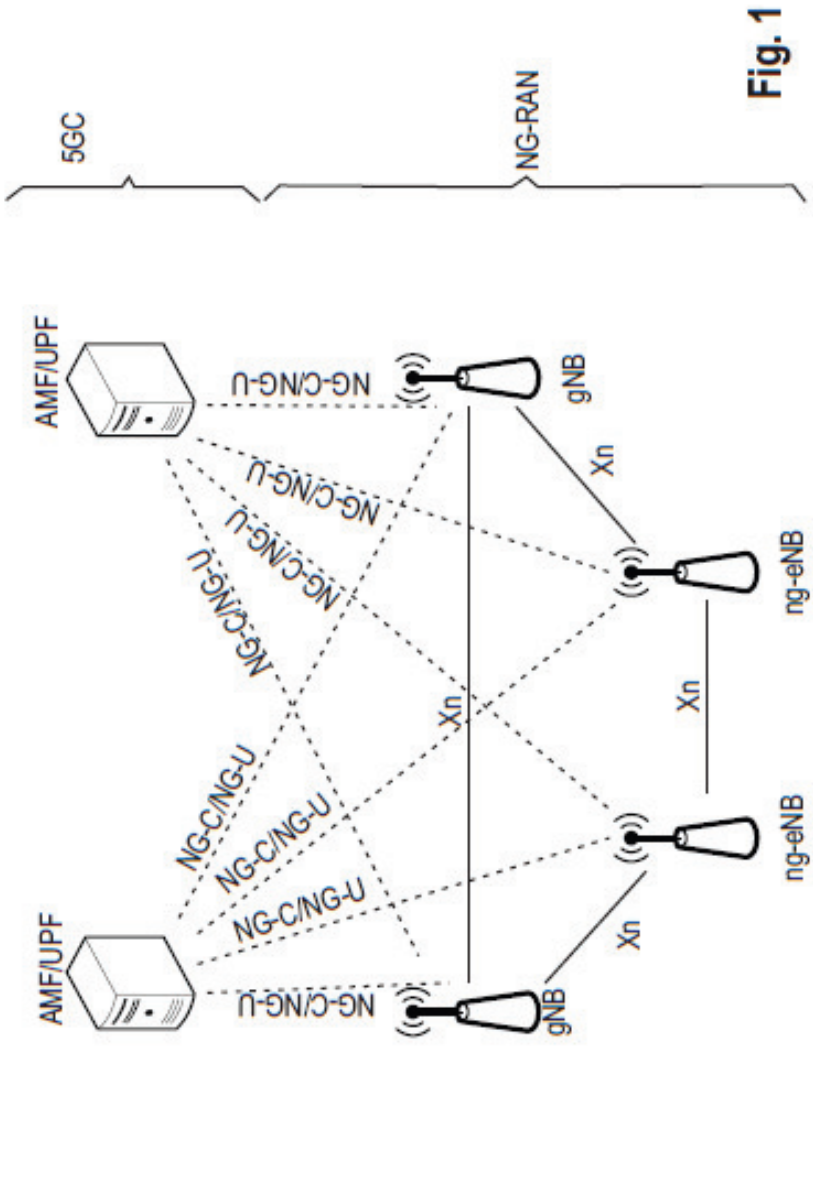

5GC
NG-RAN
AMF/UPF
AMF/UPF
gNB
gNB
ng-eNB
ng-eNB
Xn
Xn
Xn
NG-C/NG-U
NG-C/NG-U
NG-C/NG-U
NG-C/NG-U
NG-C/NG-U
NG-C/NG-U
NG-C/NG-U
NG-C/NG-U
100

Fig. 1

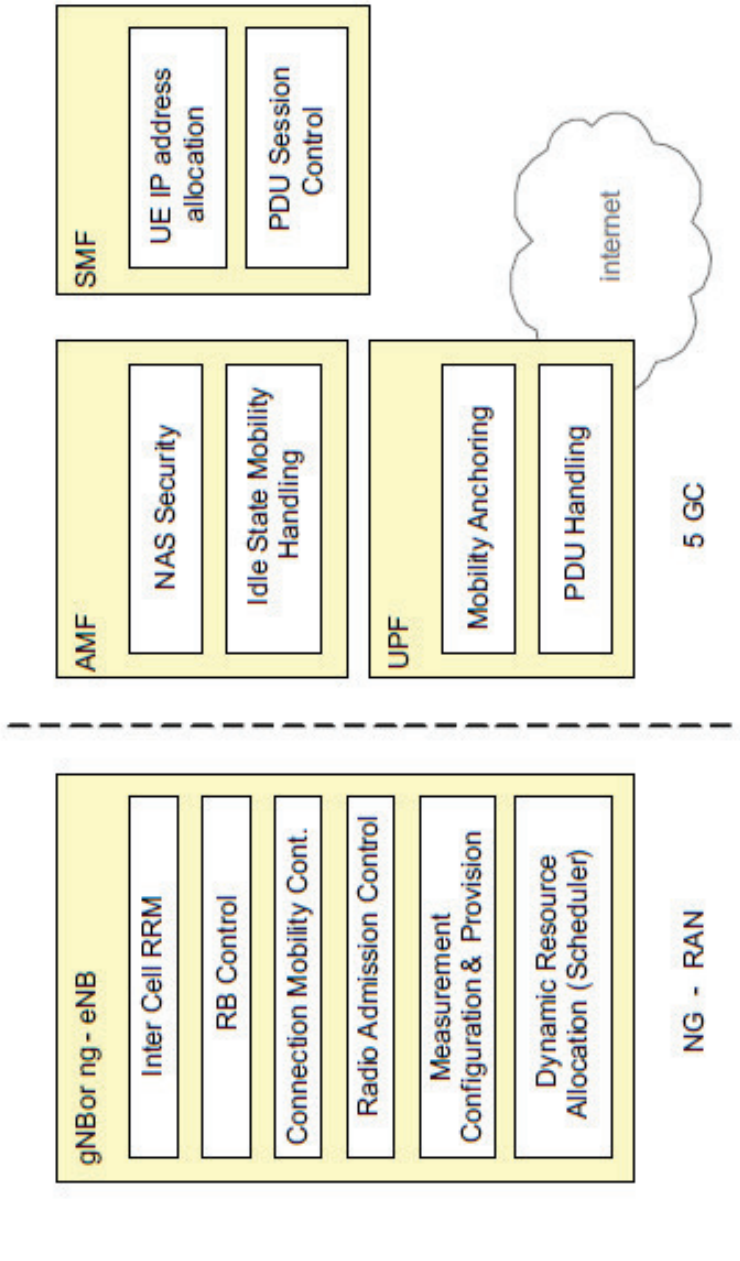

gNBor ng - eNB
Inter Cell RRM
RB Control
Connection Mobility Cont.
Radio Admission Control
Measurement Configuration & Provision
Dynamic Resource Allocation (Scheduler)
NG - RAN
AMF
NAS Security
Idle State Mobility Handling
SMF
UE IP address allocation
PDU Session Control
UPF
Mobility Anchoring
PDU Handling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

Fig. 2

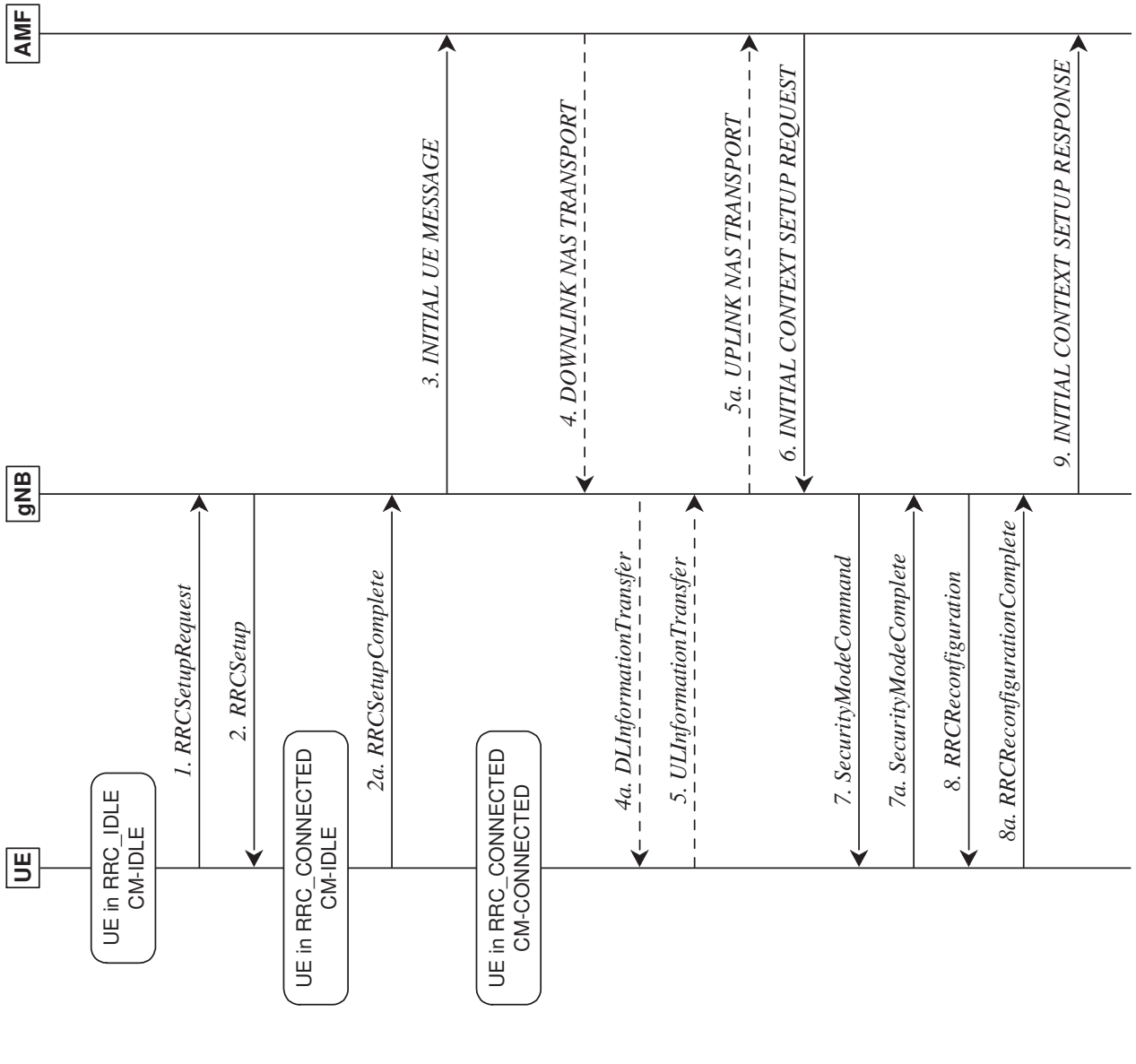

UE
gNB
AMF
UE in RRC_IDLE
CM-IDLE
1. RRCSetupRequest
2. RRCSetup
UE in RRC_CONNECTED
CM-IDLE
2a. RRCSetupComplete
3. INITIAL UE MESSAGE
4. DOWNLINK NAS TRANSPORT
5a. UPLINK NAS TRANSPORT
6. INITIAL CONTEXT SETUP REQUEST
9. INITIAL CONTEXT SETUP RESPONSE
UE in RRC_CONNECTED
CM-CONNECTED
4a. DLInformationTransfer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

Fig. 3

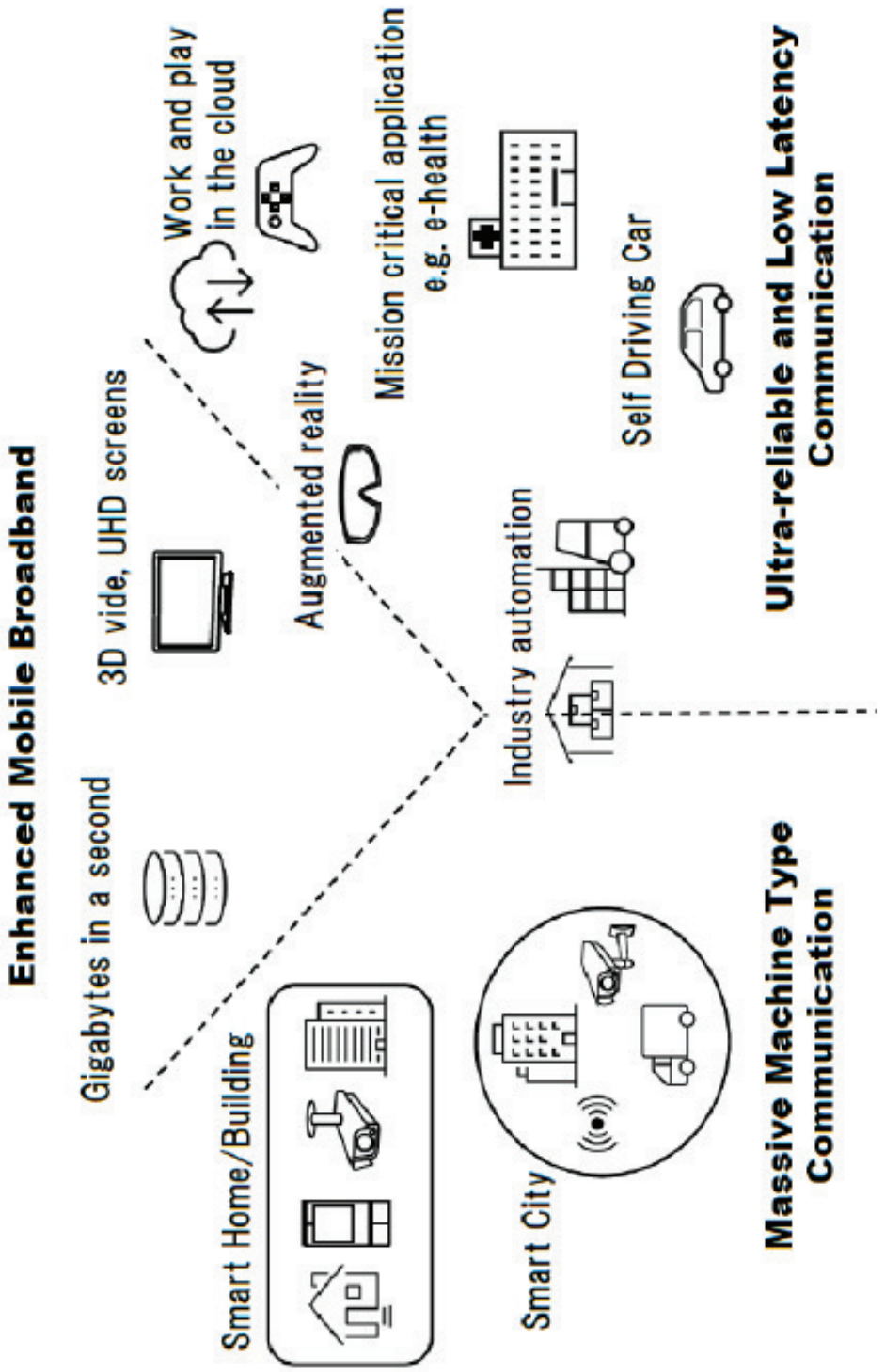

Enhanced Mobile Broadband
Gigabytes in a second
3D vide, UHD screens
Work and play in the cloud
Augmented reality
Mission critical application e.g. e-health
Smart Home/Building
Industry automation
Self Driving Car
Ultra-reliable and Low Latency Communication
Smart City
Massive Machine Type Communication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

Fig. 4

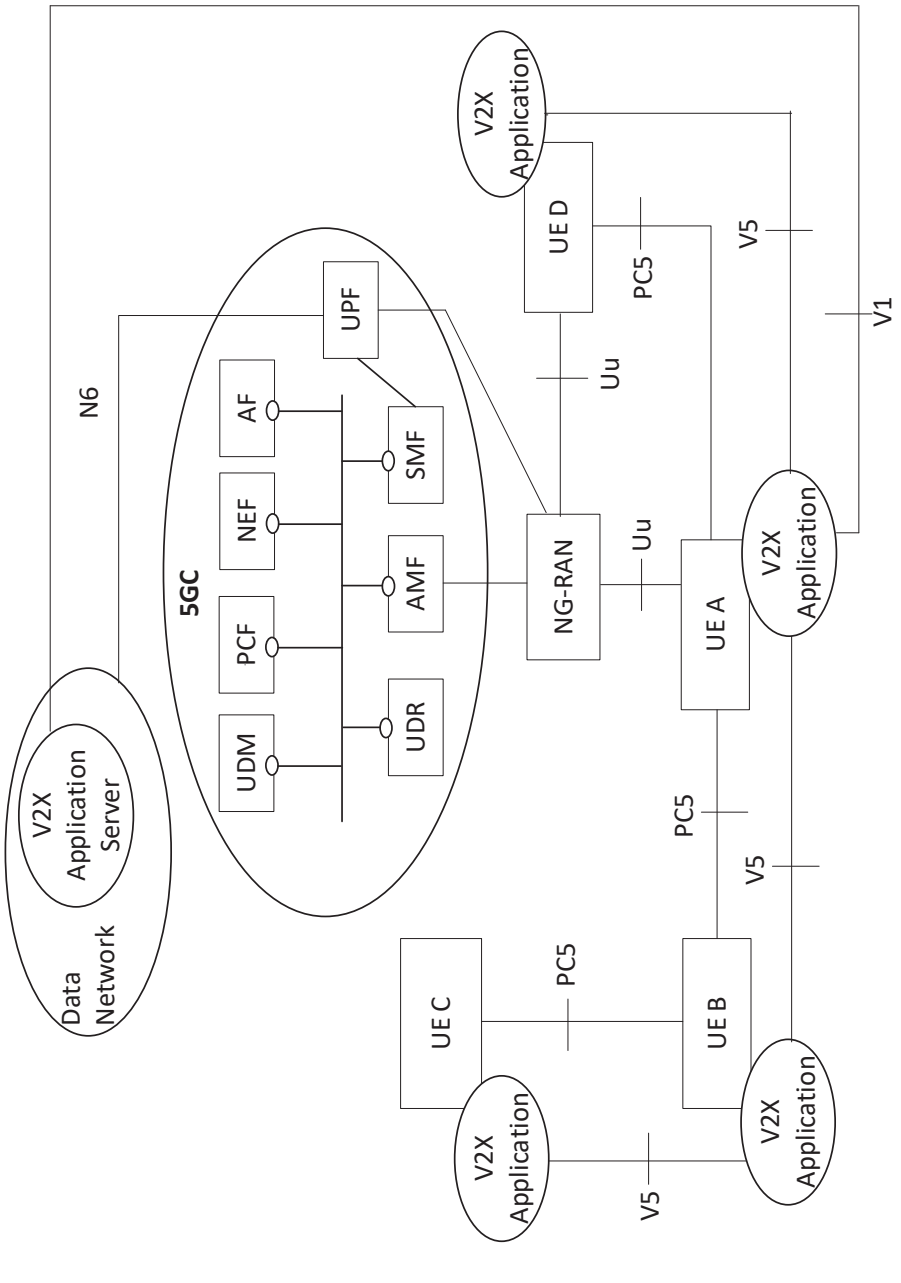

Data Network
V2X Application Server
N6
5GC
UPF
AF
NEF
PCF
UDM
SMF
AMF
UDR
NG-RAN
Uu
Uu
UE A
UE B
UE C
UE D
V2X Application
V2X Application
V2X Application
V2X Application
PC5
PC5
PC5
V5
V5
V5
V1
500

Fig. 5

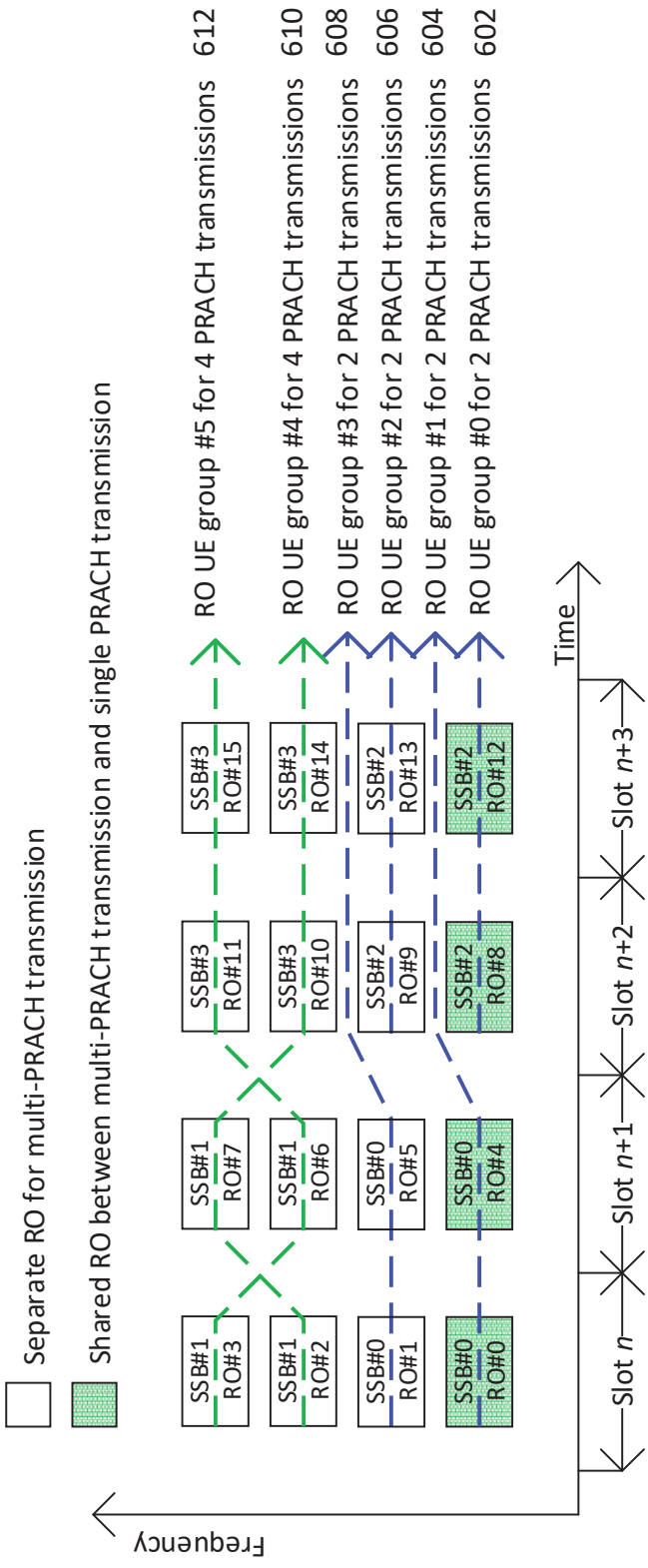
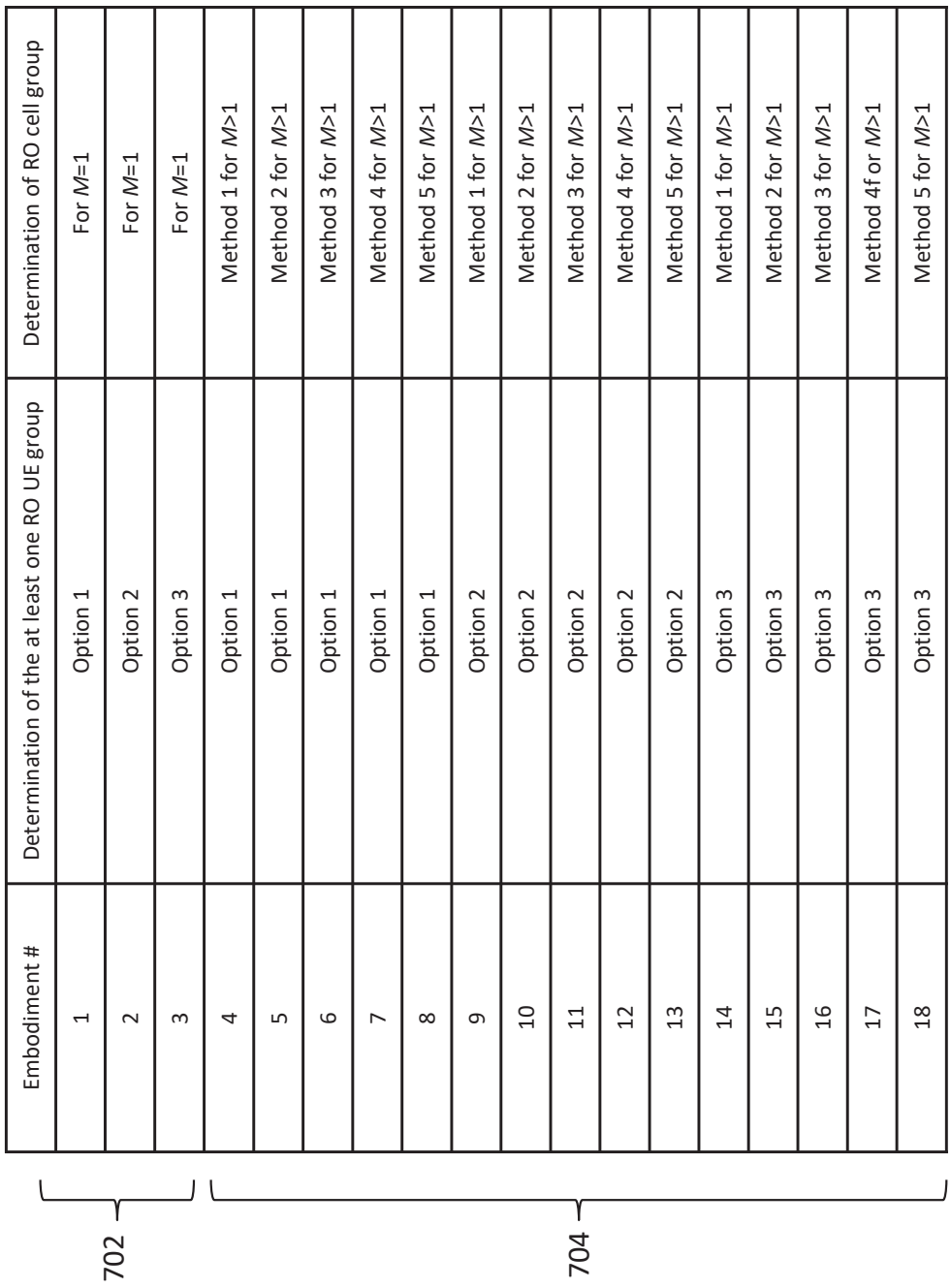

Separate RO for multi-PRACH transmission
Shared RO between multi-PRACH transmission and single PRACH transmission
Frequency
Time
Slot n
Slot n+1
Slot n+2
Slot n+3
SSB#1 RO#3
SSB#1 RO#2
SSB#0 RO#1
SSB#0 RO#0
SSB#1 RO#7
SSB#1 RO#6
SSB#0 RO#5
SSB#0 RO#4
SSB#3 RO#11
SSB#3 RO#10
SSB#2 RO#9
SSB#2 RO#8
SSB#3 RO#15
SSB#3 RO#14
SSB#2 RO#13
SSB#2 RO#12
RO UE group #5 for 4 PRACH transmissions 612
RO UE group #4 for 4 PRACH transmissions 610
RO UE group #3 for 2 PRACH transmissions 608
RO UE group #2 for 2 PRACH transmissions 606
RO UE group #1 for 2 PRACH transmissions 604
RO UE group #0 for 2 PRACH transmissions 602
600

Fig. 6



Embodiment #	Determination of the at least one RO UE group	Determination of RO cell group
1	Option 1	For M=1
2	Option 2	For M=1
3	Option 3	For M=1
4	Option 1	Method 1 for M>1
5	Option 1	Method 2 for M>1
6	Option 1	Method 3 for M>1
7	Option 1	Method 4 for M>1
8	Option 1	Method 5 for M>1
9	Option 2	Method 1 for M>1
10	Option 2	Method 2 for M>1
11	Option 2	Method 3 for M>1
12	Option 2	Method 4 for M>1
13	Option 2	Method 5 for M>1
14	Option 3	Method 1 for M>1
15	Option 3	Method 2 for M>1
16	Option 3	Method 3 for M>1
17	Option 3	Method 4f or M>1
18	Option 3	Method 5 for M>1

Fig. 7

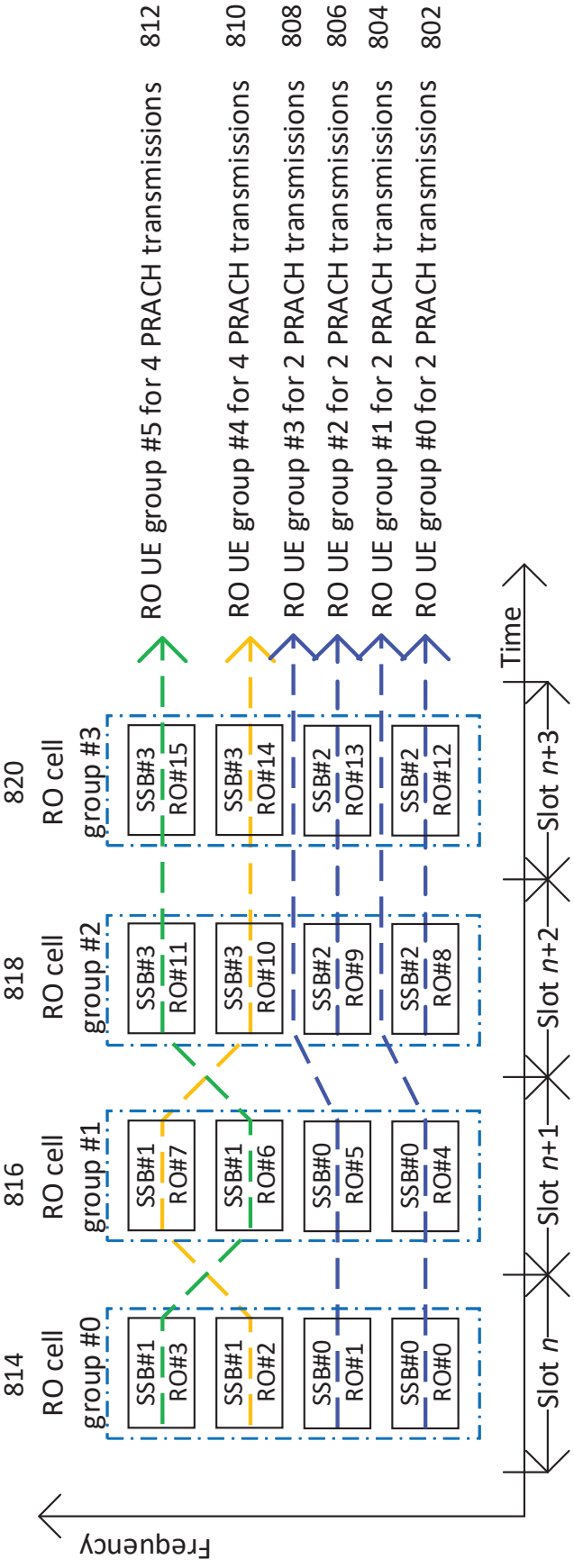

812
RO UE group #5 for 4 PRACH transmissions
810
RO UE group #4 for 4 PRACH transmissions
808
RO UE group #3 for 2 PRACH transmissions
806
RO UE group #2 for 2 PRACH transmissions
804
RO UE group #1 for 2 PRACH transmissions
802
RO UE group #0 for 2 PRACH transmissions
820
RO cell group #3
SSB#3 RO#15
SSB#3 RO#14
SSB#2 RO#13
SSB#2 RO#12
818
RO cell group #2
SSB#3 RO#11
SSB#3 RO#10
SSB#2 RO#9
SSB#2 RO#8
816
RO cell group #1
SSB#1 RO#7
SSB#1 RO#6
SSB#0 RO#5
SSB#0 RO#4
814
RO cell group #0
SSB#1 RO#3
SSB#1 RO#2
SSB#0 RO#1
SSB#0 RO#0
Time
Slot n
Slot n+1
Slot n+2
Slot n+3
Frequency
800

Fig. 8

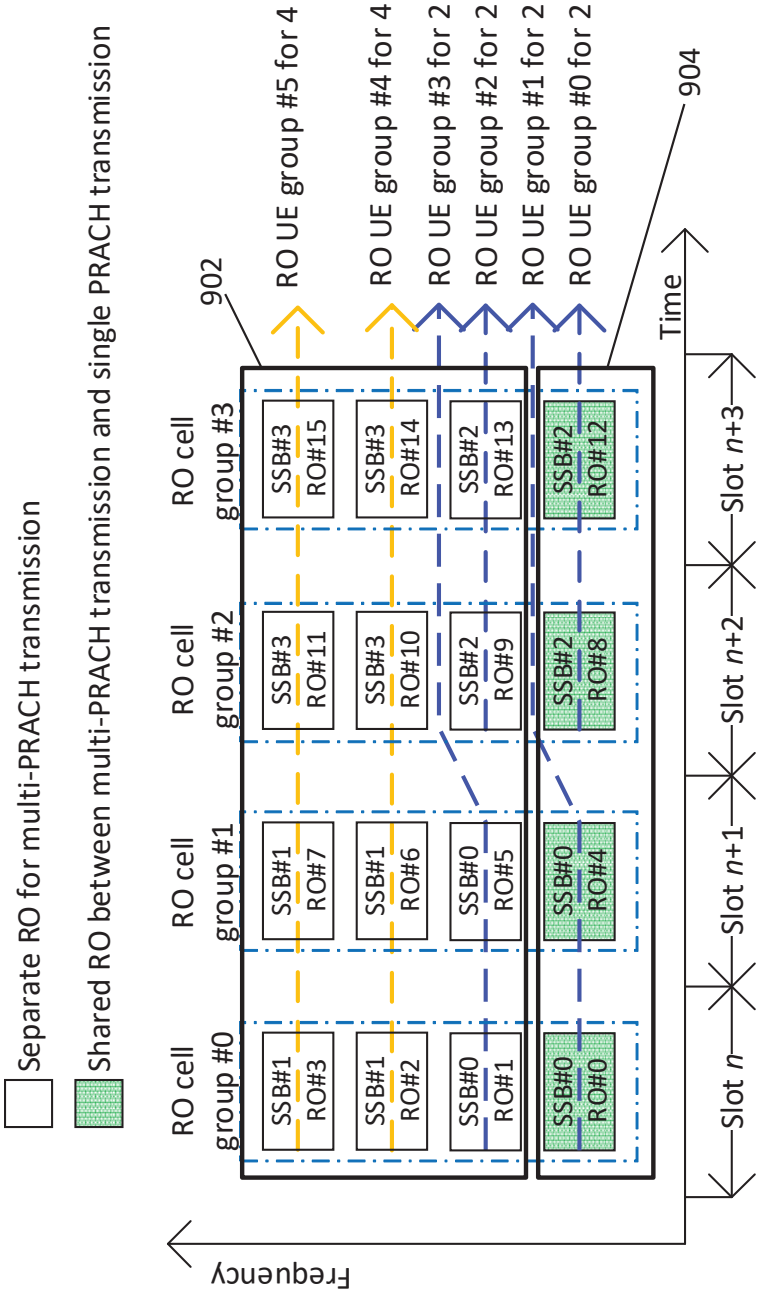

Separate RO for multi-PRACH transmission
Shared RO between multi-PRACH transmission and single PRACH transmission
RO cell group #0
RO cell group #1
RO cell group #2
RO cell group #3
SSB#1 RO#3
SSB#1 RO#2
SSB#0 RO#1
SSB#0 RO#0
SSB#1 RO#7
SSB#1 RO#6
SSB#0 RO#5
SSB#0 RO#4
SSB#3 RO#11
SSB#3 RO#10
SSB#2 RO#9
SSB#2 RO#8
SSB#3 RO#15
SSB#3 RO#14
SSB#2 RO#13
SSB#2 RO#12
902
RO UE group #5 for 4 PRACH transmissions
RO UE group #4 for 4 PRACH transmissions
RO UE group #3 for 2 PRACH transmissions
RO UE group #2 for 2 PRACH transmissions
RO UE group #1 for 2 PRACH transmissions
RO UE group #0 for 2 PRACH transmissions
904
Time
Slot n
Slot n+1
Slot n+2
Slot n+3
Frequency
900

Fig. 9

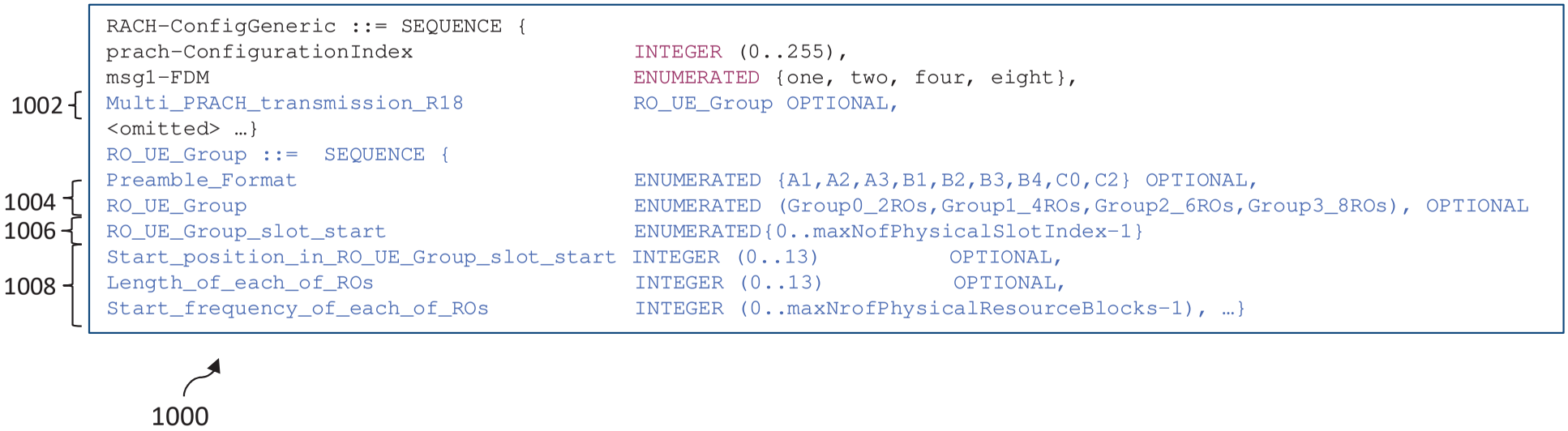
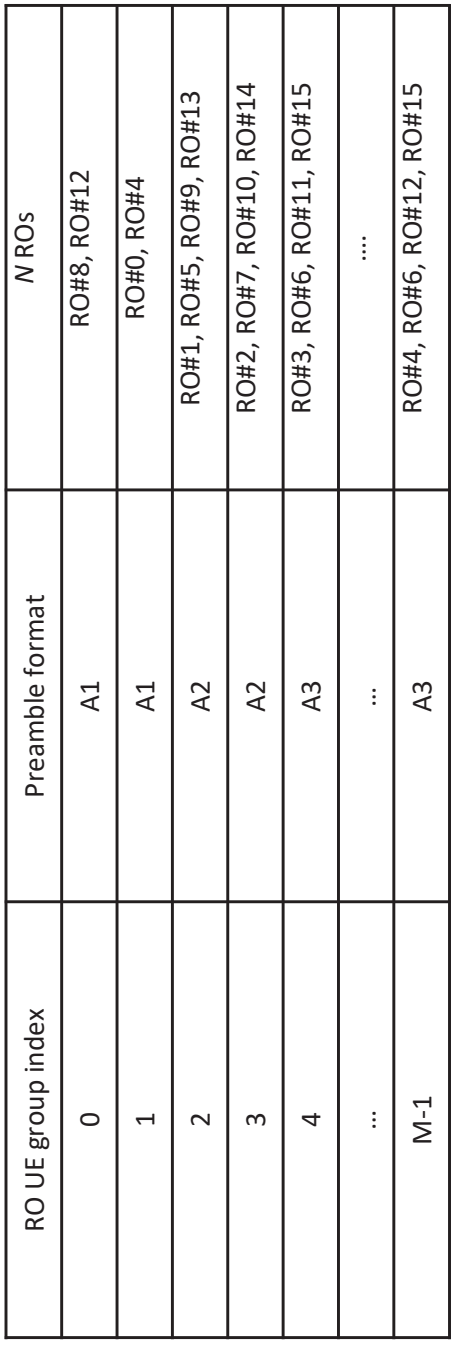

RACH-ConfigGeneric ::= SEQUENCE {
prach-ConfigurationIndex INTEGER (0..255),
msg1-FDM ENUMERATED {one, two, four, eight},
Multi_PRACH_transmission_R18 RO_UE_Group OPTIONAL,
<omitted> …}
RO_UE_Group ::= SEQUENCE {
Preamble_Format ENUMERATED {A1,A2,A3,B1,B2,B3,B4,C0,C2} OPTIONAL,
RO_UE_Group ENUMERATED (Group0_2ROs,Group1_4ROs,Group2_6ROs,Group3_8ROs), OPTIONAL
RO_UE_Group_slot_start ENUMERATED{0..maxNofPhysicalSlotIndex-1}
Start_position_in_RO_UE_Group_slot_start INTEGER (0..13) OPTIONAL,
Length_of_each_of_ROs INTEGER (0..13) OPTIONAL,
Start_frequency_of_each_of_ROs INTEGER (0..maxNrofPhysicalResourceBlocks-1), …}
1002
1004
1006
1008
1000

Fig. 10



RO UE group index	Preamble format	*N* ROs
0	A1	RO#8, RO#12
1	A1	RO#0, RO#4
2	A2	RO#1, RO#5, RO#9, RO#13
3	A2	RO#2, RO#7, RO#10, RO#14
4	A3	RO#3, RO#6, RO#11, RO#15
...	...	....
M-1	A3	RO#4, RO#6, RO#12, RO#15

1100

Fig. 11

1202

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						*N*=2	*N*=4
67	A1	16	1	9	0	2	6	2	RO#8, RO#12	RO#1, RO#5, RO#9, RO#13

1200

Fig. 12

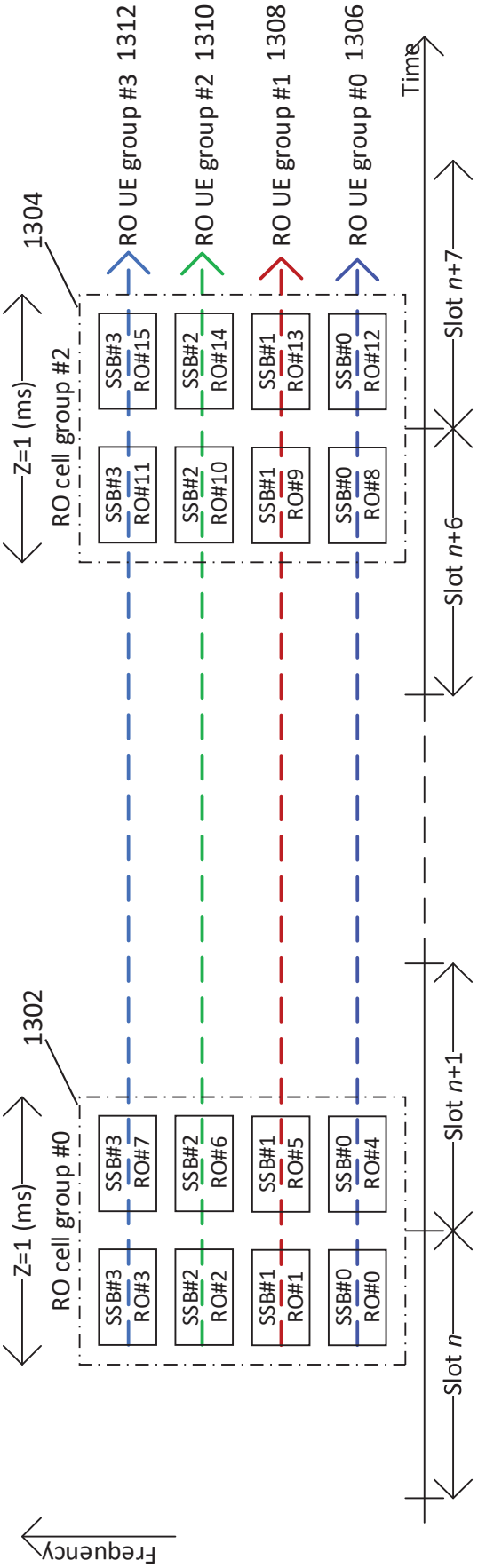

1300
Frequency
Time
Slot n
Slot n+1
Slot n+6
Slot n+7
1302
RO cell group #0
Z=1 (ms)
SSB#0 RO#0
SSB#1 RO#1
SSB#2 RO#2
SSB#3 RO#3
SSB#0 RO#4
SSB#1 RO#5
SSB#2 RO#6
SSB#3 RO#7
1304
RO cell group #2
Z=1 (ms)
SSB#0 RO#8
SSB#1 RO#9
SSB#2 RO#10
SSB#3 RO#11
SSB#0 RO#12
SSB#1 RO#13
SSB#2 RO#14
SSB#3 RO#15
RO UE group #0 1306
RO UE group #1 1308
RO UE group #2 1310
RO UE group #3 1312

Fig. 13

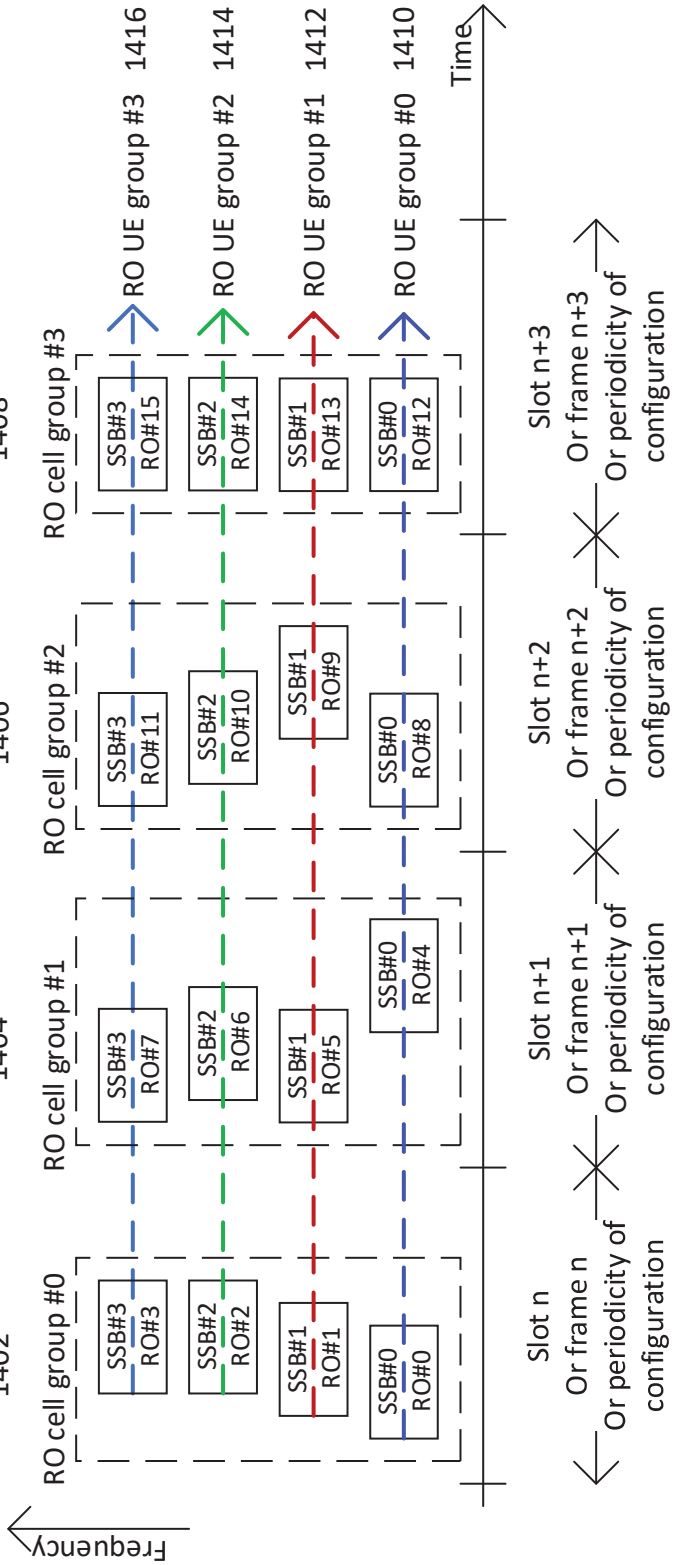

1400
Frequency
Time
1402
RO cell group #0
SSB#3 RO#3
SSB#2 RO#2
SSB#1 RO#1
SSB#0 RO#0
1404
RO cell group #1
SSB#3 RO#7
SSB#2 RO#6
SSB#1 RO#5
SSB#0 RO#4
1406
RO cell group #2
SSB#3 RO#11
SSB#2 RO#10
SSB#1 RO#9
SSB#0 RO#8
1408
RO cell group #3
SSB#3 RO#15
SSB#2 RO#14
SSB#1 RO#13
SSB#0 RO#12
RO UE group #3 1416
RO UE group #2 1414
RO UE group #1 1412
RO UE group #0 1410
Slot n
Or frame n
Or periodicity of configuration
Slot n+1
Or frame n+1
Or periodicity of configuration
Slot n+2
Or frame n+2
Or periodicity of configuration
Slot n+3
Or frame n+3
Or periodicity of configuration

Fig. 14

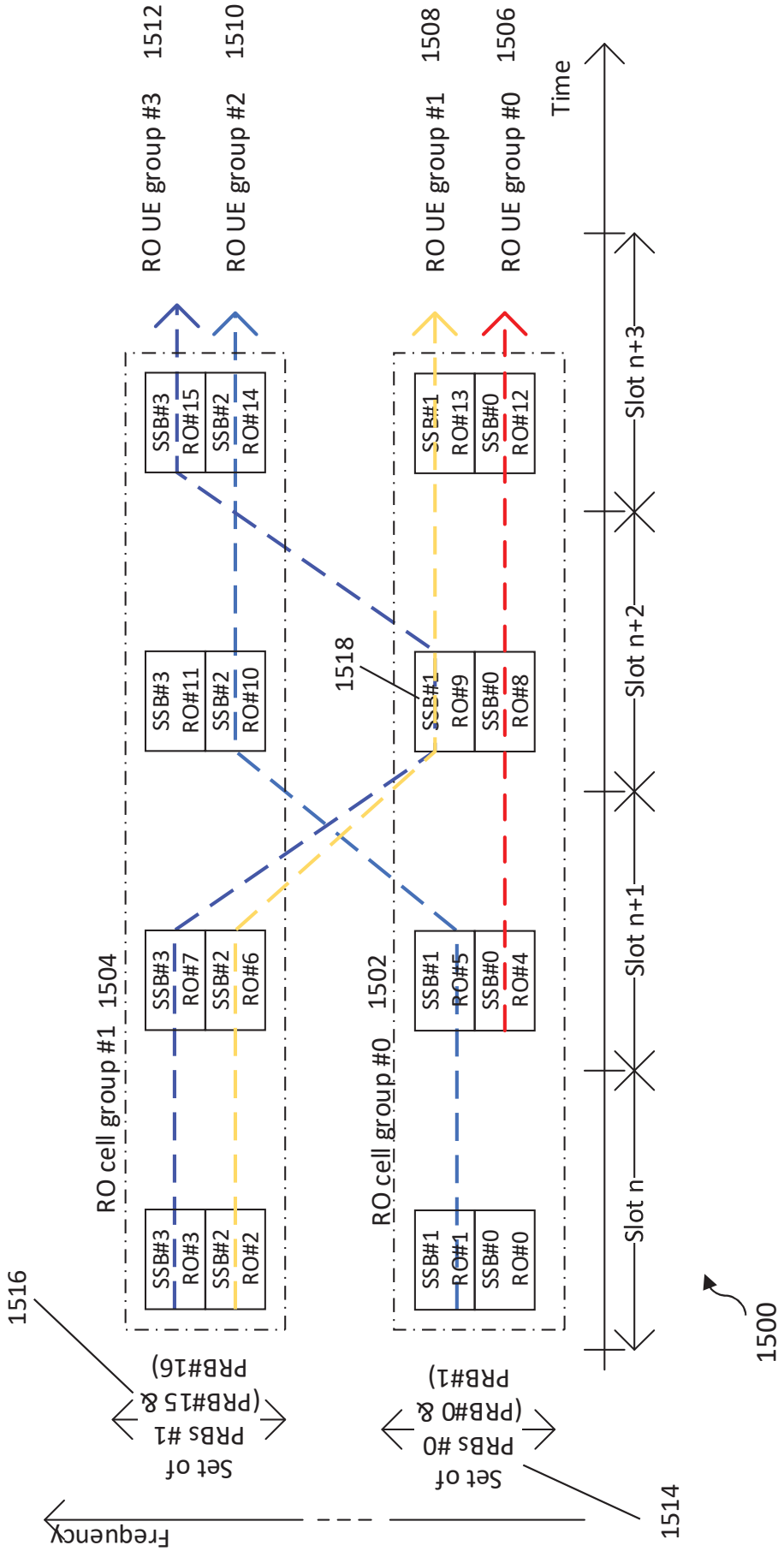

RO UE group #3 1512
RO UE group #2 1510
RO UE group #1 1508
RO UE group #0 1506
Time
RO cell group #1 1504
RO cell group #0 1502
SSB#3 RO#15
SSB#2 RO#14
SSB#1 RO#13
SSB#0 RO#12
SSB#3 RO#11
SSB#2 RO#10
SSB#1 RO#9
SSB#0 RO#8
SSB#3 RO#7
SSB#2 RO#6
SSB#1 RO#5
SSB#0 RO#4
SSB#3 RO#3
SSB#2 RO#2
SSB#1 RO#1
SSB#0 RO#0
1518
Slot n
Slot n+1
Slot n+2
Slot n+3
1516
Set of PRBs #1 (PRB#15 & PRB#16)
Set of PRBs #0 (PRB#0 & PRB#1)
Frequency
1514
1500

Fig. 15

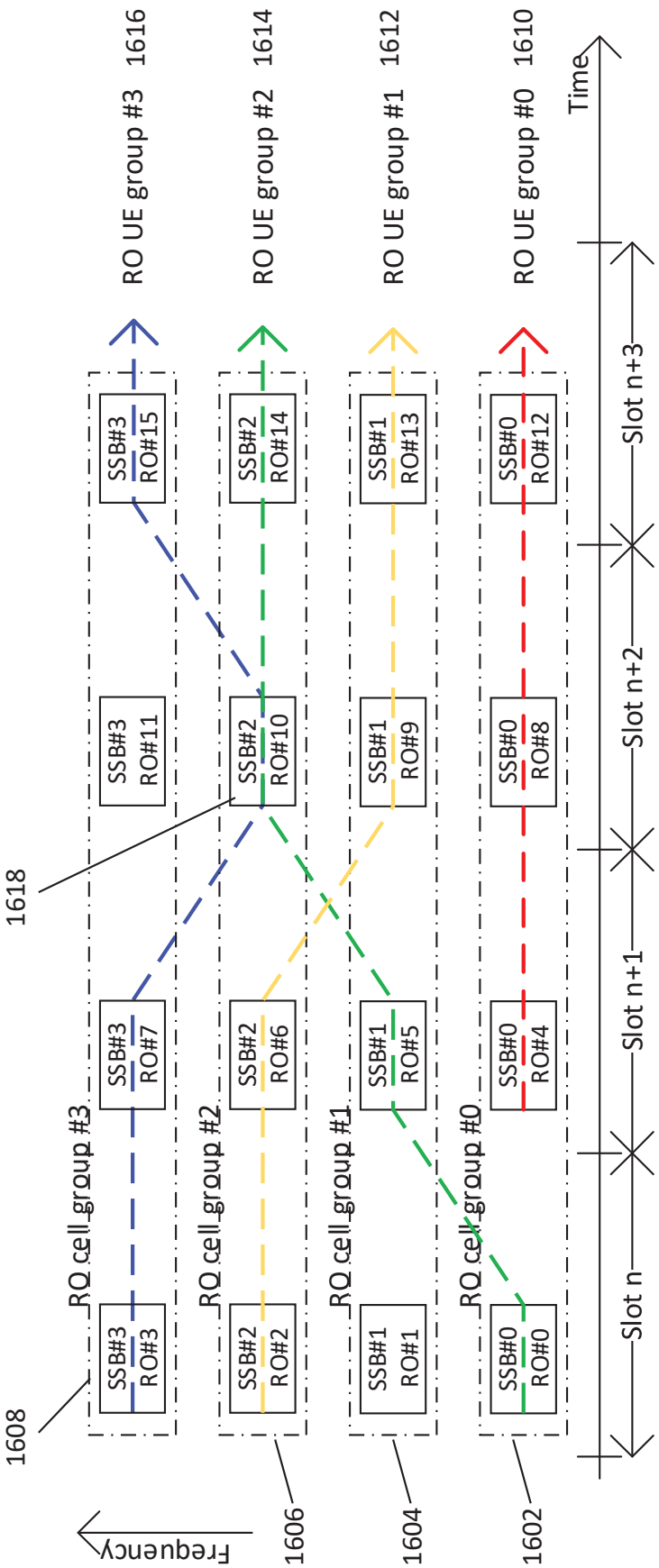

RO UE group #3 1616
RO UE group #2 1614
RO UE group #1 1612
RO UE group #0 1610
Time
Slot n
Slot n+1
Slot n+2
Slot n+3
RO cell group #3
RO cell group #2
RO cell group #1
RO cell group #0
SSB#3 RO#3
SSB#3 RO#7
SSB#3 RO#11
SSB#3 RO#15
SSB#2 RO#2
SSB#2 RO#6
SSB#2 RO#10
SSB#2 RO#14
SSB#1 RO#1
SSB#1 RO#5
SSB#1 RO#9
SSB#1 RO#13
SSB#0 RO#0
SSB#0 RO#4
SSB#0 RO#8
SSB#0 RO#12
Frequency
1608
1606
1604
1602
1618
1600

Fig. 16

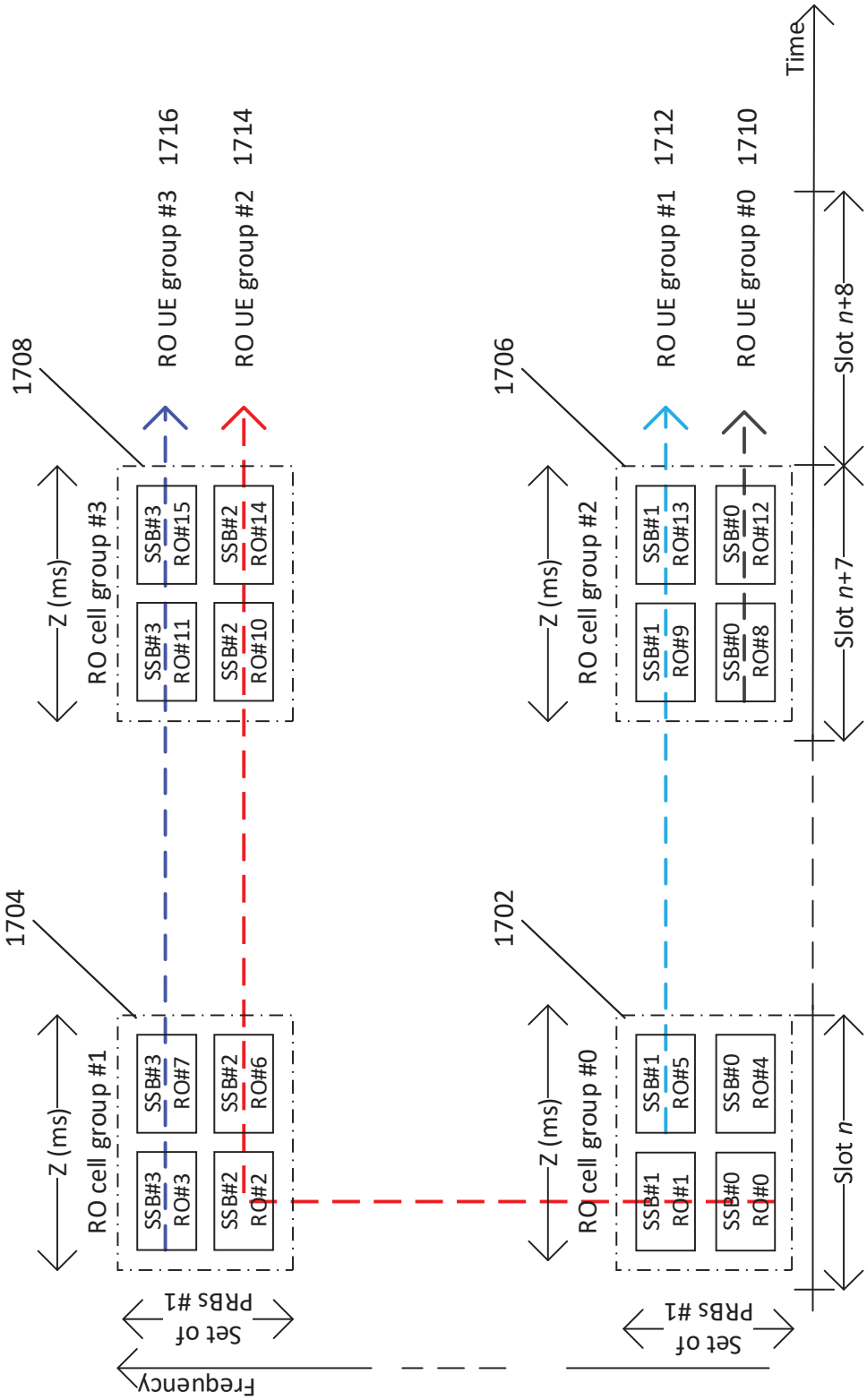

1700
Frequency
Time
Set of PRBs #1
Set of PRBs #1
Slot n
Slot n+7
Slot n+8
1702
1704
1706
1708
RO cell group #0
RO cell group #1
RO cell group #2
RO cell group #3
Z (ms)
Z (ms)
Z (ms)
Z (ms)
SSB#0 RO#0
SSB#1 RO#1
SSB#0 RO#4
SSB#1 RO#5
SSB#2 RO#2
SSB#3 RO#3
SSB#2 RO#6
SSB#3 RO#7
SSB#0 RO#8
SSB#1 RO#9
SSB#0 RO#12
SSB#1 RO#13
SSB#2 RO#10
SSB#3 RO#11
SSB#2 RO#14
SSB#3 RO#15
RO UE group #0
RO UE group #1
RO UE group #2
RO UE group #3
1710
1712
1714
1716

Fig. 17

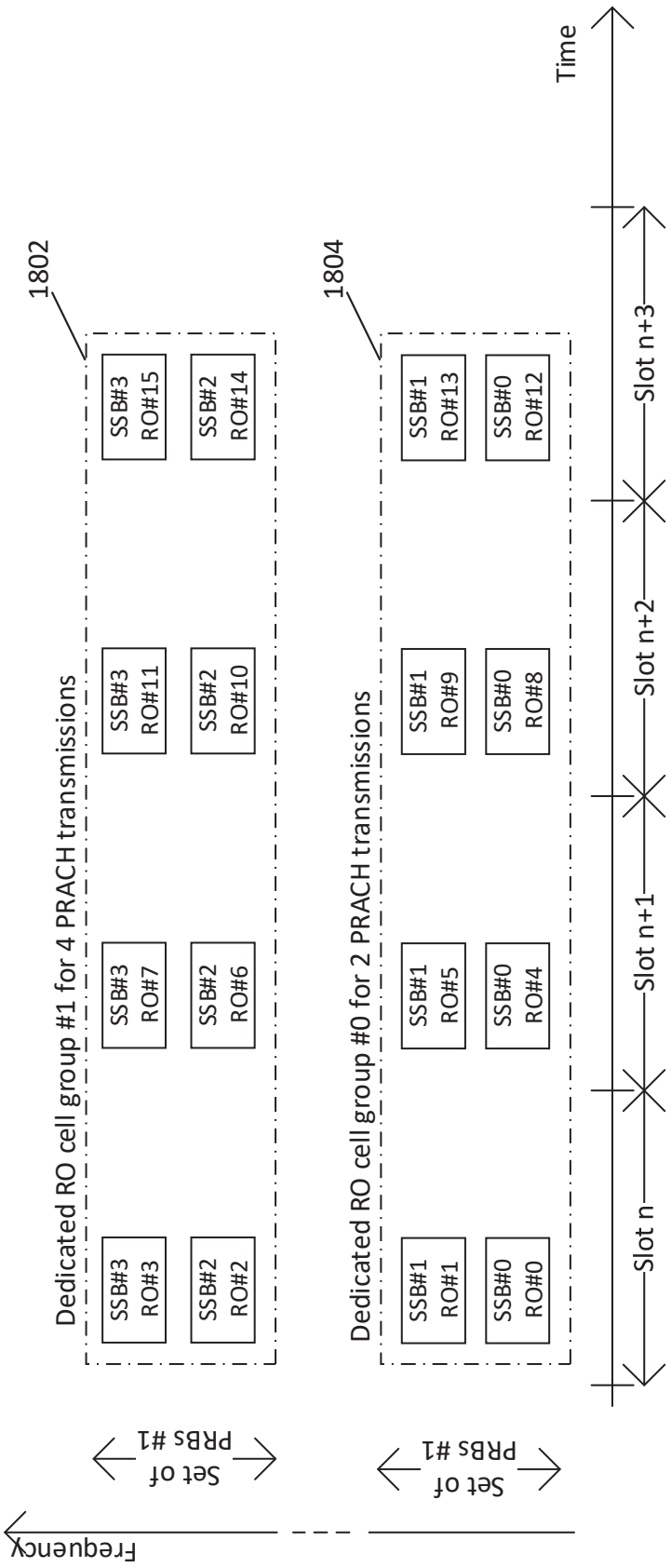

Time
Slot n
Slot n+1
Slot n+2
Slot n+3
Frequency
Set of PRBs #1
Set of PRBs #1
1800
1802
1804
Dedicated RO cell group #1 for 4 PRACH transmissions
Dedicated RO cell group #0 for 2 PRACH transmissions
SSB#3 RO#3
SSB#2 RO#2
SSB#3 RO#7
SSB#2 RO#6
SSB#3 RO#11
SSB#2 RO#10
SSB#3 RO#15
SSB#2 RO#14
SSB#1 RO#1
SSB#0 RO#0
SSB#1 RO#5
SSB#0 RO#4
SSB#1 RO#9
SSB#0 RO#8
SSB#1 RO#13
SSB#0 RO#12

Fig. 18

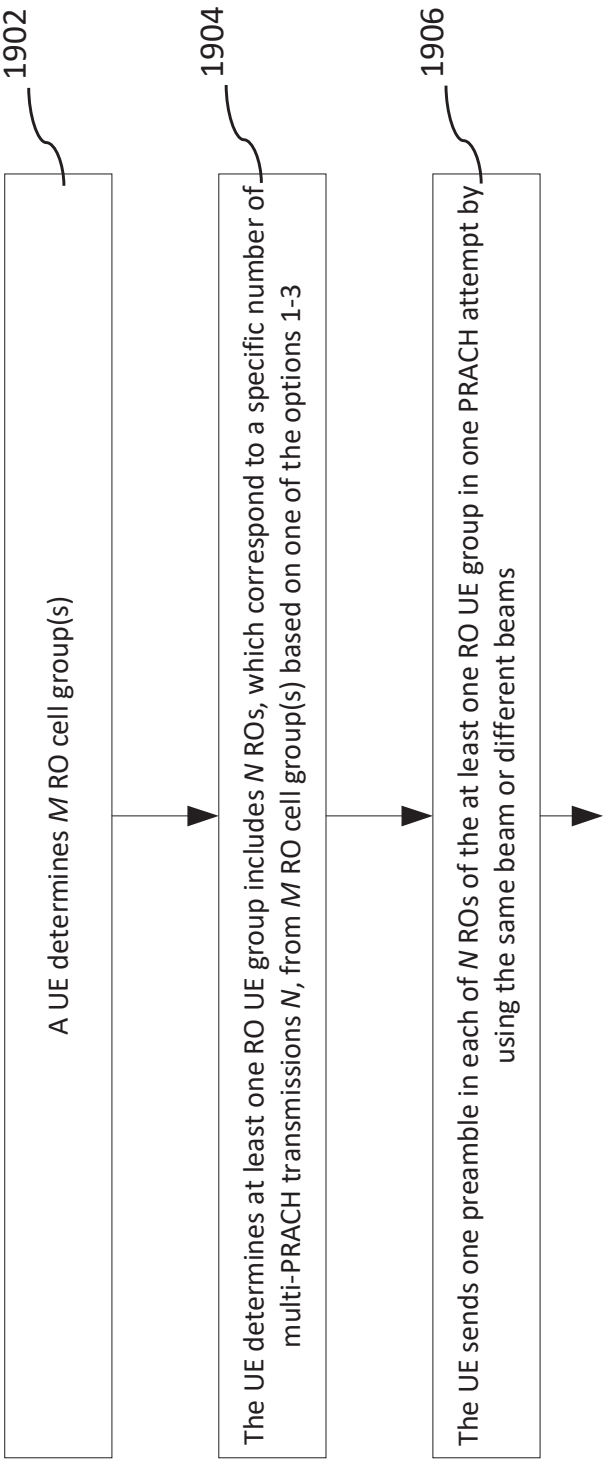

1902
A UE determines *M* RO cell group(s)
1904
The UE determines at least one RO UE group includes *N* ROs, which correspond to a specific number of multi-PRACH transmissions *N*, from *M* RO cell group(s) based on one of the options 1-3
1906
The UE sends one preamble in each of *N* ROs of the at least one RO UE group in one PRACH attempt by using the same beam or different beams
1900

Fig. 19

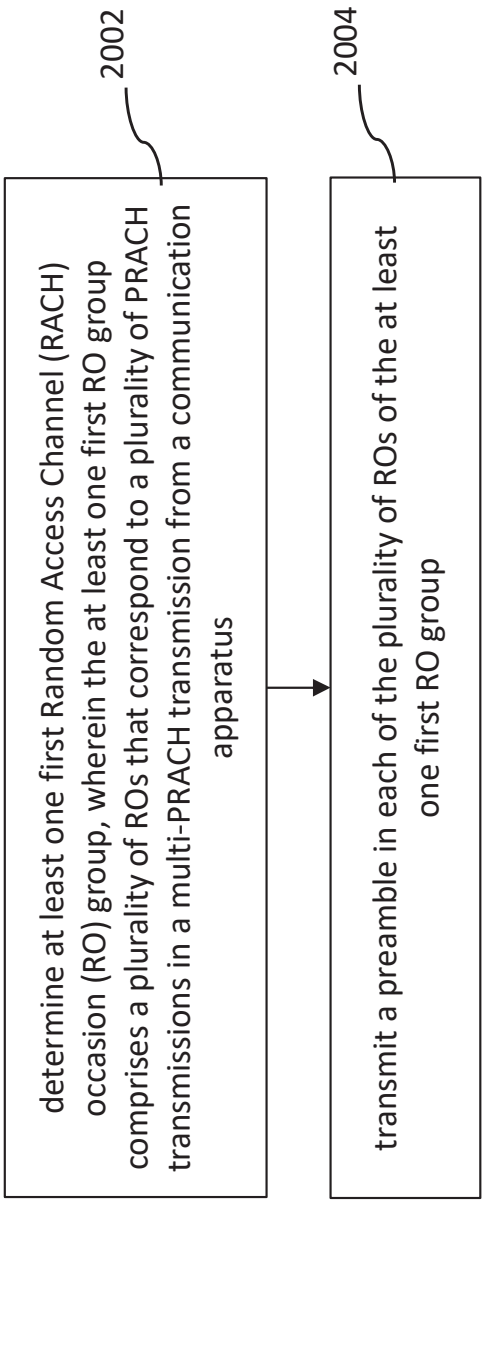

2002
2004
determine at least one first Random Access Channel (RACH) occasion (RO) group, wherein the at least one first RO group comprises a plurality of ROs that correspond to a plurality of PRACH transmissions in a multi-PRACH transmission from a communication apparatus
transmit a preamble in each of the plurality of ROs of the at least one first RO group
2000

Fig. 20

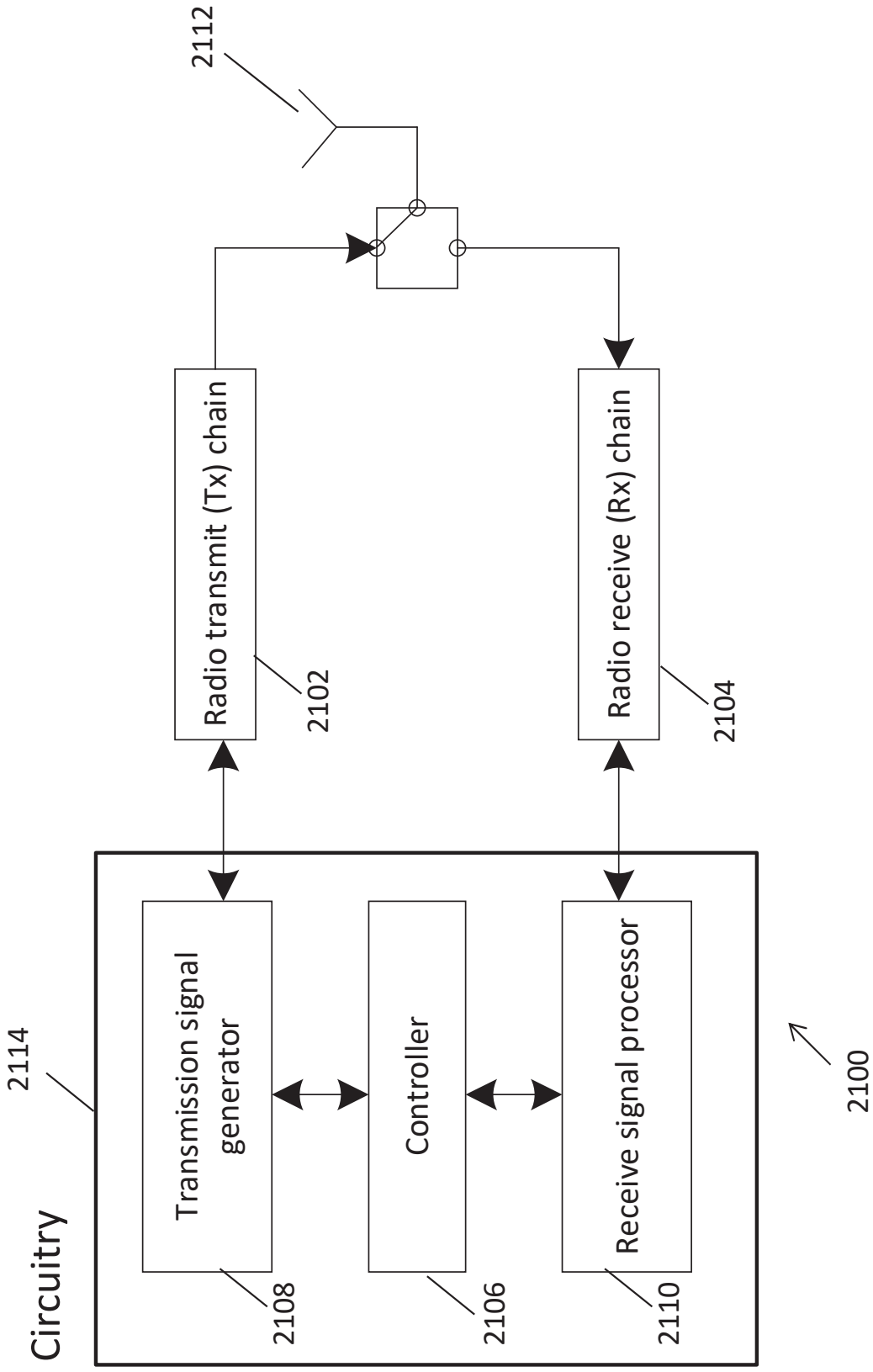

2112
Radio transmit (Tx) chain
2102
Radio receive (Rx) chain
2104
2114
Circuitry
Transmission signal generator
2108
Controller
2106
Receive signal processor
2110
2100

Fig. 21

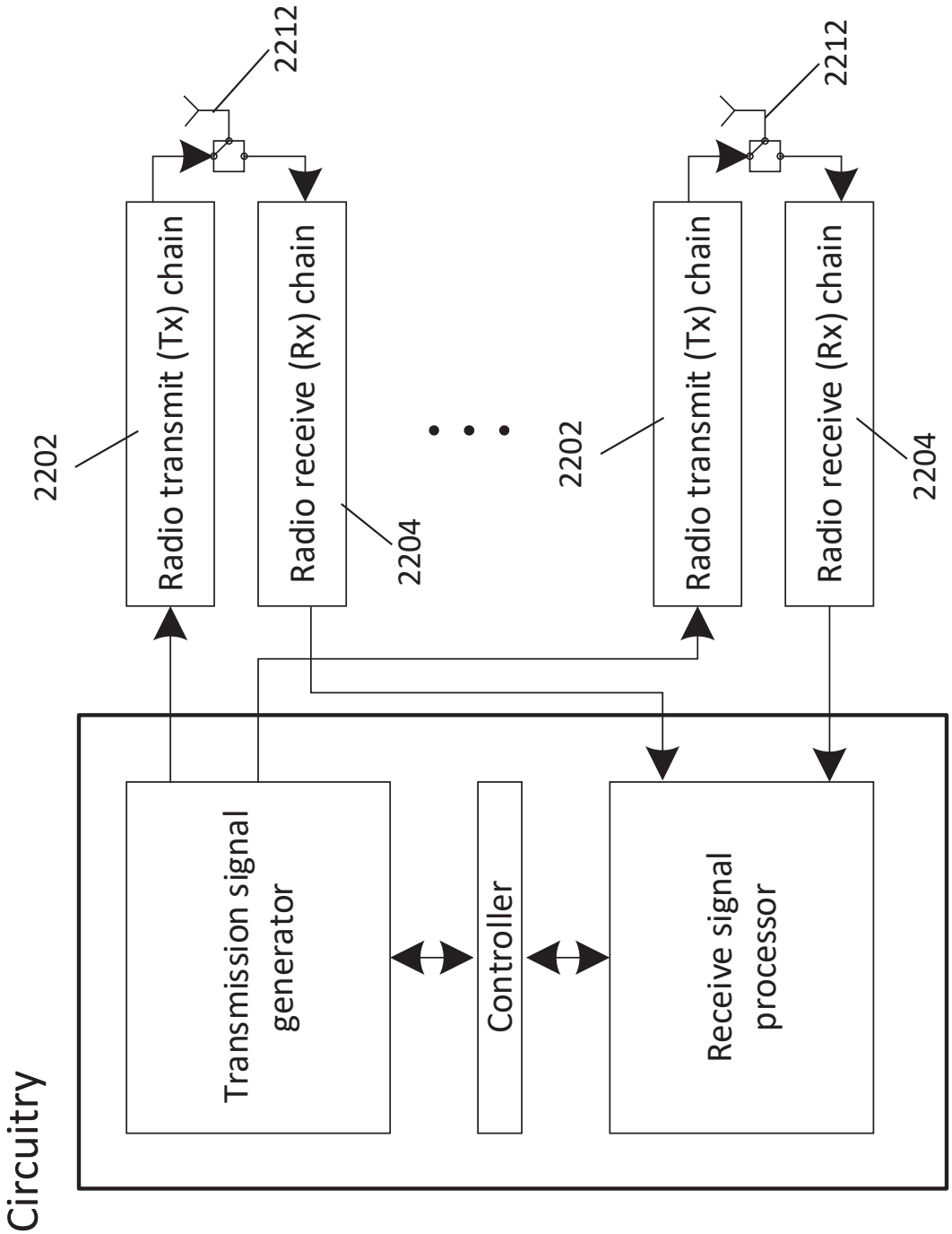

Circuitry
Transmission signal generator
Controller
Receive signal processor
2200
Radio transmit (Tx) chain
Radio receive (Rx) chain
2202
2204
2212
Radio transmit (Tx) chain
Radio receive (Rx) chain
2202
2204
2212

Fig. 22