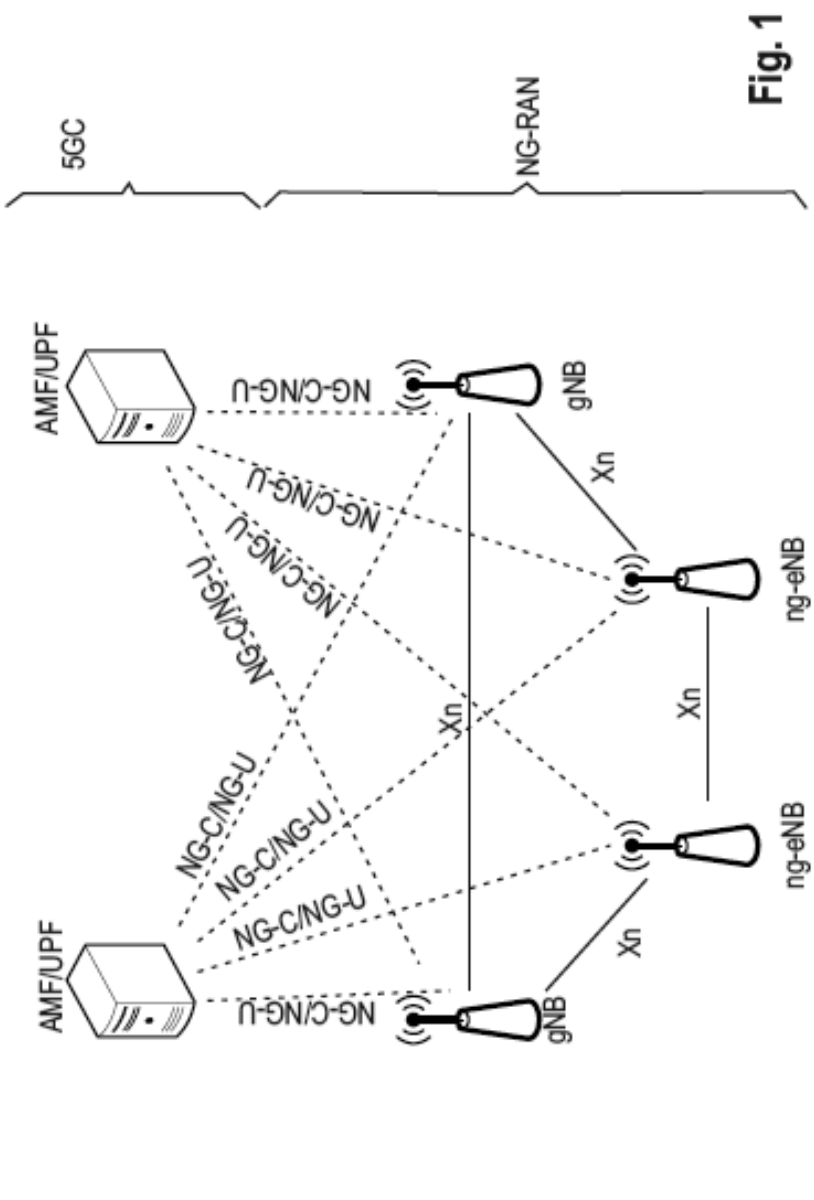

5GC
NG-RAN
AMF/UPF
AMF/UPF
NG-C/NG-U
NG-C/NG-U
NG-C/NG-U
NG-C/NG-U
NG-C/NG-U
NG-C/NG-U
NG-C/NG-U
NG-C/NG-U
gNB
gNB
ng-eNB
ng-eNB
Xn
Xn
Xn
Xn
100

Fig. 1

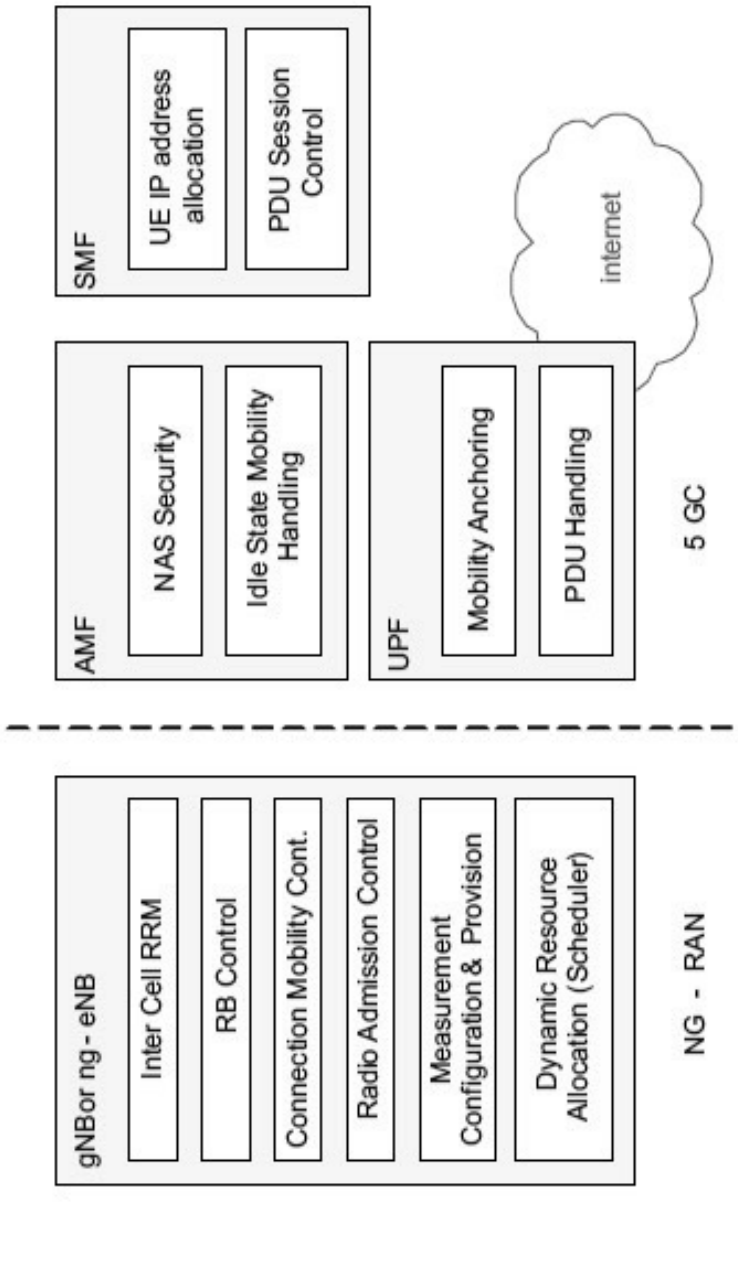

gNBor ng - eNB
Inter Cell RRM
RB Control
Connection Mobility Cont.
Radio Admission Control
Measurement Configuration & Provision
Dynamic Resource Allocation (Scheduler)
NG - RAN
AMF
NAS Security
Idle State Mobility Handling
UPF
Mobility Anchoring
PDU Handling
SMF
UE IP address allocation
PDU Session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

Fig. 2

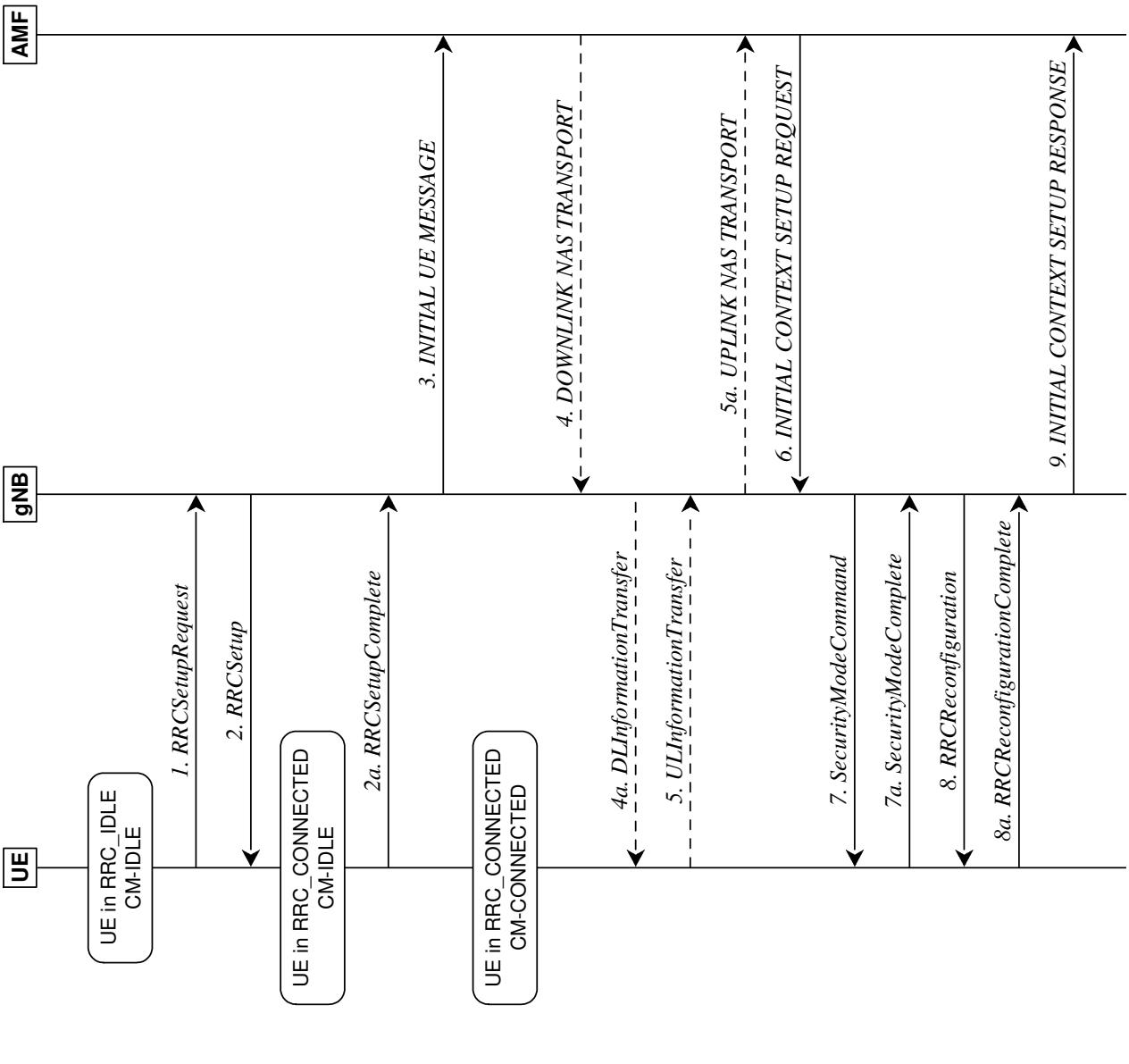

UE
gNB
AMF
UE in RRC_IDLE CM-IDLE
1. RRCSetupRequest
2. RRCSetup
UE in RRC_CONNECTED CM-IDLE
2a. RRCSetupComplete
UE in RRC_CONNECTED CM-CONNECTED
3. INITIAL UE MESSAGE
4. DOWNLINK NAS TRANSPORT
4a. DLInformationTransfer
5. ULInformationTransfer
5a. UPLINK NAS TRANSPORT
6. INITIAL CONTEXT SETUP REQUEST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

Fig. 3

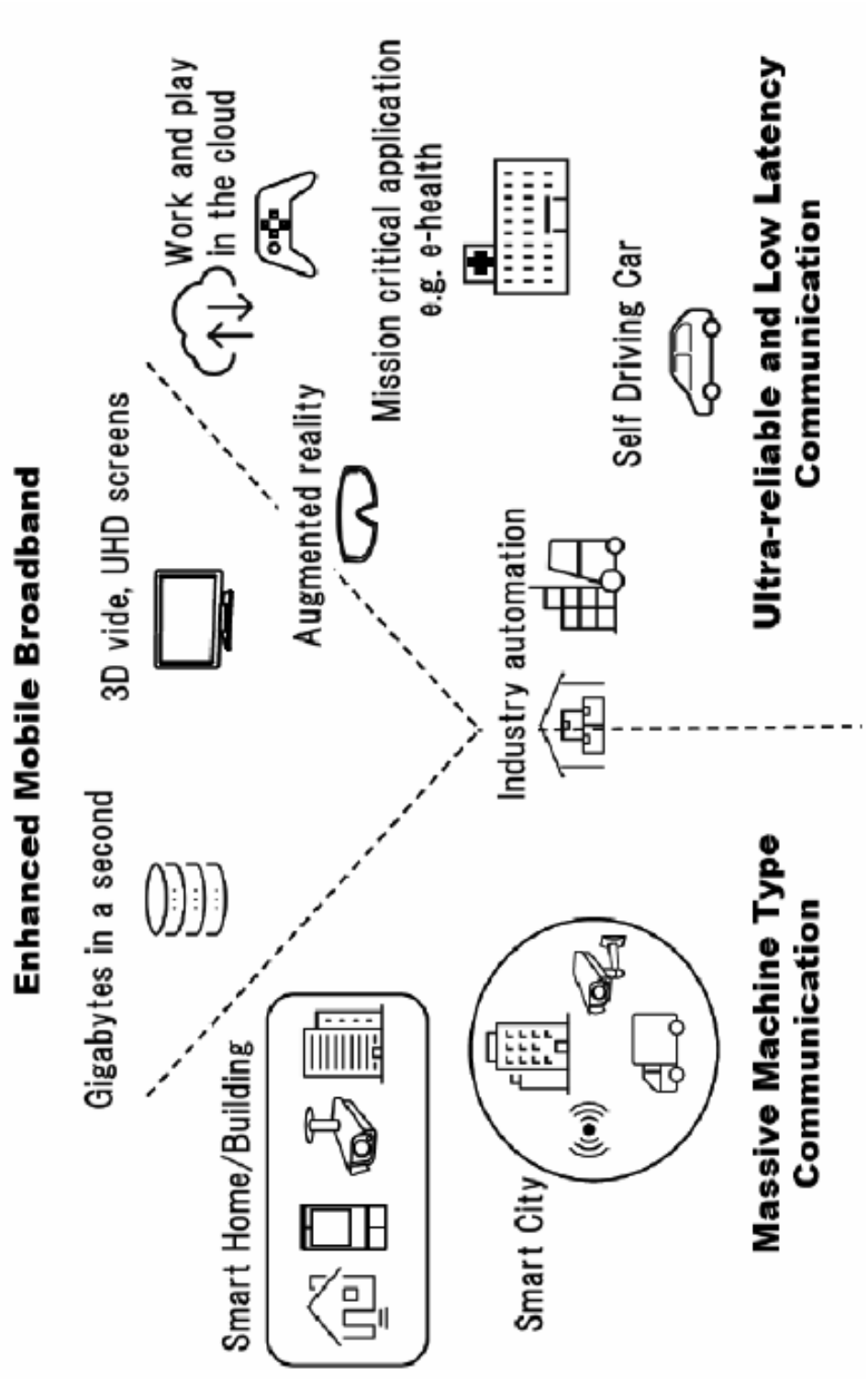

Enhanced Mobile Broadband
Gigabytes in a second
3D vide, UHD screens
Work and play in the cloud
Augmented reality
Mission critical application e.g. e-health
Smart Home/Building
Industry automation
Self Driving Car
Ultra-reliable and Low Latency Communication
Smart City
Massive Machine Type Communication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

Fig. 4

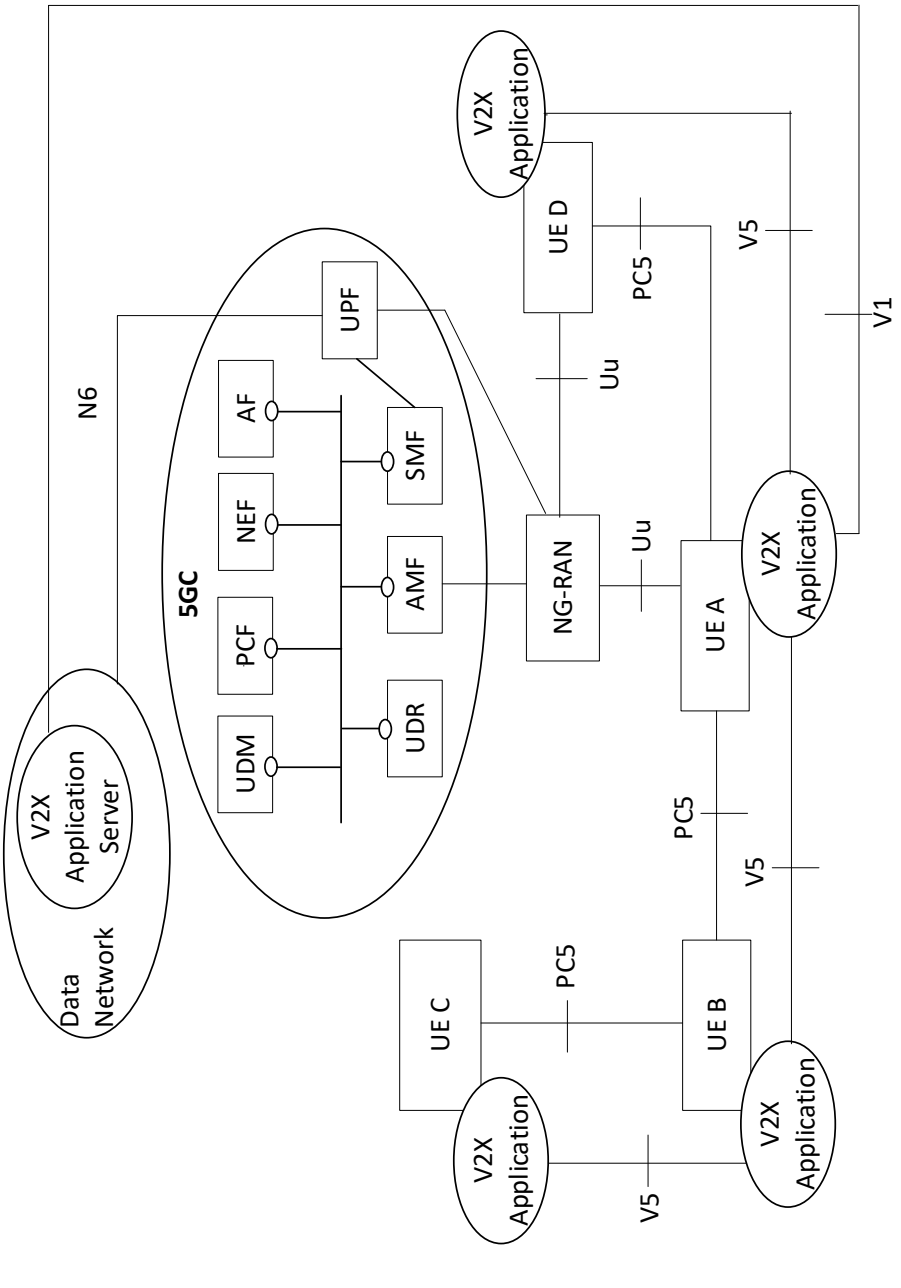

Data Network
V2X Application Server
N6
5GC
UPF
AF
NEF
PCF
UDM
SMF
AMF
UDR
NG-RAN
Uu
Uu
UE D
UE A
UE B
UE C
V2X Application
V2X Application
V2X Application
V2X Application
PC5
PC5
PC5
V5
V5
V5
V1
500

Fig. 5

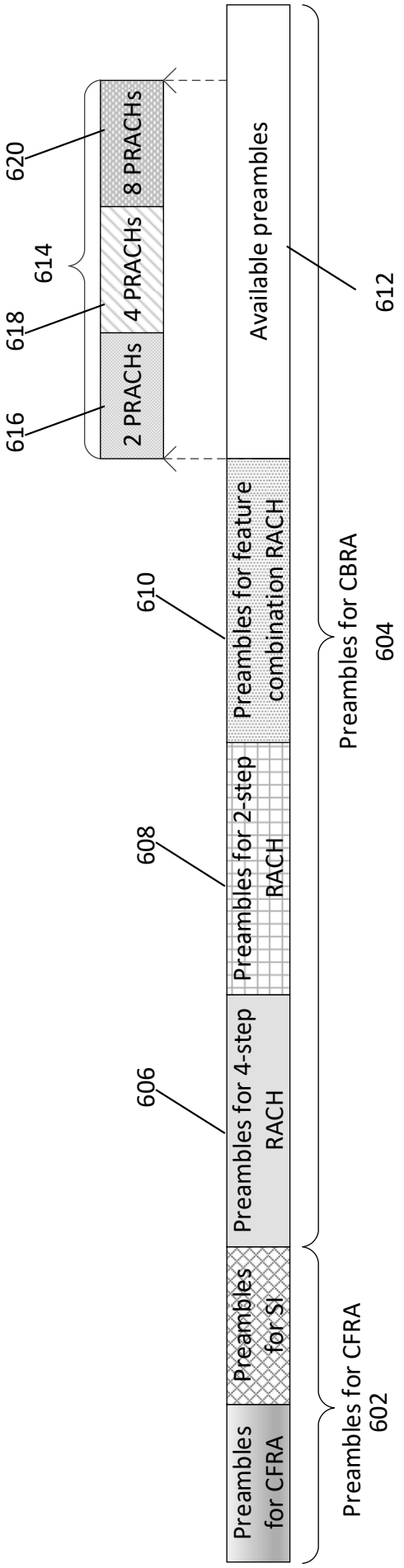

Preambles for CFRA
Preambles for SI
Preambles for 4-step RACH
Preambles for 2-step RACH
Preambles for feature combination RACH
Available preambles
2 PRACHs
4 PRACHs
8 PRACHs
602
604
606
608
610
612
614
616
618
620
600

Fig. 6

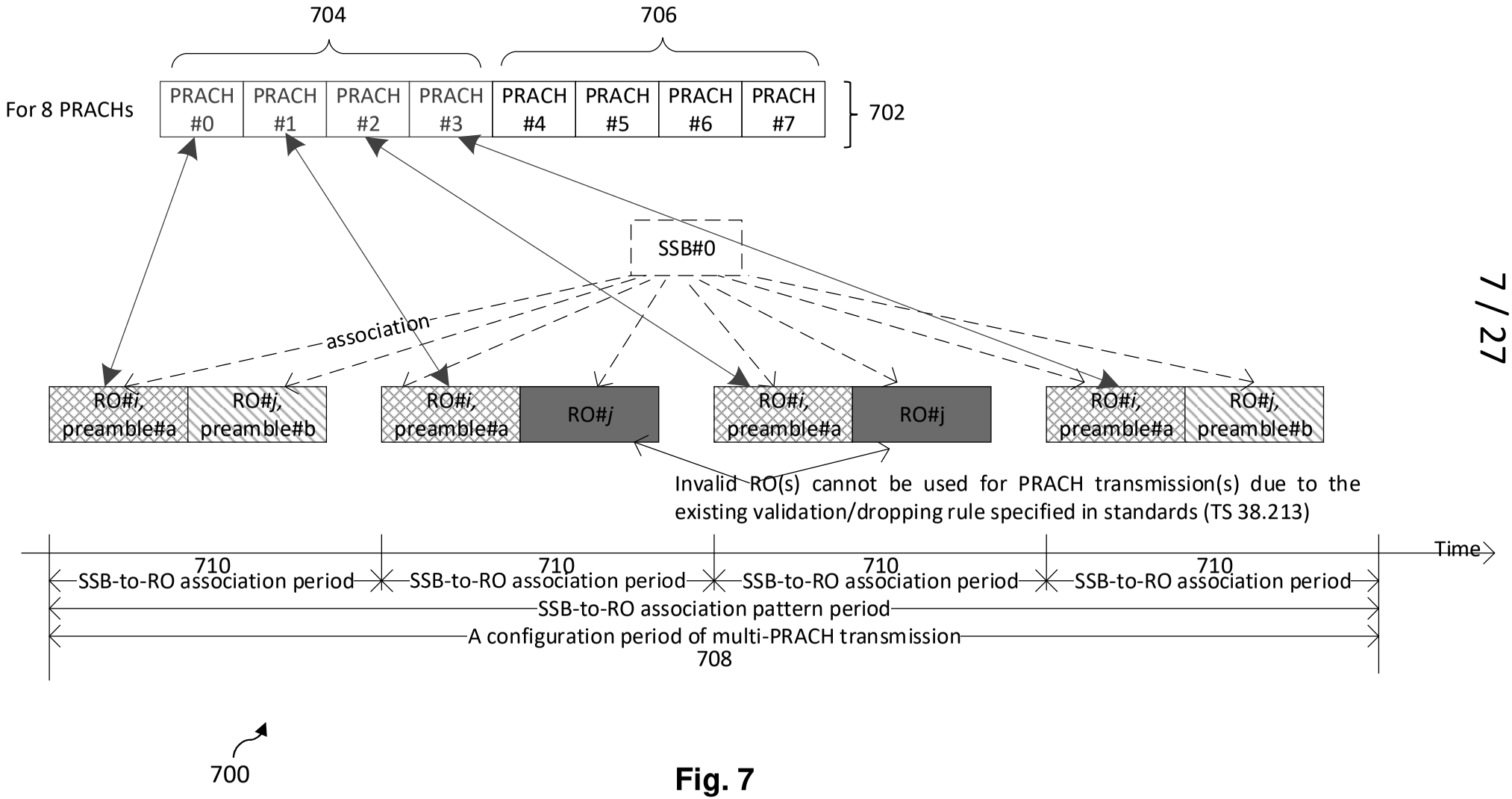

704
706
For 8 PRACHs
PRACH #0
PRACH #1
PRACH #2
PRACH #3
PRACH #4
PRACH #5
PRACH #6
PRACH #7
702
SSB#0
association
RO#i, preamble#a
RO#j, preamble#b
RO#i, preamble#a
RO#j
RO#i, preamble#a
RO#j
RO#i, preamble#a
RO#j, preamble#b
Invalid RO(s) cannot be used for PRACH transmission(s) due to the existing validation/dropping rule specified in standards (TS 38.213)
Time
710
SSB-to-RO association period
710
SSB-to-RO association period
710
SSB-to-RO association period
710
SSB-to-RO association period
SSB-to-RO association pattern period
A configuration period of multi-PRACH transmission
708
700

Fig. 7

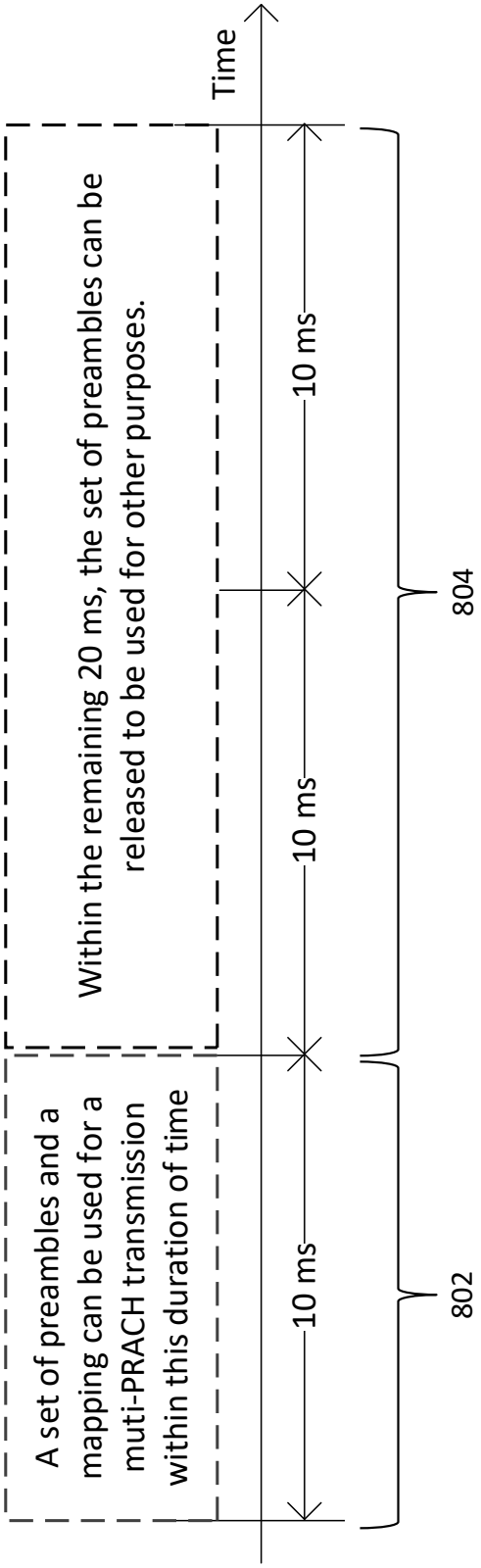

Time
A set of preambles and a mapping can be used for a muti-PRACH transmission within this duration of time
Within the remaining 20 ms, the set of preambles can be released to be used for other purposes.
10 ms
10 ms
10 ms
802
804
800

Fig. 8A

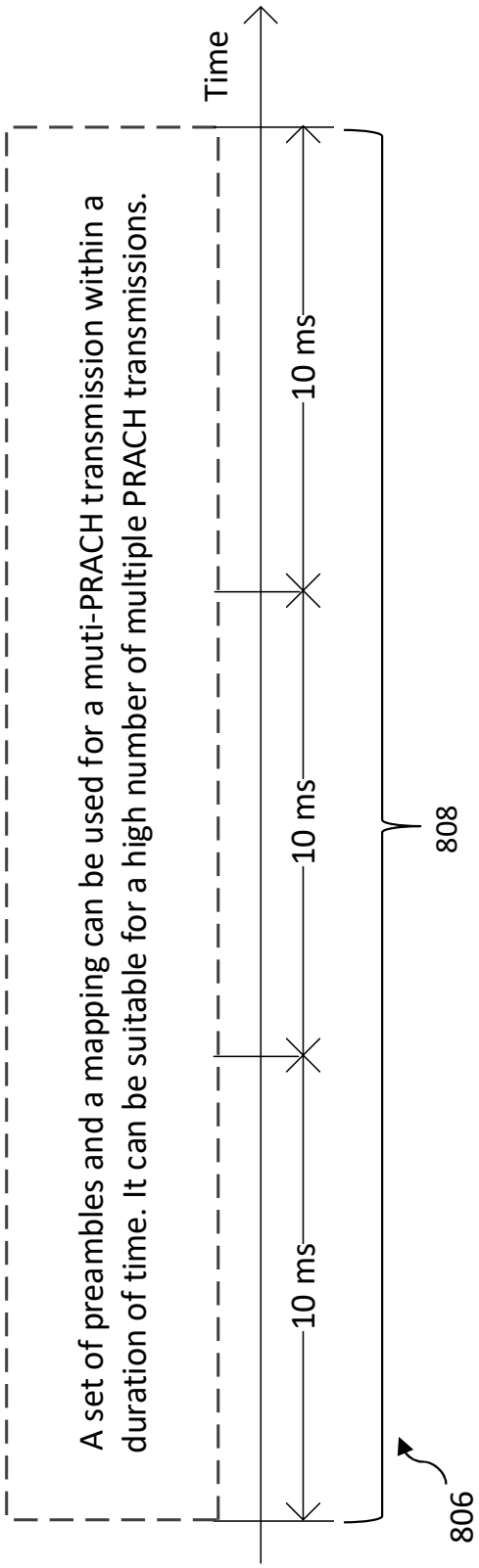

Time
A set of preambles and a mapping can be used for a muti-PRACH transmission within a duration of time. It can be suitable for a high number of multiple PRACH transmissions.
10 ms
10 ms
10 ms
808
806

Fig. 8B

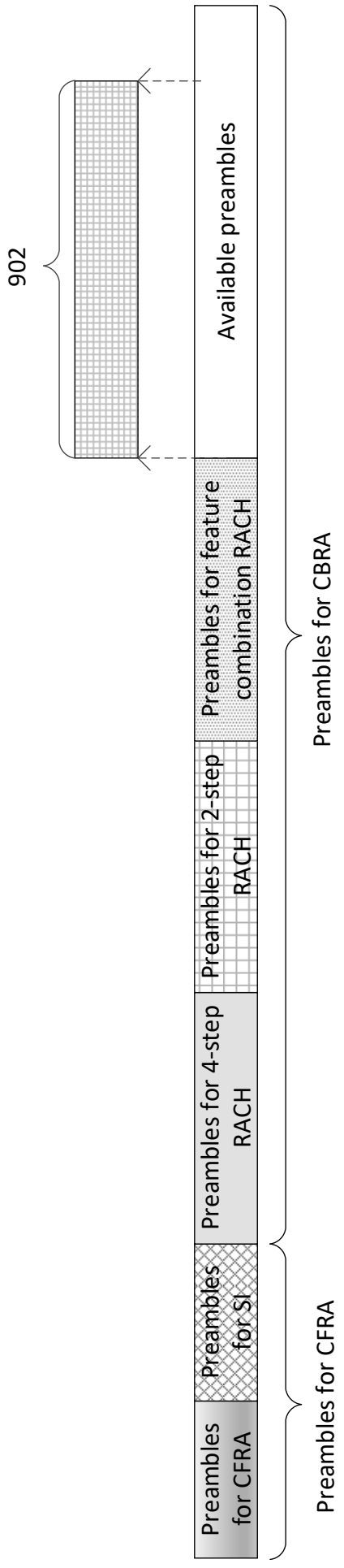

902
Available preambles
Preambles for feature combination RACH
Preambles for 2-step RACH
Preambles for 4-step RACH
Preambles for SI
Preambles for CFRA
Preambles for CBRA
900

Fig. 9

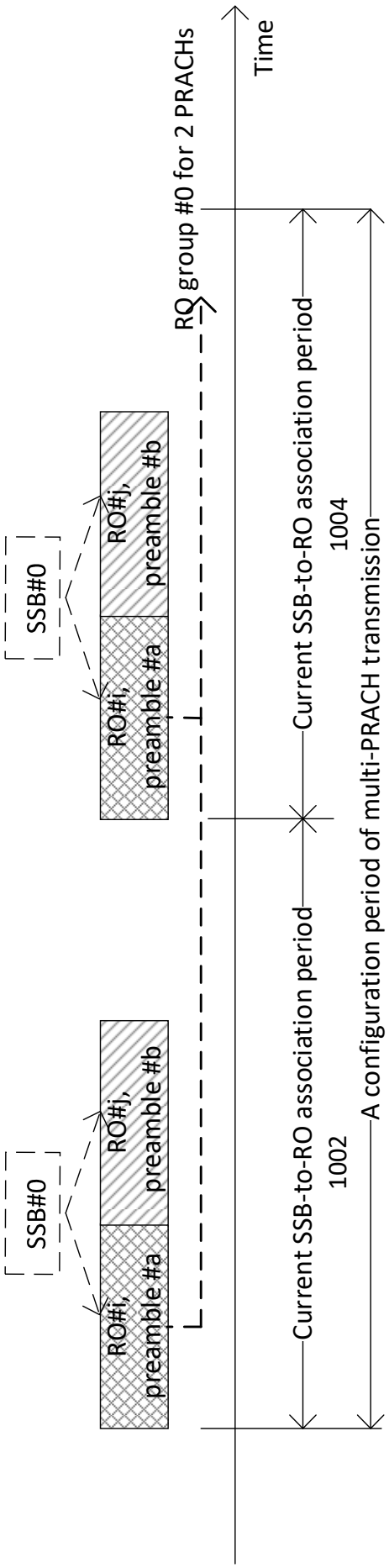


Fig. 10A

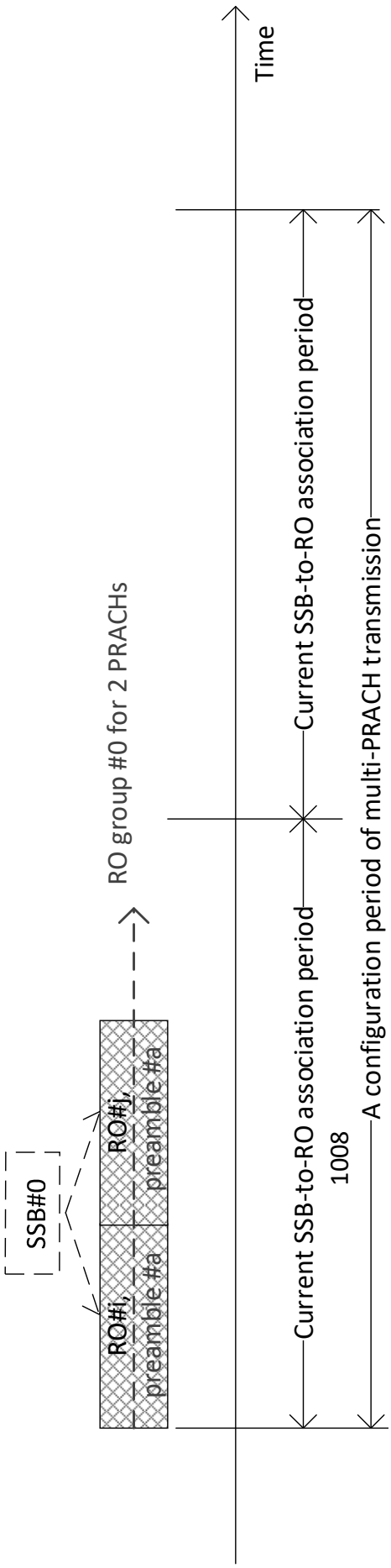


Fig. 10B

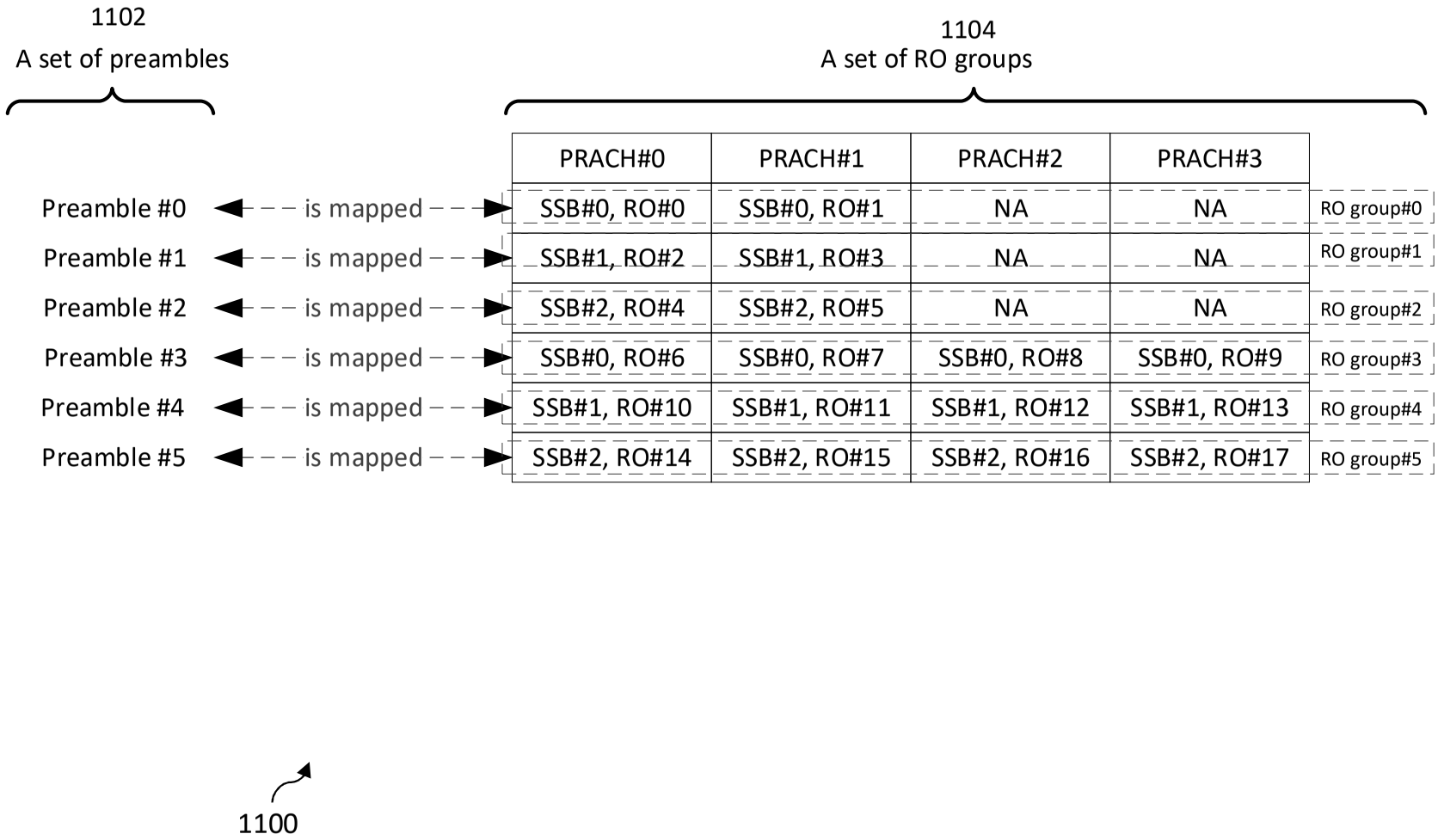

1102
A set of preambles
1104
A set of RO groups
PRACH#0
PRACH#1
PRACH#2
PRACH#3
Preamble #0
is mapped
SSB#0, RO#0
SSB#0, RO#1
NA
NA
RO group#0
Preamble #1
is mapped
SSB#1, RO#2
SSB#1, RO#3
NA
NA
RO group#1
Preamble #2
is mapped
SSB#2, RO#4
SSB#2, RO#5
NA
NA
RO group#2
Preamble #3
is mapped
SSB#0, RO#6
SSB#0, RO#7
SSB#0, RO#8
SSB#0, RO#9
RO group#3
Preamble #4
is mapped
SSB#1, RO#10
SSB#1, RO#11
SSB#1, RO#12
SSB#1, RO#13
RO group#4
Preamble #5
is mapped
SSB#2, RO#14
SSB#2, RO#15
SSB#2, RO#16
SSB#2, RO#17
RO group#5
1100

Fig. 11

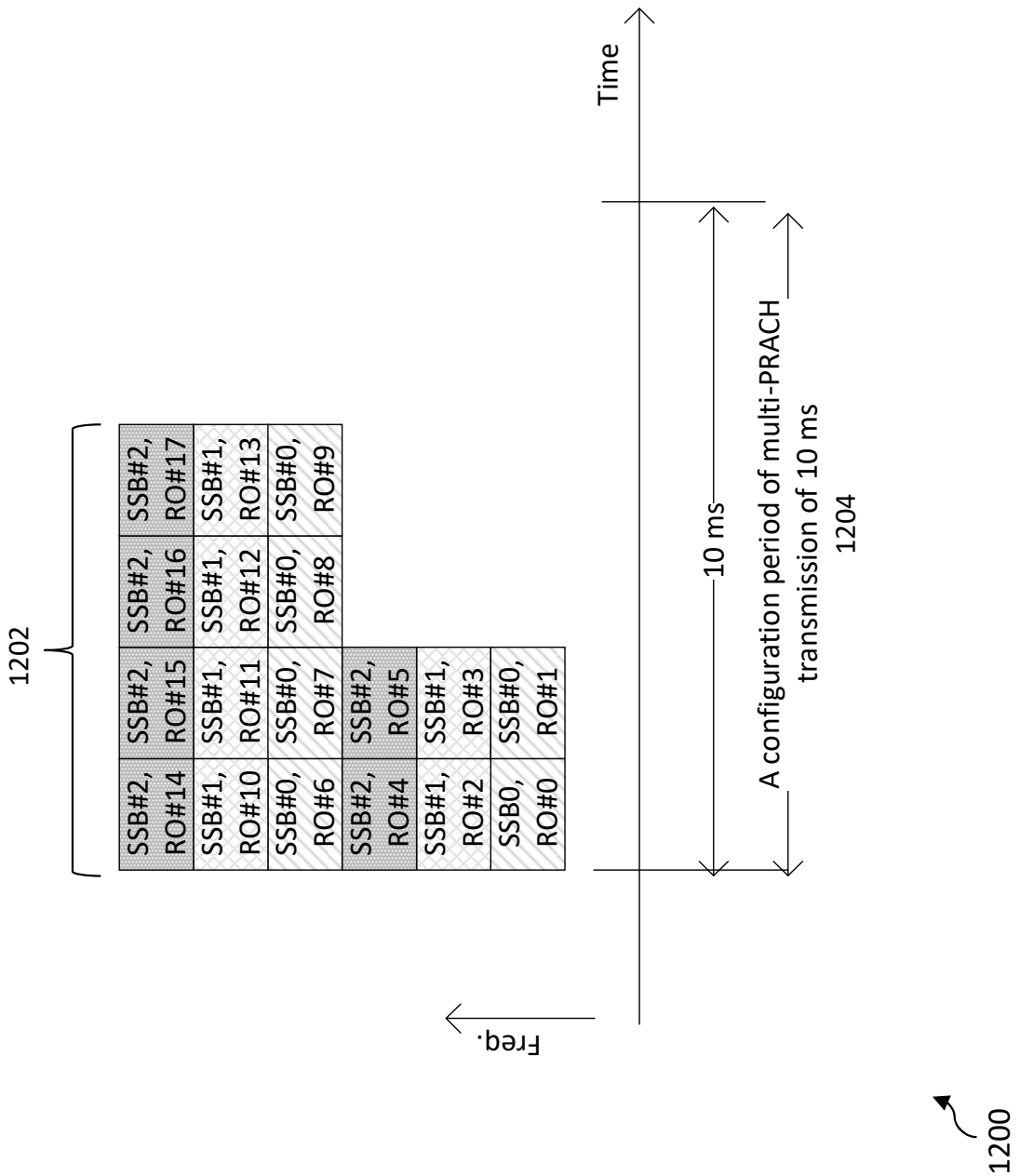

1200
Freq.
Time
1202
SSB#2, RO#14
SSB#2, RO#15
SSB#2, RO#16
SSB#2, RO#17
SSB#1, RO#10
SSB#1, RO#11
SSB#1, RO#12
SSB#1, RO#13
SSB#0, RO#6
SSB#0, RO#7
SSB#0, RO#8
SSB#0, RO#9
SSB#2, RO#4
SSB#2, RO#5
SSB#1, RO#2
SSB#1, RO#3
SSB0, RO#0
SSB#0, RO#1
10 ms
A configuration period of multi-PRACH transmission of 10 ms
1204

Fig. 12

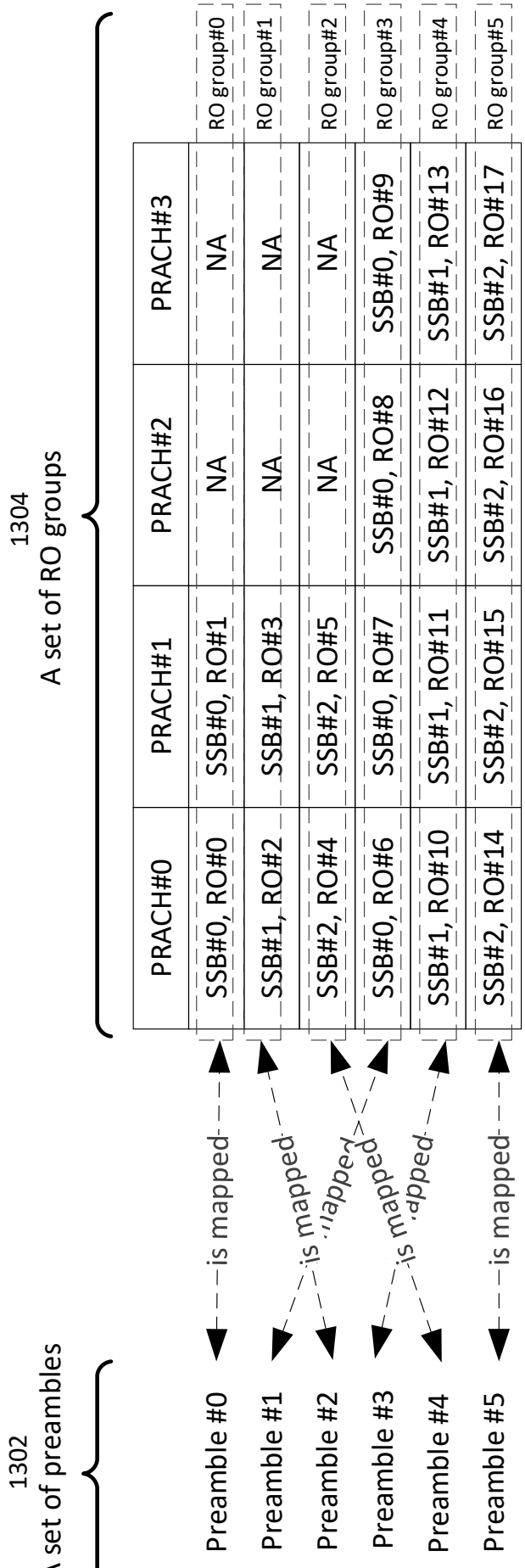

1302
A set of preambles
1304
A set of RO groups
PRACH#0
PRACH#1
PRACH#2
PRACH#3
SSB#0, RO#0
SSB#0, RO#1
NA
NA
SSB#1, RO#2
SSB#1, RO#3
NA
NA
SSB#2, RO#4
SSB#2, RO#5
NA
NA
SSB#0, RO#6
SSB#0, RO#7
SSB#0, RO#8
SSB#0, RO#9
SSB#1, RO#10
SSB#1, RO#11
SSB#1, RO#12
SSB#1, RO#13
SSB#2, RO#14
SSB#2, RO#15
SSB#2, RO#16
SSB#2, RO#17
RO group#0
RO group#1
RO group#2
RO group#3
RO group#4
RO group#5
Preamble #0
Preamble #1
Preamble #2
Preamble #3
Preamble #4
Preamble #5
is mapped
is mapped
is mapped
is mapped
is mapped
is mapped
1300

Fig. 13

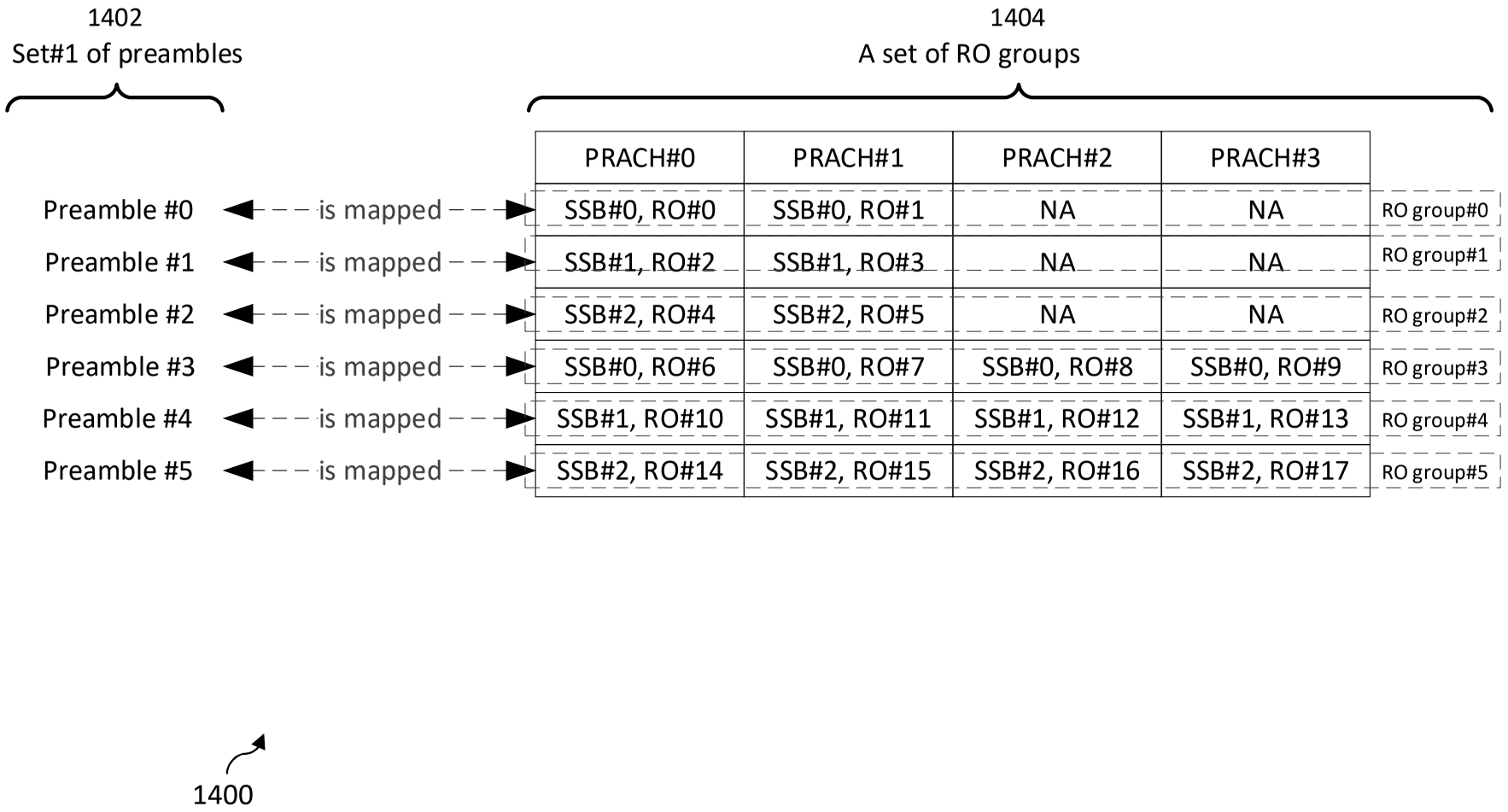

1402
Set#1 of preambles
1404
A set of RO groups
PRACH#0
PRACH#1
PRACH#2
PRACH#3
Preamble #0
is mapped
SSB#0, RO#0
SSB#0, RO#1
NA
NA
RO group#0
Preamble #1
is mapped
SSB#1, RO#2
SSB#1, RO#3
NA
NA
RO group#1
Preamble #2
is mapped
SSB#2, RO#4
SSB#2, RO#5
NA
NA
RO group#2
Preamble #3
is mapped
SSB#0, RO#6
SSB#0, RO#7
SSB#0, RO#8
SSB#0, RO#9
RO group#3
Preamble #4
is mapped
SSB#1, RO#10
SSB#1, RO#11
SSB#1, RO#12
SSB#1, RO#13
RO group#4
Preamble #5
is mapped
SSB#2, RO#14
SSB#2, RO#15
SSB#2, RO#16
SSB#2, RO#17
RO group#5
1400

Fig. 14

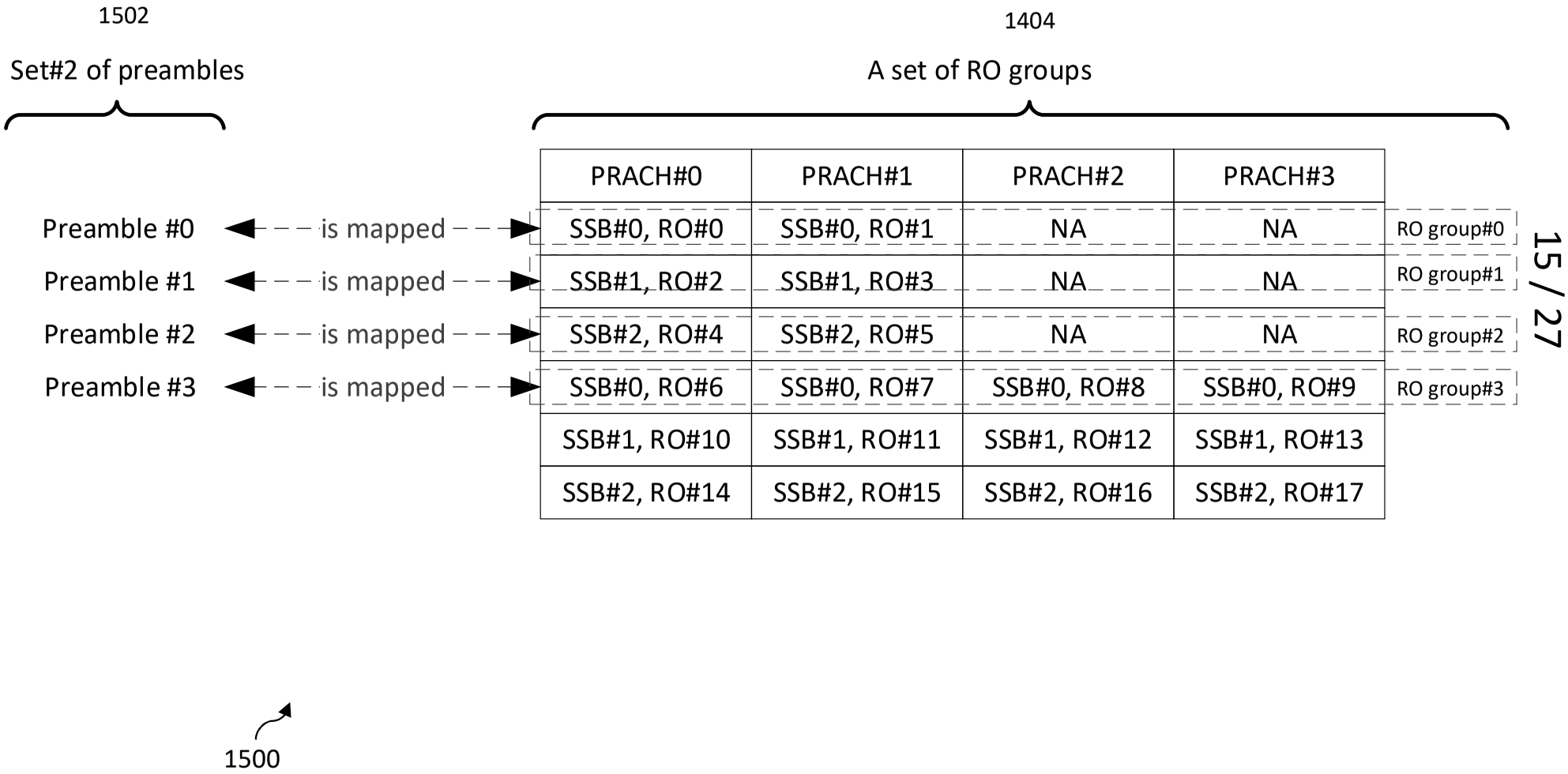

1502
Set#2 of preambles
1404
A set of RO groups
PRACH#0
PRACH#1
PRACH#2
PRACH#3
Preamble #0
is mapped
SSB#0, RO#0
SSB#0, RO#1
NA
NA
RO group#0
Preamble #1
is mapped
SSB#1, RO#2
SSB#1, RO#3
NA
NA
RO group#1
Preamble #2
is mapped
SSB#2, RO#4
SSB#2, RO#5
NA
NA
RO group#2
Preamble #3
is mapped
SSB#0, RO#6
SSB#0, RO#7
SSB#0, RO#8
SSB#0, RO#9
RO group#3
SSB#1, RO#10
SSB#1, RO#11
SSB#1, RO#12
SSB#1, RO#13
SSB#2, RO#14
SSB#2, RO#15
SSB#2, RO#16
SSB#2, RO#17
1500

Fig. 15

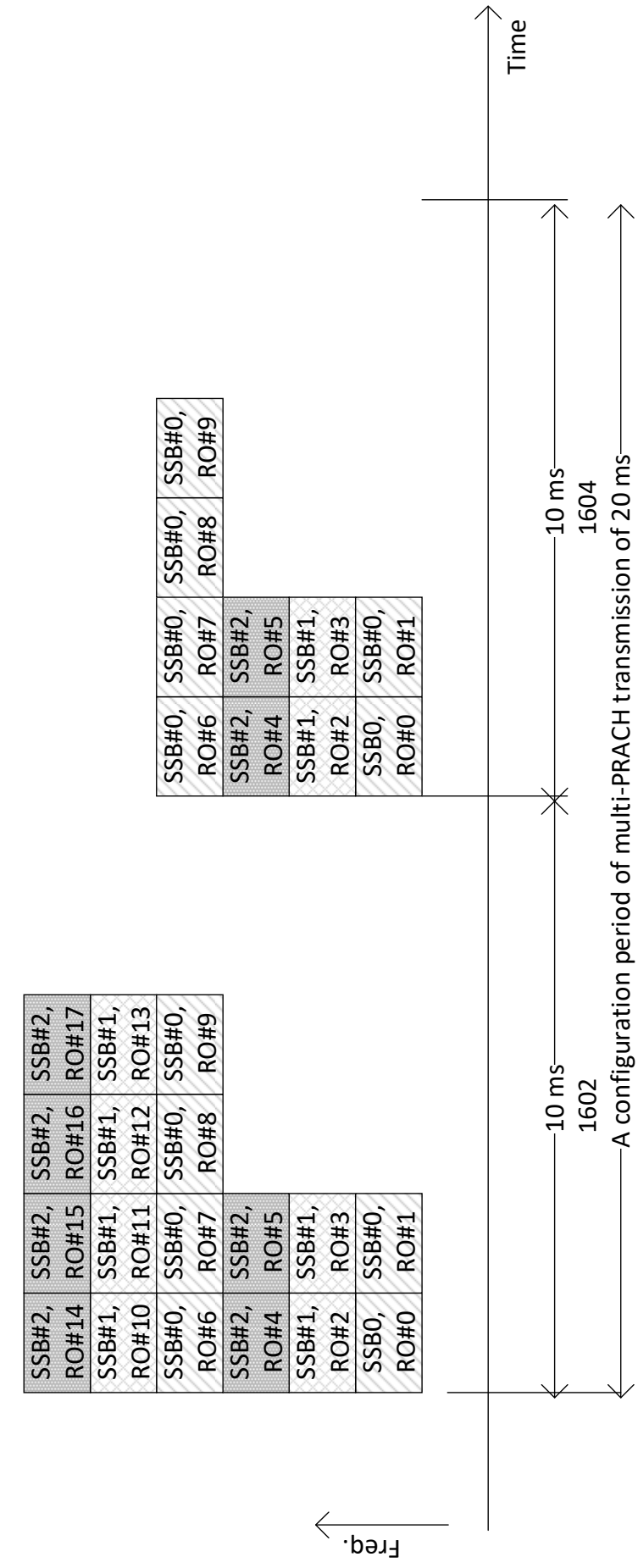

Time
Freq.
SSB#2, RO#14
SSB#2, RO#15
SSB#2, RO#16
SSB#2, RO#17
SSB#1, RO#10
SSB#1, RO#11
SSB#1, RO#12
SSB#1, RO#13
SSB#0, RO#6
SSB#0, RO#7
SSB#0, RO#8
SSB#0, RO#9
SSB#2, RO#4
SSB#2, RO#5
SSB#1, RO#2
SSB#1, RO#3
SSB0, RO#0
SSB#0, RO#1
SSB#0, RO#6
SSB#0, RO#7
SSB#0, RO#8
SSB#0, RO#9
SSB#2, RO#4
SSB#2, RO#5
SSB#1, RO#2
SSB#1, RO#3
SSB0, RO#0
SSB#0, RO#1
10 ms
1602
10 ms
1604
A configuration period of multi-PRACH transmission of 20 ms
1600

Fig. 16

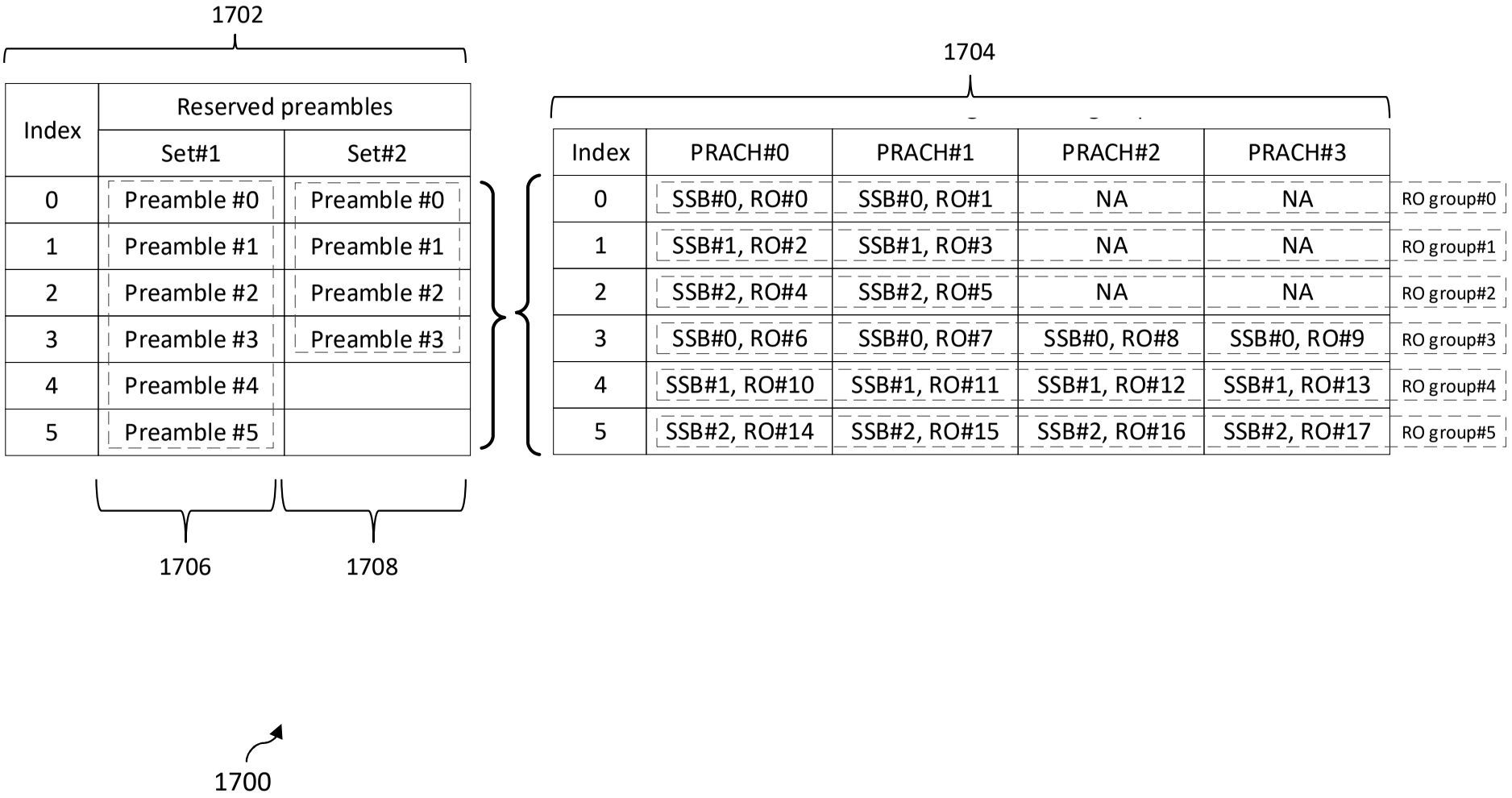

1702
1704
Index
Reserved preambles
Set#1
Set#2
0
Preamble #0
Preamble #0
1
Preamble #1
Preamble #1
2
Preamble #2
Preamble #2
3
Preamble #3
Preamble #3
4
Preamble #4
5
Preamble #5
Index
PRACH#0
PRACH#1
PRACH#2
PRACH#3
0
SSB#0, RO#0
SSB#0, RO#1
NA
NA
RO group#0
1
SSB#1, RO#2
SSB#1, RO#3
NA
NA
RO group#1
2
SSB#2, RO#4
SSB#2, RO#5
NA
NA
RO group#2
3
SSB#0, RO#6
SSB#0, RO#7
SSB#0, RO#8
SSB#0, RO#9
RO group#3
4
SSB#1, RO#10
SSB#1, RO#11
SSB#1, RO#12
SSB#1, RO#13
RO group#4
5
SSB#2, RO#14
SSB#2, RO#15
SSB#2, RO#16
SSB#2, RO#17
RO group#5
1706
1708
1700

Fig. 17

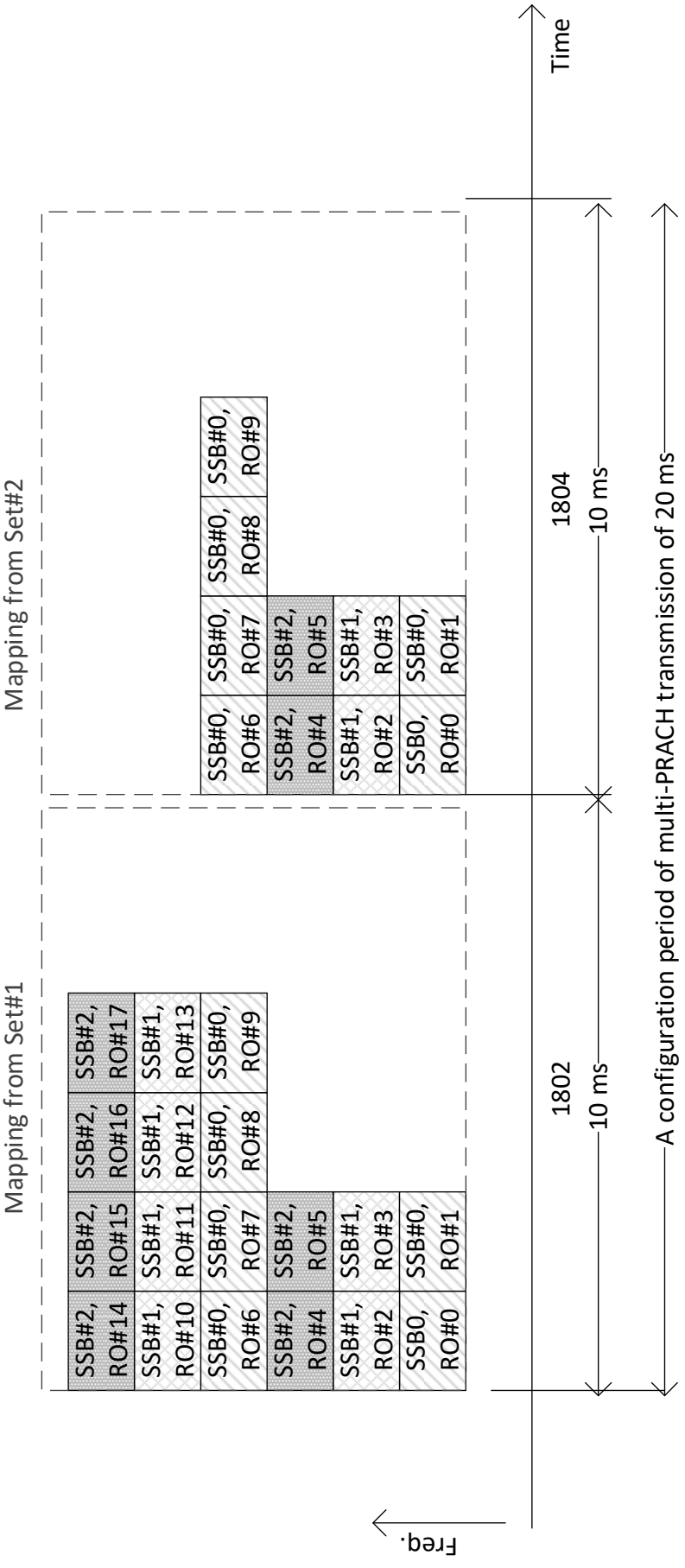

Mapping from Set#1
SSB#2, RO#14
SSB#2, RO#15
SSB#2, RO#16
SSB#2, RO#17
SSB#1, RO#10
SSB#1, RO#11
SSB#1, RO#12
SSB#1, RO#13
SSB#0, RO#6
SSB#0, RO#7
SSB#0, RO#8
SSB#0, RO#9
SSB#2, RO#4
SSB#2, RO#5
SSB#1, RO#2
SSB#1, RO#3
SSB0, RO#0
SSB#0, RO#1
Mapping from Set#2
SSB#0, RO#6
SSB#0, RO#7
SSB#0, RO#8
SSB#0, RO#9
SSB#2, RO#4
SSB#2, RO#5
SSB#1, RO#2
SSB#1, RO#3
SSB0, RO#0
SSB#0, RO#1
Freq.
Time
1802
10 ms
1804
10 ms
A configuration period of multi-PRACH transmission of 20 ms
1800

Fig. 18

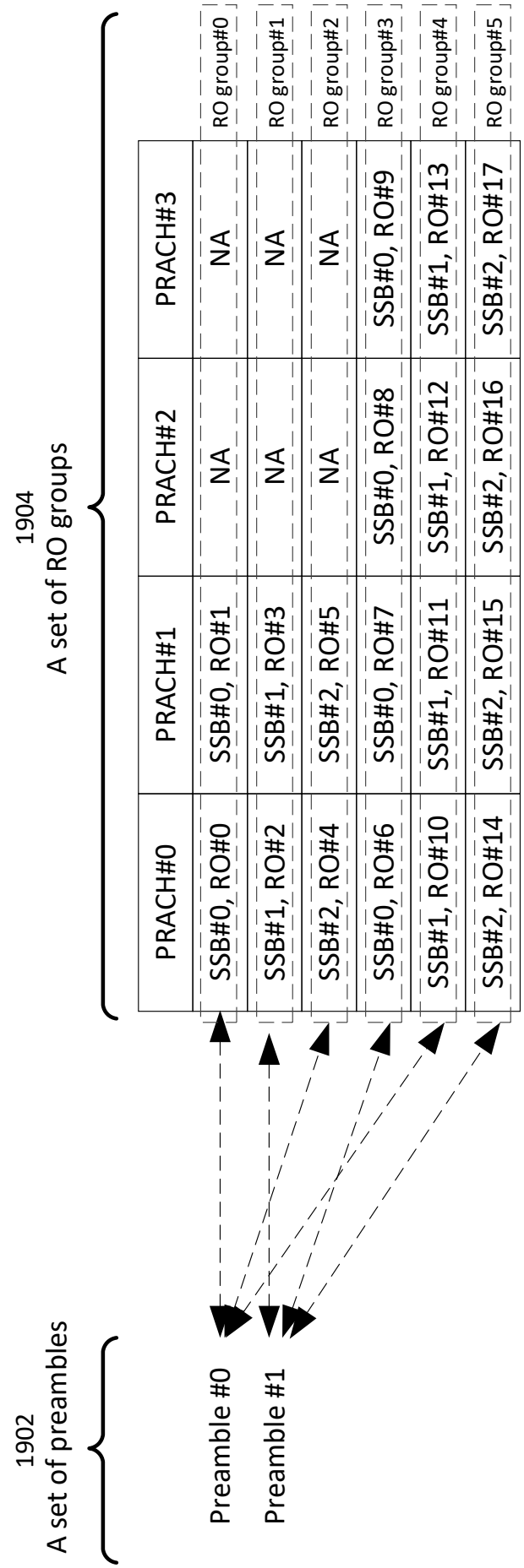

1902
A set of preambles
Preamble #0
Preamble #1
1904
A set of RO groups
PRACH#0
PRACH#1
PRACH#2
PRACH#3
SSB#0, RO#0
SSB#0, RO#1
NA
NA
SSB#1, RO#2
SSB#1, RO#3
NA
NA
SSB#2, RO#4
SSB#2, RO#5
NA
NA
SSB#0, RO#6
SSB#0, RO#7
SSB#0, RO#8
SSB#0, RO#9
SSB#1, RO#10
SSB#1, RO#11
SSB#1, RO#12
SSB#1, RO#13
SSB#2, RO#14
SSB#2, RO#15
SSB#2, RO#16
SSB#2, RO#17
RO group#0
RO group#1
RO group#2
RO group#3
RO group#4
RO group#5
1900

Fig. 19

Preambles	PRACH#0	PRACH#1	PRACH#2	PRACH#3
Preamble#0	SSB#0, RO#0	SSB#0, RO#1	NA	NA
Preamble#1	SSB#1, RO#2	SSB#1, RO#3	NA	NA
Preamble#2	SSB#2, RO#4	SSB#2, RO#5	NA	NA
Preamble#3	SSB#0, RO#6	SSB#0, RO#7	SSB#0, RO#8	SSB#0, RO#9
Preamble#4	SSB#1, RO#10	SSB#1, RO#11	SSB#1, RO#12	SSB#1, RO#13
Preamble#5	SSB#2, RO#14	SSB#2, RO#15	SSB#2, RO#16	SSB#2, RO#17



Fig. 20

Preambles	PRACH#0	PRACH#1	PRACH#2	PRACH#3
Preamble#0	SSB#0, RO#0	SSB#0, RO#1	NA	NA
Preamble#1	SSB#1, RO#2	SSB#1, RO#3	NA	NA
Preamble#0	SSB#2, RO#4	SSB#2, RO#5	NA	NA
Preamble#1	SSB#0, RO#8	SSB#0, RO#9	SSB#0, RO#10	SSB#0, RO#11
Preamble#0	SSB#1, RO#12	SSB#1, RO#12	SSB#1, RO#14	SSB#1, RO#15
Preamble#1	SSB#2, RO#16	SSB#2, RO#17	SSB#2, RO#18	SSB#2, RO#19

2102

2104

2100

Fig. 21

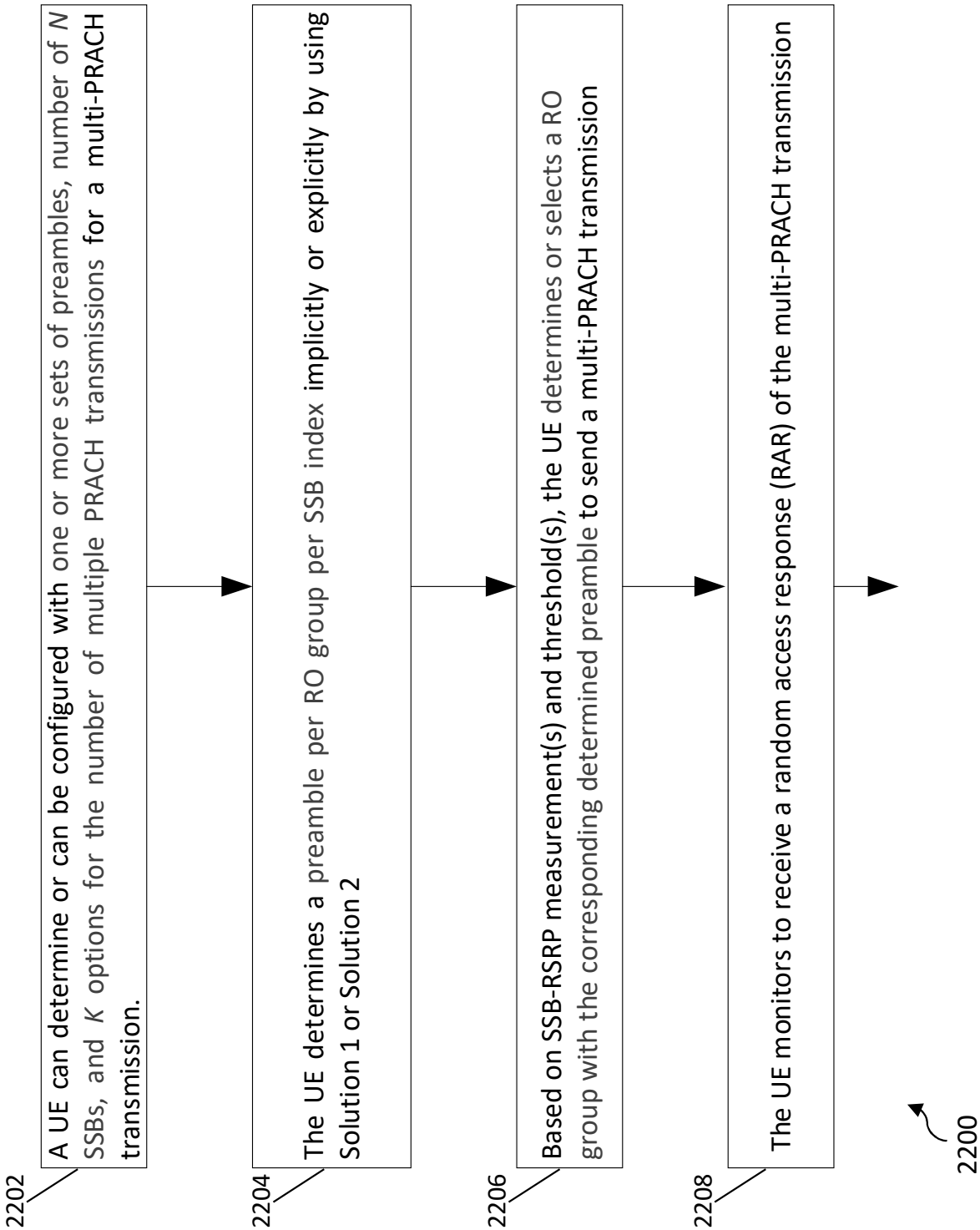

2202
A UE can determine or can be configured with one or more sets of preambles, number of N SSBs, and K options for the number of multiple PRACH transmissions for a multi-PRACH transmission.
2204
The UE determines a preamble per RO group per SSB index implicitly or explicitly by using Solution 1 or Solution 2
2206
Based on SSB-RSRP measurement(s) and threshold(s), the UE determines or selects a RO group with the corresponding determined preamble to send a multi-PRACH transmission
2208
The UE monitors to receive a random access response (RAR) of the multi-PRACH transmission
2200

Fig. 22

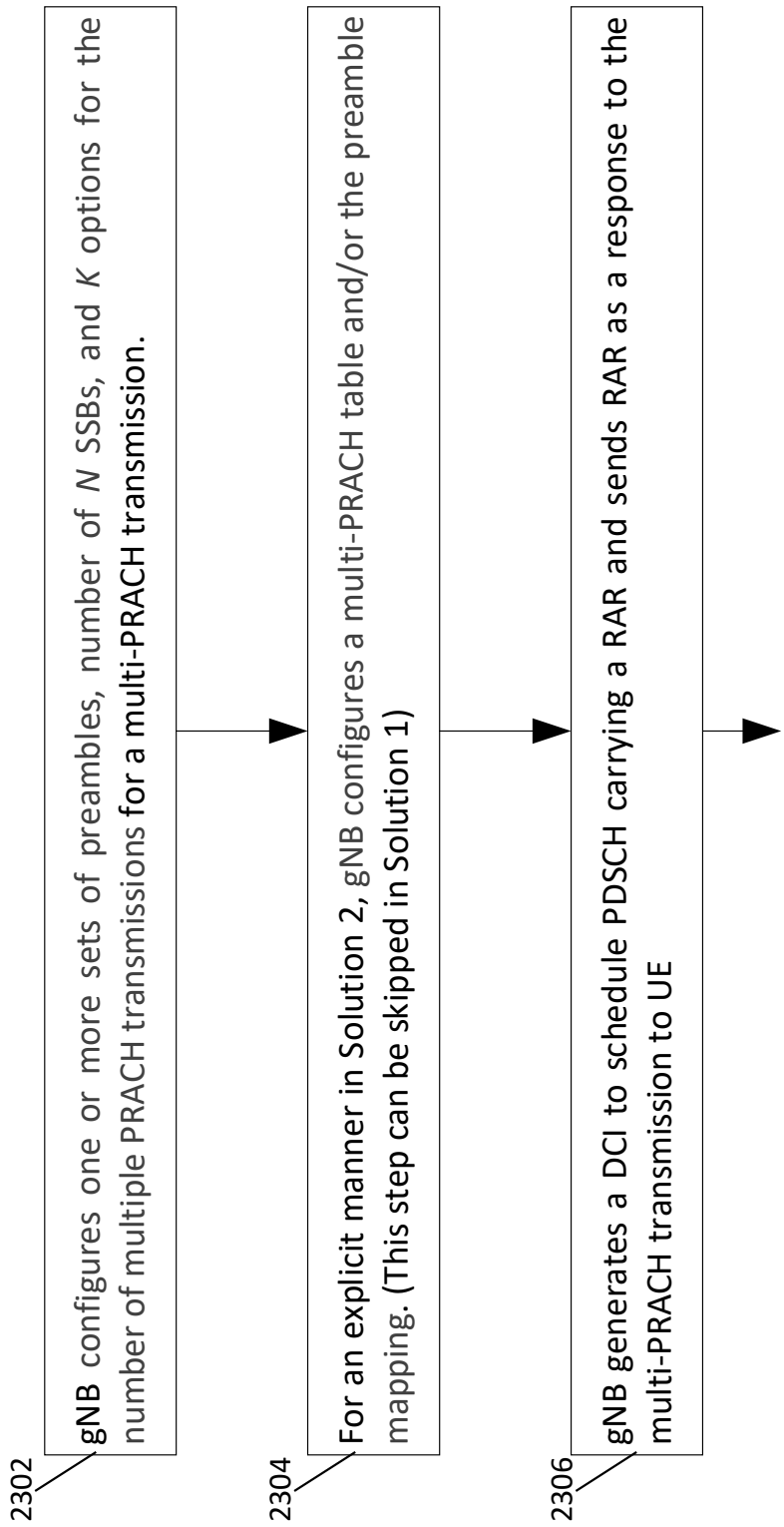

2302
gNB configures one or more sets of preambles, number of N SSBs, and K options for the number of multiple PRACH transmissions for a multi-PRACH transmission.
2304
For an explicit manner in Solution 2, gNB configures a multi-PRACH table and/or the preamble mapping. (This step can be skipped in Solution 1)
2306
gNB generates a DCI to schedule PDSCH carrying a RAR and sends RAR as a response to the multi-PRACH transmission to UE
2300

Fig. 23

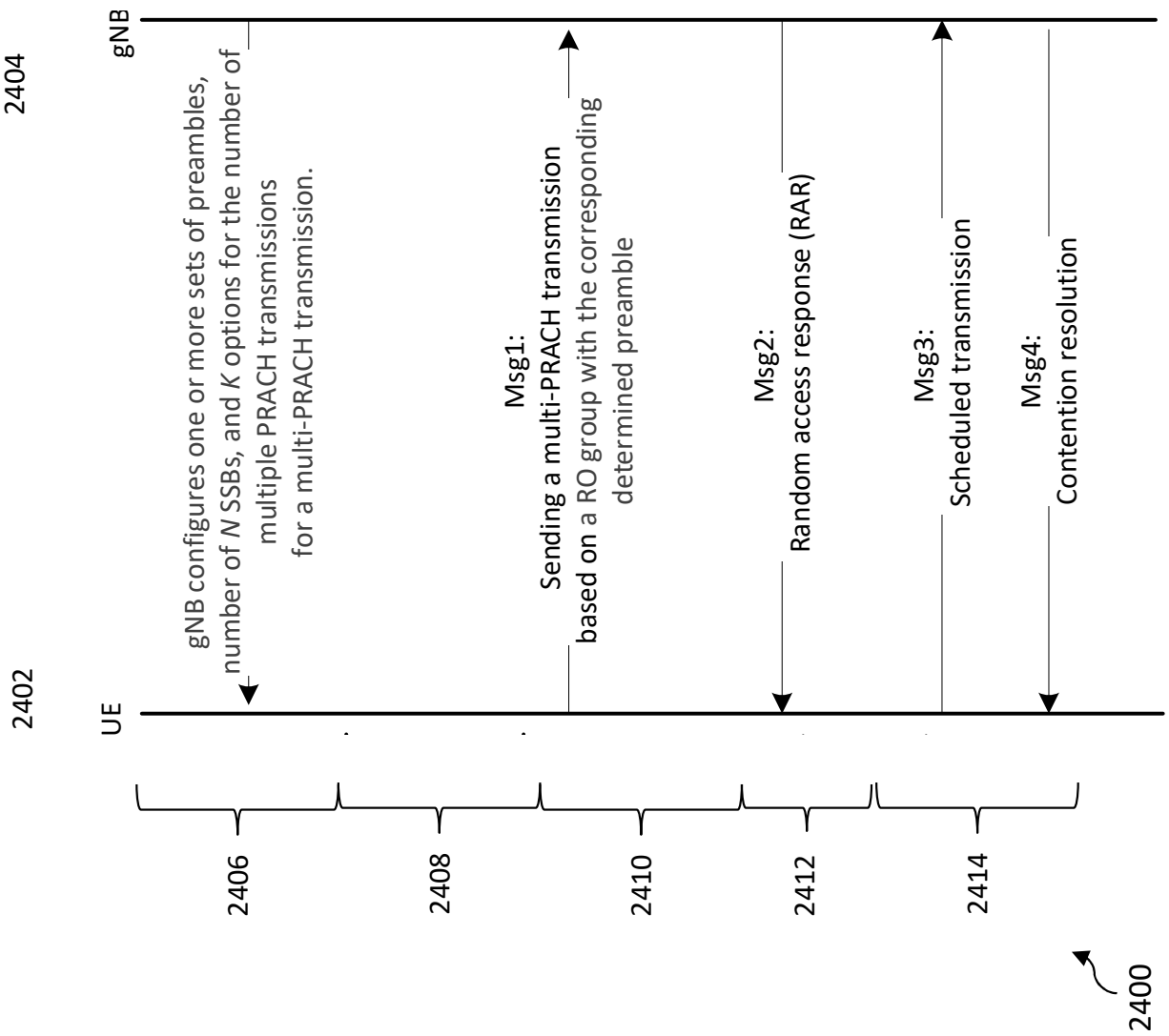

2402
2404
UE
gNB
gNB configures one or more sets of preambles, number of N SSBs, and K options for the number of multiple PRACH transmissions for a multi-PRACH transmission.
Msg1: Sending a multi-PRACH transmission based on a RO group with the corresponding determined preamble
Msg2: Random access response (RAR)
Msg3: Scheduled transmission
Msg4: Contention resolution
2406
2408
2410
2412
2414
2400

Fig. 24

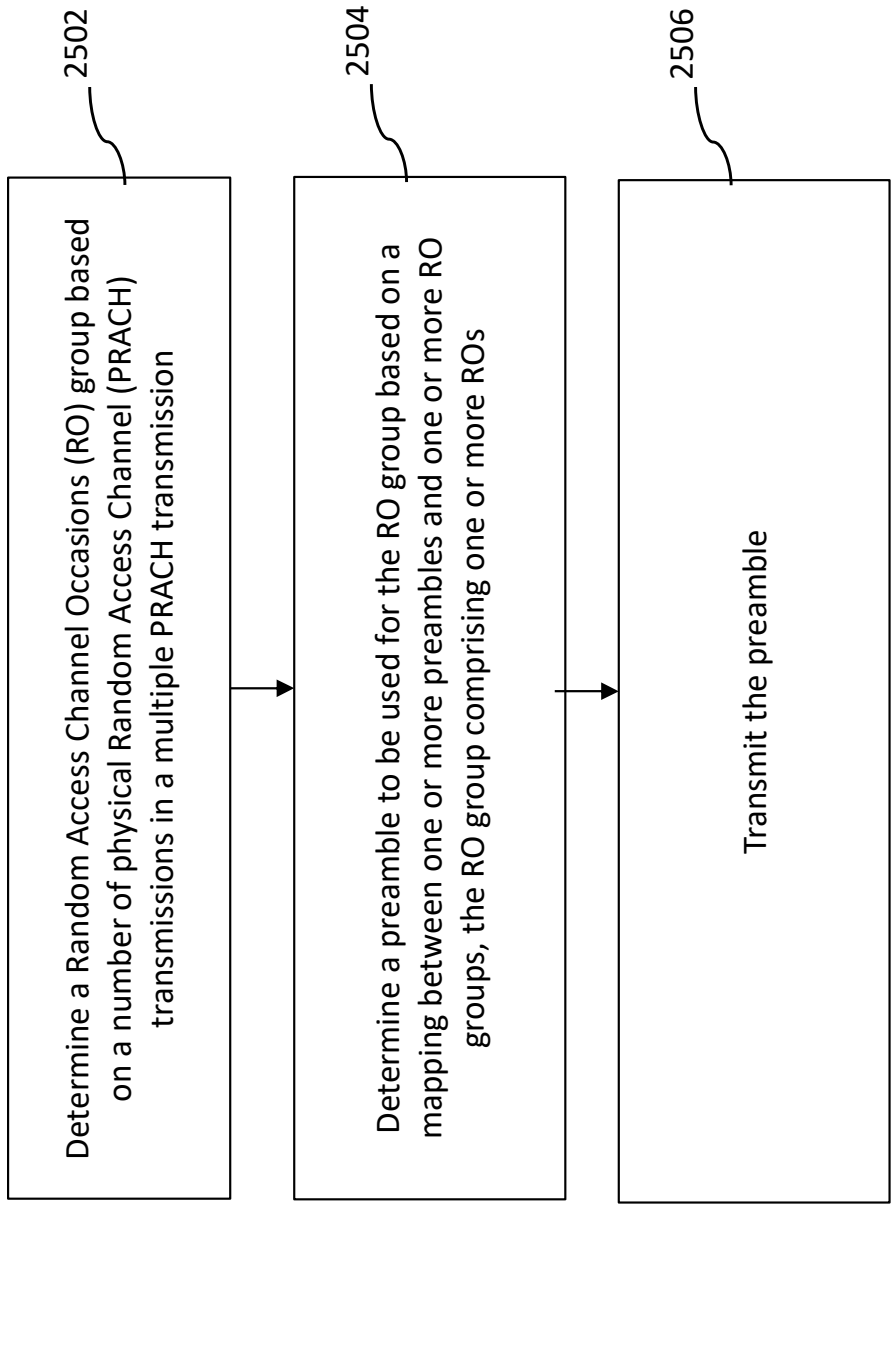

2502
Determine a Random Access Channel Occasions (RO) group based on a number of physical Random Access Channel (PRACH) transmissions in a multiple PRACH transmission
2504
Determine a preamble to be used for the RO group based on a mapping between one or more preambles and one or more RO groups, the RO group comprising one or more ROs
2506
Transmit the preamble
2500

Fig. 25

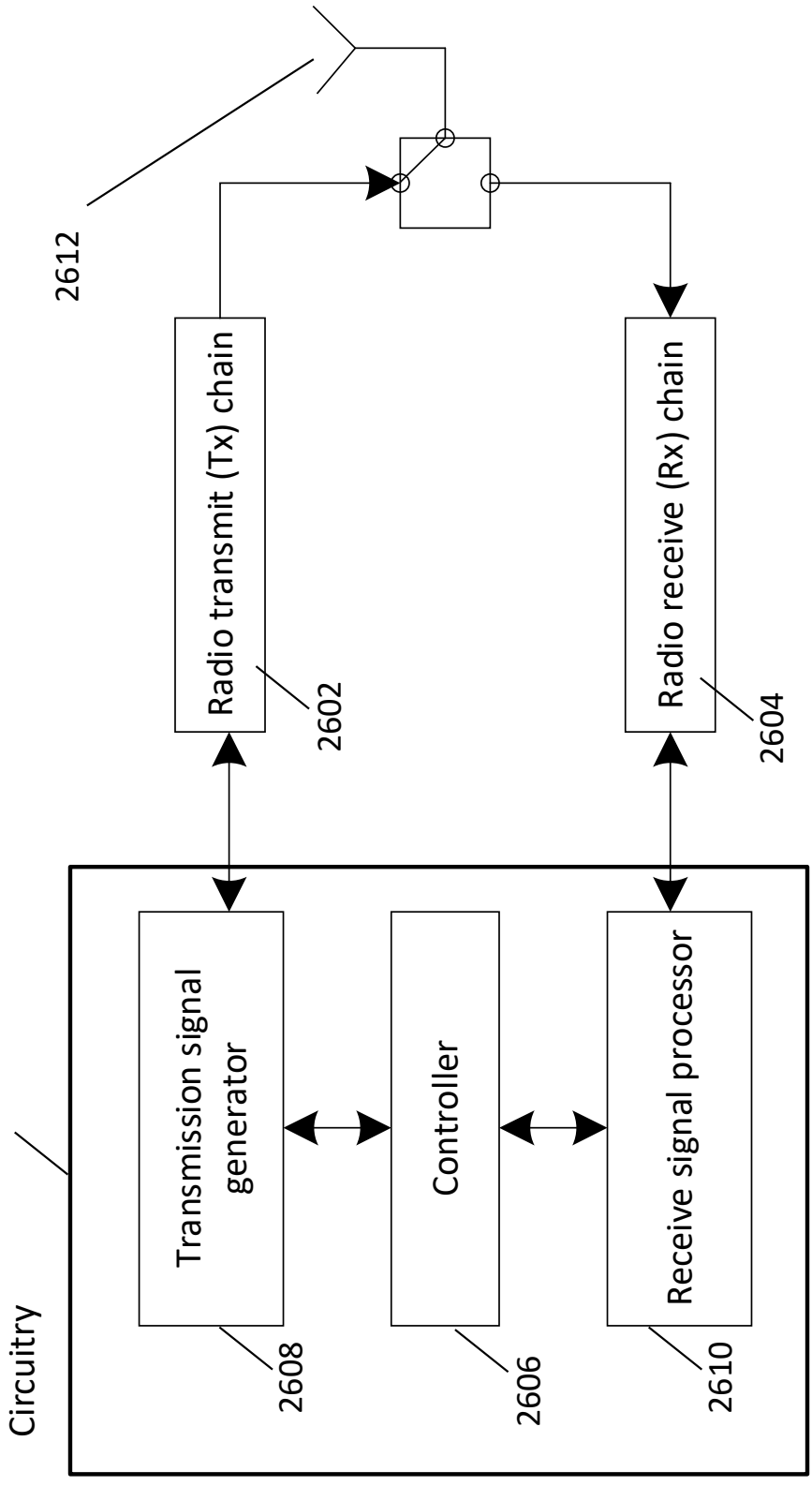

2612
Radio transmit (Tx) chain
2602
Radio receive (Rx) chain
2604
2614
Circuitry
Transmission signal generator
2608
Controller
2606
Receive signal processor
2610
2600

Fig. 26

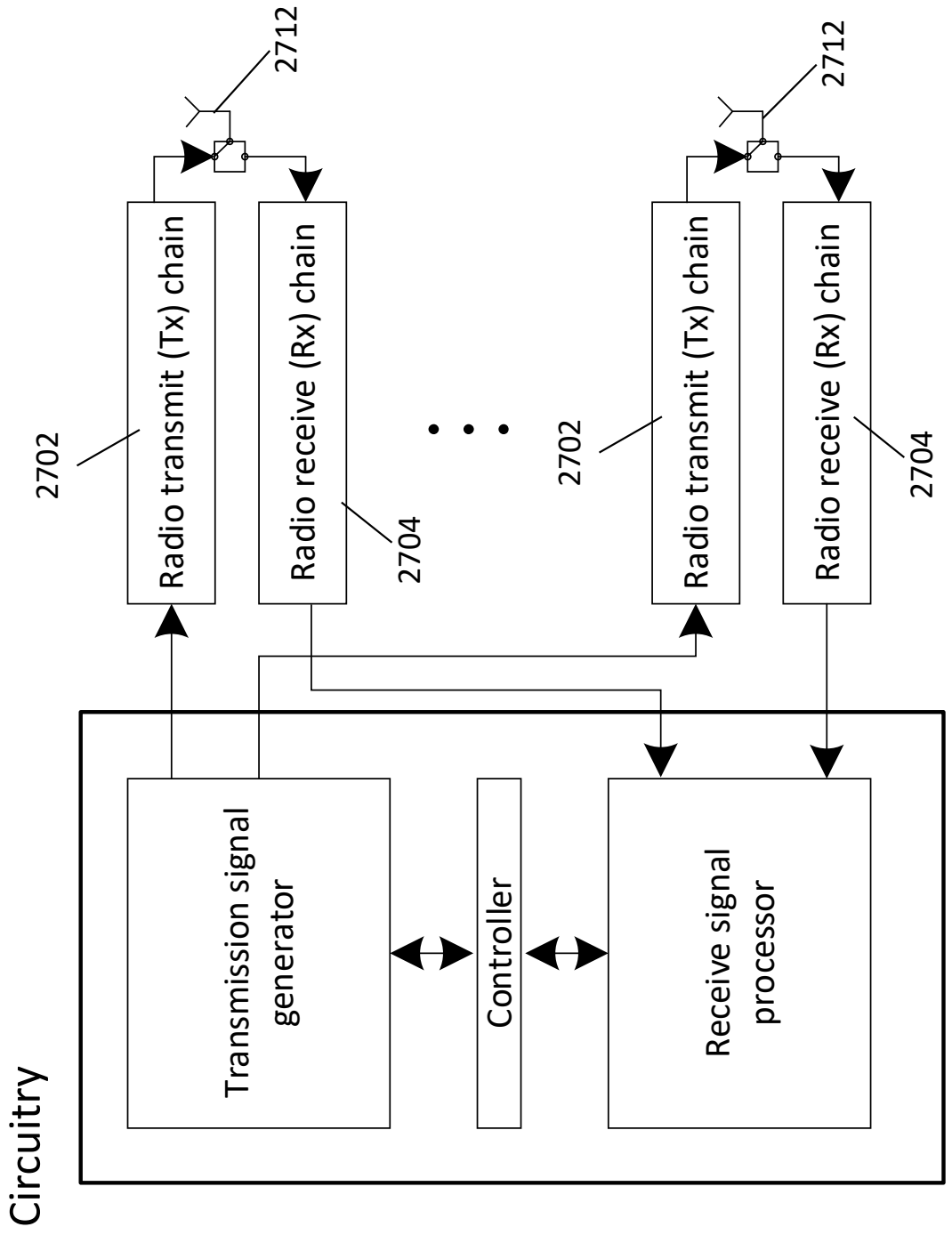

Circuitry
Transmission signal generator
Controller
Receive signal processor
2700
Radio transmit (Tx) chain
Radio receive (Rx) chain
2702
2704
2712

Fig. 27