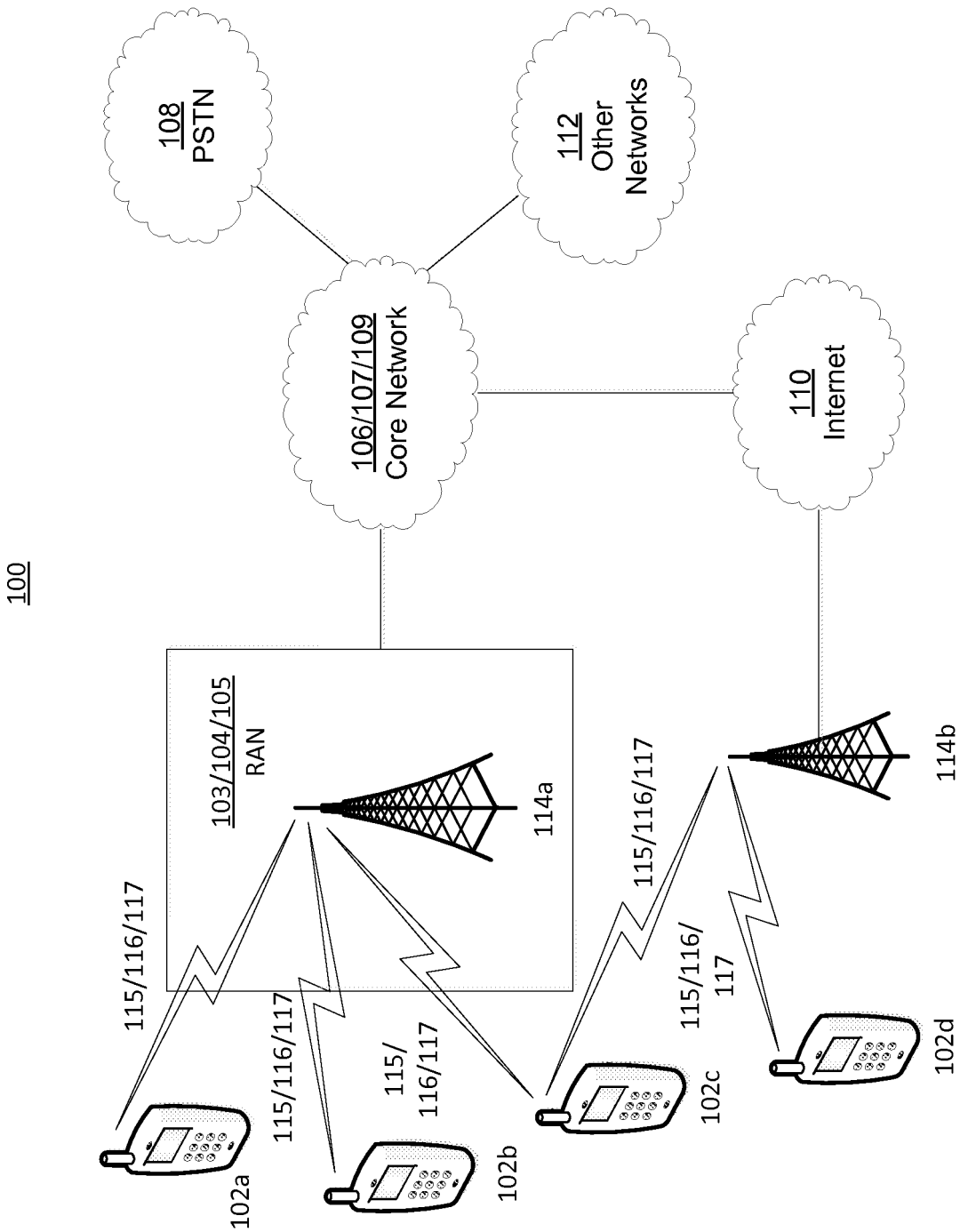

100
108
PSTN
112
Other
Networks
106/107/109
Core Network
110
Internet
103/104/105
RAN
114a
114b
115/116/117
115/116/117
115/
116/117
115/116/117
115/116/
117
102a
102b
102c
102d

FIG. 1A

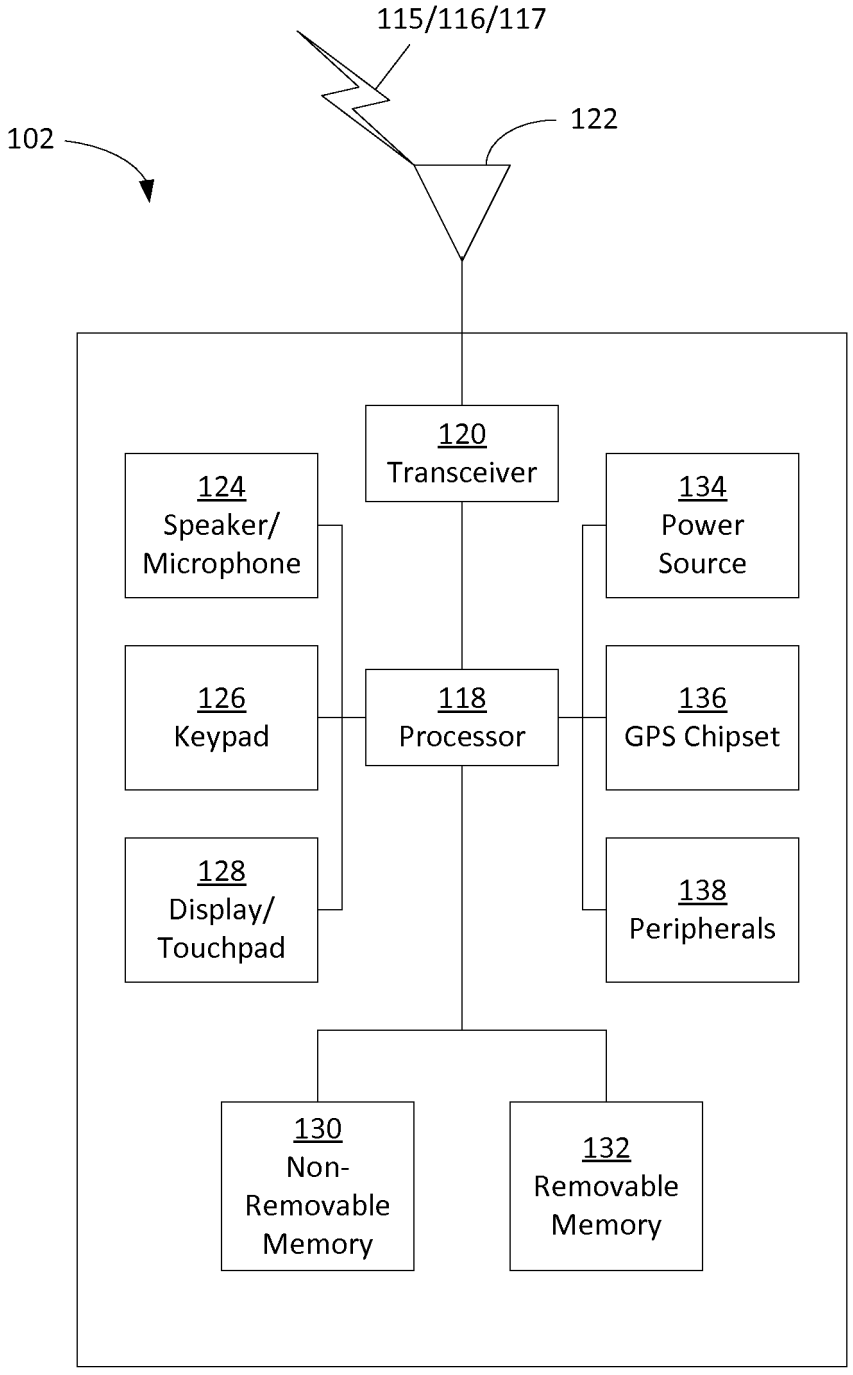

115/116/117
122
102
120
Transceiver
124
Speaker/
Microphone
134
Power
Source
126
Keypad
118
Processor
136
GPS Chipset
128
Display/
Touchpad
138
Peripherals
130
Non-
Removable
Memory
132
Removable
Memory

FIG. 1B

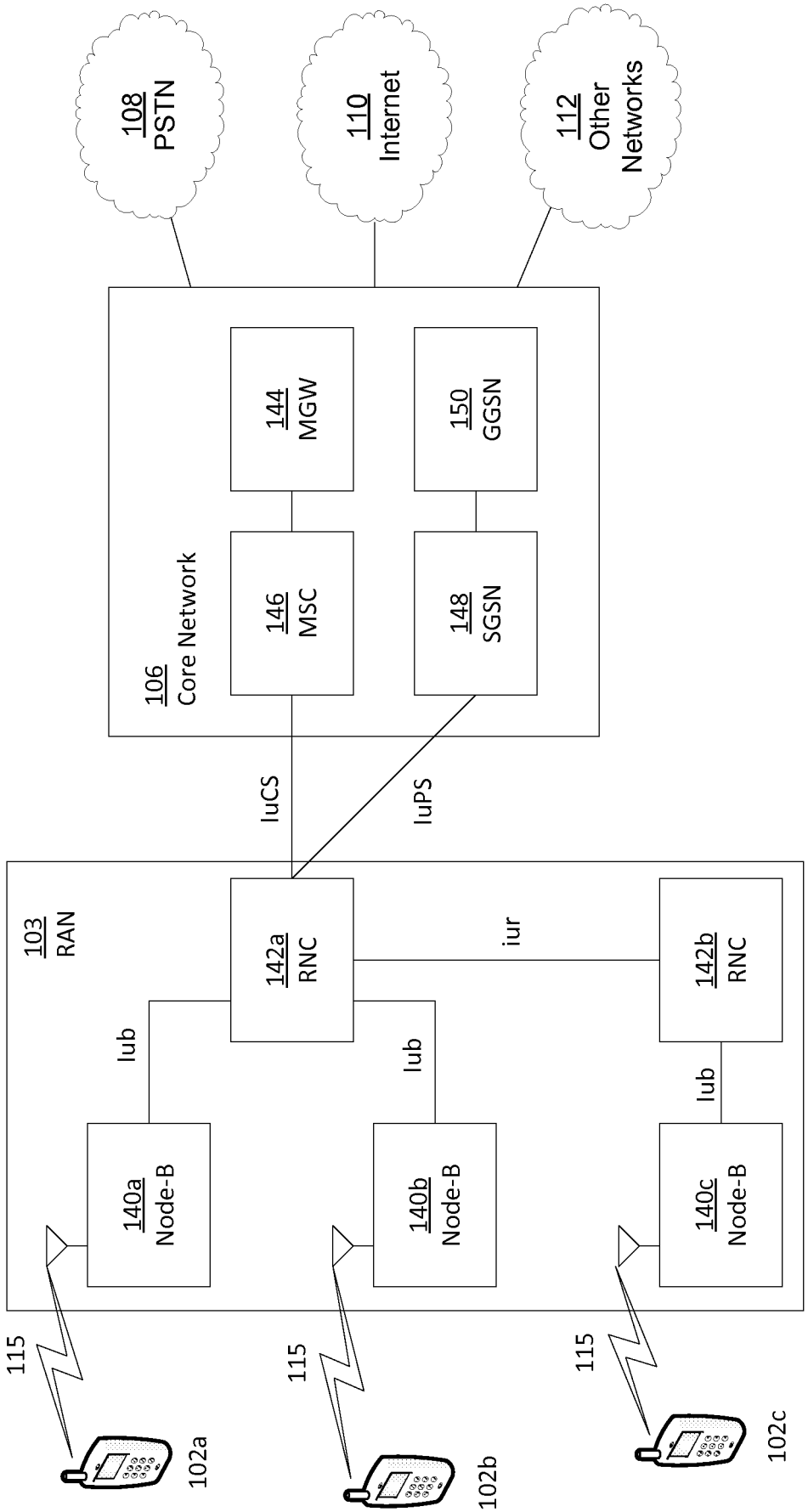

108 PSTN
110 Internet
112 Other Networks
106 Core Network
144 MGW
150 GGSN
146 MSC
148 SGSN
IuCS
IuPS
103 RAN
142a RNC
142b RNC
iur
Iub
Iub
Iub
140a Node-B
140b Node-B
140c Node-B
115
115
115
102a
102b
102c

FIG. 1C

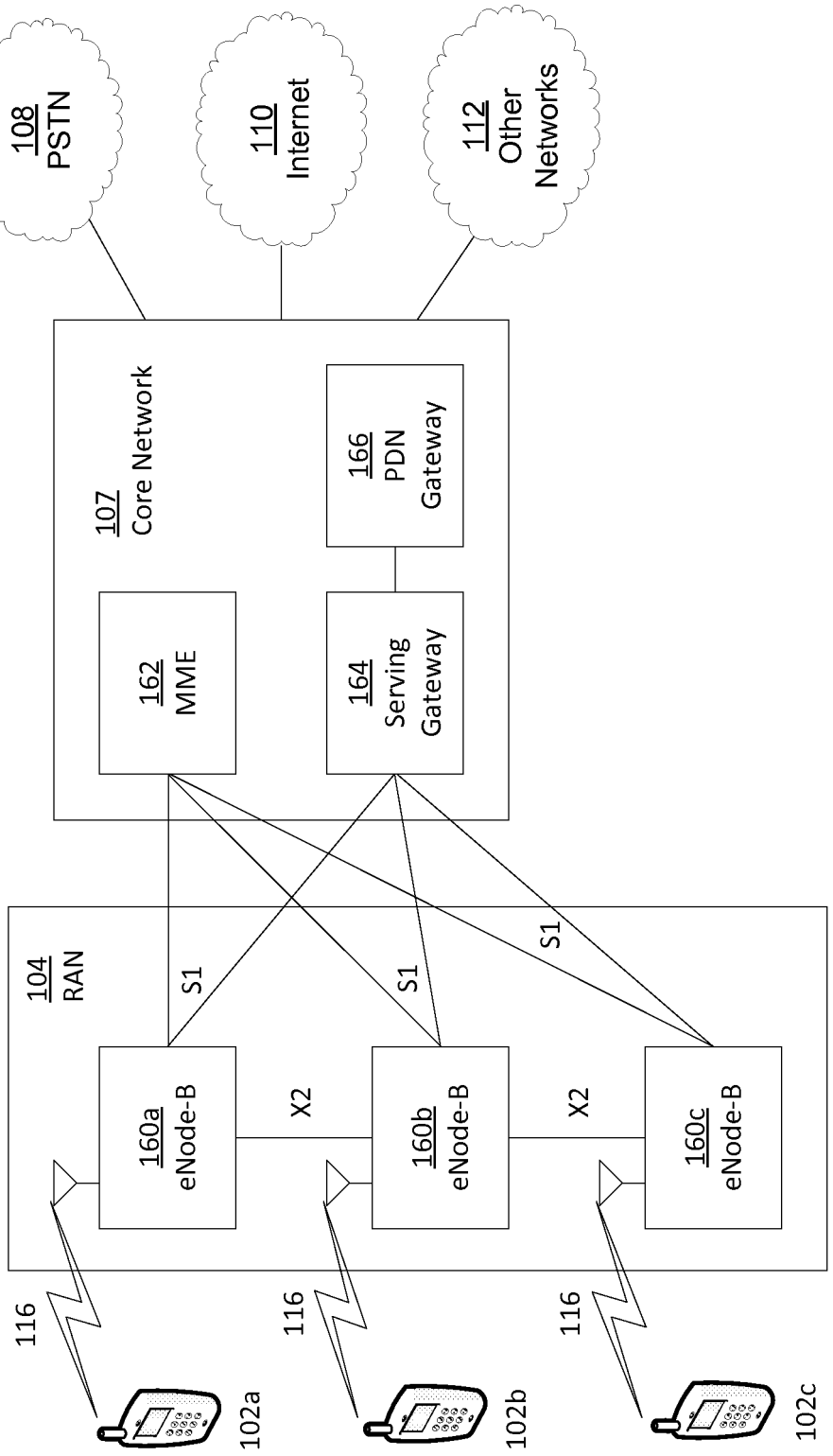

108 PSTN
110 Internet
112 Other Networks
107 Core Network
166 PDN Gateway
162 MME
164 Serving Gateway
104 RAN
S1
S1
S1
160a eNode-B
160b eNode-B
160c eNode-B
X2
X2
116
116
116
102a
102b
102c

FIG. 1D

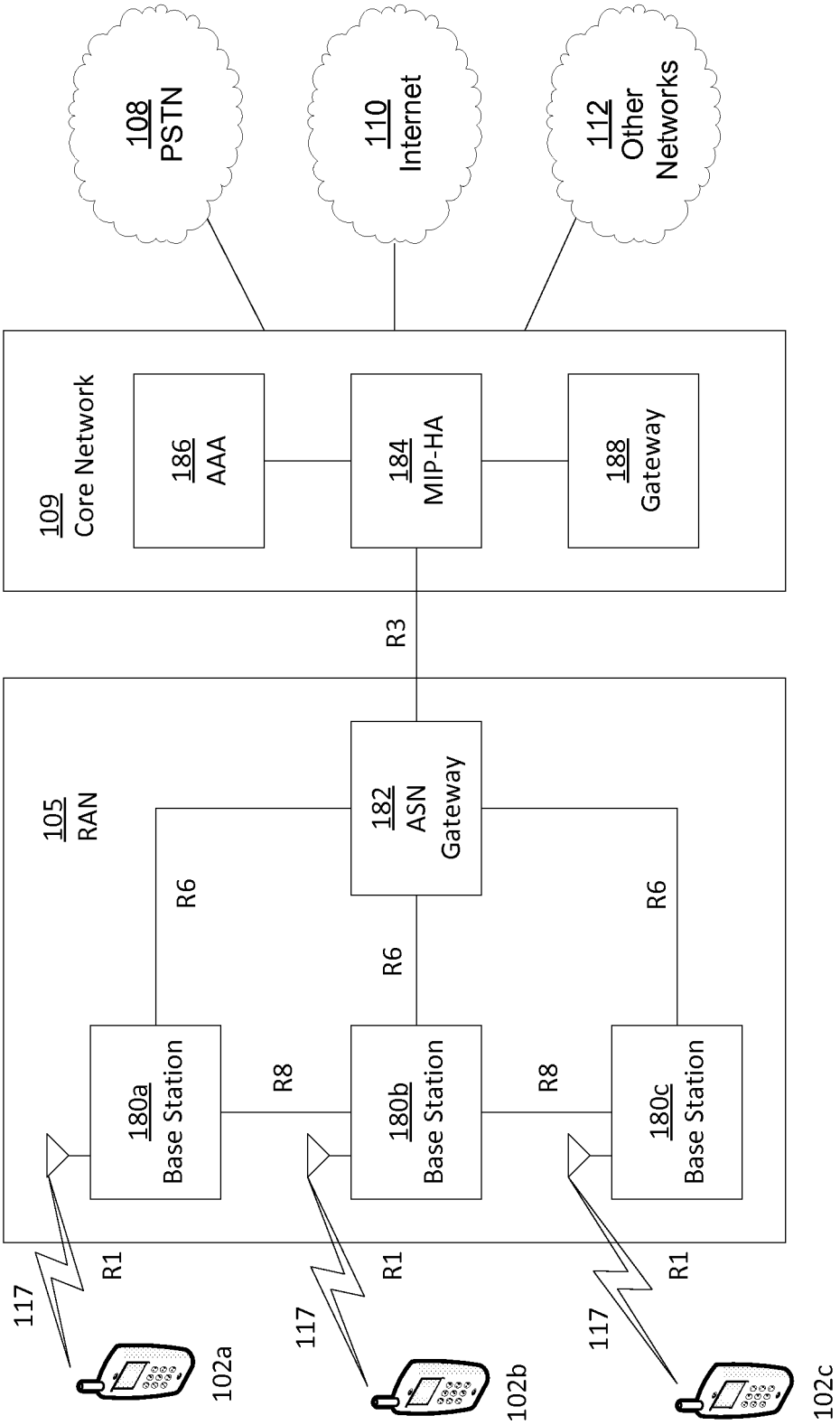

108 PSTN
110 Internet
112 Other Networks
109 Core Network
186 AAA
184 MIP-HA
188 Gateway
R3
105 RAN
182 ASN Gateway
R6
R6
R6
180a Base Station
180b Base Station
180c Base Station
R8
R8
R1
R1
R1
117
117
117
102a
102b
102c

FIG. 1E

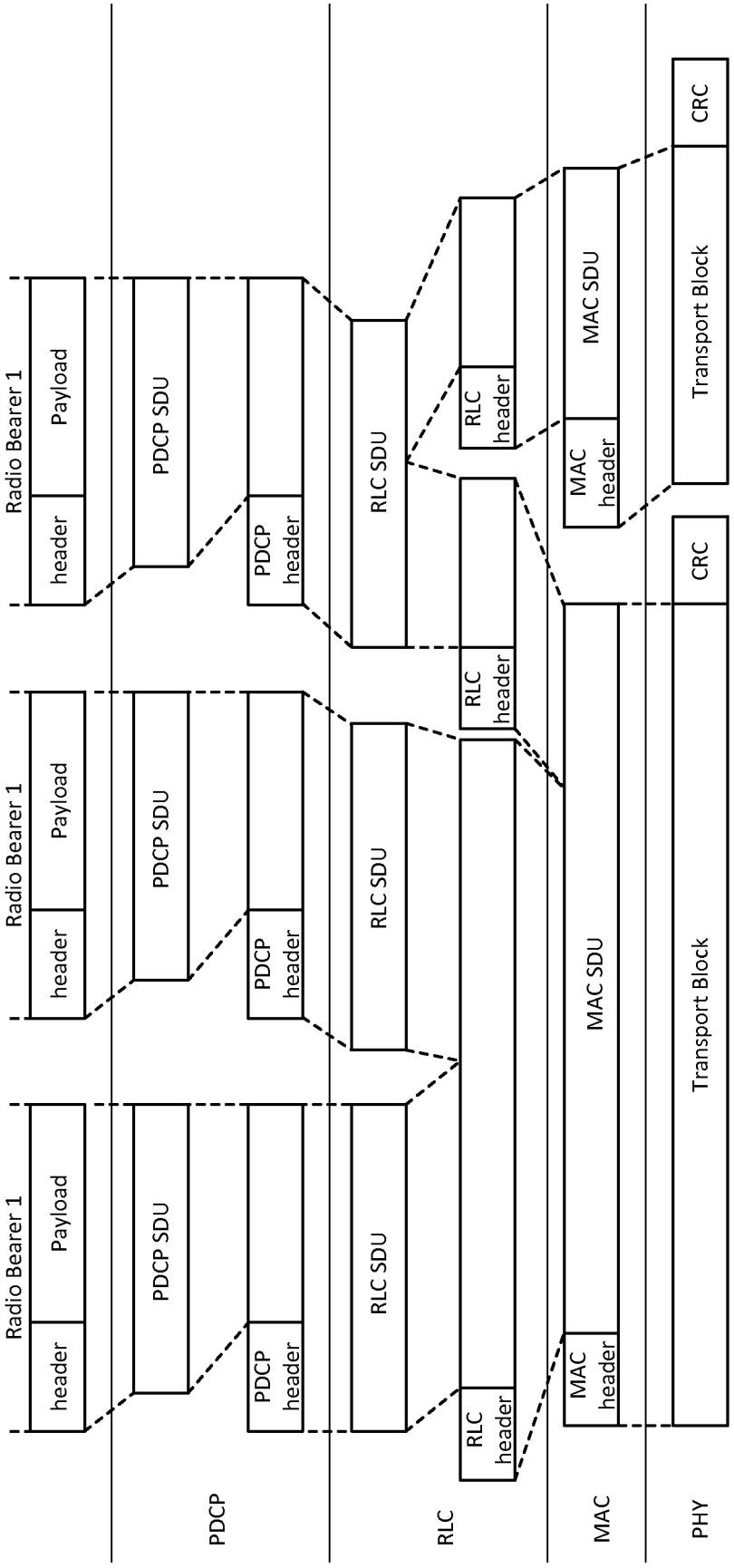

Radio Bearer 1
header
Payload
PDCP SDU
PDCP header
RLC SDU
RLC header
MAC SDU
MAC header
Transport Block
CRC
PDCP
RLC
MAC
PHY

FIG. 2

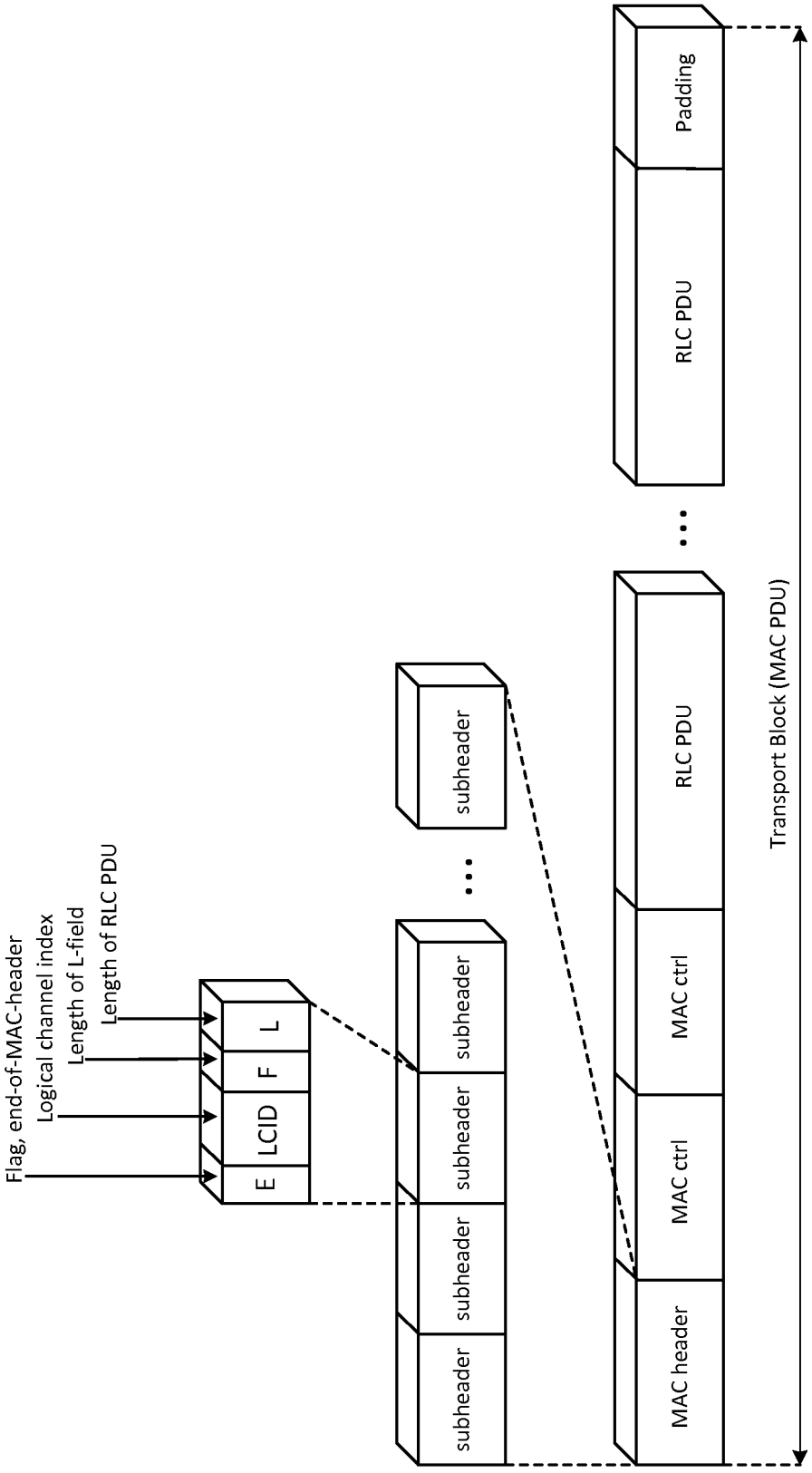

Flag, end-of-MAC-header
Logical channel index
Length of L-field
Length of RLC PDU
E
LCID
F
L
subheader
subheader
subheader
subheader
MAC header
MAC ctrl
MAC ctrl
RLC PDU
RLC PDU
Padding
Transport Block (MAC PDU)

FIG. 3

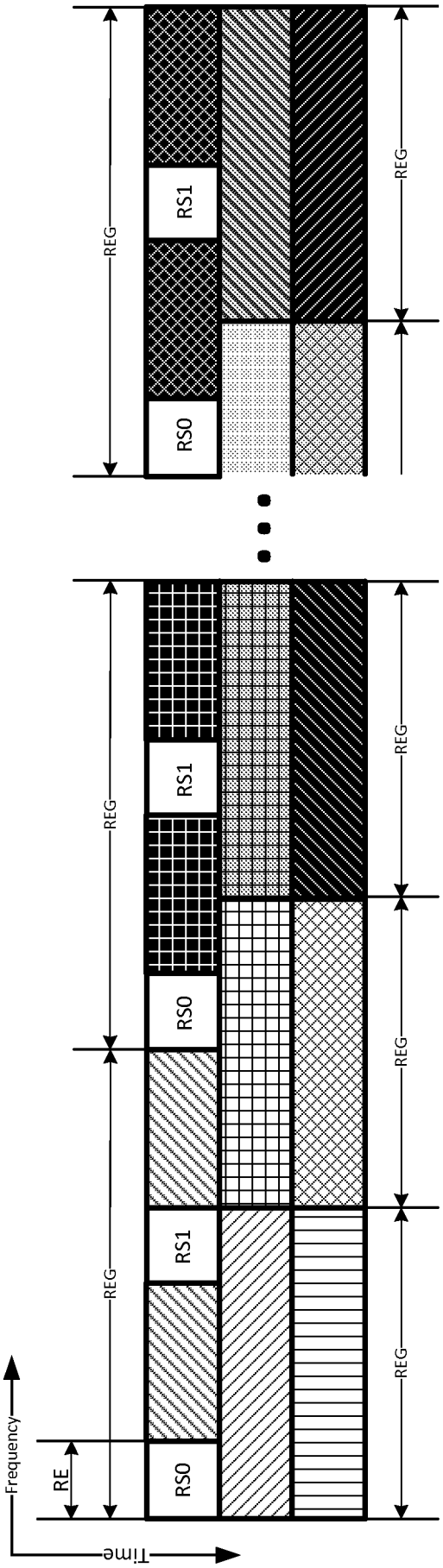

REG
RS1
RS0
REG
REG
RS1
RS0
REG
REG
RS1
RS0
REG
RE
Frequency
Time

FIG. 4

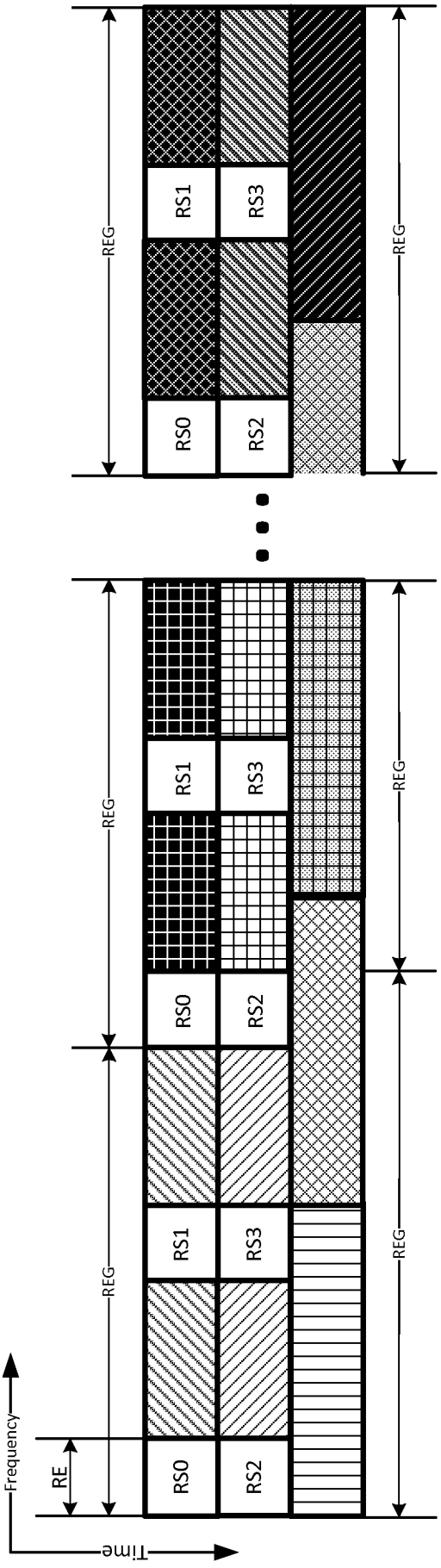

REG
RS1
RS3
RS0
RS2
REG
REG
RS1
RS3
RS0
RS2
REG
REG
RS1
RS3
RS0
RS2
REG
Frequency
RE
Time

FIG. 5

CFI	CFI codeword < b_0, b_1, …, b_{31} >
1	<0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1>
2	<1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0>
3	<1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1>
4 (Reserved)	<0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0>

FIG. 6

Subframe	Number of OFDM symbols for PDCCH when $N_{RB}^{DL} > 10$	Number of OFDM symbols for PDCCH when $N_{RB}^{DL} \leq 10$
Subframe 1 and 6 for frame structure type 2	1, 2	2
MBSFN subframes on a carrier supporting PDSCH, configured with 1 or 2 cell-specific antenna ports	1, 2	2
MBSFN subframes on a carrier supporting PDSCH, configured with 4 cell-specific antenna ports	2	2
Subframes on a carrier not supporting PDSCH	0	0
Non-MBSFN subframes (except subframe 6 for frame structure type 2) configured with positioning reference signals	1, 2, 3	2, 3
All other cases	1, 2, 3	2, 3, 4

FIG. 7

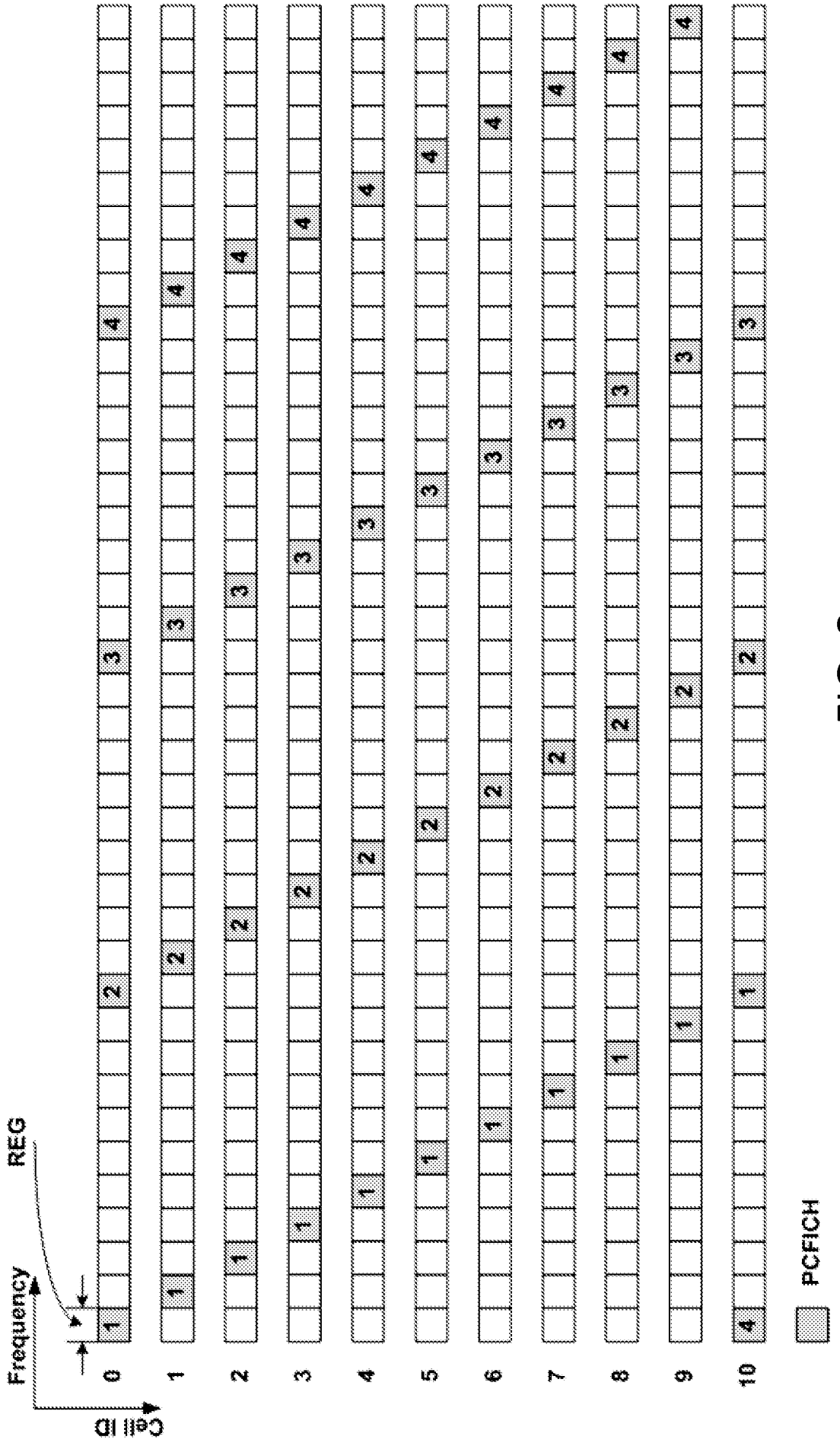


FIG. 8

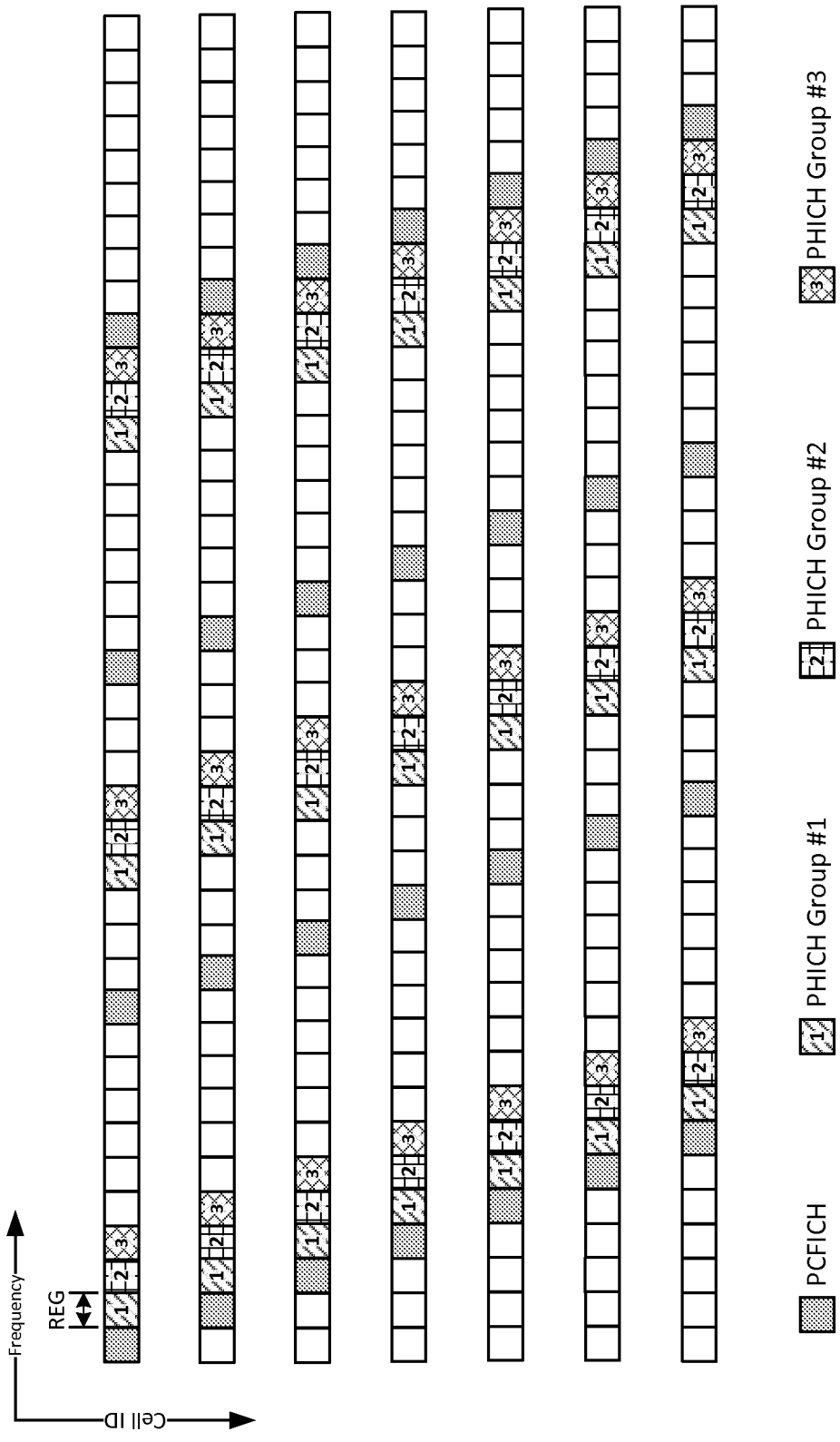

Frequency
REG
Cell ID
PCFICH
PHICH Group #1
PHICH Group #2
PHICH Group #3

FIG. 9

Sequence index n_{PHICH}^{seq}	Orthogonal sequence	
	Normal cyclic prefix $N_{SF}^{PHICH} = 4$	Extended cyclic prefix $N_{SF}^{PHICH} = 2$
0	$[+1 \quad +1 \quad +1 \quad +1]$	$[+1 \quad +1]$
1	$[+1 \quad -1 \quad +1 \quad -1]$	$[+1 \quad -1]$
2	$[+1 \quad +1 \quad -1 \quad -1]$	$[+j \quad +j]$
3	$[+1 \quad -1 \quad -1 \quad +1]$	$[+j \quad -j]$
4	$[+j \quad +j \quad +j \quad +j]$	-
5	$[+j \quad -j \quad +j \quad -j]$	-
6	$[+j \quad +j \quad -j \quad -j]$	-
7	$[+j \quad -j \quad -j \quad +j]$	-

FIG. 10

PDCCH format	Number of CCEs	Number of resource-element groups	Number of PDCCH bits
0	1	9	72
1	2	18	144
2	4	36	288
3	8	72	576

FIG. 11

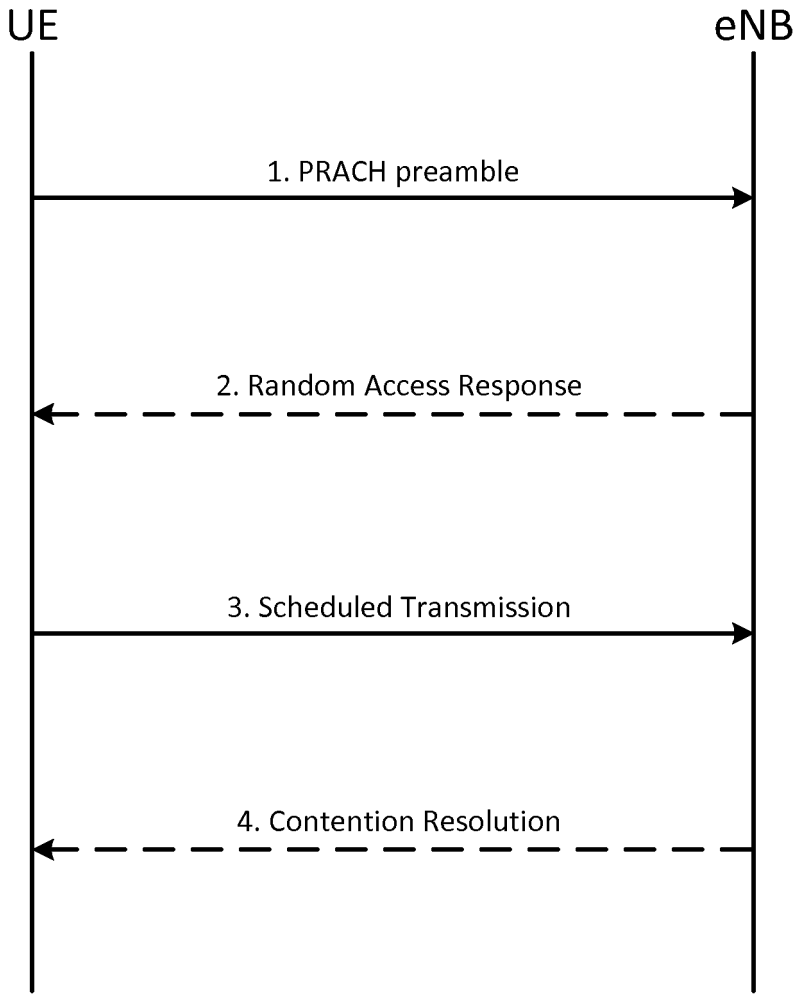

UE
eNB
1. PRACH preamble
2. Random Access Response
3. Scheduled Transmission
4. Contention Resolution

FIG. 12

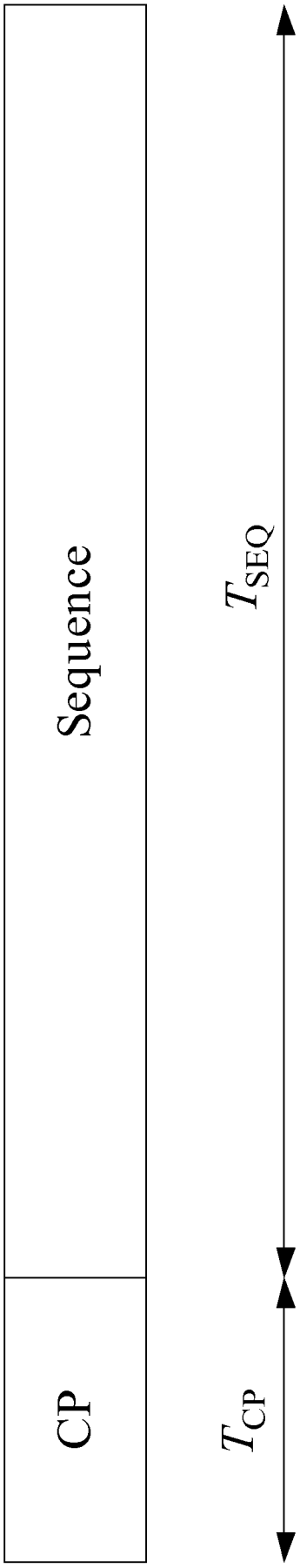


FIG. 13

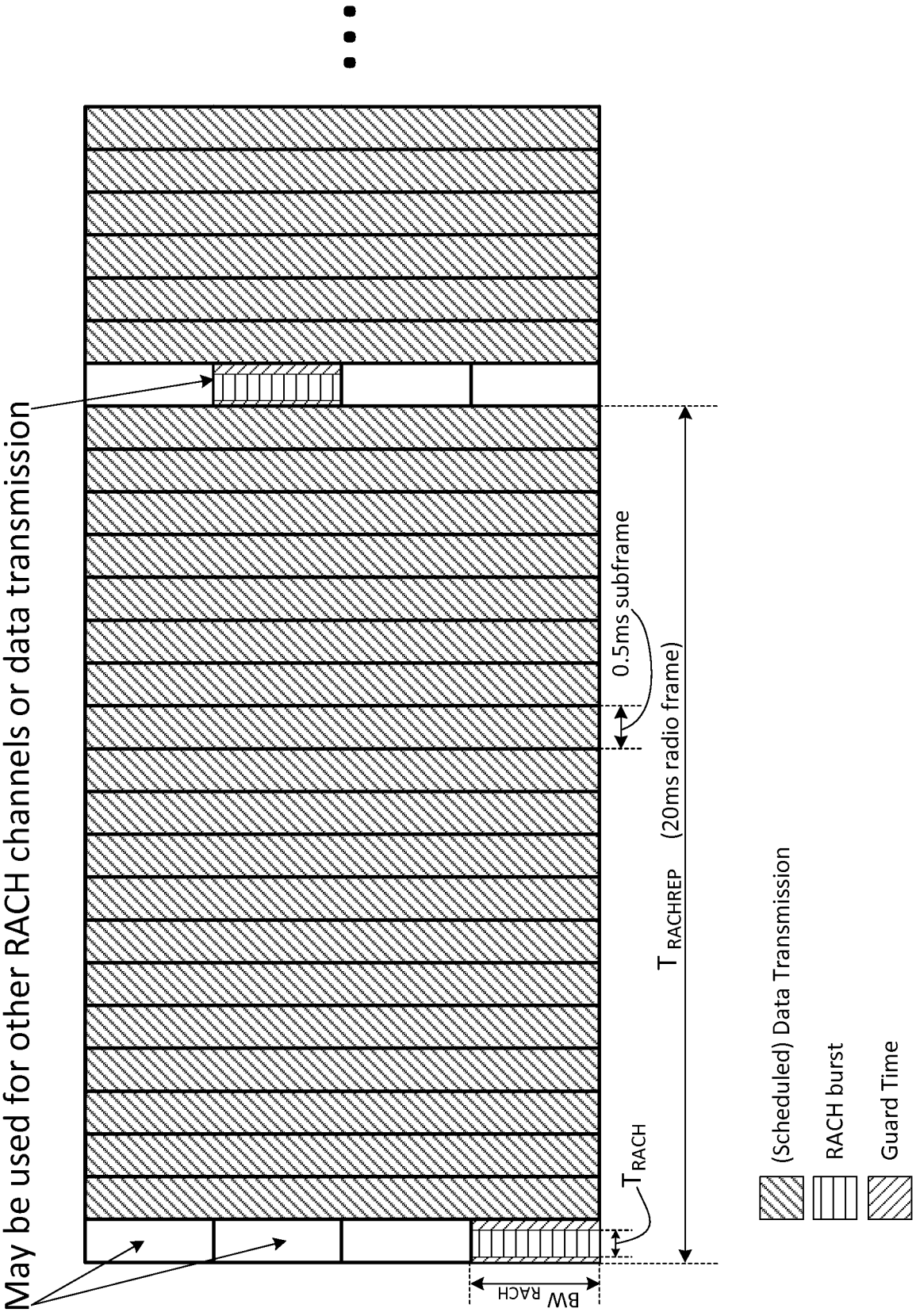

May be used for other RACH channels or data transmission
0.5ms subframe
(20ms radio frame)
T RACHREP
T RACH
BW RACH
(Scheduled) Data Transmission
RACH burst
Guard Time

FIG. 14

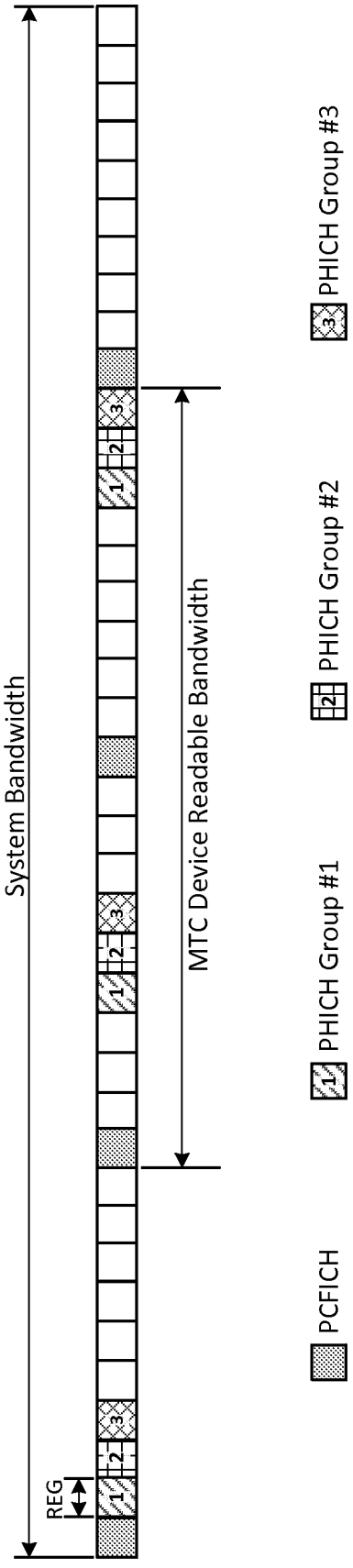

System Bandwidth
MTC Device Readable Bandwidth
REG
PCFICH
PHICH Group #1
PHICH Group #2
PHICH Group #3

FIG. 15

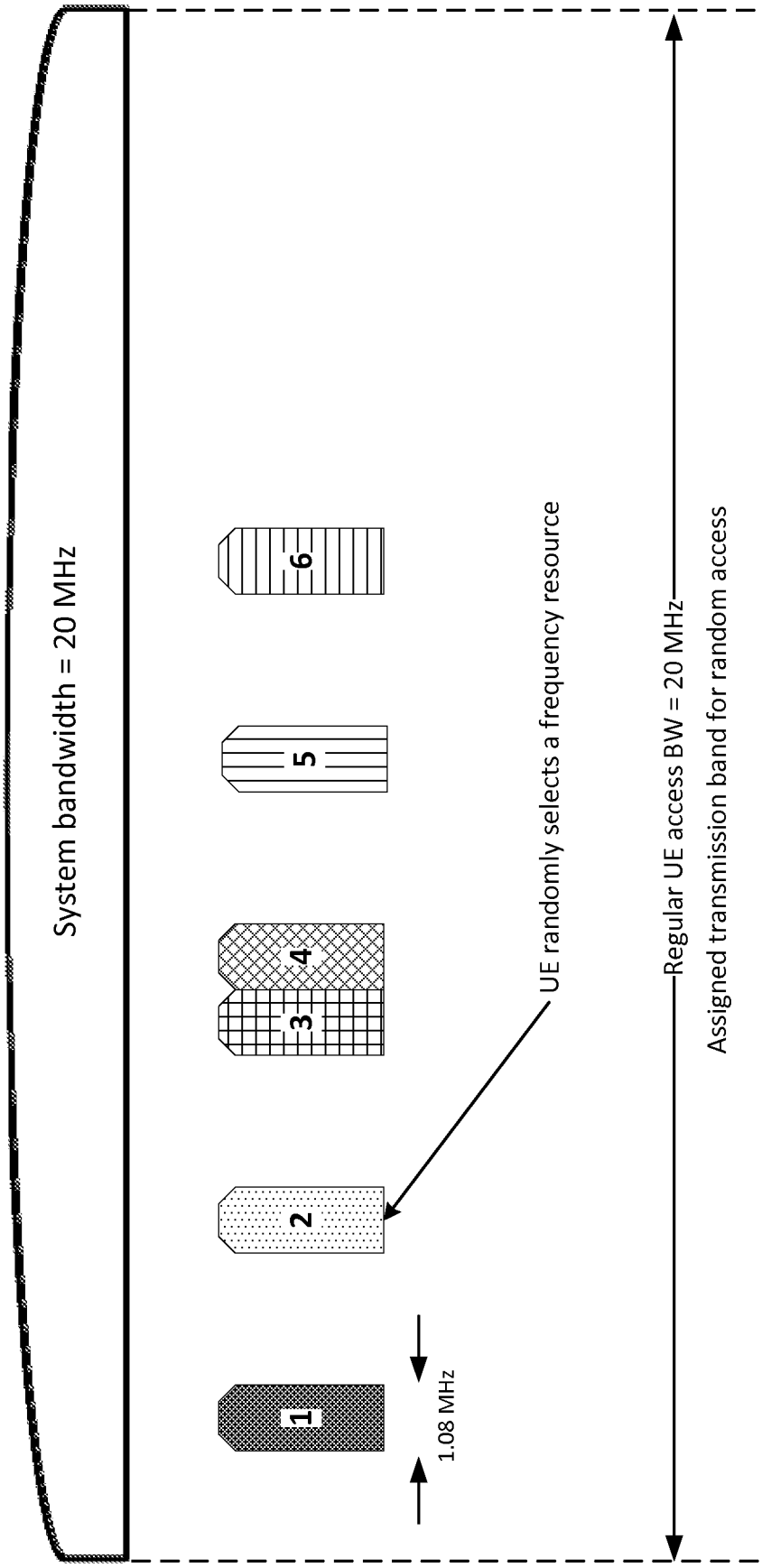

System bandwidth = 20 MHz
1
2
3
4
5
6
1.08 MHz
UE randomly selects a frequency resource
Regular UE access BW = 20 MHz
Assigned transmission band for random access

FIG. 16

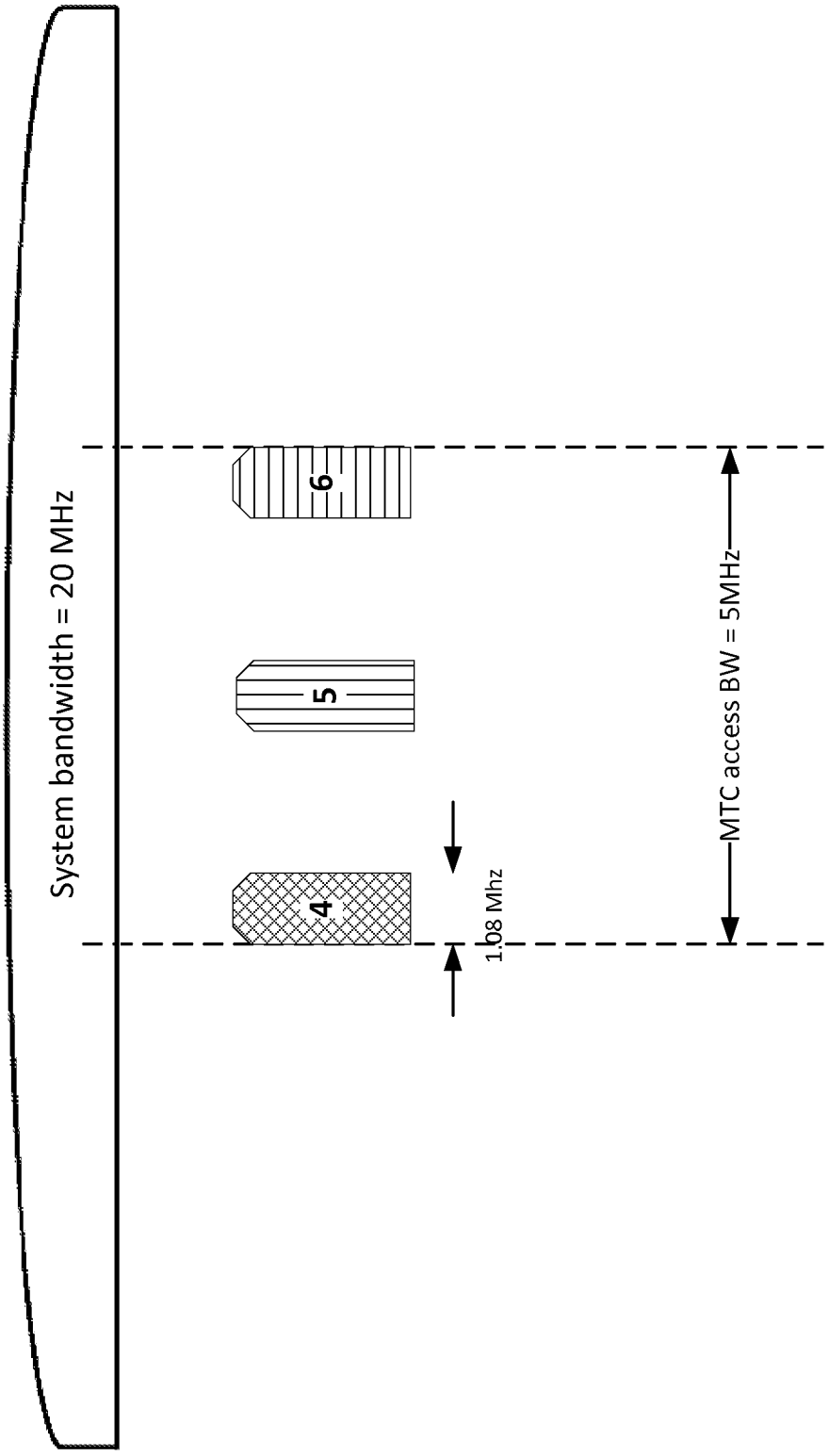


FIG. 17

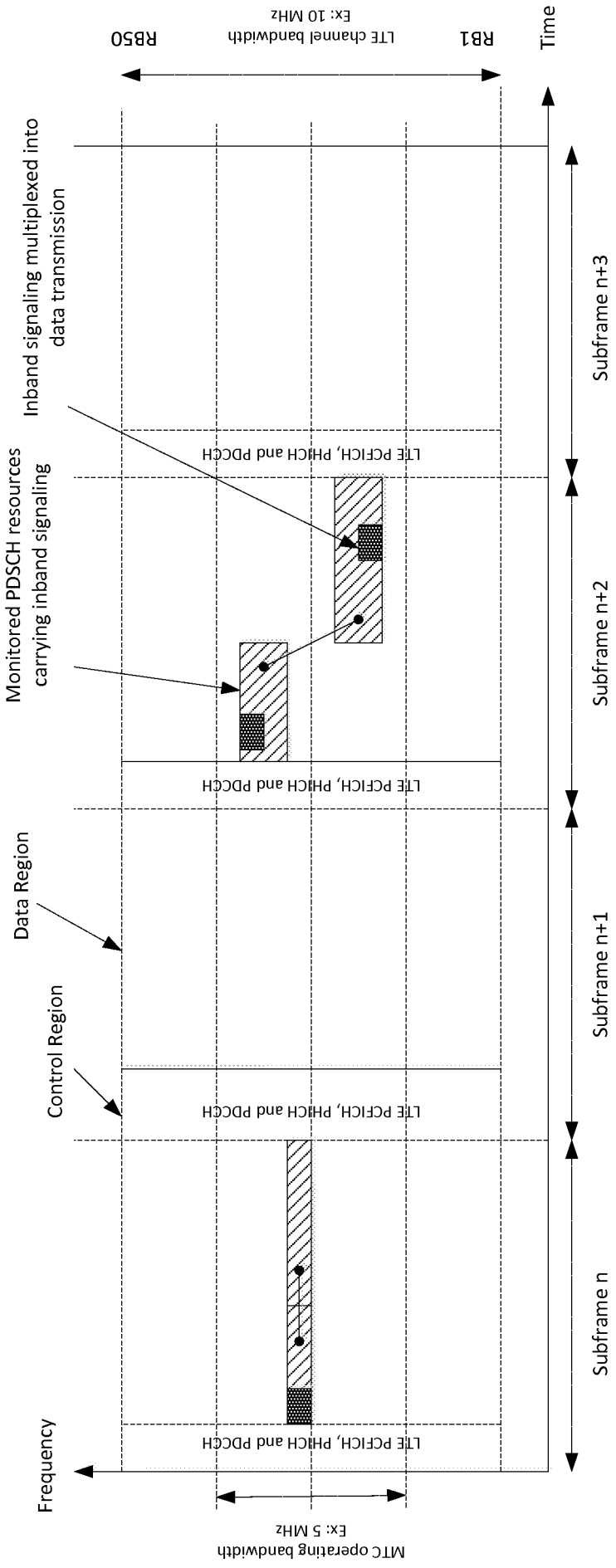

Time
RB1
RB50
LTE channel bandwidth
Ex: 10 MHz
Frequency
MTC operating bandwidth
Ex: 5 MHz
Subframe n
Subframe n+1
Subframe n+2
Subframe n+3
LTE PCFICH, PHICH and PDCCH
Control Region
Data Region
Monitored PDSCH resources carrying inband signaling
Inband signaling multiplexed into data transmission

FIG. 18

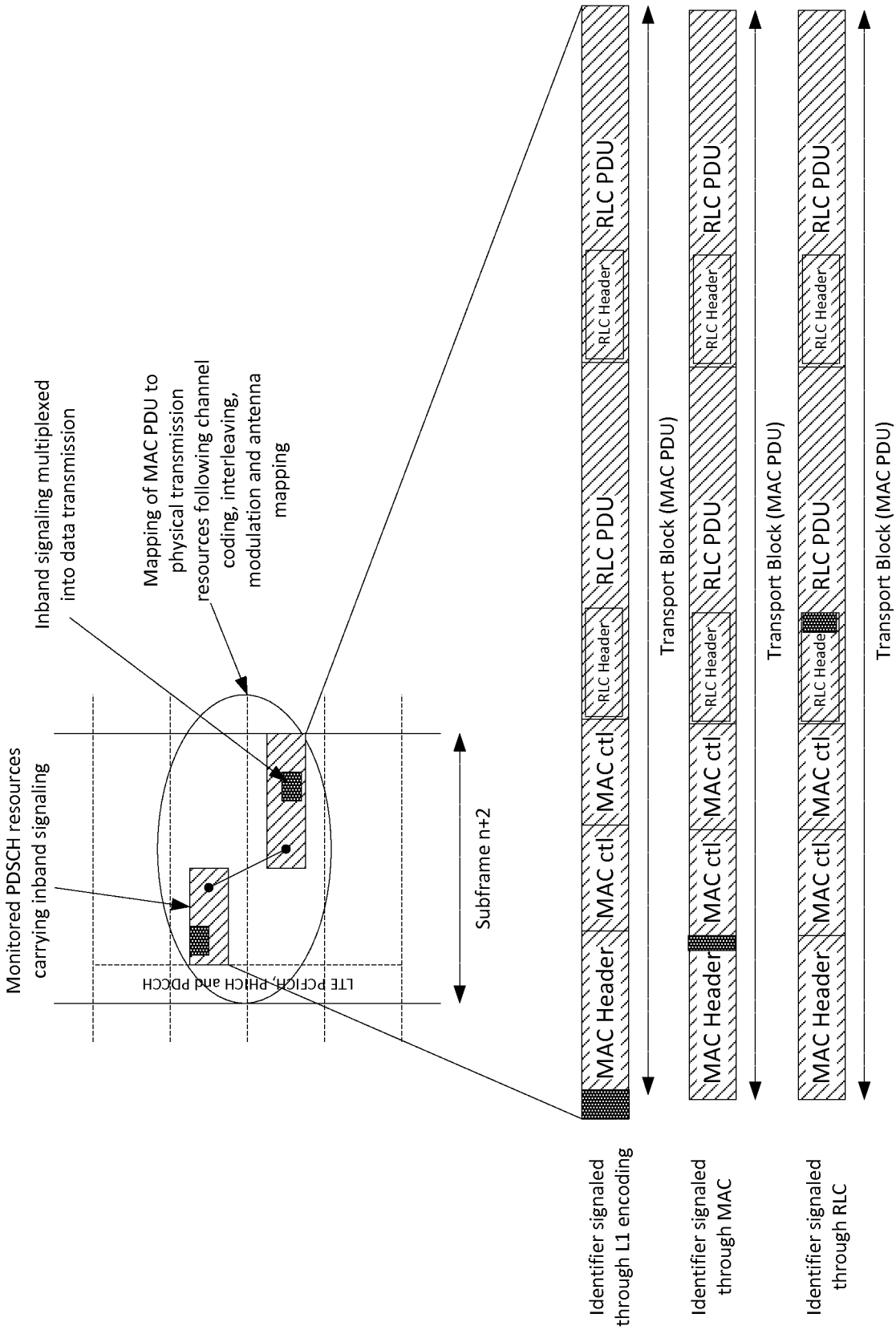

Monitored PDSCH resources carrying inband signaling
Inband signaling multiplexed into data transmission
Mapping of MAC PDU to physical transmission resources following channel coding, interleaving, modulation and antenna mapping
LTE PCFICH, PHICH and PDCCH
Subframe n+2
MAC Header
MAC ctl
RLC Header
RLC PDU
Transport Block (MAC PDU)
Identifier signaled through L1 encoding
Identifier signaled through MAC
Identifier signaled through RLC

FIG. 19

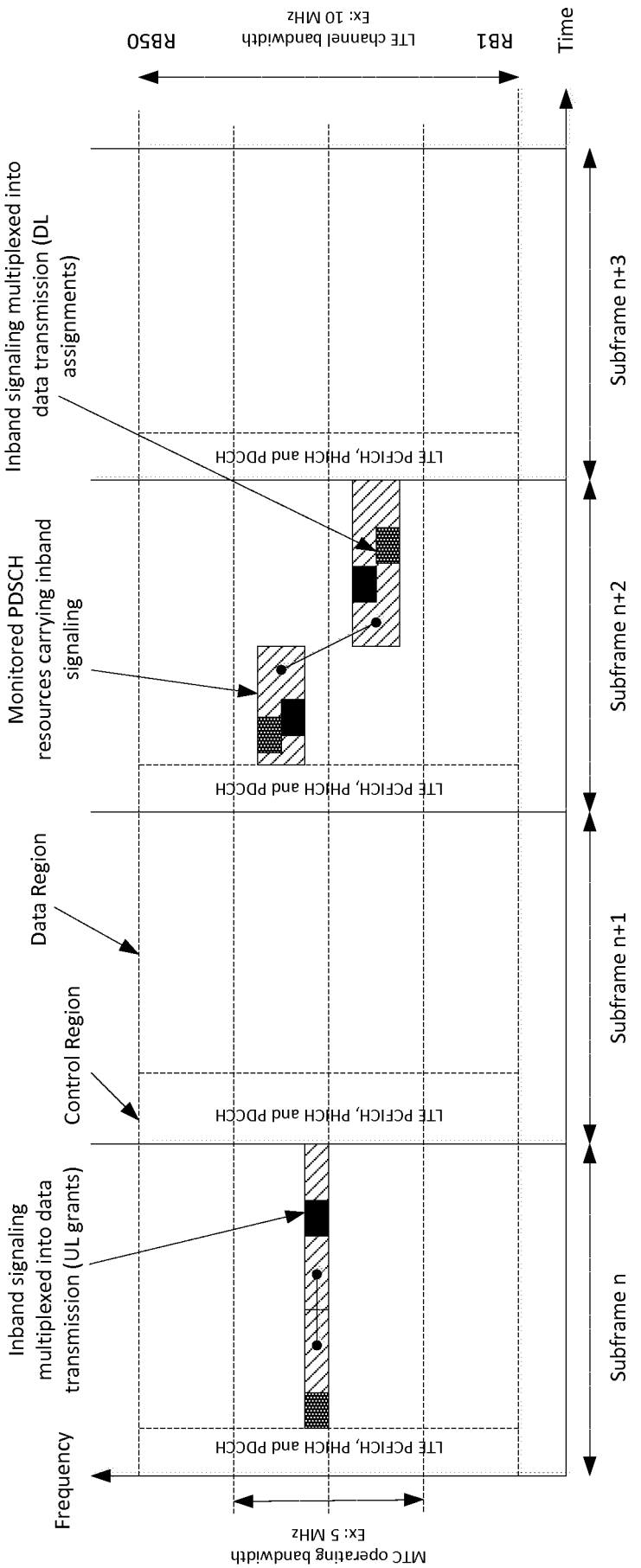

Time
RB1
RB50
LTE channel bandwidth
Ex: 10 MHz
Frequency
MTC operating bandwidth
Ex: 5 MHz
Subframe n
Subframe n+1
Subframe n+2
Subframe n+3
LTE PCFICH, PHICH and PDCCH
Inband signaling multiplexed into data transmission (DL assignments)
Monitored PDSCH resources carrying inband signaling
Data Region
Control Region
Inband signaling multiplexed into data transmission (UL grants)

FIG. 20

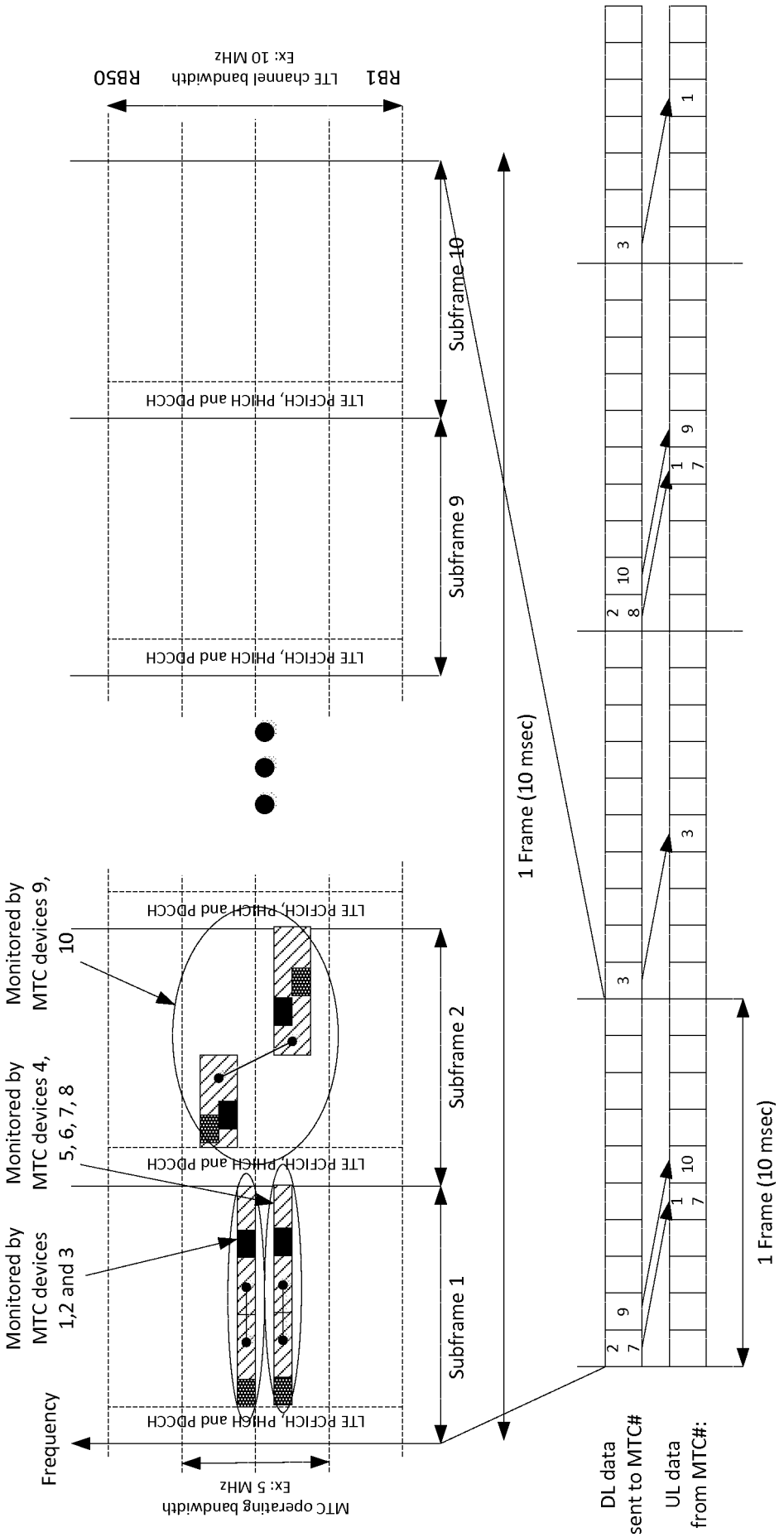

RB1
RB50
LTE channel bandwidth
Ex: 10 MHz
Subframe 10
Subframe 9
Subframe 2
Subframe 1
LTE PCFICH, PHICH and PDCCH
1 Frame (10 msec)
Monitored by MTC devices 9, 10
Monitored by MTC devices 4, 5, 6, 7, 8
Monitored by MTC devices 1,2 and 3
Frequency
MTC operating bandwidth
Ex: 5 MHz
DL data sent to MTC#
UL data from MTC#:
1 Frame (10 msec)

FIG. 21

CSI reference signal Configuration	Number of CSI reference signals configured 4	
	(k', l')	$n_s \bmod 2$
0	(9,5)	0
1	(11,2)	1
2	(9,2)	1
3	(7,2)	1
4	(9,5)	1
5	(8,5)	0
6	(10,2)	1
7	(8,2)	1
8	(6,2)	1
9	(8,5)	1

FIG. 22

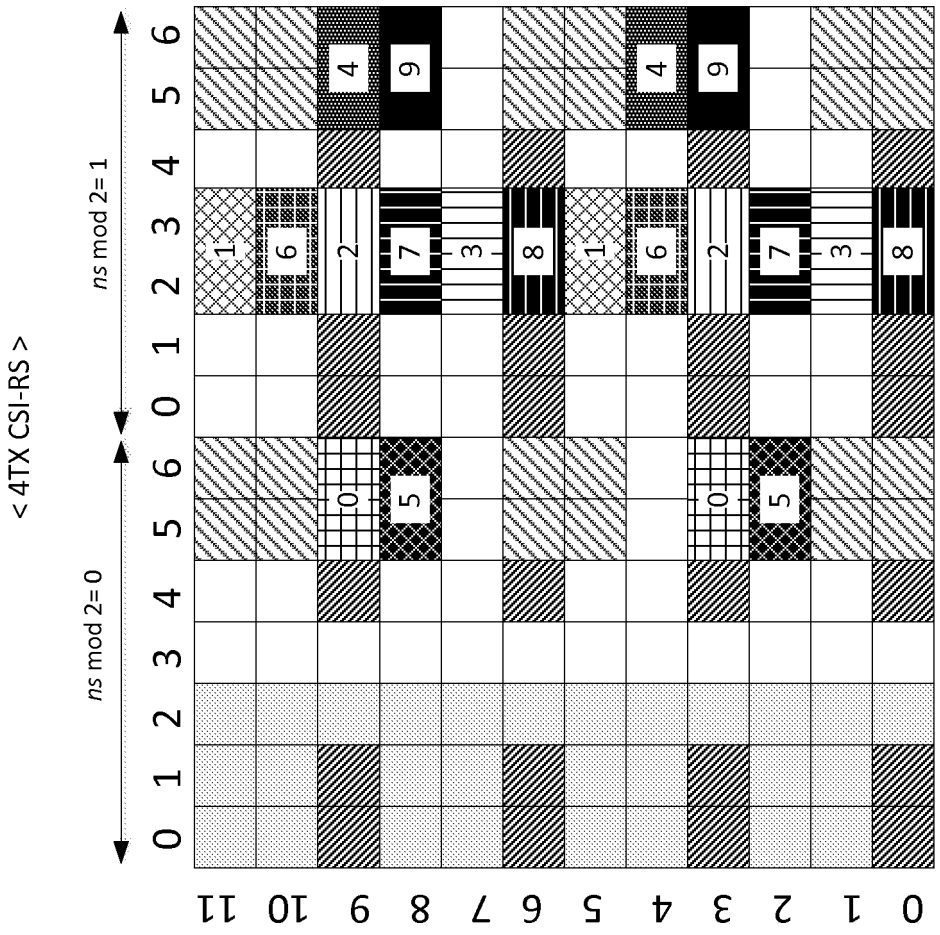

< 4TX CSI-RS >
ns mod 2= 0
ns mod 2= 1
0 1 2 3 4 5 6 0 1 2 3 4 5 6
0 1 2 3 4 5 6 7 8 9 10 11

FIG. 23

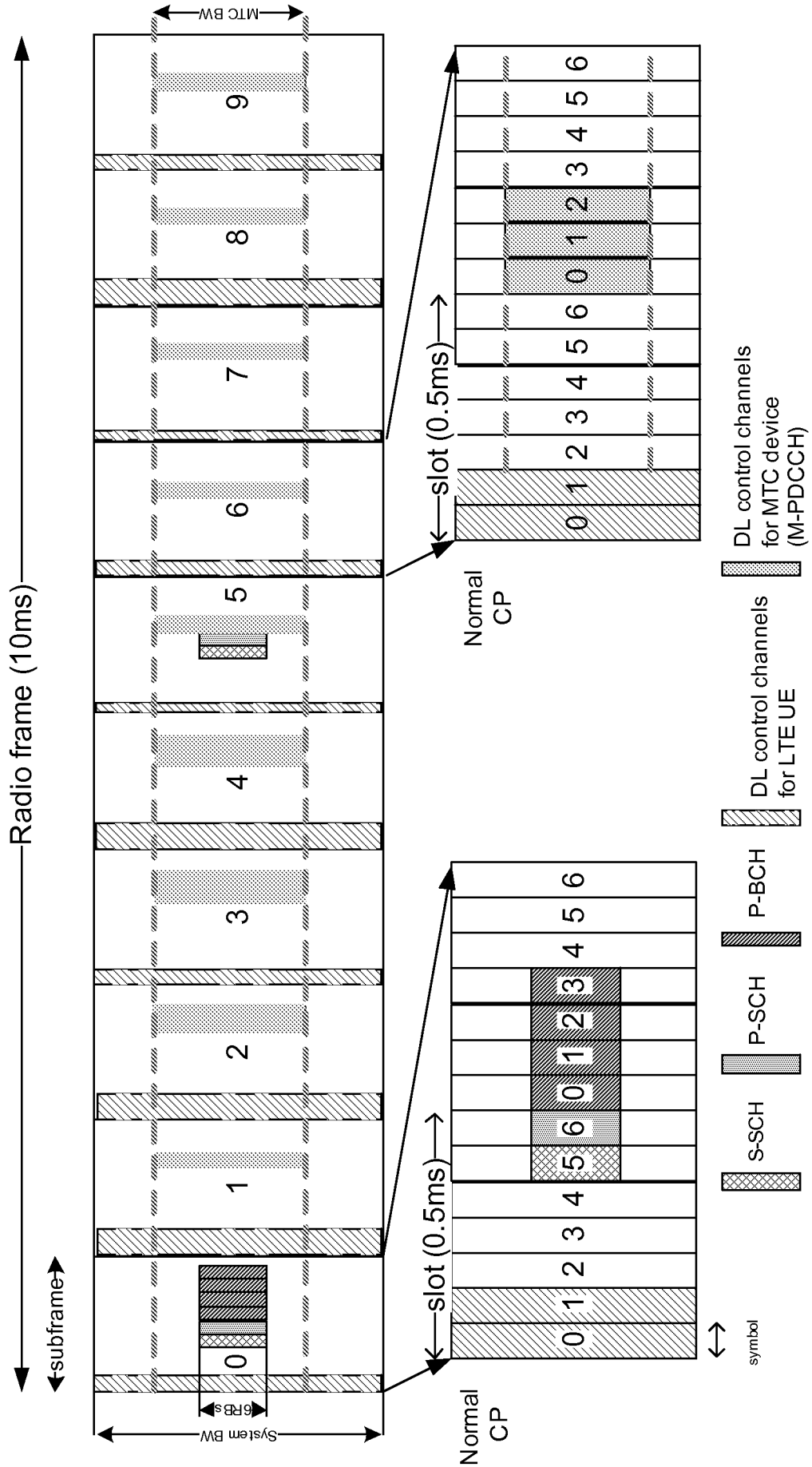

Radio frame (10ms)
subframe
MTC BW
System BW
6RBs
0
1
2
3
4
5
6
7
8
9
slot (0.5ms)
Normal CP
symbol
DL control channels for MTC device (M-PDCCH)
DL control channels for LTE UE
P-BCH
P-SCH
S-SCH

FIG. 24

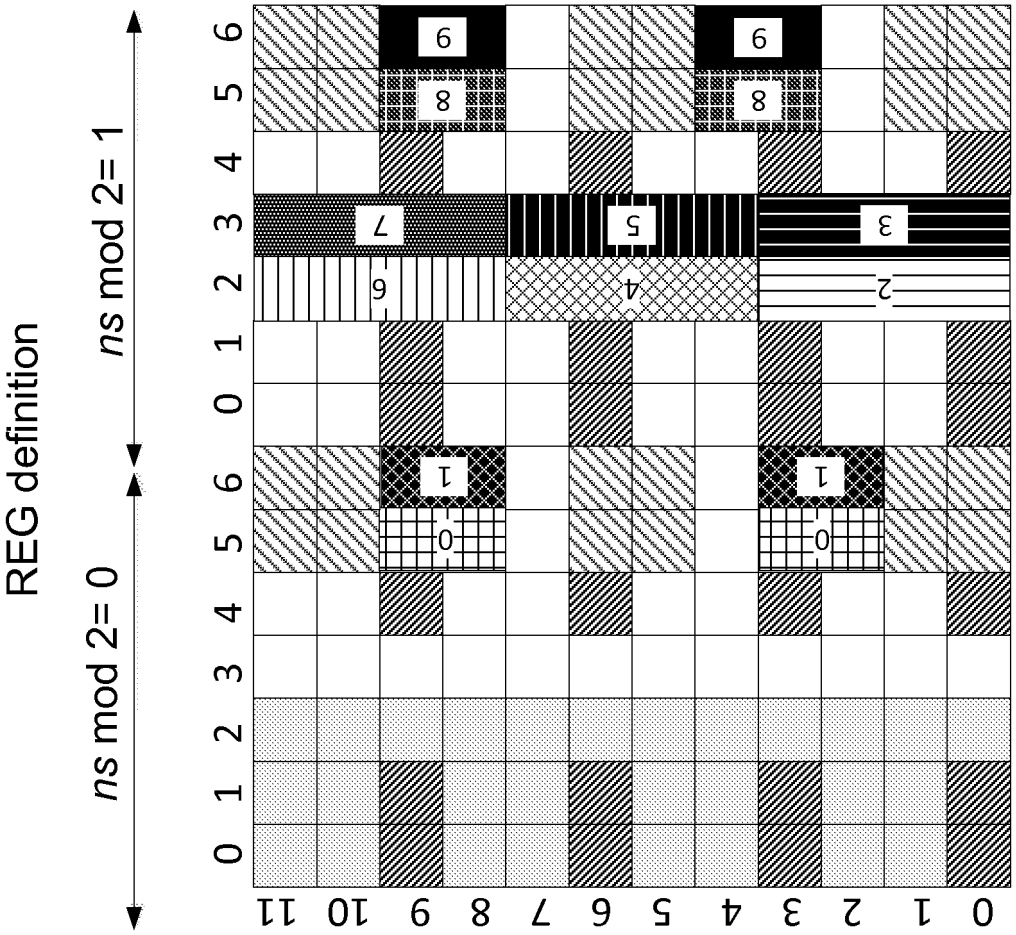

REG definition
ns mod 2= 0
ns mod 2= 1
0 1 2 3 4 5 6 7 8 9 10 11
0 1 2 3 4 5 6
9
8
7
6
5
4
3
2
1
0

FIG. 25

CFI	CFI code word < b_0, b_1, …, b_{31} >
1	<1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1>
2	<1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1>
3	<0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0>
4 (Reserved)	<0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0>

FIG. 26

CFI	CFI code word < b_0, b_1, …, b_{31} >
1	<1,0,1,1,0,1,1,0>
2	<1,1,0,1,1,0,1,1>
3	<0,1,1,0,1,1,0,1>
4 (Reserved)	<0,0,0,0,0,0,0,0>

FIG. 27

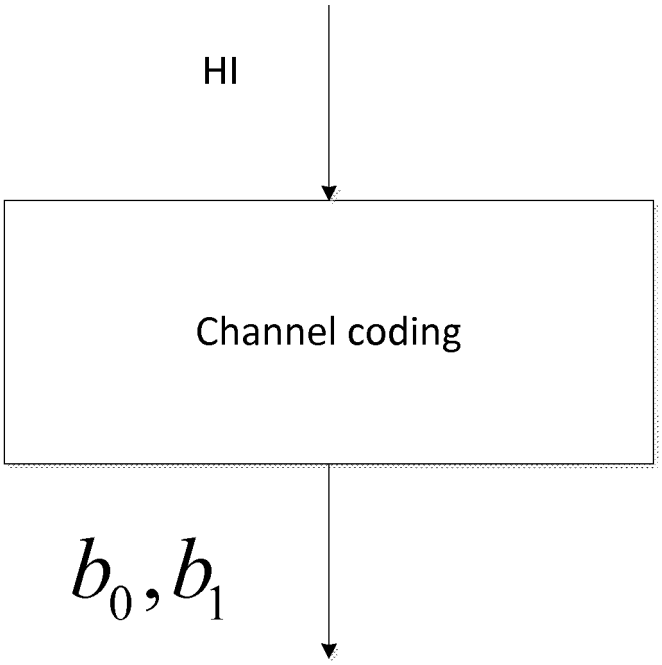


FIG. 28

HI	HI code word $< b_0, b_1 >$
0	$< 0,0 >$
1	$< 1,1 >$

FIG. 29

System Bandwidth N_{RB}^{DL}	RBG Size (*P*)
=10	1
11 – 26	2
27 – 63	3
64 – 110	4

FIG. 30A

MTC Bandwidth $N_{RB}^{DL_MTC}$	RBG Size (*P'*)
=10	1
11 – 26	2
27 – 63	3

FIG. 30B

Reporting Priority	Reporting type	Reporting contents	Max. Info. Bits (bits/BP)
1st priority	2a	wideband first PMI	4
	3	RI	3
	4	Wideband CQI	4
	6	RI / PTI	4
2nd priority	2	wideband CQI/PMI	11
	2b	Wideband CQI / second PMI	11
	2c	Wideband CQI / first PMI / second PMI	11
	5	RI / first PMI	5
3rd priority	1	Sub-band CQI	7+L
	1a	Sub-band CQI / second PMI	9+L ((7+ L) + 2)

FIG. 31

UE Category	Maximum number of DL-SCH transport block bits received within a TTI	Maximum number of bits of a DL-SCH transport block received within a TTI	Total number of soft channel bits	Maximum number of supported layers for spatial multiplexing in DL
Category 0	4392	4392	109800	1
Category 1	10296	10296	250368	1
Category 2	51024	51024	1237248	2
Category 3	102048	75376	1237248	2
Category 4	150752	75376	1827072	2
Category 5	299552	149776	3667200	4
Category 6	301504	149776 (4 layers) 75376 (2 layers)	3654144	2 or 4
Category 7	301504	149776 (4 layers) 75376 (2 layers)	3654144	2 or 4
Category 8	2998560	299856	35982720	8

FIG. 32

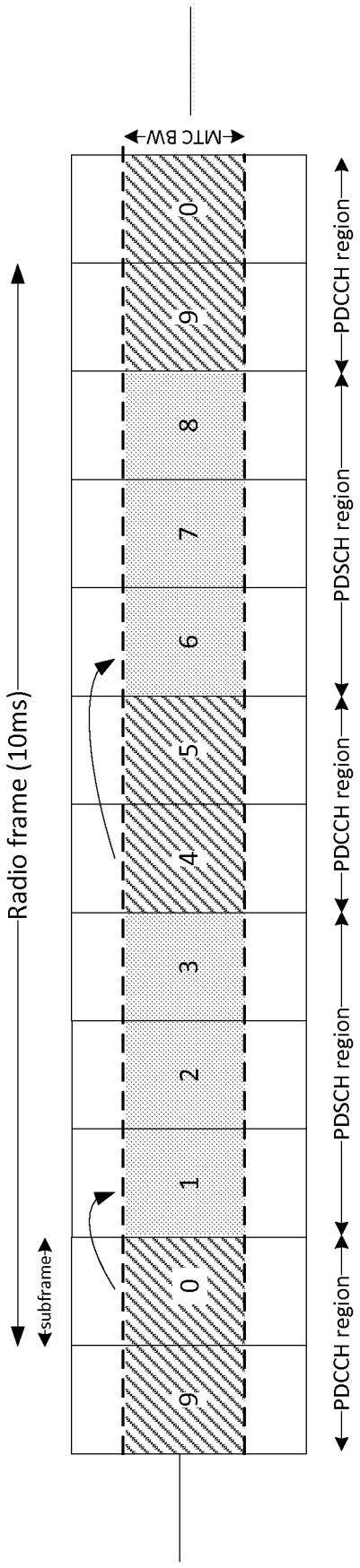


FIG. 33

Configuration number	Subframe number									
	0	1	2	3	4	5	6	7	8	9
0	C	C	D	D	D	C	C	D	D	D
1	C	D	D	D	D	C	D	D	D	D
2	C	C	C	C	C	D	D	D	D	D
3	C	C	D	D	D	D	D	D	D	D

FIG. 34

Configuration number	Subframe number									
	0	1	2	3	4	5	6	7	8	9
0	C	N	D	N	N	C	N	D	N	N
1	C	N	N	D	N	C	N	N	D	N
2	C	N	N	N	D	C	N	N	N	D
3	N	C	D	N	N	N	C	D	N	N
4	N	C	N	D	N	N	C	N	D	N
5	N	C	N	N	D	N	C	N	N	D
6	Reserved									
7	Reserved									

FIG. 35

MCS index I_{MCS}	Modulation order Q_m	TBS index I_{TBS}	N_{PRB}					
			1	2	3	4	5	6
0	2	0	16	32	56	88	120	152
1	2	1	24	56	88	144	176	208
2	2	2	32	72	144	176	208	256
3	2	3	40	104	176	208	256	328
4	2	4	56	120	208	256	328	408
5	2	5	72	144	224	328	424	504
6	2	6	328	176	256	392	504	600
7	2	7	104	224	328	472	584	712
8	2	8	120	256	392	536	680	808
9	2	9	136	296	456	616	776	936
10	4	9	136	296	456	616	776	936
11	4	10	144	328	504	680	872	1032
12	4	11	176	376	584	776	1000	1192
13	4	12	208	440	680	904	1128	1352
14	4	13	224	488	744	1000	1256	1544
15	4	14	256	552	840	1128	1416	1736
16	4	15	280	600	904	1224	1544	1800
17	6	15	280	600	904	1224	1544	1800
18	6	16	328	632	968	1288	1608	1928
19	6	17	336	696	1064	1416	1800	2152
20	6	18	376	776	1160	1544	1992	2344
21	6	19	408	840	1288	1736	2152	2600
22	6	20	440	904	1384	1864	2344	2792
23	6	21	488	1000	1480	1992	2472	2984
24	6	22	520	1064	1608	2152	2664	3240
25	6	23	552	1128	1736	2280	2856	3496
26	6	24	584	1192	1800	2408	2984	3624
27	6	25	616	1256	1864	2536	3112	3752
28	6	26	712	1480	2216	2984	3752	4392
29	2	Reserved	-	-	-	-	-	-
30	4	Reserved	-	-	-	-	-	-
31	6	Reserved	-	-	-	-	-	-

FIG. 36

MCS index I_{MCS}	Modulation order Q_m	TBS index I_{TBS}	N_{PRB}					
			1	2	3	4	5	6
0	2	0	16	16	16	16	16	16
1	2	1	24	24	24	24	24	24
2	2	2	32	32	32	32	32	32
3	2	3	40	40	40	40	40	40
4	2	4	56	56	56	56	56	56
5	2	5	72	72	72	72	72	72
6	2	6	328	104	88	88	120	152
7	2	7	104	120	144	144	176	208
8	2	8	120	144	176	176	208	256
9	2	9	136	176	208	208	256	328
10	4	9	136	224	224	256	328	408
11	4	10	144	256	256	328	424	504
12	4	11	176	296	328	392	504	600
13	4	12	208	296	392	472	584	712
14	4	13	224	328	456	536	680	808
15	4	14	256	376	456	616	776	936
16	4	15	280	440	504	616	776	936
17	6	15	280	488	584	680	872	1032
18	6	16	328	552	680	776	1000	1192
19	6	17	336	600	744	904	1128	1352
20	6	18	376	600	840	1000	1256	1544
21	6	19	408	632	904	1128	1416	1736
22	6	20	440	696	904	1224	1544	1800
23	6	21	488	776	968	1224	1544	1800
24	6	22	520	840	1064	1288	1608	1928
25	6	23	552	904	1160	1416	1800	2152
26	6	24	584	1000	1288	1544	1992	2344
27	6	25	616	1064	1384	1736	2152	2600
28	6	26	712	1128	1480	1864	2344	2792
29	2	Reserved	-	-	-	-	-	-
30	4	Reserved	-	-	-	-	-	-
31	6	Reserved	-	-	-	-	-	-

FIG. 37

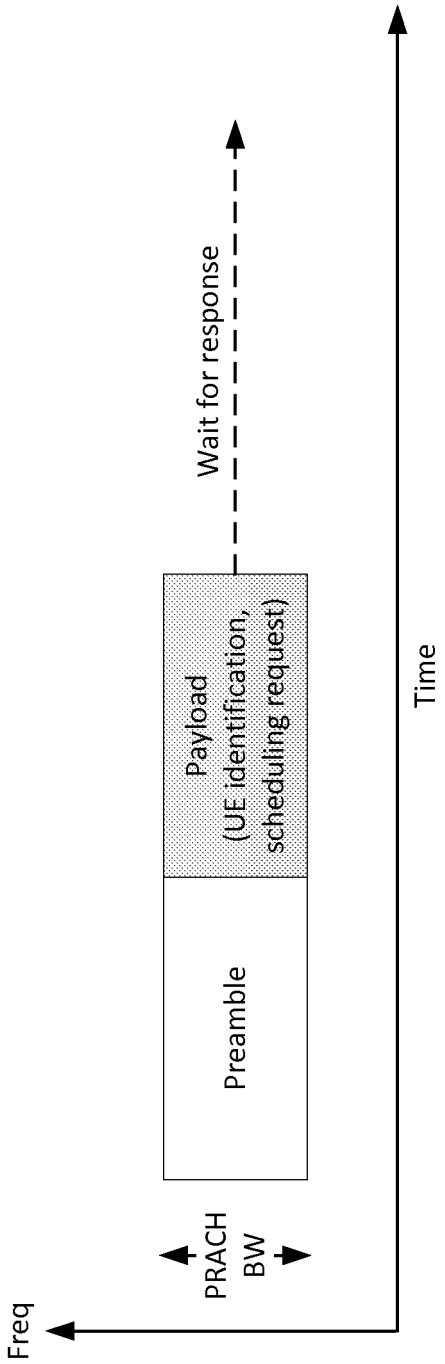

Wait for response
Payload
(UE identification,
scheduling request)
Preamble
PRACH
BW
Freq
Time

FIG. 38

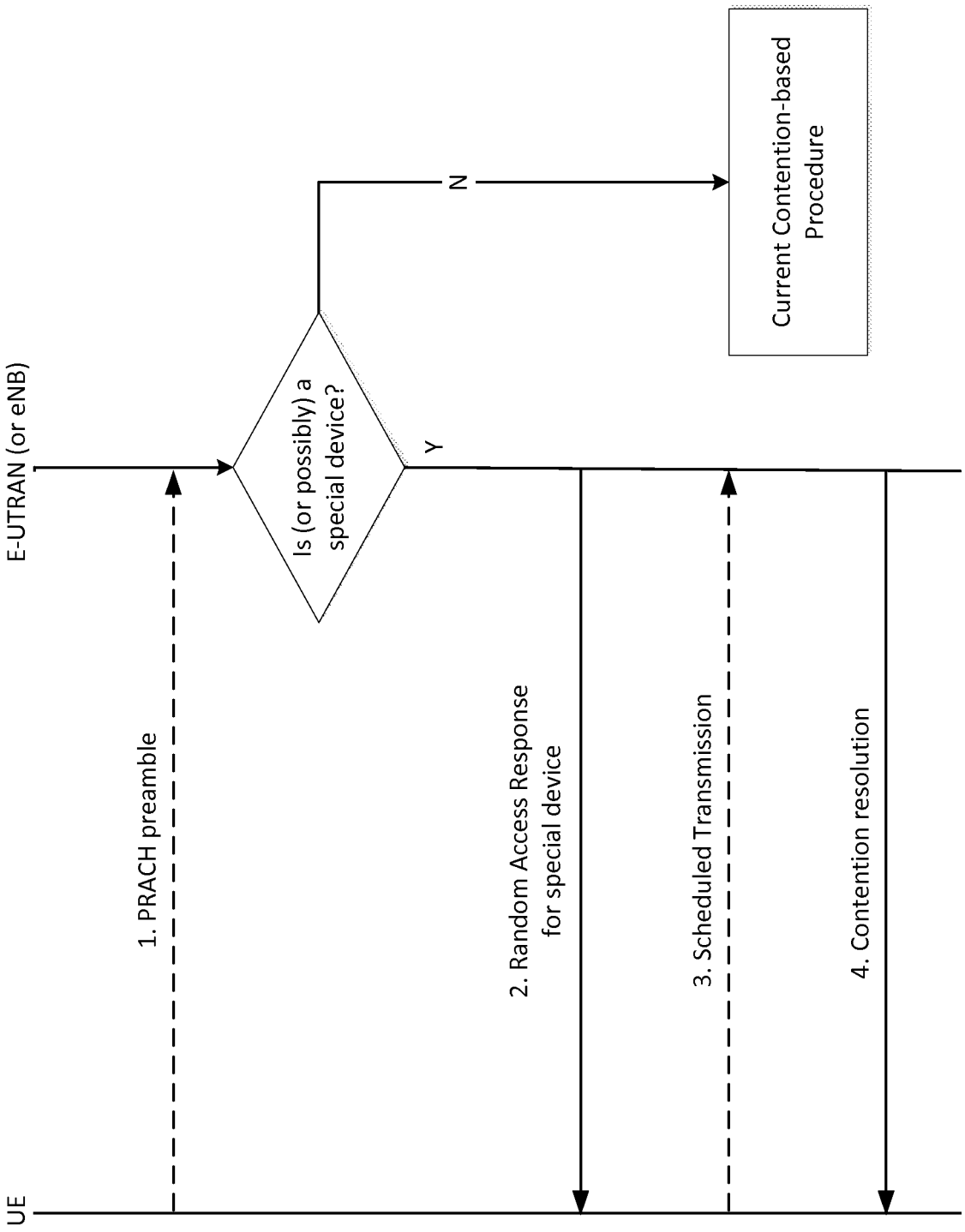

E-UTRAN (or eNB)
UE
1. PRACH preamble
Is (or possibly) a special device?
N
Y
Current Contention-based Procedure
2. Random Access Response for special device
3. Scheduled Transmission
4. Contention resolution

FIG. 39

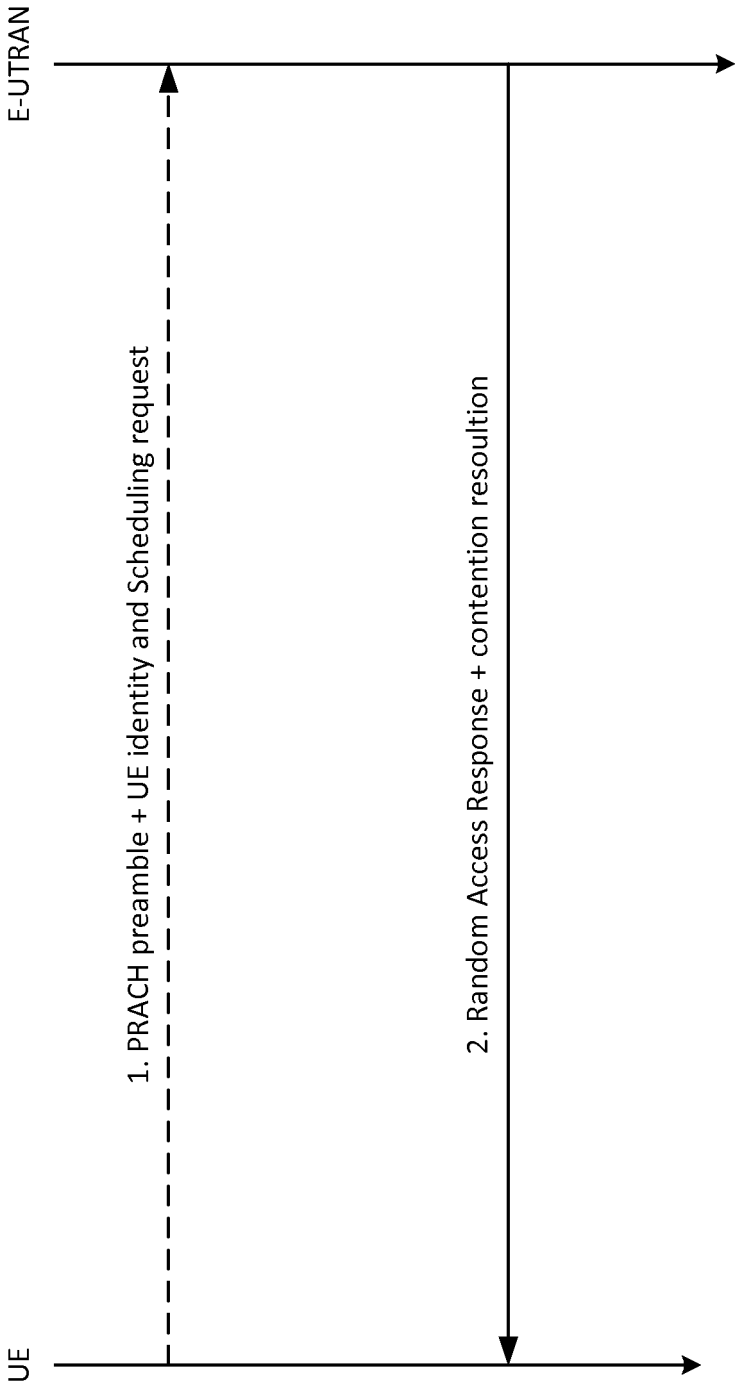

E-UTRAN
UE
1. PRACH preamble + UE identity and Scheduling request
2. Random Access Response + contention resoultion

FIG. 40

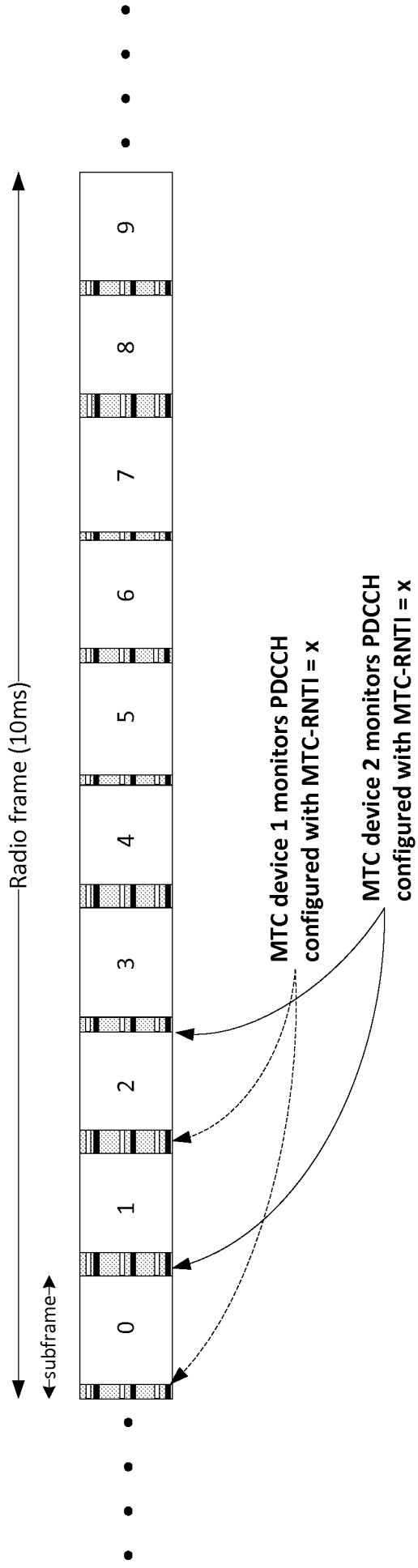

Radio frame (10ms)
subframe
0
1
2
3
4
5
6
7
8
9
MTC device 1 monitors PDCCH configured with MTC-RNTI = x
MTC device 2 monitors PDCCH configured with MTC-RNTI = x

FIG. 41

DCI format	Search Space	Transmission scheme of PDSCH corresponding to PDCCH
DCI format 1A	Common and UE-specific	If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used, otherwise Transmit diversity

FIG. 42

DCI format	Search Space	Transmission scheme of PDSCH corresponding to PDCCH
DCI format 1	UE-specific	Single-antenna port, port 7

FIG. 43

DCI format	Search Space	Transmission scheme of PDSCH corresponding to PDCCH
DCI format 1A	Common and UE-specific	If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used, otherwise Transmit diversity
DCI format 1	UE-specific	Single-antenna port, port 7

FIG. 44

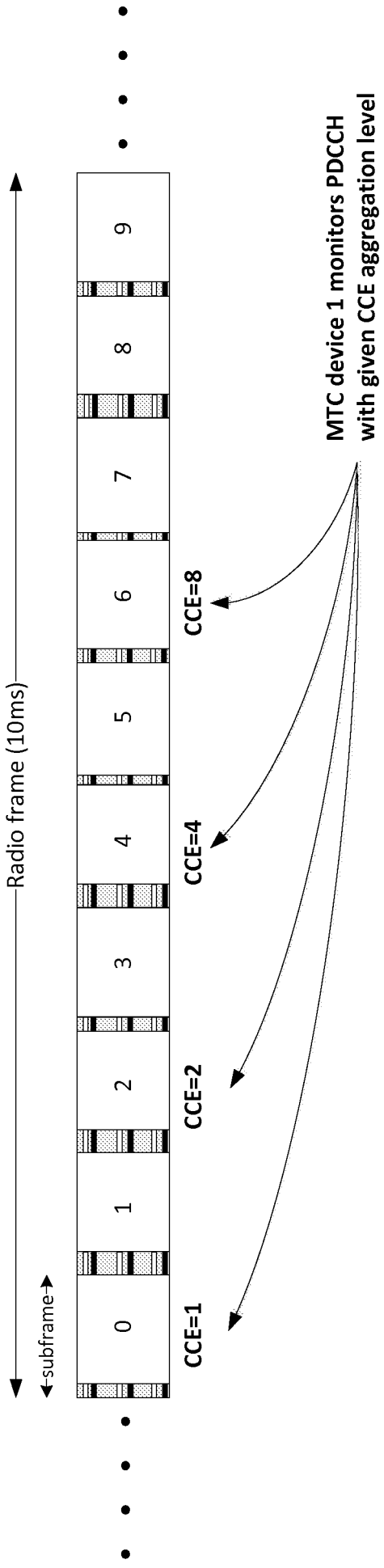

Radio frame (10ms)
subframe
0
1
2
3
4
5
6
7
8
9
CCE=1
CCE=2
CCE=4
CCE=8
MTC device 1 monitors PDCCH
with given CCE aggregation level

FIG. 45