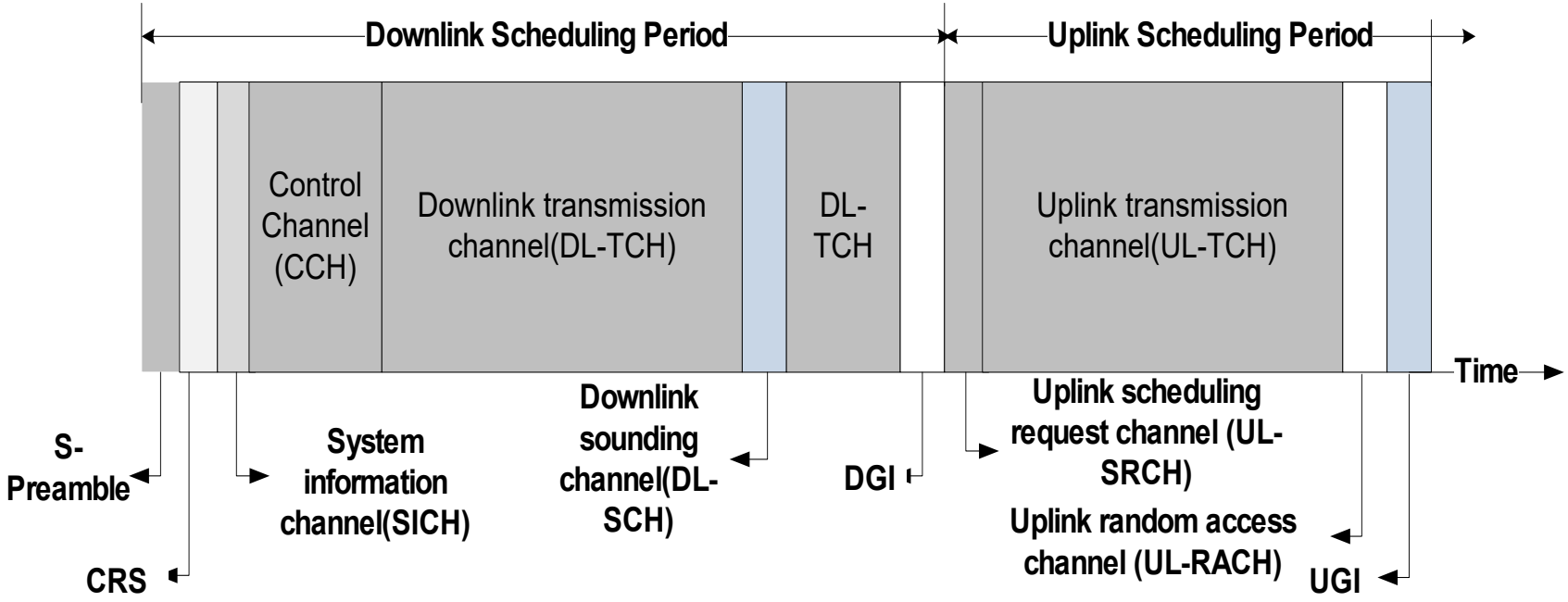
Duplex	TDD
Waveform	CP-OFDM for both DL/UL
CP length	Normal (1/4) or Short (1/8)
Physical Layer Frame Structure	Highly Flexible, Self-Contained
Multiple-access	TDMA, OFDMA, SDMA
Supported Band	Sub-6GHz, mmWave
Carrier Aggregation	Up to 16 Component Carriers (CC)
Bandwidth per CC	Sub-6GHz: up to 100 MHz. mmWave: up to 1GHz
MIMO	SU-MIMO and MU-MIMO, Open loop and closed loop
Max. MCS	1024QAM， 7/8 code rate, BCC/LDPC

General Frame Structure of physical layer

- The system frame structure adopts a self-contained frame format, and the frame length, DL/UL ratio can be dynamically adjusted in unit of one OFDM symbol.



- The demodulation reference signal (DRS) can be inserted periodically in the traffic channel to estimate time-varying channel.

Part 02

Major Changes

Background

- In 2019, Nufront submitted EUHT as IMT-2020 candidate technology
- From 2019 to 2021, several Independent Evaluation Groups (IEGs) submitted the evaluation report of EUHT to WP 5D. Nufront appreciates the effort of all the IEGs made.
- During evaluation process, some IEGs raised questions about EUHT technology on
  - ✓ The reliability of control channel
  - ✓ Support of high order modulation
  - ✓ Support of multiple spatial streams
  - ✓ Support of carrier aggregation
- In this submission, Nufront would like to clarify or sovle the concerns with the enhanced EUHT-5G specification. Special thanks to these IEGs for helping us make a better specification!

More robust SICH (System Information Channel)

- Indicates the information of current frame
  - ✓ length of CCH
  - ✓ length of DL/UL TCH
  - ✓ length of DGI/UGI
  - ✓ Normal or Short CP
  - ✓ Sub-carrier spacing
  - ✓ …
- One more robust type of SICH is defined
  - ✓ Type I
    - BPSK, ½ code rate
  - ✓ Type II:
    - QPSK, 3/14 code rate, 2x repetition

TABLE 66

System Information field definition in Type-II SICH

Bit	Definition	Notes
$b_7b_6…b_0$	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
$b_{19}b_{18}…b_{14}$	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
$b_{30}…b_{22}$	Downlink traffic channel length indication	Number of OFDM symbols in downlink traffic channel
$b_{39}…b_{31}$	Uplink traffic channel length indication	Number of OFDM symbols in uplink traffic channel

More robust CCH (Control Channel)

- Indicates the Resouce allocation of DL/UL TCH for each user
  - ✓ TDMA: Starting index and length of OFDM symbols
  - ✓ OFDMA: Resource Units (RU) indication
  - ✓ SDMA: Spatial streams indication
  - ✓ MCS index
  - ✓ …
- Two more robust types of CCH are defined
  - ✓ Type I: QPSK, 4/7 coding rate
  - ✓ Type II: QPSK, 3/14 coding rate
  - ✓ Type III: 2x repetition of Type II CCH in time domain

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} ⋯ b_{56}together. Each bit indicates the corresponding index RU is occupied. (b_{68} b_{67} ⋯ $b_{56}b_7$)	
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	

More MCS Options （Modulation and Coding Scheme)

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- There are two codewords, each codeword has its own MCS
  - ✓ The typo about the 1024QAM support of 2nd codeword is fixed
- 7 bits are used to indicate the MCS index
  - ✓ The information includes modulation order, coding rate and number of spatial streams
- Note: For each codeword, EQM and UEQM modes are supported
  - ✓ EQM: all the spatial streams employ same modulation and coding
  - ✓ UEQM: different spatial streams can employ different modulation, Can achieve better performance with precoding since the SINR of spatial streams are different.

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

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

Spectral efficiency of MCS with single spatial stream

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- Up to 8.75 bit/s/Hz
  - ✓ 1024 QAM, 7/8 code rate
- Down to 0.047 bit/s/Hz
  - ✓ QPSK, 4/7 code rate, 24x repetition in time and frequency domain
- Two more MCS are added for smoother SE change
  - ✓ MCS 122, QPSK, 4/7 code rate, 3x repetition in time domain
  - ✓ MCS 123 , QPSK, 4/7 code rate, 4x repetition in time domain

Repetition number	N_{BPSC}	R	Spetral efficiency
24	2	0.57	0.047
16	2	0.57	0.071
12	2	0.57	0.095
8	2	0.57	0.142
6	2	0.57	0.190
4	2	0.57	0.285

MCS index number	N_{BPSC}	R	Spetral efficiency
123	2	0.1429	0.285
122	2	0.19	0.38
0	1	0.5	0.5
100	1	0.57	0.57
1	2	0.5	1
101	2	0.57	1.14
2	2	0.75	1.5
121	2	0.875	1.75
3	4	0.5	2
102	4	0.57	2.28
4	4	0.63	2.5
5	4	0.75	3
6	4	0.86	3.5
7	6	0.67	4
8	6	0.75	4.5
9	6	0.83	5
10	6	0.875	5.25
11	8	0.75	6
12	8	0.83	6.64
13	8	0.875	7
103	10	0.75	7.5
104	10	0.875	8.75

Support of More Antennas

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- The maximum number of antenna ports supported is 16 (previous value is 8).

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

TABLE 65

System Information field definition in Type-I SICH

$b_{23}b_{22}…b_{21}$	CAP antenna configuration	0:1 antenna; 1:2 antennas; 2:4 antennas; 3:6 antennas; 4:8 antennas; 5:16 antennas; 6~7: reserved

- It should be noted that STAs use up to 8 antenna ports in the self-evaluation to follow the guidelines of M.2412.
- More antennas at CAP side will increase the average and 5th percentile spectral efficiency
  - ✓ Higher Spatial Multiplex Gain: Will increase the probability of high number of spatial streams in both SU-MIMO and MU-MIMO
  - ✓ Higher diversity gain
  - ✓ Higher array gain

Support SU-MIMO and MU-MIMO

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- EUHT-5G support SU-MIMO and MU-MIMO both in Downlink and Uplink traffic channel
- The relative information is indicated in CCH
  - ✓ SU MIMO – up to 8 spatial streams
  - ✓ Downlink MU MIMO indication – up to 16 spatial streams
  - ✓ Uplink MU MIMO indication – up to 8 spatial streams

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	

SU or MU MIMO

b_{42} b_{41}... b_{33}	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

DL MU MIMO Indication

	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.

UL MU MIMO Indication

More complete and flexible support of Carrier Aggregation (CA)

FIGURE 56

Multi-carrier working mode of EUHT-5G system

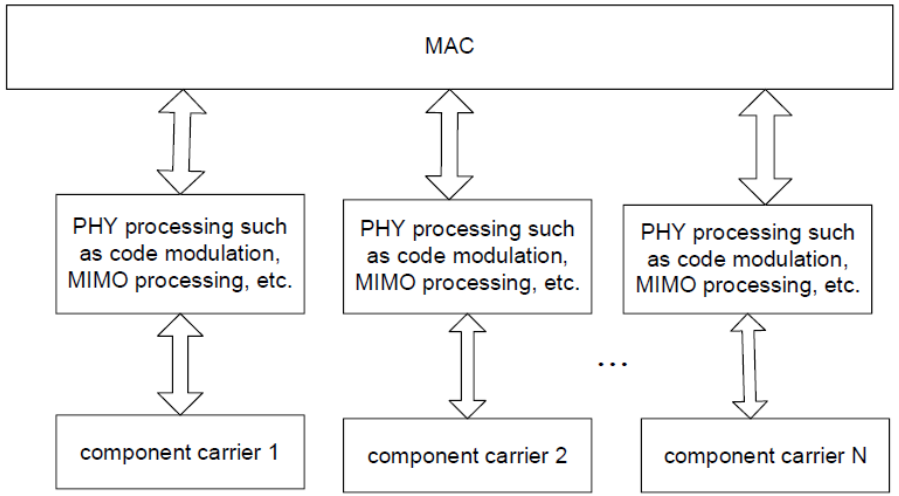
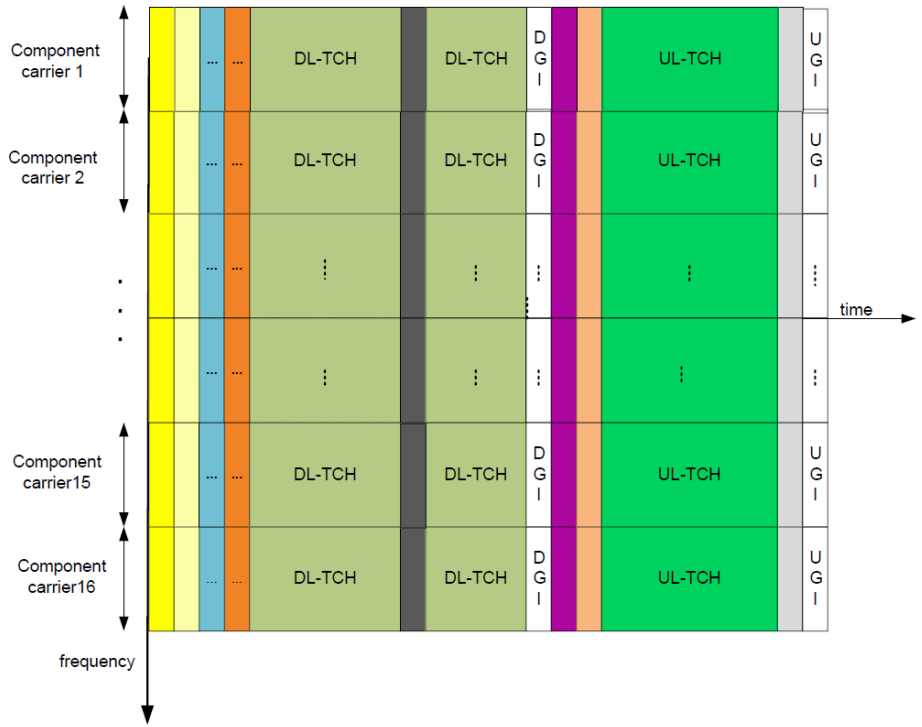


FIGURE 94

Carrier aggregation mode



- In EUHT-5G system, the MAC layer entity uniformly manages and controls multiple component carriers.
- The SICH, CCH and TCH of each component carrier (CC) are independent with that of other component carriers. 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.

CA Related Information

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- **The CA Information broadcasted by CAP (Central Access Point, BS)**
  - ✓ Number of component carriers (CC)
  - ✓ The frequency, bandwidth and tx power of each CC
- **The CA Capability of STA (Station, UE)**
  - ✓ Indicates which component carriers broadcasted in BCF are supported by this STA.
- **The CA support of STA decided by CAP**
  - ✓ CAP notifies which component carriers broadcasted in BCF are used by the STA based on the capability request frame sent by STA.

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

TABLE 13

STA basic capability request frame body

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.

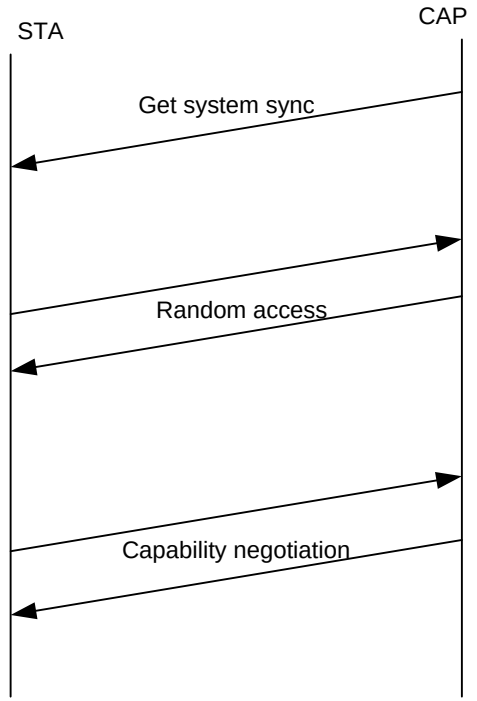
TABLE 14

STA basic capability response frame body

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.

Network Join Process in CA Mode

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 (see previous slide). Then the STA can choose one of the CCs to start random access procedure.
3. The capability negotiation procedure will be performed on the chosen CC. 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 (see previous slide).
4. 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.
5. CAP or STA can decide which CCs are used to initiate the follow-up network join signaling procedures.
6. More details can be found in Section 1.6.4 and 1.6.15

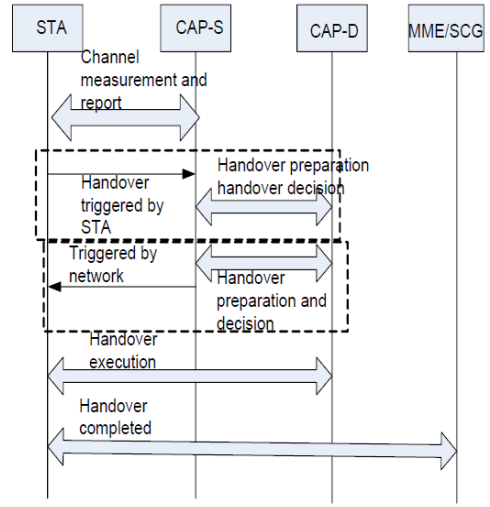


Handover Process in CA Mode (1)

1. 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.
2. 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.
3. 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.

FIGURE 62

Basic process of handover



Handover Process in CA Mode (2)

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4. 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 proactively 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.

5. In handover execution phase, STA will join CAP-D on the working channel specified in HO-CMD. If the CAP-D supports CA, STA can work in CA mode in the target cell after capability negotiation.

6. More details can be found in Section 1.6.15 and 1.6.19

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.

HO-REQ Frame

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.

HO-CMD Frame

Larger Bandwidth Support in mmWave

- Bandwidth for each Component Carrier
  - *Sub-6GHz band: up to 100MHz*
  - *mmWave band: up to 1GHz (previous: 400MHz)*

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 }

TABLE 51

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]

Typos and Clarifications

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- Typos
  - ✓ 1024QAM in the 2nd codeword

Current

If b_1=0,

b_{39}...b_{33}: indicates th MCS of codeword II;

Previous

0000000~1100011, MCS of SU-MIMO codeword II and number of streams (see Annex B)

- Clarifcations
  - ✓ Phase shift of preamble in low error mode is more clearly defined in section 1.7.3
  - ✓ Power related values are more clearly defined, For example

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

Changes in other submission documents

NUFRONT

- Characteristics template, Link budget, self-evaluation report are modified based on the EUHT-5G specification
- More antennas are used in self-evaluation to encourage IEGs consider more antennas in evaluation
  - ✓ 16x8 in eMBB (16x4 in LMLC)
    - Previous configuration is 8x8 (8x4 in LMLC)
  - ✓ 16x8 in URLLC
    - Previous configuration is 8x2
  - ✓ 1x8 in mMTC
    - Previous configuration is 1x2