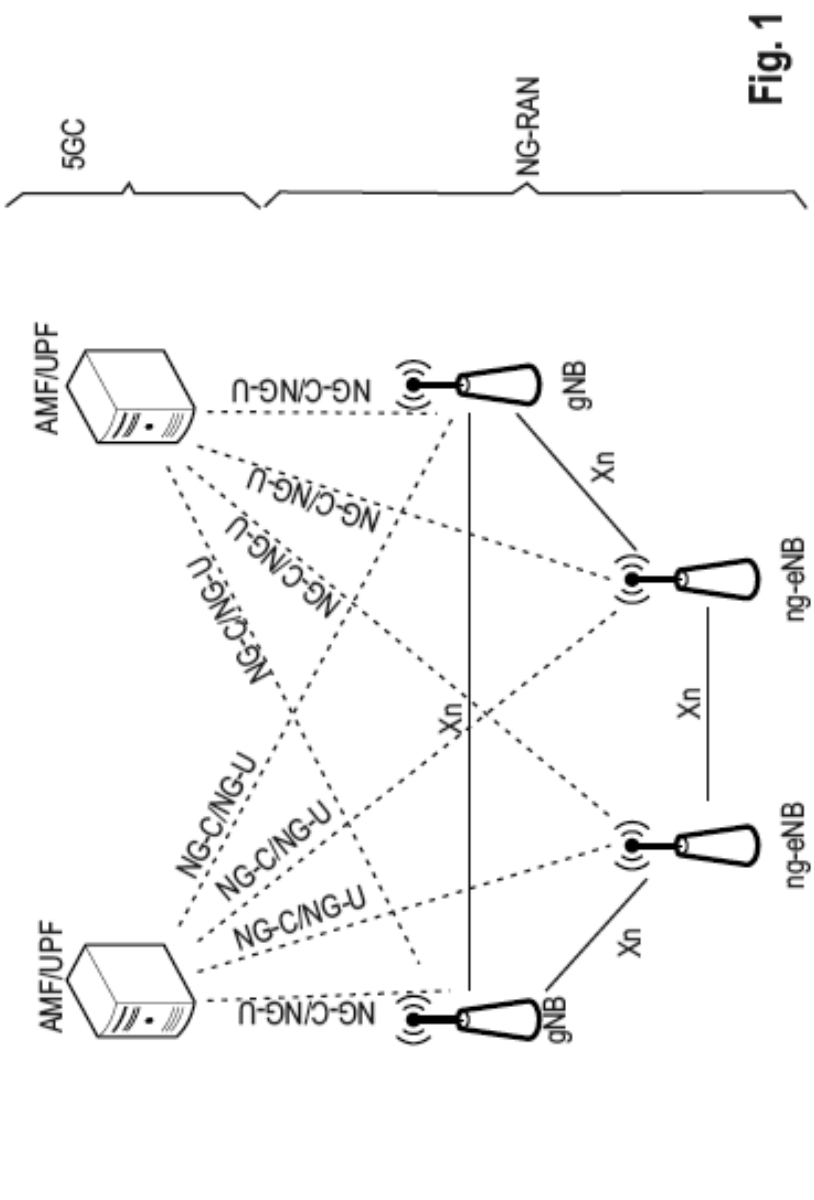

5GC
NG-RAN
AMF/UPF
AMF/UPF
NG-C/NG-U
NG-C/NG-U
NG-C/NG-U
NG-C/NG-U
NG-C/NG-U
NG-C/NG-U
NG-C/NG-U
NG-C/NG-U
gNB
gNB
ng-eNB
ng-eNB
Xn
Xn
Xn
Xn
100

Fig. 1

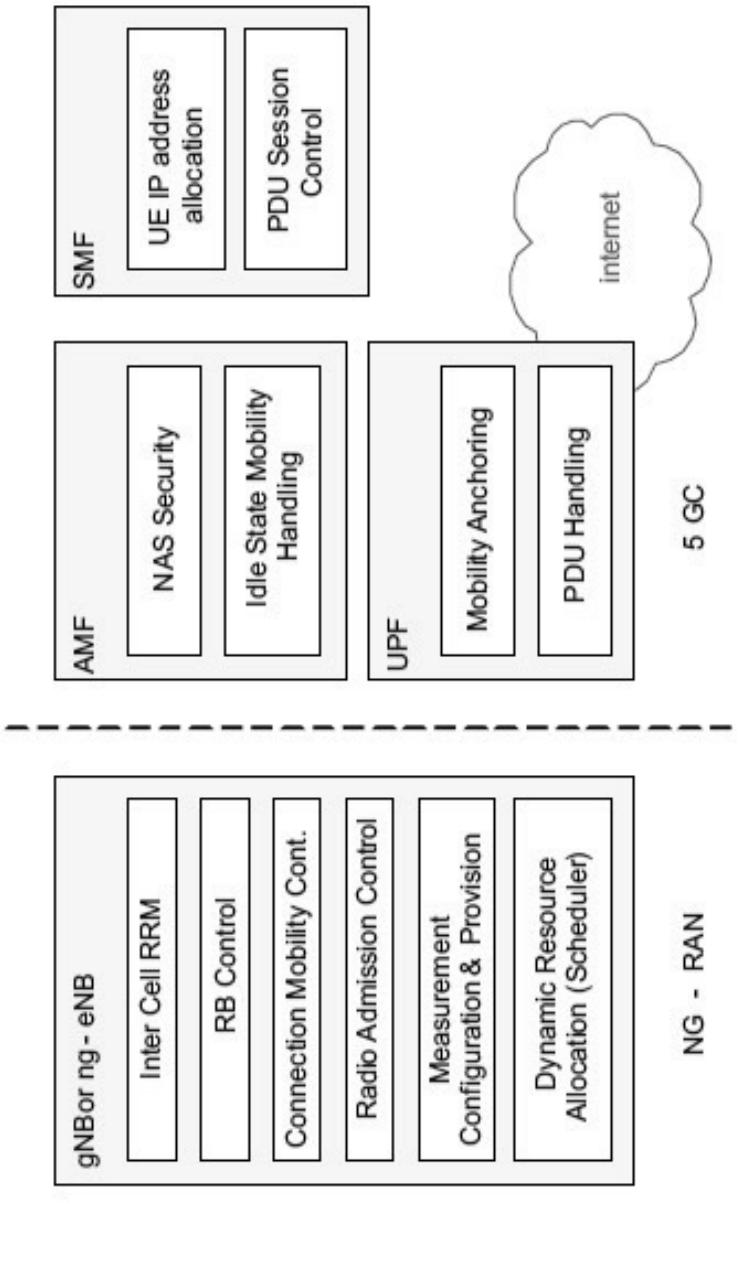

gNBor ng - eNB
Inter Cell RRM
RB Control
Connection Mobility Cont.
Radio Admission Control
Measurement Configuration & Provision
Dynamic Resource Allocation (Scheduler)
NG - RAN
AMF
NAS Security
Idle State Mobility Handling
UPF
Mobility Anchoring
PDU Handling
SMF
UE IP address allocation
PDU Session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

Fig. 2

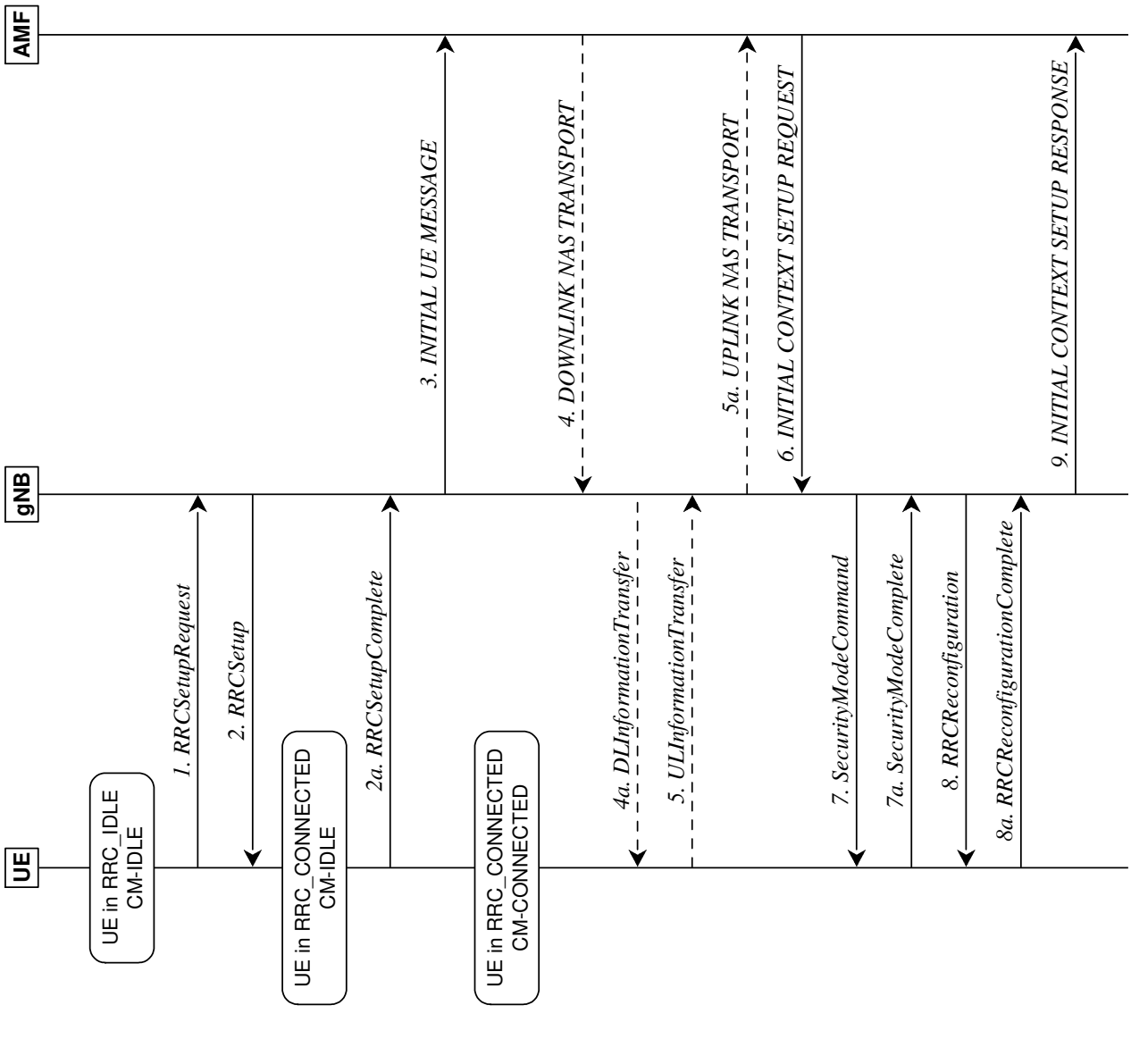

UE
gNB
AMF
UE in RRC_IDLE CM-IDLE
1. RRCSetupRequest
2. RRCSetup
UE in RRC_CONNECTED CM-IDLE
2a. RRCSetupComplete
UE in RRC_CONNECTED CM-CONNECTED
3. INITIAL UE MESSAGE
4. DOWNLINK NAS TRANSPORT
4a. DLInformationTransfer
5. ULInformationTransfer
5a. UPLINK NAS TRANSPORT
6. INITIAL CONTEXT SETUP REQUEST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

Fig. 3

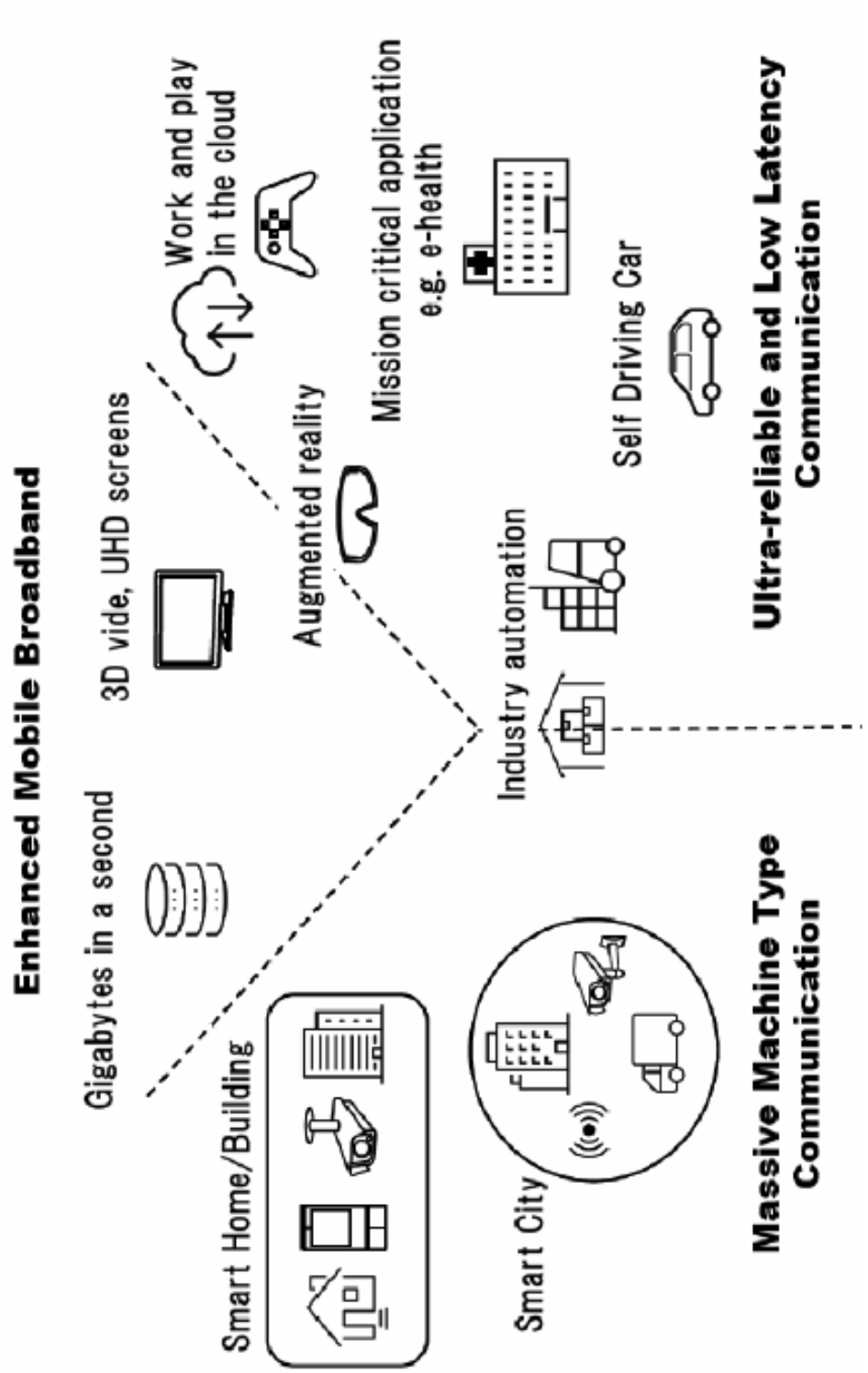

Enhanced Mobile Broadband
Gigabytes in a second
3D vide, UHD screens
Work and play in the cloud
Augmented reality
Mission critical application e.g. e-health
Smart Home/Building
Industry automation
Self Driving Car
Ultra-reliable and Low Latency Communication
Smart City
Massive Machine Type Communication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

Fig. 4

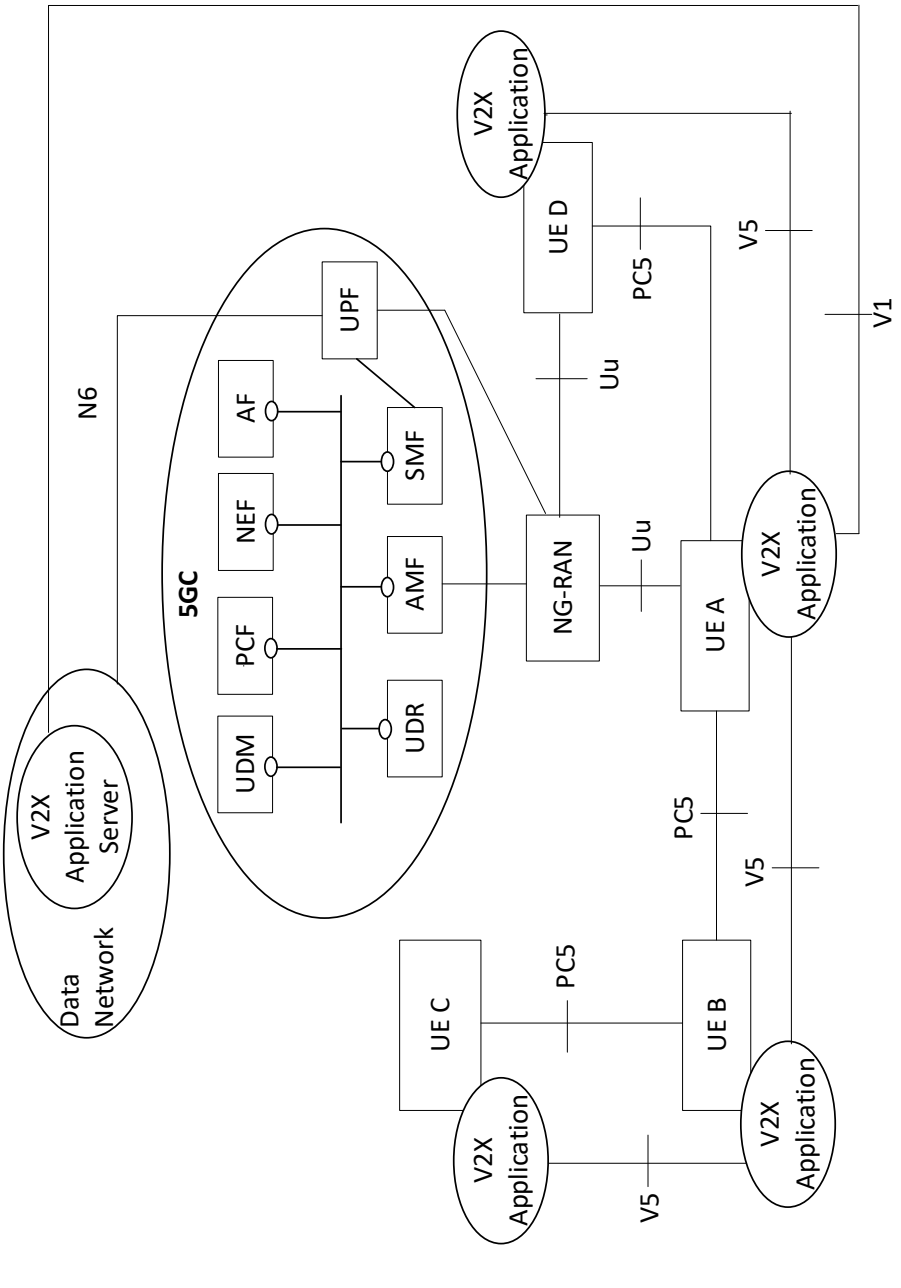

Data Network
V2X Application Server
N6
5GC
UPF
AF
NEF
PCF
UDM
SMF
AMF
UDR
NG-RAN
Uu
Uu
UE D
UE A
UE B
UE C
V2X Application
V2X Application
V2X Application
V2X Application
PC5
PC5
PC5
V5
V5
V5
V1
500

Fig. 5

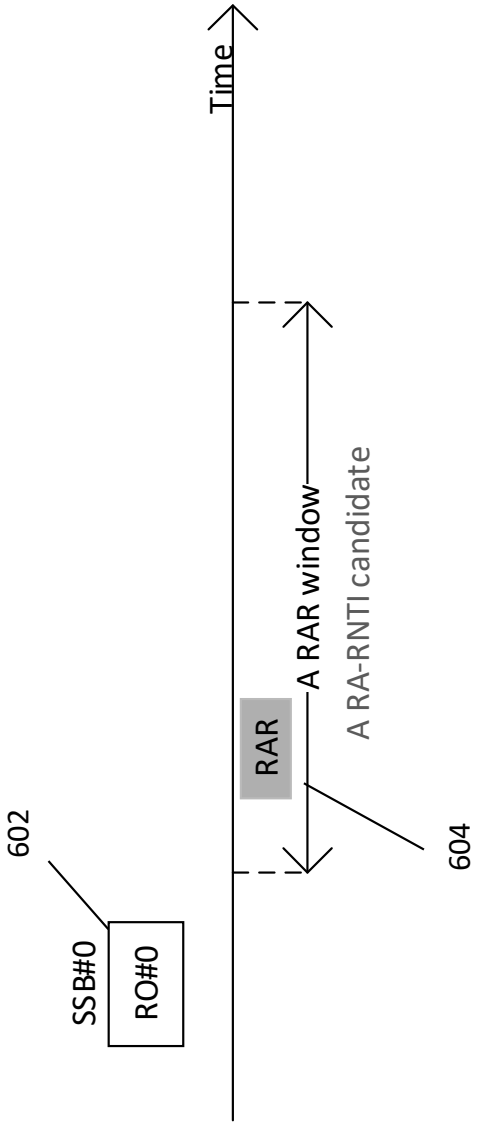


Fig. 6

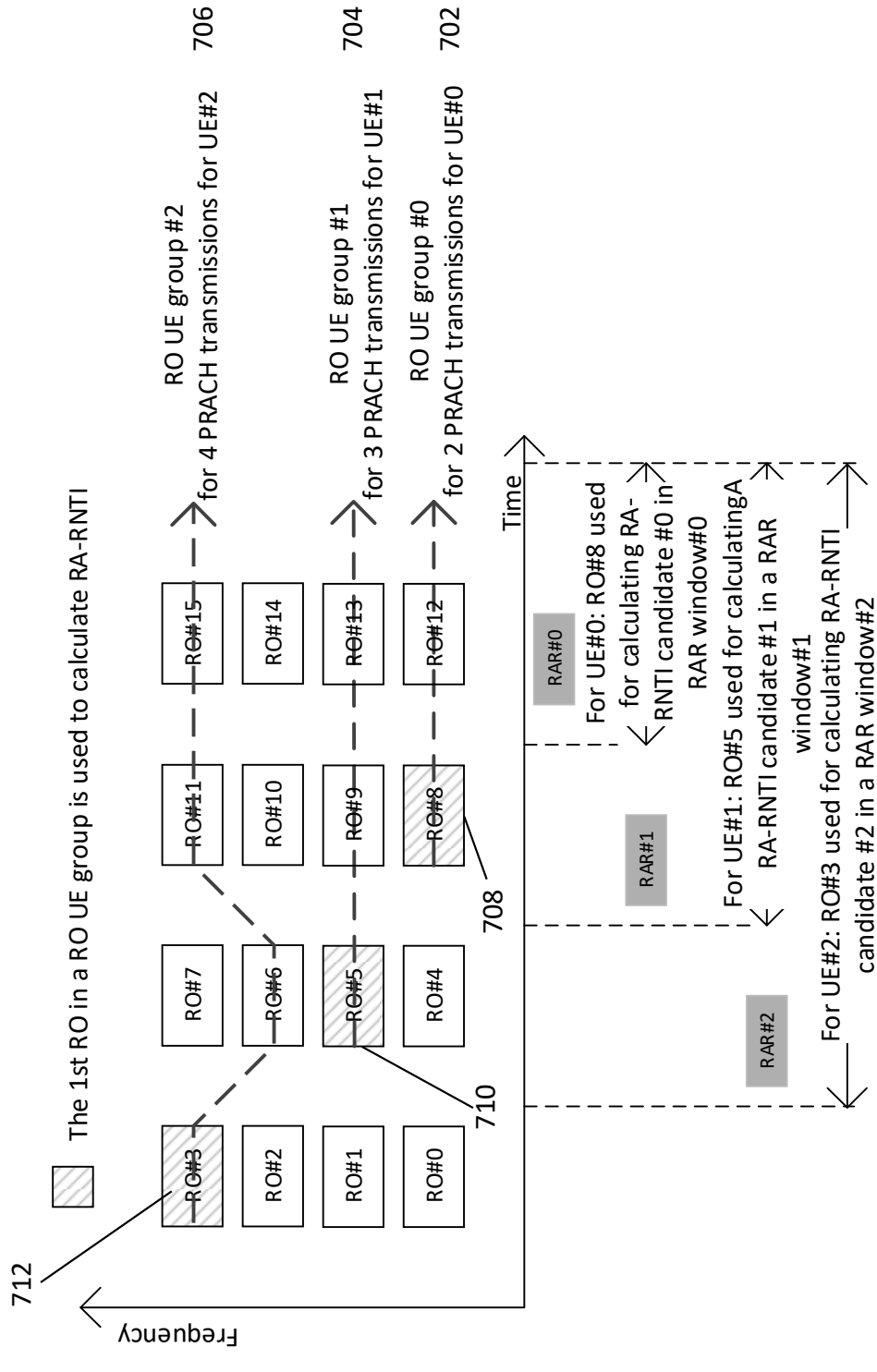

The 1st RO in a RO UE group is used to calculate RA-RNTI
RO UE group #2
for 4 PRACH transmissions for UE#2
706
RO UE group #1
for 3 PRACH transmissions for UE#1
704
RO UE group #0
for 2 PRACH transmissions for UE#0
702
RO#15
RO#14
RO#13
RO#12
RO#11
RO#10
RO#9
RO#8
RO#7
RO#6
RO#5
RO#4
RO#3
RO#2
RO#1
RO#0
708
710
712
Frequency
Time
RAR#0
RAR#1
RAR#2
For UE#0: RO#8 used for calculating RA-RNTI candidate #0 in RAR window#0
For UE#1: RO#5 used for calculatingA RA-RNTI candidate #1 in a RAR window#1
For UE#2: RO#3 used for calculating RA-RNTI candidate #2 in a RAR window#2

Fig. 7

700

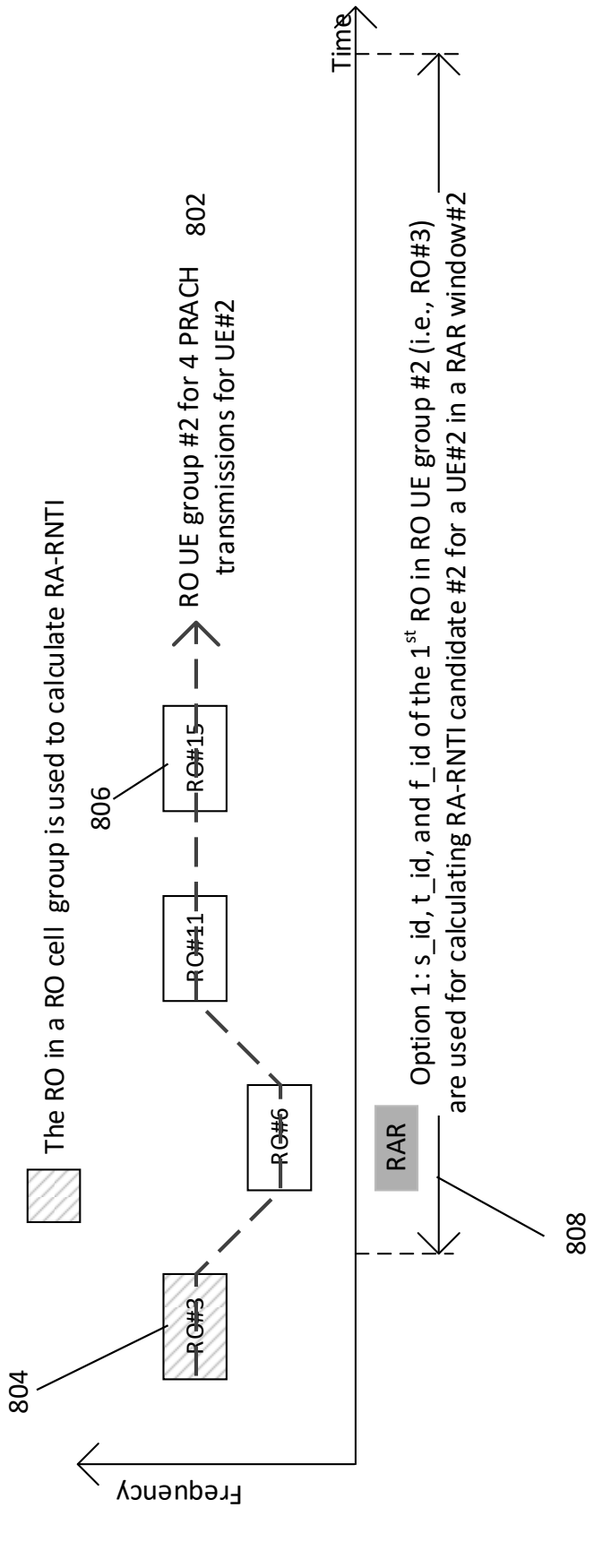

Time
Frequency
The RO in a RO cell group is used to calculate RA-RNTI
RO#3
RO#6
RO#11
RO#15
804
806
RO UE group #2 for 4 PRACH transmissions for UE#2
802
RAR
Option 1: s_id, t_id, and f_id of the 1st RO in RO UE group #2 (i.e., RO#3) are used for calculating RA-RNTI candidate #2 for a UE#2 in a RAR window#2
808
800

Fig. 8

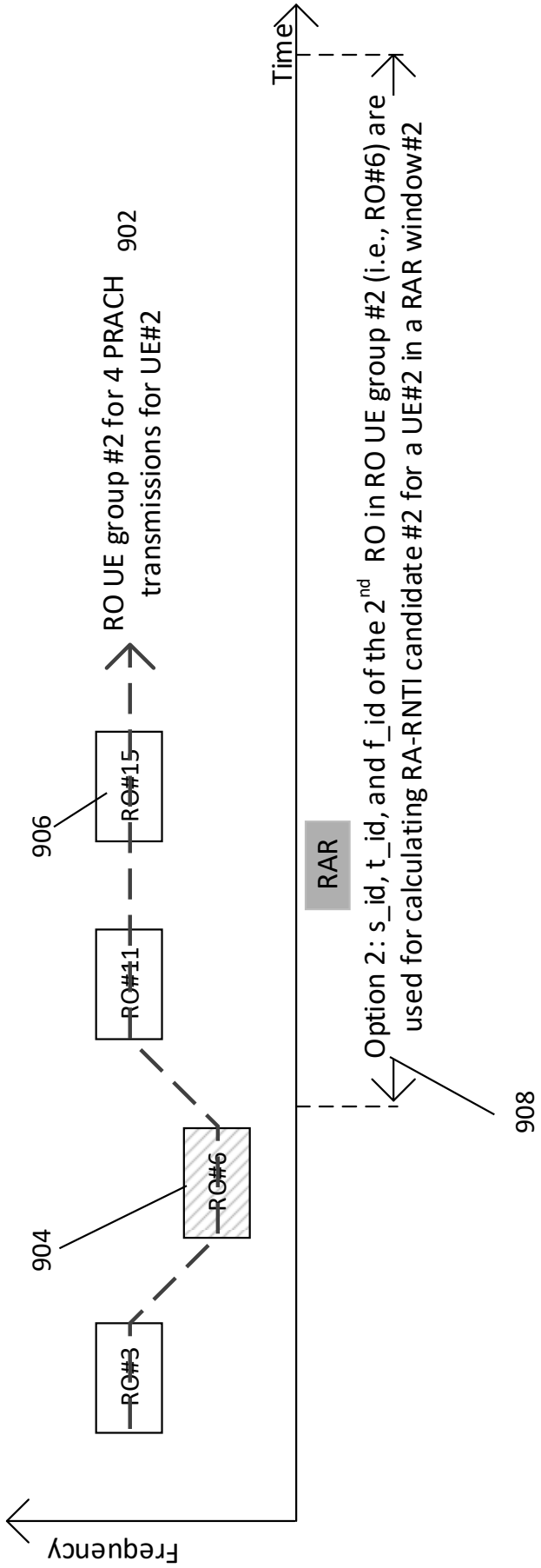

Time
Frequency
RO#3
RO#6
RO#11
RO#15
904
906
RAR
RO UE group #2 for 4 PRACH transmissions for UE#2
902
Option 2: s_id, t_id, and f_id of the 2nd RO in RO UE group #2 (i.e., RO#6) are used for calculating RA-RNTI candidate #2 for a UE#2 in a RAR window#2
908

Fig. 9

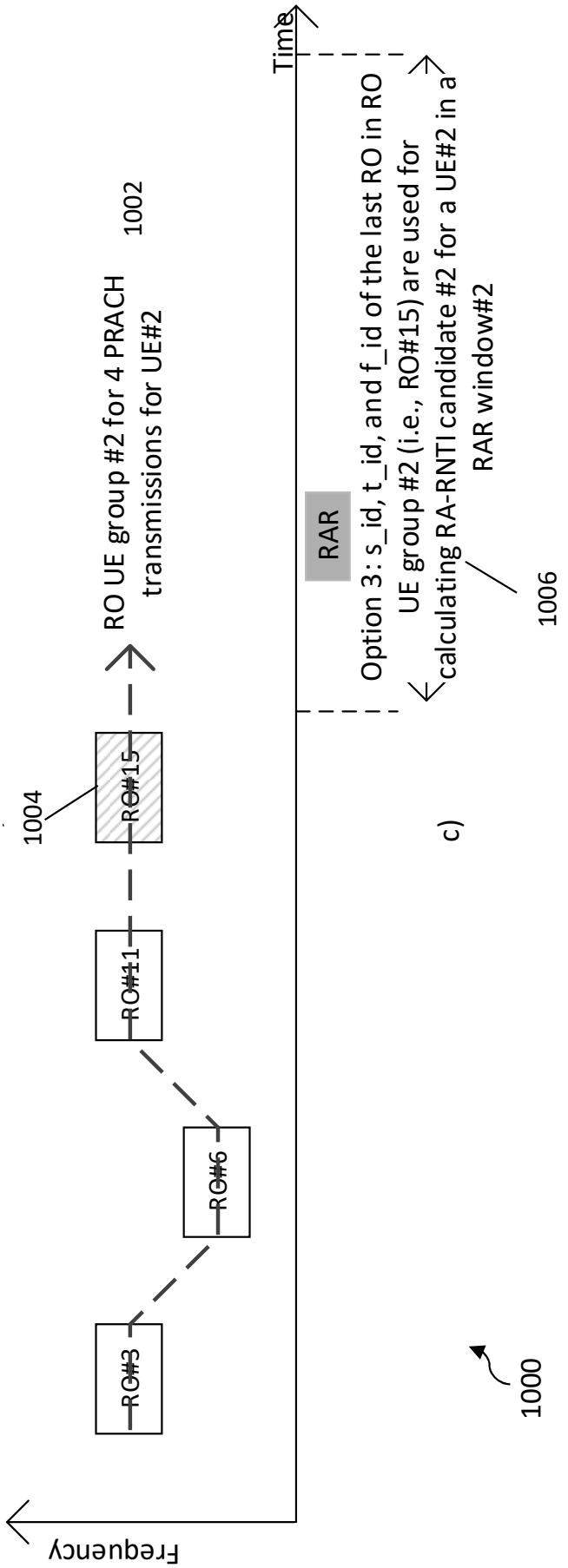

Frequency
Time
RO#3
RO#6
RO#11
RO#15
1004
RO UE group #2 for 4 PRACH transmissions for UE#2
1002
RAR
Option 3: s_id, t_id, and f_id of the last RO in RO UE group #2 (i.e., RO#15) are used for calculating RA-RNTI candidate #2 for a UE#2 in a RAR window#2
1006
c)
1000

Fig. 10

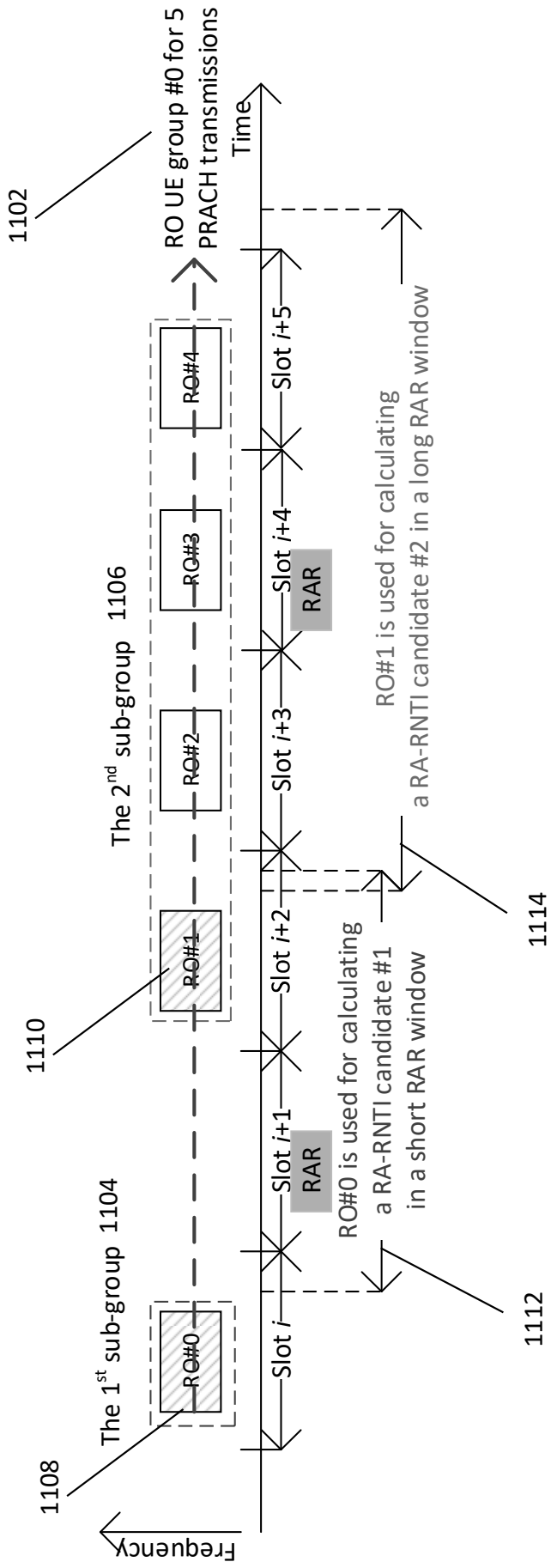

1102
RO UE group #0 for 5 PRACH transmissions
Time
Frequency
The 1st sub-group 1104
The 2nd sub-group 1106
1108
1110
1112
1114
RO#0
RO#1
RO#2
RO#3
RO#4
Slot i
Slot i+1
Slot i+2
Slot i+3
Slot i+4
Slot i+5
RAR
RAR
RO#0 is used for calculating a RA-RNTI candidate #1 in a short RAR window
RO#1 is used for calculating a RA-RNTI candidate #2 in a long RAR window
1100

Fig. 11

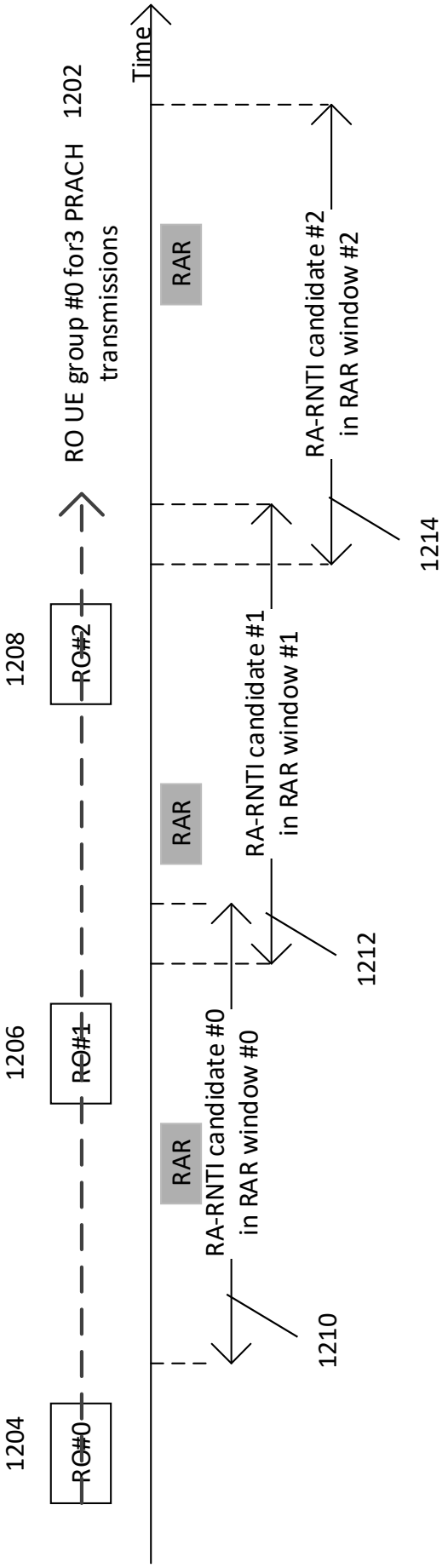

Time
RO UE group #0 for3 PRACH transmissions
1202
RO#0
1204
RO#1
1206
RO#2
1208
RAR
RA-RNTI candidate #0 in RAR window #0
1210
RAR
RA-RNTI candidate #1 in RAR window #1
1212
RAR
RA-RNTI candidate #2 in RAR window #2
1214
1200

Fig. 12

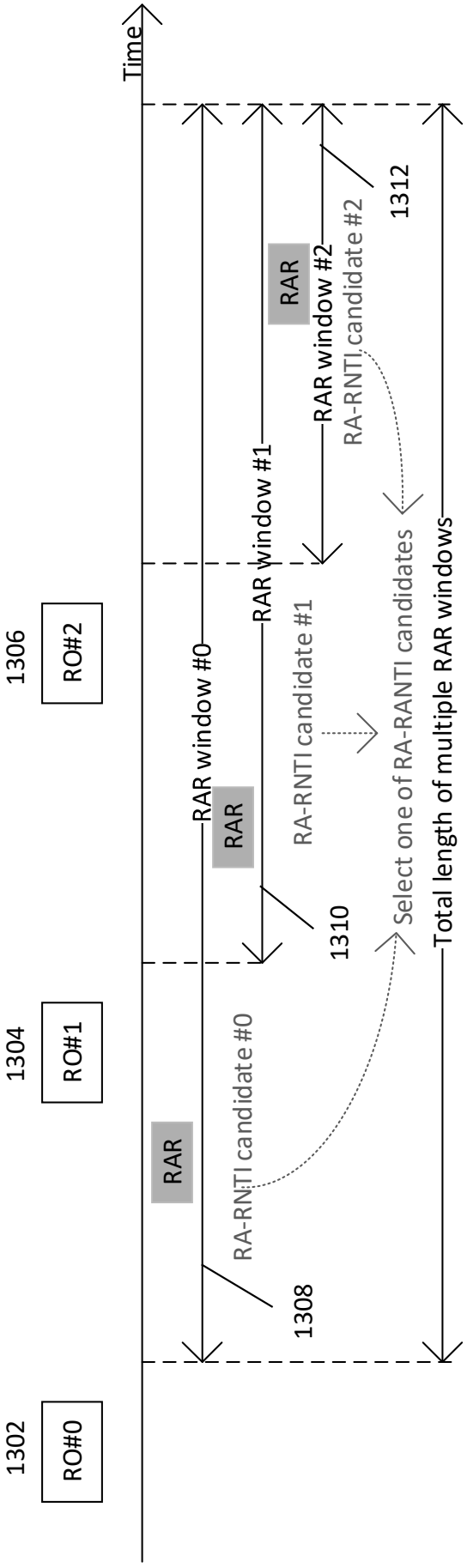

Time
RO#0
RO#1
RO#2
1302
1304
1306
RAR window #0
RAR window #1
RAR window #2
RAR
RAR
RAR
RA-RNTI candidate #0
RA-RNTI candidate #1
RA-RNTI candidate #2
Select one of RA-RANTI candidates
Total length of multiple RAR windows
1308
1310
1312
1300

Fig. 13

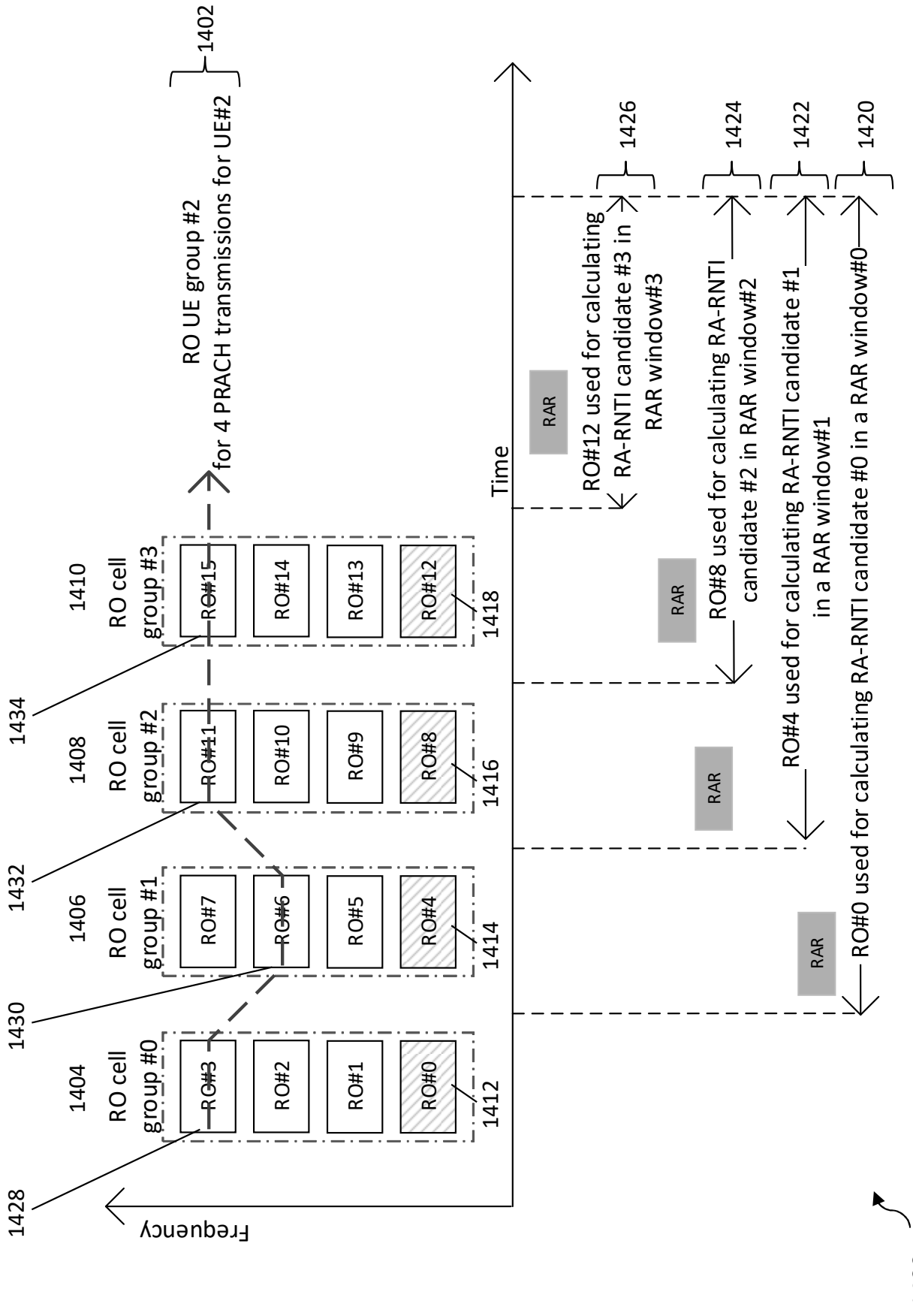

1402
RO UE group #2
for 4 PRACH transmissions for UE#2
1410
RO cell group #3
RO#15
RO#14
RO#13
RO#12
1418
1408
RO cell group #2
RO#11
RO#10
RO#9
RO#8
1416
1406
RO cell group #1
RO#7
RO#6
RO#5
RO#4
1414
1404
RO cell group #0
RO#3
RO#2
RO#1
RO#0
1412
1434
1432
1430
1428
Frequency
Time
RAR
RAR
RAR
RAR
1426
1424
1422
1420
RO#12 used for calculating RA-RNTI candidate #3 in RAR window#3
RO#8 used for calculating RA-RNTI candidate #2 in RAR window#2
RO#4 used for calculating RA-RNTI candidate #1 in a RAR window#1
RO#0 used for calculating RA-RNTI candidate #0 in a RAR window#0
1400

Fig. 14

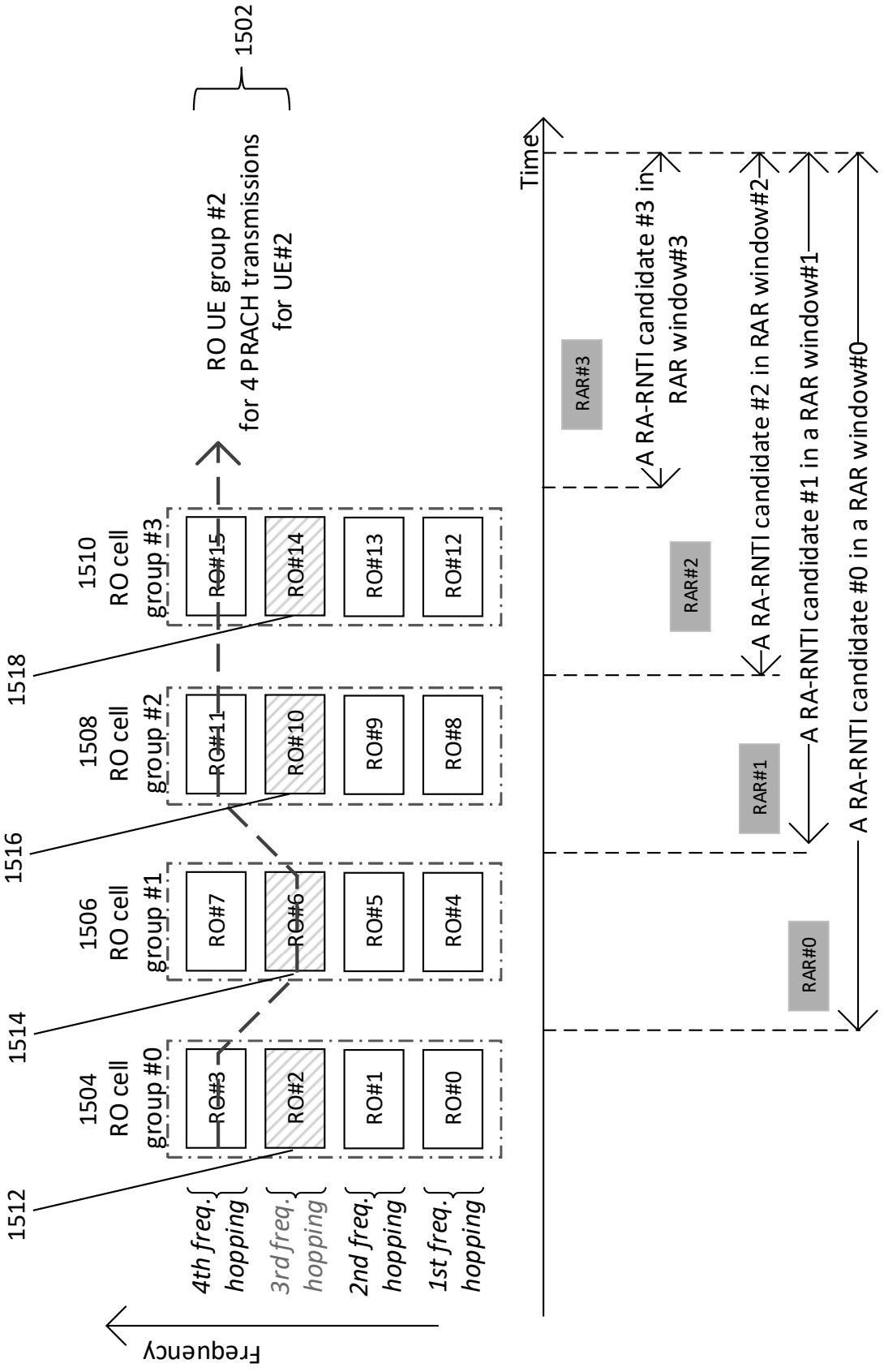

1502
RO UE group #2
for 4 PRACH transmissions
for UE#2
1510
RO cell
group #3
RO#15
RO#14
RO#13
RO#12
1508
RO cell
group #2
RO#11
RO#10
RO#9
RO#8
1506
RO cell
group #1
RO#7
RO#6
RO#5
RO#4
1504
RO cell
group #0
RO#3
RO#2
RO#1
RO#0
1518
1516
1514
1512
4th freq. hopping
3rd freq. hopping
2nd freq. hopping
1st freq. hopping
Frequency
Time
RAR#3
RAR#2
RAR#1
RAR#0
A RA-RNTI candidate #3 in RAR window#3
A RA-RNTI candidate #2 in RAR window#2
A RA-RNTI candidate #1 in a RAR window#1
A RA-RNTI candidate #0 in a RAR window#0
1500

Fig. 15

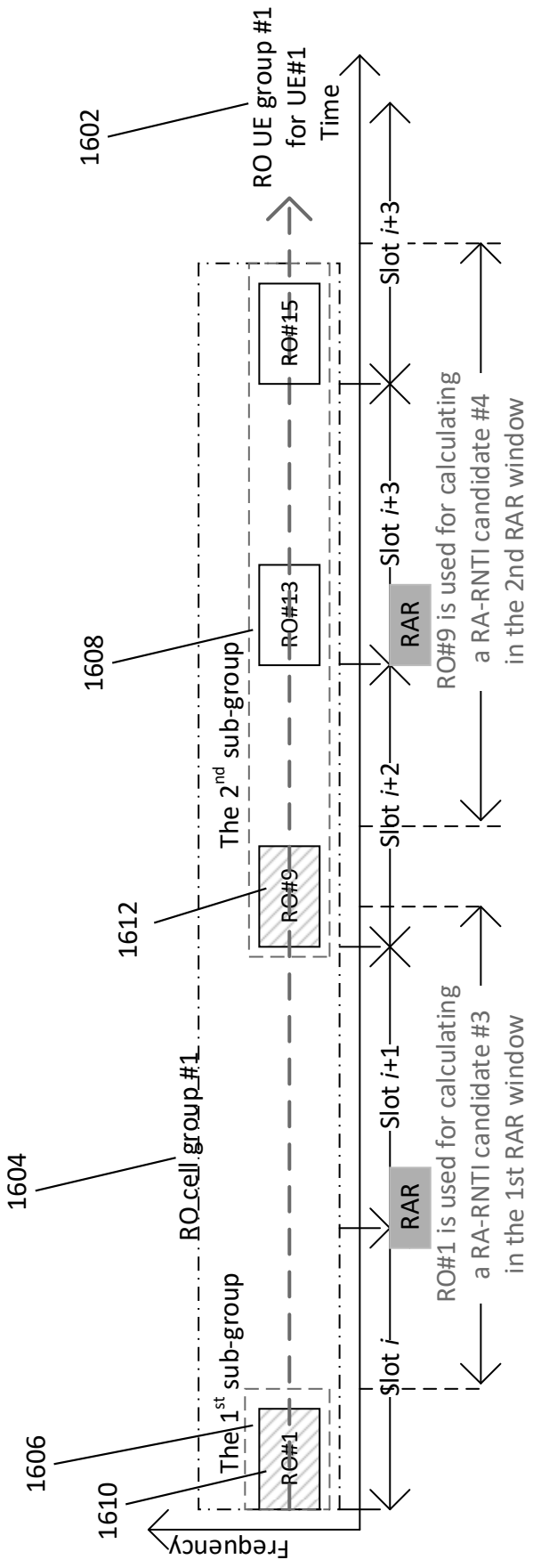

1602
RO UE group #1 for UE#1
Time
1608
The 2nd sub-group
RO#15
RO#13
RO#9
1612
1604
RO cell group #1
1606
The 1st sub-group
RO#1
1610
Frequency
Slot i
Slot i+1
Slot i+2
Slot i+3
Slot i+3
RAR
RAR
RO#1 is used for calculating a RA-RNTI candidate #3 in the 1st RAR window
RO#9 is used for calculating a RA-RNTI candidate #4 in the 2nd RAR window
1600

Fig. 16

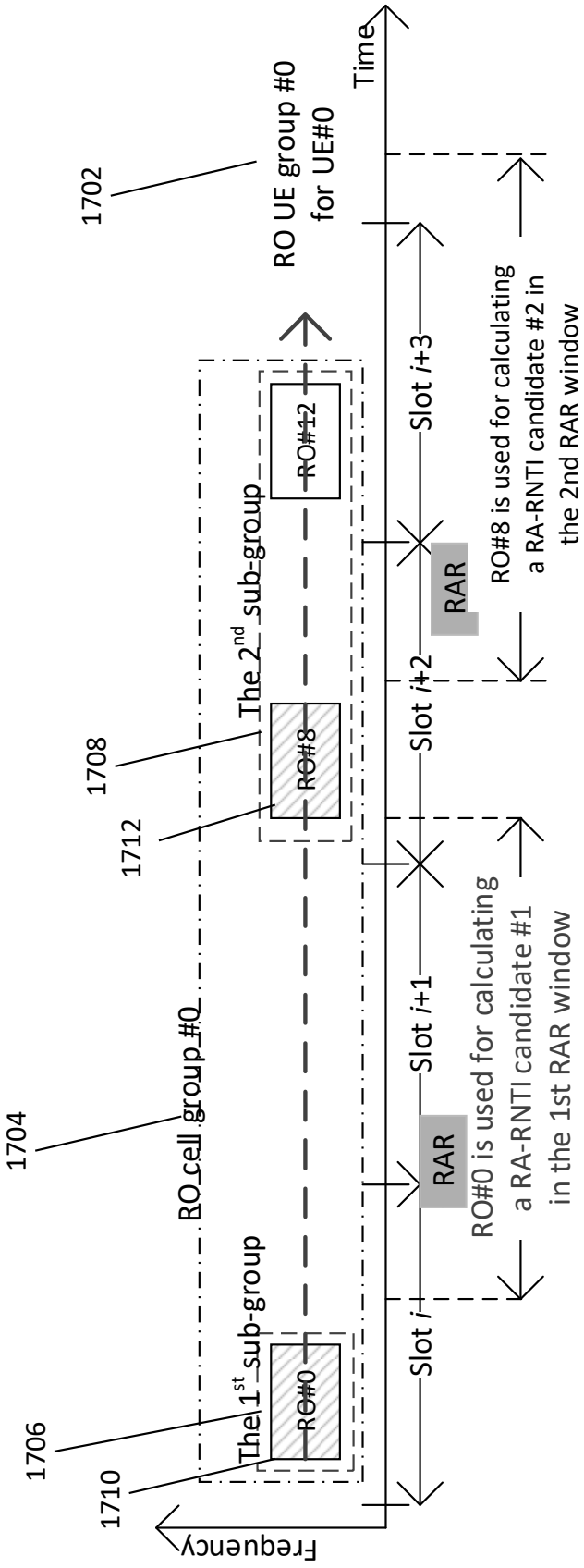

1702
RO UE group #0
for UE#0
Time
1704
RO cell group #0
1708
The 2nd sub-group
RO#12
RO#8
1712
Slot i+3
Slot i+2
Slot i+1
Slot i
RAR
RAR
RO#8 is used for calculating
a RA-RNTI candidate #2 in
the 2nd RAR window
RO#0 is used for calculating
a RA-RNTI candidate #1
in the 1st RAR window
1706
The 1st sub-group
RO#0
1710
Frequency
1700

Fig. 17

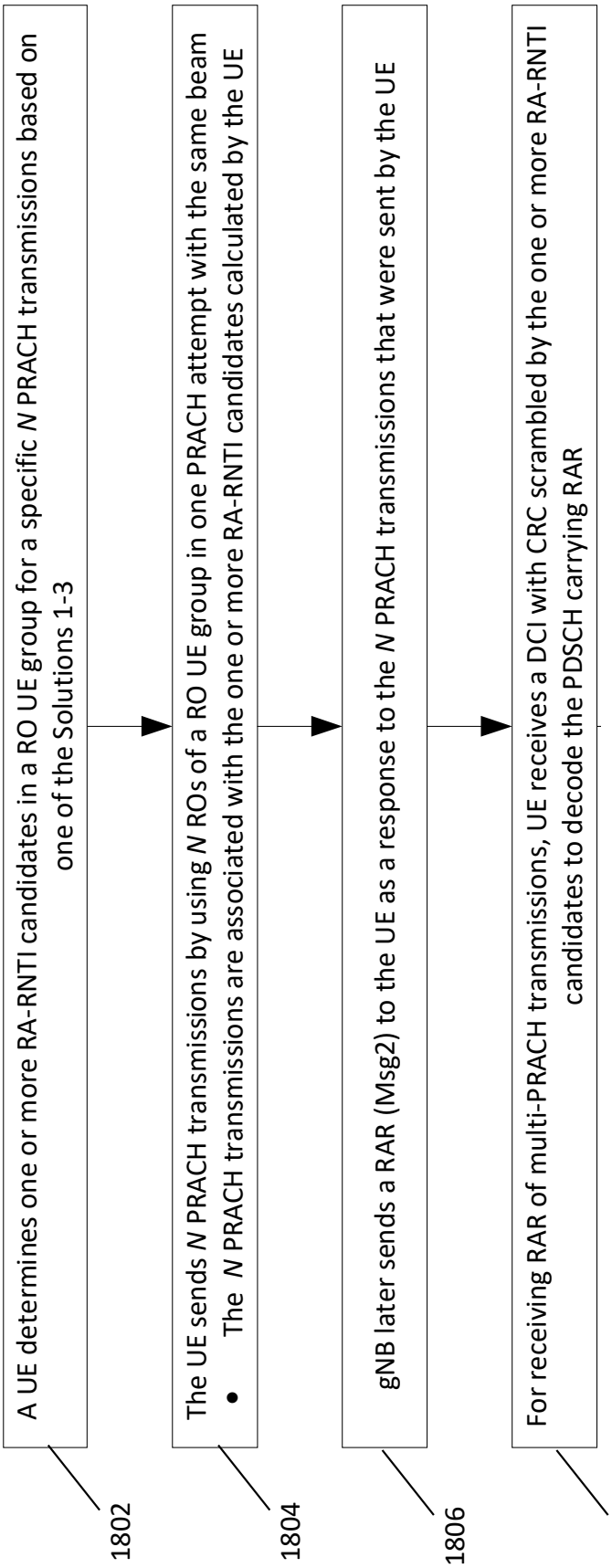

A UE determines one or more RA-RNTI candidates in a RO UE group for a specific N PRACH transmissions based on one of the Solutions 1-3
1802
The UE sends N PRACH transmissions by using N ROs of a RO UE group in one PRACH attempt with the same beam
• The N PRACH transmissions are associated with the one or more RA-RNTI candidates calculated by the UE
1804
gNB later sends a RAR (Msg2) to the UE as a response to the N PRACH transmissions that were sent by the UE
1806
For receiving RAR of multi-PRACH transmissions, UE receives a DCI with CRC scrambled by the one or more RA-RNTI candidates to decode the PDSCH carrying RAR
1808
1800

Fig. 18

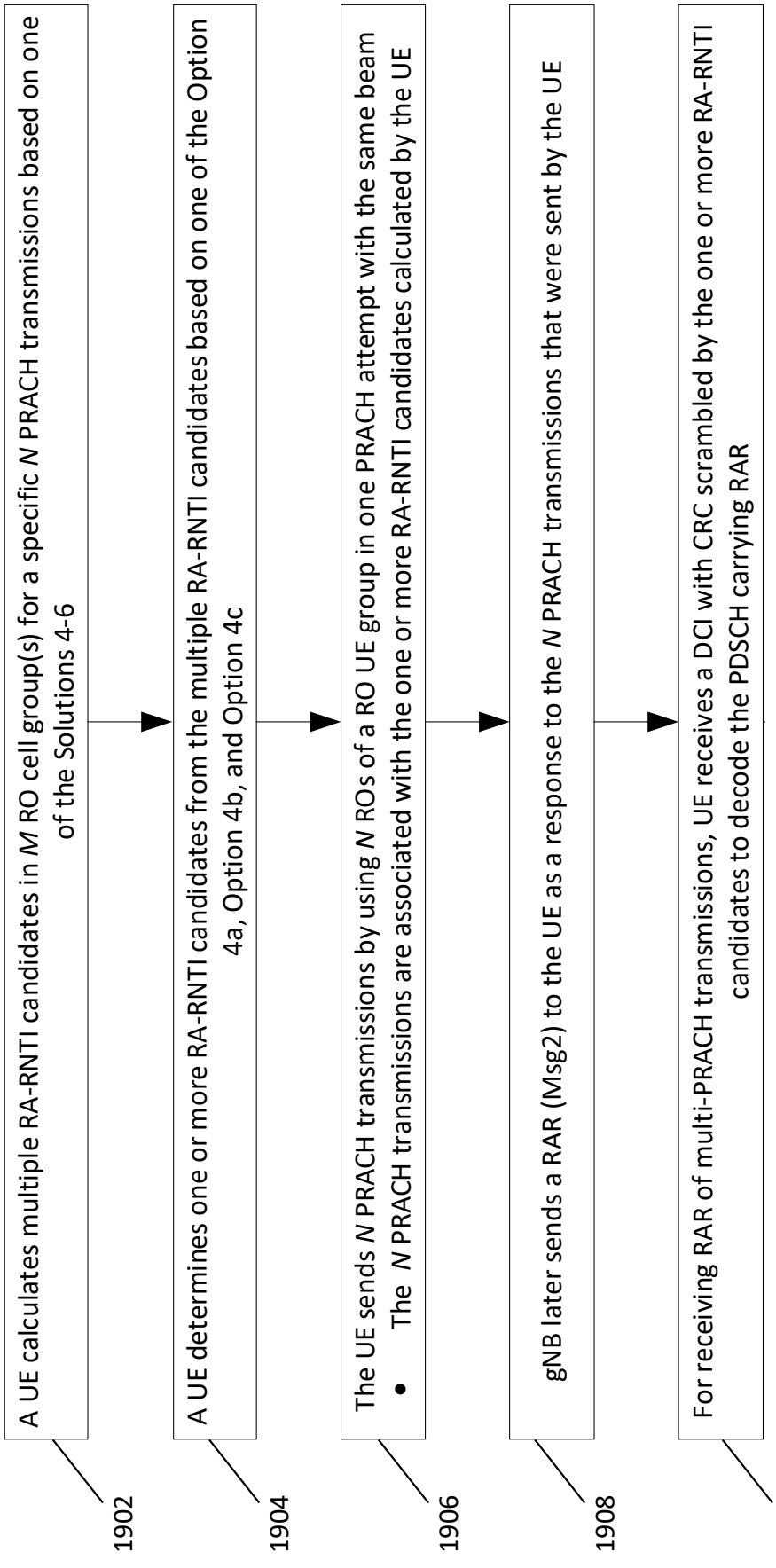

A UE calculates multiple RA-RNTI candidates in *M* RO cell group(s) for a specific *N* PRACH transmissions based on one of the Solutions 4-6
1902
A UE determines one or more RA-RNTI candidates from the multiple RA-RNTI candidates based on one of the Option 4a, Option 4b, and Option 4c
1904
The UE sends *N* PRACH transmissions by using *N* ROs of a RO UE group in one PRACH attempt with the same beam
• The *N* PRACH transmissions are associated with the one or more RA-RNTI candidates calculated by the UE
1906
gNB later sends a RAR (Msg2) to the UE as a response to the *N* PRACH transmissions that were sent by the UE
1908
For receiving RAR of multi-PRACH transmissions, UE receives a DCI with CRC scrambled by the one or more RA-RNTI candidates to decode the PDSCH carrying RAR
1910
1900

Fig. 19

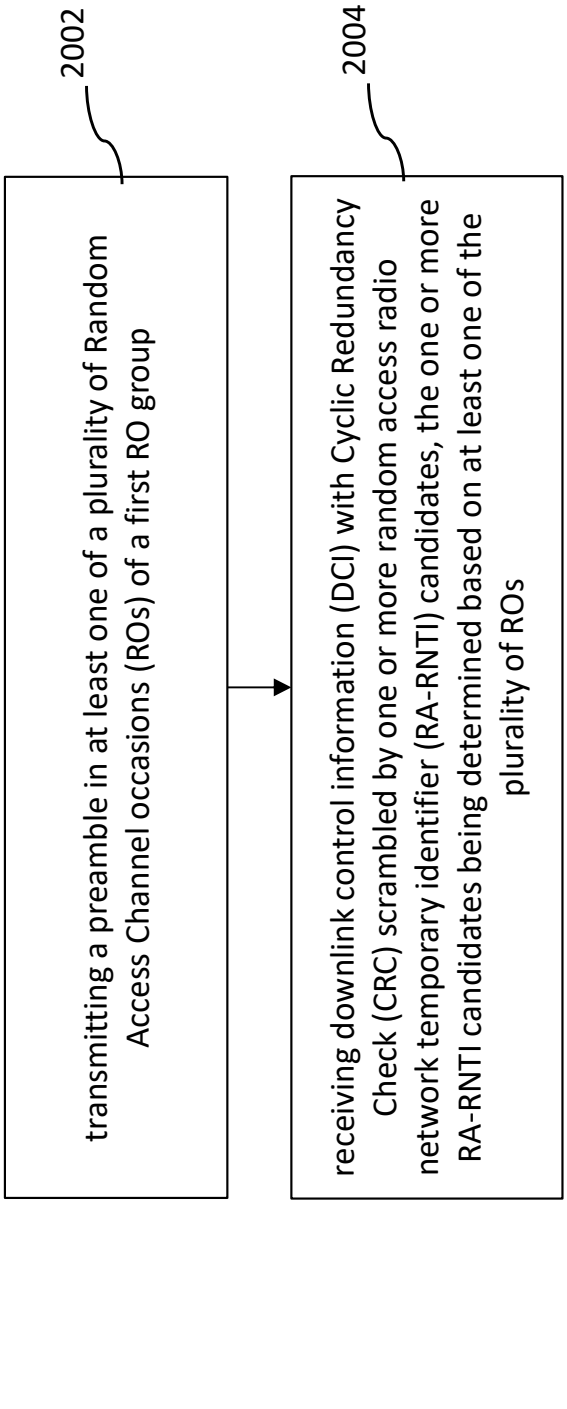

2002
transmitting a preamble in at least one of a plurality of Random Access Channel occasions (ROs) of a first RO group
2004
receiving downlink control information (DCI) with Cyclic Redundancy Check (CRC) scrambled by one or more random access radio network temporary identifier (RA-RNTI) candidates, the one or more RA-RNTI candidates being determined based on at least one of the plurality of ROs
2000

Fig. 20

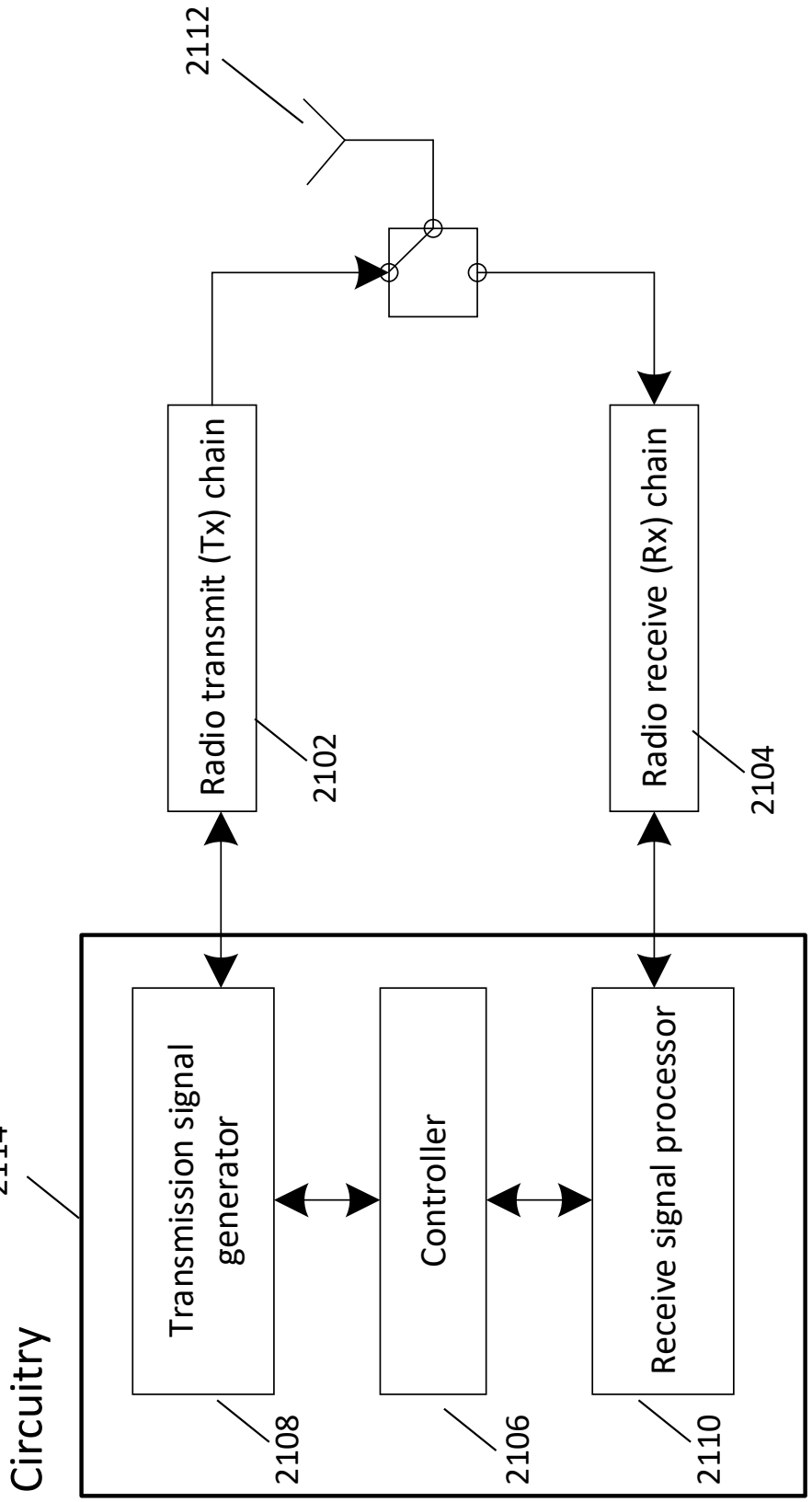

2112
Radio transmit (Tx) chain
2102
Radio receive (Rx) chain
2104
2114
Circuitry
Transmission signal generator
2108
Controller
2106
Receive signal processor
2110
2100

Fig. 21

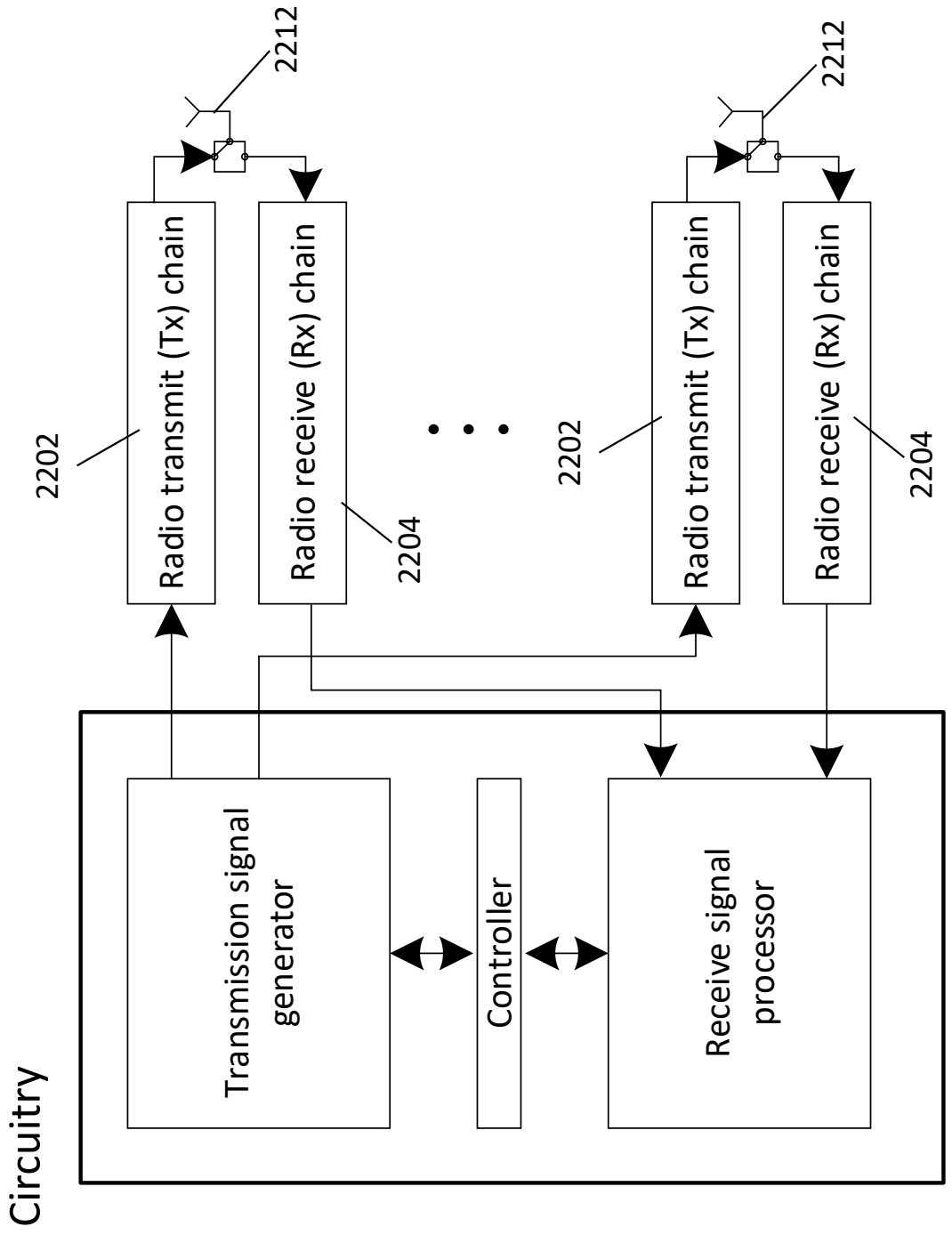

Circuitry
Transmission signal generator
Controller
Receive signal processor
2200
Radio transmit (Tx) chain
Radio receive (Rx) chain
2202
2204
2212

Fig. 22