EUHT Introduction

Nufront

Feb 2021

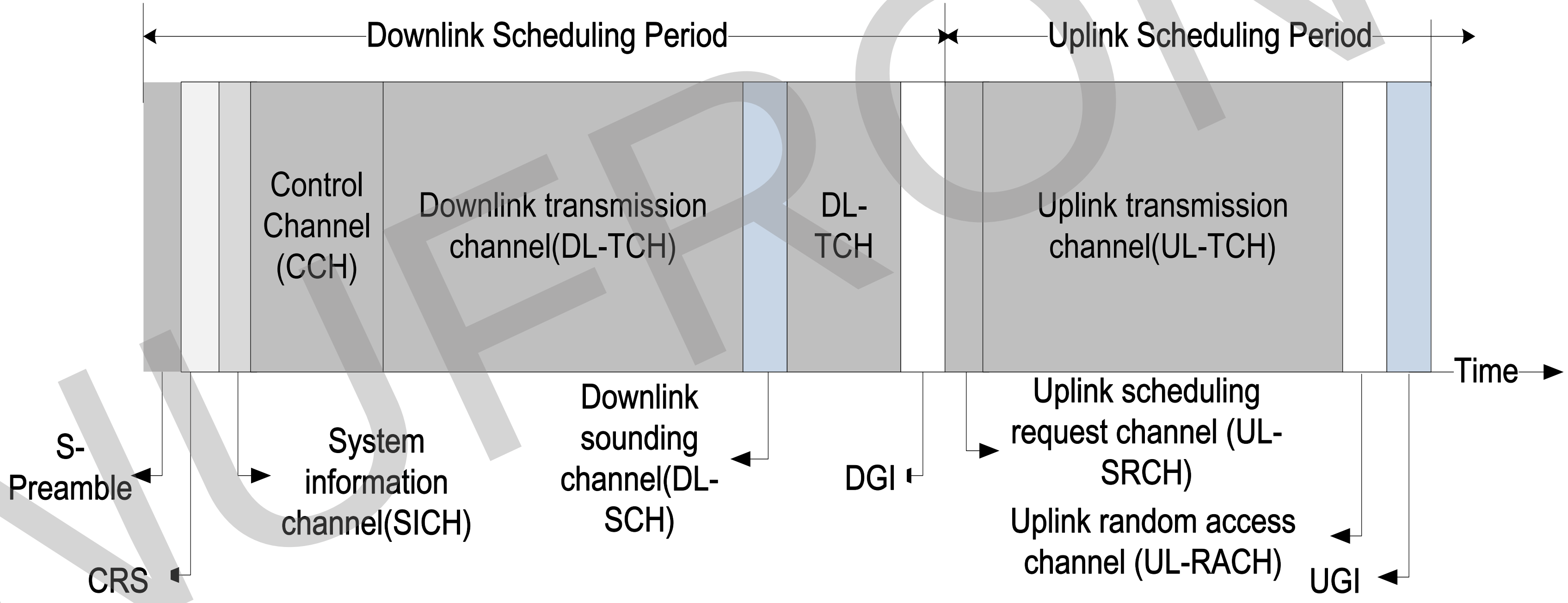
START

System Parameters

Duplex	**TDD**
Waveform	**CP-OFDM for both DL/UL,**
CP length	**1/4 or 1/8 ratio**
Frame Structure	**Highly Flexible, Self-Contained**
Multiple-access	**TDMA, OFDMA, SDMA**
Supported Band	**Sub-6GHz, mmWave**
CA number	**Up to 16 CC**
Bandwidth(per CC)	**Sub-6GHz: up to 100 MHz.** **mmWave: up to 400 MHz**
MIMO	**Both SU-MIMO and MU-MIMO,** **Up to 8 Streams**
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 can be dynamically adjusted within the allowable range.



- The demodulation reference signal (DRS) can be inserted periodically in the traffic channel to resist time-varying channel and obtain better performance. Different time domain intervals of DRS can be configured and indicated by control channel (CCH).

Field function in frame structure

Name	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

SICH(System Information Channel)

- Number of CCH, DL/UL TCH and DGI/UGI OFDM symbols is defined, which indicates varied frame length.
- Full-bandwith and OFDMA scheme is defined.
- Subcarrier spacing and CP mode(normal/short CP) are defined.
- CAP working bandwidth set is defined.

Table 55 **System Information field definition**

Bit	Definition	Notes
$b_7b_6\cdots b_0$	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 For mmWave mode, 000: 50M working bandwidth mode 001: 100M working bandwidth mode 010: 200M working bandwidth mode 011: 400M 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
$b_{19}\cdots b_{13}$	Reserved	Reserved
b_{20}	Cyclic Prefix Type for CCH and TCH	0: Normal CP; 1: Short CP
$b_{23}b_{22}\cdots b_{21}$	CAP antenna configuration	000:1 antenna; 001:2 antennas; … 111: 8 antennas;
$b_{29}b_{28}\cdots b_{24}$	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
$b_{42}b_{39}\cdots b_{32}$	Downlink traffic channel length indication	Number of OFDM symbols in downlink traffic channel For normal mode, $b_{40}b_{39}\cdots b_{32}$ is used, $b_{42}b_{41}$ is reserved. For mmWave mode, $b_{42}b_{41}\cdots b_{32}$ is used.
$b_{45}b_{44}b_{43}$	Reserved	Reserved
$b_{56}b_{55}\cdots b_{46}$	Uplink traffic channel length indication	Number of OFDM symbols in uplink traffic channel For normal mode, $b_{54}b_{53}\cdots b_{46}$ is used, $b_{56}b_{56}$ is reserved. For mmWave mode, $b_{56}b_{55}\cdots b_{46}$ is used.
$b_{63}b_{62}\cdots b_{57}$	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, the parameters of sounding signal is shown in Annex C.
b_{65}	DRS pattern	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, the parameters of sounding signal is shown in Annex C.
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	b72=0，RACH b72=1，ranging
$b_{75}b_{74}b_{73}$	Reserved	Reserved
$b_{87}b_{86}\cdots b_{76}$	Frame number	0~4095, frame number counter
$b_{103}b_{102}\cdots b_{88}$	16-bit CRC	CRC protection
$b_{111}b_{110}\cdots b_{104}$	Convolutional encoder zero bit	Return the end state of the convolutional code to zero

CCH(Control Channel)

- DL/UL is defined.
- SU/MU-MIMO is defined.
- MCS of codeword I/II is defined.
- Time domain DRS interval mode (short/long) is defined.
- RU index in OFDMA scheme is defined.

Table 56 Definition of control channel field

Bit	Definition: DL	Definition: 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... b_2	[$b_5 b_4 \dots b_2$], 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	
b_{23} b_{22}... b_{17}	MCS of codeword I indication (see Annex B)	
b_{32} b_{31}... b_{24}	Number of consecutive OFDM symbols in the user resource group, field value: 0 to 511	
b_{39} b_{38}... b_{33}	MCS of codeword II and number of parallel spatial streams indication: 1111111, this transmission uses only one codeword 1111110, this transmission is a 2-stream MU-MIMO; 1111101, this transmission is a 3-stream MU-MIMO; 1111100, this transmission is 4-stream MU-MIMO; 1111011, this transmission is 5-stream MU-MIMO; 1111010, this transmission is 6-stream MU-MIMO; 1111001, this transmission is 7-stream MU-MIMO; 1111000, this transmission is 8-stream MU-MIMO; 0000000~1100011, MCS of SU-MIMO codeword II and number of streams (see Annex B)	When $b_{42}b_{41} \neq 11$, b_{36}... b_{33}, Bitmap indicates CQI or CSI, feedback subchannel $b_{39}\ b_{38} b_{37}$ When $b_{42}b_{41} = 11$, indicates the MCS of codeword II 1111111, this transmission uses only one codeword 0000000~1100011, MCS and number of streams for SU-MIMO codeword II (see Annex B).
b_{42} b_{41} b_{40}	SU-MIMO: 000; MU-MIMO: spatial stream starting position index, field value 0~7	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); 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 3).	
$b_{47}b_{46}$	00: frequency domain demodulation reference signal interval pattern 1 (DPI = 1); 01: frequency domain demodulation reference signal interval pattern 2 (DPI = 2); 10: frequency domain demodulation reference signal interval pattern 3 (DPI = 4); 11: Reserved.	
b_{54} b_{53}... b_{48}	$b_1 = 0$, SU-MIMO transmission, b_{48}=0, $b_{54} \cdots b_{49}$ indicates the resources used for signaling and feedback transmission in the user resource group, the field value is 0~63; b_{48}=1, $b_{54} \cdots b_{49}$ reserved.	
	$b_1 = 1$, downlink MU-MIMO transmission, b54…b48, reserved.	$b_1 = 1$, 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 a 8-stream MU-MIMO; b51..b49, Spatial stream starting position index, field value 0~7. b1 = 0, the uplink sounding configuration b54 1: uplink sounding signals exists after the whole UL-TCH; 0: uplink sounding signals exists after current STA's UL-TCH; b53…b51 indicate the starting OFDM symbol index of uplink sounding signal in the uplink sounding channel if b54 is set to '1'. b50b49 indicate the phase shift index of sounding signal, ranging from 0 to 3, see 8.5.3.4. b48 reserved
b_{55}	Format 0 (capability negotiation decision, STBC mode): 0, STBC transmission not adopted; 1, STBC transmission adopted. Format 1 (capability negotiation decision, Precoding mode): 0, precoding group size = 8(SU-MIMO), 1(MU-MIMO) 1, precoding group size = 16(SU-MIMO), 4(MU-MIMO)	
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 and STA ID identification	

MCS（Modulation and Coding Scheme)

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- For MCS of each codeword, EUHT supports EQM mode and UEQM mode, as stated in Annex B in EUHT specification
  - EQM: all the spatial streams employ same modulation and coding
  - UEQM: different spatial streams can employ different modulation, which may achieve better performance with precoding.

Annex B
(Normative)
MCS Parameters

Table B. 1 defines the symbols used for the MCS parameter table, and the symbols in the symbol-dependent rate table.

Table B. 1 **Symbols used for the MCS parameter table**

Symbol	Definition
R	Code rate
N_{BPSC}	The sum of the number of encoded bits of each spatial stream per subcarrier

Table B. 2 defines the MCS set for each spatial stream in equal-order modulation.

Table B. 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
...				...
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

Table B. 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 B. 4 defines the MCS set for 3 spatial streams in unequal modulations.

Table B. 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

MCS（Modulation and Coding Scheme)

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- Up to 1024QAM, 7/8 code rate is supported

Table B. 6 **MCS parameters in EQM mode**

MCS index number	Modulation mode	Nss	R	NBPSC
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

Table B. 7 **MCS parameters of UEQM with higher order modulation**

MCS index number	Modulation mode				R	NBPSC
	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

Spectral efficiency of MCS

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- Note that the N_{BPSC} in the MCS table is the number of encoded bits per sub-carrier. To obtain the Spectral efficiency value of one spatial stream, the N_{BPSC} must multiply with the code rate. See the table on the left.
- EUHT supports repetition in frequency and time domain. In that case, the spectral efficiency should be divided by the the number of repetition. See the table on the right.

MCS index number	N_{BPSC}	R	Spetral efficiency
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
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

Repetition number	N_{BPSC}	R	Spetral efficiency
32	2	0.5	0.031
32	2	0.57	0.036
24	2	0.5	0.042
24	2	0.57	0.048
16	2	0.5	0.063
16	2	0.57	0.071
12	2	0.5	0.083
12	2	0.57	0.096
8	2	0.5	0.125
8	2	0.57	0.142
6	2	0.5	0.166
6	2	0.57	0.190
4	2	0.5	0.25
4	2	0.57	0.285
3	2	0.5	0.333
3	2	0.57	0.38
2	2	0.5	0.5
2	2	0.57	0.57

Transmitter block diagram at the CAP (Central Access Point) side

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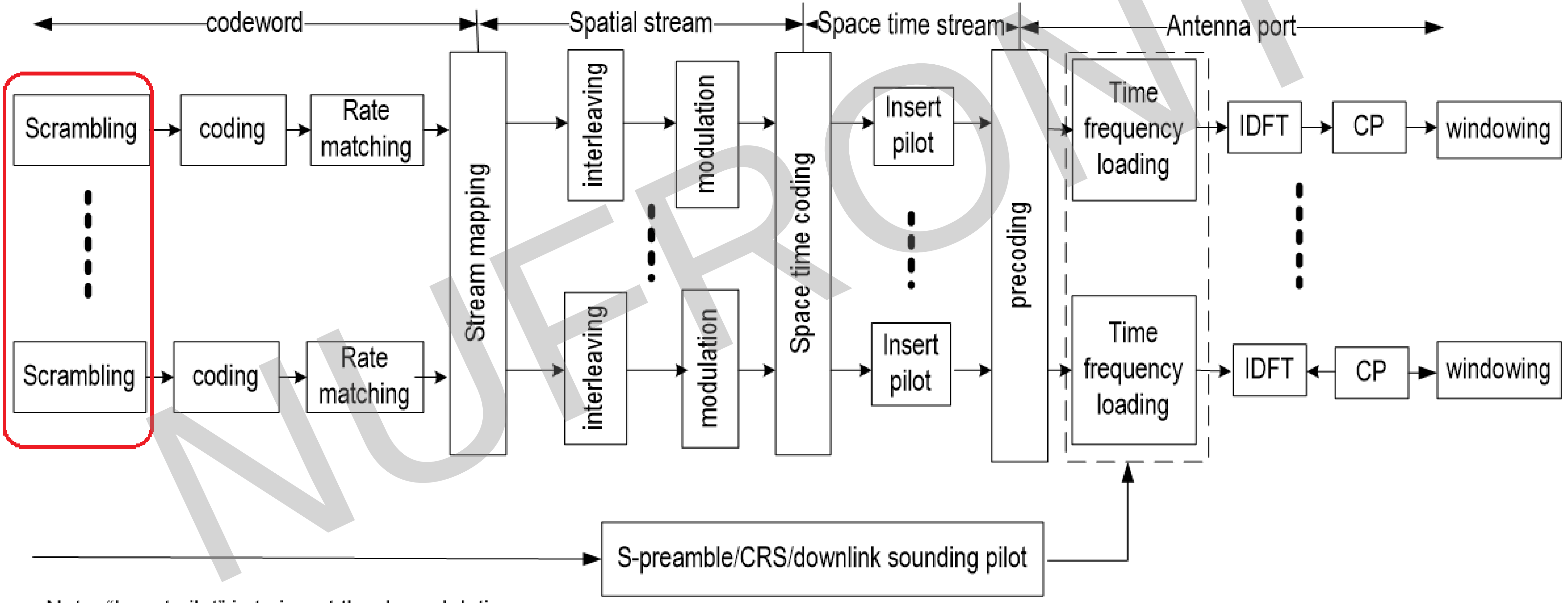
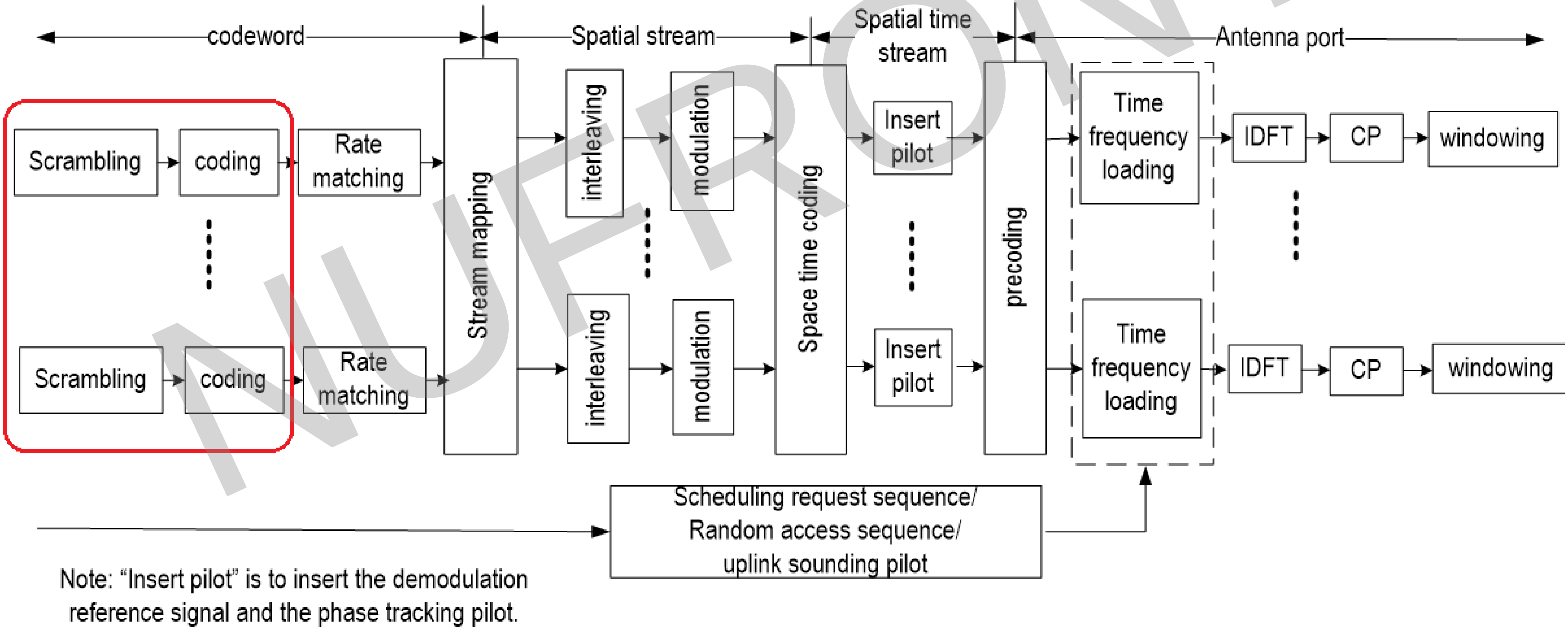


Note: "Insert pilot" is to insert the demodulation reference signal and the phase tracking pilot.

- Up to two codewords is supported, and each codeword supports up to 4 spatial streams..

Transmitter block diagram at the STA (terminal)side

- The STA transmitter block diagram is similar to CAP, but without Preambles, SICH and CCH.



MIMO of EUHT - Support up to 8 streams

- EUHT support up to 8 streams both in Downlink and Uplink channel
  - "One codeword supports up to 4 streams. Up to two codewords is supported", which is quoted from section 8.2.1 Transmitter block diagram
  - Each codeword has its own MCS indication in Control Channel, which is stated in Table 56, section 8.4.2 "Control channel field ", as shown in the figure below

Table 56 **Definition of control channel field**

$b_{23}\, b_{22} \ldots b_{17}$	MCS of codeword I indication (see Annex B)	
$b_{32}\, b_{31} \ldots b_{24}$	Number of consecutive OFDM symbols in the user resource group, field value: 0 to 511	
$b_{39}\, b_{38} \ldots b_{33}$	MCS of codeword II	

  - Each codeword corresponds to one MCS (Modulation and Coding Scheme), the maximum stream number of one MCS (one coedword) is 4, See Annex B (Normative) MCS Parameters, as explained in next page.

MIMO of EUHT - Support SU-MIMO and MU-MIMO

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- EUHT support SU-MIMO and MU-MIMO both in Downlink and Uplink channel

Indication of MU-MIMO capability of the STA	1	0: Not supported; 1: Support

Table 7 STA basic capability request frame(section 6.3.4.4)

b_1	b_1=0, SU-MIMO transmission; b_1=1, MU-MIMO transmission

Table 56 Control channel field(section 8.4.2)

The downlink multi-antenna transmission includes:

Mode 1: Open loop SU-MIMO;

Mode 2: Closed loop SU-MIMO;

Mode 3: Closed loop MU-MIMO.

The uplink multi-antenna transmission supports:

Mode 1: Open loop SU-MIMO;

Mode 2: Closed-loop SU-MIMO.

Mode 3: Uplink MU-MIMO.

Multi-antenna schemes for DL (section 8.5.4) and UL (section 8.5.5) traffic channel

Working Bandwidth per CC

- The working bandwidth (Working_BW) of each component carrier is obtained through the working bandwidth mode in SICH(refer to section 8.4.1 in EUHT specification) and the working bandwidth value in BCF's fixed part (refer to section 6.3.4.1 in EUHT specification).

Table 55 **System Information field definition**

Bit	Definition	Notes
$b_7b_6 \cdots b_0$	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 For mmWave mode, 000: 50M working bandwidth mode 001: 100M working bandwidth mode 010: 200M working bandwidth mode 011: 400M working bandwidth mode Others: reserved

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

- Combing the indication in SICH and BCF, EUHT can support the following bandwidth for each component carrier
  - ✓ 5~100 MHz in Sub-6GHz band
  - ✓ 50~400 MHz in mmWave band

Carrier Aggregation working mode

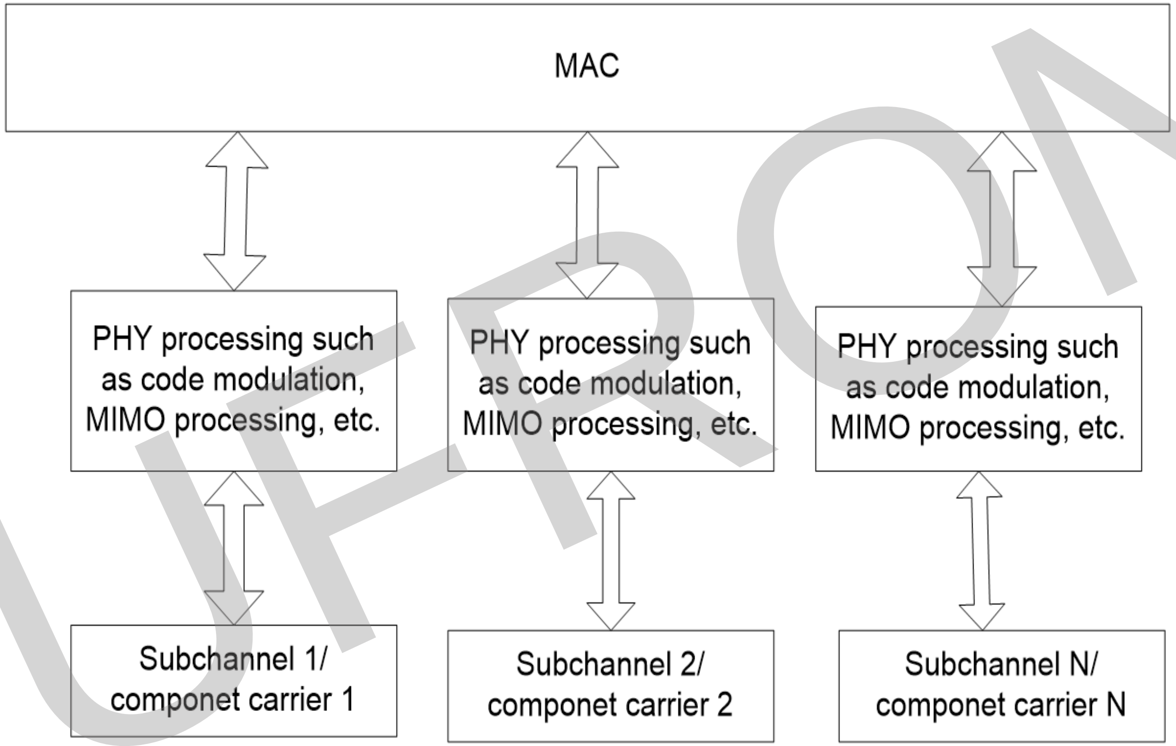

Figure 57 ***Multi-carrier and multichannel working mode of EUHT system***

- As shown by Fig. 57 in EUHT specification, spectrum aggregation is defined. Each component carrier is independently processed in physical layer. All the component carriers are processed by a single MAC layer entity.

CA Management in MAC Layer

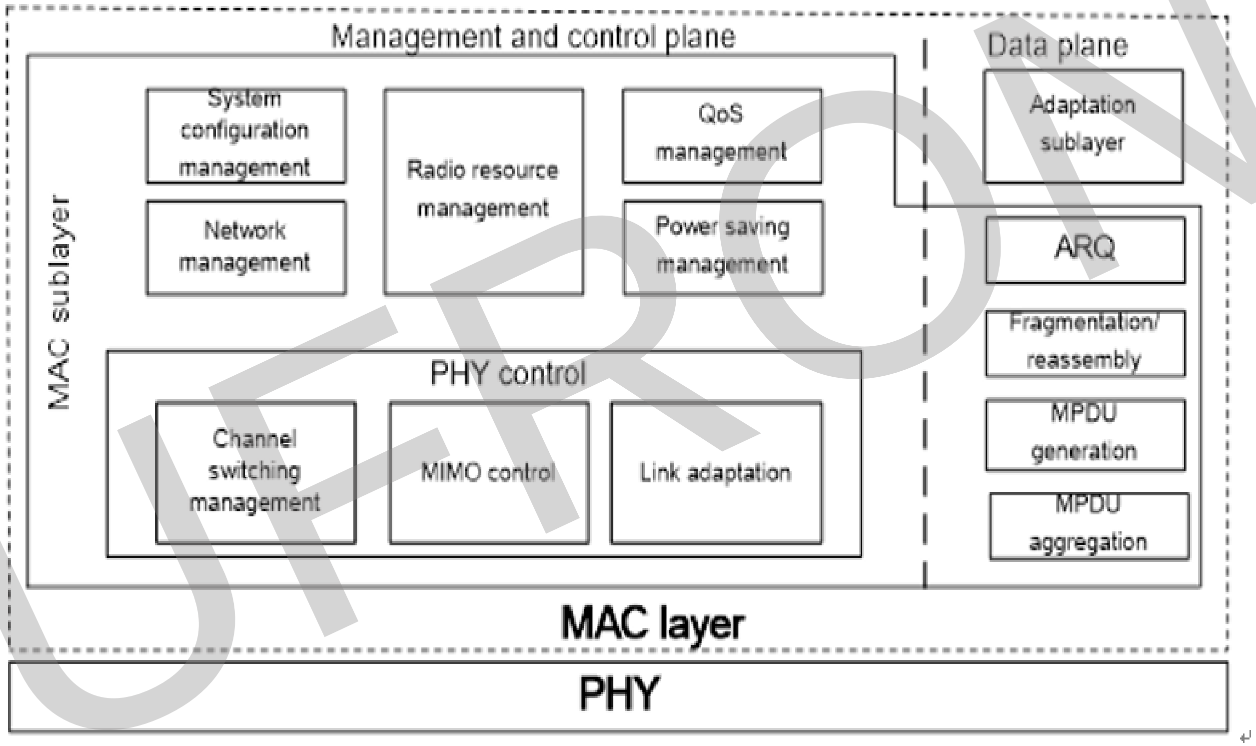

Figure 2 **Functions of MAC layer**

- As shown by Fig.2 in EUHT specification, The MAC layer entity function includes a radio resource management module. One of the function of radio resource management is to divide and aggregate data packets onto/from multiple component carriers. The detailed method of packet processing is implementation related.

CA Management in PHY Layer

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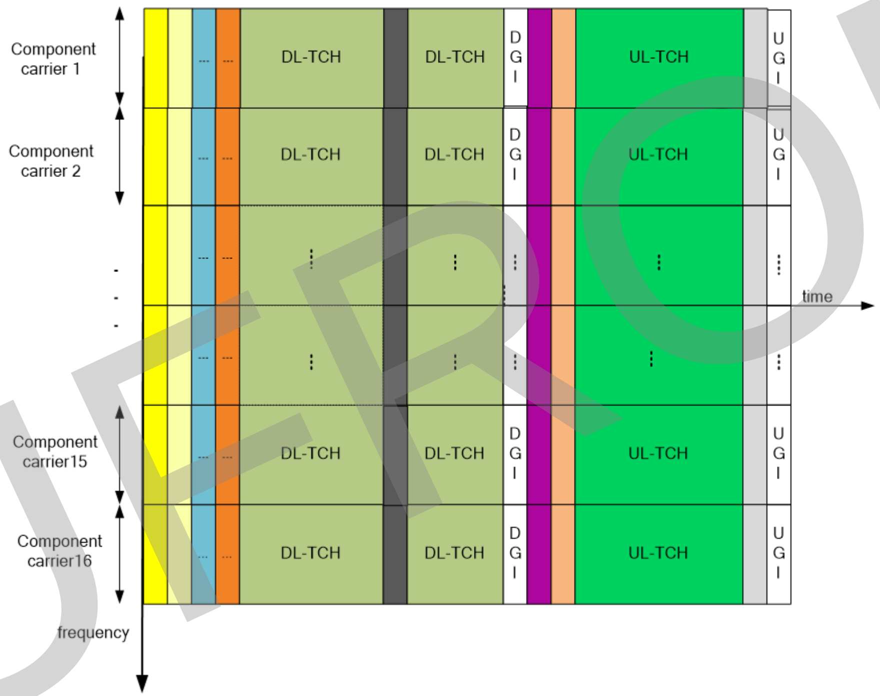

Figure 84 Spectrum aggregation mode

- In section 8.11, CCH and TCH in each component carrier can be different. In the figure above, there are 16 aggregated component carriers. each CC have its own SICH/CCH/TCH channel respectively, which means the resource allocation and data transmission in time/frequency/spatial domain can be accomplished for each CC independently.

CA Procedure

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1. CAP broadcast starting frequency (EUHT-ARFCN) of each component carrier (up to 16) in BCF TLV as below, the frequency value is defined as F_start for later use(refer to TLV frame of section 6.3.4.1 in EUHT specification).

Table G.1-3: 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
6000-24250(MHz)	78.125	6000	76800	76800-310399
24250-100000(MHz)	390.625	24250	310400	310400-504319

The frequency is calculated by below equation:

$$F = F_{Offs} + \Delta F * (N_{chn} - N_{chn\text{-}Offs})$$

The Data field with TLV_type=0 of BCF_TLV frame is defined in table below.

Name	Length/ bit	Value
starting frequency of carrier #1	19	Indicates starting frequency of carrier #1, i.e frequency when channel number=0. Refer to Annex G for EUHT-ARFCN
starting frequency of carrier #2	19	Same as above while carrier #2 corresponds to channel number 1
starting frequency of carrier #3	19	Same as above while carrier #3 corresponds to channel number 2
starting frequency of carrier #4	19	Same as above while carrier #4 corresponds to channel number 3
starting frequency of carrier #5	19	Same as above while carrier #5 corresponds to channel number 4
starting frequency of carrier #6	19	Same as above while carrier #6 corresponds to channel number 5
starting frequency of carrier #7	19	Same as above while carrier #7 corresponds to channel number 6
starting frequency of carrier #8	19	Same as above while carrier #8 corresponds to channel number 7

2. CAP broadcast the relative working channel number in BCF frame. The working channel number is defined WCN as for later use(refer to fixed part of section 6.3.4.1 in EUHT specification).

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

CA Procedure

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3. The working bandwidth (Working_BW) of each component carrier is obtained through the working bandwidth mode in SICH(refer to section 8.4.1 in EUHT specification) and the working bandwidth value in BCF's fixed part (refer to section 6.3.4.1 in EUHT specification).

$b_{10}b_9b_8$	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 For mmWave mode, 000: 50M working bandwidth mode 001: 100M working bandwidth mode 010: 200M working bandwidth mode 011: 400M working bandwidth mode Others: reserved

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

4. The center frequency value of each component carrier can be calculated as below

$$F\_center = F\_start + (WCN + 0.5)*Working\_BW;$$

CA Procedure

5. STA reports its capability to support CA or not in STA capability request frame(refer to Table 7 of section 6.3.4.4 in EUHT specification).

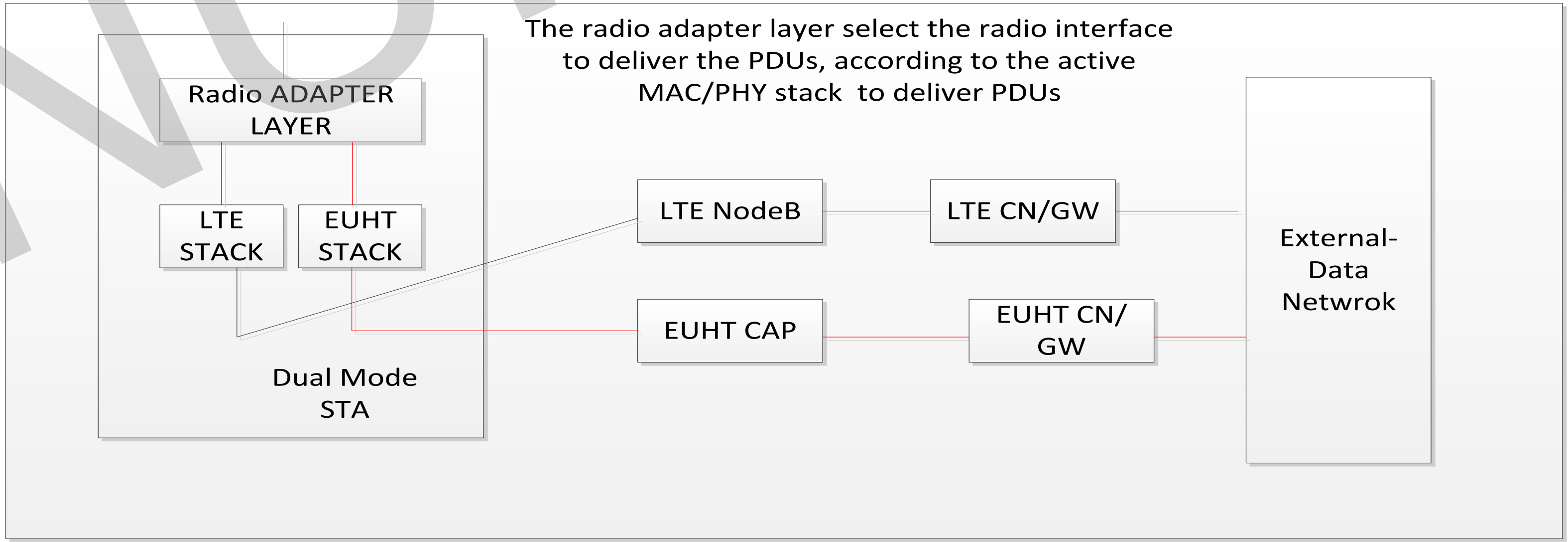
STA supporting spectrum aggregation	2	0: Not supported; 1: Support spectrum aggregation mode; 2~3: reserved

6. CAP notifies the STA to activate/deactivate the CA mode in STA capability response frame(refer to Table 8 of section 6.3.4.5 in EUHT specification).

Spectrum aggregation mode	2	0: No aggregation; 1: Aggregation mode; 2~3: reserved

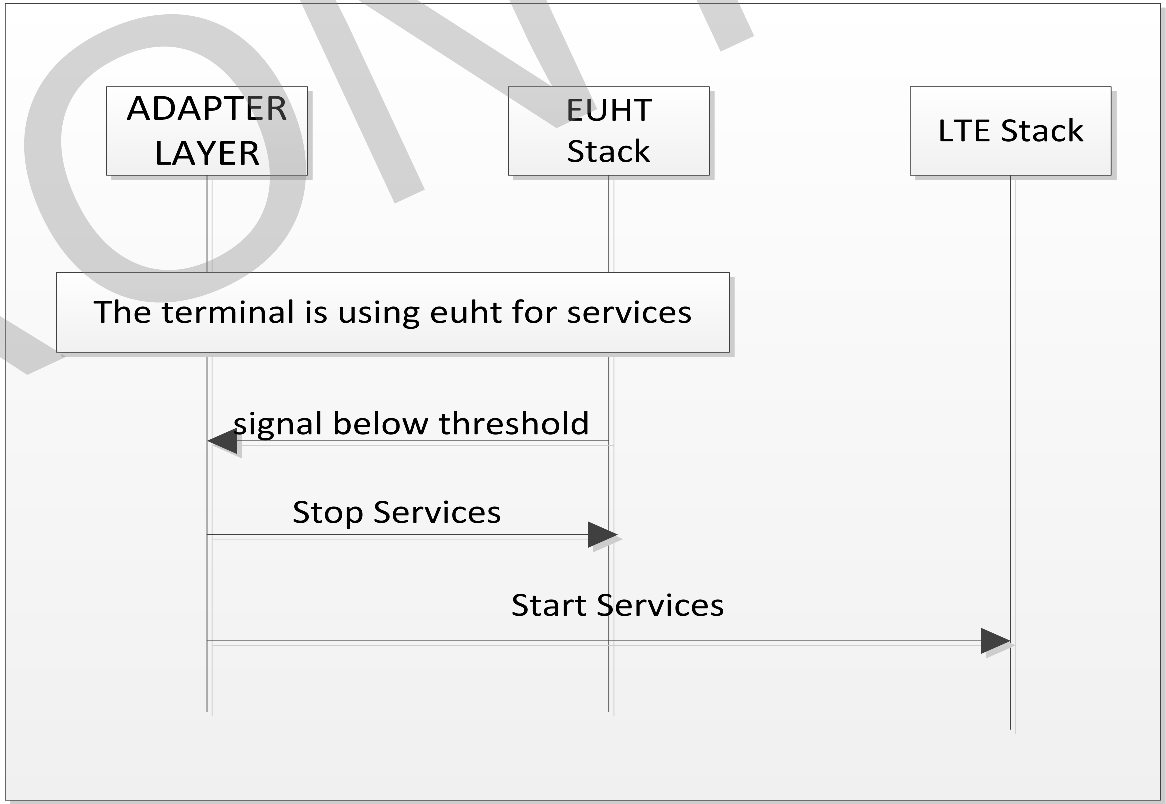
Inter system handover Procedure

- EUHT access network and LTE access network are independent and the core networks of the two systems are independent too. EUHT can support inter-system handover with the LTE system (legacy IMT system).
- A dual-mode EUHT STA that integrates LTE functions to achieve inter-working with LTE system.
- A radio adaptation layer is added in the dual-mode terminal on top of both LTE and EUHT protocol stack, which can dynamically select and activate the specific radio access technology.
- This solution does not need to modify the existing network, and has no impact on the existing network. All the inter-working control signalling and procedure in the dual-mode STA is implementation related.



A possible Inter-system handover Procedure implementation

- 1) The dual-mode STA monitors the wireless qualities and the traffic load of the two wireless networks, and selects the better radio access network to carry out services according to an appropriate criteria.
- 2) For example,when the STA is using the EUHT access network for services, if the signal quality of the EUHT network becomes worse and the signal quality of the LTE network is better, the STA 's adaptation layer will choose to use the LTE network for services and vice versa.



EUHT Development History

- ***2007: The development of EUHT started***
- ***2012/2014/2016: Standardization***
  - *EUHT was announced as national standard for*
    - *wireless communication, vehicle network and metro.*
- ***2013 ~ Present: SoC***
  - *3 generations of EUHT core chipsets, including baseband, analog, RF, SoC,.*
- ***2014 ~ Present: Deployment***
  - *EUHT systems and products have been massively deployed in many scenarios, including high speed train, vehicle network, industrial internet, 8K HDTV transmission, and wide area internet coverage.*
- ***2019: ISSCC Award***
  - *In February 2019, ISSCC gave Nufront the Technology Innovation Award to acknowledge EUHT as the first deployed URLLC system and chip in the world.*

EUHT is multiple industrial and national standards

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- ***Industrial Standard for Wireless Communication (2012)***
  - *YD/T 2394-2012*
- ***National Standard for Cooperative Vehicle and Road Communication (2014)***
  - *GB/T 31024-2014*
- ***Industrial Standard for Realtime HD Video Surveillance transmission in Metro (2016)***
  - *CJ/T 500-2016*
- ***National Standard for Wireless Communication (2018)***
  - *GB/T 36454-2018*

EUHT is Cost effective and total solution *[for Rail Transit]*

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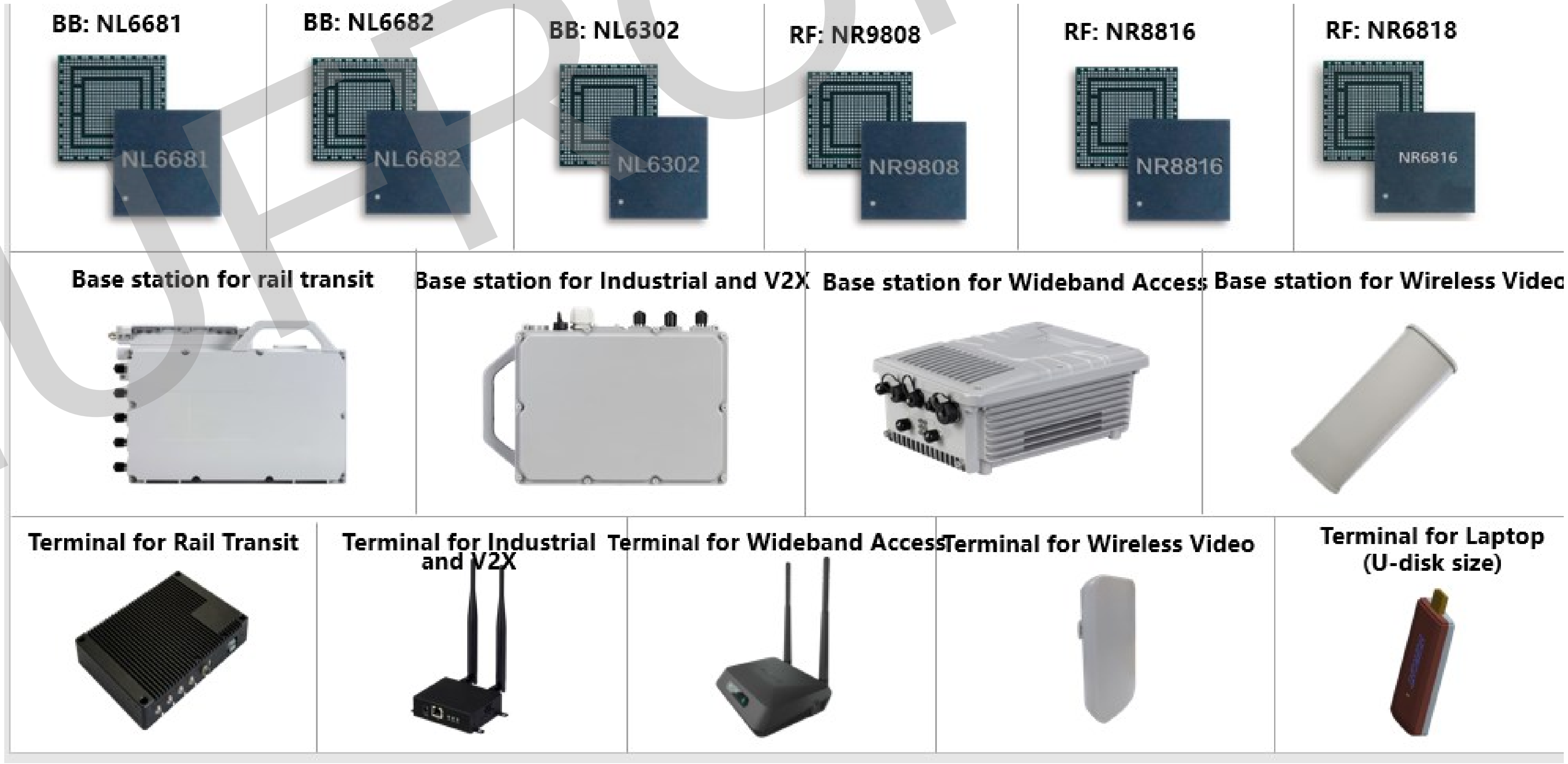
- ***Total Solution***
  - *Innovative PHY/MAC Protocol*
  - *Core SoCs(baseband/Analog/RF)*
  - *Base Stations*
  - *Terminals*
  - *Management Software*
- ***High performance***
  - *Reliability/Latency*
  - *Throughput*
  - *High speed*
- ***Low Cost***
  - *Much lower cost than LTE/NR products*



EUHT vs IEEE 802.11

- The first release of EUHT specification was submitted as "N14746" to ISO/IEC JTC1 /SC6 in 2011
- IEEE 802.11 compared EUHT and 802.11ac later in 2011 as below
  - Different key features of EUHT: 78.125KHz sub-carrier spacing, UL MU-MIMO and 8 streams.
- The same features are supported in 802.11ax, which is started in 2014.

Potential Areas of Overlap and Incremental Features in N14746

- A high level comparison of the China NB proposal and 802.11ac highlights the following areas of overlap:
  - Targeted frequency (<6GHz)
  - 20/40/80 MHz modes
  - MU-MIMO
  - 256 QAM
  - LDPC
- The proposal introduces a set of incremental features which, in theory, can lead to higher throughputs, e.g.:
  - Code rate 7/8 for 256 QAM
  - Non-contiguous 20 MHz channels
  - Denser carrier spacing for OFDM (4x)
  - Up to 8 SS support of DL MU-MIMO
  - Unequal Modulation
  - Uplink MU MIMO
  - Expanded LDPC Matrix
  - Scheduled TDMA MAC

Note: Document N14746 contains a high level overview of the proposed standard and no detailed analysis of the overlap and differences can be provided at this time

IEEE 802

Flexible and Efficient for Various Scenarios

Scenarios	Requirements	Impact of System Design
Home broadband access	Static	Sparse Pilot Density, Long frame length downlink-dominant
Wireless video surveillance	Static	Sparse Pilot Density, Long frame length Uplink-dominant
Metro video surveillance	High vehicle speed	Dense Pilot Density, middle frame length Uplink-dominant
HST passengers network service	Very High vehicle speed	Denser Pilot Density, short frame length Downlink-dominant;

- **Different requirements for Different application scenarios**
- **EUHT is extremely flexible and easy to adapt to given scenario**
  - *Frame length : 0.1ms ~ 14 ms*
  - *Pilot Density: 0.04ms ~ 14ms Pilot interval*
  - *DL/UL ratio can be fine-tuned in unit of one OFDM symbols*

EUHT Use Cases

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Wireless Broadband

- *Coverage > 3km*
- *500+ concurrent terminals*
- *Extremely low cost*
- *Deployments*
- *5,000+ Base stations*
- *1 million terminals*
- *Guangdong, Fujian, Jiangxi*

Rail Transit

- *Integrated services including train control*
- *350km/h speed*
- *100% Handover Success*
- *Deployments*
  - *Jing-jin High Speed Rail*
  - *Beijing/ Guangzhou/Tianjin Metro*

Vehicle Network

- *99.9999% Reliability*
- *4ms End-to-end Latency*
- *V2I, V2V*
- *Deployments*
  - *Guang-Shen Highway*
  - *Beijing V2X network*
  - *BAIC Platooning*

Industrial Internet

- *99.99999% Reliability*
- *200 us air interface latency*
- *>1000 concurrent terminals*
- *Deployments*
  - *Shenyang*
  - *Guangzhou*
  - *Huizhou*

Typical EUHT HST Network

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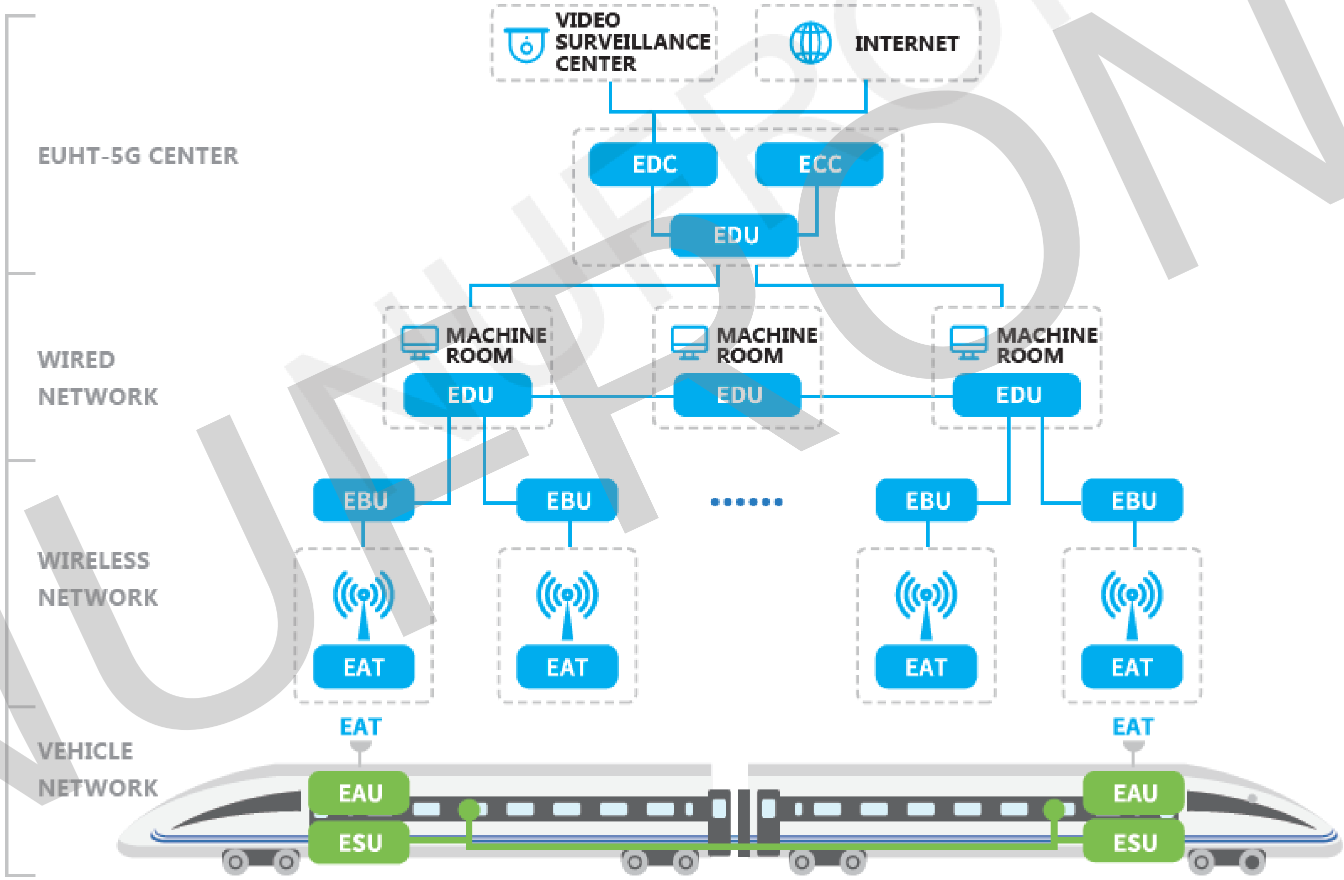

ESU: EUHT-5G Switch Unit
EAU: EUHT-5G Access Unit
EAT: EUHT-5G Antenna
EBU: EUHT-5G Base Unit
EDU: EUHT-5G Data Unit
EDC: EUHT-5G Data Center
ECC: EUHT-5G Control Center

- High Throughput, High Reliable, Low Latency Wireless Access Network
- Light Weight, Low Latency core network with Mobile Edge Computing capability

EUHT Rail Transit Commercial Cases

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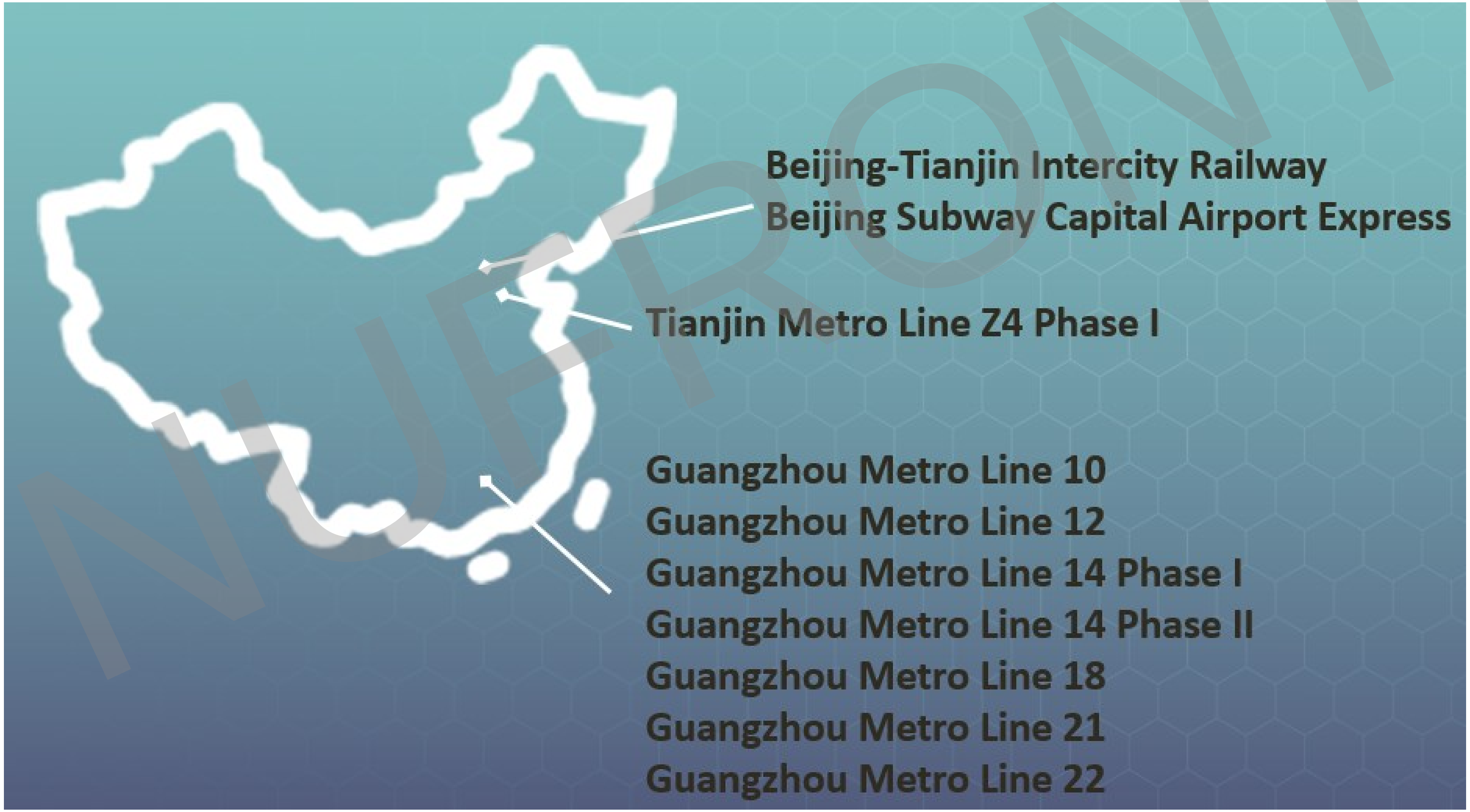

So far, the total mileage of EUHT in the field of rail transit is **287** km, and the mileage under construction is **213** km.

Jingjin Intercity High-Speed Rail

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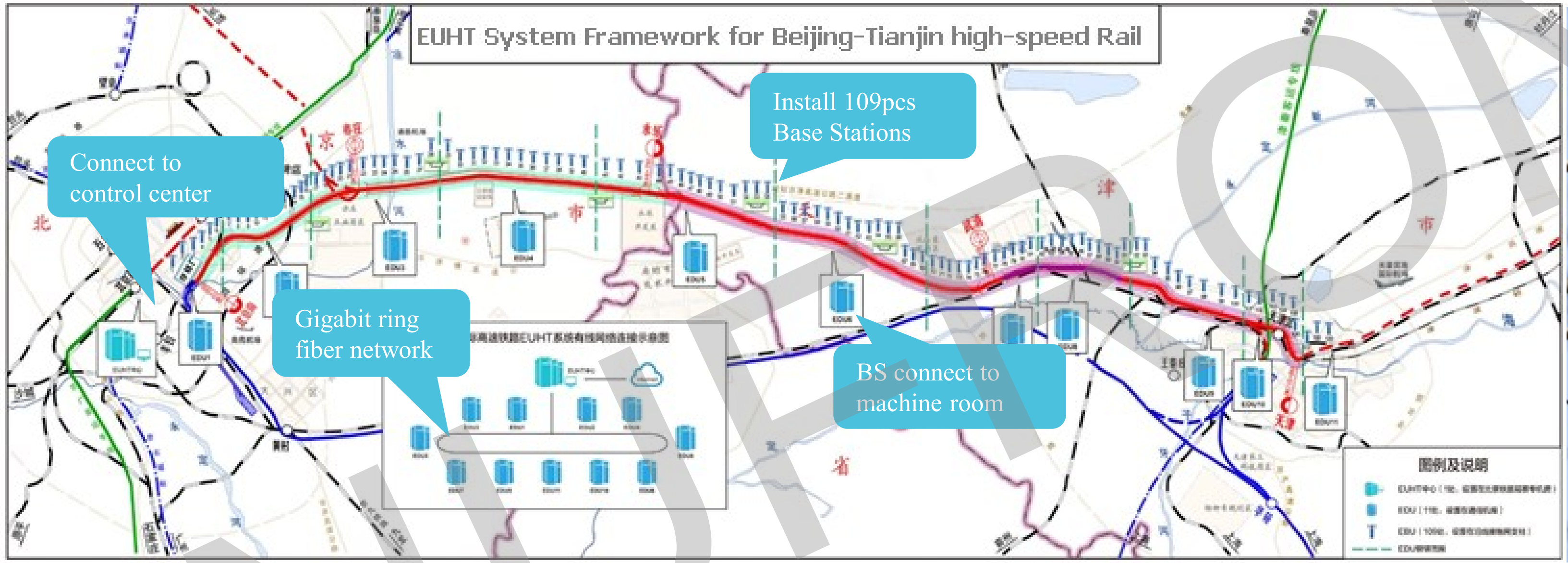

- Commercial use: Jan 2017
- 120km, 109 Base stations
- 300km/h
- 100% Handover Success ratio @ 300km/h

Guangzhou Metro

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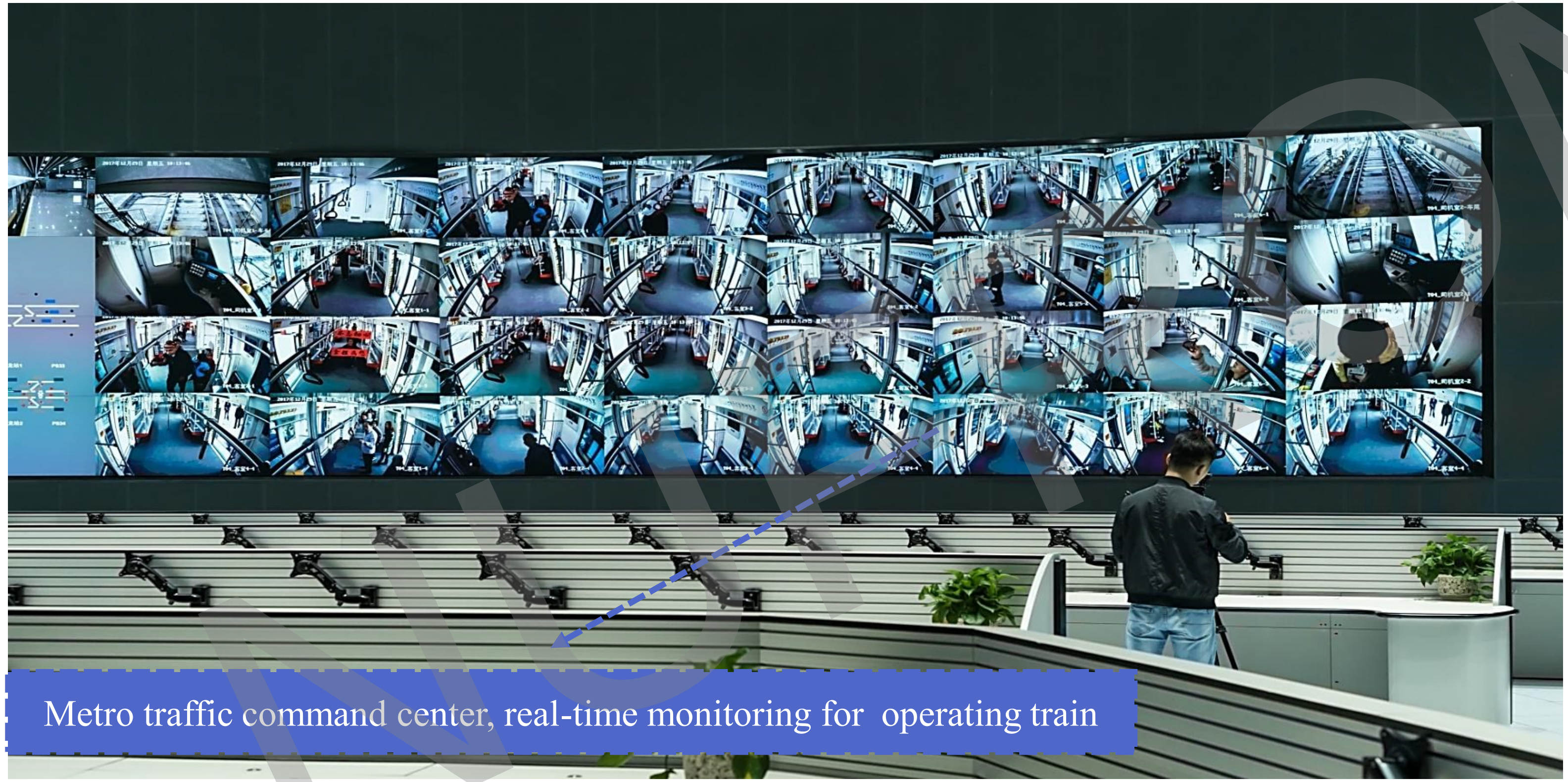
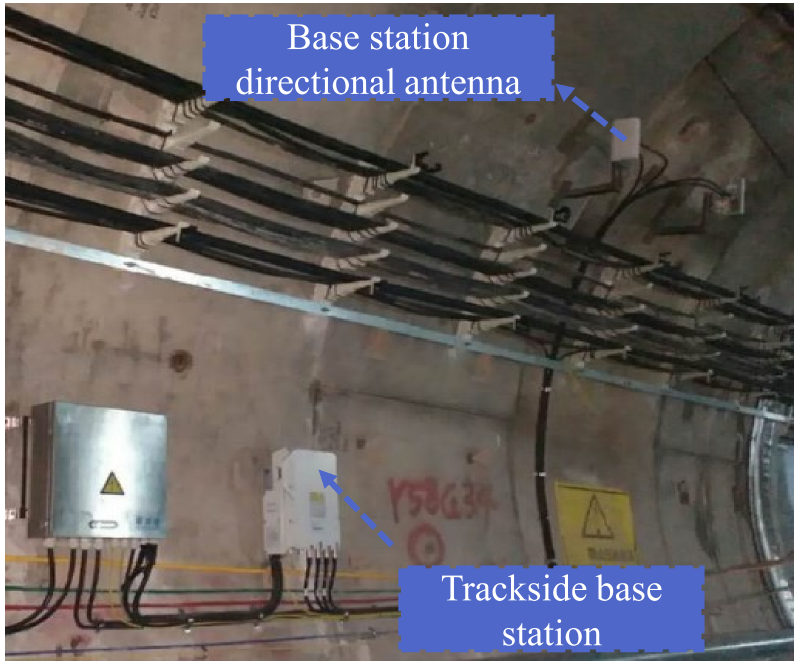


Metro traffic command center, real-time monitoring for operating train

- Commercial use: Dec 2017
- 120km/h
- 30+ channel HD-CCTV per train



Beijing Subway Capital Airport Express

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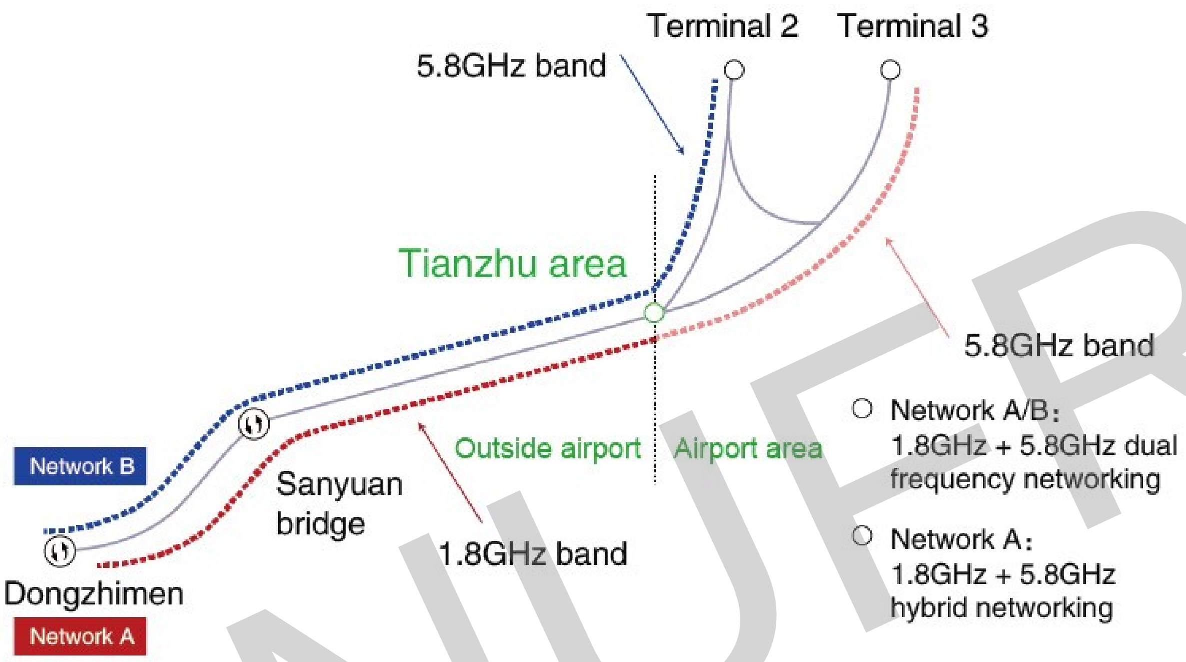

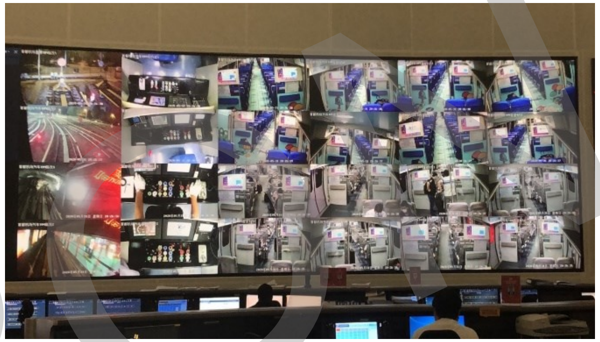

- In April 2020, EUHT successfully realizes **1.8GHz + 5.8GHz** network in Beijing Subway Capital Airport Express as **Integrated business bearer**:
- CBTC / PIS / VMS / Carriage Broadcast / Passenger Emergency Intercom / Flight Information / TCMS

Beijing EUHT-5G Vehicle Network

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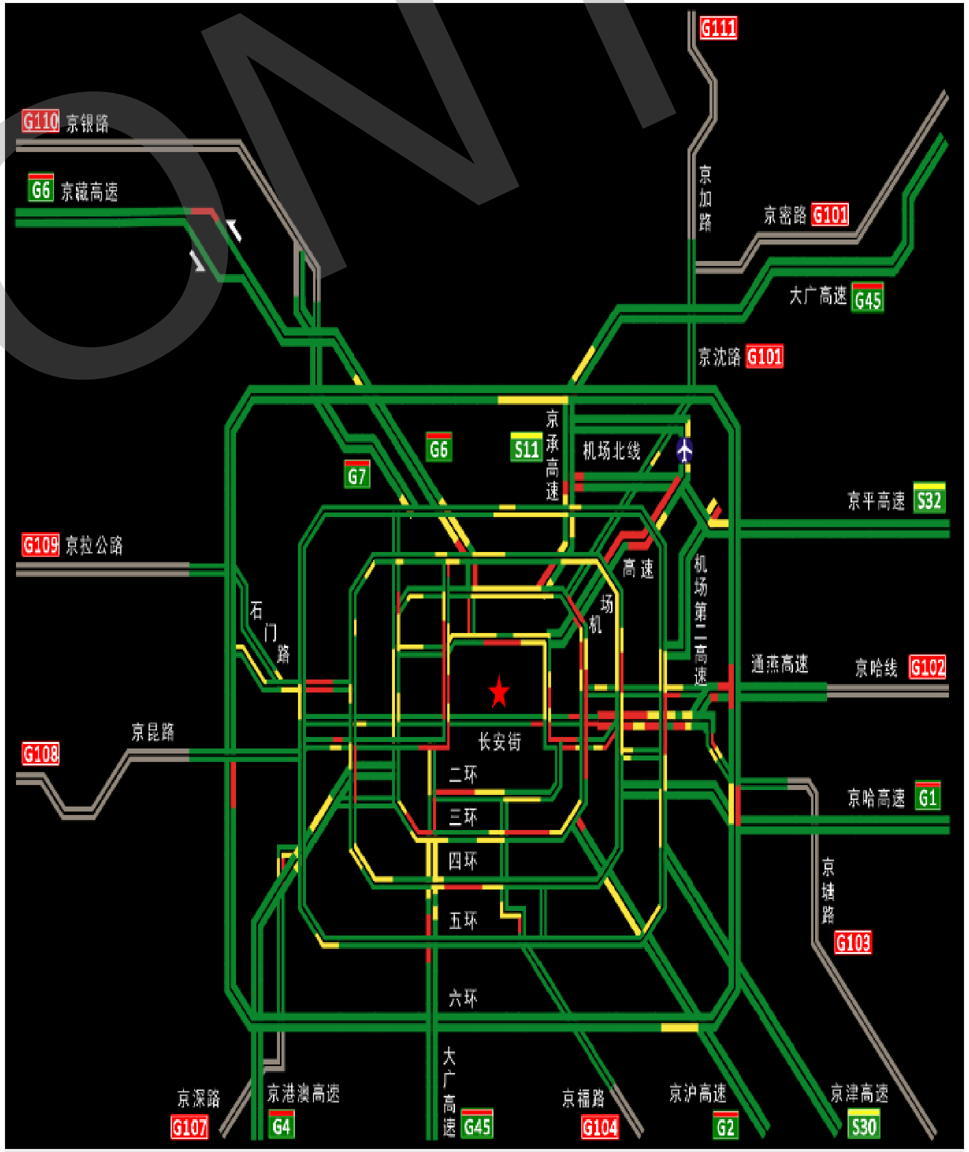
- *Self-Driving based on EUHT 5G V2X network*
- *Partners: Unicom, Baidu, DiDi, JD, Pony.ai,*
- *World's Largest V2X network – 6000 km*
  - *2020: 1200 km*
  - *2021: 4800 km*



Industrial Internet Use Case: Biel Crystal Factory

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- 1058 machine tools for iPhone 11 glass
- Replace cable to support flexible manufacture
- Reduce the maintenance cost

EUHT Project Case —Broadband Coverage in Rural Areas

- 2015 ~ Present
- Most cost effective solution to solve the “last mile” problem
- Single Base station coverage > 3km
- 5,000 villages, 1 million families

EUHT Project Case — 8K Ultra-HD Live Transmission

- Jan 2019, with China Telecom
- Ultra high uplink throughput with low error and low latency
- Commercial use in
  - International Horticultural Exposition
  - Basketball World cup
  - China Open for Tennis

Q/A

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Thank You

END