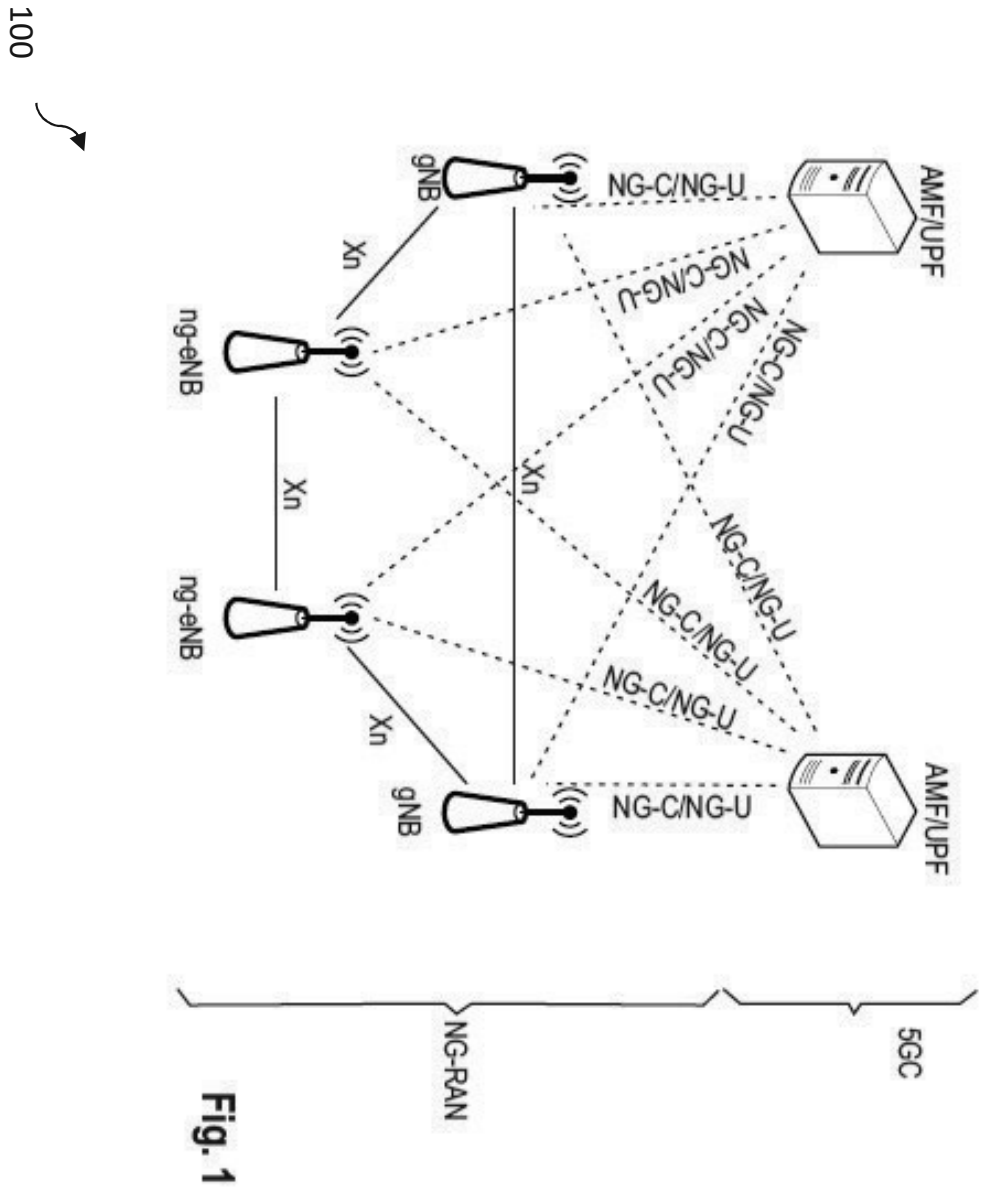

100
gNB
NG-C/NG-U
AMF/UPF
Xn
ng-eNB
NG-C/NG-U
NG-C/NG-U
NG-C/NG-U
Xn
Xn
NG-C/NG-U
ng-eNB
NG-C/NG-U
NG-C/NG-U
Xn
gNB
NG-C/NG-U
AMF/UPF
NG-RAN
5GC

Fig. 1

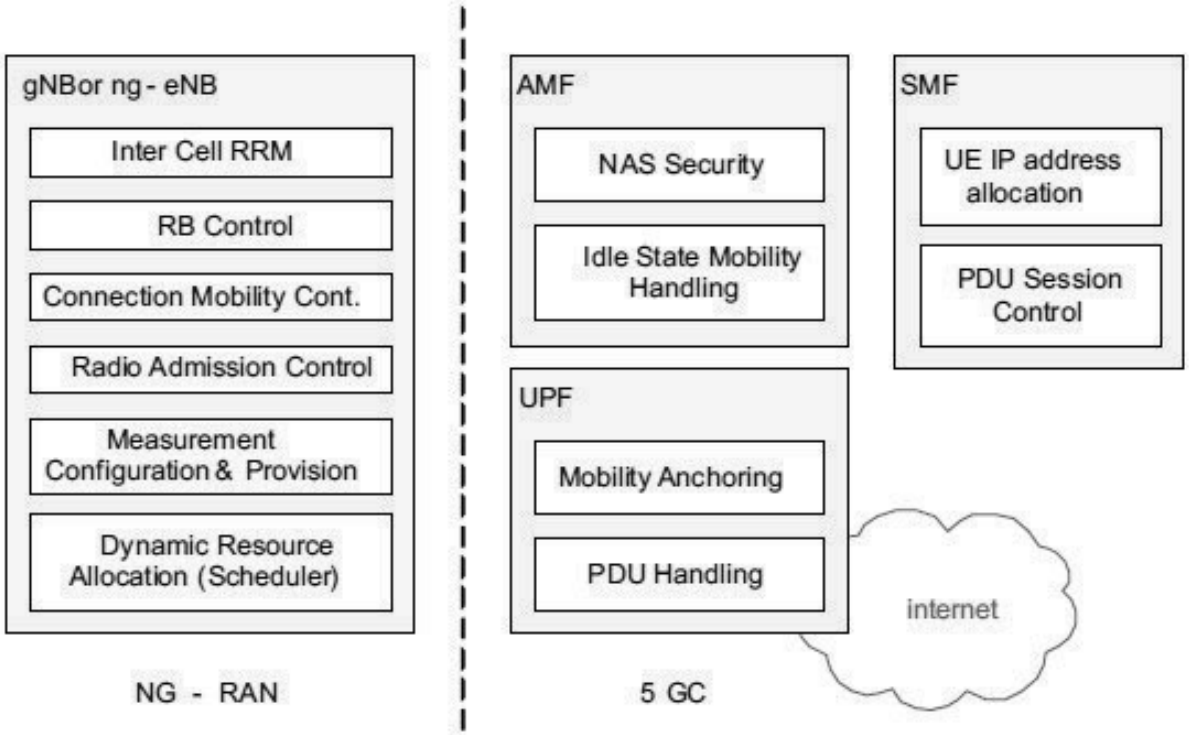

gNBor ng - eNB
Inter Cell RRM
RB Control
Connection Mobility Cont.
Radio Admission Control
Measurement Configuration & Provision
Dynamic Resource Allocation (Scheduler)
NG - RAN
AMF
NAS Security
Idle State Mobility Handling
SMF
UE IP address allocation
PDU Session Control
UPF
Mobility Anchoring
PDU Handling
internet
5 GC
200

Fig. 2

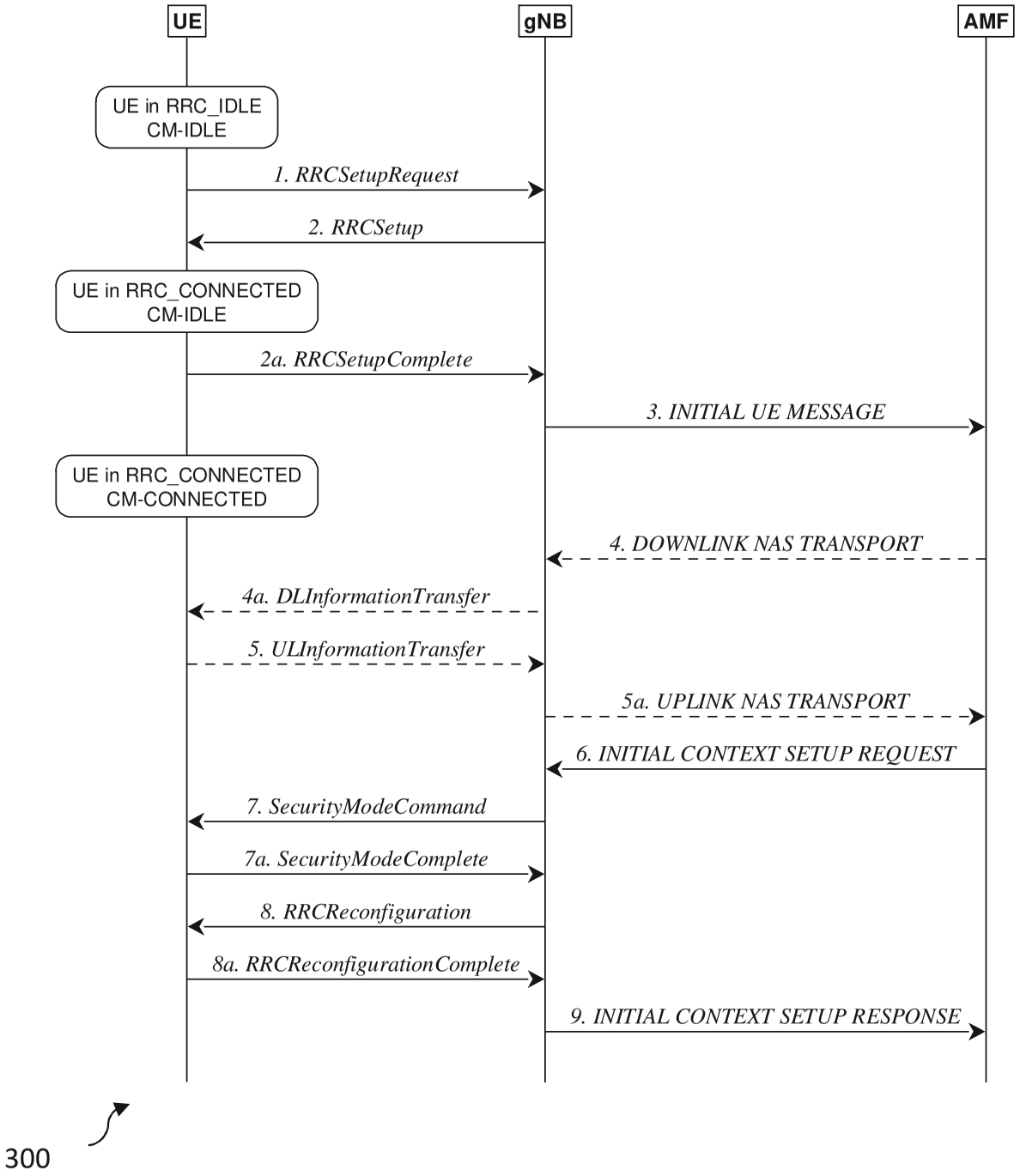

UE
gNB
AMF
UE in RRC_IDLE
CM-IDLE
1. RRCSetupRequest
2. RRCSetup
UE in RRC_CONNECTED
CM-IDLE
2a. RRCSetupComplete
3. INITIAL UE MESSAGE
UE in RRC_CONNECTED
CM-CONNECTED
4. DOWNLINK NAS TRANSPORT
4a. DLInformationTransfer
5. ULInformationTransfer
5a. UPLINK NAS TRANSPORT
6. INITIAL CONTEXT SETUP REQUEST
7. SecurityModeCommand
7a. SecurityModeComplete
8. RRCReconfiguration
8a. RRCReconfigurationComplete
9. INITIAL CONTEXT SETUP RESPONSE
300

Fig. 3

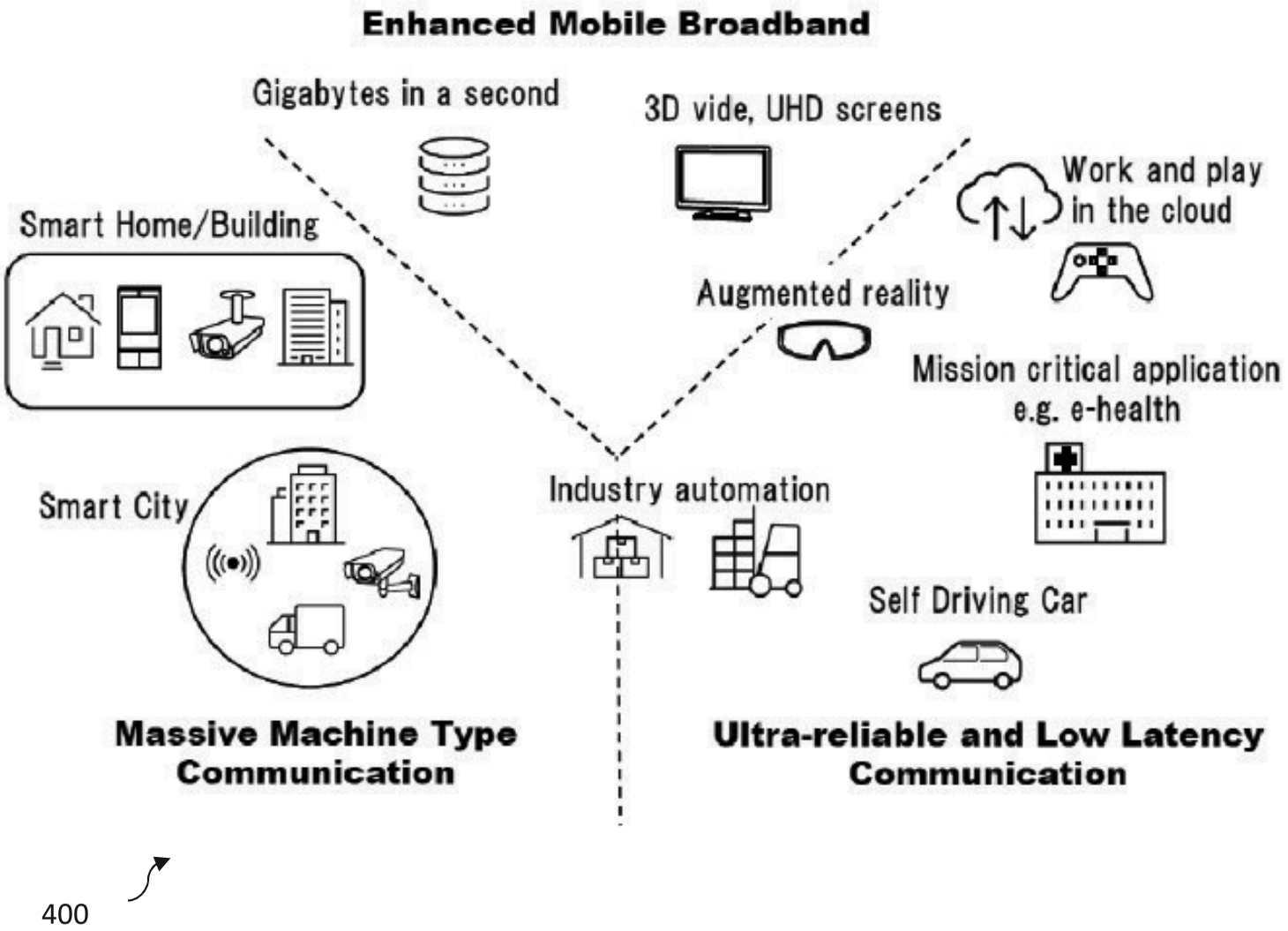

Enhanced Mobile Broadband
Gigabytes in a second
3D vide, UHD screens
Work and play in the cloud
Smart Home/Building
Augmented reality
Mission critical application e.g. e-health
Smart City
Industry automation
Self Driving Car
Massive Machine Type Communication
Ultra-reliable and Low Latency Communication
400

Fig. 4

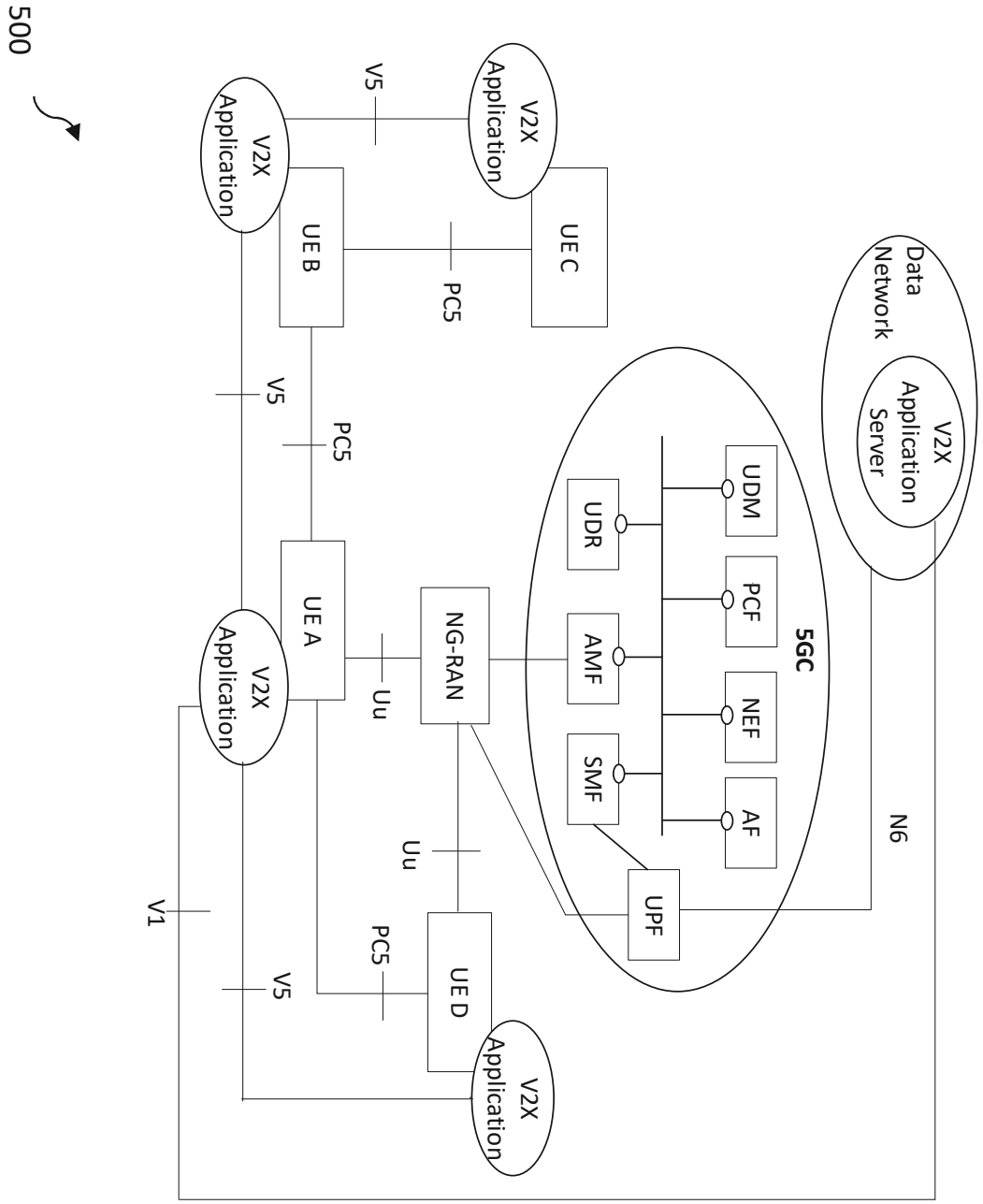

500
Data Network
V2X Application Server
N6
5GC
UDM
PCF
NEF
AF
UDR
AMF
SMF
UPF
NG-RAN
Uu
Uu
V2X Application
V2X Application
V2X Application
V2X Application
UE A
UE B
UE C
UE D
V5
V5
V5
PC5
PC5
PC5
V1

Fig. 5

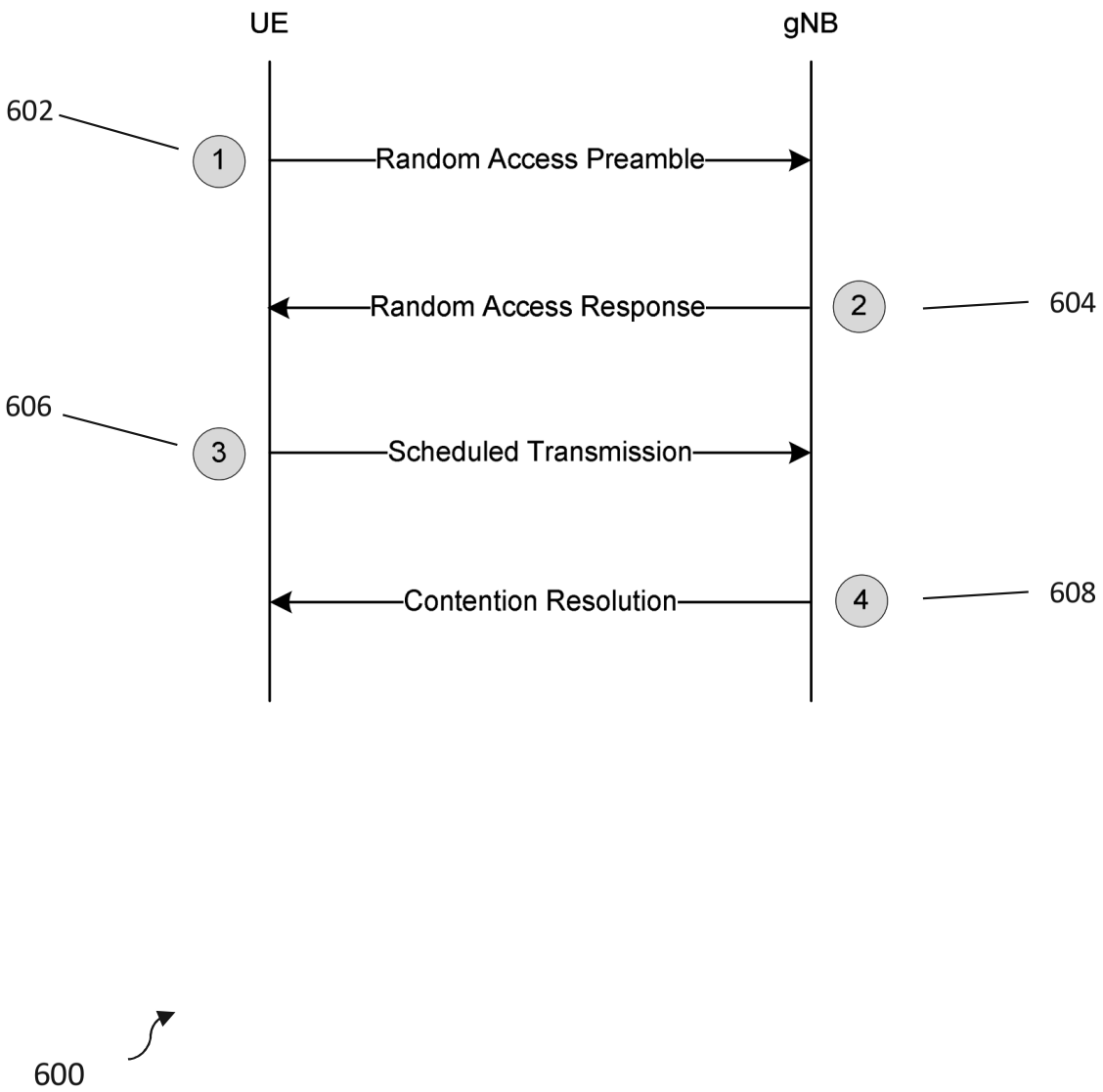
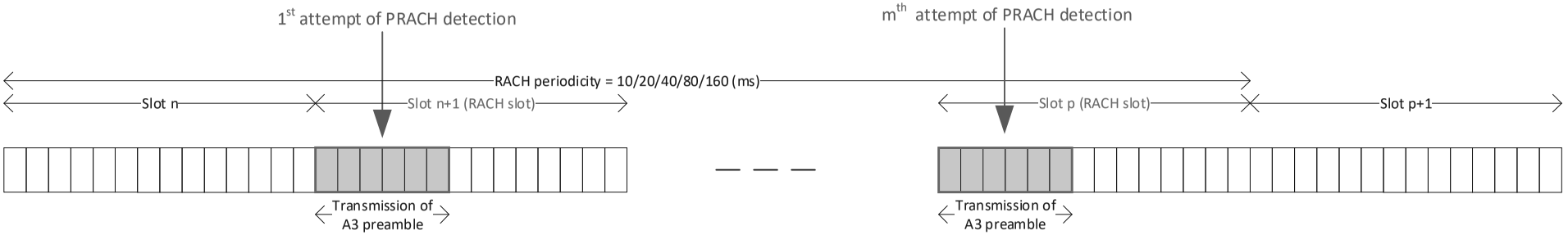
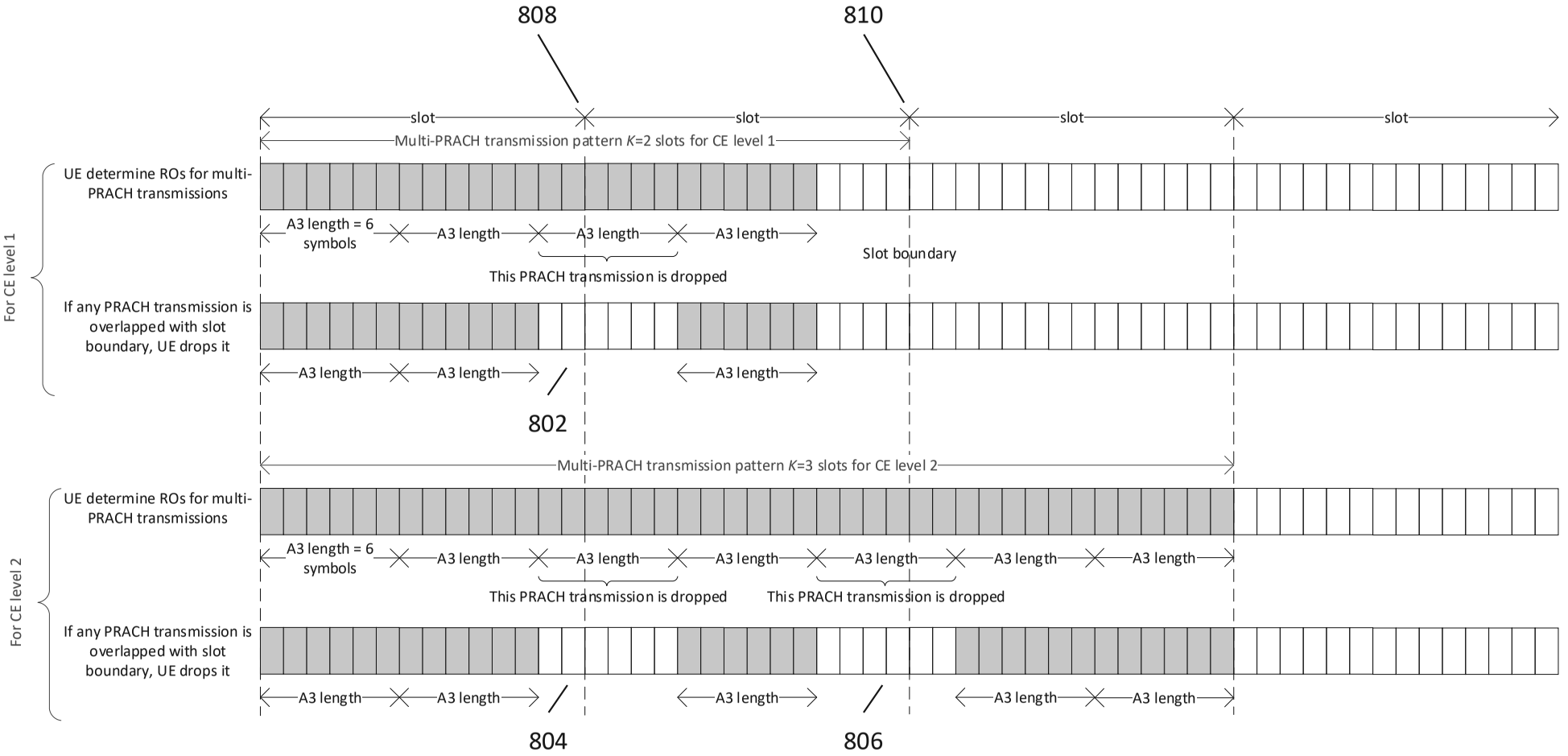

UE
gNB
602
1
Random Access Preamble
Random Access Response
2
604
606
3
Scheduled Transmission
Contention Resolution
4
608
600

Fig. 6


1st attempt of PRACH detection
mth attempt of PRACH detection
RACH periodicity = 10/20/40/80/160 (ms)
Slot n
Slot n+1 (RACH slot)
Slot p (RACH slot)
Slot p+1
Transmission of A3 preamble
Transmission of A3 preamble
702
704

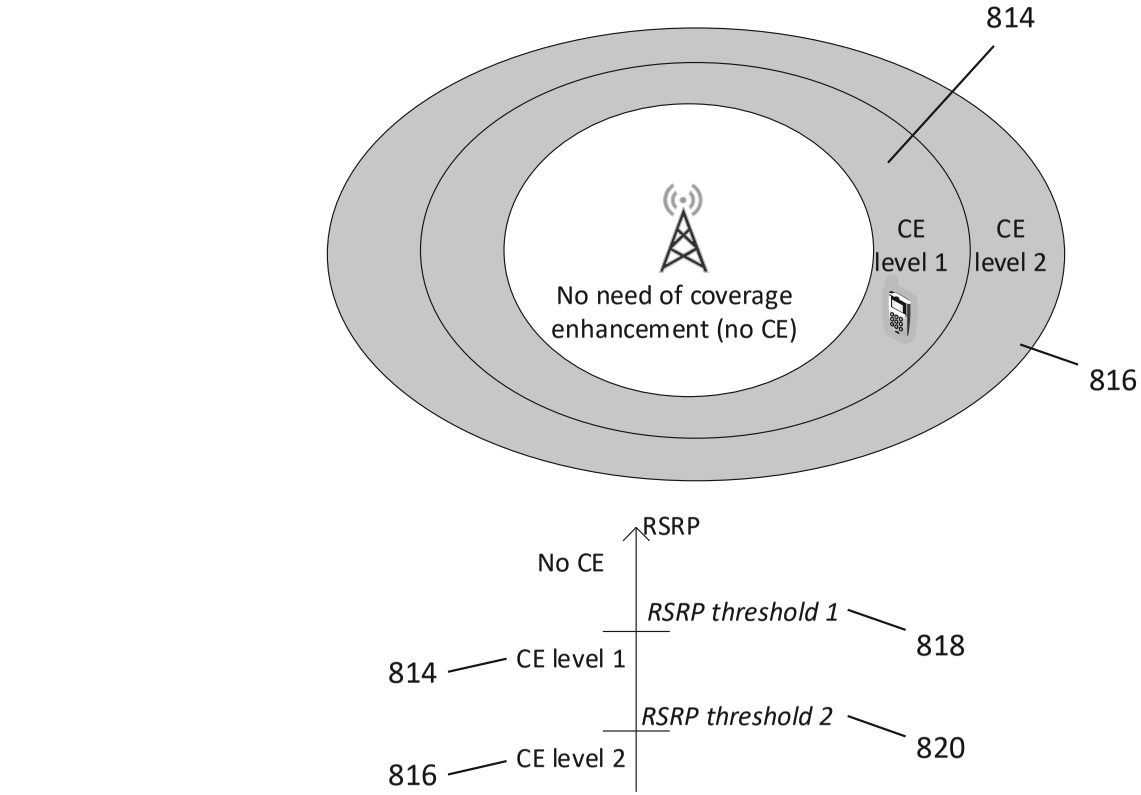
700

Fig. 7


808
810
slot
slot
slot
slot
Multi-PRACH transmission pattern K=2 slots for CE level 1
For CE level 1
UE determine ROs for multi-PRACH transmissions
A3 length = 6 symbols
A3 length
A3 length
A3 length
Slot boundary
This PRACH transmission is dropped
If any PRACH transmission is overlapped with slot boundary, UE drops it
A3 length
A3 length
A3 length
802
Multi-PRACH transmission pattern K=3 slots for CE level 2
For CE level 2
UE determine ROs for multi-PRACH transmissions
A3 length = 6 symbols
A3 length
A3 length
A3 length
A3 length
A3 length
A3 length
This PRACH transmission is dropped
This PRACH transmission is dropped
If any PRACH transmission is overlapped with slot boundary, UE drops it
A3 length
A3 length
A3 length
A3 length
A3 length
804
806

800

Fig. 8A


814
CE
level 1
CE
level 2
No need of coverage
enhancement (no CE)
816
RSRP
No CE
RSRP threshold 1
818
814
CE level 1
RSRP threshold 2
820
816
CE level 2

812

Fig. 8B

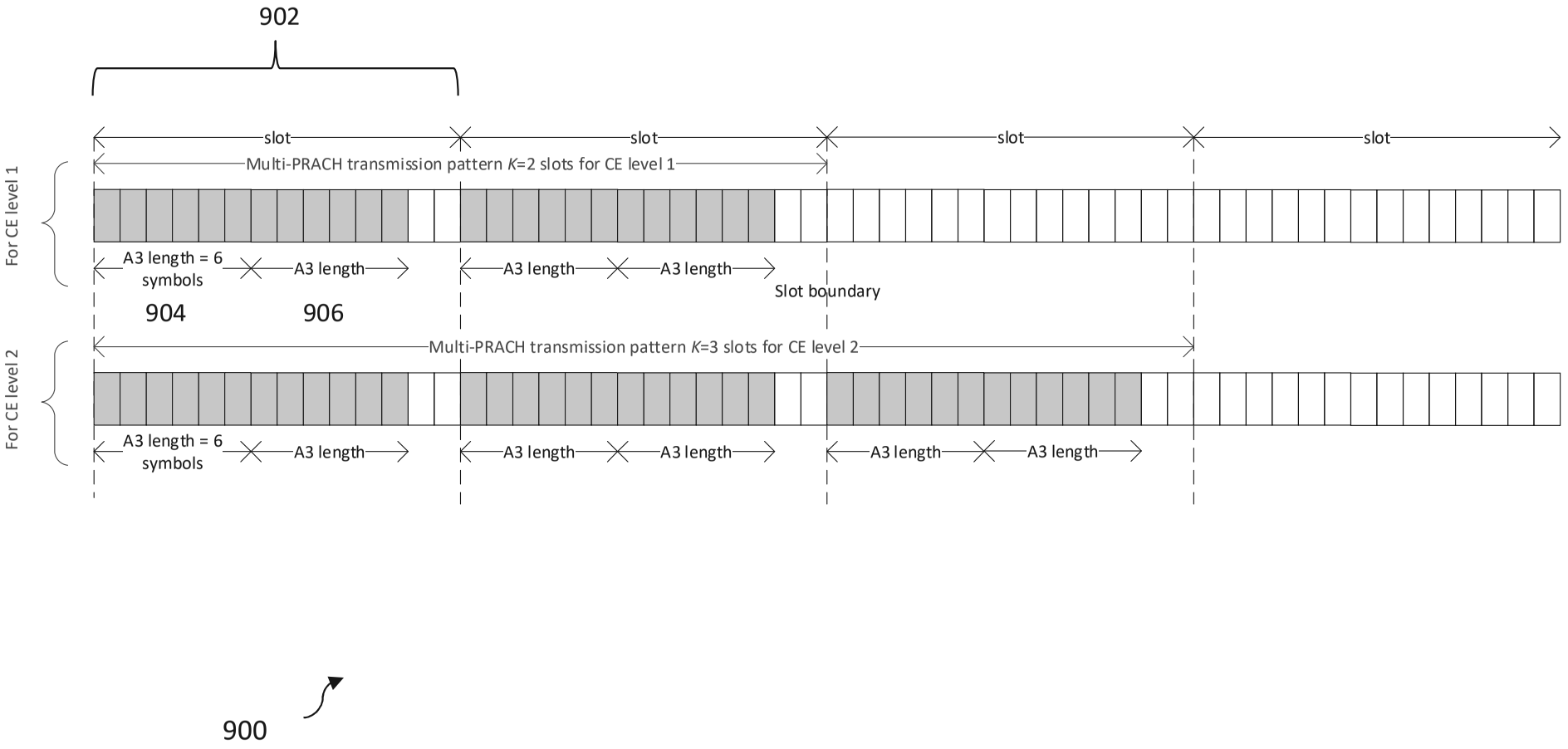

902
slot
slot
slot
slot
Multi-PRACH transmission pattern K=2 slots for CE level 1
For CE level 1
A3 length = 6 symbols
A3 length
A3 length
A3 length
Slot boundary
904
906
Multi-PRACH transmission pattern K=3 slots for CE level 2
For CE level 2
A3 length = 6 symbols
A3 length
A3 length
A3 length
A3 length
A3 length
900

Fig. 9

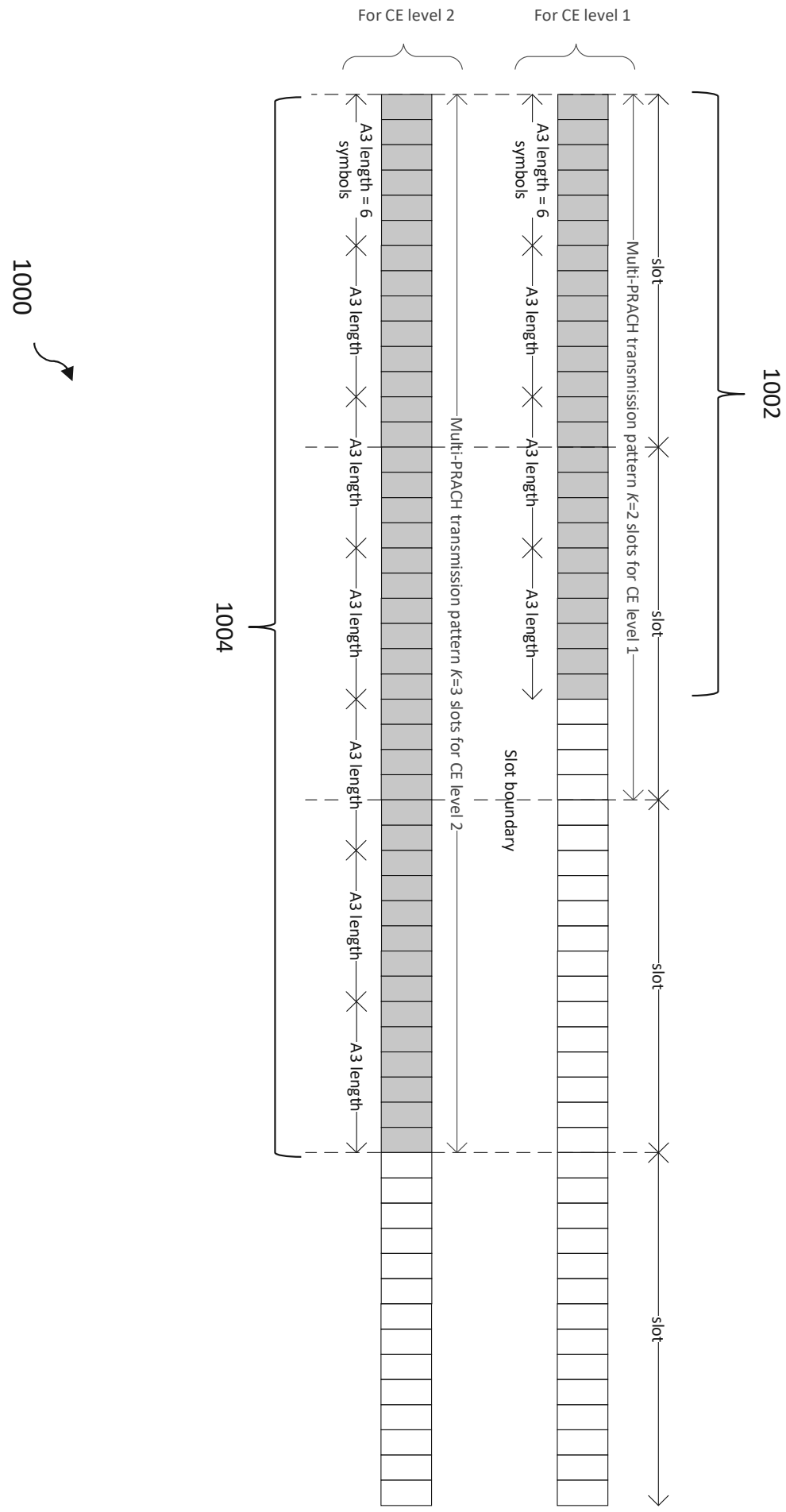

1000
1002
1004
For CE level 2
For CE level 1
A3 length = 6 symbols
A3 length
slot
Multi-PRACH transmission pattern K=2 slots for CE level 1
Slot boundary
Multi-PRACH transmission pattern K=3 slots for CE level 2

Fig. 10

```
RACH-ConfigGeneric ::= SEQUENCE {
prach-ConfigurationIndex              INTEGER (0..255),
msg1-FDM                              ENUMERATED {one, two, four, eight},
msg1-FrequencyStart                   INTEGER (0..maxNrofPhysicalResourceBlocks-1),
zeroCorrelationZoneConfig             INTEGER(0..15),
preambleReceivedTargetPower           INTEGER (-202..-60),
preambleTransMax                      ENUMERATED {n3, n4, n5, n6, n7, n8, n10, n20, n50, n100, n200},
powerRampingStep                      ENUMERATED {dB0, dB2, dB4, dB6},
ra-ResponseWindow                     ENUMERATED {sl1, sl2, sl4, sl8, sl10, sl20, sl40, sl80},
multi-PRACH-transmission              multi-PRACH-transmission OPTIONAL,
<omitted>
…}

multi-PRACH-transmission ::=  SEQUENCE {
Preamble_Format                       ENUMERATED {A1,A2,A3,B1,B2,B3,B4,C0,C2} OPTIONAL,
RACH_slot_start                       ENUMERATED{0..maxNofPhysicalSlotIndex-1}
Start_Position_in_RACH_slot           INTEGER (0..13)           OPTIONAL,
numberOfPRACH_Repetitions             ENUMERATED {n1, n2, n3, n4, n7, n8, n12, n16} OPTIONAL,
…}
```

1104
1106
1108
1102
1100

Fig. 11A

PRACH Configuration Index	Preamble format	$n_{SFN} \bmod x = y$		Subframe number	Starting symbol	Number of PRACH slots within a subframe	$N_t^{RA,slot}$, number of time domain PRACH occasions within a PRACH slot	N_{dur}^{RA}, PRACH duration	Multi-PRACH transmission	
		x	y						Subframe number for CE level 1	Subframe number for CE level 2
<omitted>										
67	A1	16	1	9	0	2	6	2	9,10	9,10,11
<omitted>										

1112

1110

Fig. 11B

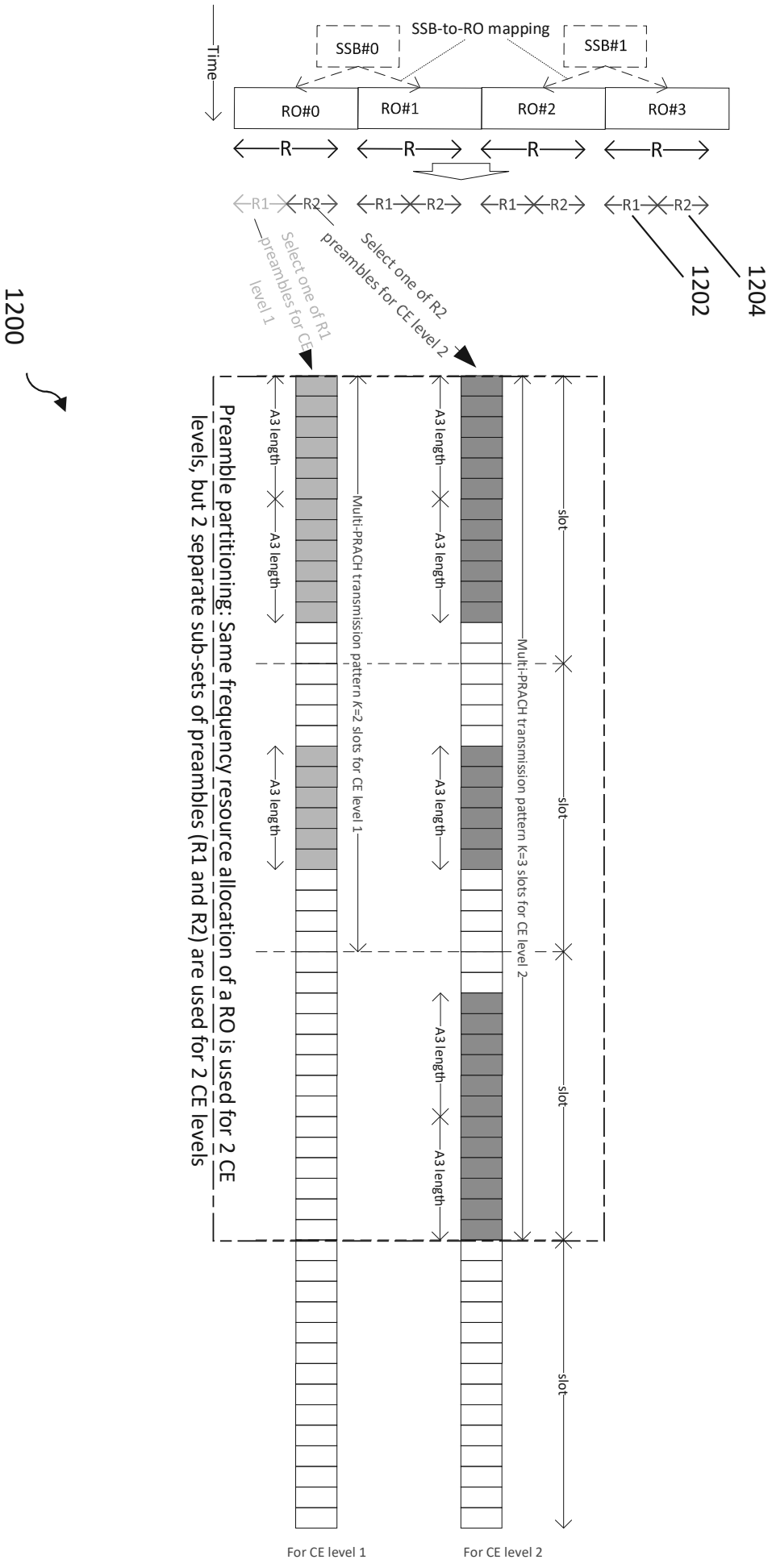
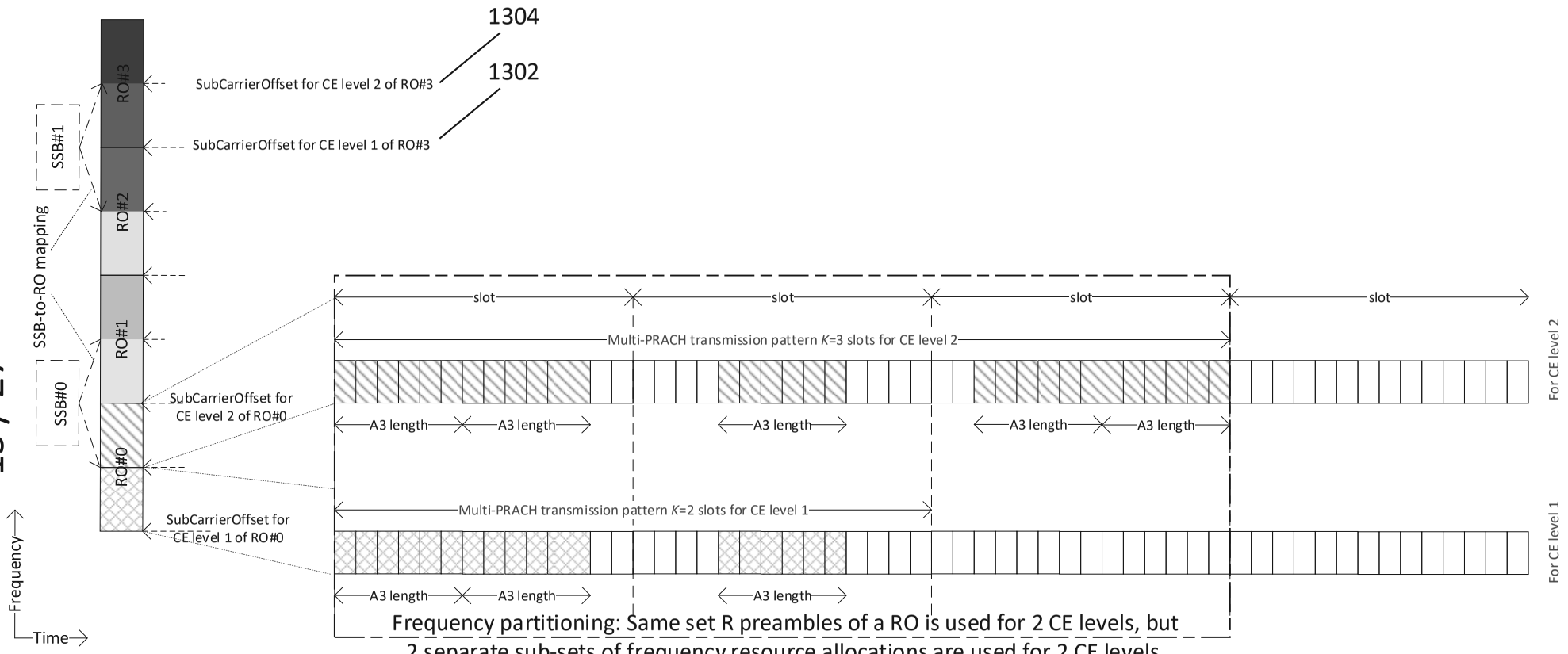

1200
Time
SSB-to-RO mapping
SSB#0
SSB#1
RO#0
RO#1
RO#2
RO#3
R
R1
R2
Select one of R1 preambles for CE level 1
Select one of R2 preambles for CE level 2
1202
1204
A3 length
Multi-PRACH transmission pattern K=2 slots for CE level 1
Multi-PRACH transmission pattern K=3 slots for CE level 2
slot
Preamble partitioning: Same frequency resource allocation of a RO is used for 2 CE levels, but 2 separate sub-sets of preambles (R1 and R2) are used for 2 CE levels
For CE level 1
For CE level 2

Fig. 12


1304
1302
SubCarrierOffset for CE level 2 of RO#3
SubCarrierOffset for CE level 1 of RO#3
RO#3
RO#2
RO#1
RO#0
SSB#1
SSB#0
SSB-to-RO mapping
SubCarrierOffset for CE level 2 of RO#0
SubCarrierOffset for CE level 1 of RO#0
slot
slot
slot
slot
Multi-PRACH transmission pattern K=3 slots for CE level 2
A3 length
A3 length
A3 length
A3 length
A3 length
For CE level 2
Multi-PRACH transmission pattern K=2 slots for CE level 1
A3 length
A3 length
A3 length
For CE level 1
Frequency
Time
Frequency partitioning: Same set R preambles of a RO is used for 2 CE levels, but
2 separate sub-sets of frequency resource allocations are used for 2 CE levels

1300

Fig. 13

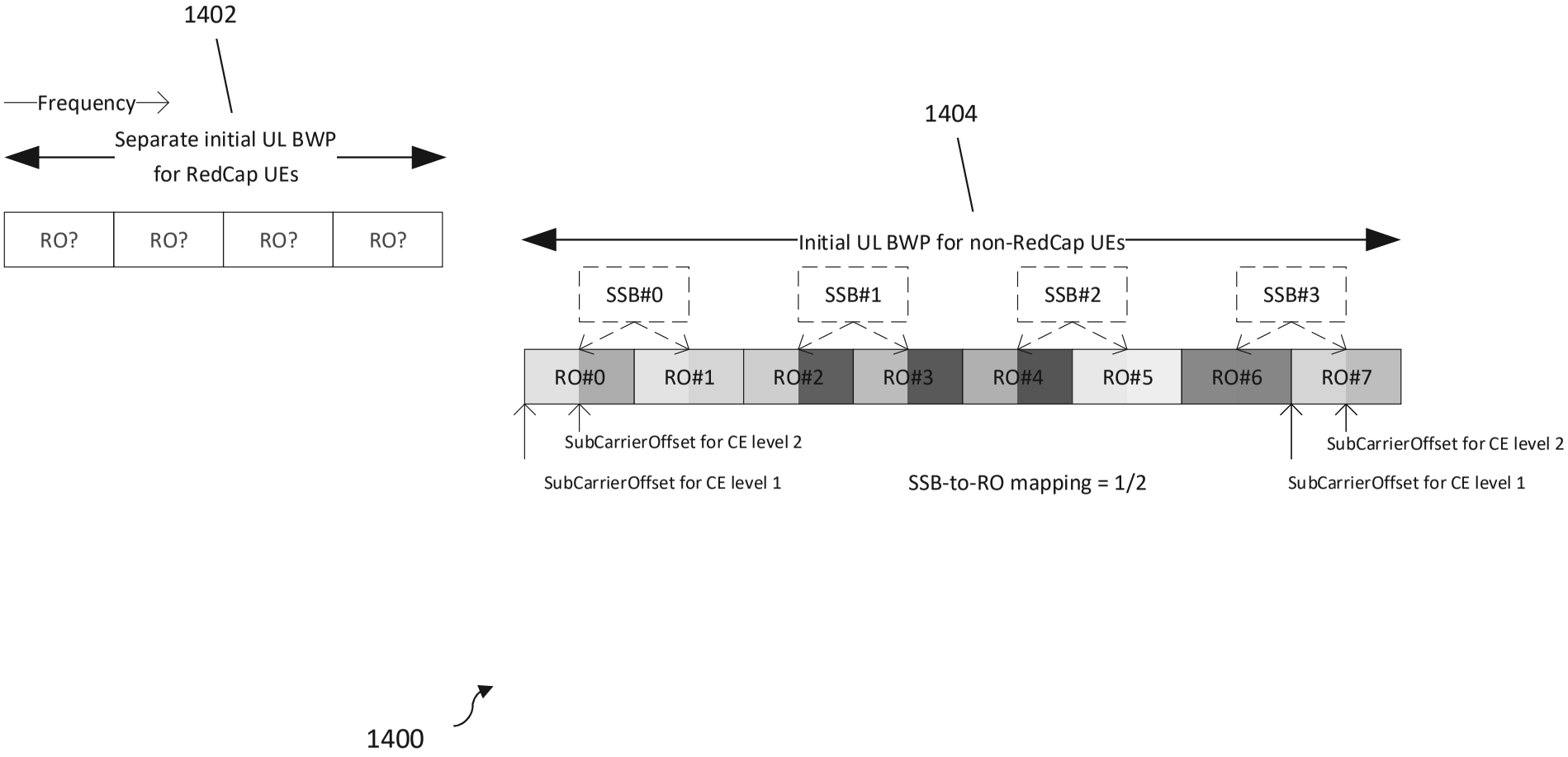

1402
Frequency
Separate initial UL BWP
for RedCap UEs
RO?
RO?
RO?
RO?
1404
Initial UL BWP for non-RedCap UEs
SSB#0
SSB#1
SSB#2
SSB#3
RO#0
RO#1
RO#2
RO#3
RO#4
RO#5
RO#6
RO#7
SubCarrierOffset for CE level 2
SubCarrierOffset for CE level 2
SubCarrierOffset for CE level 1
SSB-to-RO mapping = 1/2
SubCarrierOffset for CE level 1
1400

Fig. 14

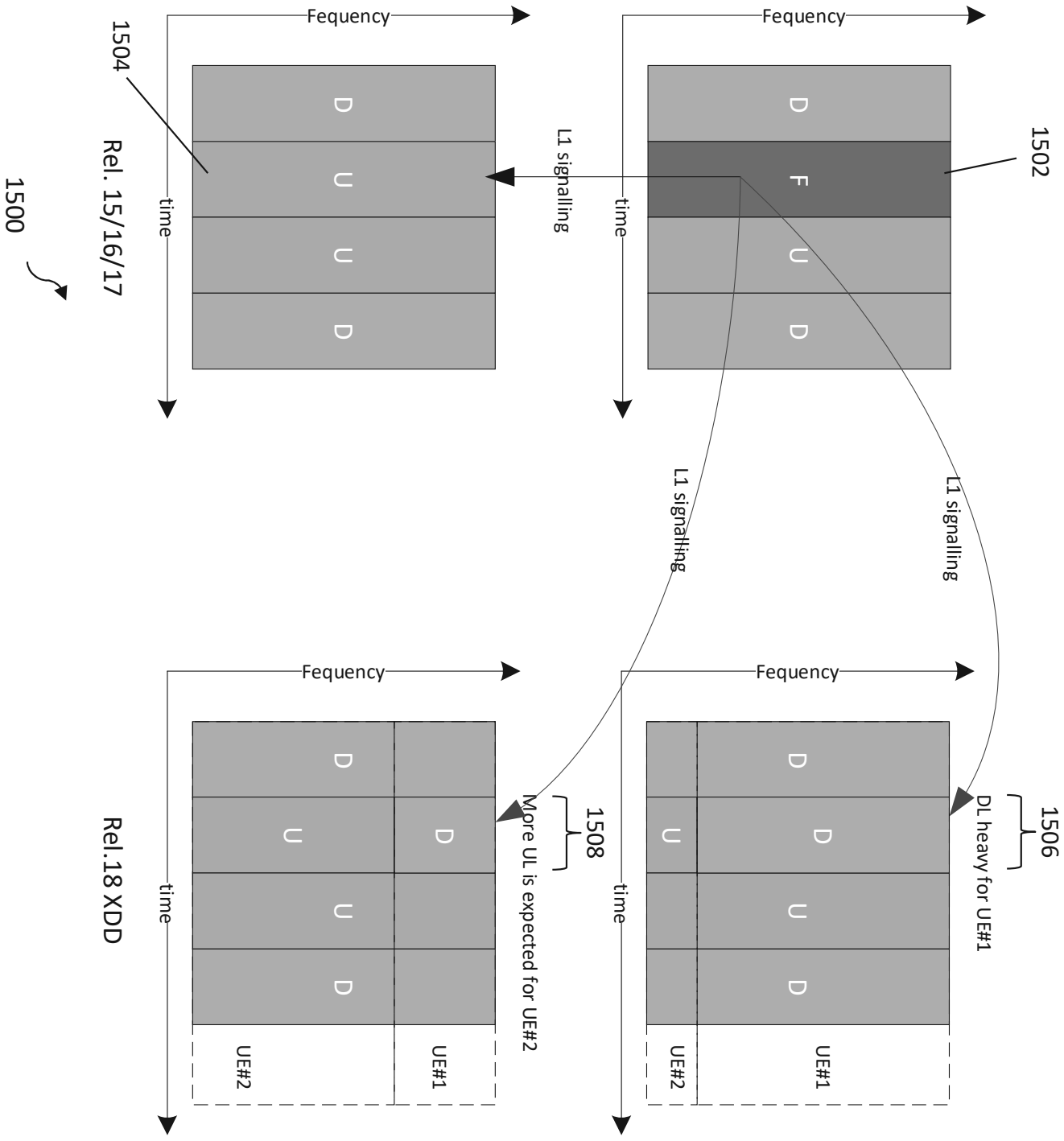

1500
1502
1504
Rel. 15/16/17
Rel.18 XDD
1506
DL heavy for UE#1
1508
More UL is expected for UE#2
L1 signalling
L1 signalling
L1 signalling
Fequency
time
D
F
U
UE#1
UE#2

Fig. 15

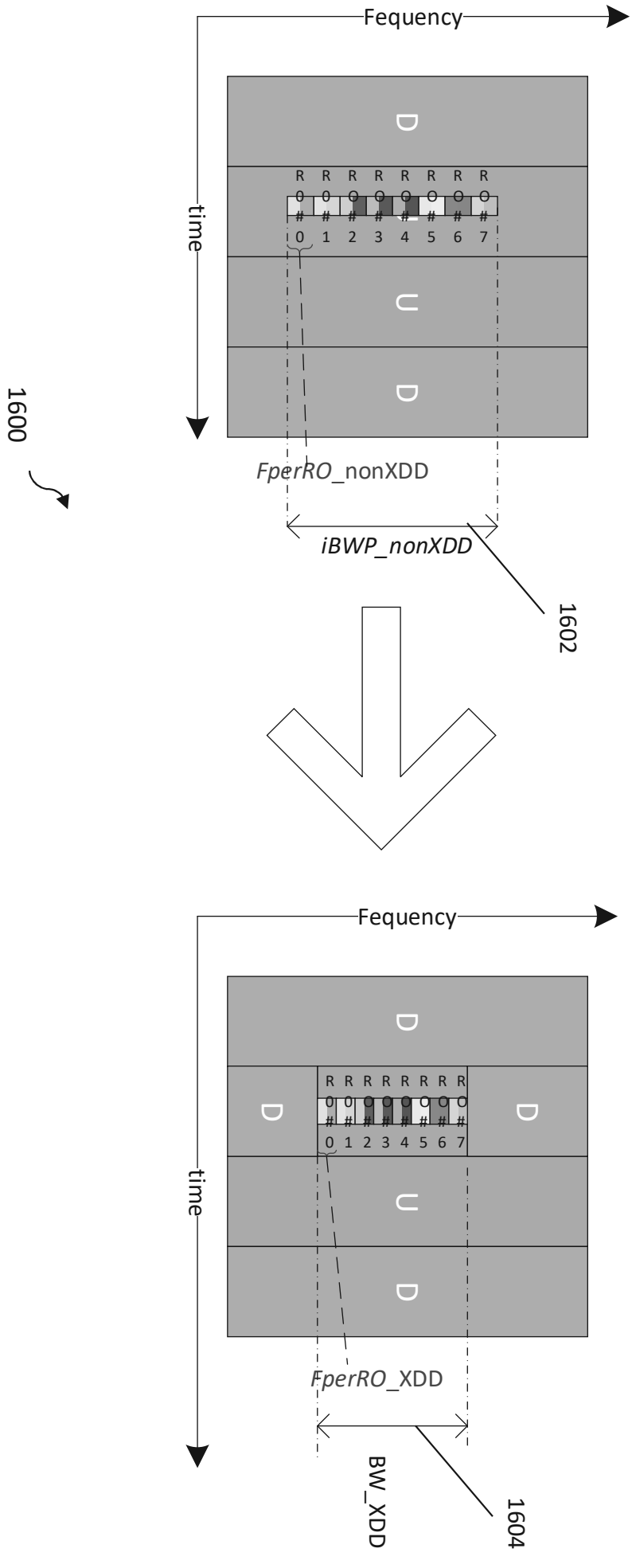

1600
Fequency
time
D
U
D
R R R R R R R R
0 0 0 0 0 0 0 0
# # # # # # # #
0 1 2 3 4 5 6 7
FperRO_nonXDD
iBWP_nonXDD
1602
Fequency
time
D
U
D
FperRO_XDD
BW_XDD
1604

Fig. 16

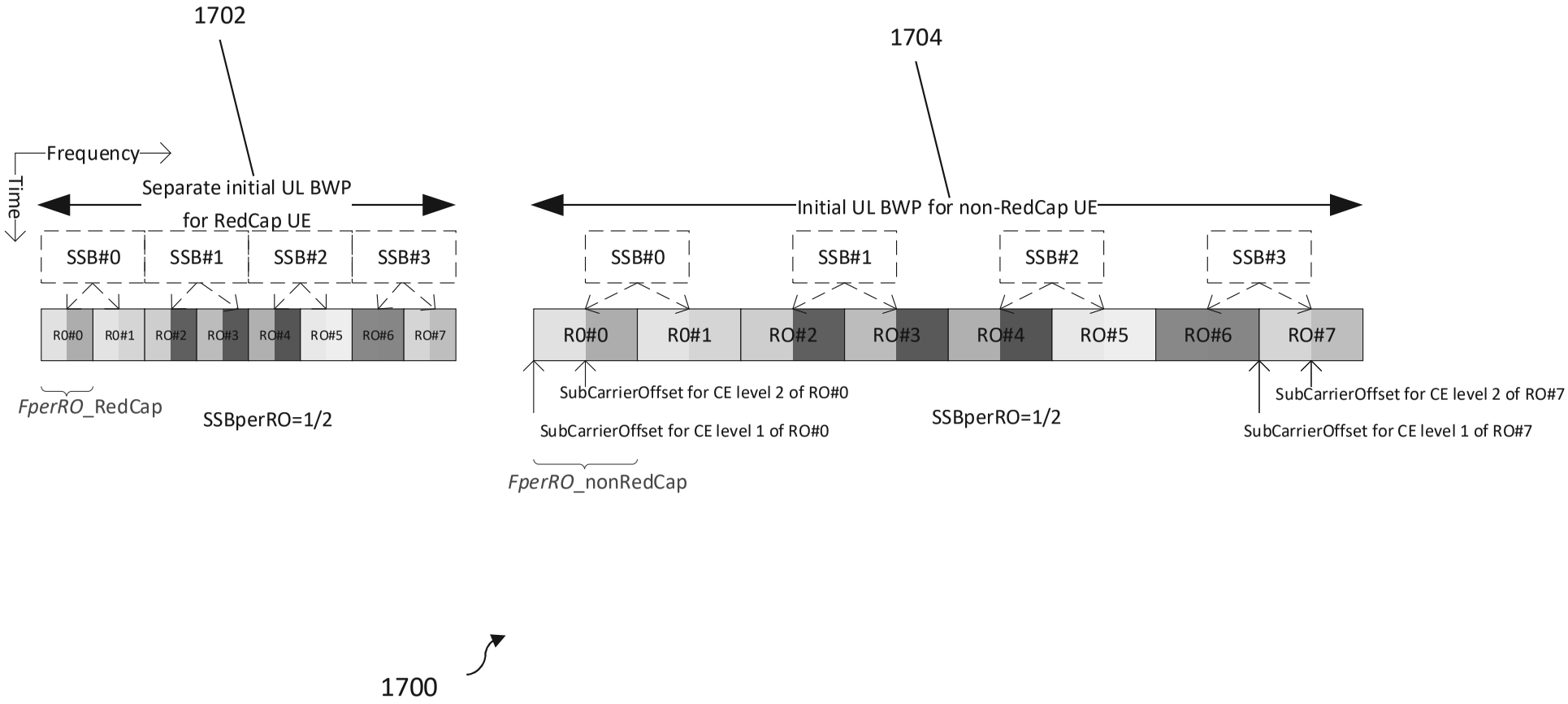

1702
1704
Frequency
Time
Separate initial UL BWP
for RedCap UE
Initial UL BWP for non-RedCap UE
SSB#0
SSB#1
SSB#2
SSB#3
RO#0
RO#1
RO#2
RO#3
RO#4
RO#5
RO#6
RO#7
FperRO_RedCap
SSBperRO=1/2
SubCarrierOffset for CE level 2 of RO#0
SubCarrierOffset for CE level 1 of RO#0
SSBperRO=1/2
SubCarrierOffset for CE level 2 of RO#7
SubCarrierOffset for CE level 1 of RO#7
FperRO_nonRedCap
1700

Fig. 17

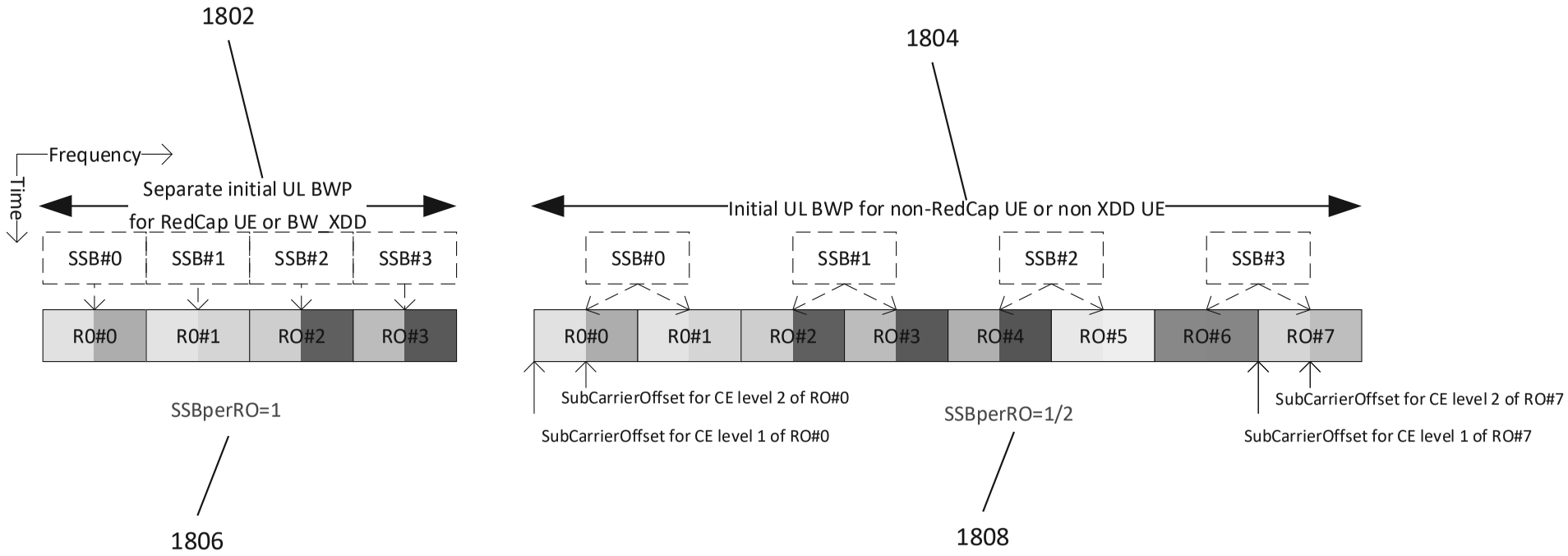

1802
Frequency
Time
Separate initial UL BWP
for RedCap UE or BW_XDD
SSB#0
SSB#1
SSB#2
SSB#3
R0#0
R0#1
RO#2
RO#3
SSBperRO=1
1806
1804
Initial UL BWP for non-RedCap UE or non XDD UE
SSB#0
SSB#1
SSB#2
SSB#3
R0#0
R0#1
RO#2
RO#3
RO#4
RO#5
RO#6
RO#7
SubCarrierOffset for CE level 2 of RO#0
SubCarrierOffset for CE level 1 of RO#0
SSBperRO=1/2
SubCarrierOffset for CE level 2 of RO#7
SubCarrierOffset for CE level 1 of RO#7
1808
1800

Fig. 18

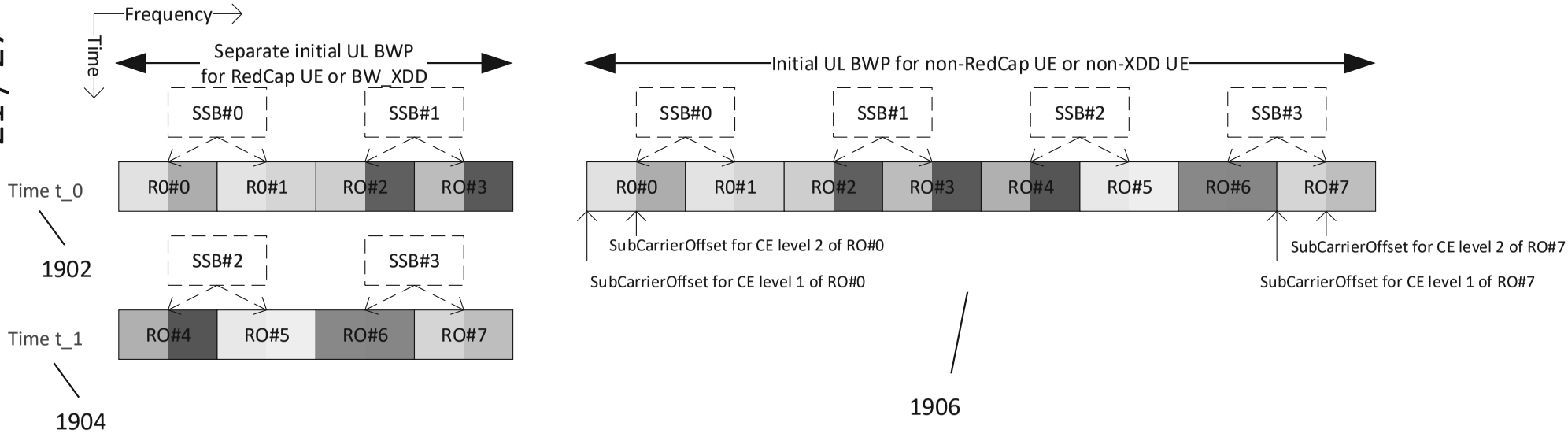
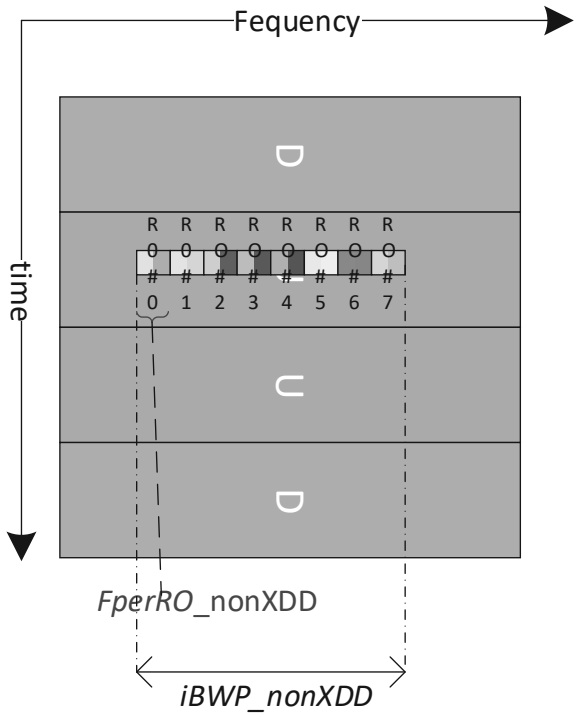
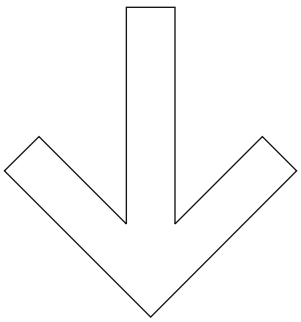

Frequency
Time
Separate initial UL BWP
for RedCap UE or BW_XDD
SSB#0
SSB#1
SSB#2
SSB#3
Time t_0
R0#0
R0#1
RO#2
RO#3
RO#4
RO#5
RO#6
RO#7
Time t_1
1902
1904
Initial UL BWP for non-RedCap UE or non-XDD UE
SubCarrierOffset for CE level 2 of RO#0
SubCarrierOffset for CE level 1 of RO#0
SubCarrierOffset for CE level 2 of RO#7
SubCarrierOffset for CE level 1 of RO#7
1906
1900

Fig. 19A


Fequency
time
D
U
D
R0#0
R0#1
R0#2
R0#3
R0#4
R0#5
R0#6
R0#7
FperRO_nonXDD
iBWP_nonXDD



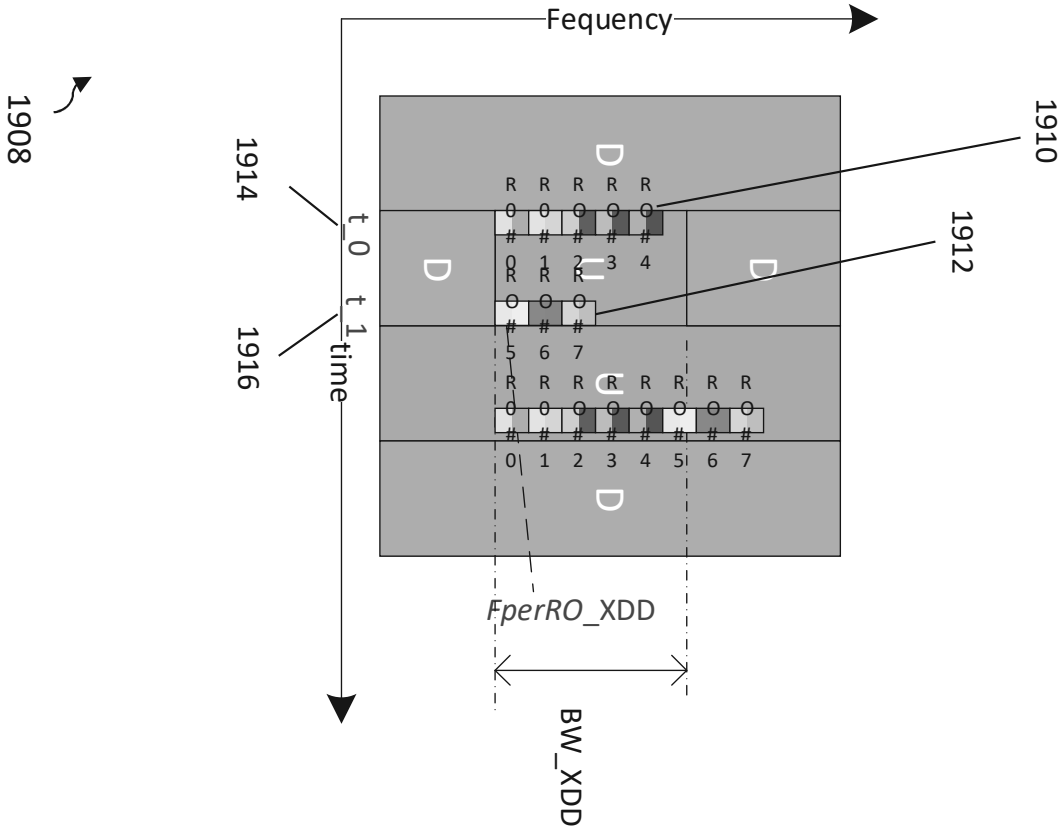

1908
Fequency
time
t 0
t 1
1914
1916
1910
1912
D
U
D
R0#0
R0#1
R0#2
R0#3
R0#4
R0#5
R0#6
R0#7
FperRO_XDD
BW_XDD

Fig. 19B

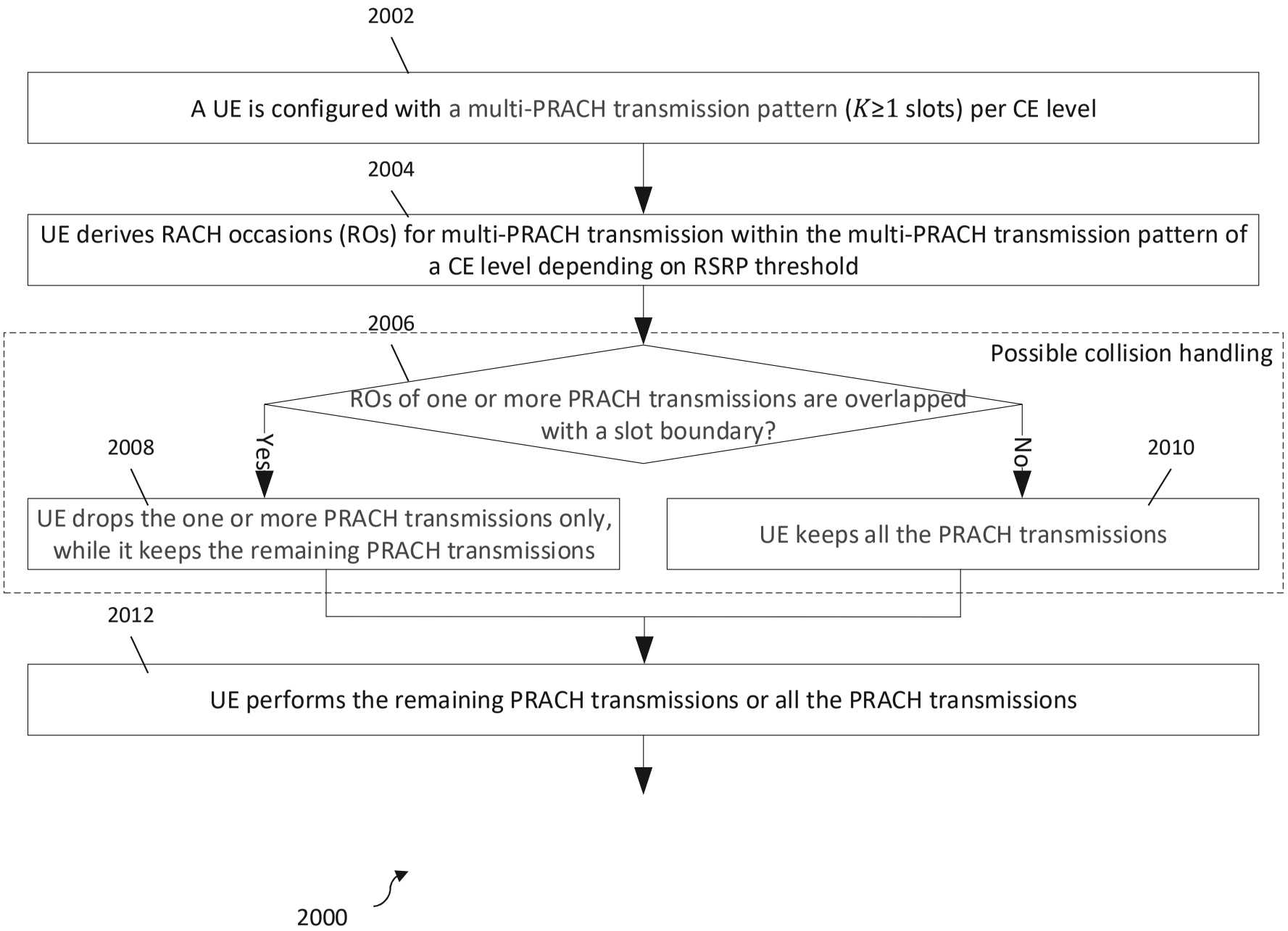

2002
A UE is configured with a multi-PRACH transmission pattern ($K \geq 1$ slots) per CE level
2004
UE derives RACH occasions (ROs) for multi-PRACH transmission within the multi-PRACH transmission pattern of a CE level depending on RSRP threshold
2006
Possible collision handling
ROs of one or more PRACH transmissions are overlapped with a slot boundary?
Yes
No
2008
UE drops the one or more PRACH transmissions only, while it keeps the remaining PRACH transmissions
2010
UE keeps all the PRACH transmissions
2012
UE performs the remaining PRACH transmissions or all the PRACH transmissions
2000

Fig. 20A

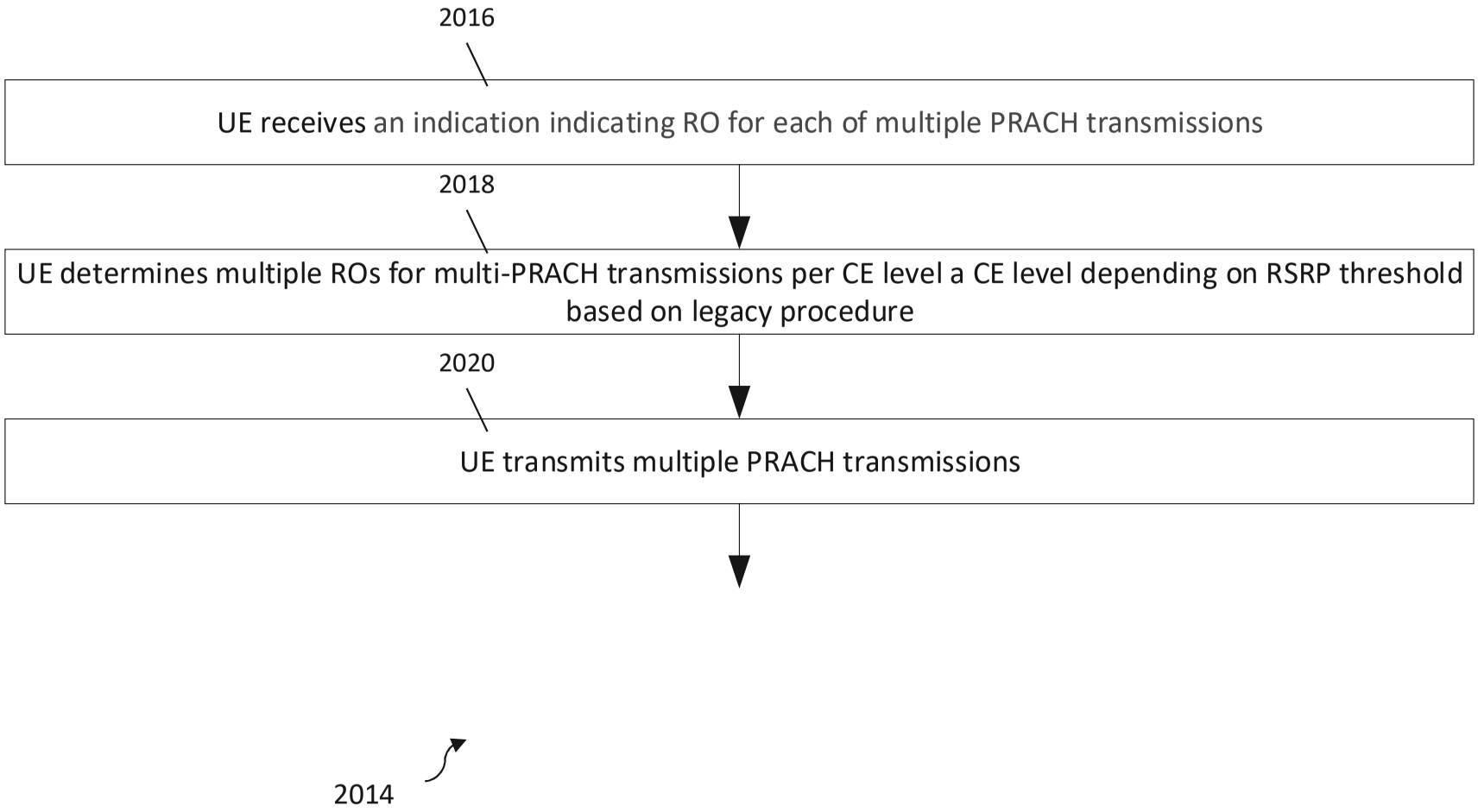

2016
UE receives an indication indicating RO for each of multiple PRACH transmissions
2018
UE determines multiple ROs for multi-PRACH transmissions per CE level a CE level depending on RSRP threshold based on legacy procedure
2020
UE transmits multiple PRACH transmissions
2014

Fig. 20B

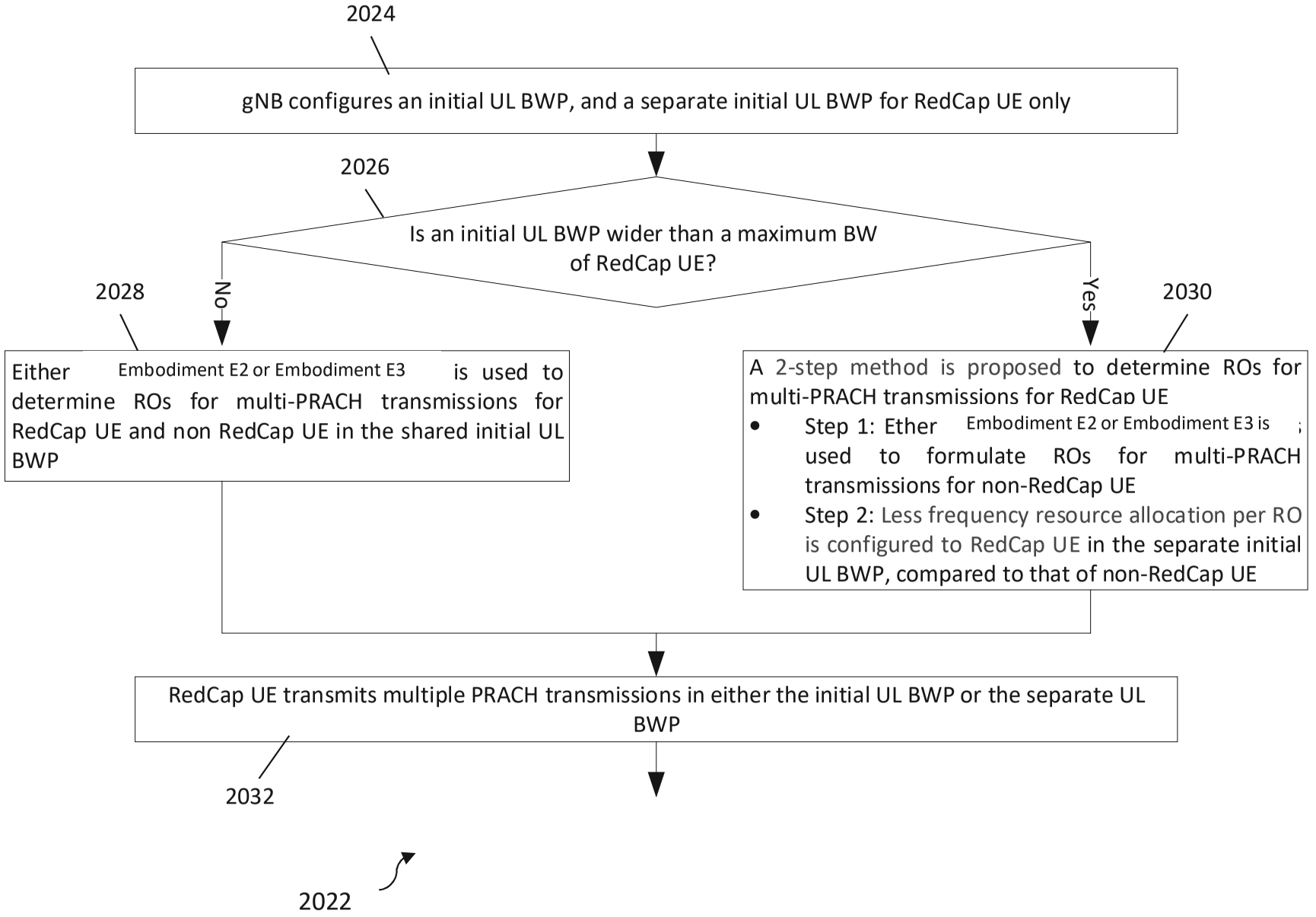

2024
gNB configures an initial UL BWP, and a separate initial UL BWP for RedCap UE only
2026
Is an initial UL BWP wider than a maximum BW of RedCap UE?
No
Yes
2028
Either Embodiment E2 or Embodiment E3 is used to determine ROs for multi-PRACH transmissions for RedCap UE and non RedCap UE in the shared initial UL BWP
2030
A 2-step method is proposed to determine ROs for multi-PRACH transmissions for RedCap UE
Step 1: Ether Embodiment E2 or Embodiment E3 is used to formulate ROs for multi-PRACH transmissions for non-RedCap UE
Step 2: Less frequency resource allocation per RO is configured to RedCap UE in the separate initial UL BWP, compared to that of non-RedCap UE
RedCap UE transmits multiple PRACH transmissions in either the initial UL BWP or the separate UL BWP
2032
2022

Fig. 20C

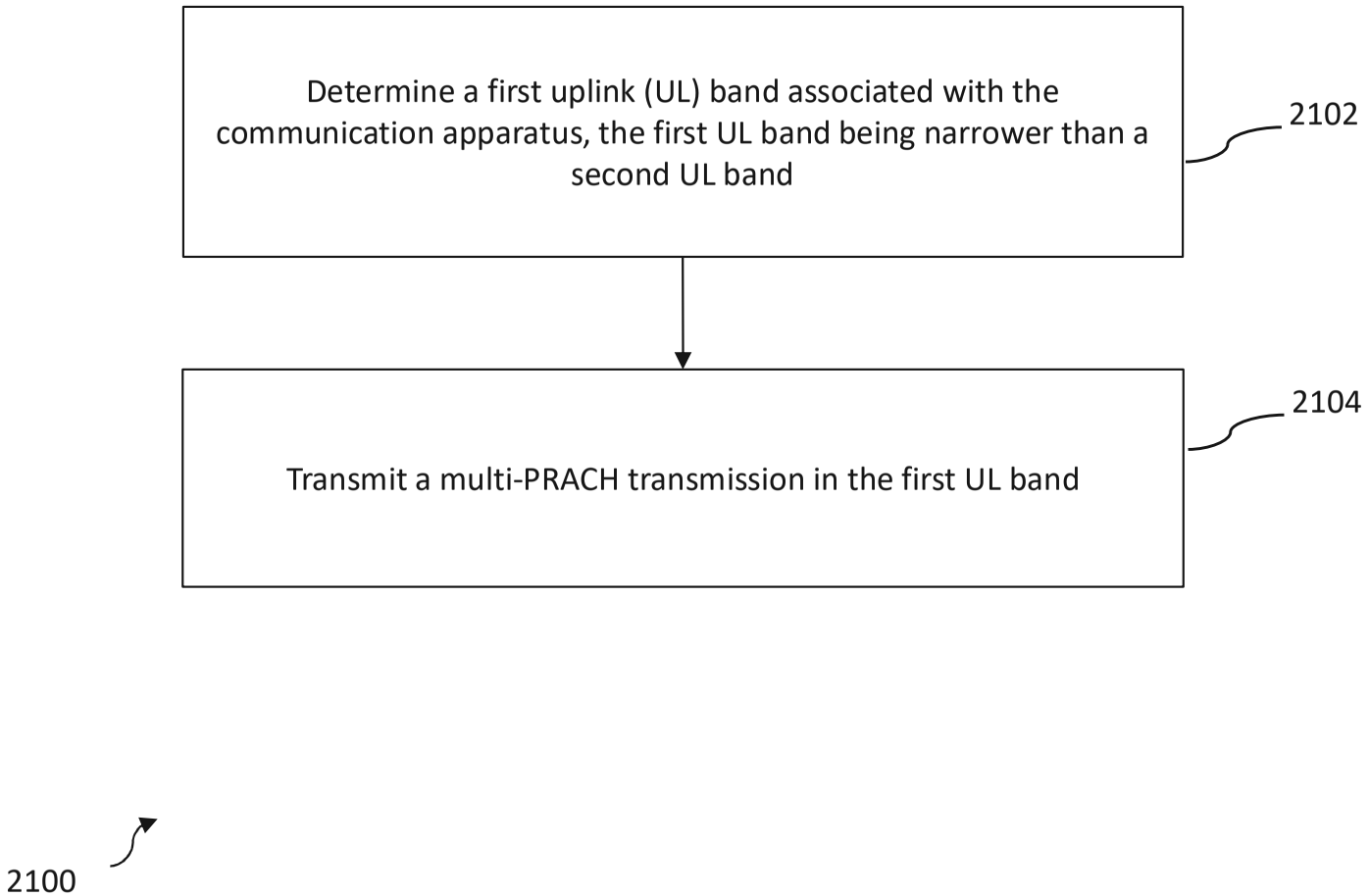

Determine a first uplink (UL) band associated with the communication apparatus, the first UL band being narrower than a second UL band
2102
Transmit a multi-PRACH transmission in the first UL band
2104
2100

Fig. 21

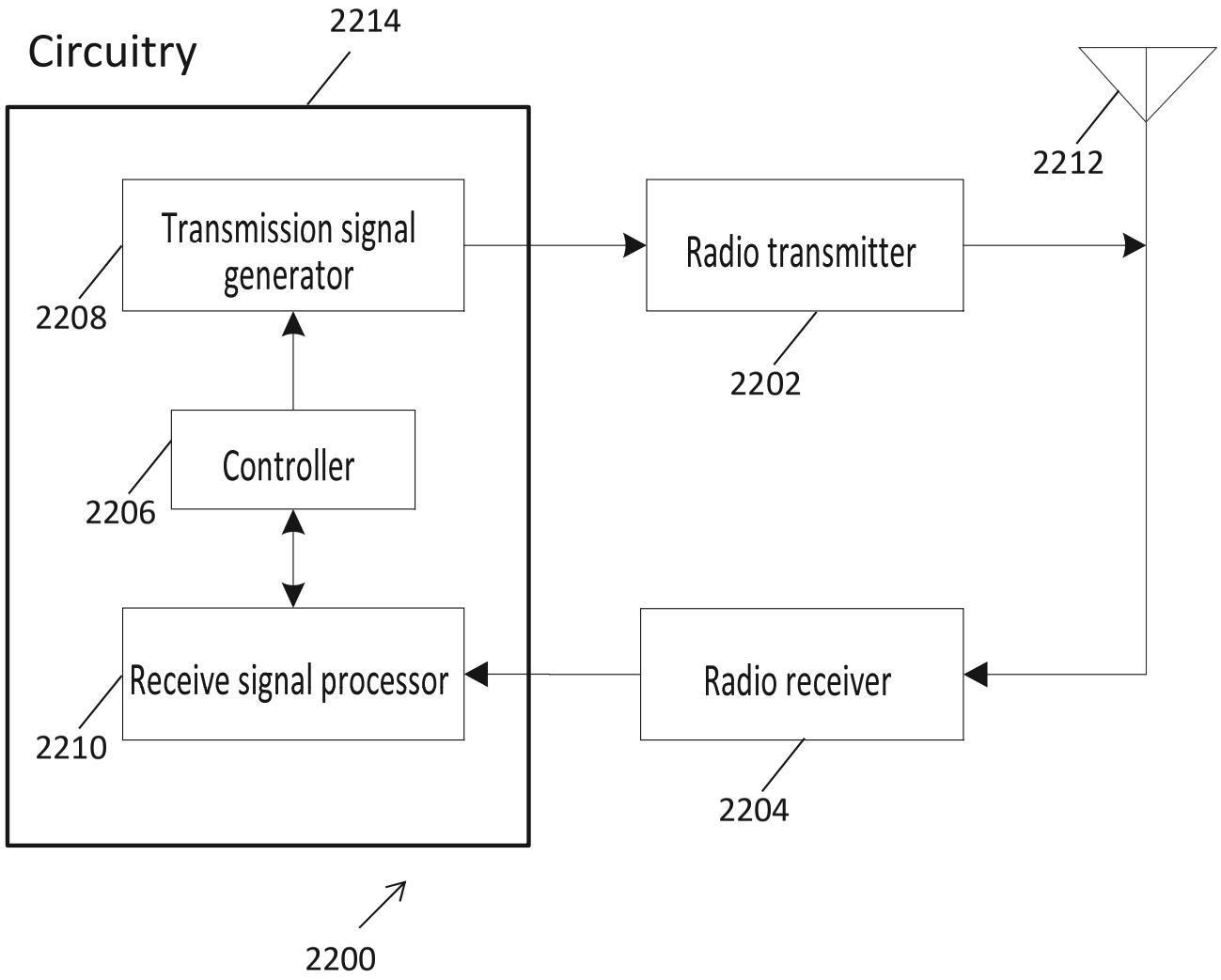

Circuitry
2214
Transmission signal generator
2208
Radio transmitter
2202
2212
Controller
2206
Receive signal processor
2210
Radio receiver
2204
2200

Fig. 22