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(54) **GRANT-LESS UPLINK TRANSMISSION FOR NEW RADIO**

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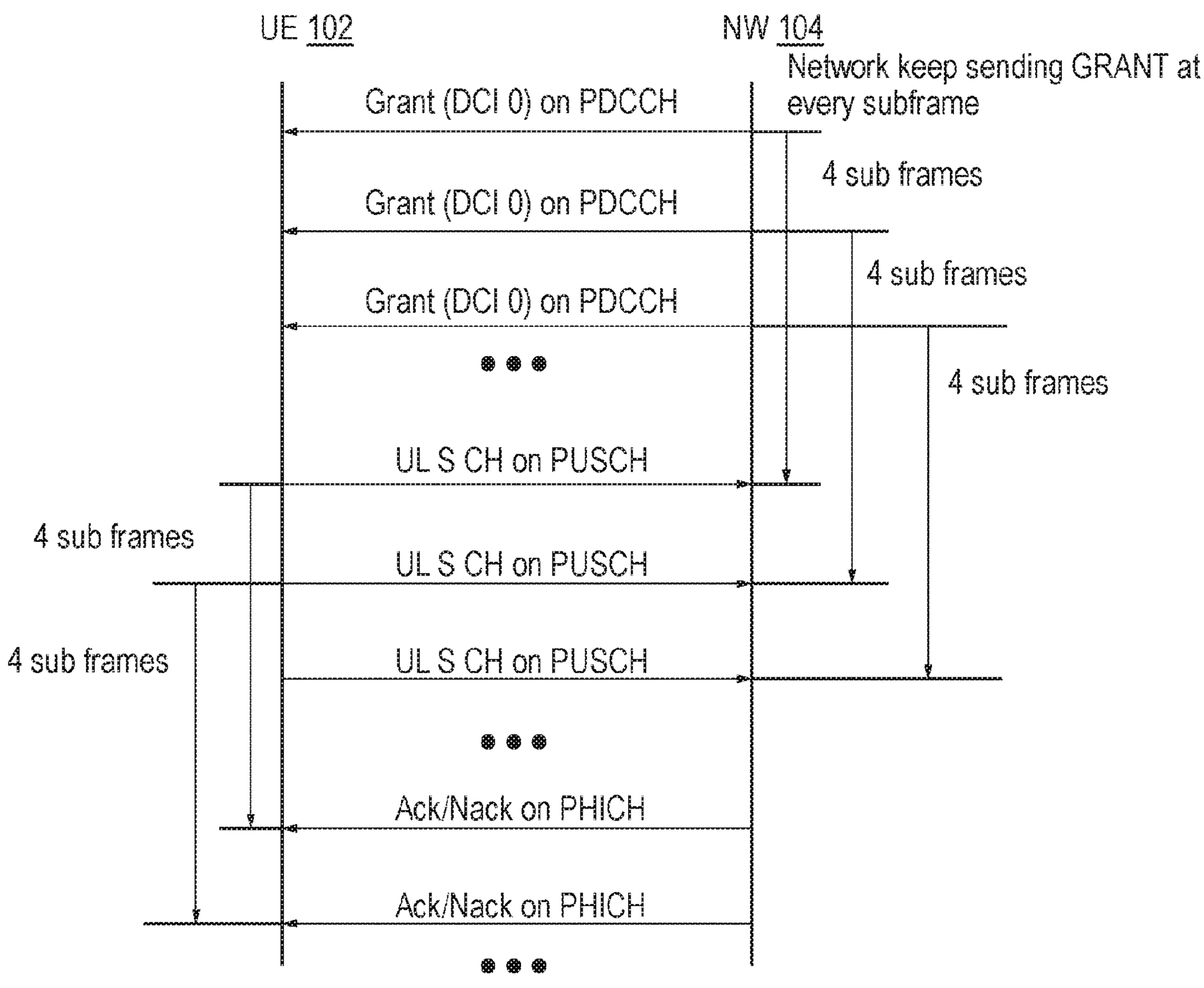
| *H04W 4/00* | (2009.01) |

(52) **U.S. Cl.**
CPC ... ***H04W 72/1268*** (2013.01); ***H04W 74/0816*** (2013.01); ***H04L 5/0007*** (2013.01); *H04W 4/005* (2013.01)

(57) **ABSTRACT**

Current approaches to transmitting uplink data in a network often require resources to be granted. In an example, a node or apparatus may configure a plurality of devices to operate in a grant-less mode in accordance with a respective grant-less access allocation, such that, when the plurality of devices transmit messages uplink in the network, the messages are transmitted using frequency resources defined by the respective grant-less access allocation, and the plurality of devices transmit the messages without being granted access to transmit the messages, so as to operate in the grant-less mode.



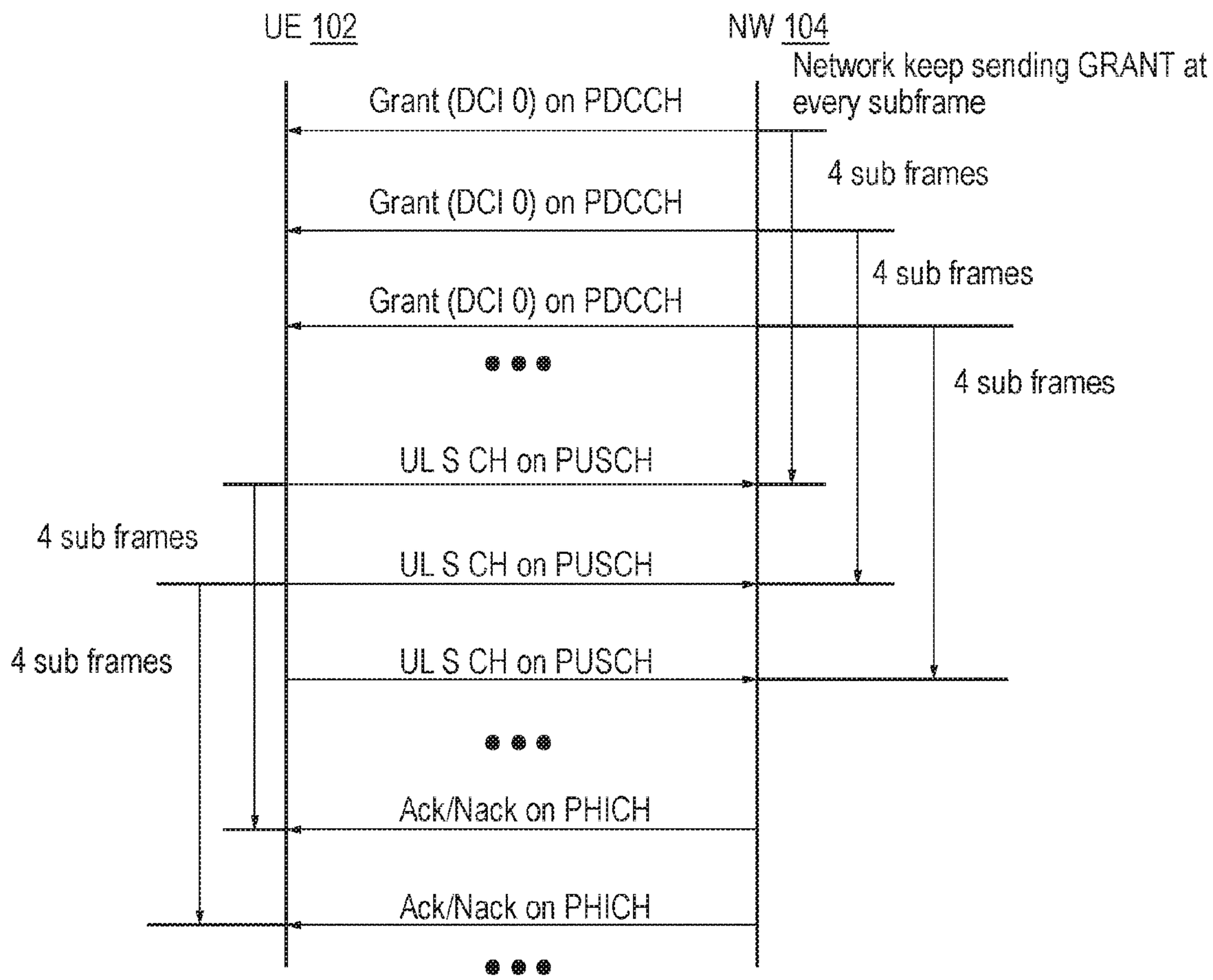

UE 102
NW 104
Network keep sending GRANT at every subframe
Grant (DCI 0) on PDCCH
4 sub frames
Grant (DCI 0) on PDCCH
4 sub frames
Grant (DCI 0) on PDCCH
4 sub frames
UL S CH on PUSCH
4 sub frames
UL S CH on PUSCH
4 sub frames
UL S CH on PUSCH
Ack/Nack on PHICH
Ack/Nack on PHICH

FIG. 1

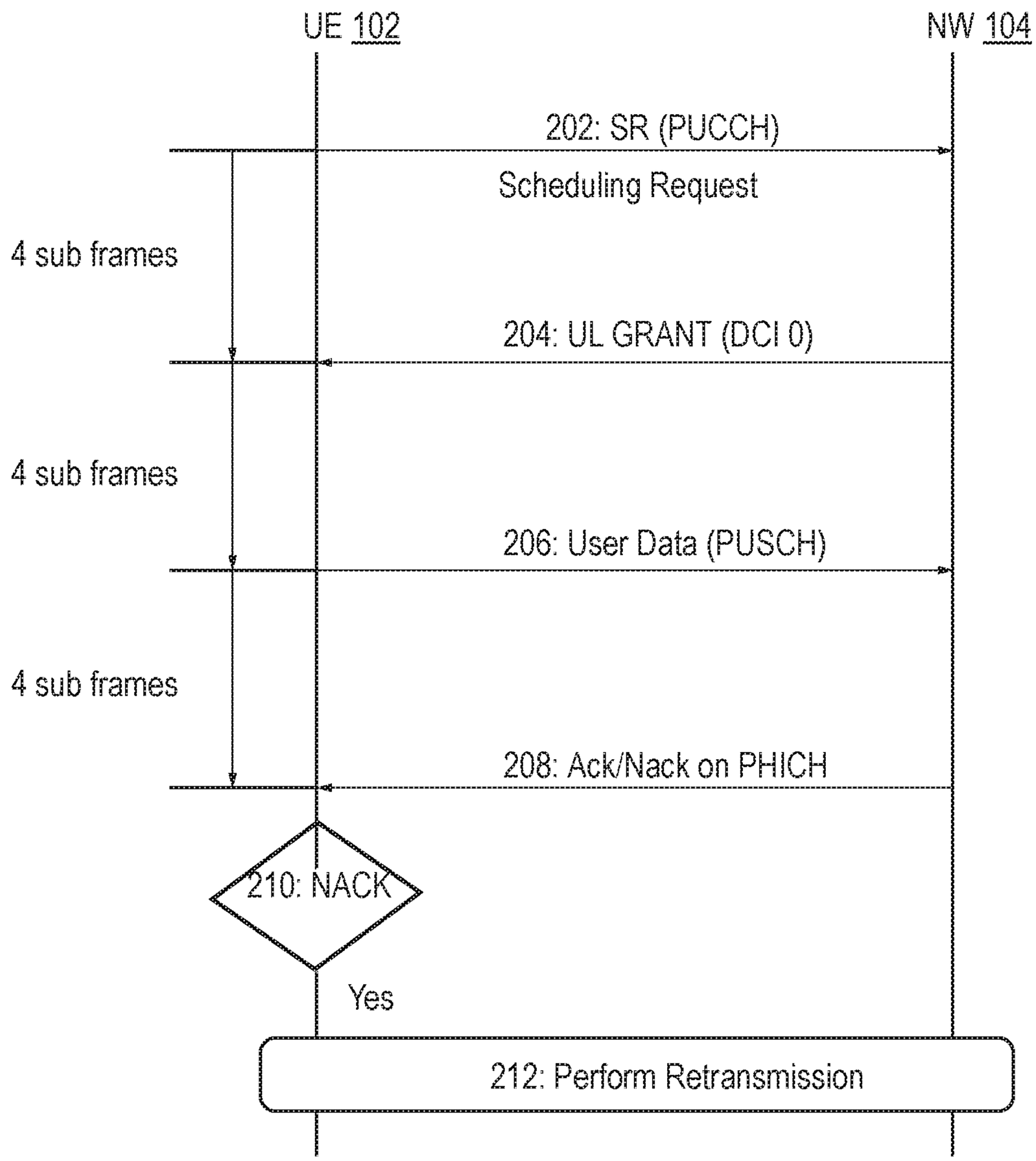

UE 102
NW 104
202: SR (PUCCH)
Scheduling Request
4 sub frames
204: UL GRANT (DCI 0)
4 sub frames
206: User Data (PUSCH)
4 sub frames
208: Ack/Nack on PHICH
210: NACK
Yes
212: Perform Retransmission

FIG. 2

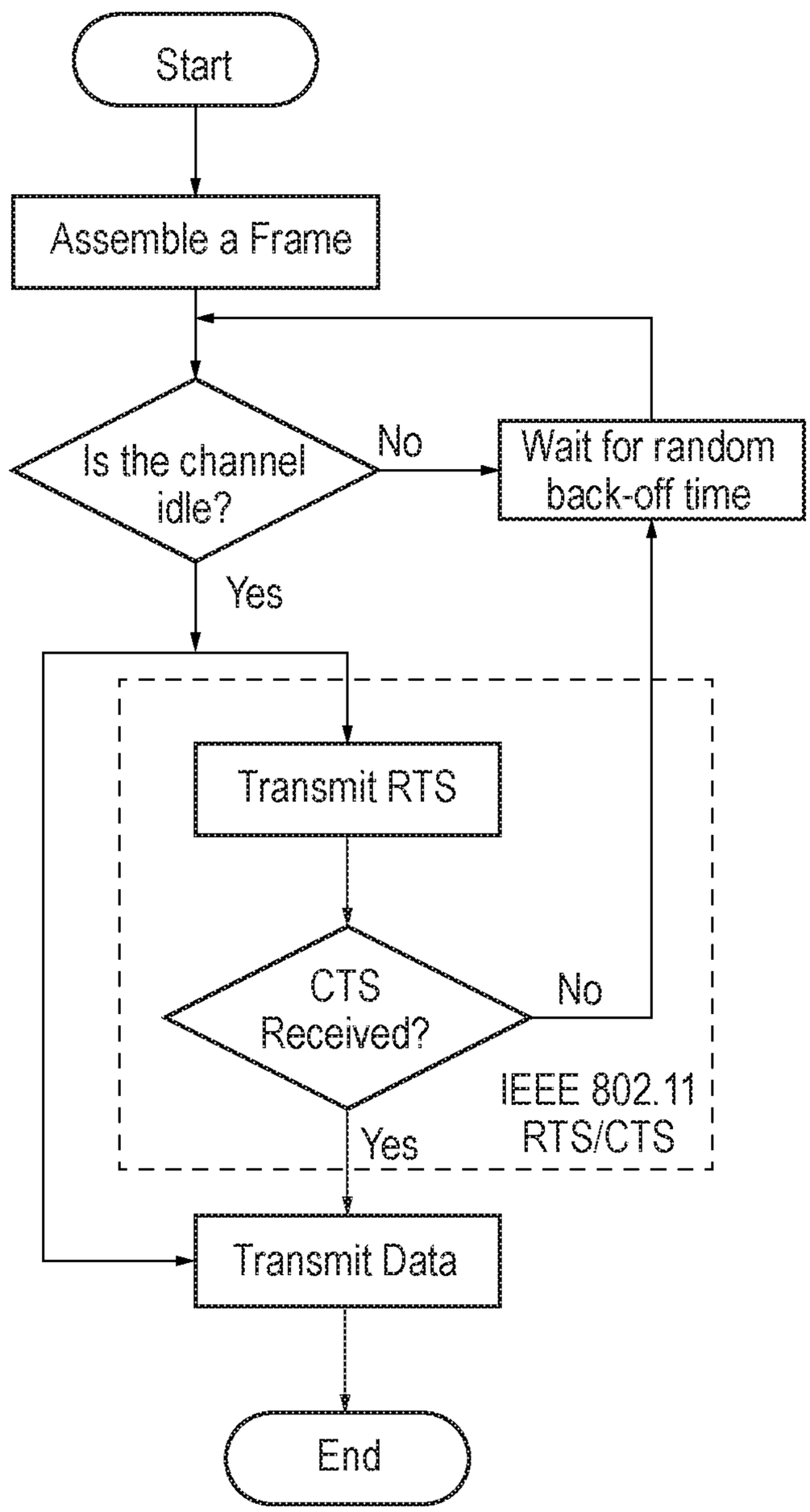

Start
Assemble a Frame
Is the channel idle?
No
Wait for random back-off time
Yes
Transmit RTS
CTS Received?
No
IEEE 802.11 RTS/CTS
Yes
Transmit Data
End

FIG. 3

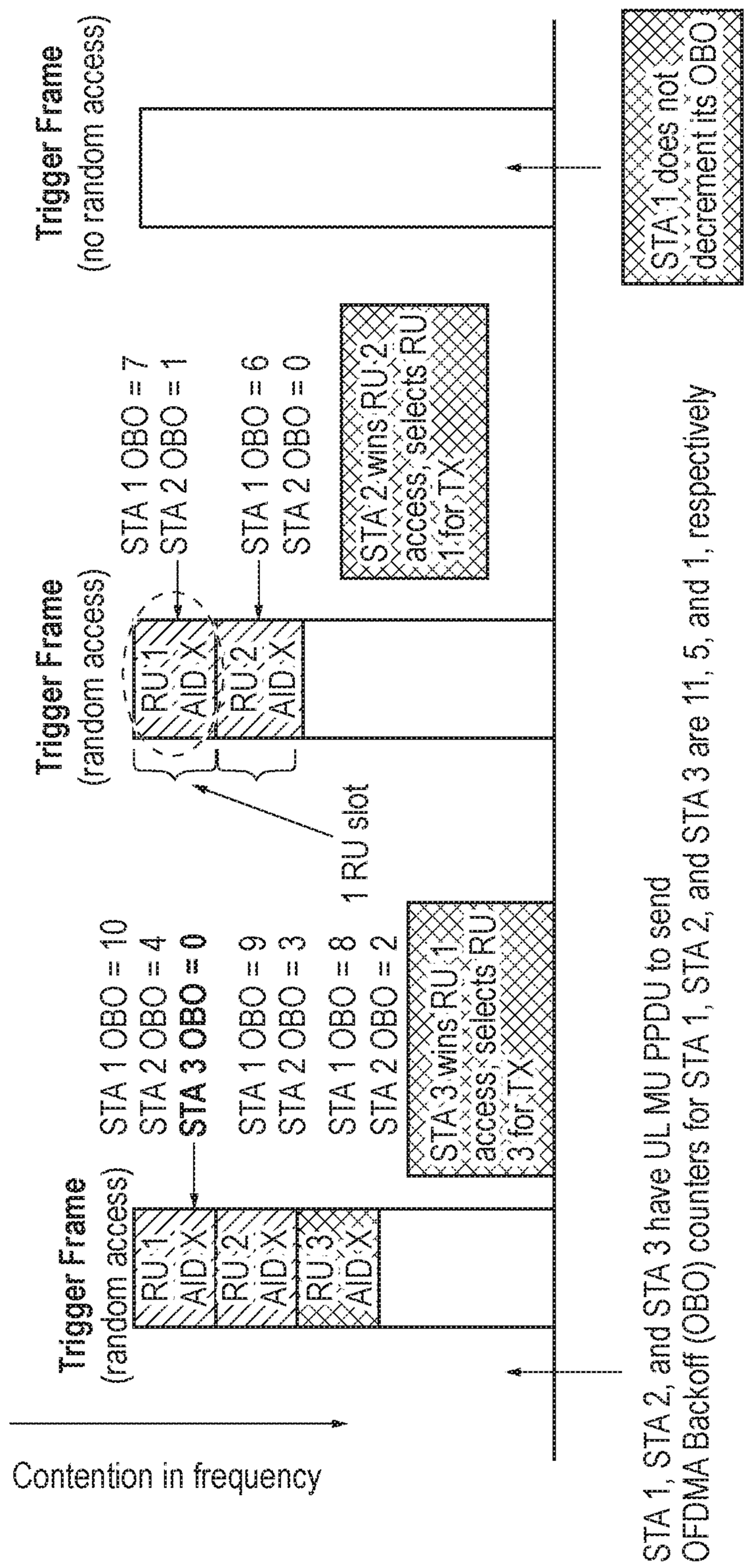

Trigger Frame
(no random access)
STA 1 does not decrement its OBO
Trigger Frame
(random access)
STA 1 OBO = 7
STA 2 OBO = 1
STA 1 OBO = 6
STA 2 OBO = 0
RU 1
AID X
RU 2
AID X
STA 2 wins RU 2, access, selects RU 1 for TX
1 RU slot
STA 1 OBO = 10
STA 2 OBO = 4
STA 3 OBO = 0
STA 1 OBO = 9
STA 2 OBO = 3
STA 1 OBO = 8
STA 2 OBO = 2
STA 3 wins RU 1, access, selects RU 3 for TX
Trigger Frame
(random access)
RU 1
AID X
RU 2
AID X
RU 3
AID X
Contention in frequency
STA 1, STA 2, and STA 3 have UL MU PPDU to send
OFDMA Backoff (OBO) counters for STA 1, STA 2, and STA 3 are 11, 5, and 1, respectively

FIG. 4

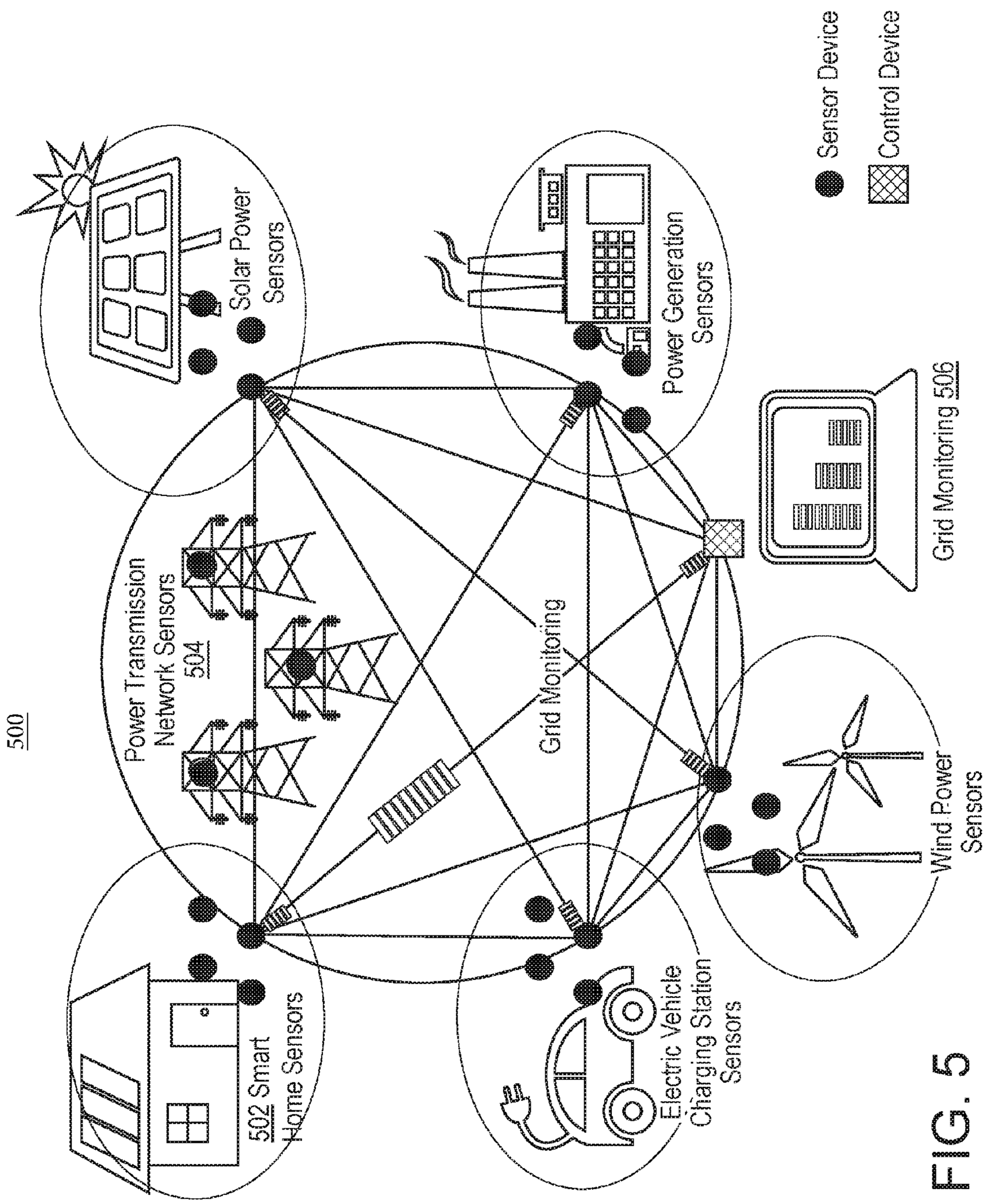

500
Sensor Device
Control Device
Solar Power Sensors
Power Generation Sensors
Grid Monitoring 506
Power Transmission Network Sensors 504
Grid Monitoring
Wind Power Sensors
502 Smart Home Sensors
Electric Vehicle Charging Station Sensors

FIG. 5

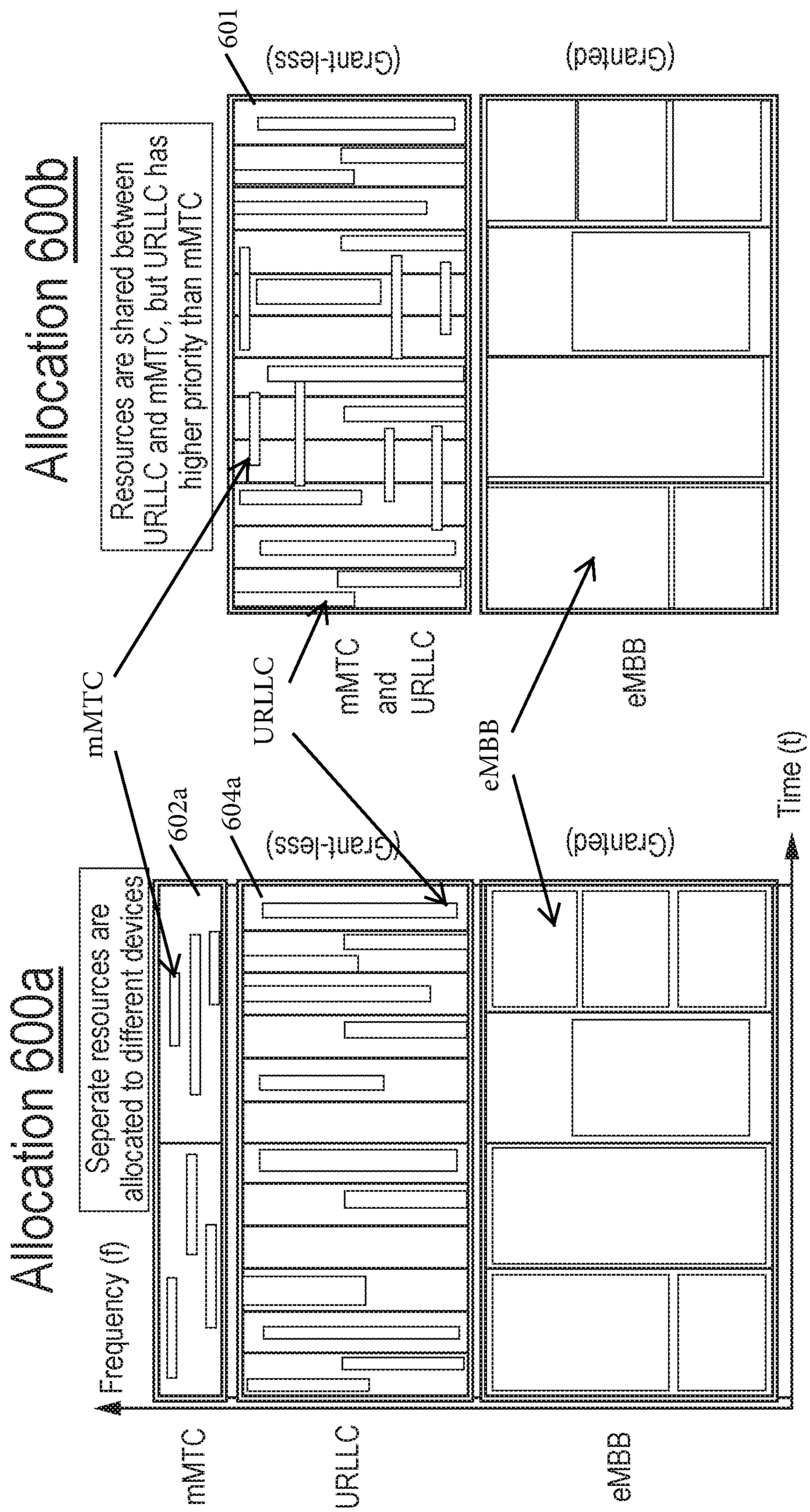

Allocation 600a
Seperate resources are allocated to different devices
Frequency (f)
mMTC
URLLC
eMBB
602a
604a
(Grant-less)
(Granted)
Time (t)
Allocation 600b
Resources are shared between URLLC and mMTC, but URLLC has higher priority than mMTC
601
(Grant-less)
(Granted)
mMTC
URLLC
mMTC and URLLC
eMBB

FIG. 6

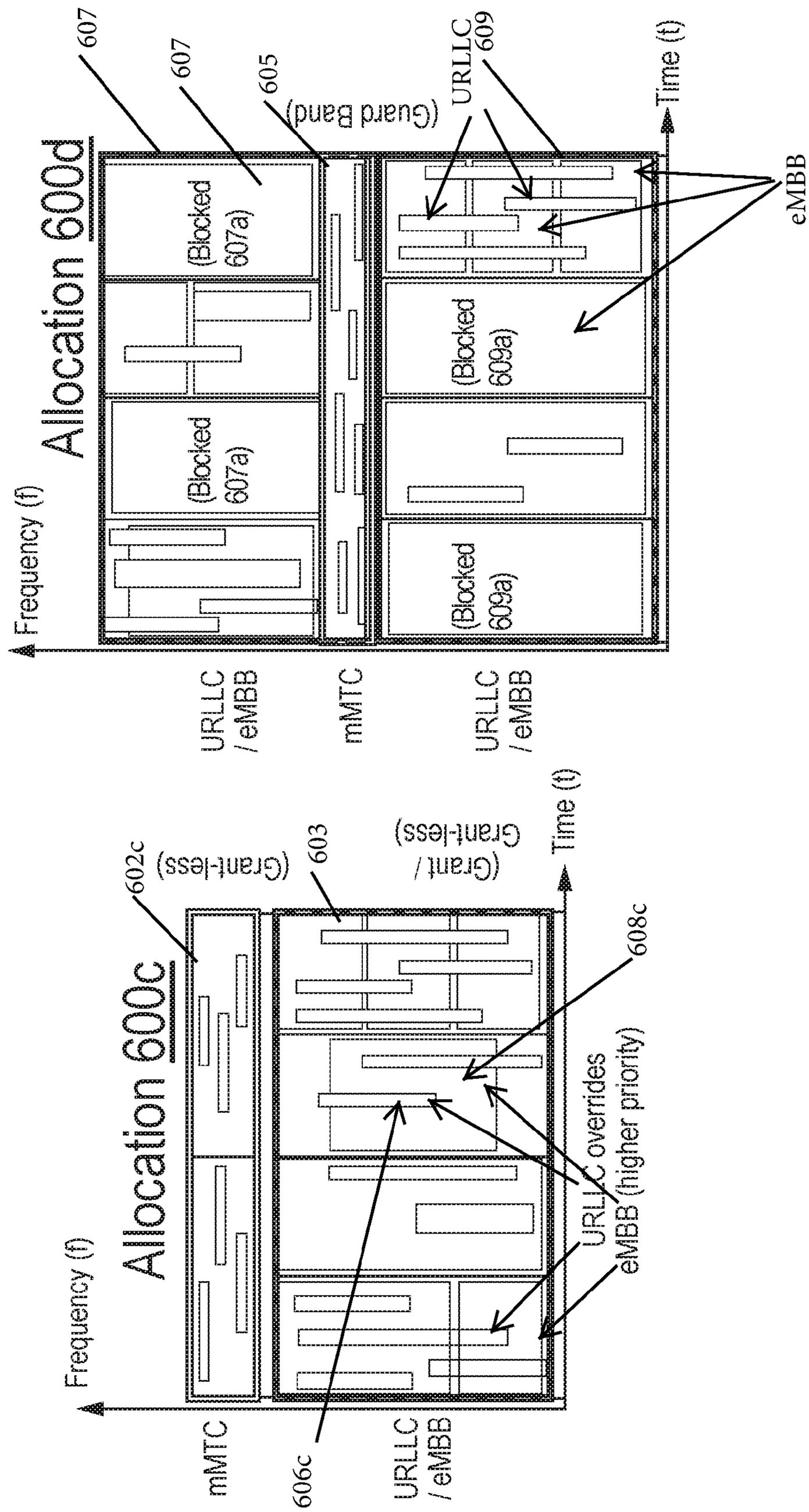

Allocation 600d
Frequency (f)
Time (t)
607
607
605
(Guard Band)
URLLC
609
eMBB
(Blocked 607a)
(Blocked 607a)
(Blocked 609a)
(Blocked 609a)
URLLC / eMBB
mMTC
URLLC / eMBB
Allocation 600c
Frequency (f)
Time (t)
602c
(Grant-less)
603
(Grant / Grant-less)
608c
URLLC overrides eMBB (higher priority)
606c
mMTC
URLLC / eMBB

FIG. 7

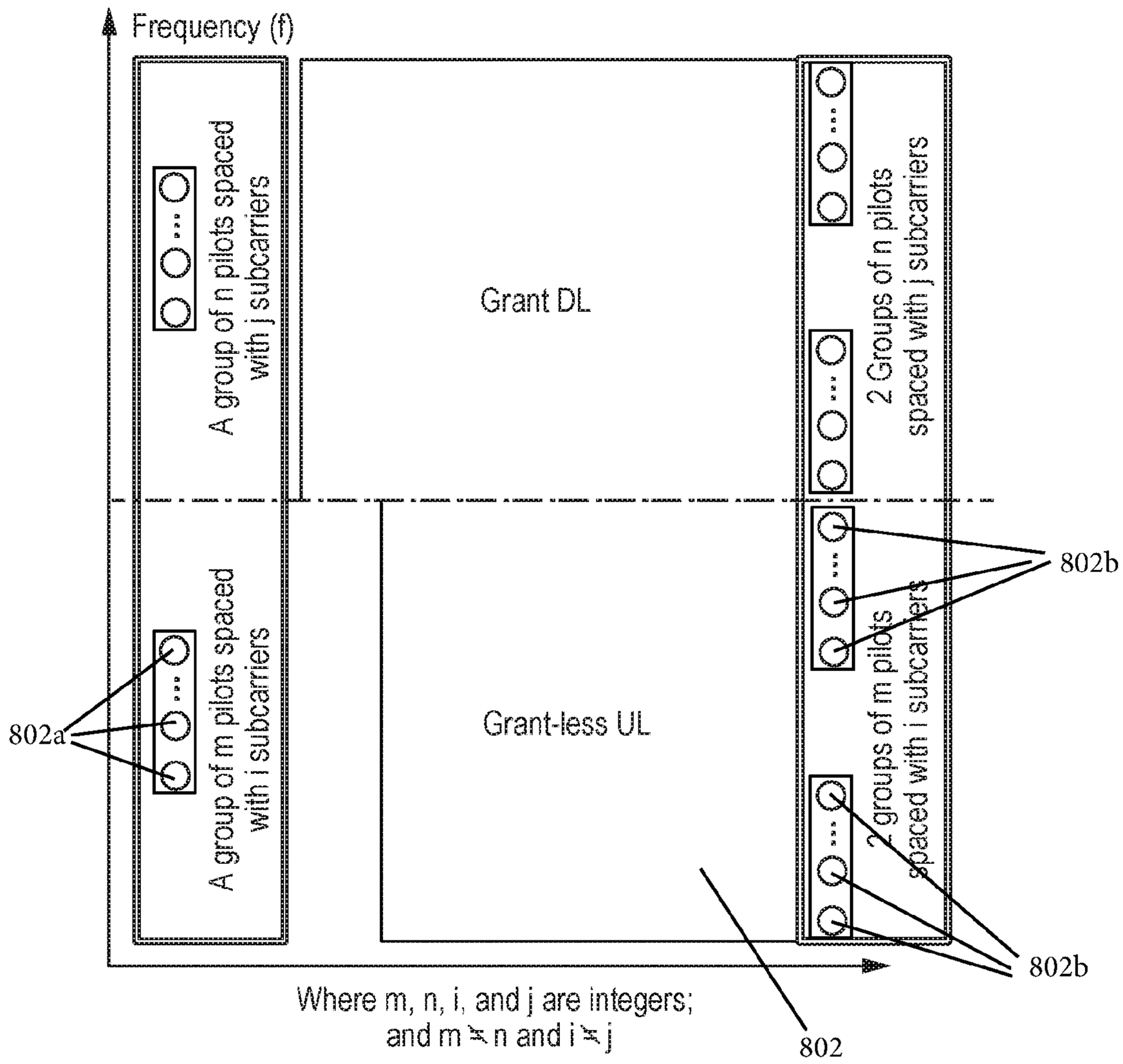

Frequency (f)
A group of n pilots spaced with j subcarriers
Grant DL
2 Groups of n pilots spaced with j subcarriers
A group of m pilots spaced with i subcarriers
Grant-less UL
2 groups of m pilots spaced with i subcarriers
802a
802b
802b
802
Where m, n, i, and j are integers;
and m ≯ n and i ≯ j

FIG. 8

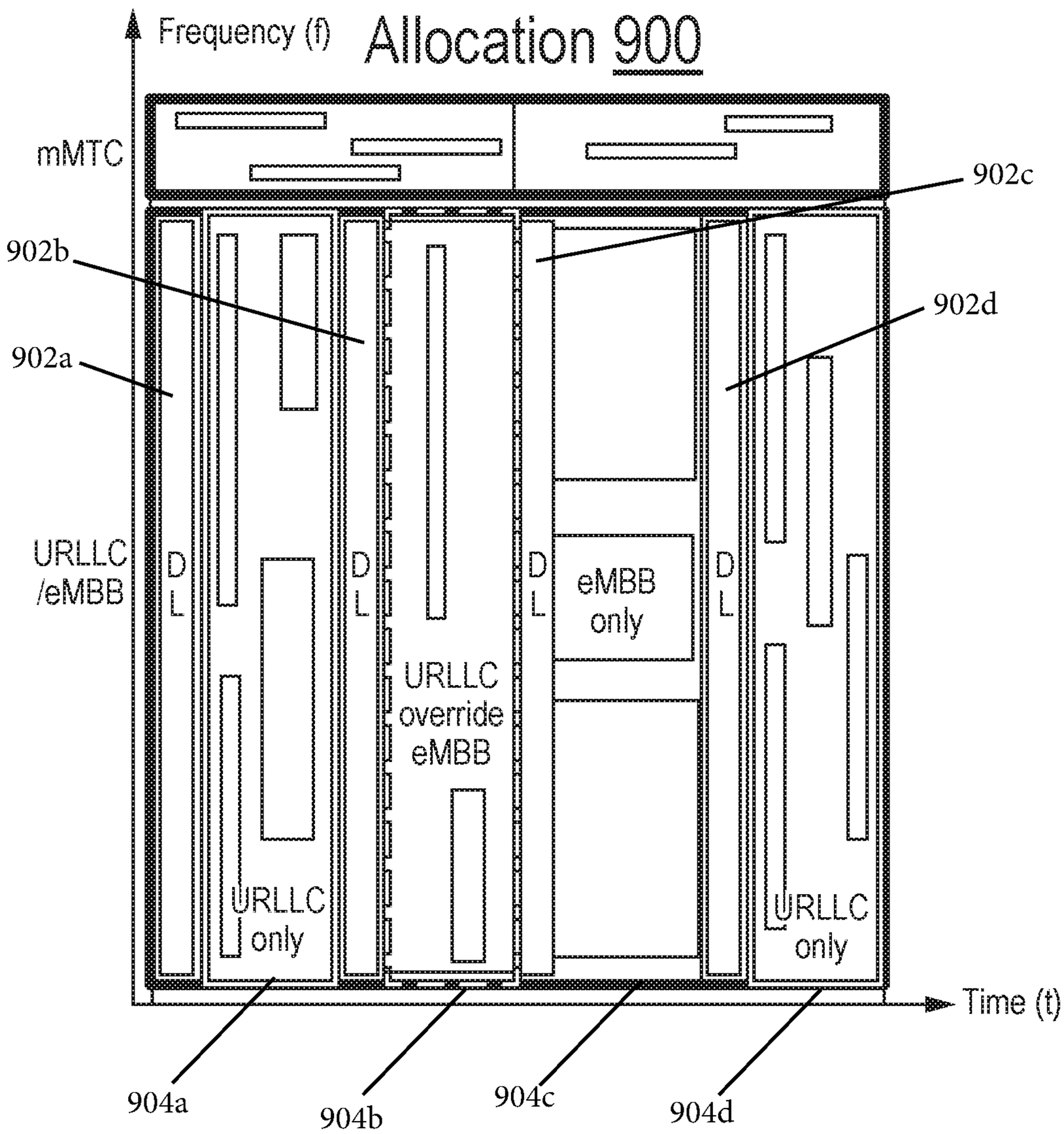

Frequency (f)
Allocation 900
mMTC
902c
902b
902d
902a
URLLC
/eMBB
D
L
D
L
D
L
eMBB
only
D
L
URLLC
override
eMBB
URLLC
only
URLLC
only
Time (t)
904a
904b
904c
904d

FIG. 9

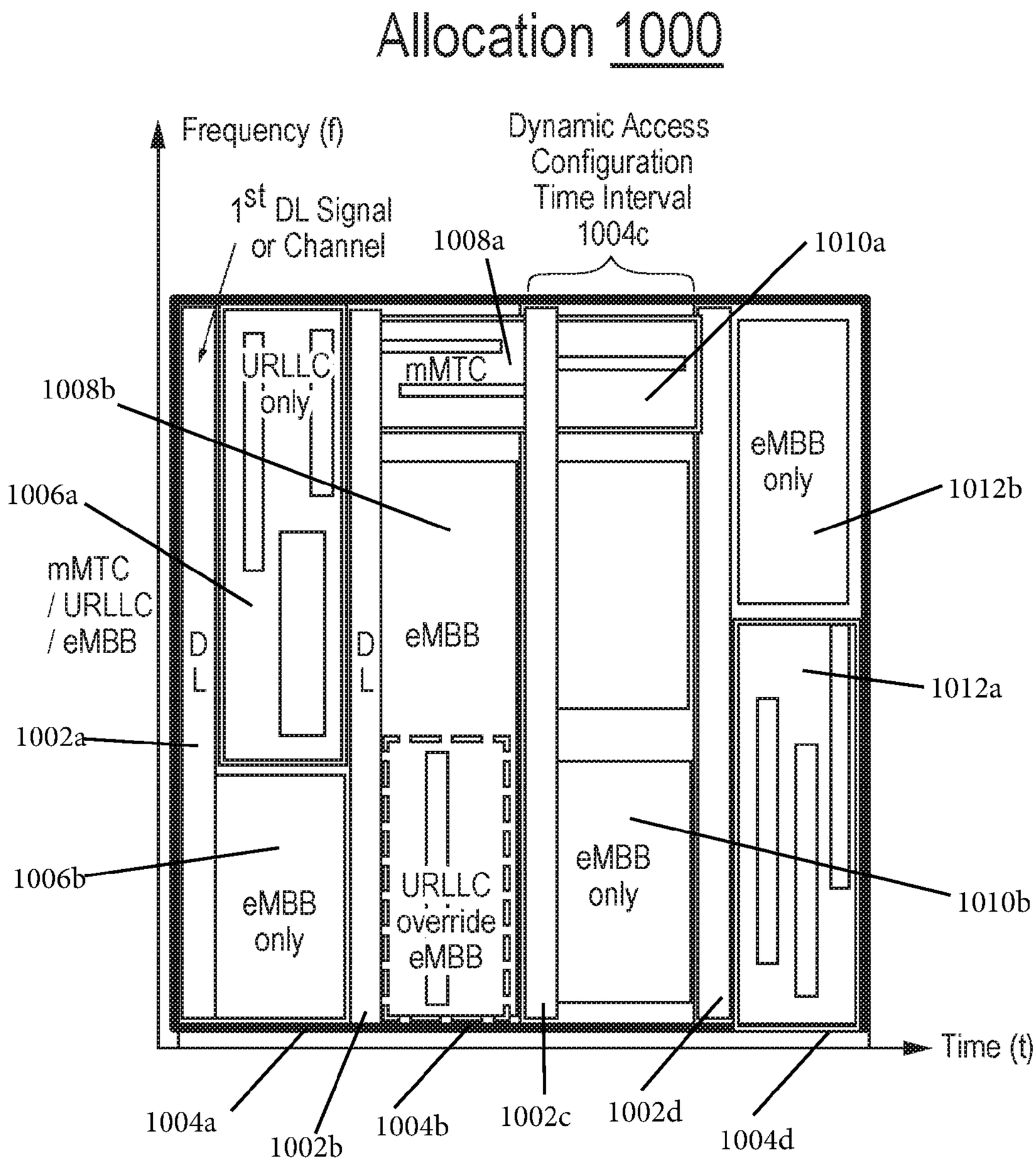

Allocation 1000
Frequency (f)
Dynamic Access Configuration Time Interval 1004c
1st DL Signal or Channel
1008a
1010a
URLLC only
mMTC
1008b
eMBB only
1012b
1006a
mMTC / URLLC / eMBB
D L
D L
eMBB
1012a
1002a
1006b
eMBB only
URLLC override eMBB
eMBB only
1010b
Time (t)
1004a
1002b
1004b
1002c
1002d
1004d

FIG. 10

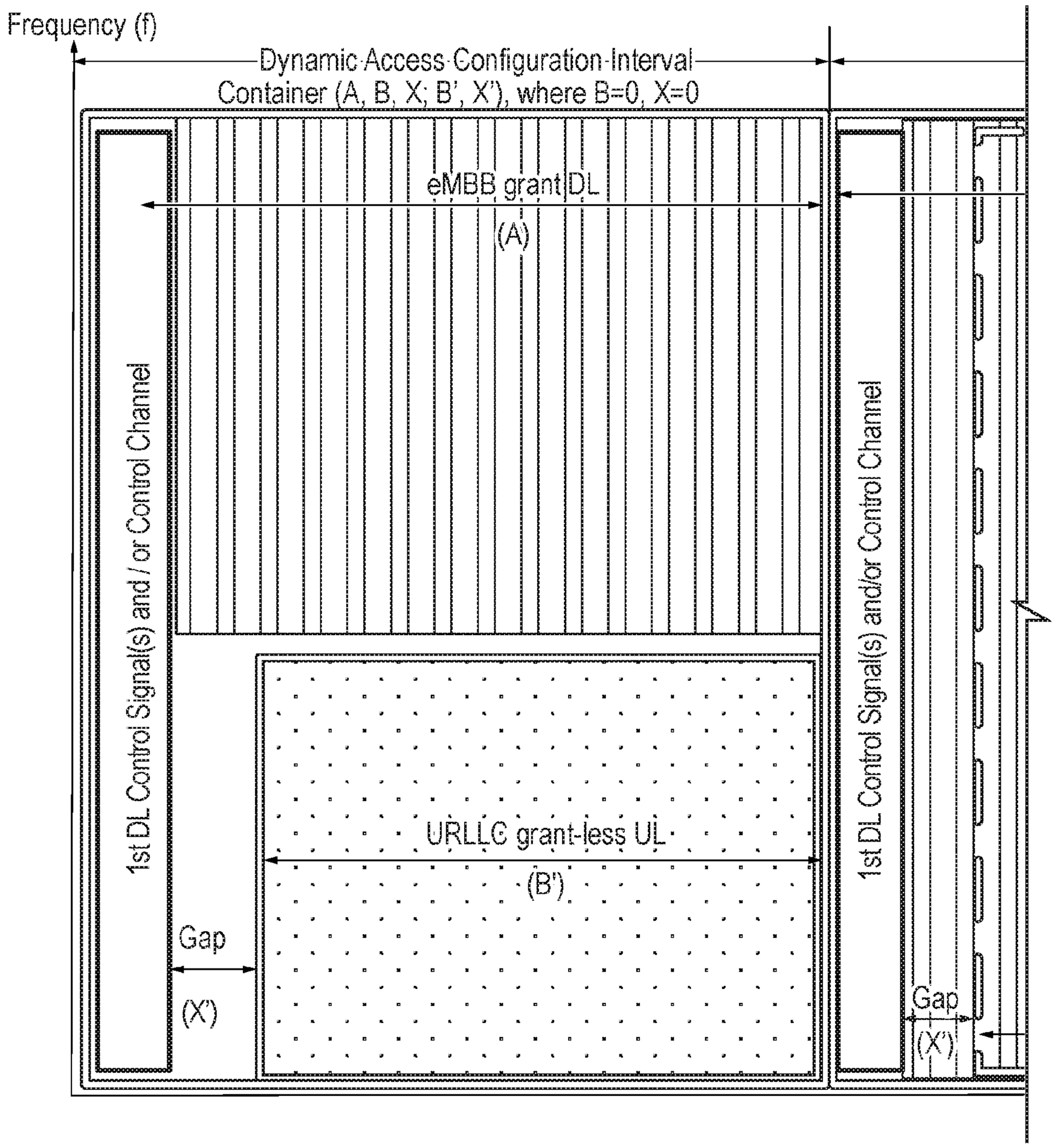

Frequency (f)
Dynamic Access Configuration Interval
Container (A, B, X; B', X'), where B=0, X=0
eMBB grant DL
(A)
1st DL Control Signal(s) and / or Control Channel
1st DL Control Signal(s) and/or Control Channel
URLLC grant-less UL
(B')
Gap
(X')
Gap
(X')

FIG. 11A

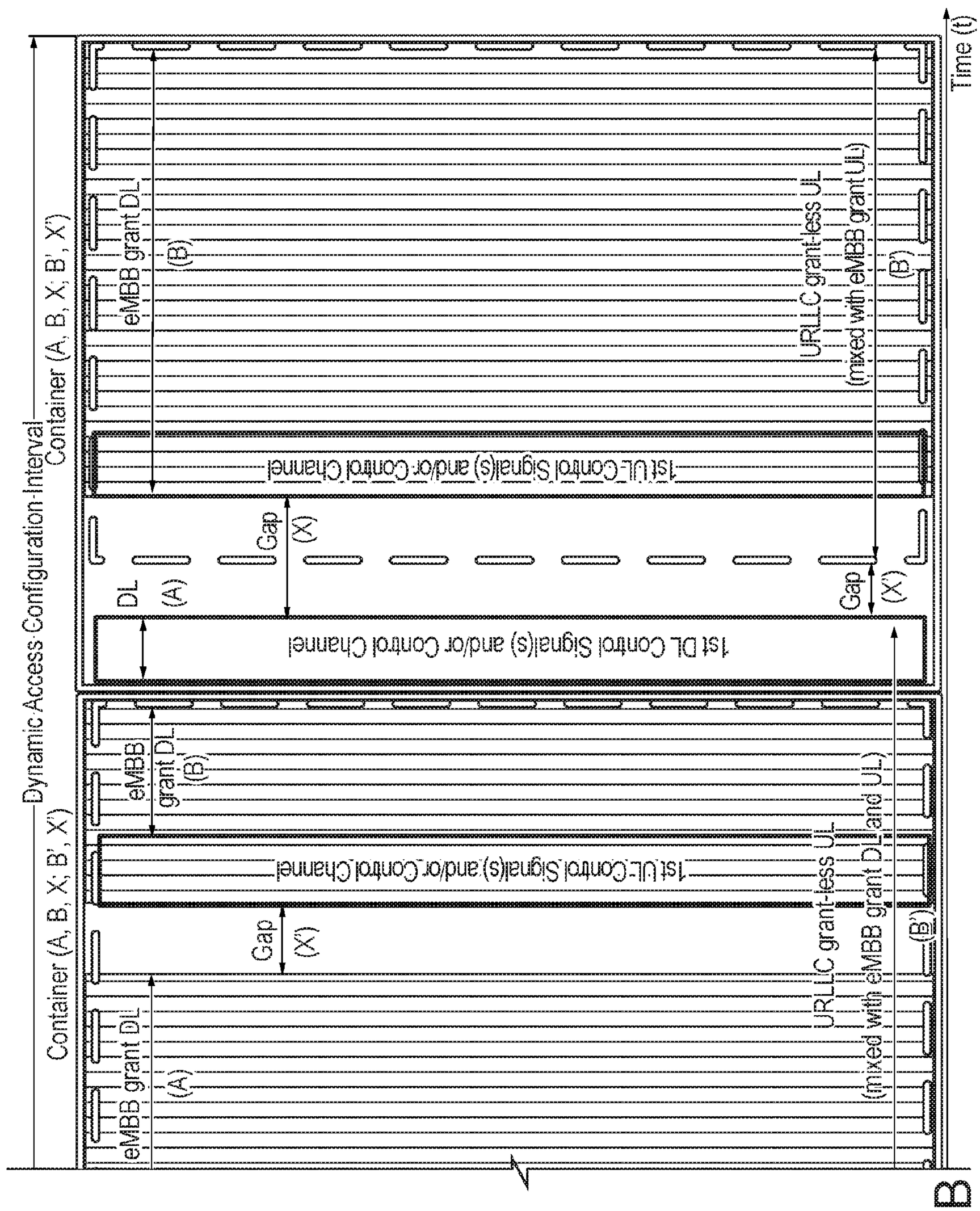

Dynamic Access Configuration Interval
Container (A, B, X, B', X')
eMBB grant DL
(A)
Gap
(X)
1st DL Control Signal(s) and/or Control Channel
DL
(A)
1st UL Control Signal(s) and/or Control Channel
eMBB grant DL
(B)
URLLC grant-less UL
(mixed with eMBB grant UL)
Gap
(X')
(B')
Container (A, B, X, B', X')
eMBB grant DL
(A)
Gap
(X')
1st UL Control Signal(s) and/or Control Channel
eMBB grant DL
(B)
URLLC grant-less UL
(mixed with eMBB grant DL and UL)
(B')
Time (t)

FIG. 11B

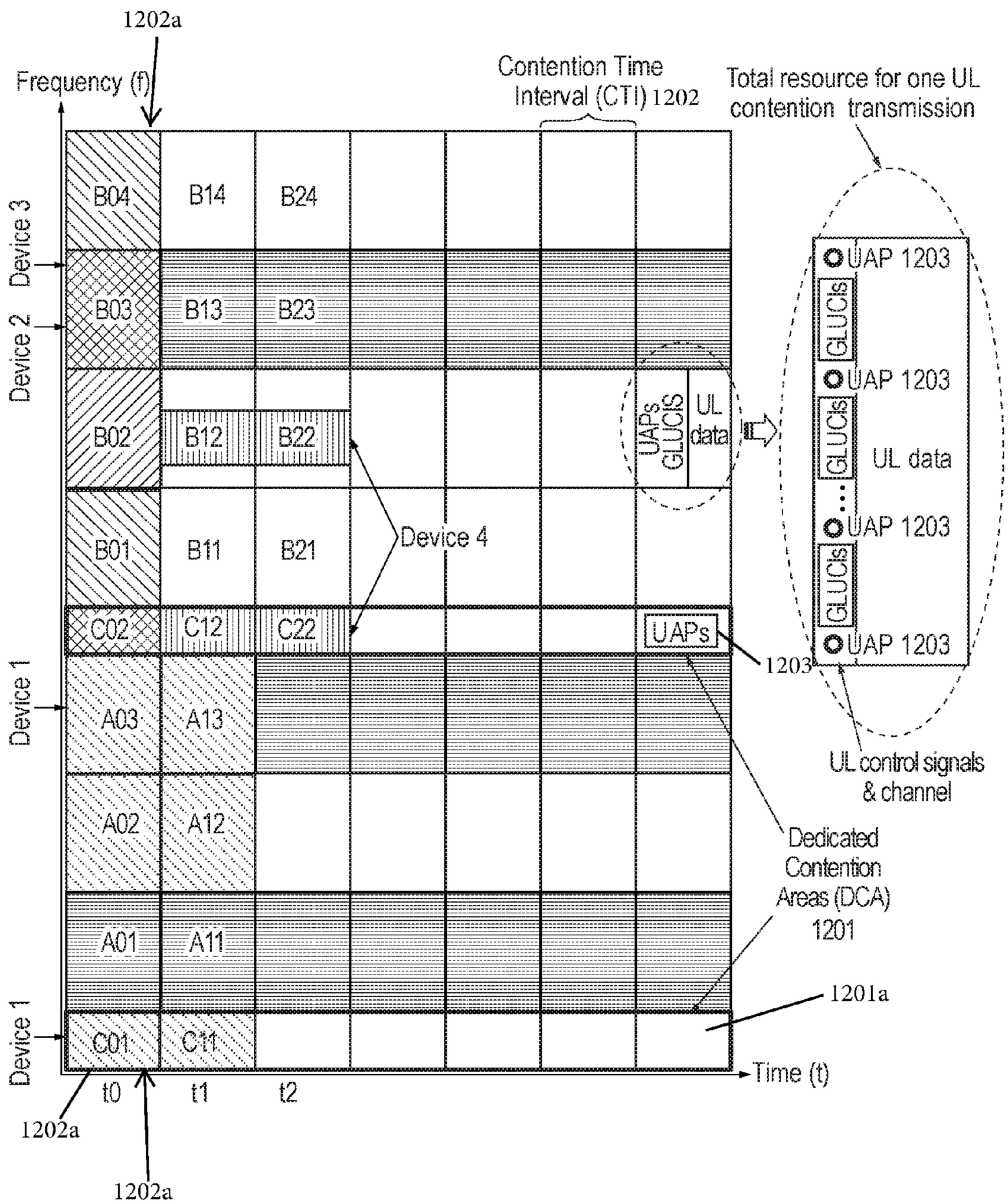
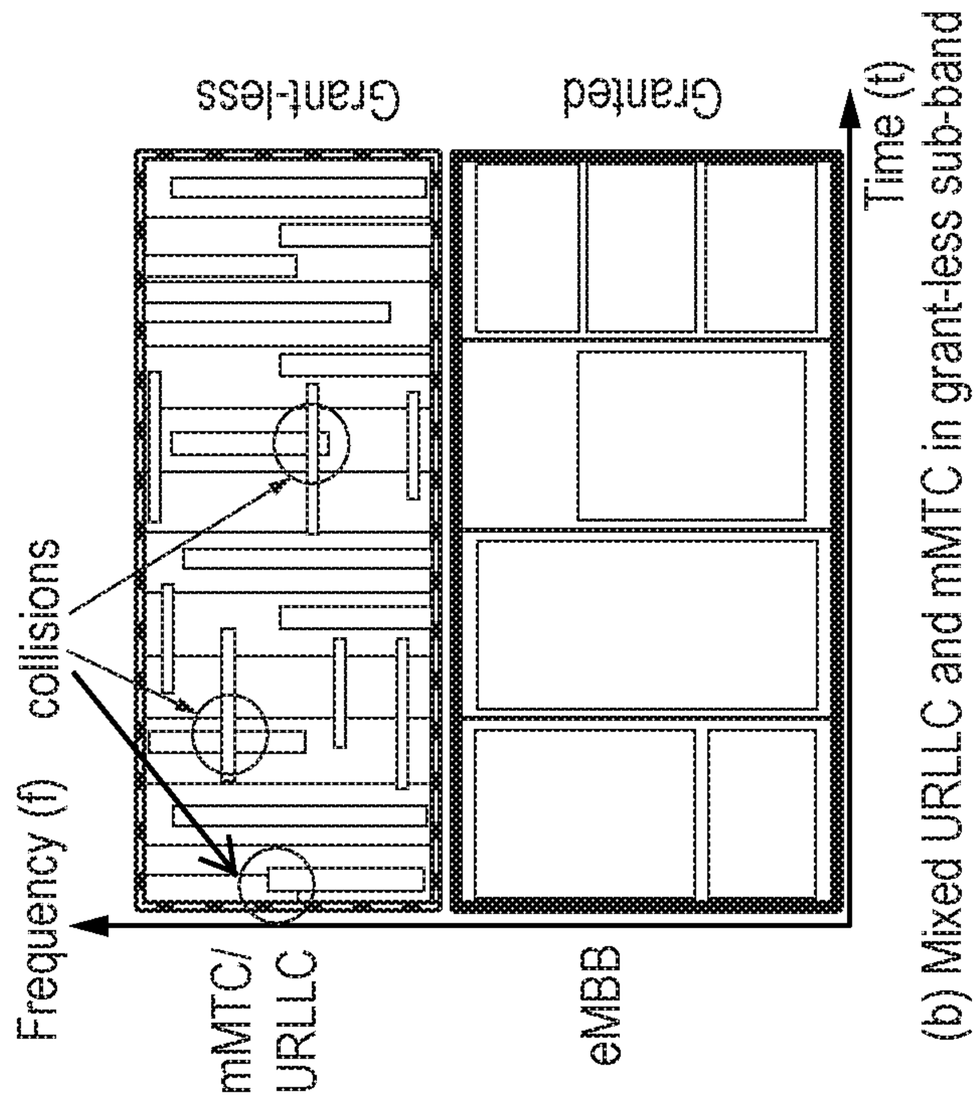
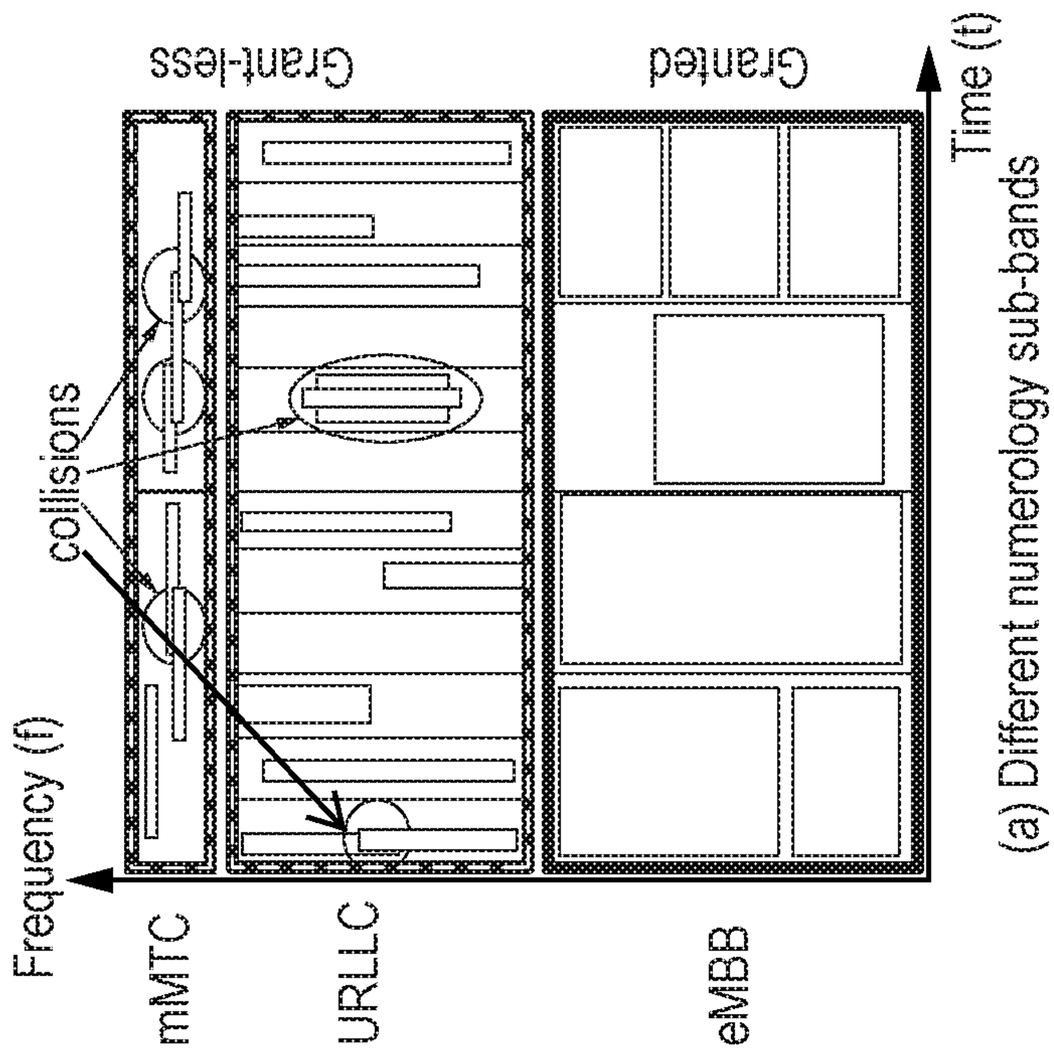

1202a
Frequency (f)
Contention Time Interval (CTI) 1202
Total resource for one UL contention transmission
Device 3
Device 2
Device 1
Device 1
B04
B14
B24
B03
B13
B23
B02
B12
B22
B01
B11
B21
C02
C12
C22
A03
A13
A02
A12
A01
A11
C01
C11
Device 4
UAPs
GLUCIs
UL data
UAP 1203
GLUCIs
UAP 1203
GLUCIs
UL data
UAP 1203
GLUCIs
UAP 1203
1203
UL control signals & channel
Dedicated Contention Areas (DCA) 1201
1201a
Time (t)
t0
t1
t2
1202a
1202a

FIG. 12



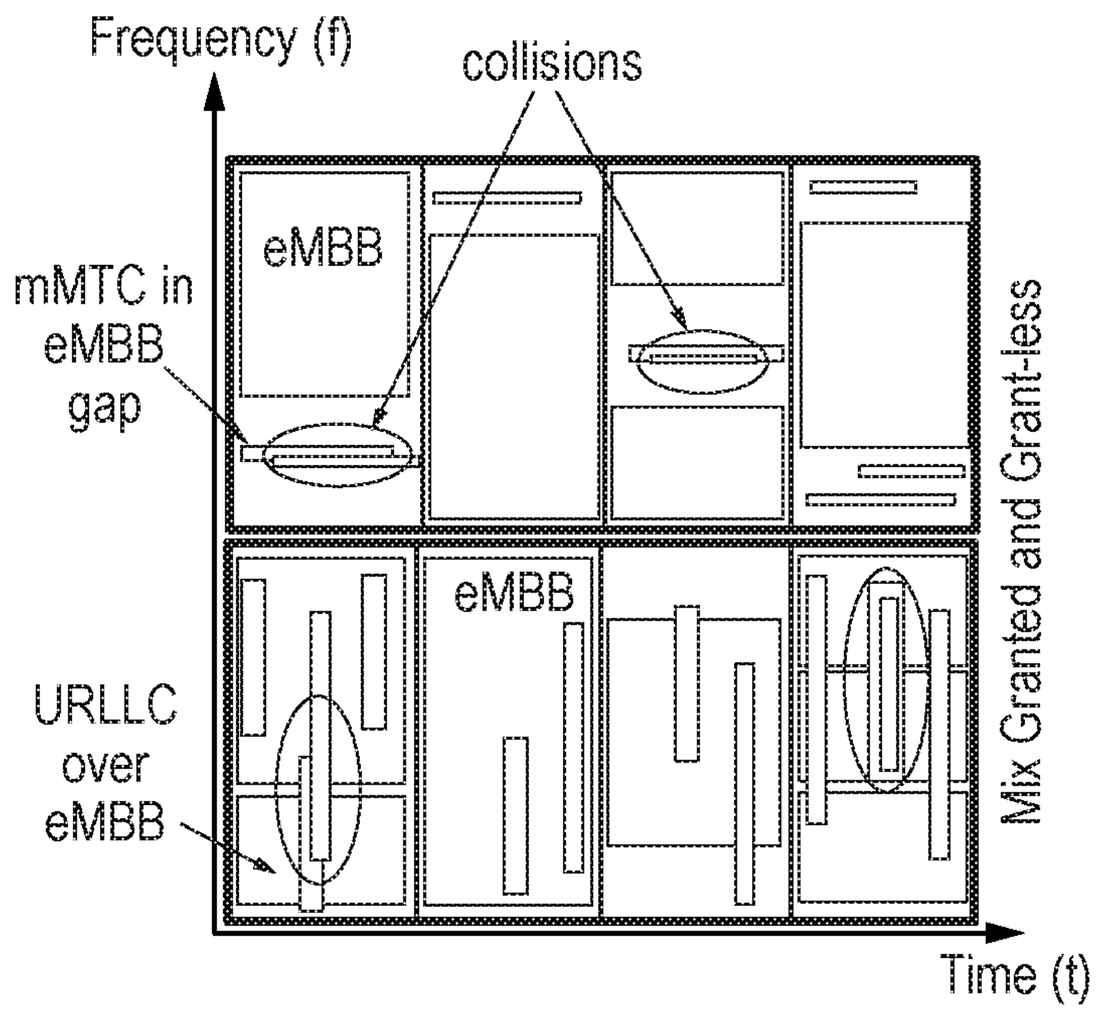

(b) Mixed URLLC and mMTC in grant-less sub-band

FIG. 13B




(a) Different numerology sub-bands

FIG. 13A




(c) Mixed eMBB and mMTC, eMBB and URLLC

FIG. 13C

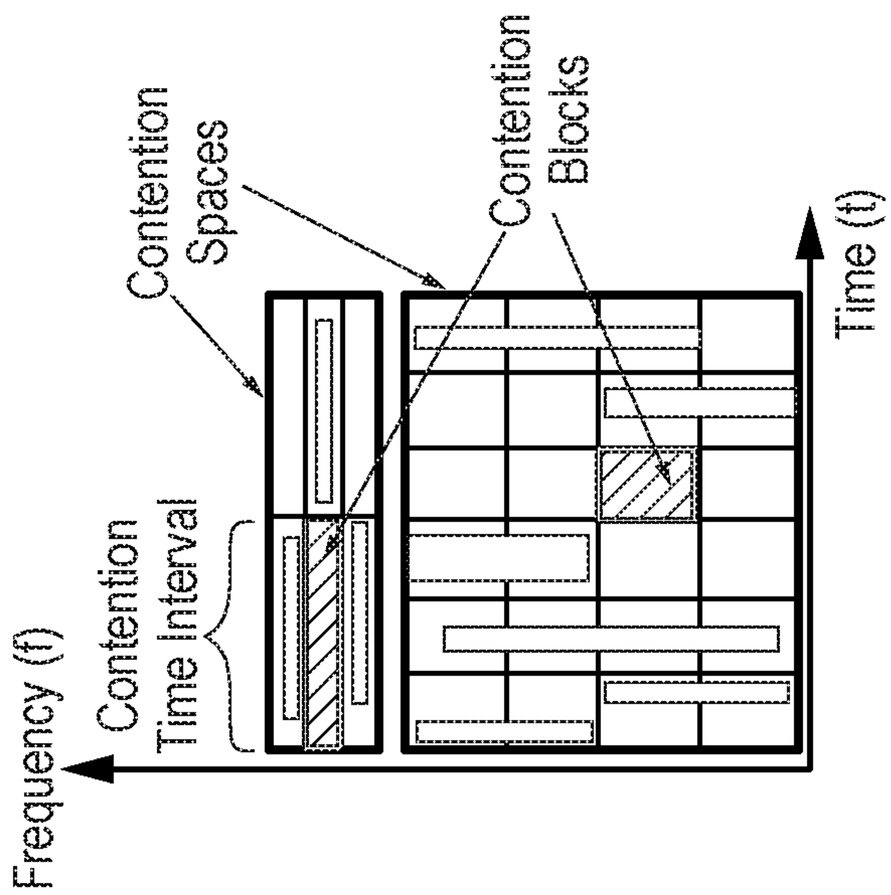



FIG. 14C

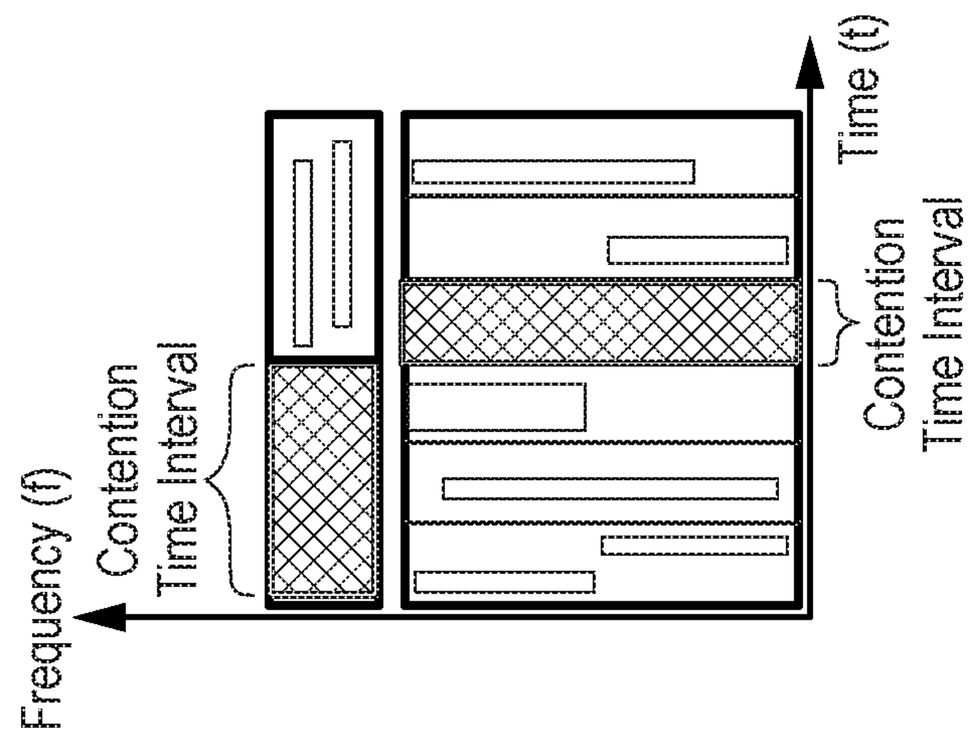



FIG. 14B

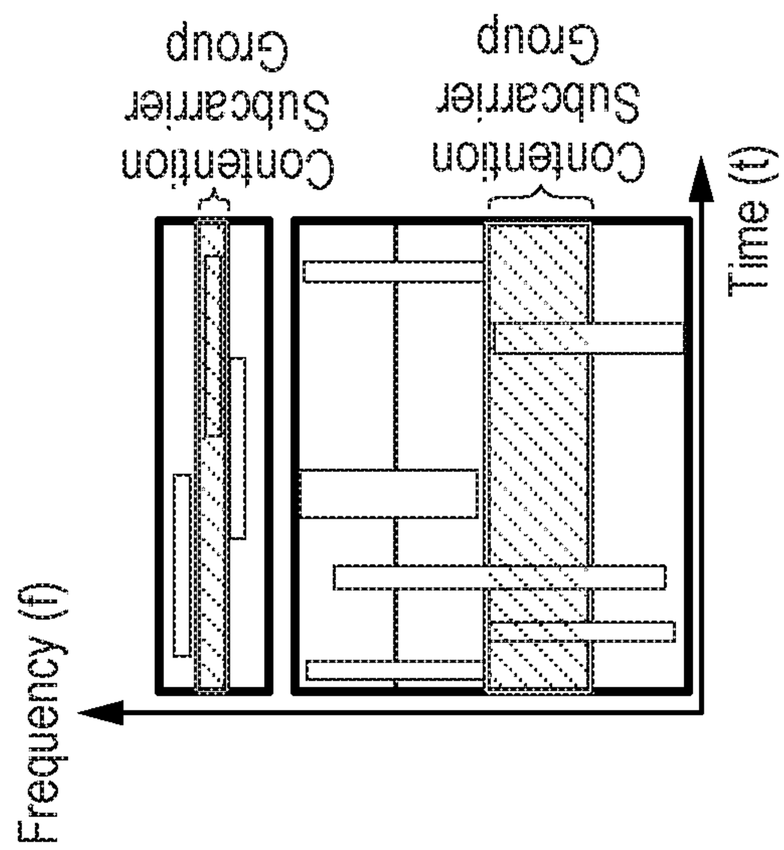



FIG. 14A

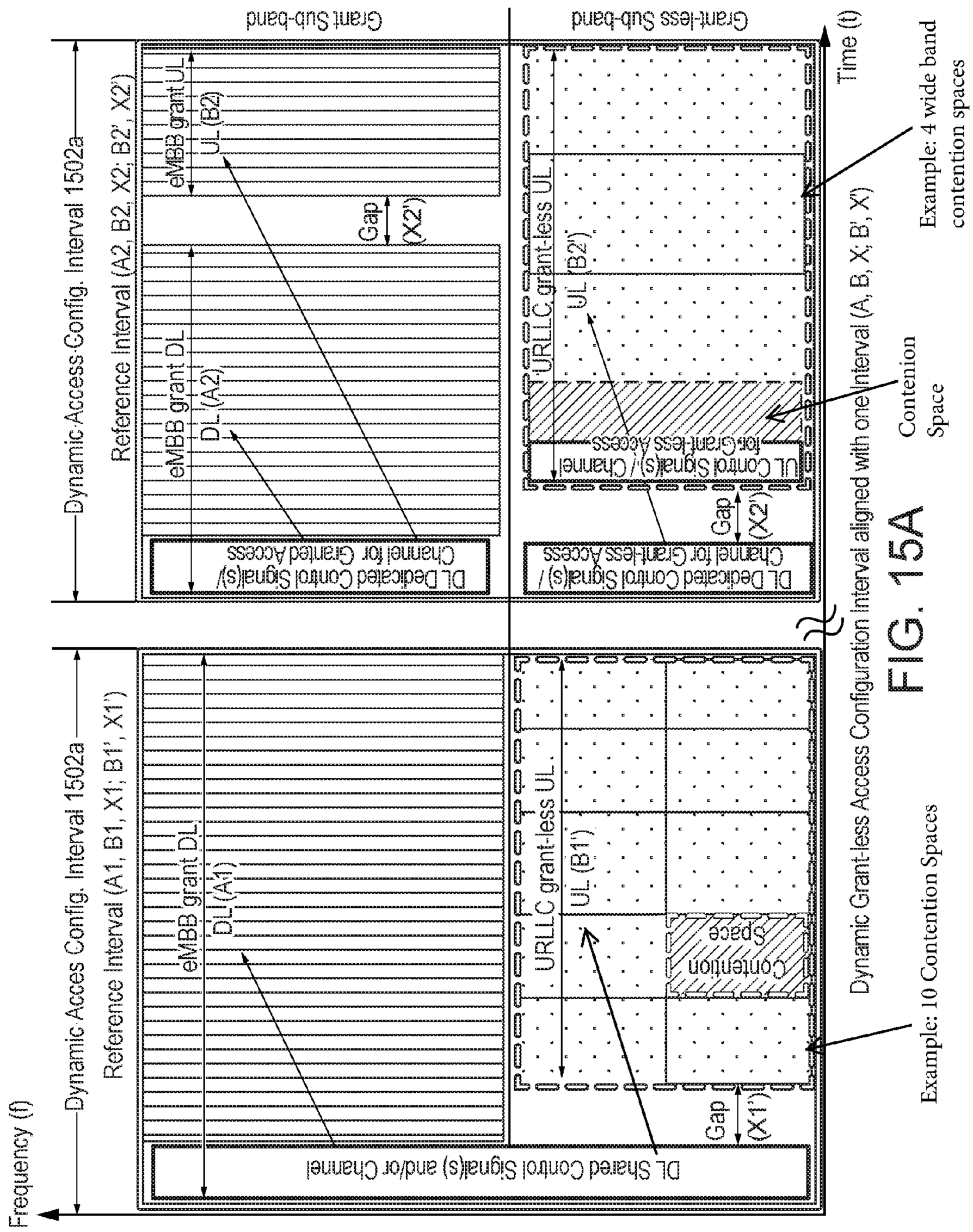

Frequency (f)
Dynamic Acces Config. Interval 1502a
Reference Interval (A1, B1, X1; B1', X1')
eMBB grant DL
DL (A1)
DL Shared Control Signal(s) and/or Channel
URLLC grant-less UL
UL (B1')
Contention Space
Gap (X1')
Example: 10 Contention Spaces
Dynamic Grant-less Access Configuration Interval aligned with one Interval (A, B, X; B', X')
Dynamic Access Config. Interval 1502a
Reference Interval (A2, B2, X2; B2', X2')
eMBB grant DL
DL (A2)
DL Dedicated Control Signal(s)/ Channel for Granted Access
eMBB grant UL
UL (B2)
Gap (X2')
Grant Sub-band
Grant-less Sub-band
URLLC grant-less UL
UL (B2')
UL Control Signal(s)/ Channel for Grant-less Access
DL Dedicated Control Signal(s) / Channel for Grant-less Access
Gap (X2')
Contention Space
Example: 4 wide band contention spaces
Time (t)

FIG. 15A

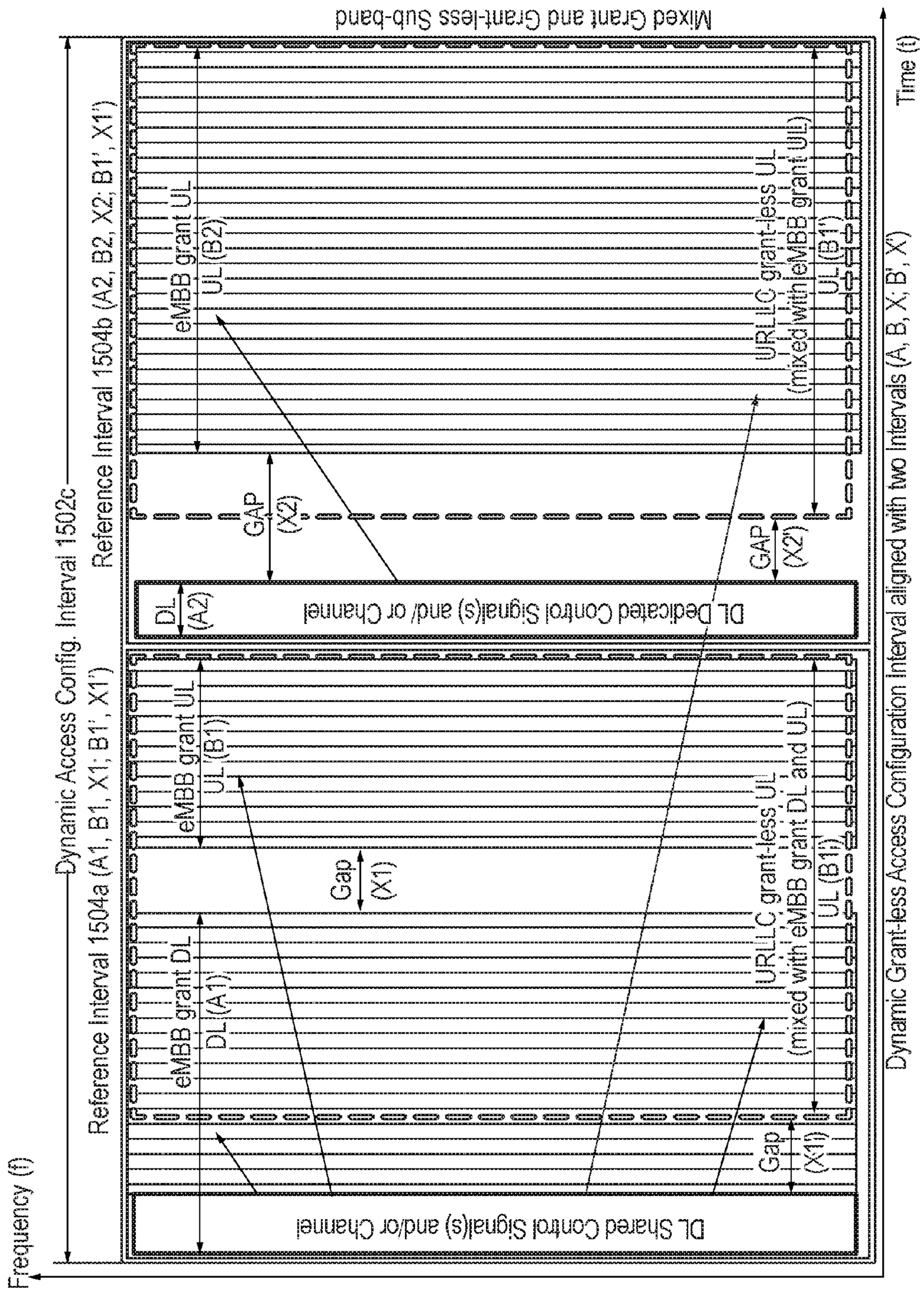

Dynamic Access Config. Interval 1502c
Reference Interval 1504a (A1, B1, X1; B1', X1')
Reference Interval 1504b (A2, B2, X2; B1', X1')
Mixed Grant and Grant-less Sub-band
Frequency (f)
Time (t)
eMBB grant DL
DL (A1)
Gap (X1)
eMBB grant UL
UL (B1)
DL Shared Control Signal(s) and/or Channel
URLLC grant-less UL (mixed with eMBB grant DL and UL)
UL (B1')
Gap (X1')
DL (A2)
GAP (X2)
eMBB grant UL
UL (B2)
DL Dedicated Control Signal(s) and/ or Channel
URLLC grant-less UL (mixed with eMBB grant UL)
UL (B1')
GAP (X2')
Dynamic Grant-less Access Configuration Interval aligned with two Intervals (A, B, X; B', X')

FIG. 15B

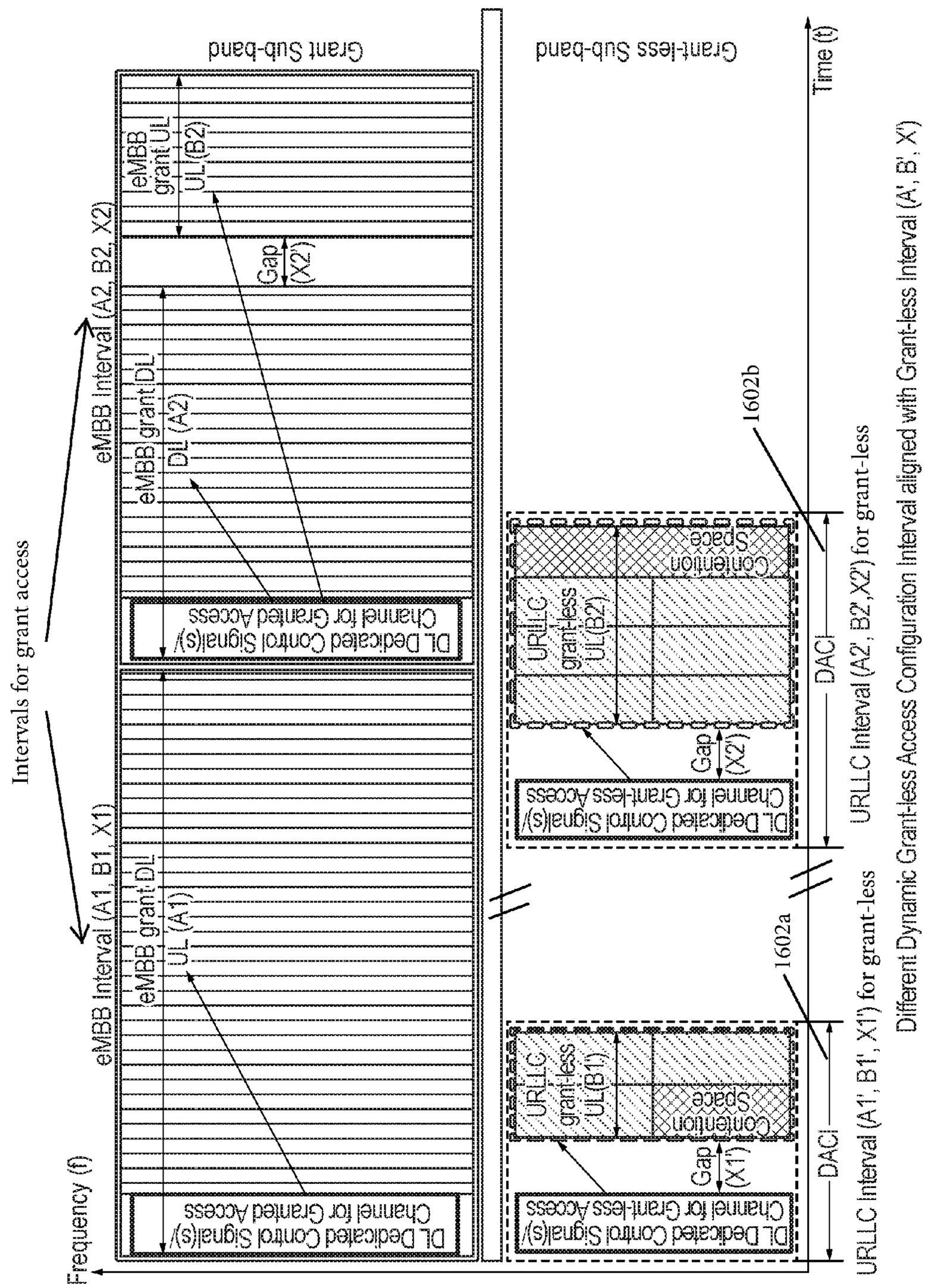

Intervals for grant access
Frequency (f)
Time (t)
Grant Sub-band
Grant-less Sub-band
eMBB Interval (A1, B1, X1)
eMBB Interval (A2, B2, X2)
eMBB grant DL
UL (A1)
eMBB grant DL
DL (A2)
eMBB grant UL
UL(B2)
Gap
(X2')
DL Dedicated Control Signal(s)/
Channel for Granted Access
DL Dedicated Control Signal(s)/
Channel for Grant-less Access
URLLC
grant-less
UL(B1')
URLLC
grant-less
UL(B2')
Contention
Space
Gap
(X1')
Gap
(X2')
DACI
DACI
1602a
1602b
URLLC Interval (A1', B1', X1') for grant-less
URLLC Interval (A2', B2', X2') for grant-less
Different Dynamic Grant-less Access Configuration Interval aligned with Grant-less Interval (A', B', X')

FIG. 16A

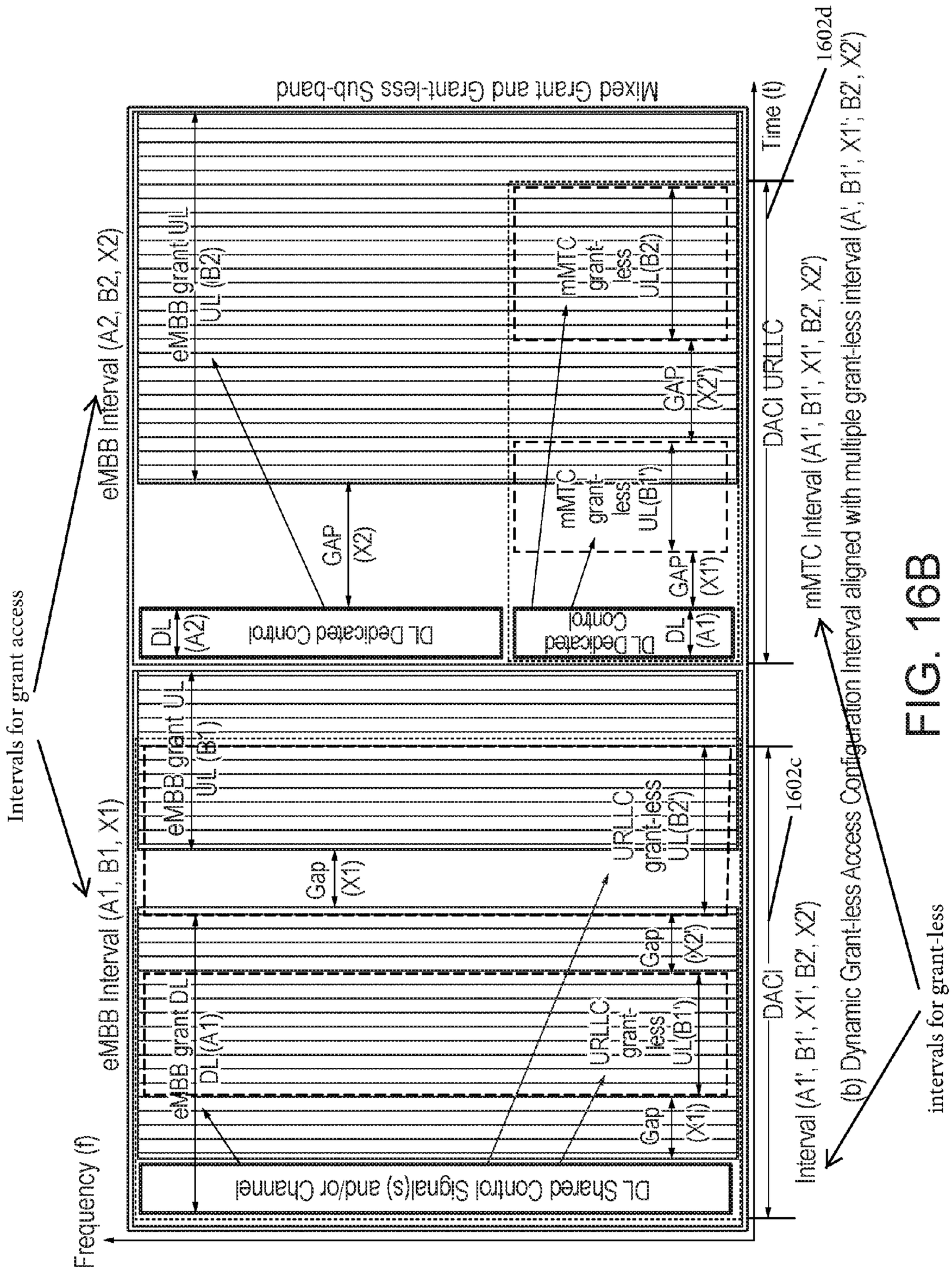

Intervals for grant access
eMBB Interval (A2, B2, X2)
eMBB Interval (A1, B1, X1)
Frequency (f)
Mixed Grant and Grant-less Sub-band
Time (t)
1602d
eMBB grant UL
UL (B2)
mMTC grant-less UL(B2)
GAP (X2')
GAP (X2)
mMTC grant-less UL(B1')
GAP (X1')
DL (A2)
DL Dedicated Control
DL Dedicated Control
DL (A1)
DACI URLLC
mMTC Interval (A1', B1', X1', B2', X2')
eMBB grant UL
UL (B1')
Gap (X1)
URLLC grant-less UL(B2')
1602c
Gap (X2')
eMBB grant DL
DL(A1)
URLLC grant-less UL(B1')
Gap (X1')
DL Shared Control Signal(s) and/or Channel
DACI
Interval (A1', B1', X1', B2', X2')
(b) Dynamic Grant-less Access Configuration Interval aligned with multiple grant-less interval (A', B1', X1', B2', X2')
intervals for grant-less

FIG. 16B

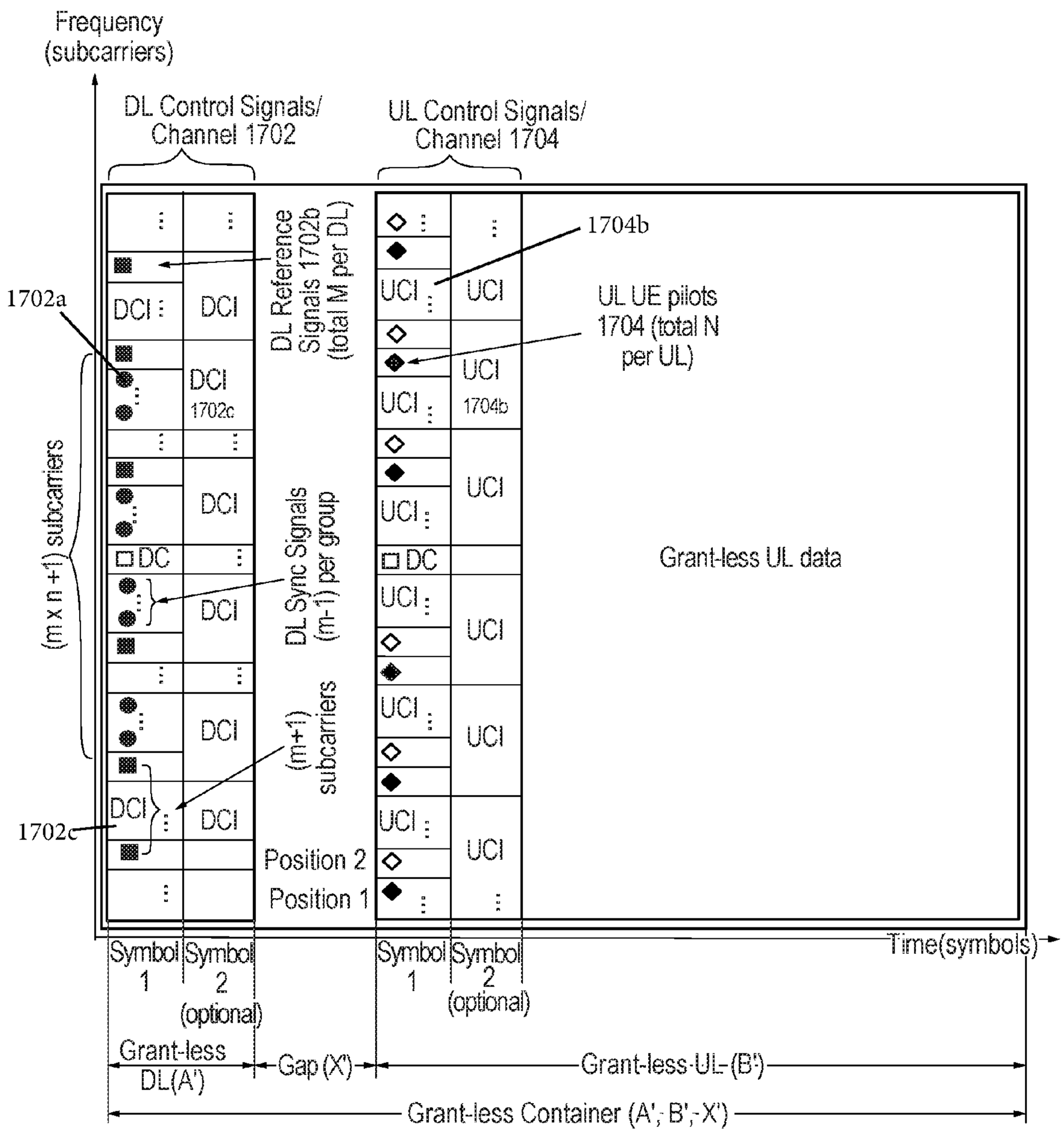

Frequency
(subcarriers)
DL Control Signals/
Channel 1702
UL Control Signals/
Channel 1704
1702a
1704b
DL Reference
Signals 1702b
(total M per DL)
UL UE pilots
1704 (total N
per UL)
DCI
DCI
1702c
UCI
UCI
1704b
(m x n +1) subcarriers
DL Sync Signals
(m-1) per group
DC
Grant-less UL data
(m+1)
subcarriers
1702c
Position 2
Position 1
Symbol
1
Symbol
2
(optional)
Time(symbols)
Grant-less
DL(A')
Gap (X')
Grant-less-UL-(B')
Grant-less Container (A'; B'; X')

FIG. 17

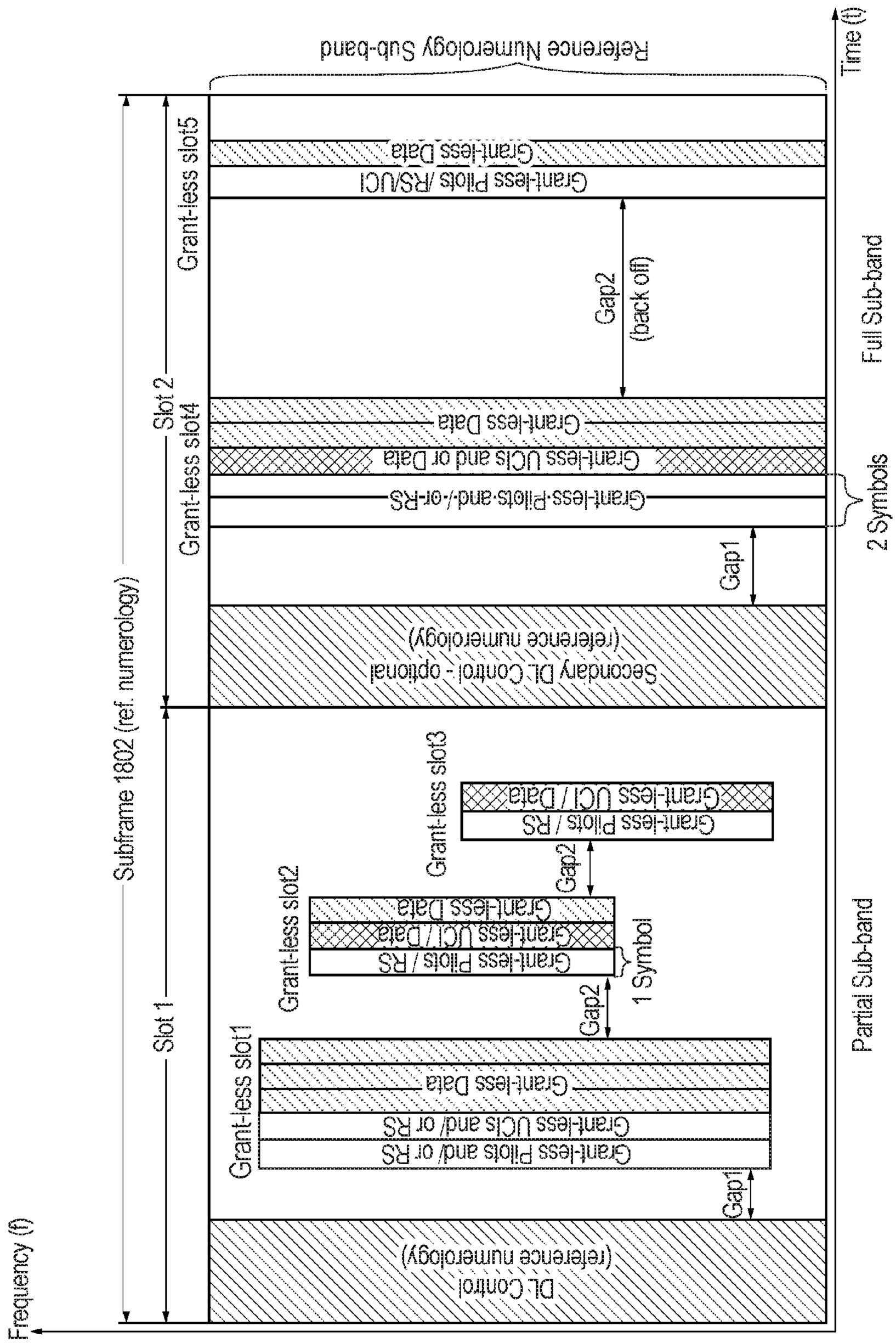

Frequency (f)
Time (t)
Subframe 1802 (ref. numerology)
Slot 1
Slot 2
Reference Numerology Sub-band
Full Sub-band
Partial Sub-band
DL Control
(reference numerology)
Grant-less slot1
Grant-less Pilots and/ or RS
Grant-less UCIs and/ or RS
Grant-less Data
Gap1
Grant-less slot2
Grant-less Pilots / RS
Grant-less UCI / Data
Grant-less Data
Gap2
1 Symbol
Grant-less slot3
Grant-less Pilots / RS
Grant-less UCI / Data
Gap2
Secondary DL Control - optional
(reference numerology)
Gap1
Grant-less Pilots-and-/-or-RS
Grant-less UCIs and or Data
2 Symbols
Grant-less slot4
Grant-less Data
Gap2
(back off)
Grant-less Pilots /RS/UCI
Grant-less Data
Grant-less slot5

FIG. 18

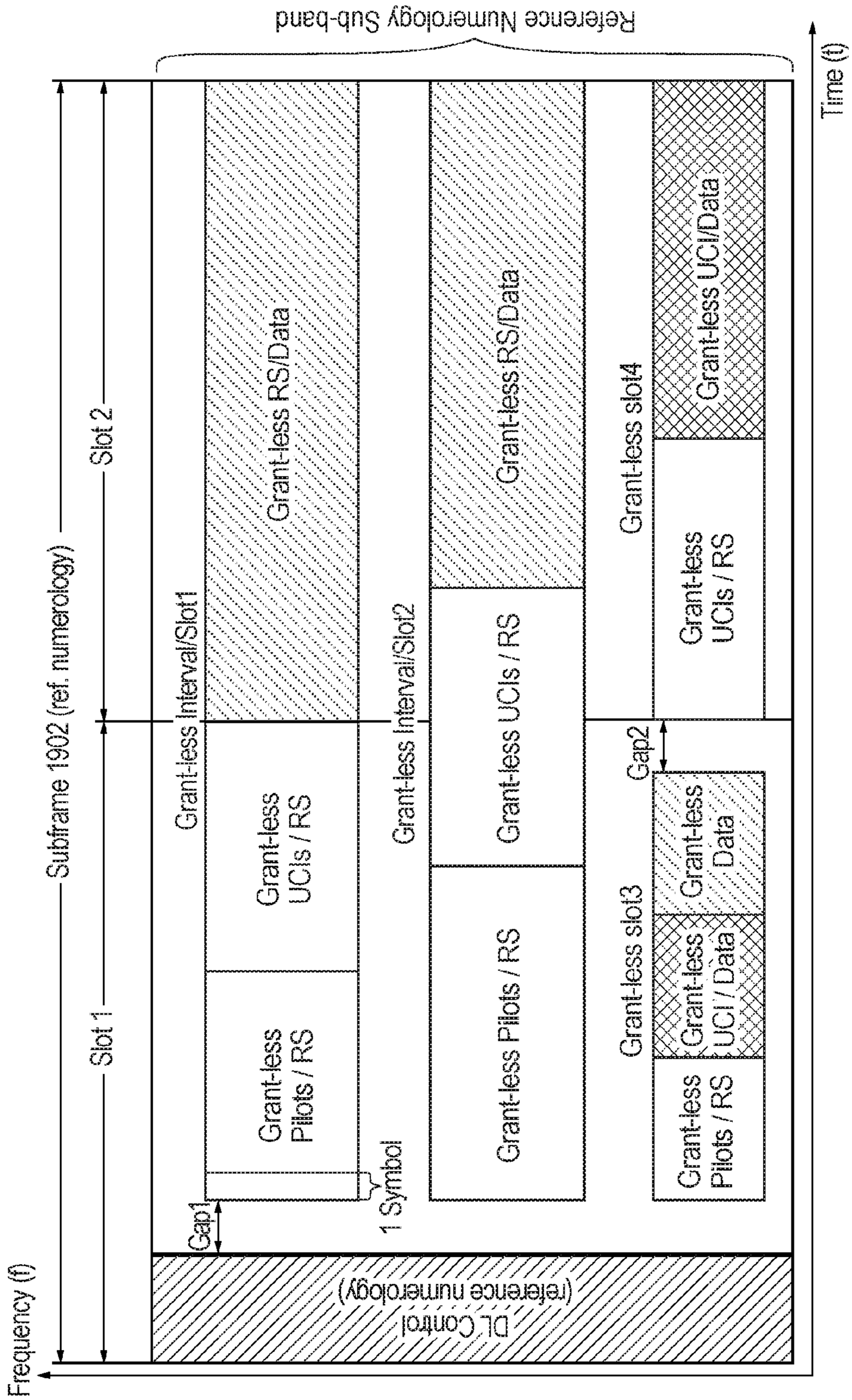

Reference Numerology Sub-band
Time (t)
Subframe 1902 (ref. numerology)
Slot 1
Slot 2
Grant-less Interval/Slot1
Grant-less Interval/Slot2
Grant-less RS/Data
Grant-less RS/Data
Grant-less UCI/Data
Grant-less UCIs / RS
Grant-less UCIs / RS
Grant-less UCIs / RS
Grant-less Pilots / RS
Grant-less Pilots / RS
Grant-less Pilots / RS
Grant-less slot3
Grant-less slot4
Gap1
Gap2
1 Symbol
Grant-less Data
Grant-less UCI / Data
DL Control (reference numerology)
Frequency (f)

FIG. 19

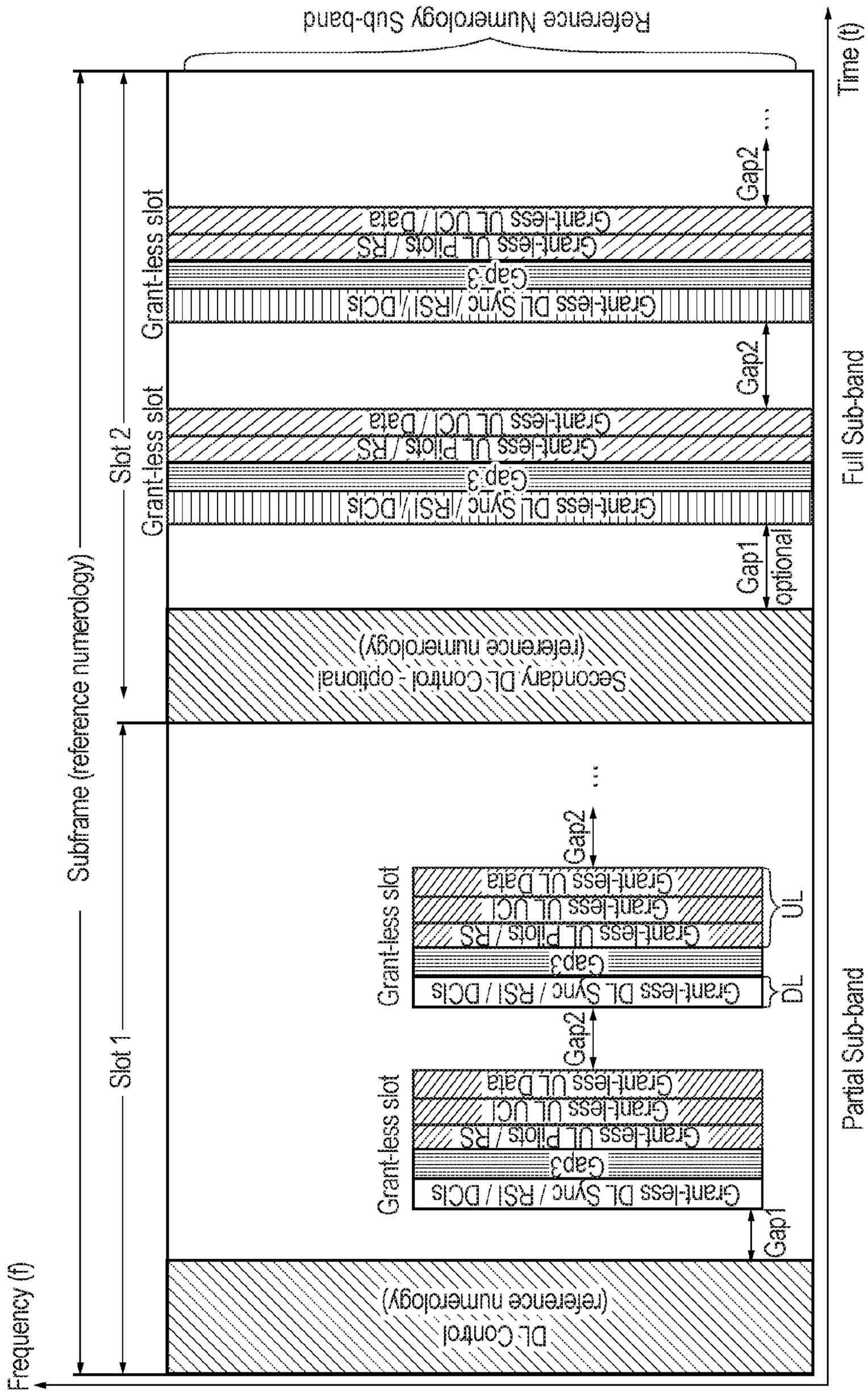

Reference Numerology Sub-band
Time (t)
Subframe (reference numerology)
Slot 2
Grant-less slot
Gap2
Grant-less UL UCI / Data
Grant-less UL Pilots / RS
Gap3
Grant-less DL Sync / RSI / DCIs
Gap2
Grant-less UL UCI / Data
Grant-less UL Pilots / RS
Gap3
Grant-less DL Sync / RSI / DCIs
Gap1
optional
Full Sub-band
Secondary DL Control - optional
(reference numerology)
Slot 1
Gap2
Grant-less slot
Grant-less UL Data
Grant-less UL UCI
Grant-less UL Pilots / RS
Gap3
Grant-less DL Sync / RSI / DCIs
UL
DL
Gap2
Grant-less slot
Grant-less UL Data
Grant-less UL UCI
Grant-less UL Pilots / RS
Gap3
Grant-less DL Sync / RSI / DCIs
Gap1
Partial Sub-band
DL Control
(reference numerology)
Frequency (f)

FIG. 20

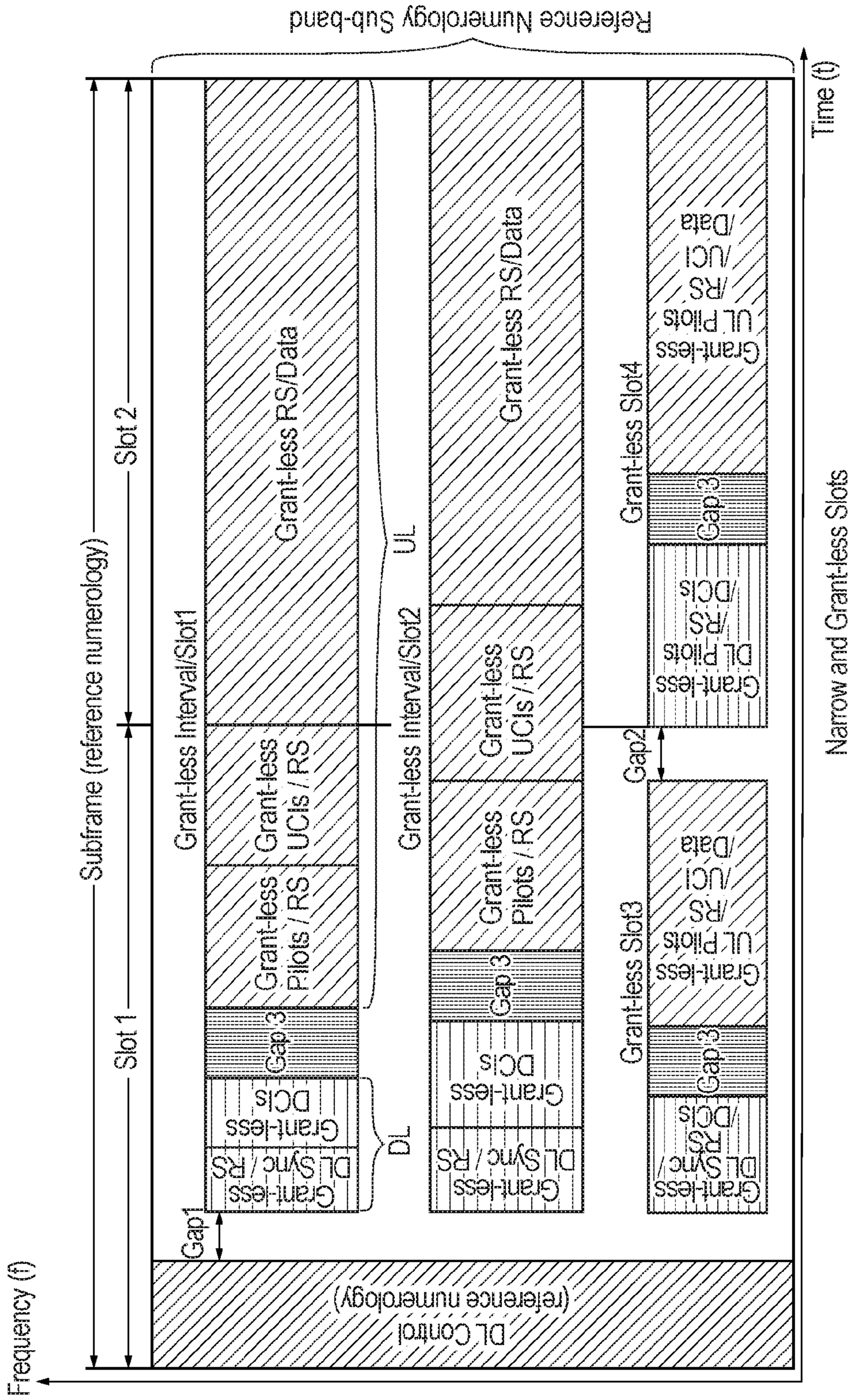

Reference Numerology Sub-band
Time (t)
Frequency (f)
Subframe (reference numerology)
Slot 1
Slot 2
Grant-less Interval/Slot1
Grant-less Interval/Slot2
UL
DL
Gap1
Gap2
Gap 3
Grant-less Slot3
Grant-less Slot4
Narrow and Grant-less Slots
DL Control (reference numerology)
Grant-less DL Sync / RS
Grant-less DCIs
Grant-less Pilots / RS
Grant-less UCIs / RS
Grant-less RS/Data
Grant-less UL Pilots /RS /UCI /Data
Grant-less DL Sync / RS /DCIs

FIG. 21

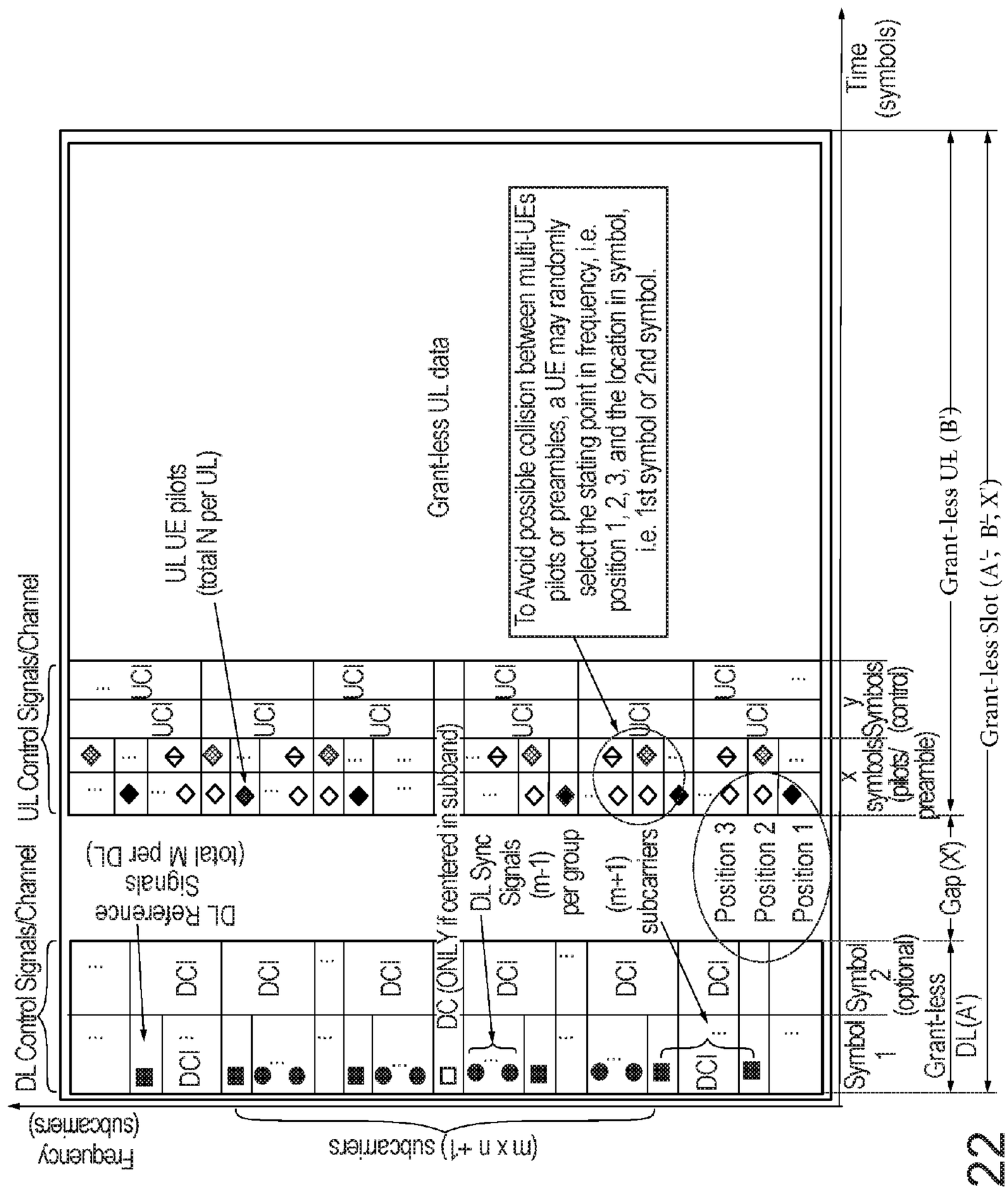

2200
DL Control Signals/Channel
UL Control Signals/Channel
Frequency (subcarriers)
(m x n +1) subcarriers
DCI
DC (ONLY if centered in subband)
DL Reference Signals (total M per DL)
DL Sync Signals (m-1) per group
(m+1) subcarriers
UCI
UL UE pilots (total N per UL)
Grant-less UL data
To Avoid possible collision between multi-UEs pilots or preambles, a UE may randomly select the stating point in frequency, i.e. position 1, 2, 3, and the location in symbol, i.e. 1st symbol or 2nd symbol.
Position 3
Position 2
Position 1
Symbol 1
Symbol 2 (optional)
Grant-less DL(A')
Gap (X')
x symbols (pilots/ preamble)
y symbols (control)
Grant-less UL (B')
Grant-less Slot (A'; B'; X')
Time (symbols)

FIG. 22

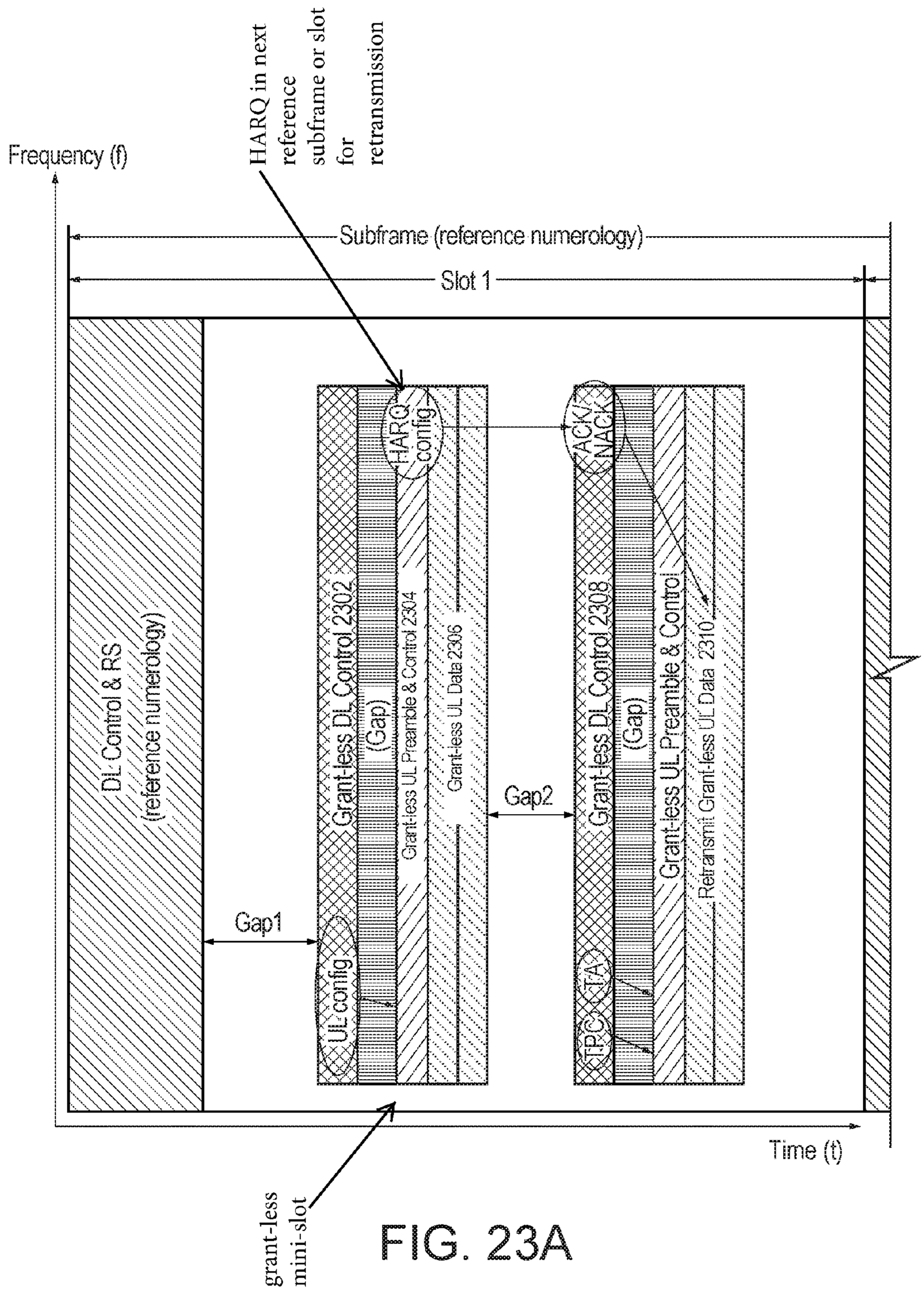

HARQ in next reference subframe or slot for retransmission
Frequency (f)
Subframe (reference numerology)
Slot 1
DL Control & RS (reference numerology)
Gap1
Grant-less DL Control 2302
(Gap)
Grant-less UL Preamble & Control 2304
Grant-less UL Data 2306
HARQ config
UL config
Gap2
Grant-less DL Control 2308
(Gap)
Grant-less UL Preamble & Control
Retransmit Grant-less UL Data 2310
ACK/NACK
TA
TPC
Time (t)
grant-less mini-slot

FIG. 23A

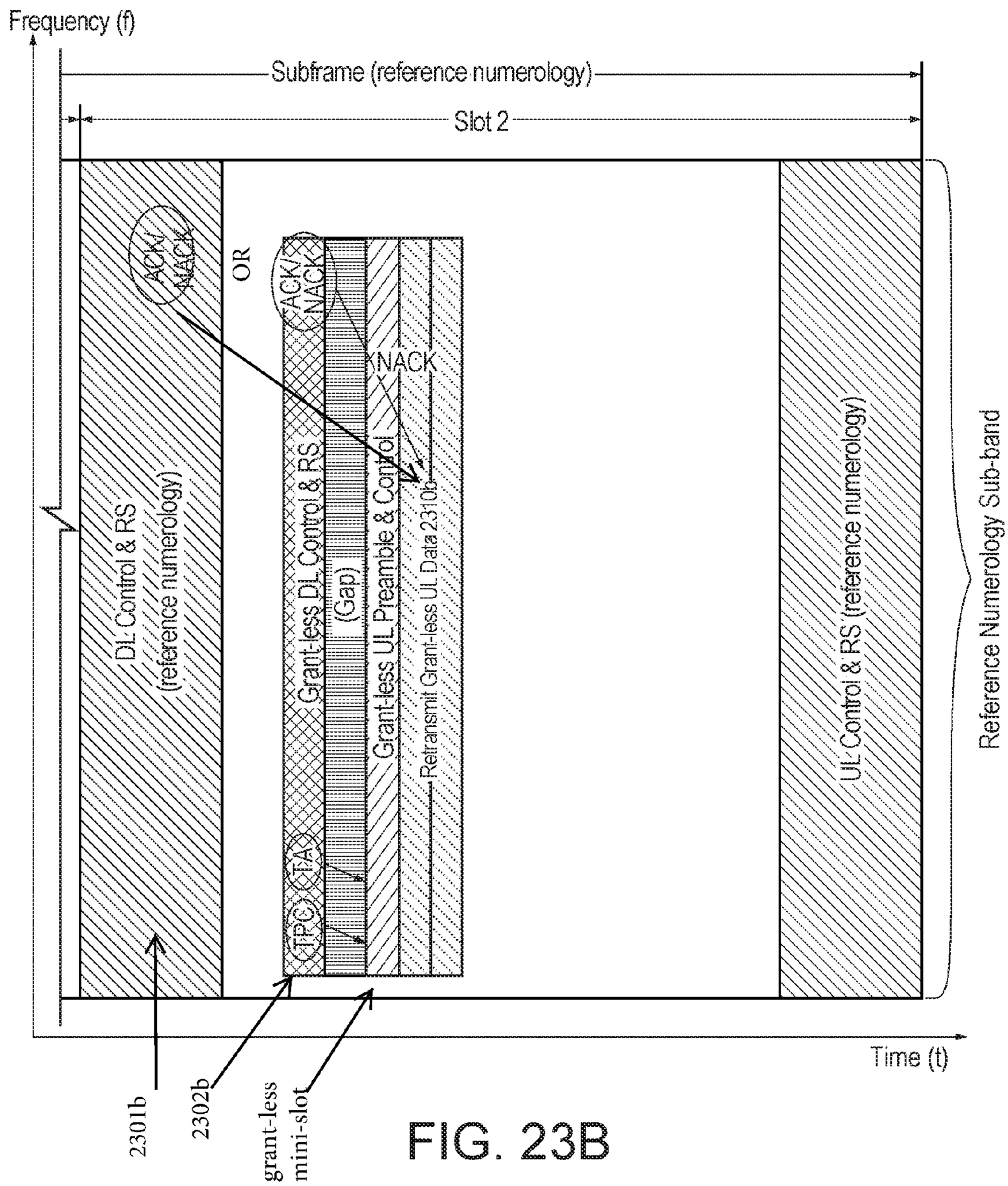

Frequency (f)
Subframe (reference numerology)
Slot 2
DL Control & RS
(reference numerology)
ACK/
NACK
OR
ACK/
NACK
Grant-less DL Control & RS
(Gap)
Grant-less UL Preamble & Control
Retransmit Grant-less UL Data 2310b
NACK
TPC
TA
UL Control & RS (reference numerology)
Reference Numerology Sub-band
Time (t)
2301b
2302b
grant-less
mini-slot

FIG. 23B

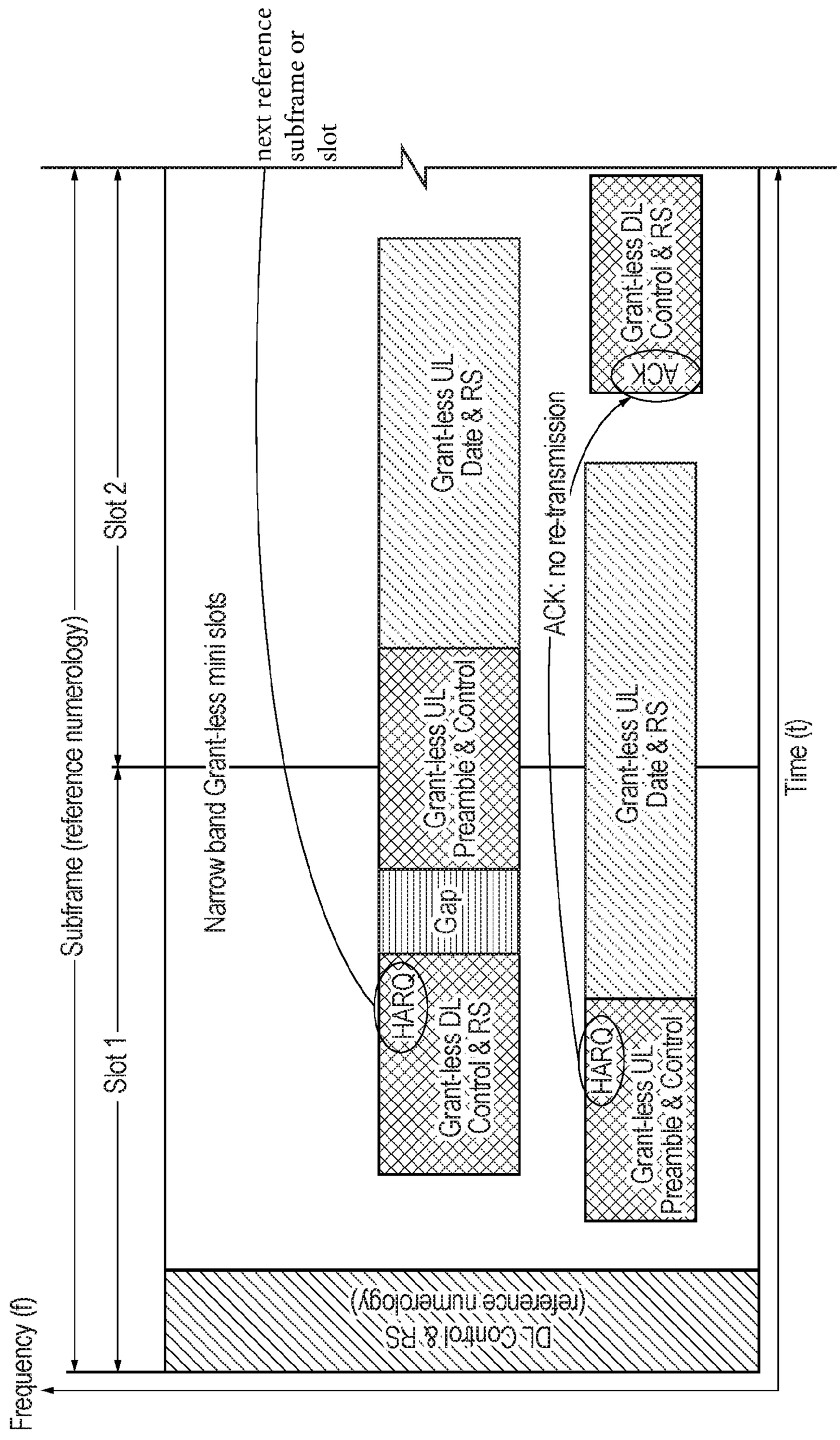

next reference subframe or slot
Subframe (reference numerology)
Slot 2
Slot 1
Narrow band Grant-less mini slots
Grant-less UL Date & RS
Grant-less DL Control & RS
ACK
ACK: no re-transmission
Grant-less UL Preamble & Control
Gap
CHARQ
Grant-less DL Control & RS
Grant-less UL Date & RS
CHARQ
Grant-less UL Preamble & Control
DL Control & RS (reference numerology)
Time (t)
Frequency (f)

FIG. 24A

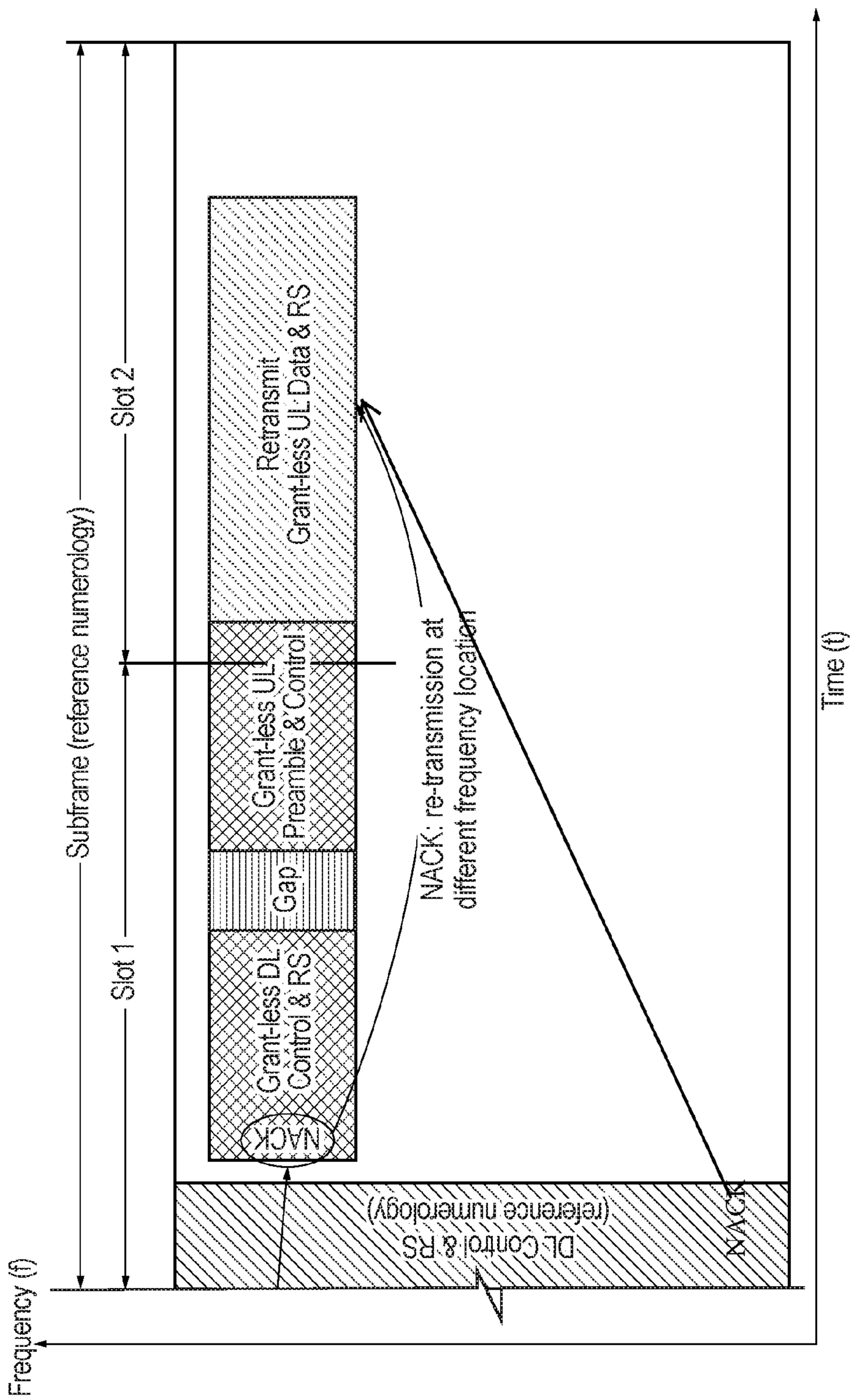

Subframe (reference numerology)
Slot 1
Slot 2
Frequency (f)
Time (t)
DL Control & RS
(reference numerology)
NACK
Grant-less DL
Control & RS
Gap
Grant-less UL
Preamble & Control
Retransmit
Grant-less UL Data & RS
NACK
NACK: re-transmission at
different frequency location

FIG. 24B

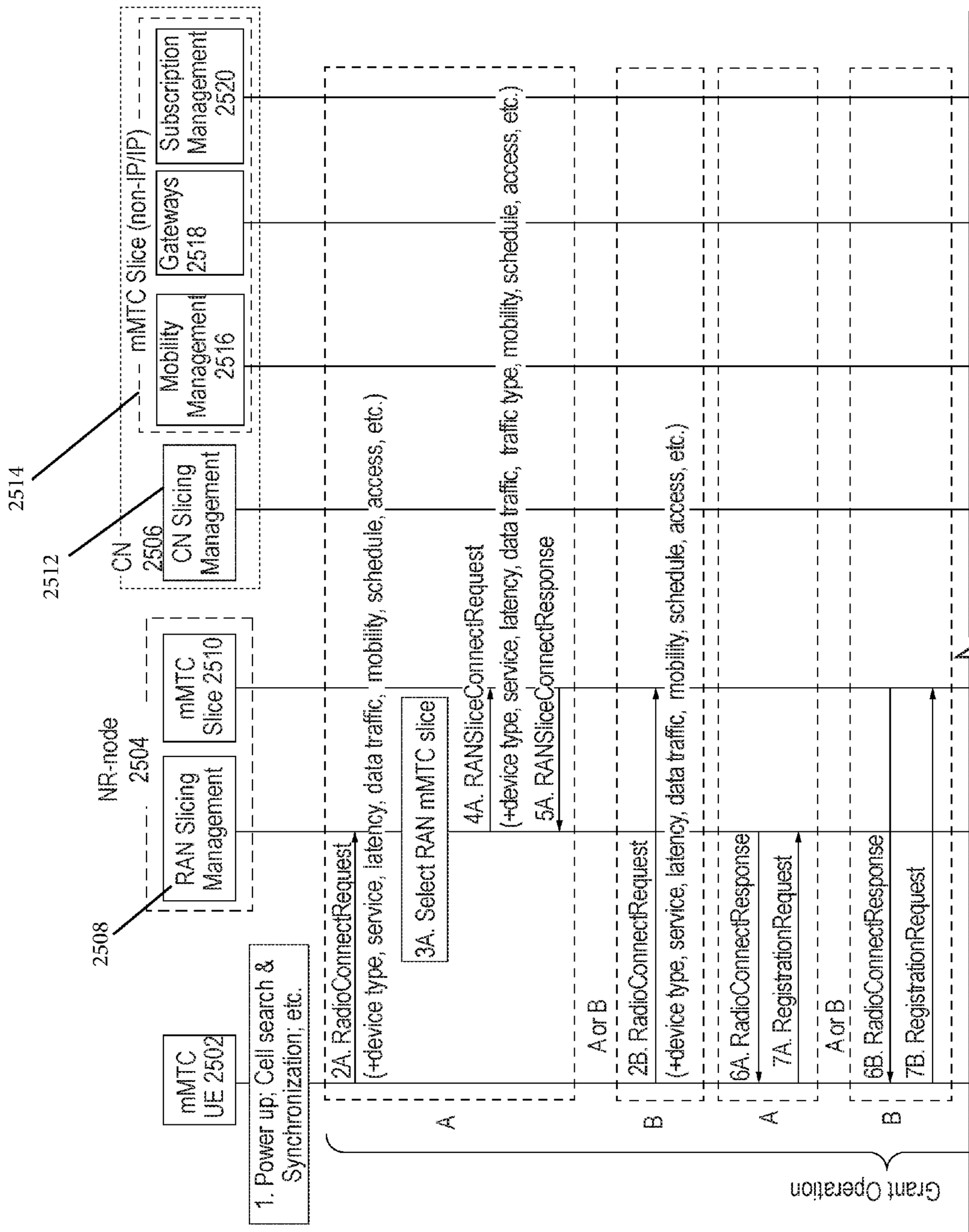

mMTC UE 2502
NR-node 2504
2508
RAN Slicing Management
mMTC Slice 2510
CN 2506
2512
CN Slicing Management
mMTC Slice (non-IP/IP)
2514
Mobility Management 2516
Gateways 2518
Subscription Management 2520
1. Power up; Cell search & Synchronization; etc.
2A. RadioConnectRequest
(+device type, service, latency, data traffic, mobility, schedule, access, etc.)
A or B
2B. RadioConnectRequest
(+device type, service, latency, data traffic, mobility, schedule, access, etc.)
3A. Select RAN mMTC slice
4A. RANSliceConnectRequest
(+device type, service, latency, data traffic, traffic type, mobility, schedule, access, etc.)
5A. RANSliceConnectResponse
6A. RadioConnectResponse
7A. RegistrationRequest
A or B
6B. RadioConnectResponse
7B. RegistrationRequest
A
B
A
B
Grant Operation

FIG. 25A

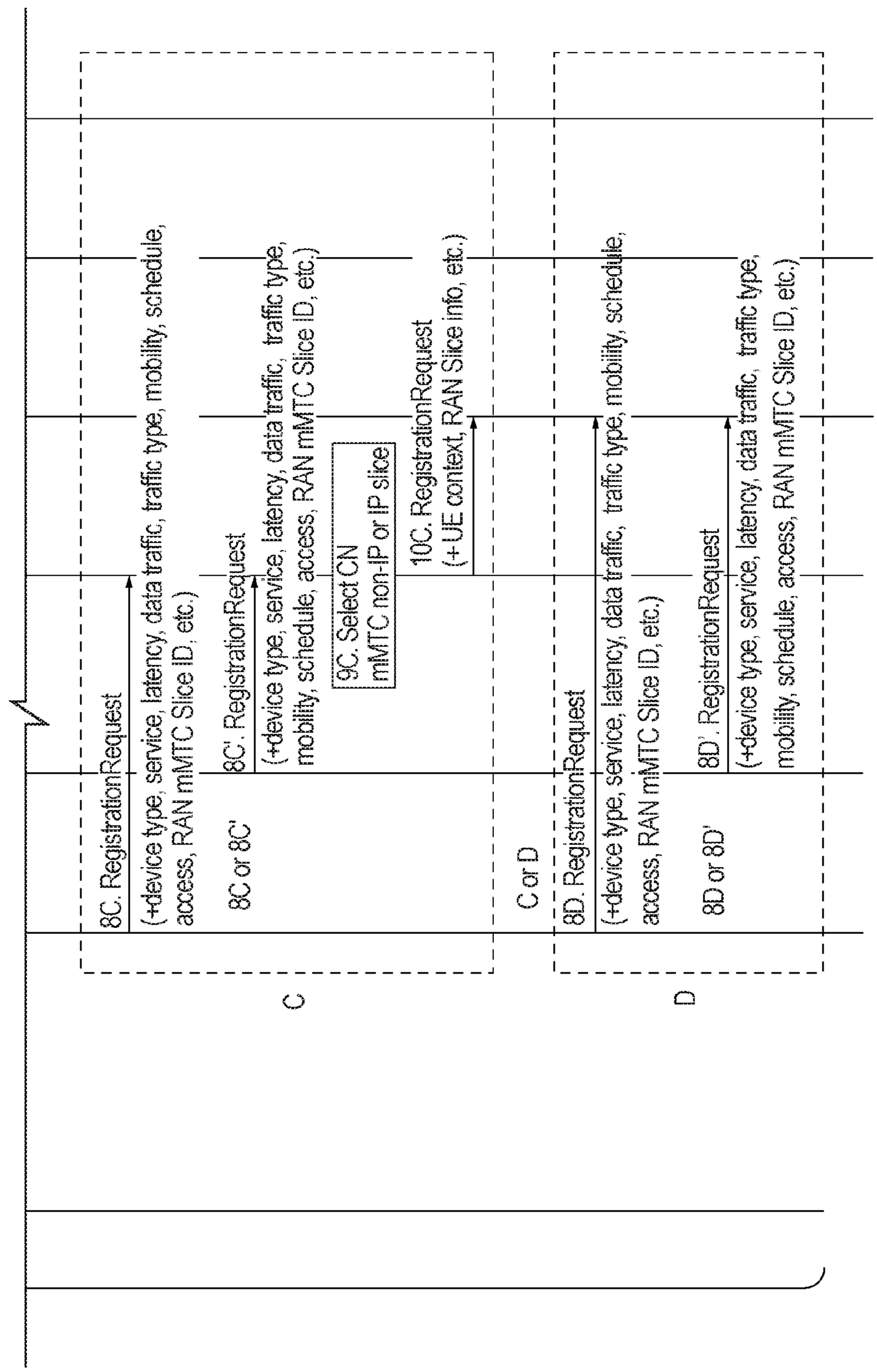

8C. RegistrationRequest
(+device type, service, latency, data traffic, traffic type, mobility, schedule, access, RAN mMTC Slice ID, etc.)
8C or 8C'
8C'. RegistrationRequest
(+device type, service, latency, data traffic, traffic type, mobility, schedule, access, RAN mMTC Slice ID, etc.)
9C. Select CN
mMTC non-IP or IP slice
10C. RegistrationRequest
(+UE context, RAN Slice info, etc.)
C
C or D
8D. RegistrationRequest
(+device type, service, latency, data traffic, traffic type, mobility, schedule, access, RAN mMTC Slice ID, etc.)
8D or 8D'
8D'. RegistrationRequest
(+device type, service, latency, data traffic, traffic type, mobility, schedule, access, RAN mMTC Slice ID, etc.)
D

FIG. 25B

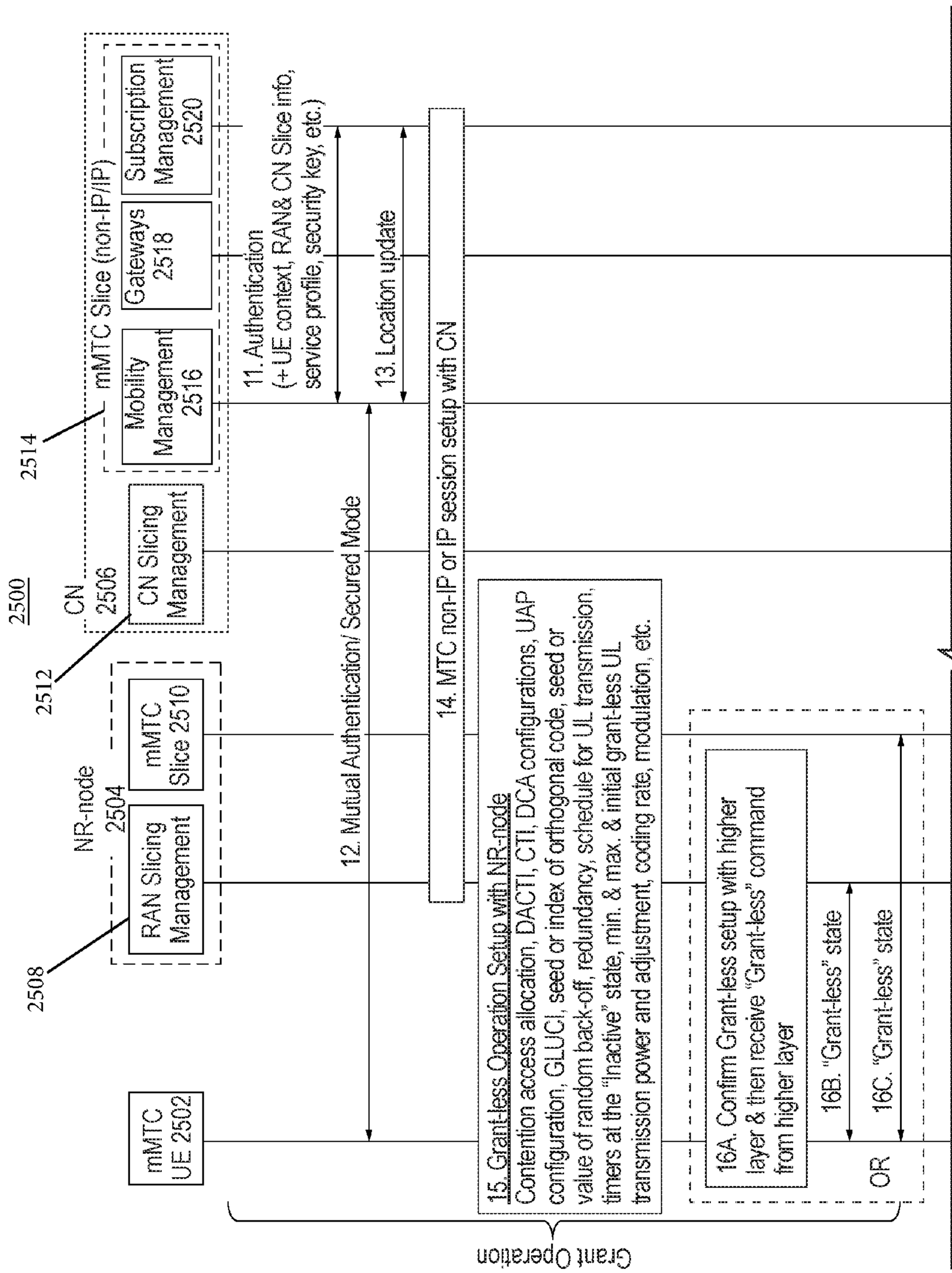

2500
2514
mMTC Slice (non-IP/IP)
Mobility Management 2516
Gateways 2518
Subscription Management 2520
CN 2506
2512
CN Slicing Management
NR-node 2504
2508
RAN Slicing Management
mMTC Slice 2510
mMTC UE 2502
11. Authentication (+ UE context, RAN& CN Slice info, service profile, security key, etc.)
13. Location update
12. Mutual Authentication/ Secured Mode
14. MTC non-IP or IP session setup with CN
15. Grant-less Operation Setup with NR-node
Contention access allocation, DACTI, CTI, DCA configurations, UAP configuration, GLUCI, seed or index of orthogonal code, seed or value of random back-off, redundancy, schedule for UL transmission, timers at the "Inactive" state, min. & max. & initial grant-less UL transmission power and adjustment, coding rate, modulation, etc.
16A. Confirm Grant-less setup with higher layer & then receive "Grant-less" command from higher layer
16B. "Grant-less" state
OR
16C. "Grant-less" state
Grant Operation

FIG. 26A

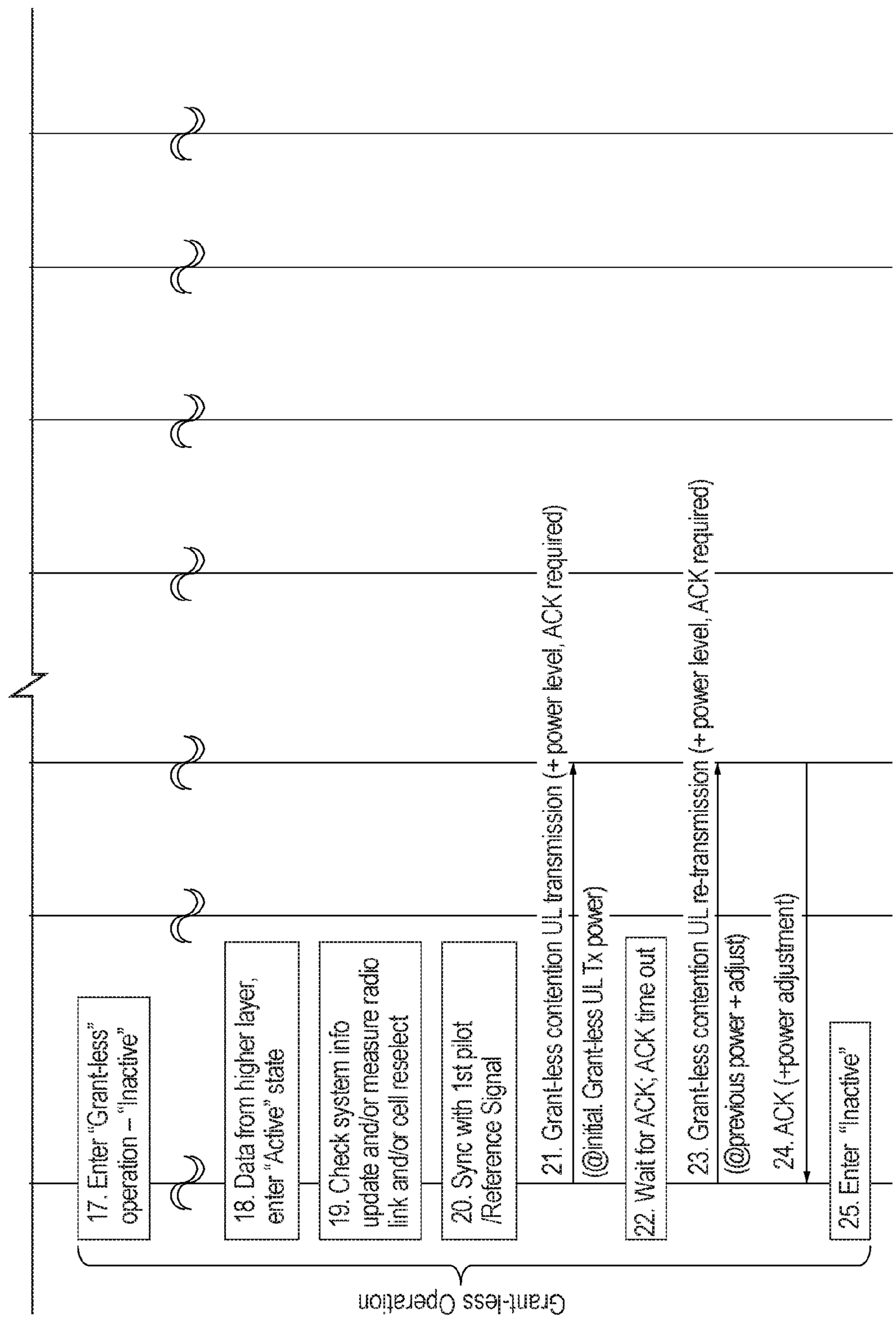

N
17. Enter "Grant-less" operation – "Inactive"
18. Data from higher layer, enter "Active" state
19. Check system info update and/or measure radio link and/or cell reselect
20. Sync with 1st pilot /Reference Signal
21. Grant-less contention UL transmission (+ power level, ACK required)
(@initial Grant-less UL Tx power)
22. Wait for ACK, ACK time out
23. Grant-less contention UL re-transmission (+ power level, ACK required)
(@previous power + adjust)
24. ACK (+power adjustment)
25. Enter "Inactive"
Grant-less Operation

FIG. 26B

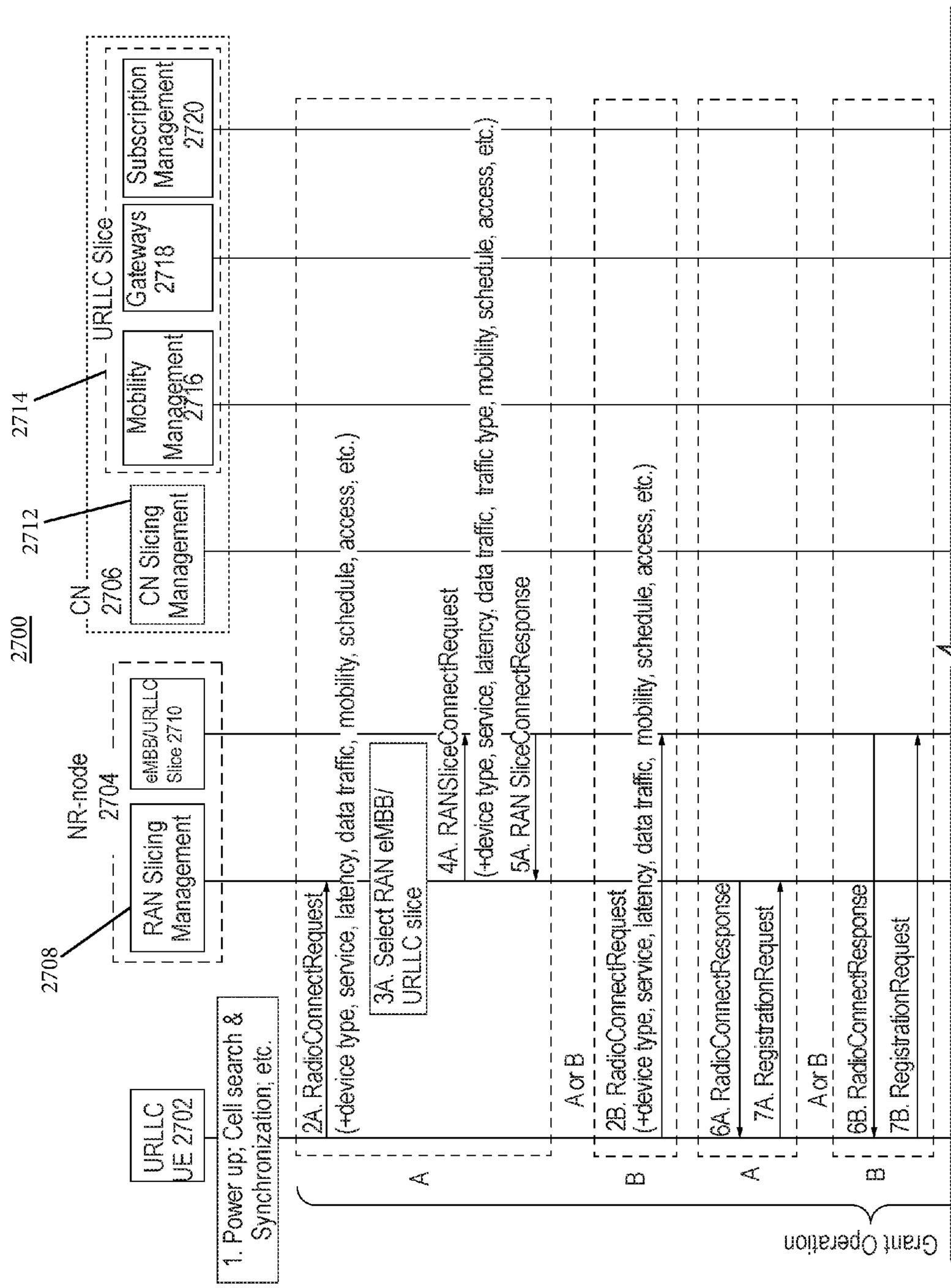

2700
2714
2712
2708
URLLC UE 2702
NR-node 2704
CN 2706
URLLC Slice
RAN Slicing Management
eMBB/URLLC Slice 2710
CN Slicing Management
Mobility Management 2716
Gateways 2718
Subscription Management 2720
1. Power up; Cell search & Synchronization; etc.
2A. RadioConnectRequest
(+device type, service, latency, data traffic, mobility, schedule, access, etc.)
3A. Select RAN eMBB/ URLLC slice
4A. RANSliceConnectRequest
(+device type, service, latency, data traffic, traffic type, mobility, schedule, access, etc.)
5A. RAN SliceConnectResponse
A or B
2B. RadioConnectRequest
(+device type, service, latency, data traffic, mobility, schedule, access, etc.)
6A. RadioConnectResponse
7A. RegistrationRequest
A or B
6B. RadioConnectResponse
7B. RegistrationRequest
A
B
A
B
Grant Operation

FIG. 27A

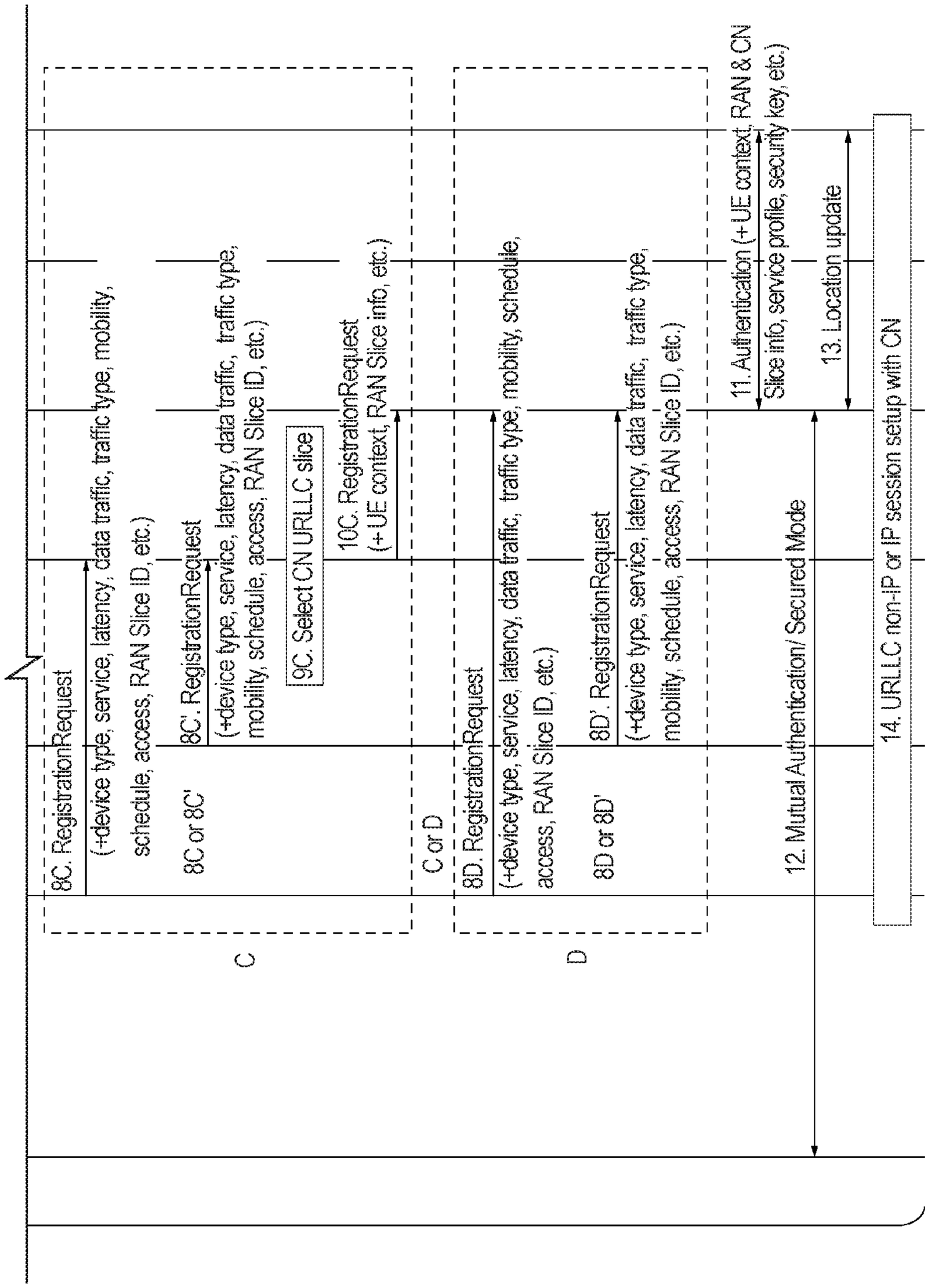

8C. RegistrationRequest
(+device type, service, latency, data traffic, traffic type, mobility, schedule, access, RAN Slice ID, etc.)
8C or 8C'
8C'. RegistrationRequest
(+device type, service, latency, data traffic, traffic type, mobility, schedule, access, RAN Slice ID, etc.)
9C. Select CN URLLC slice
10C. RegistrationRequest
(+UE context, RAN Slice info, etc.)
C
C or D
8D. RegistrationRequest
(+device type, service, latency, data traffic, traffic type, mobility, schedule, access, RAN Slice ID, etc.)
8D or 8D'
8D'. RegistrationRequest
(+device type, service, latency, data traffic, traffic type, mobility, schedule, access, RAN Slice ID, etc.)
D
12. Mutual Authentication/ Secured Mode
11. Authentication (+UE context, RAN & CN Slice info, service profile, security key, etc.)
13. Location update
14. URLLC non-IP or IP session setup with CN

FIG. 27B

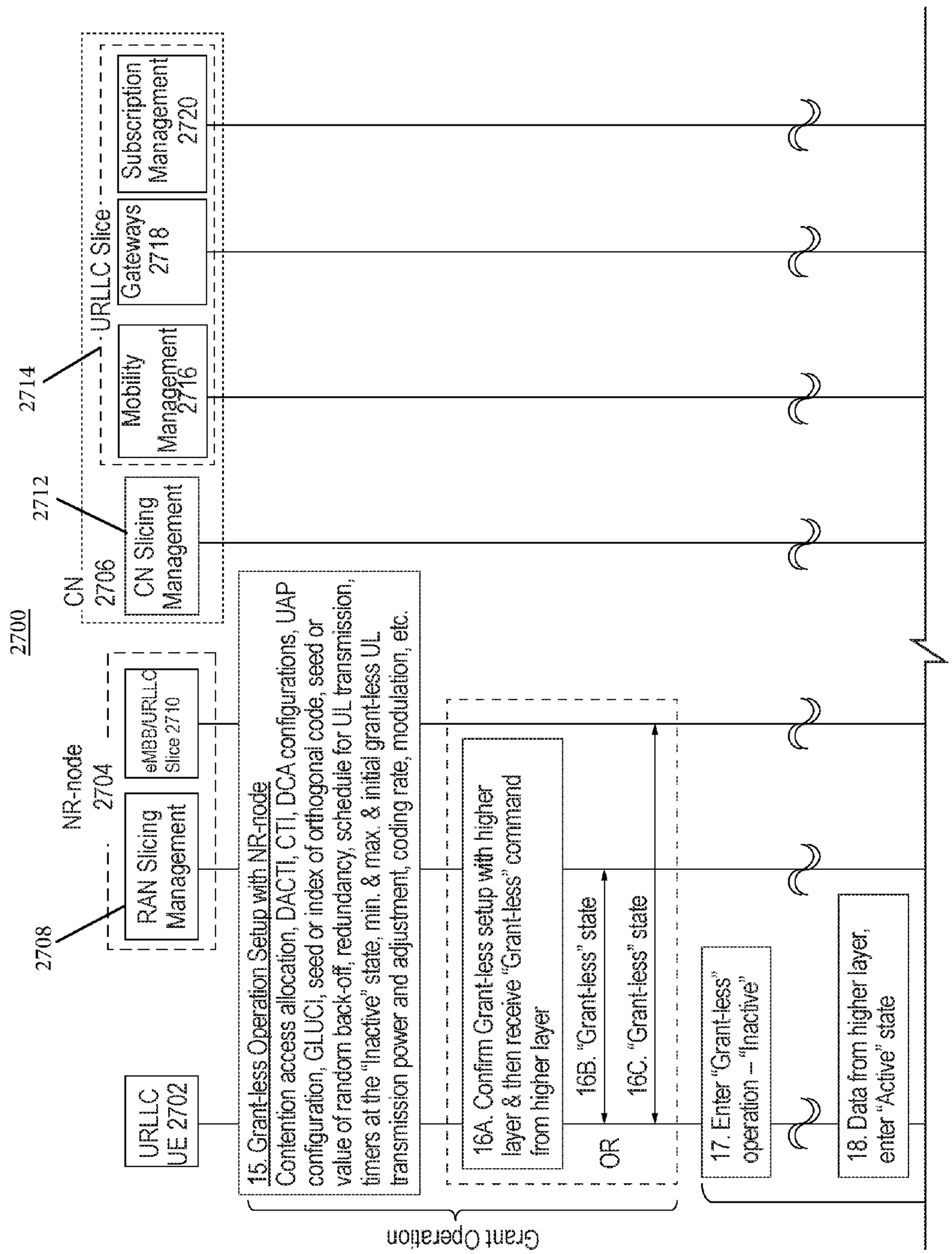

2700
CN
2706
2712
CN Slicing Management
2714
URLLC Slice
Mobility Management 2716
Gateways 2718
Subscription Management 2720
NR-node
2704
2708
RAN Slicing Management
eMBB/URLLC Slice 2710
URLLC UE 2702
15. Grant-less Operation Setup with NR-node
Contention access allocation, DACTI, CTI, DCA configurations, UAP configuration, GLUCI, seed or index of orthogonal code, seed or value of random back-off, redundancy, schedule for UL transmission, timers at the "Inactive" state, min. & max. & initial grant-less UL transmission power and adjustment, coding rate, modulation, etc.
16A. Confirm Grant-less setup with higher layer & then receive "Grant-less" command from higher layer
16B. "Grant-less" state
OR
16C. "Grant-less" state
17. Enter "Grant-less" operation – "Inactive"
18. Data from higher layer, enter "Active" state
Grant Operation

FIG. 28A

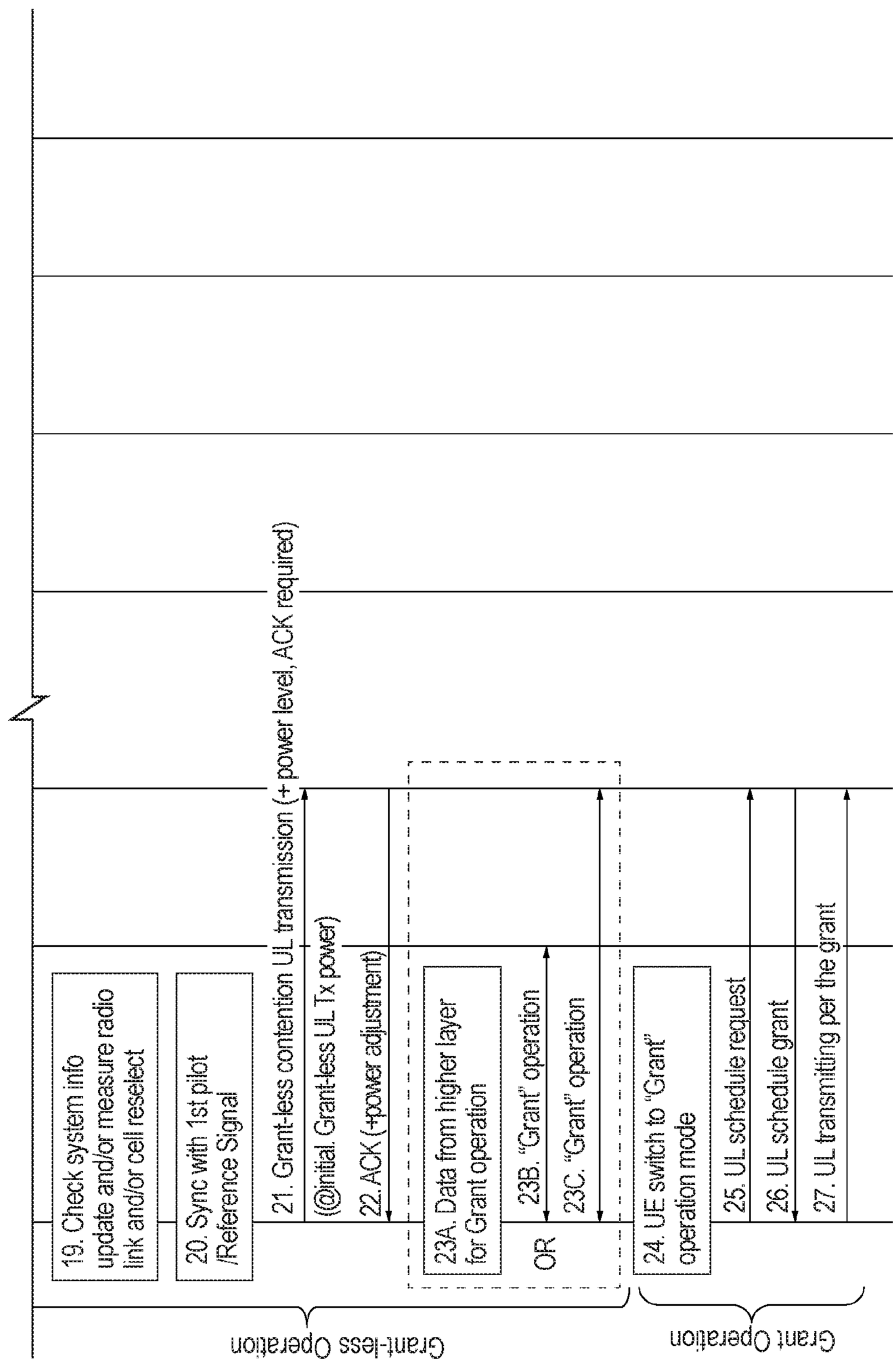

19. Check system info update and/or measure radio link and/or cell reselect
20. Sync with 1st pilot /Reference Signal
21. Grant-less contention UL transmission (+ power level, ACK required)
(@initial. Grant-less UL Tx power)
22. ACK (+power adjustment)
23A. Data from higher layer for Grant operation
OR
23B. "Grant" operation
23C. "Grant" operation
24. UE switch to "Grant" operation mode
25. UL schedule request
26. UL schedule grant
27. UL transmitting per the grant
Grant-less Operation
Grant Operation

FIG. 28B

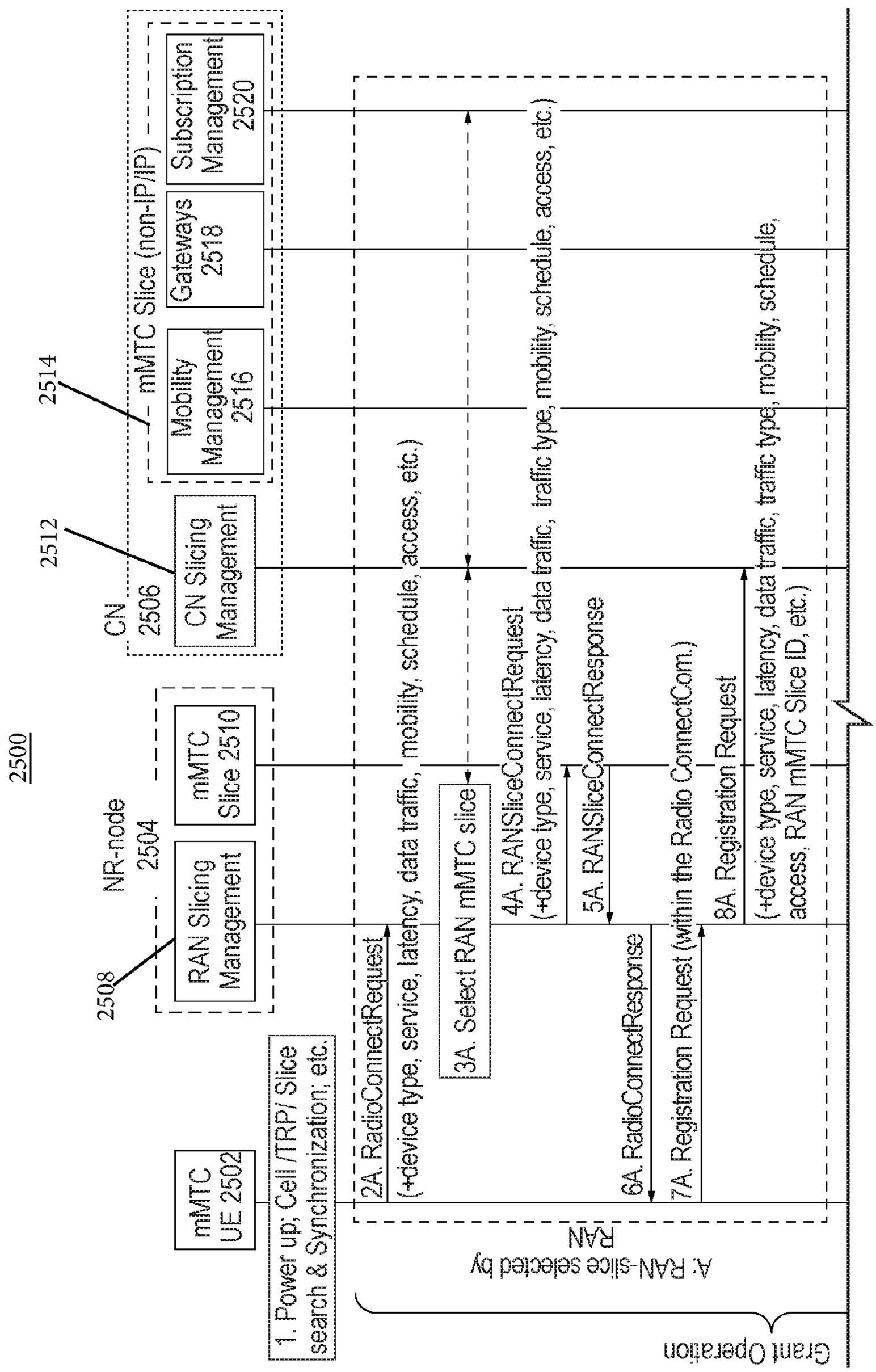

2500
mMTC UE 2502
1. Power up; Cell /TRP/ Slice search & Synchronization; etc.
NR-node 2504
2508
RAN Slicing Management
mMTC Slice 2510
CN 2506
2512
CN Slicing Management
mMTC Slice (non-IP/IP)
2514
Mobility Management 2516
Gateways 2518
Subscription Management 2520
A: RAN-slice selected by RAN
2A. RadioConnectRequest (+device type, service, latency, data traffic, mobility, schedule, access, etc.)
3A. Select RAN mMTC slice
4A. RANSliceConnectRequest (+device type, service, latency, data traffic, traffic type, mobility, schedule, access, etc.)
5A. RANSliceConnectResponse
6A. RadioConnectResponse
7A. Registration Request (within the Radio ConnectCom.)
8A. Registration Request (+device type, service, latency, data traffic, traffic type, mobility, schedule, access, RAN mMTC Slice ID, etc.)
Grant Operation

FIG. 29A

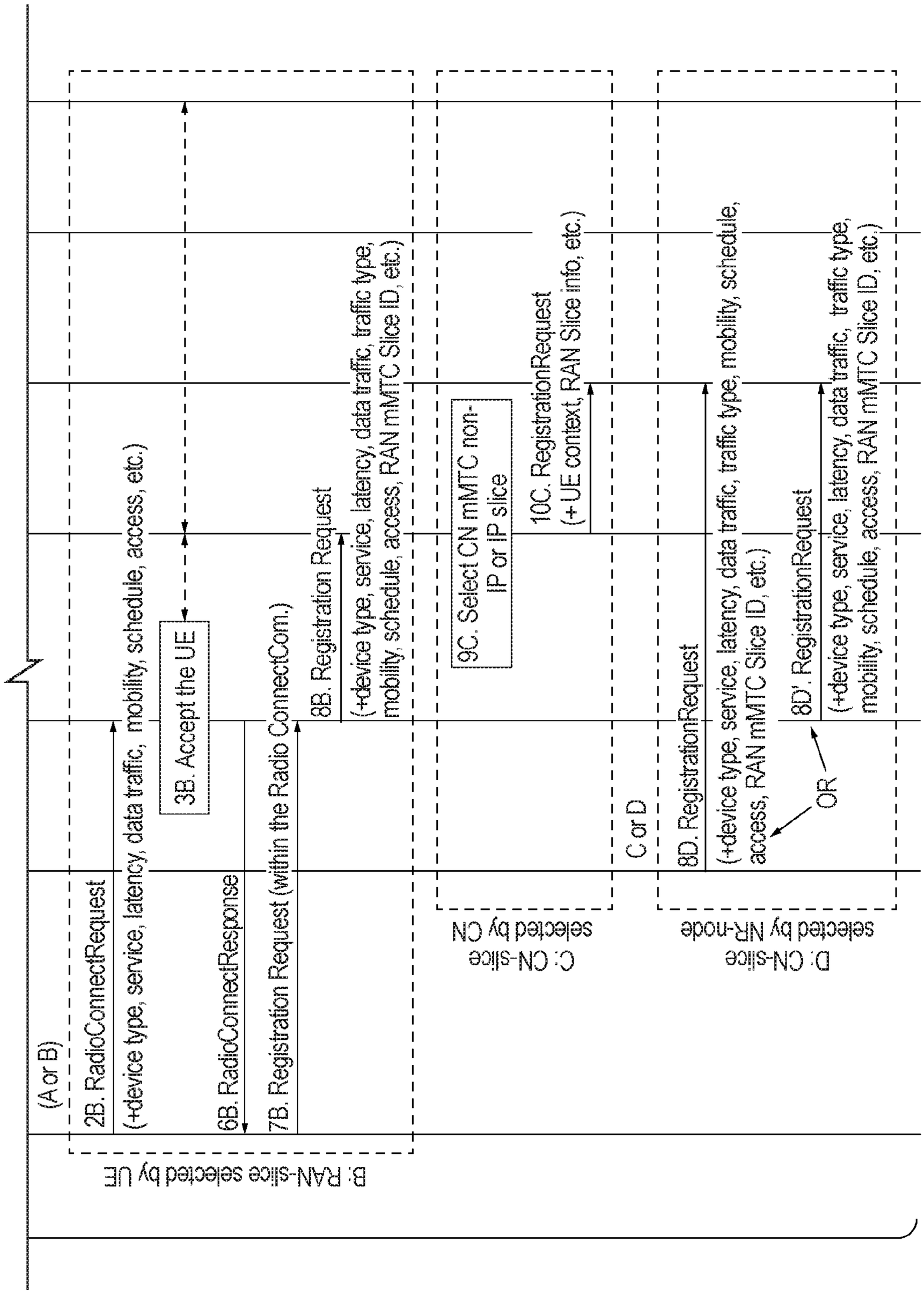

N
(A or B)
2B. RadioConnectRequest
(+device type, service, latency, data traffic, mobility, schedule, access, etc.)
3B. Accept the UE
6B. RadioConnectResponse
7B. Registration Request (within the Radio ConnectCom.)
8B. Registration Request
(+device type, service, latency, data traffic, traffic type, mobility, schedule, access, RAN mMTC Slice ID, etc.)
9C. Select CN mMTC non-IP or IP slice
10C. RegistrationRequest
(+UE context, RAN Slice info, etc.)
C or D
8D. RegistrationRequest
(+device type, service, latency, data traffic, traffic type, mobility, schedule, access, RAN mMTC Slice ID, etc.)
OR
8D'. RegistrationRequest
(+device type, service, latency, data traffic, traffic type, mobility, schedule, access, RAN mMTC Slice ID, etc.)
B: RAN-slice selected by UE
C: CN-slice selected by CN
D: CN-slice selected by NR-node

FIG. 29B

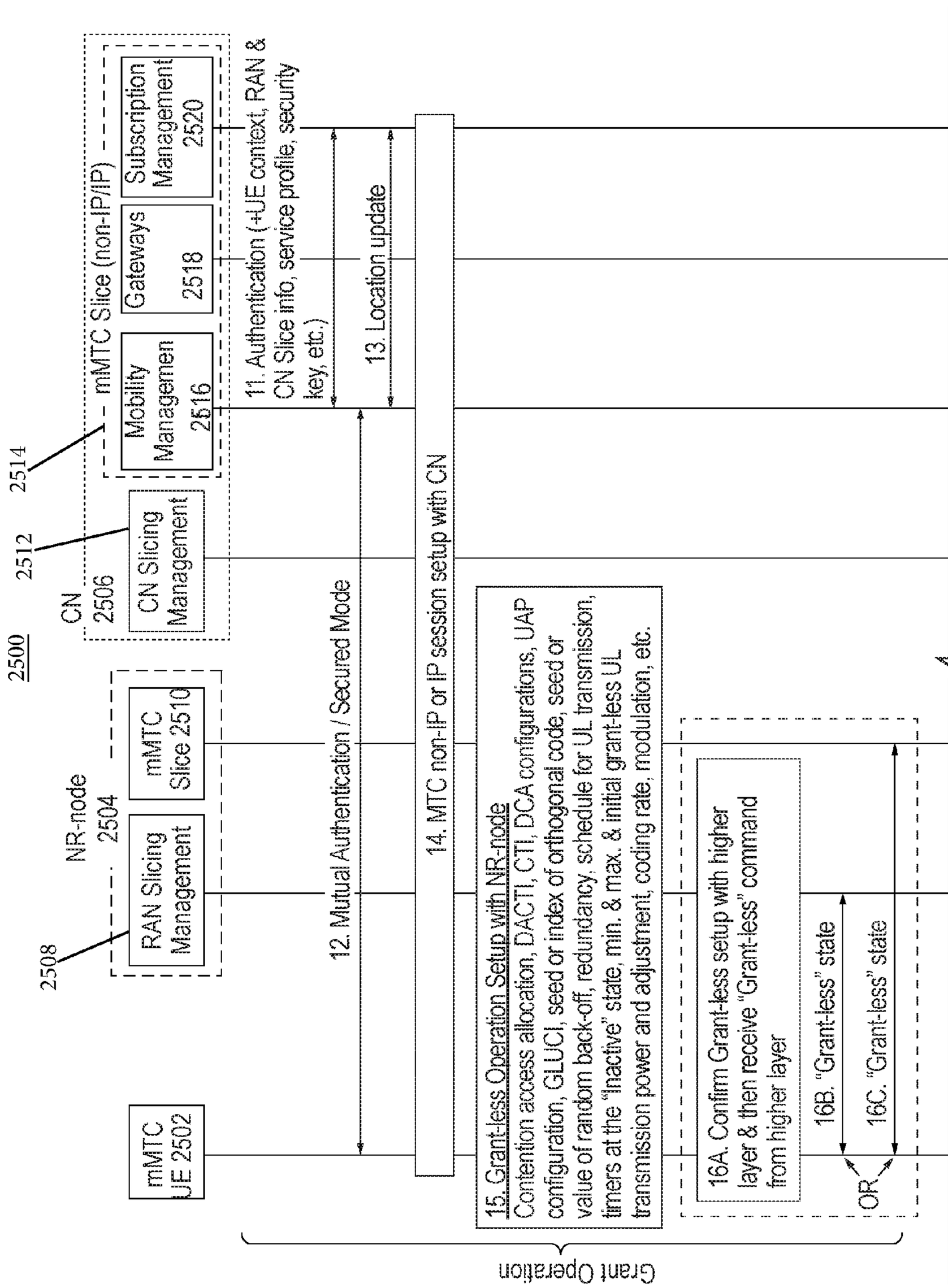

2500
2514
2512
2508
CN
2506
mMTC Slice (non-IP/IP)
Mobility Managemen 2516
Gateways 2518
Subscription Management 2520
CN Slicing Management
NR-node
2504
RAN Slicing Management
mMTC Slice 2510
mMTC UE 2502
11. Authentication (+UE context, RAN & CN Slice info, service profile, security key, etc.)
13. Location update
12. Mutual Authentication / Secured Mode
14. MTC non-IP or IP session setup with CN
15. Grant-less Operation Setup with NR-node
Contention access allocation, DACTI, CTI, DCA configurations, UAP configuration, GLUCI, seed or index of orthogonal code, seed or value of random back-off, redundancy, schedule for UL transmission, timers at the "inactive" state, min. & max. & initial grant-less UL transmission power and adjustment, coding rate, modulation, etc.
16A. Confirm Grant-less setup with higher layer & then receive "Grant-less" command from higher layer
16B. "Grant-less" state
OR
16C. "Grant-less" state
Grant Operation

FIG. 30A

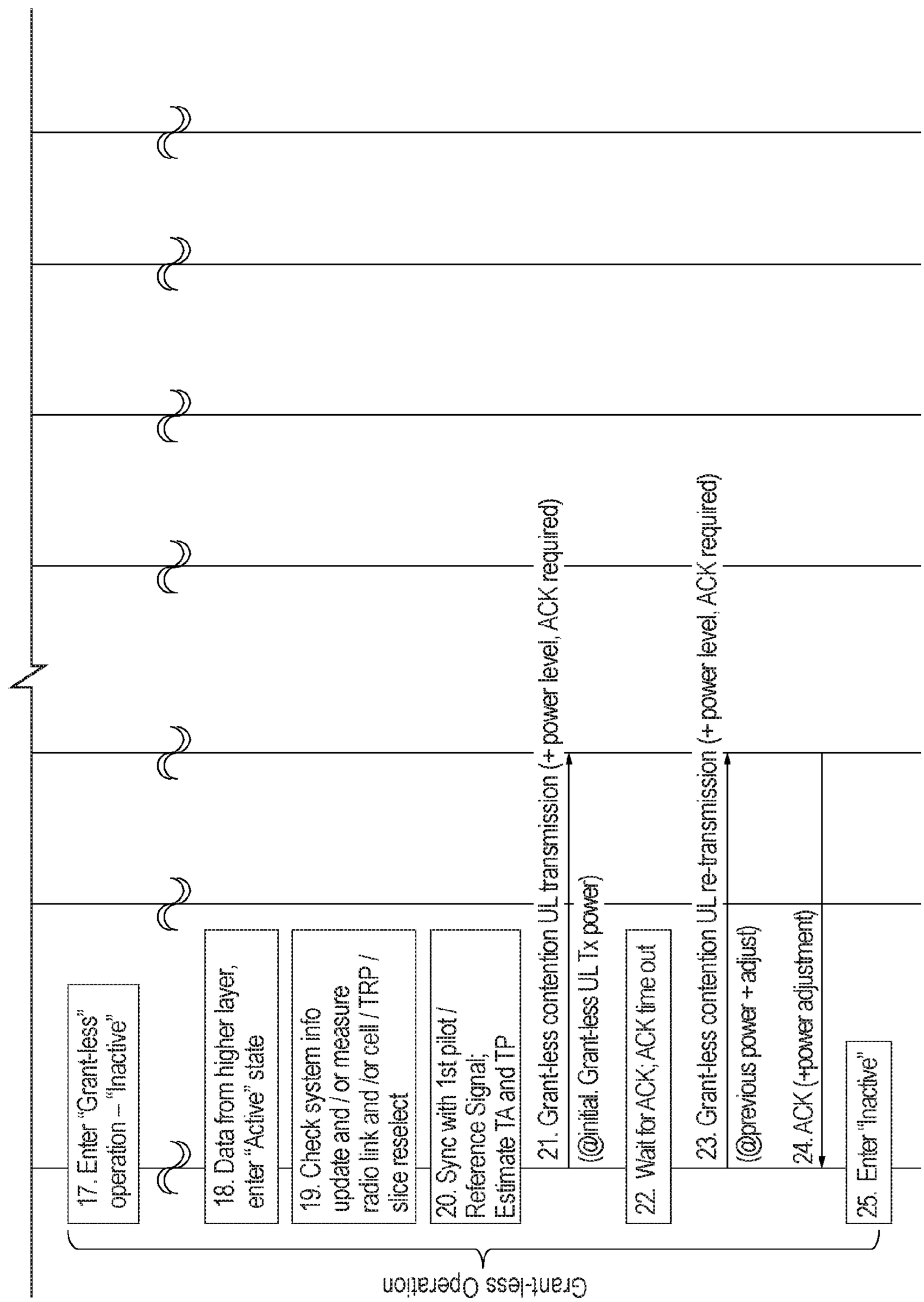

N
17. Enter "Grant-less" operation – "Inactive"
18. Data from higher layer, enter "Active" state
19. Check system info update and / or measure radio link and /or cell / TRP / slice reselect
20. Sync with 1st pilot / Reference Signal; Estimate TA and TP
21. Grant-less contention UL transmission (+ power level, ACK required)
(@initial. Grant-less UL Tx power)
22. Wait for ACK; ACK time out
23. Grant-less contention UL re-transmission (+ power level, ACK required)
(@previous power + adjust)
24. ACK (+power adjustment)
25. Enter "Inactive"
Grant-less Operation

FIG. 30B

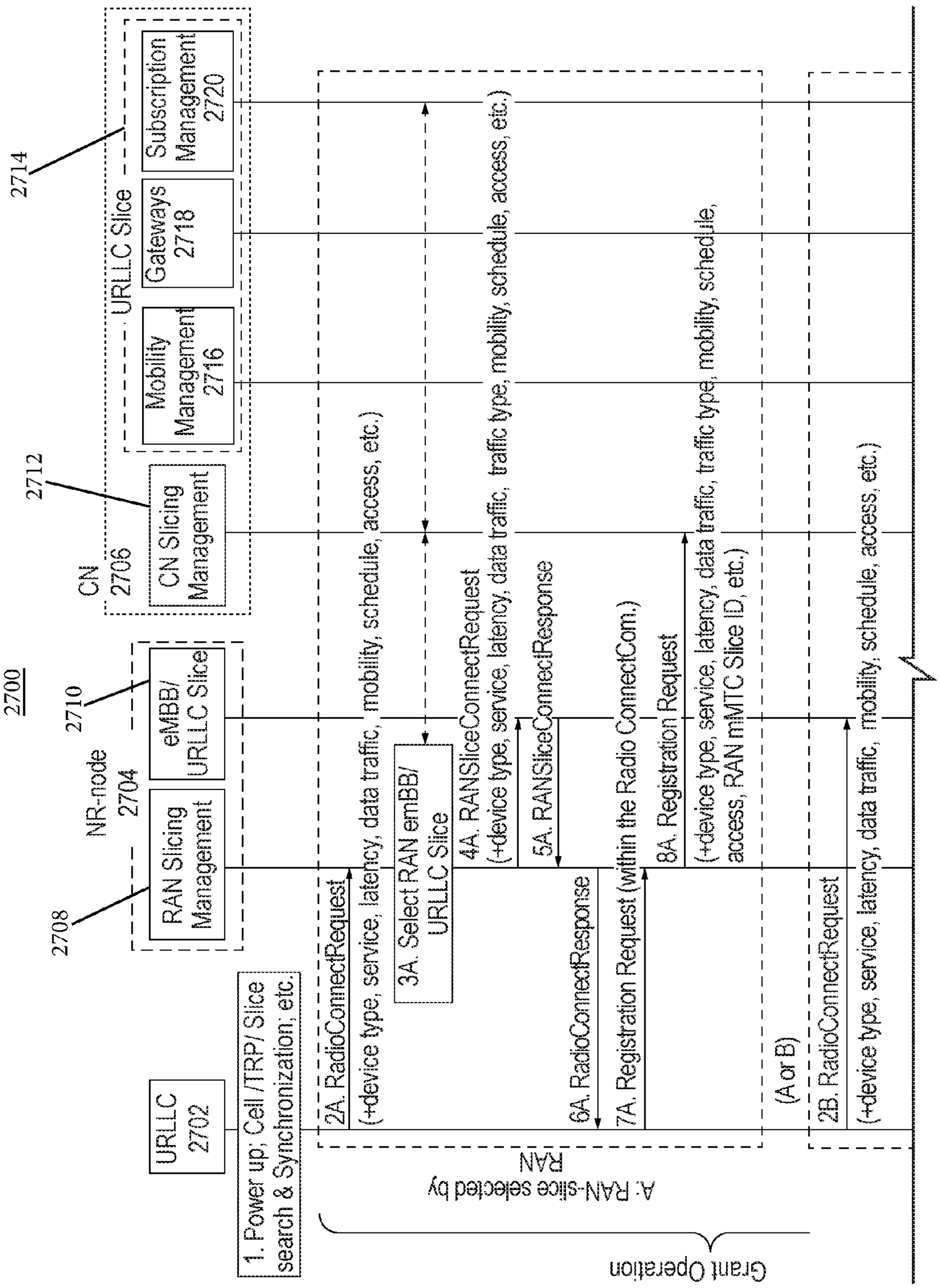

2700
URLLC 2702
2708
RAN Slicing Management
NR-node 2704
2710
eMBB/ URLLC Slice
CN 2706
2712
CN Slicing Management
URLLC Slice
2714
Mobility Management 2716
Gateways 2718
Subscription Management 2720
1. Power up; Cell /TRP/ Slice search & Synchronization; etc.
2A. RadioConnectRequest
(+device type, service, latency, data traffic, mobility, schedule, access, etc.)
3A. Select RAN emBB/ URLLC Slice
4A. RANSliceConnectRequest
(+device type, service, latency, data traffic, traffic type, mobility, schedule, access, etc.)
5A. RANSliceConnectResponse
6A. RadioConnectResponse
7A. Registration Request (within the Radio ConnectCom.)
8A. Registration Request
(+device type, service, latency, data traffic, traffic type, mobility, schedule, access, RAN mMTC Slice ID, etc.)
(A or B)
2B. RadioConnectRequest
(+device type, service, latency, data traffic, mobility, schedule, access, etc.)
A: RAN-slice selected by RAN
Grant Operation

FIG. 31A

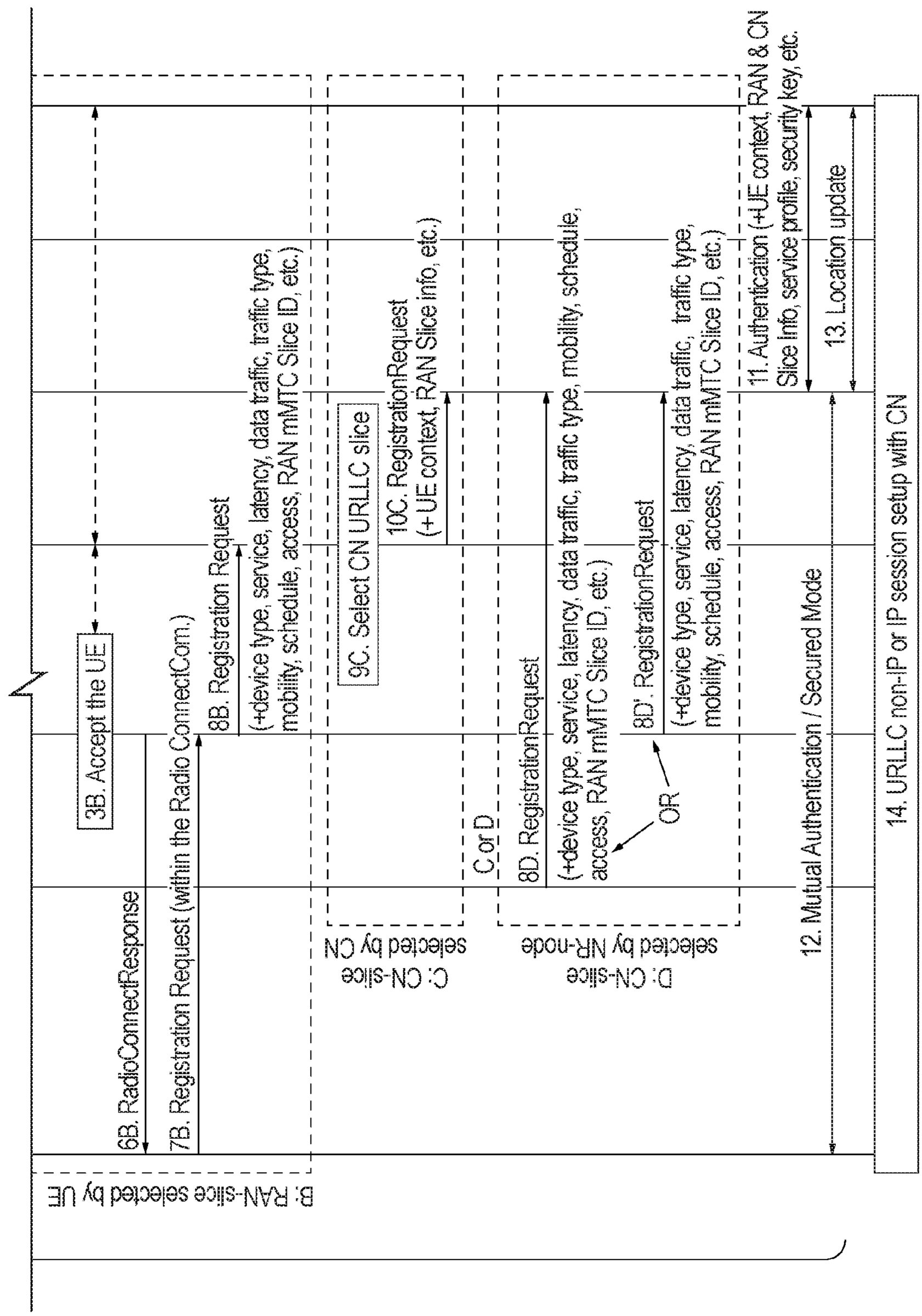

B: RAN-slice selected by UE
C: CN-slice selected by CN
D: CN-slice selected by NR-node
3B. Accept the UE
6B. RadioConnectResponse
7B. Registration Request (within the Radio ConnectCom.)
8B. Registration Request
(+device type, service, latency, data traffic, traffic type, mobility, schedule, access, RAN mMTC Slice ID, etc.)
9C. Select CN URLLC slice
10C. RegistrationRequest
(+UE context, RAN Slice info, etc.)
C or D
8D. RegistrationRequest
(+device type, service, latency, data traffic, traffic type, mobility, schedule, access, RAN mMTC Slice ID, etc.)
OR
8D'. RegistrationRequest
(+device type, service, latency, data traffic, traffic type, mobility, schedule, access, RAN mMTC Slice ID, etc.)
11. Authentication (+UE context, RAN & CN Slice Info, service profile, security key, etc.
12. Mutual Authentication / Secured Mode
13. Location update
14. URLLC non-IP or IP session setup with CN

FIG. 31B

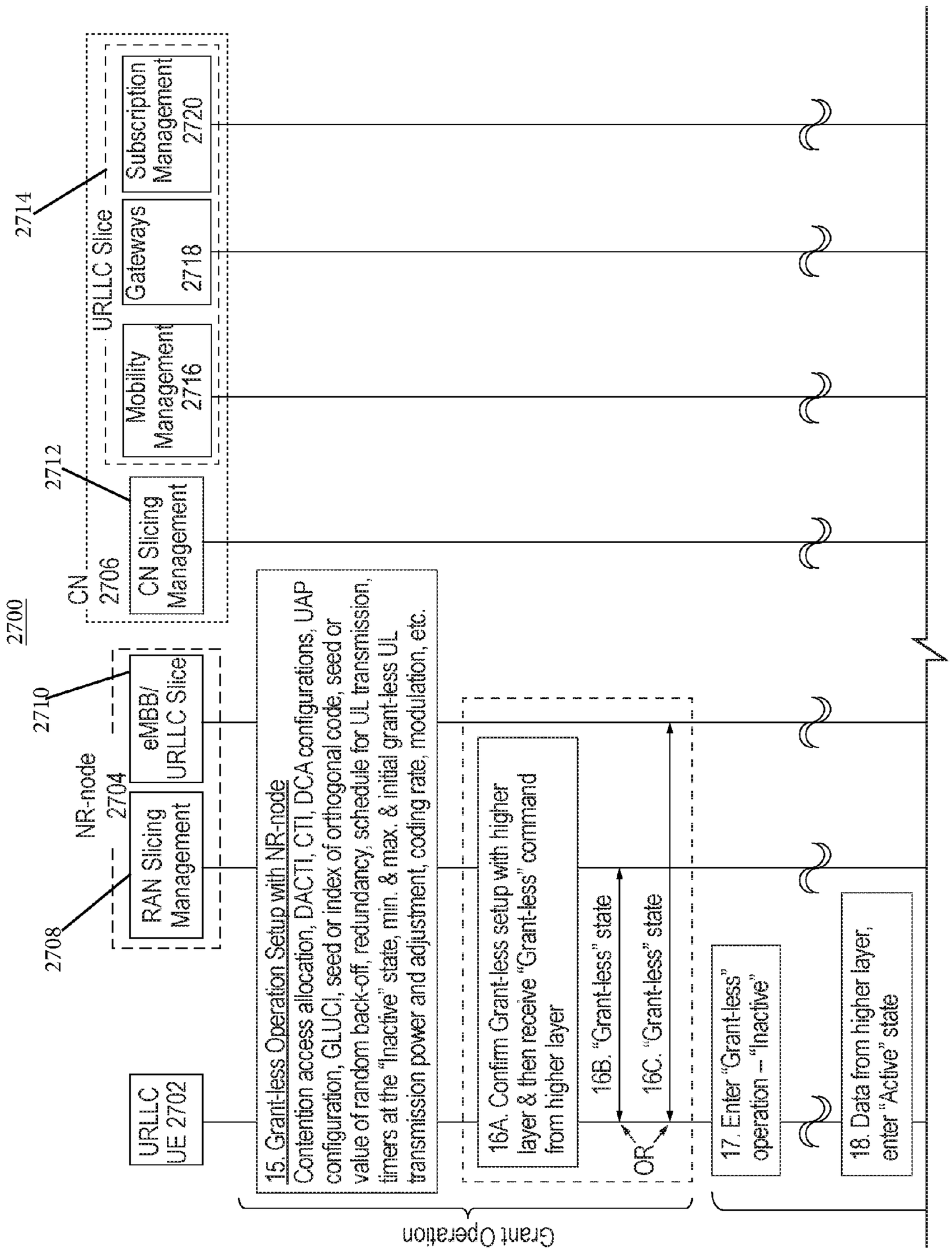

2700
2714
URLLC Slice
Subscription Management 2720
Gateways 2718
Mobility Management 2716
2712
CN 2706
CN Slicing Management
2710
eMBB/ URLLC Slice
NR-node 2704
2708
RAN Slicing Management
URLLC UE 2702
15. Grant-less Operation Setup with NR-node
Contention access allocation, DACTI, CTI, DCA configurations, UAP configuration, GLUCI, seed or index of orthogonal code, seed or value of random back-off, redundancy, schedule for UL transmission, timers at the "Inactive" state, min. & max. & initial grant-less UL transmission power and adjustment, coding rate, modulation, etc.
16A. Confirm Grant-less setup with higher layer & then receive "Grant-less" command from higher layer
16B. "Grant-less" state
OR
16C. "Grant-less" state
17. Enter "Grant-less" operation – "Inactive"
18. Data from higher layer, enter "Active" state
Grant Operation

FIG. 32A

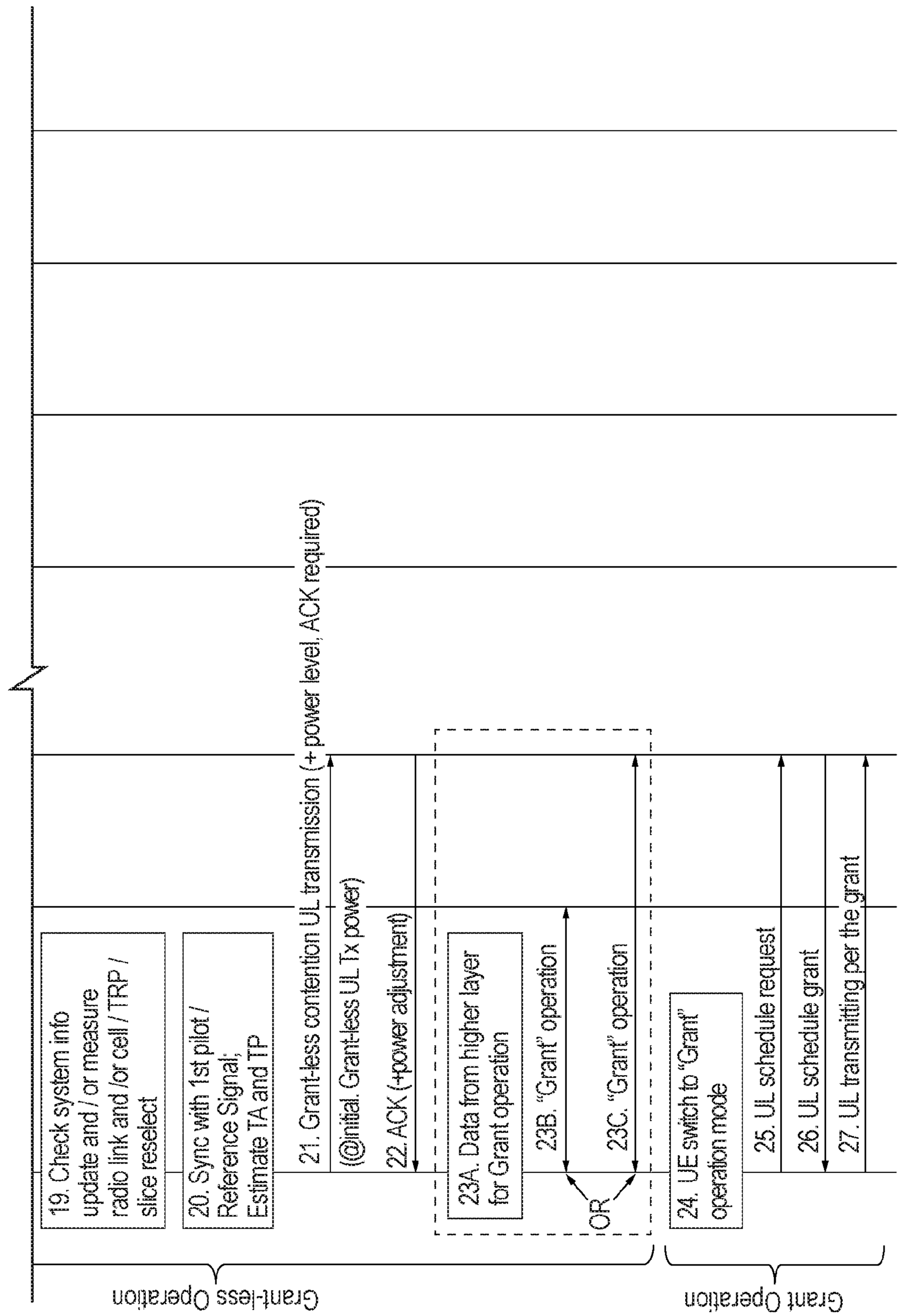

19. Check system info update and / or measure radio link and /or cell / TRP / slice reselect
20. Sync with 1st pilot / Reference Signal; Estimate TA and TP
21. Grant-less contention UL transmission (+ power level, ACK required)
(@initial. Grant-less UL Tx power)
22. ACK (+power adjustment)
23A. Data from higher layer for Grant operation
23B. "Grant" operation
OR
23C. "Grant" operation
24. UE switch to "Grant" operation mode
25. UL schedule request
26. UL schedule grant
27. UL transmitting per the grant
Grant-less Operation
Grant Operation

FIG. 32B

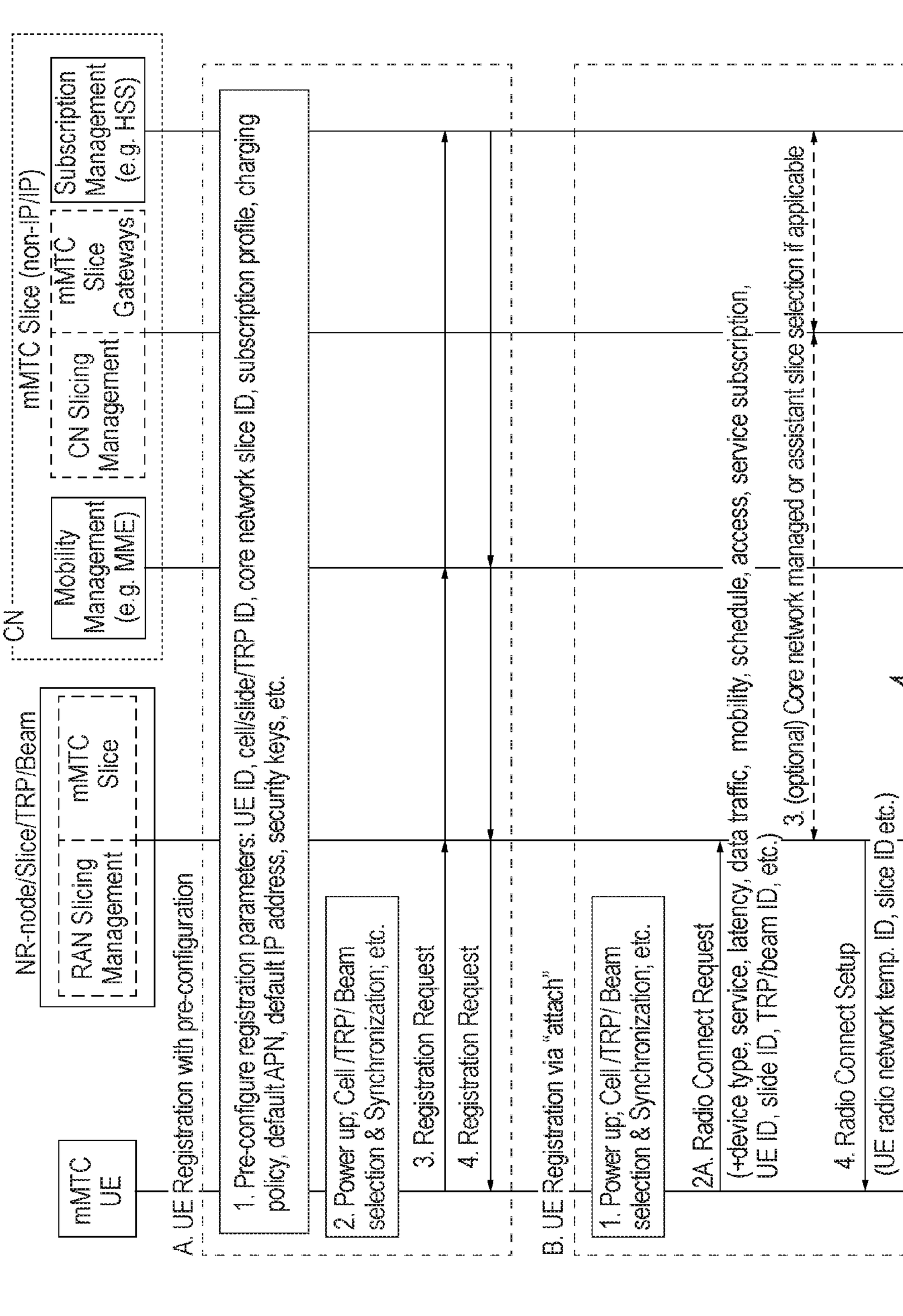

mMTC UE
NR-node/Slide/Slice/TRP/Beam
RAN Slicing Management
mMTC Slice
CN
Mobility Management (e.g. MME)
CN Slicing Management
mMTC Slice Gateways
mMTC Slice Slice
Subscription Management (e.g. HSS)
A. UE Registration with pre-configuration
1. Pre-configure registration parameters: UE ID, cell/slide/TRP ID, core network slice ID, subscription profile, charging policy, default APN, default IP address, security keys, etc.
2. Power up; Cell /TRP/ Beam selection & Synchronization; etc.
3. Registration Request
4. Registration Request
B. UE Registration via "attach"
1. Power up; Cell /TRP/ Beam selection & Synchronization; etc.
2A. Radio Connect Request
(+device type, service, latency, data traffic, mobility, schedule, access, service subscription, UE ID, slide ID, TRP/beam ID, etc.)
3. (optional) Core network managed or assistant slice selection if applicable
4. Radio Connect Setup
(UE radio network temp. ID, slice ID etc.)

FIG. 33A

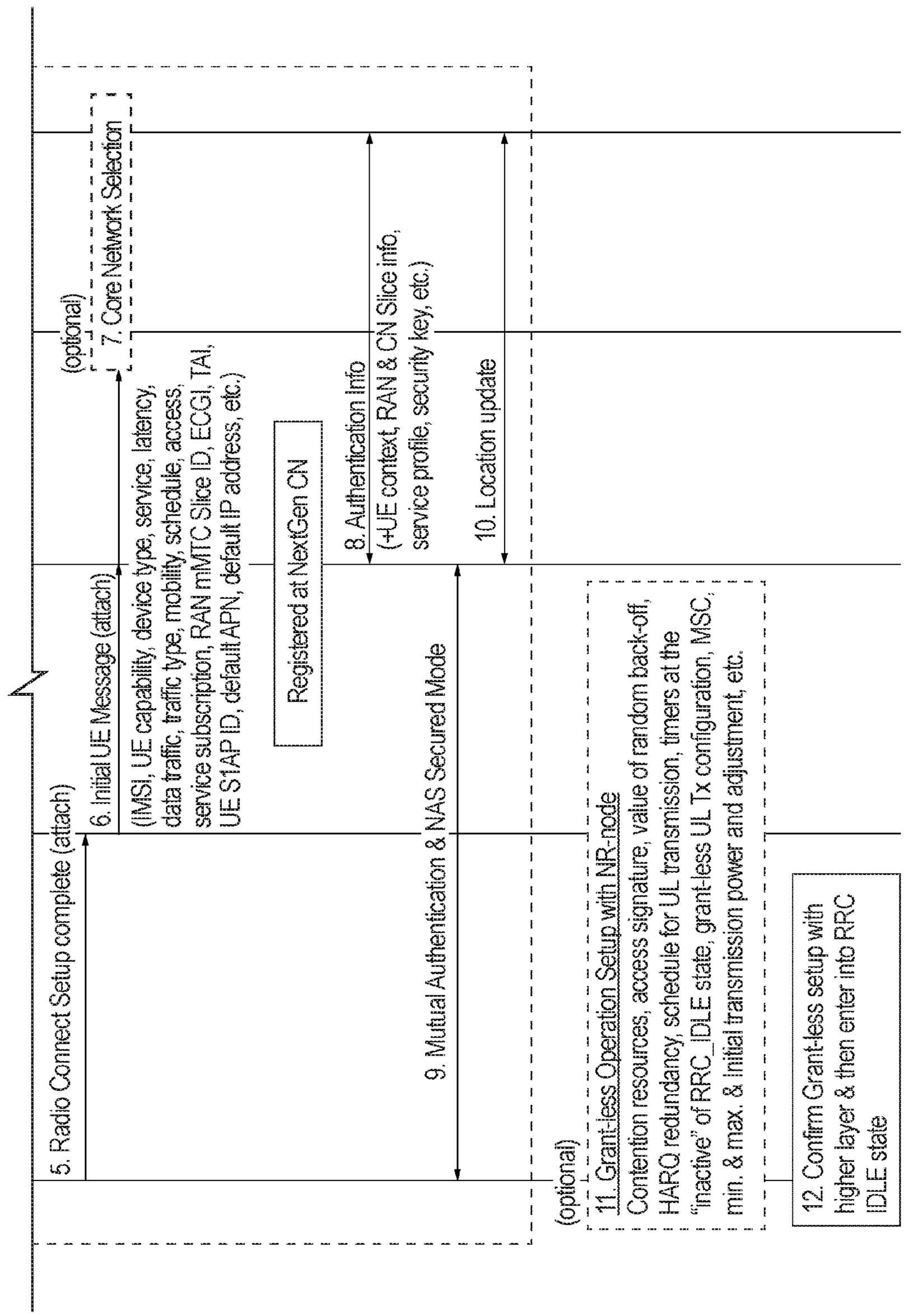

N
5. Radio Connect Setup complete (attach)
6. Initial UE Message (attach)
(IMSI, UE capability, device type, service, latency, data traffic, traffic type, mobility, schedule, access, service subscription, RAN mMTC Slice ID, ECGI, TAI, UE S1AP ID, default APN, default IP address, etc.)
(optional)
7. Core Network Selection
Registered at NextGen CN
8. Authentication Info
(+UE context, RAN & CN Slice info, service profile, security key, etc.)
9. Mutual Authentication & NAS Secured Mode
10. Location update
(optional)
11. Grant-less Operation Setup with NR-node
Contention resources, access signature, value of random back-off, HARQ redundancy, schedule for UL transmission, timers at the "inactive" of RRC_IDLE state, grant-less UL Tx configuration, MSC, min. & max. & initial transmission power and adjustment, etc.
12. Confirm Grant-less setup with higher layer & then enter into RRC IDLE state

FIG. 33B

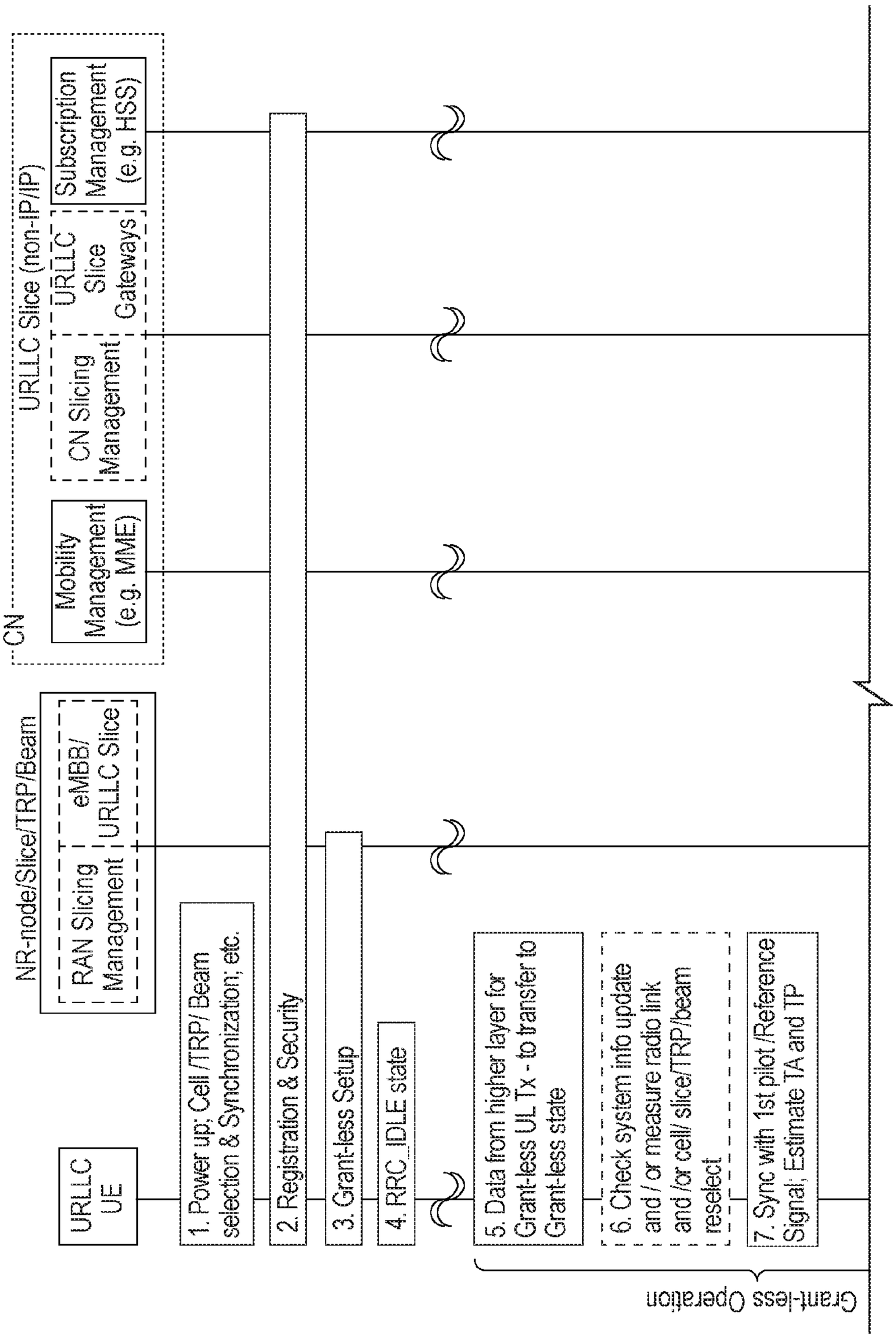

URLLC UE
NR-node/Slice/TRP/Beam
RAN Slicing Management
eMBB/ URLLC Slice
CN
Mobility Management (e.g. MME)
URLLC Slice (non-IP/IP)
CN Slicing Management
URLLC Slice Gateways
Subscription Management (e.g. HSS)
1. Power up; Cell /TRP/ Beam selection & Synchronization; etc.
2. Registration & Security
3. Grant-less Setup
4. RRC_IDLE state
5. Data from higher layer for Grant-less UL Tx - to transfer to Grant-less state
6. Check system info update and / or measure radio link and /or cell/ slice/TRP/beam reselect
7. Sync with 1st pilot /Reference Signal; Estimate TA and TP
Grant-less Operation

FIG. 34A

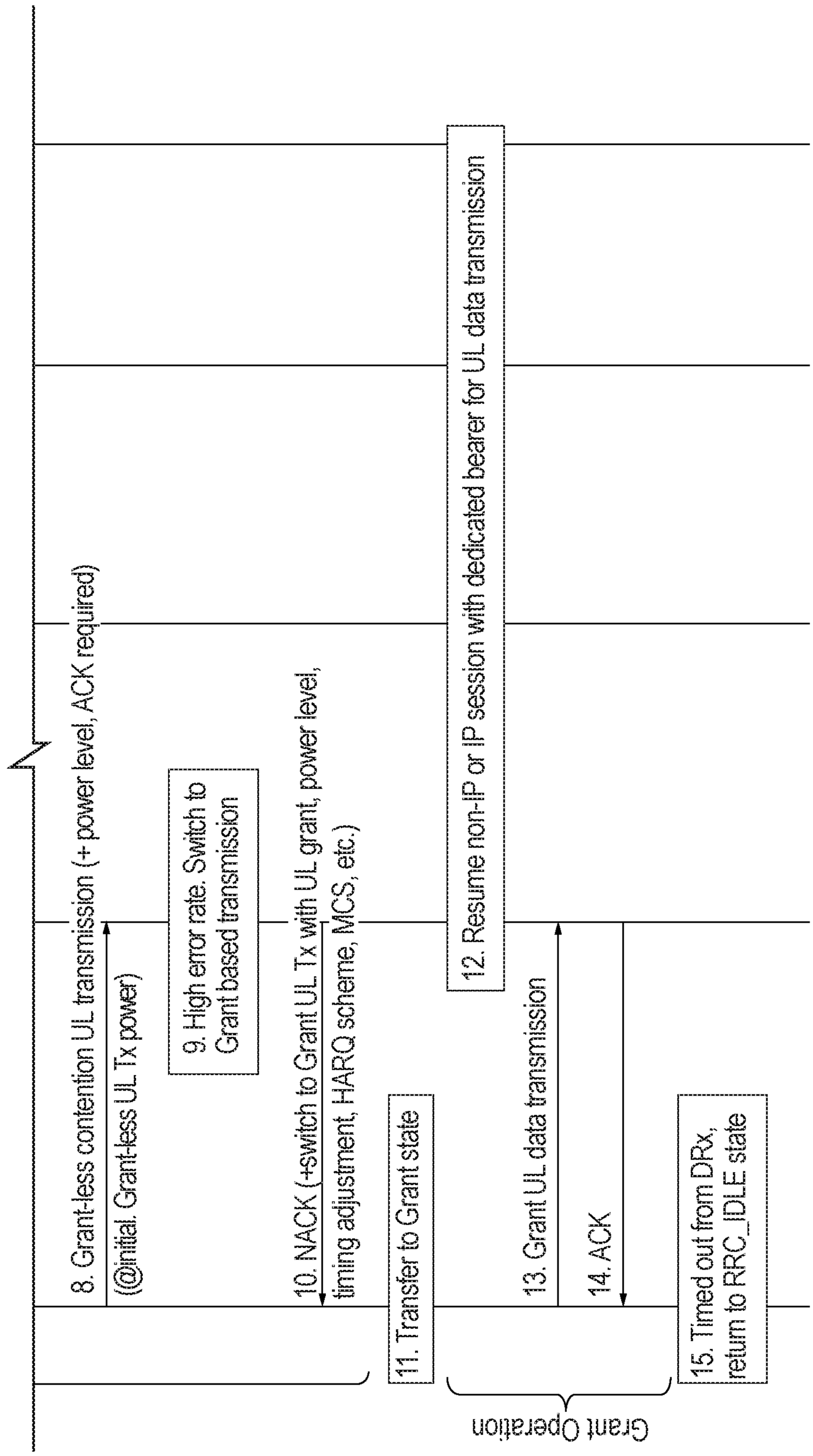

8. Grant-less contention UL transmission (+ power level, ACK required)
(@initial. Grant-less UL Tx power)
9. High error rate. Switch to Grant based transmission
10. NACK (+switch to Grant UL Tx with UL grant, power level, timing adjustment, HARQ scheme, MCS, etc.)
11. Transfer to Grant state
12. Resume non-IP or IP session with dedicated bearer for UL data transmission
13. Grant UL data transmission
14. ACK
15. Timed out from DRx, return to RRC_IDLE state
Grant Operation

FIG. 34B

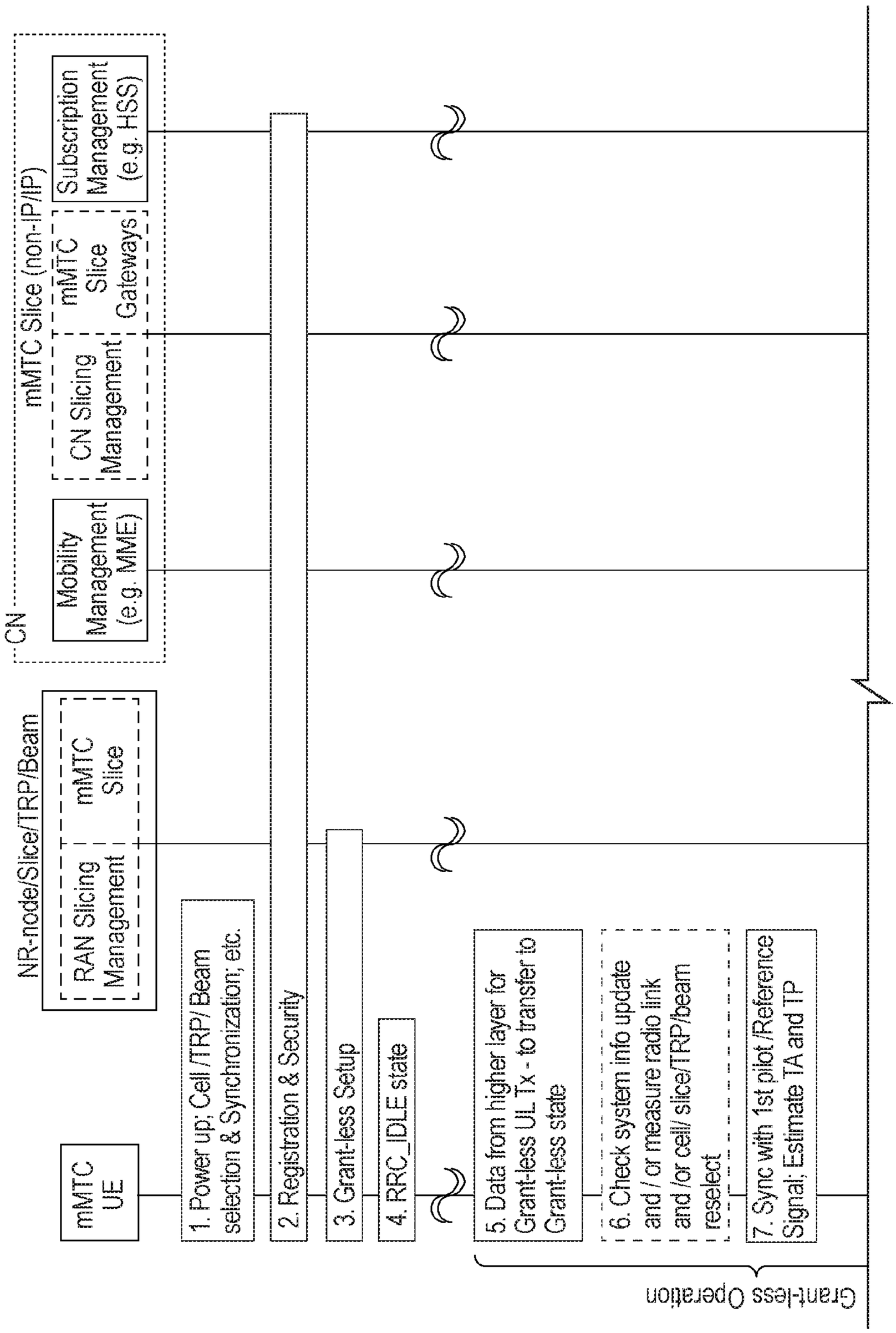

CN
mMTC Slice (non-IP/IP)
Mobility Management (e.g. MME)
CN Slicing Management
mMTC Slice Gateways
Subscription Management (e.g. HSS)
NR-node/Slice/TRP/Beam
RAN Slicing Management
mMTC Slice
mMTC UE
1. Power up; Cell /TRP/ Beam selection & Synchronization; etc.
2. Registration & Security
3. Grant-less Setup
4. RRC_IDLE state
5. Data from higher layer for Grant-less UL Tx - to transfer to Grant-less state
6. Check system info update and / or measure radio link and /or cell/ slice/TRP/beam reselect
7. Sync with 1st pilot /Reference Signal; Estimate TA and TP
Grant-less Operation

FIG. 35A

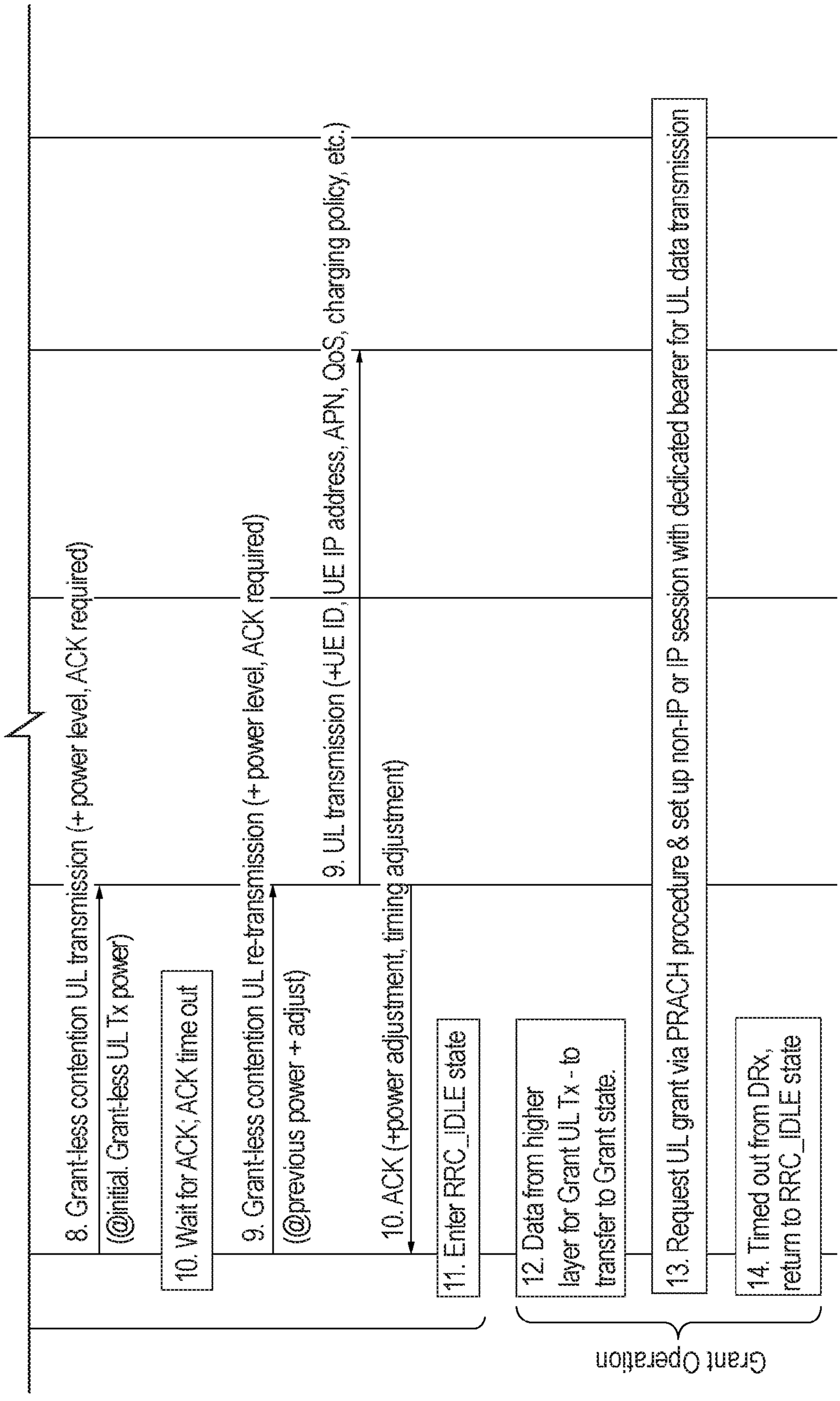

8. Grant-less contention UL transmission (+ power level, ACK required)
(@initial. Grant-less UL Tx power)
10. Wait for ACK; ACK time out
9. Grant-less contention UL re-transmission (+ power level, ACK required)
(@previous power + adjust)
9. UL transmission (+UE ID, UE IP address, APN, QoS, charging policy, etc.)
10. ACK (+power adjustment, timing adjustment)
11. Enter RRC_IDLE state
12. Data from higher layer for Grant UL Tx - to transfer to Grant state.
13. Request UL grant via PRACH procedure & set up non-IP or IP session with dedicated bearer for UL data transmission
14. Timed out from DRx, return to RRC_IDLE state
Grant Operation

FIG. 35B

3600

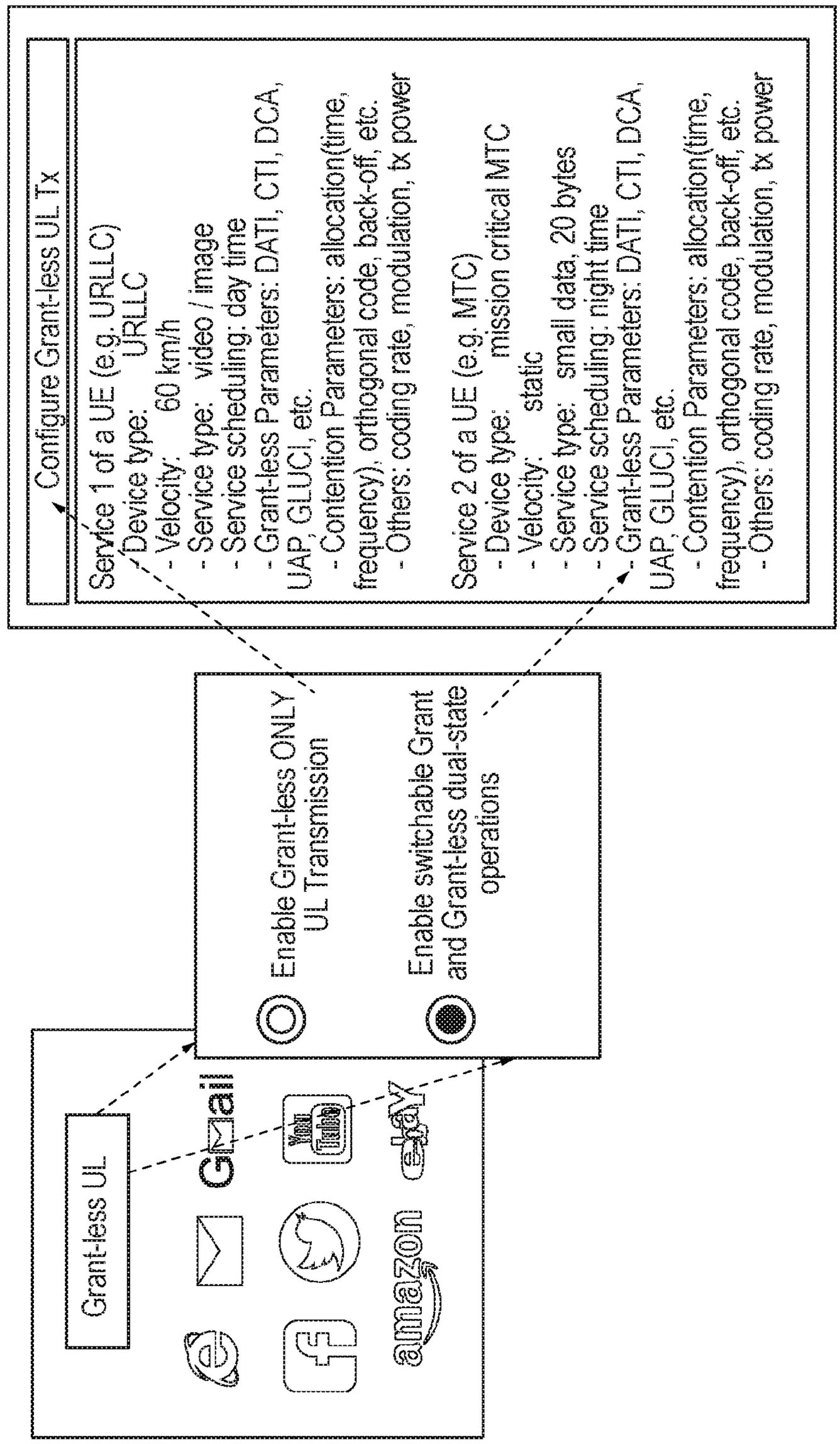

Grant-less UL
Enable Grant-less ONLY UL Transmission
Enable switchable Grant and Grant-less dual-state operations
Configure Grant-less UL Tx
Service 1 of a UE (e.g. URLLC)
Device type: URLLC
- Velocity: 60 km/h
- Service type: video / image
- Service scheduling: day time
- Grant-less Parameters: DATI, CTI, DCA, UAP, GLUCI, etc.
- Contention Parameters: allocation(time, frequency), orthogonal code, back-off, etc.
- Others: coding rate, modulation, tx power
Service 2 of a UE (e.g. MTC)
- Device type: mission critical MTC
- Velocity: static
- Service type: small data, 20 bytes
- Service scheduling: night time
- Grant-less Parameters: DATI, CTI, DCA, UAP, GLUCI, etc.
- Contention Parameters: allocation(time, frequency), orthogonal code, back-off, etc.
- Others: coding rate, modulation, tx power

FIG. 36

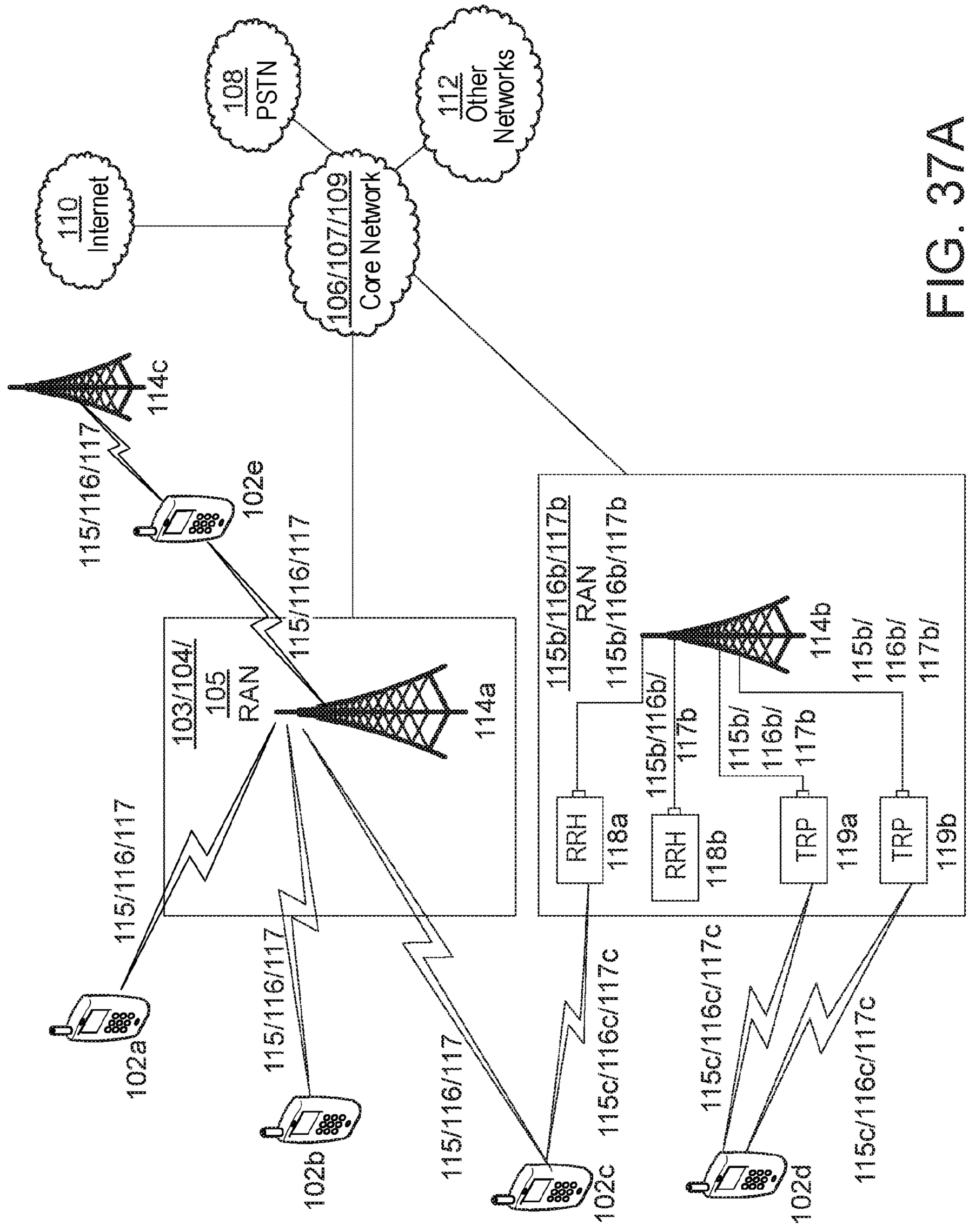

110
Internet
108
PSTN
112
Other
Networks
106/107/109
Core Network
114c
115/116/117
102e
115/116/117
103/104/
105
RAN
114a
115/116/117
115/116/117
115/116/117
102a
102b
115/116/117
115b/116b/117b
RAN
115b/116b/117b
114b
115b/
116b/
117b/
115b/116b/
117b
115b/
116b/
117b
RRH
118a
RRH
118b
TRP
119a
TRP
119b
115c/116c/117c
115c/116c/117c
115c/116c/117c
102c
102d

FIG. 37A

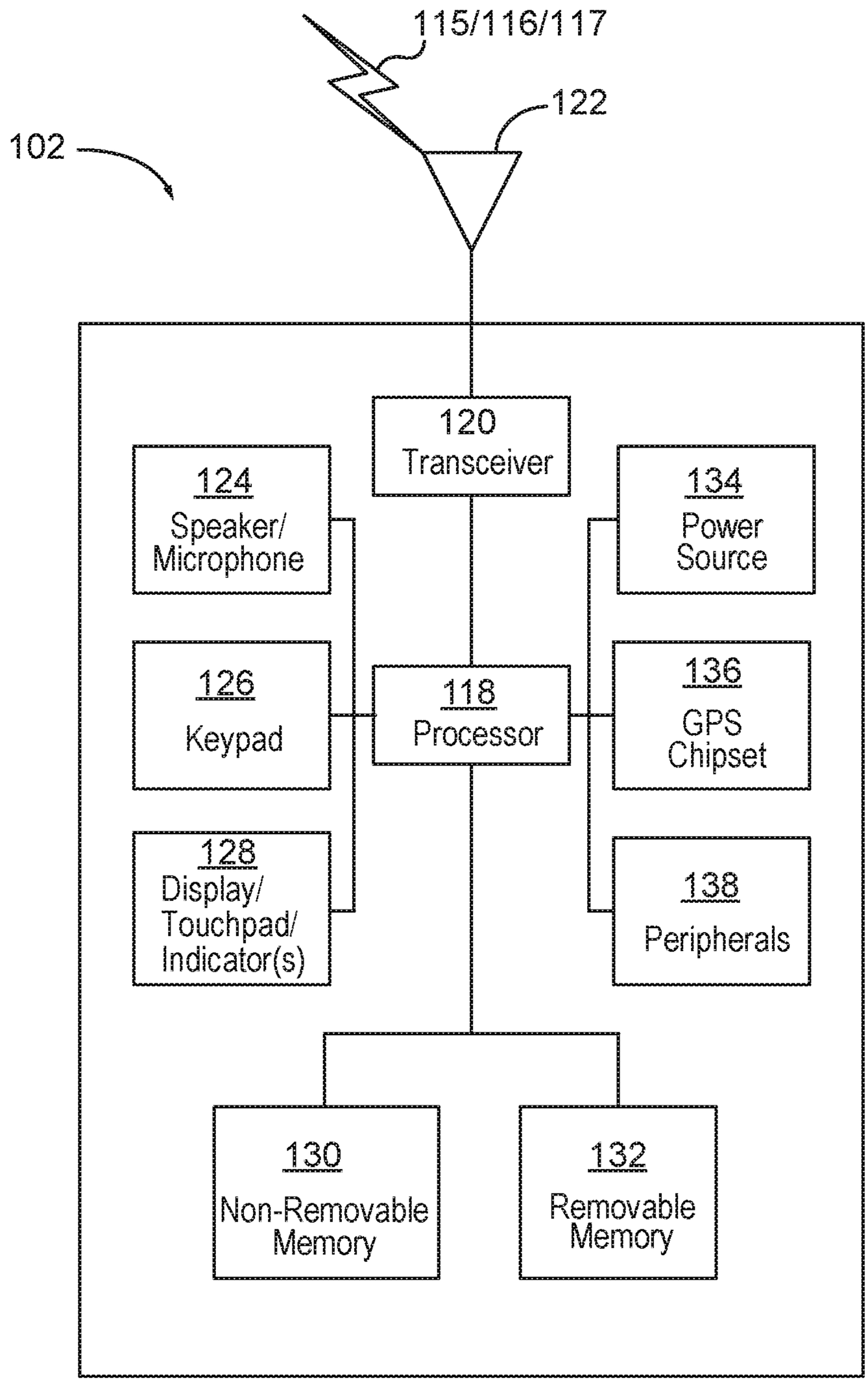

115/116/117
122
102
120
Transceiver
124
Speaker/
Microphone
134
Power
Source
126
Keypad
118
Processor
136
GPS
Chipset
128
Display/
Touchpad/
Indicator(s)
138
Peripherals
130
Non-Removable
Memory
132
Removable
Memory

FIG. 37B

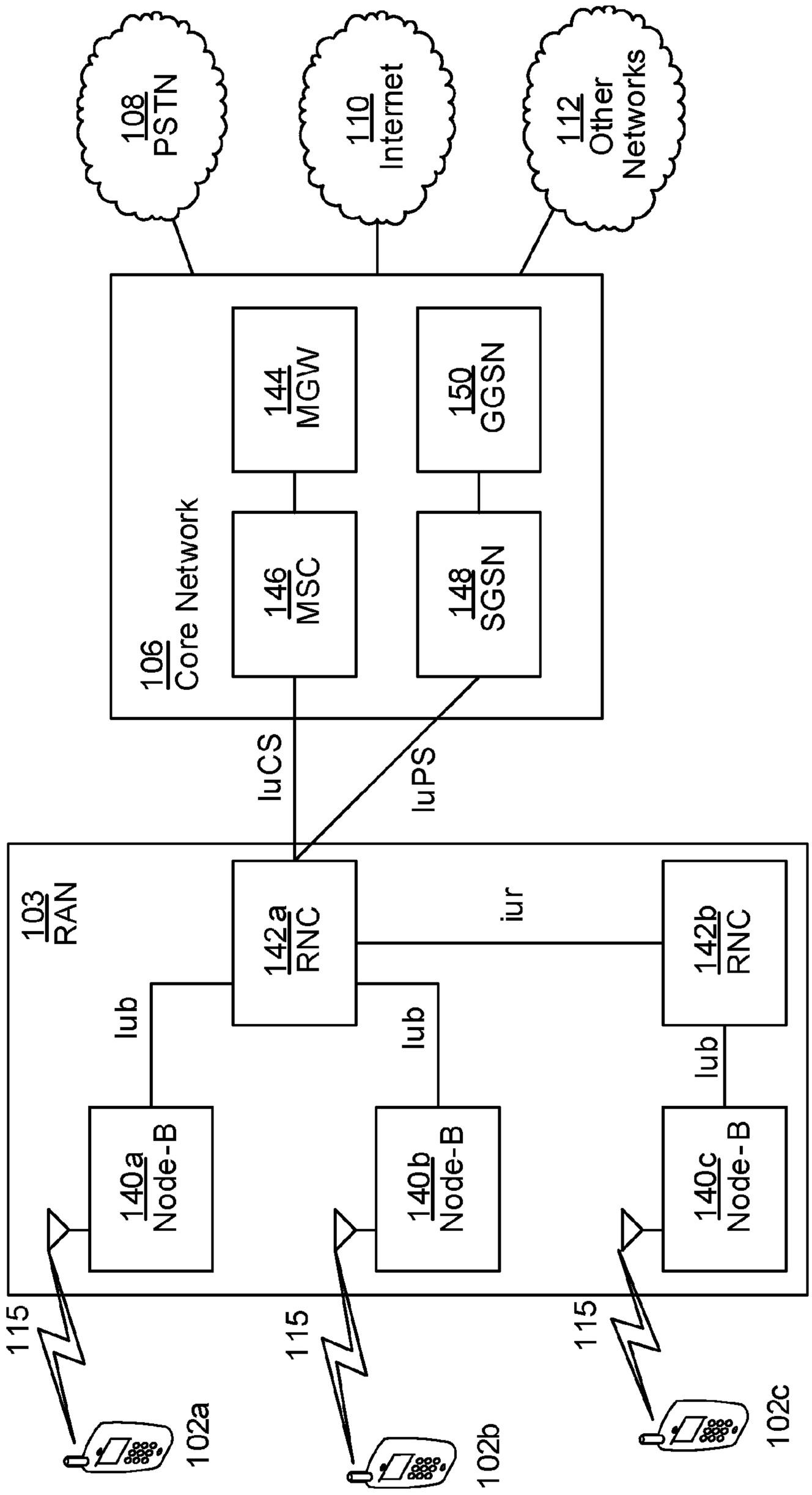

108
PSTN
110
Internet
112
Other
Networks
106
Core Network
144
MGW
150
GGSN
146
MSC
148
SGSN
IuCS
IuPS
103
RAN
142a
RNC
iur
142b
RNC
Iub
Iub
Iub
140a
Node-B
140b
Node-B
140c
Node-B
115
115
115
102a
102b
102c

FIG. 37C

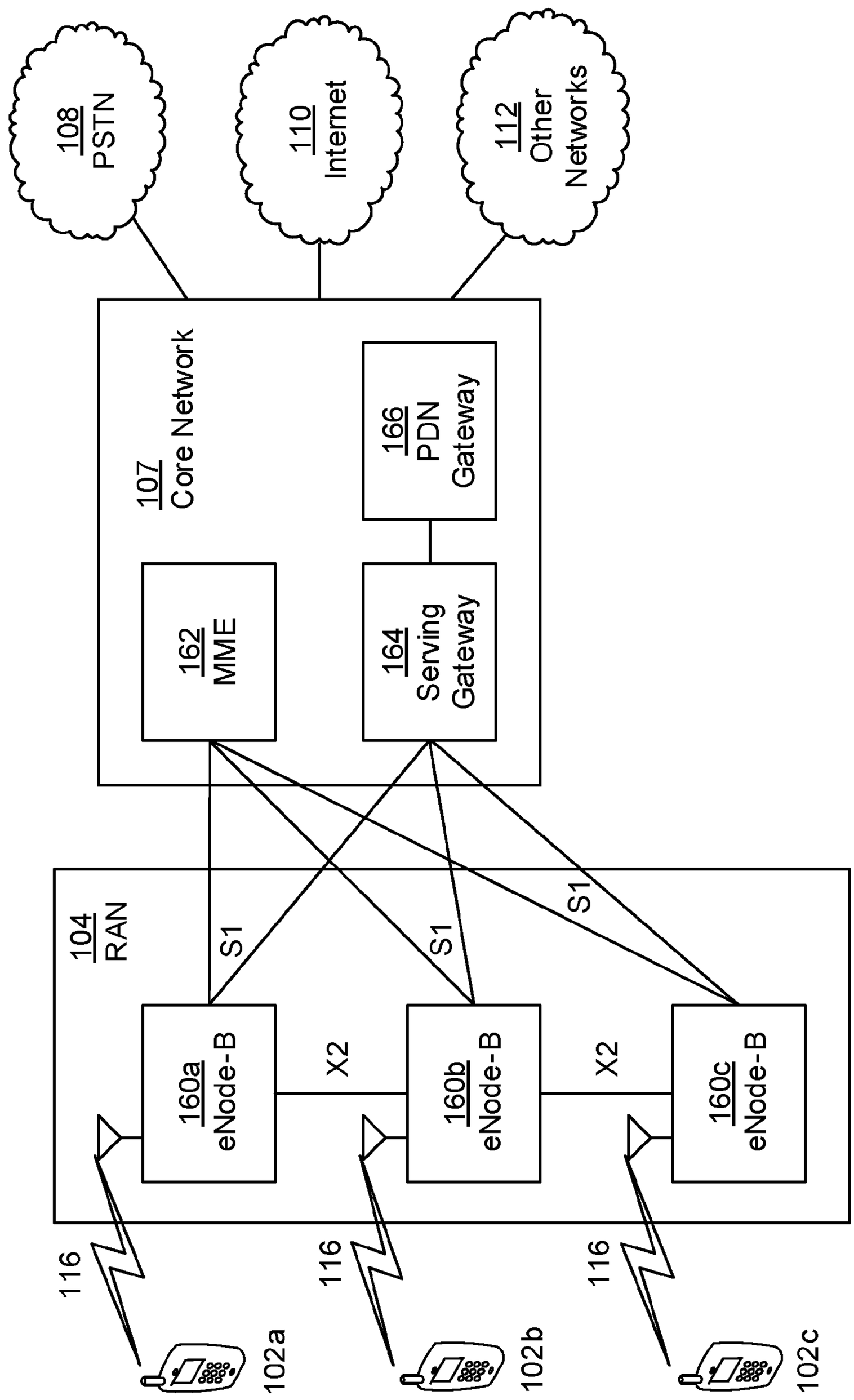

108
PSTN
110
Internet
112
Other
Networks
107
Core Network
162
MME
164
Serving
Gateway
166
PDN
Gateway
104
RAN
S1
S1
S1
160a
eNode-B
X2
160b
eNode-B
X2
160c
eNode-B
116
116
116
102a
102b
102c

FIG. 37D

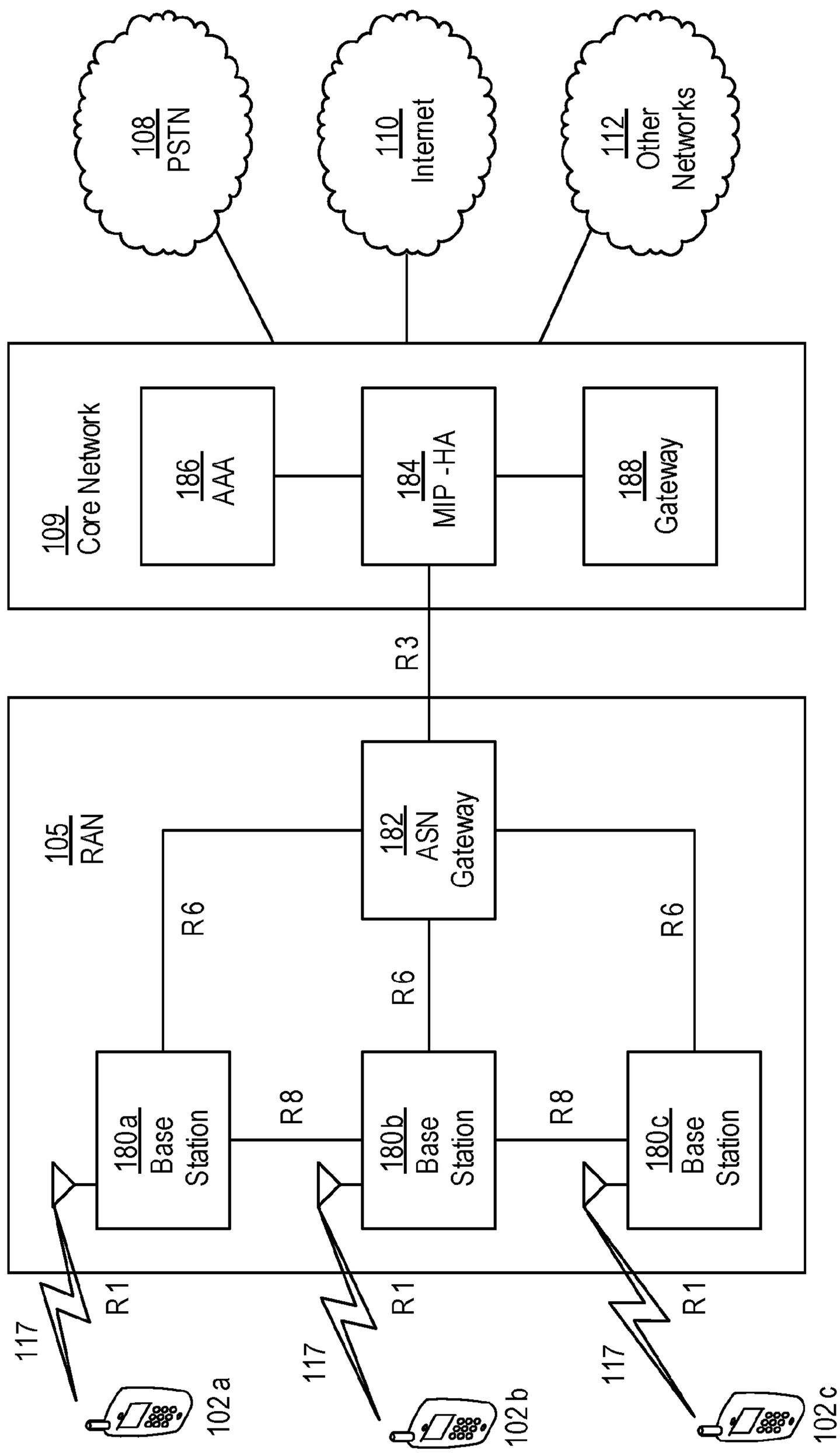

108
PSTN
110
Internet
112
Other
Networks
109
Core Network
186
AAA
184
MIP -HA
188
Gateway
R3
105
RAN
182
ASN
Gateway
R6
R6
R6
180a
Base
Station
R8
180b
Base
Station
R8
180c
Base
Station
R1
R1
R1
117
117
117
102 a
102 b
102 c

FIG. 37E

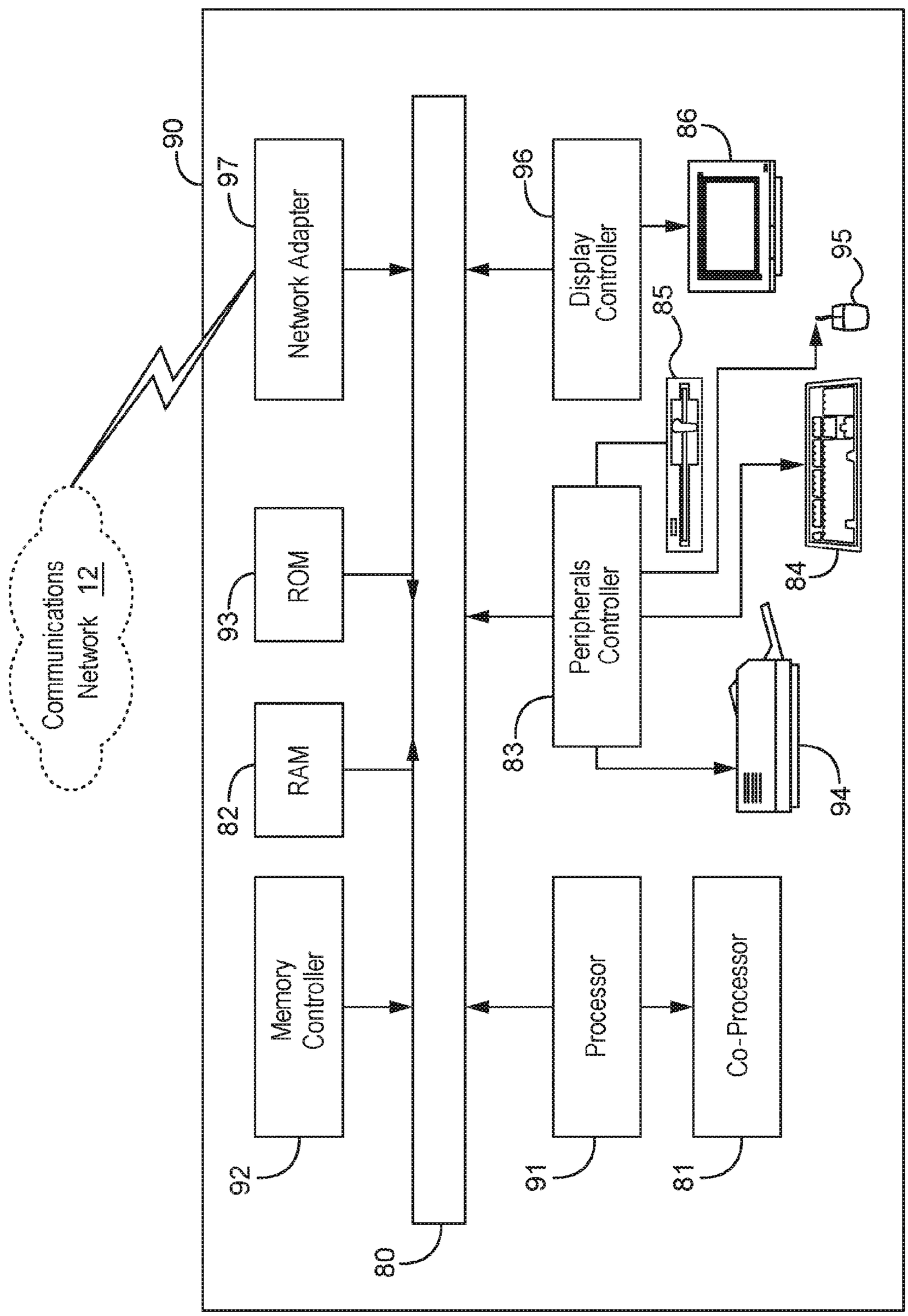

90
Communications Network 12
97
Network Adapter
93
ROM
82
RAM
92
Memory Controller
80
96
Display Controller
86
95
85
84
83
Peripherals Controller
94
91
Processor
81
Co-Processor

FIG. 37F

# GRANT-LESS UPLINK TRANSMISSION FOR NEW RADIO

## CROSS REFERENCE TO RELATED APPLICATIONS

**[0001]** This application claims the benefit of priority to U.S. Provisional Patent Application No. 62/350,550, filed Jun. 15, 2016, U.S. Provisional Patent Application No. 62/373,691 filed Aug. 11, 2016, U.S. Provisional Patent Application No. 62/399,921, filed Sep. 26, 2016, and U.S. Provisional Patent Application No. 62/401,062, filed Sep. 28, 2016, the disclosures of which are incorporated by reference in their entireties.

## BACKGROUND

**[0002]** International Mobile Telecommunications (IMT) for 2020 and beyond (e.g., IMT 2020) is envisaged to expand and support diverse families of usage scenarios and applications that will continue beyond the current IMT. Furthermore, a broad variety of capabilities may be tightly coupled with these different usage scenarios. Example families of usage scenarios include enhanced Mobile Broadband (eMBB), Ultra-Reliable and Low Latency Communications (URLLC), massive Machine Type Communications (mMTC), and Network Operations. Example operating characteristics of eMBB may include macro and small cells, 1 ms Latency (air interface), support for high mobility, etc. Example operating characteristics of URLLC may include low to medium data rates (e.g., 50 kbps-10 Mbps), less than 1 ms air interface latency, 99.999% reliability and availability, low connection establishment latency, 0-500 km/h mobility, etc. Example mMTC operating characteristics may include low data date (e.g., 1-100 kbps), high density of devices (e.g., 200,000/km2), varying latency, low power required (e.g., up to 15 years battery autonomy), asynchronous access, etc. Network operations address various subjects such as Network Slicing, Routing, Migration and Interworking, Energy Saving, etc.

**[0003]** With respect to New Radio (NR) requirements, 3GPP TR 38.913 defines scenarios and requirements for New Radio (NR) technologies. Key Performance Indicators (KPIs) for URLLC and mMTC devices are summarized in Table 1 below:

TABLE 1

KPIs for URLLC and mMTC Devices

| Device | KPI | Description | Requirement |
|---|---|---|---|
| URLLC | Control Plane Latency | Control plane latency refers to the time to move from a battery efficient state (e.g., IDLE) to start of continuous data transfer (e.g., ACTIVE). | 10 ms |
| | Data Plane Latency | For URLLC the target for user plane latency for UL and DL. Furthermore, if possible, the latency should also be low enough to support the use of the next generation access technologies as a wireless transport technology that can be used within the next generation access architecture. | 0.5 ms |
| | Reliability | Reliability can be evaluated by the success probability of transmitting X bytes[NOTE1] within 1 ms, which is the time it takes to deliver a small data packet from the radio protocol layer 2/3 SDU ingress point to the radio protocol layer 2/3 SDU egress point of the radio interface, at a certain channel quality (e.g., coverage-edge). [NOTE1]Specific value for X is FFS. | $1\text{-}10^{-5}$ within 1 ms. |
| mMTC | Coverage | "Maximum coupling loss" (MCL) in uplink and downlink between device and Base Station site (antenna connector(s)) for a data rate of [X bps], where the data rate is observed at the egress/ingress point of the radio protocol stack in uplink and downlink. | 164 dB |
| | UE Battery Life | User Equipment (UE) battery life can be evaluated by the battery life of the UE without recharge. For mMTC, UE battery life in extreme coverage shall be based on the activity of mobile originated data transfer consisting of [200 bytes] Uplink (UL) per day followed by [20 bytes] Downlink (DL) from Maximum Coupling Loss (MCL) of [tbd] dB, assuming a stored energy capacity of [5 Wh]. | 15 years |
| | Connection Density | Connection density refers to total number of devices fulfilling specific Quality of Service (QoS) per unit area (per $km^2$). QoS definition should take into account the amount of data or access request generated within a time t_gen that can be sent or received within a given time, t_sendrx, with x % probability. | $10^6$ devices/$km^2$ |

## SUMMARY

**[0004]** In accordance with various embodiments, mechanisms for grant-less uplink transmissions are disclosed. In one embodiment, access allocation for grant-less uplink transmission may be static via a device graphical user interface (GUI) or an Open Mobile Alliance (OMA) Device

Management (DM) system configuration. In another embodiment, access allocation for grant-less uplink transmission may be semi-static via the system broadcasting/multicasting and unicast or RRC/MAC messages. In yet another embodiment, access allocation may include a dynamic allocation via the downlink control signals or channel. Various mechanisms for grant-less contention based uplink transmissions are disclosed herein. A two-dimensional (e.g., time and frequency) priority collision avoidance scheme is disclosed herein for contention based accessing.

**[0005]** In an example embodiment, a node or apparatus configures a plurality of devices to operate in a grant-less mode in accordance with a respective grant-less access allocation, such that, when the plurality of devices transmit messages uplink in the network, the messages are transmitted using frequency resources defined by the respective grant-less access allocation, and the plurality of devices transmit the messages without being granted access to transmit the messages, so as to operate in the grant-less mode.

**[0006]** In various embodiments described herein, grant-less uplink transmissions include Multi-user Orthogonality and Contention management, static contention space allocation via device GUI or OMA DM system configuration, Semi-static contention space allocation via the system broadcasting/multicasting and unicast or RRC/MAC messages, Dynamic contention space allocation via the downlink control signal or channel, and/or Multi-user orthogonality management via the contention space.

**[0007]** In an example embodiment, different configurations are used for Grant-less Slot in a subframe of a reference numerology. In some cases, a wide band Grant-less Slot is configured for high reliable and low latency use cases such as Ultra-Reliable and Low Latency Communications (URLLC), and a narrow band Grant-less Slot is configured for low data rate and latency tolerant use cases such as massive Machine Type Communications (mMTC). The Grant-less Slot may be configured using symbols in time and subcarriers in frequency of the reference numerology, or UE service specific numerology.

**[0008]** This Summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used to limit the scope of the claimed subject matter. Furthermore, the claimed subject matter is not limited to limitations that solve any or all disadvantages noted in any part of this disclosure.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0009]** A more detailed understanding may be had from the following description, given by way of example in conjunction with accompanying drawings wherein:

**[0010]** FIG. **1** is a call flow that shows an example of an uplink (UL) transmission with dynamic scheduling;

**[0011]** FIG. **2** is a call flow that shows an example of UL transmission with non-persistent scheduling;

**[0012]** FIG. **3** is an example CSMA/CA algorithm;

**[0013]** FIG. **4** shows an example of a UL OFDMA-based Random Access procedure;

**[0014]** FIG. **5** shows an example use case that includes a power grid of a smart city;

**[0015]** FIG. **6** shows dedicated sub-bands for grant-less access in accordance with an example embodiment;

**[0016]** FIG. **7** shows example sub-bands for mixed grant and grant-less access in accordance with an example embodiment;

**[0017]** FIG. **8** depicts an example of access allocations indicated by pilot patterns in accordance with an example embodiment;

**[0018]** FIG. **9** shows an example dynamic allocation in accordance with an example embodiment;

**[0019]** FIG. **10** shows another example dynamic allocation in accordance with another example embodiment;

**[0020]** FIGS. **11**A and **11**B show example containers for a dynamic access allocation in accordance with an example embodiment;

**[0021]** FIG. **12** shows an example of a two dimensional (2D) priority collision avoidance contention access in accordance with an example embodiment;

**[0022]** FIGS. **13**A-C depict examples of contention-based access;

**[0023]** FIGS. **14**A-C depict examples of contention spaces for grant-less access;

**[0024]** FIGS. **15**A and **15**B depict an example of a dynamic grant-less access configuration interval aligned with one and two intervals, respectively;

**[0025]** FIGS. **16**A and **16**B depict another example of a dynamic grant-less access configuration interval aligned with different grant-less intervals, such that the grant-less intervals are not aligned with the grant intervals;

**[0026]** FIG. **17** depicts example physical control signals and channels for grant-less UL transmissions in accordance with an example embodiment;

**[0027]** FIG. **18** shows an example of grant-less slot types with UL only (wide band);

**[0028]** FIG. **19** shows an example of grant-less interval/slot types with UL only (narrow Band);

**[0029]** FIG. **20** shows an example of a grant-less slot configuration with DL and UL (wide Band);

**[0030]** FIG. **21** shows an example of a grant-less slot configuration with DL and UL (narrow Band);

**[0031]** FIG. **22** shows an example of a grant-less slot structure and content;

**[0032]** FIGS. **23**A and **23**B show an example of retransmission in wide band grant-less mini-slots, in accordance with an example embodiment;

**[0033]** FIGS. **24**A and **24**B show an example of retransmission in narrow band grant-less mini-slots, in accordance with an example embodiment;

**[0034]** FIGS. **25**A-**26**B depict a call flow for grant-less UL transmission for massive Machine Type Communications (mMTC) devices in accordance with an example embodiment;

**[0035]** FIGS. **27**A-**28**B depict another example call flow for grantless UL transmission for Ultra-Reliable and Low Latency Communications (URLLC) devices in accordance with another example embodiment;

**[0036]** FIGS. **29**A-**30**B depict an example procedure for grant-less UL transmission for mMTC devices in accordance with an example embodiment;

**[0037]** FIG. **31**A-**32**B depict an example procedure for grant-less UL transmission for URLLC devices in accordance with an example embodiment;

**[0038]** FIGS. **33**A and **33**B depict an example call flow for registration and grant-less setup in accordance with an example embodiment;

**[0039]** FIGS. **34**A and **34**B depict an example call flow for grant-less and grant UL transmissions for URLLC devices, in accordance with an example embodiment;

**[0040]** FIGS. **35**A and **35**B depict an example call flow for grant-less and grant UL transmissions for mMTC devices, in accordance with an example embodiment;

**[0041]** FIG. **36** is an example GUI for UE configuration in accordance with an example embodiment;

**[0042]** FIG. **37**A illustrates one embodiment of an example communications system in which the methods and apparatuses described and claimed herein may be embodied;

**[0043]** FIG. **37**B is a block diagram of an example apparatus or device configured for wireless communications in accordance with the embodiments illustrated herein;

**[0044]** FIG. **37**C is a system diagram of an example radio access network (RAN) and core network in accordance with an example embodiment;

**[0045]** FIG. **37**D is another system diagram of a RAN and core network according to another embodiment;

**[0046]** FIG. **37**E is another system diagram of a RAN and core network according to another embodiment; and

**[0047]** FIG. **37**F is a block diagram of an exemplary computing system **90** in which one or more apparatuses of the communications networks illustrated in FIGS. **37**C-F may be embodied.

## DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

**[0048]** As an initial matter, for different RAN architectures, the mechanisms described herein may be conducted at, for example and without limitation, an NR-node, Transmission and Reception Point (TRP), or Remote Radio Head (RRH), as well as the central controller in RAN or control function in a RAN slice. Unless otherwise specified, the mechanisms described herein may applicable to TRP, RRH, central controller, and control functions in different RAN architectures.

**[0049]** As specified in 3GPP TS 36.213, in order to transmit on the uplink shared channel (e.g., Physical Downlink Shared Channel (PDSCH)) using current approaches, a UE has a valid UpLink (UL) grant, which it may receive dynamically on the Physical Downlink Control Channel (PDCCH) or in a Random Access Response, or which may be configured semi-persistently. As shown in FIG. **1**, a UL transmission with dynamic scheduling may include the following steps, for example. A Radio Access Network (RAN) **104** may send the first data on DL PDSCH and/or PDCCH that has Downlink Control Information (DCI) format **0** for UL Grant and DCI format **1** for DL Data Decoding. If there is no DL data, the radio access network **104** might transmit only DPCCH with DCI format **0** without any DPSCH data. A user equipment (UE) **102** may decode the Physical Control Format Indicator Channel (PCFICH) to figure a Control Format Indicator (CFI) value. The UE **102** may decode the PDCCH and get the information on DCI format **1**. Based on DCI format **1**, the UE **102** may decode the DL data. The UE **102** may decode the information on DCI format **0** from PDCCH. The UE **102** may send an ACK/NAK for DL data through Uplink Control Information (UCI) that is carried by Physical Uplink Control Channel (PUCCH). In the example, the UE **102** checks the Grant field in DCI format **0**. If Grant is allowed, the UE **102** may transmit the UL data through the Physical Uplink Shared Channel (PUSCH) per the Grant. The Radio Access Network **104** decodes PUSCH data and sends an Acknowledgement (ACK)/Negative Acknowledgement (NACK) via Physical Hybrid ARQ Indicator Channel (PHICH). The UE **102** decodes PHICH and may retransmit the data, for example, if PHICH carries a NACK.

**[0050]** In some cases of semi-persistent scheduling, the radio access network **104** can assign a predefined group of radio resources for VoIP users with an interval of 20 ms, instead of scheduling each uplink or downlink transmission as described above. Therefore, the UE **102** is not required to request resources each TTI, which can reduce the scheduling assignment overhead significantly. This scheduling is semi-persistent in the sense that eNB can change the resource allocation type or location if required for link adaptation or for other factors.

**[0051]** Turning now to an example UL Transmission with Non-persistent Scheduling, as shown in FIG. **2**, the UL transmission with non-persistent scheduling may include the following steps, for example. At **202**, the UE **102** sends a Scheduling Request (SR) on PUCCH. At **204**, the Radio Access Network **104** sends UL Grant (DCI **0**) on PDCCH. At **206**, the UE **206** decodes DCI **0** and transmits PUSCH based on the Resource Blocks (RBs) specified by DCI **0**. The Radio Access Network **104** decodes the PUSCH. At **208**, as shown, the Radio Access Network **104** sends ACK/NACK on PHICH. At **210**, the UE **102** determines whether the message received at **208** is an ACK or a NACK. If the message is a NACK, the UE **102** may retransmit (at **212**), which may be the same message as operation **202**.

**[0052]** Turning now to Contention Based Multiple Access, in statistical time division multiplexing, contention is a media accessing method that is used to share a medium by multiple devices. In contention, any device in the network can transmit data at any time on the shared channel on a first-come, first-serve basis. This accessing system breaks down when two devices attempt to transmit at the same time. This is referred to as a collision. One approach to handle collisions in a contention based system is to optimize collision detection and the subsequent recovery. A collision can be detected by listening to the shared medium immediately after transmitting, and identifying collision characteristic. Alternatively, data can be collected from the medium and error detection can be performed. For recovery, some systems cause senders to re-transmit collided data (e.g., with backing-off algorithms that reduce the sender's re-transmit rate when collisions keep occurring) or use Error Correction techniques such as FEC for example. Examples of Collision Detection and Recovery multiple access protocols include Aloha, Slotted ALOHA, Reservation ALOHA, etc.

**[0053]** An alternative approach to handling collisions in a contention based system is to attempt to avoid them (collision avoidance). Some systems may utilize a strict scheduling guideline to identify who may use which resources when. Other systems may have the senders listen to the shared channel immediately prior to transmitting to determine suitable times to transmit. Examples of Collision Avoidance multiple access protocols include Carrier Sensing Multiple Access (CSMA), CSMA with Collision Detection (CSMA/CD), CSMA with Collision Avoidance (CSMA/CA), etc. With respect to a CSMA accessing

scheme, each device listens to the network before attempting to transmit. If the network is busy, the device waits until the network quiets down.

**[0054]** With respect to Collision Detection (CD), devices continue to listen to the network as they transmit. If the device detects another signal that interferes with the signal it is sending, it stops transmitting, for example, to shorten the time required before a retry can be attempted. Both devices may wait for a random amount of time, referred to as a back-off time, and then attempt to transmit again. With respect to Collision Avoidance (CA), a device may attempt to avoid collisions by transmitting only when the channel is sensed to be "idle". If the transmission channel is sensed to be busy before transmission, then the transmission is deferred for a random interval. This random interval reduces the likelihood that two or more nodes that are waiting to transmit will simultaneously begin transmission upon termination of the detected transmission, thus reducing the incidence of collision. When transmitting, the device transmits its packet data entirely. A typical algorithm of CSMA/CA used in 802.11 is illustrated in FIG. **3**, for purposes of example, where Request to Send (RTS) and Clear to Send (CTS) are used between a Base Station (BS) and an Access Point (AP) to solve the hidden terminal problem.

**[0055]** Turning now to random access, two typical random access schemes in an Orthogonal Frequency Division Multiplex (OFDM) System are now described. With respect to Random Access in LTE, Random Accessing in LTE is initiated by a random access preamble. As specified in TS 36.211, the random access opportunities for each Physical Random Access Channel (PRACH) configuration shall be allocated in time first and then in frequency if and only if time multiplexing is not sufficient to hold all opportunities of a PRACH configuration needed for a certain density value without overlap in time. For preamble format **0-3**, the frequency multiplexing is performed done according to:

$$n_{PRB}^{RA} = \begin{cases} n_{PRBoffset}^{RA} + 6\left\lfloor \frac{f_{RA}}{2} \right\rfloor, & \text{if } f_{RA} \bmod 2 = 0 \\ N_{RB}^{UL} - 6 - n_{PRBoffset}^{RA} - 6\left\lfloor \frac{f_{RA}}{2} \right\rfloor, & \text{otherwise} \end{cases}$$

where $N_{RB}^{UL}$ is the number of uplink resource blocks, $n_{PRB}^{RA}$ is the first physical resource block allocated to the PRACH opportunity considered, and where $n_{PRB\ offset}^{RA}$ is the first physical resource block available for PRACH.

**[0056]** For preamble format **4**, the frequency multiplexing is performed according to

$$n_{PRB}^{RA} = \begin{cases} 6f_{RA}, & \text{if}(n_f \bmod 2) \times (2 - N_{SP}) + t_{RA}^{(1)}) \bmod 2 = 0 \\ N_{RB}^{UL} - 6(f_{RA} + 1), & \text{otherwise} \end{cases}$$

where $n_f$ is the system frame number, and where $N_{SP}$ is the number of DL to UL switch points within the radio frame. Each random access preamble occupies a bandwidth corresponding to 6 consecutive resource blocks for both frame structures.

**[0057]** With respect to random accessing 802.11, the UL OFDM-based random access is specified as the following. UL OFDMA-based distributed random access is a random access mechanism for High Efficient (HE) Stations (STAs) that randomly select Resource Units (RUs) assigned by an Access Point (AP) for transmission of UL PLCP Protocol Data Unit (PPDUs). The HE AP may indicate a parameter in the Trigger frame for HE STAs to initiate random access following the Trigger Frame transmission. An HE AP may indicate the value of OCWmin for the random access operation. The random access procedure initiates with an HE STA receiving a Trigger frame for random access.

**[0058]** For an initial UL PPDU transmission, when an HE STA obtains the value of OCWmin from the HE AP, it may set the value of OCW to the OCWmin and shall initialize its OFDM Backoff (OBO) counter to a random value in the range of 0 and OCWmin.

**[0059]** If the OBO counter for an HE STA is smaller than the number of RUs assigned to Association Identifier AID value in a Trigger frame, then the HE STA may decrease its OBO counter to zero. Otherwise, the HE STA decreases its OBO counter by a value equal to the number of RUs assigned to the AID value in a Trigger frame. For instance, as shown in FIG. **4**, the HE STA **1** and HE STA **2** may decrease their non-zero OBO counters by 1 in every RU assigned to AID value TBD for random access within the Trigger frame. If the OBO counter for an HE STA is a zero value, or if the OBO counter decreases s to 0, it randomly selects any one of the assigned RUs for random access and transmits its UL PPDU in the selected RU. Otherwise, the STA resumes with its OBO counter in the next Trigger frame for random access.

**[0060]** Turning to timing advance in LTE, timing advance is a negative offset, at the UE, between the start of a received downlink subframe and a transmitted uplink subframe. This offset at the UE ensures that the downlink and uplink subframes are synchronized at the eNodeB. For example, a given UE**1** far from the eNodeB may encounter a larger propagation delay, such that its uplink transmission is advanced as compared to a given UE**2** that is closer to the eNodeB as compared to UE**1**. Both UE**1** and UE**2** take the downlink subframe arrival (together with Timing Advance) as a reference to calculate uplink subframe timing so that their UL transmissions are synchronized and received at the same time at the eNodeB.

**[0061]** The eNodeB may estimates the initial Timing Advance from PRACH sent by the UE. PRACH is used as timing reference for uplink during UE's initial access. The eNodeB sends Timing advance command in Random Access Response (RAR). Once the UE is in connected mode, the eNodeB keep estimating Timing Advance and sends Timing Advance Command MAC Control Element to the UE, if correction is required. In examples, as long as a UE sends some uplink data (PUSCH/PUCCH/SRS), the eNodeB can estimate the uplink signal arrival time, which can then be used to calculate the required Timing Advance value.

**[0062]** With respect to transmit power control in LTE, the initial PRACH power control is conducted in an open loop, where a UE estimates the initial transmit power level based on path loss calculated from the referenceSignalPower broadcasted in SIB2 and the measured reference signal power received. Once initial PRACH is completed, the UE power may be controlled dynamically by Transmission Power Control (PCT) commands (MAC CE or TPC field in DCI **0**). For example, the closed loop UL transmit power may be controlled by feedback input from the eNB.

**[0063]** Referring now to FIG. **5**, an example use case is shown in which different sensors or monitoring devices of an

example Smart City's power grid system **500** are illustrated. Sensors of a Smart Home **502** (e.g., massive Machine Type Communications (mMTC devices) may send electrical usage data once a week or a month with a very relaxed latency requirement. Sensors on a Smart City's Power Transmission Network **504** (e.g., Ultra-Reliable and Low Latency Communications (URLLC) devices) may monitor the power level continually and report to a Grid Monitoring System **506** periodically, but when an abnormal power level is detected, for example, it is recognized herein that the sensors **504** need to send the warning to the Grid Monitoring System **506** immediately so that the Grid Monitoring System **506** may shut down the malfunctioned power supply system, and so that a backup power supply system can be implemented instantly to avoid possible damage to the Smart City's power grid system **500** and to avoid negative impacts to the Smart City's operations.

**[0064]** By way of another example use case, forest fire monitoring sensors (e.g., mission critical MTC devices), can send small data periodically with a very low duty cycle, but they might need to send a fire warning message or messages immediately and reliably. These devices may be located sparsely and may cover a large area of the forest. The devices may also have constrained battery life (e.g., 15 or 20 years).

**[0065]** By way of yet another example use case, medical devices on an ambulance may be active while carrying the patient to the emergency room. For example, Ultra-Reliable and Low Latency Communications (URLLC) devices can send the patient's temperature and blood pressure data and heart monitoring images to the hospital and the doctor's office. It will be understood that embodiments described herein can be applied to a variety of use cases as desired.

**[0066]** The use cases may utilize URLLC and mMTC devices. For example, URLLC devices without battery constraint may support both small and medium UL data rate transmission with ultra-low latency and very high reliability. URLLC or mission critical MTC devices with battery constraint might support small UL data rate transmission with ultra-low latency and very high reliability. mMTC devices with battery constraint and dense connections might support small UL data rate transmission either prescheduled or tolerant to long latency.

**[0067]** As exemplified by the above uses cases, URLLC devices may fail the latency requirement for UL data transmission if the current grant-based UL data transmission in LTE systems is used. With respect to mMTC devices, the signaling overhead for UL grant messages may be very significant as compared to infrequent small UL data transmissions. It is recognized herein that this challenges the battery life requirement for mMTC devices. To reduce UL transmission signaling overhead for mMTC devices and to reduce UL transmission latency for URLLC devices, UL grant-less transmission (e.g., contention-based UL transmissions that do not undergo grant procedures performed by the UE and the network node, such as those illustrated in FIGS. **1** and **2**) may be used. As described below, embodiments perform grant-less UL transmission that can meet the ultra-reliability and low latency requirements for non-power-constrained URLLC devices. Further, embodiments described herein perform grant-less UL transmission that meet the battery life requirement for mMTC devices

**[0068]** Turning now to access allocation for grant-less UL transmission, in accordance with an example embodiment, a new radio (NR) radio access network node (a NR-node) manages the grant-less access allocations for UL transmissions to, for example and without limitation, ensure a high success rate for contention based accessing, to avoid unnecessary interference to the other devices of services, and to optimize the overall UL resource utilizations in the NR system. The access allocations may be managed by the NR-node statically or dynamically, as described in detail below. The sub-band or carrier is a region or group of continuous subcarriers in the frequency domain. Sub-band and carrier are used interchangeably herein, without limitation.

**[0069]** Turning now to Static or Semi-static Access Allocations, as exemplified in the use cases described above, the URLLC devices may require short latency and high reliability for delivering small or medium size data, and mMTC devices may require low signaling overhead and reasonable reliability for delivering small data. To meet these requirements, in some examples, with respect to UL resources, devices that require Ultra-Reliable and Low Latency Communications (referred to herein as URLLC devices) may use short transmitting time intervals over a wide bandwidth. In an example, URLLC devices use a small number of symbols that are scaled down via a decreased symbol length within a short transmitting time, for example, to meet latency requirements. Further, with respect to UL resources, URLLC devices may use a large number of subcarriers, which may provide sufficient bandwidth for small to medium data with frequency diversity and coding/spreading gains built in the frequency domain, for example, to meet ultra-reliable requirements. To meet various requirements, in some examples, with respect to UL resources, devices that may be classified as performing massive Machine Type Communications (referred to herein as mMTC devices) may use long transmitting time intervals over a narrow bandwidth. In an example, mMTC devices may use scaled up symbols with increased symbol length and coding/spreading/time diversity gains in the time domain within a longer transmitting time, for example, to meet low power consumption and reliability requirements. Further, with respect to UL resources, mMTC devices may use a small number of subcarriers, for example for small data to meet low complexity and lower power consumption requirements.

**[0070]** In accordance with the general UL resource mappings summarized above, example grant-less access allocations **600***a* and **600***b* are shown in FIG. **6**, and example grant-less allocations **600***c* and **600***d* are shown in FIG. **7**. The allocations **600***a-d* may be statically configured, for instance via a UE graphic user interface (GUI) or an Open Mobile Alliance (OMA) Device Management (DM) system, or semi-statically managed via periodic system information broadcasting and/or multi-casting. Such semi-static management may be based on the system traffic loading and resource status. Further, the allocations **600***a-d* may be semi-statically managed via aperiodic unicasting, for example, by system information on demand per a UE's request.

**[0071]** Referring in particular to FIG. **6**, dedicated sub-band(s) for grant-less access are illustrated. In example allocation **600***a*, sub-band **602***a* for mMTC devices and sub-band **604***a* for URLLC devices are separated from each other with respect to the frequency domain. In some examples, allocation **600***a* optimizes grant-less access from the UE's perspective and/or a service's perspective. In an

example, each sub-band **602***a* and **604***a* is a RAN slice optimized for a specific type of device or service. By way of example, the mMTC sub-band **602***a* may be optimized for saving battery life, and the URLLC sub-band **604***a* may be optimized for short latency and high reliability. Each of the sub-bands **602***a* and **604***a* may have the same or different numerology, which may depend, in some cases, on the optimization criteria.

**[0072]** In example allocation **600***b*, mMTC devices and URLLC devices use the same sub-band **601** with respect to the frequency and time domains. The example allocation **600***b* may optimize system resources for various example use cases, such as, for example, when both the URLLC and mMTC devices have low UL traffic, or when the mMTC devices and the URLLC devices have different schedules for UL traffic with respect to each other. By sharing the total grant-less resources between them, for instance in sub-band **601**, mMTC and URLLC devices may have the advantage of wider system bandwidth as compared to approaches in which resources are not shared. The wider system bandwidth may allow high redundancy schemes to be used. Examples schemes may allow low coding rates, high spreading rates, and more frequency diversity, which may increase reliability for UL transmissions as compared to approaches in which resources are not shared. In an example embodiment, URLLC devices may have a higher access priority than mMTC devices, for example, due to more stringent latency and reliability requirements that may be placed on URLLC devices as compared to mMTC devices. In an example priority collision avoidance scheme, which is described further below, URLLC and mMTC devices may use the same or different numerologies for sub-carrier spacing, symbol length, and for the number of symbols in a transmitting time interval. Alternatively, URLLC and mMTC devices may use partially different numerologies. For example, URLLC and mMTC devices may use the same subcarrier spacing, but use a different number of symbols for the transmitting time interval with respect to each other.

**[0073]** FIG. **7** shows example allocations **600***c* and **600***d* in which sub-bands contain both mixed grant and grant-less access, which may maximize the utilization of the system resources in some cases. In accordance with the illustrated example, one or more URLLC devices may have UL grant-less transmitting time intervals or subframes that override a device using enhanced mobile broadband (eMBB) (referred to herein as an eMBB device), in particular the eMBB device's transmitting time interval or subframe. By way of example, a UE may be granted to transmit eMBB data using the resource **608***c*, and an URLLC grant-less UL transmission may be inserted at the resource **606***c*, which overlaps with **608***c*. If the same UE wants to transmit the eMMB data and the URLLC grantless-less UL transmission, for example, the URLLC data may pre-empt the eMBB data at **608***c*. If different UEs are sending the eMBB data and the URLLC data, the URLLC data may super position the eMBB data at **608***c* by, for example, using higher power, spreading code, spatial pre-coding, etc., as compared to the eMBB data.

**[0074]** In example allocation **600***c*, mMTC devices send UL messages via a dedicated sub-band **602***c* that is only for mMTC devices. Further, in the example allocation **600***c*, URLLC devices send grant-less UL via a shared sub-band **603**, and eMBB devices send granted DL messages and/or UL messages in same sub-band **603**. In this example scenario, URLLC devices may take advantage of the wide bandwidth of eMBB to meet or exceed reliability and latency requirements (e.g., with lower coding rate, higher spreading factor, more frequency diversity). With respect to the eMBB devices, in some cases, the impact of the shared sub-band **603** may be minimized due to wide frequency diversity, MIMO spatial gain, HARQ re-transmission, etc. For example, the eMBB data may be overridden by URLLC data at resource **608***c*, as shown in FIG. **7**, and thus the eMBB data may be re-transmitted later, for example, if the original transmitted data is indicated to the UE as a failure (e.g., via a NACK or via a HARQ process)

**[0075]** In example allocation **600***d*, mMTC devices send grant-less messages via a guard band **605** of the eMBB devices. In an alternative example, mMTC devices may send grant-less messages via a band that is shared with granted DL and/or UL messages associated with eMBB devices. In accordance with the illustrated example allocation **600***d*, URLLC devices may send grant-less messages in one or more shared sub-bands with respect to the frequency domain, for instance shared subbands **607** and **609**. The subbands **607** and **609** may also be used by eMMB devices for granted DL and/or UL messages. In some cases, using the allocation **600***d*, mMTC and URLLC devices may each achieve reliability gains, particularly when the traffic of mMTC devices is prescheduled and/or tolerant to long latency (e.g., by being scheduled at a time when there is very low eMBB traffic).

**[0076]** In some cases, certain times and frequency within the sub-bands shown in allocations **600***c* and **600***d* can be blocked out for grant-less access, for example, to reduce potential interference caused from the grant-less access, thereby ensuring QoS for certain eMBB devices. In accordance with the example, sub-bands **607** and **609** each include a plurality of blocked regions **607***a* and **609***a*, respectively.

**[0077]** With respect to static allocation, the example allocations **600***a-d*, among others, may be preconfigured via a GUI on the devices, for instance GUI **3600** shown in FIG. **36**. Alternatively, example allocations **600***a-d* may be configured by device manufacturers or service providers. Alternatively still, allocations **600***a-d* may be statically provisioned on the device using Open Mobile Alliance Device Management (OMA DM) protocol or any other Over-The-Air (OTA) device provisioning protocol. A static grant-less access allocation generally refers to an allocation that is known to the devices prior to the respective communication session being established.

**[0078]** With respect to semi-static allocation, the above example allocations **600***a-d* may also be signaled to the device sending the UL messages (e.g., a UE), for example and without limitation, via common RRC signaling, dedicated RRC signaling or MAC Control Element (MAC CE) signaling. For example, using a common RRC signaling mechanism, the allocations **600***a-d* may be periodically broadcast or multi-cast by an NR-node, for example, as part of System Information (SI). Similarly, using dedicated RRC signaling, the example allocations **600***a-d* may be, for example and without limitation, aperiodically unicasted by an NR-node in an RRC message or MAC CE message as System Info on-demand. In some cases, a given UE may acquire the access allocation information by searching the system information on a DL broadcasting or multicasting channel that is transmitted from an NR-node. In other cases,

a UE may send a request to the NR-node for the access allocation information as on-demand system information. The NR-node, or apparatus, (e.g., a NextGen RAN Node) may signal the UL transmission grant-less (e.g., for use by a URLLC device) resource allocation (configuration) to the UE in a response to a request from the UE, or as result of an autonomous NR-node decision.

**[0079]** The example below shows an example of how the grant-less allocation may be signaled to UEs in RadioResourceConfigCommon System Information (SI), which may be indicated to a UE via an RRC signal. Additionally, or alternatively, the SI may be broadcast on a physical broadcast channel or a physical shared channel:

```
-- ASN1START
RadioResourceConfigCommonSIB ::=   SEQUENCE {
   rach-ConfigCommon                    RACH-ConfigCommon,
   bcch-Config                          BCCH-Config,
   pcch-Config                          PCCH-Config,
   prach-Config                         PRACH-ConfigSIB,
   pdsch-ConfigCommon                   PDSCH-ConfigCommon,
   pusch-ConfigCommon                   PUSCH-ConfigCommon,
   pucch-ConfigCommon                   PUCCH-ConfigCommon,
   soundingRS-UL-ConfigCommon           SoundingRS-UL-ConfigCommon,
   uplinkGrantlessControlCommon         uplinkGrantlessControlCommon
   uplinkPowerControlCommon             UplinkPowerControlCommon,
   ul-CyclicPrefixLength                UL-CyclicPrefixLength,
   ...,
   [[ uplinkGrantlessControlCommon-v1020(?)   UplinkPowerControlCommon-v1020(?)   OPTIONAL
   -- Need
OR
   ]],
   [[ uplinkPowerControlCommon-v1020    UplinkPowerControlCommon-v1020    OPTIONAL    -- Need
OR
   ]],
   [[ rach-ConfigCommon-v1250           RACH-ConfigCommon-v1250     OPTIONAL    -- Need OR
   ]],
   [[ pusch-ConfigCommon-v1270          PUSCH-ConfigCommon-v1270       OPTIONAL       -- Need
OR
   ]]
}
RadioResourceConfigCommon ::=      SEQUENCE {
   rach-ConfigCommon                    RACH-ConfigCommon                   OPTIONAL,   -- Need
ON
   prach-Config PRACH-Config,
   pdsch-ConfigCommon                   PDSCH-ConfigCommon                  OPTIONAL,   -- Need
ON
   pusch-ConfigCommon                   PUSCH-ConfigCommon,
   phich-Config                         PHICH-Config                        OPTIONAL,   -- Need
ON
   pucch-ConfigCommon                   PUCCH-ConfigCommon                  OPTIONAL,   -- Need
ON
   soundingRS-UL-ConfigCommon           SoundingRS-UL-ConfigCommon          OPTIONAL,   -- Need
ON
   uplinkGrantlessControlCommon         UplinkGrantlessControlCommon        OPTIONAL,   -- Need
ON
   uplinkPowerControlCommon             UplinkPowerControlCommon            OPTIONAL,   -- Need
ON
   antennaInfoCommon                    AntennaInfoCommon                OPTIONAL,   -- Need ON
   p-Max                                P-Max                               OPTIONAL,   -- Need
OP
   tdd-Config                           TDD-Config                          OPTIONAL,   -- Cond
TDD
   ul-CyclicPrefixLength                UL-CyclicPrefixLength,
   ...,
   [[ uplinkGrantlessControlCommon-v1020   UplinkGrantlessControlCommon-v1020   OPTIONAL   -
- Need
ON
   ]],
   [[ uplinkPowerControlCommon-v1020    UplinkPowerControlCommon-v1020    OPTIONAL    -- Need
ON
   ]],
   [[ tdd-Config-v1130                  TDD-Config-v1130                    OPTIONAL       -- Cond TDD3
   ]],
   [[ pusch-ConfigCommon-v1270          PUSCH-ConfigCommon-v1270       OPTIONAL    -- Need
OR
   ]],
   [[ uplinkPowerControlCommon-v13xy    UplinkPowerControlCommon-v13xy    OPTIONAL    -- Need
ON
   ]]
}
RadioResourceConfigCommonPSCell-r12 ::= SEQUENCE {
   basicFields-r12                      RadioResourceConfigCommonSCell-r10,
```

-continued

```
  pucch-ConfigCommon-r12                    PUCCH-ConfigCommon,
  rach-ConfigCommon-r12                     RACH-ConfigCommon,
  uplinkGrantlessControlCommonPSCell-r12    UplinkGrantlessControlCommonPSCell-r12,
  uplinkPowerControlCommonPSCell-r12  UplinkPowerControlCommonPSCell-r12,
  ...,
  [[ uplinkPowerControlCommon-v13xy    UplinkPowerControlCommon-v13xy    OPTIONAL    -- Need
ON
  ]]
}
RadioResourceConfigCommonSCell-r10 ::= SEQUENCE {
  -- DL configuration as well as configuration applicable for DL and UL
  nonUL-Configuration-r10                     SEQUENCE {
    -- 1: Cell characteristics
    dl-Bandwidth-r10                            ENUMERATED {n6, n15, n25, n50, n75, n100},
    -- 2: Physical configuration, general
    antennaInfoCommon-r10                       AntennaInfoCommon,
    mbsfn-SubframeConfigList-r10                MBSFN-SubframeConfigList       OPTIONAL,    -- Need
OR
    -- 3: Physical configuration, control
    phich-Config-r10                            PHICH-Config,
    -- 4: Physical configuration, physical channels
    pdsch-ConfigCommon-r10                      PDSCH-ConfigCommon,
    tdd-Config-r10                              TDD-Config                     OPTIONAL    -- Cond
TDDSCell
  },
  -- UL configuration
  ul-Configuration-r10                          SEQUENCE {
    ul-FreqInfo-r10                           SEQUENCE {
      ul-CarrierFreq-r10                        ARFCN-ValueEUTRA               OPTIONAL,    -- Need
OP
      ul-Bandwidth-r10                          ENUMERATED {n6, n15,
                                                  n25, n50, n75, n100}         OPTIONAL,    -- Need
OP
      additionalSpectrumEmissionSCell-r10       AdditionalSpectrumEmission
    },
    p-Max-r10                               P-Max                          OPTIONAL,    -- Need OP
    uplinkGrantlessControlCommonSCell-r10   UplinkGrantlessControlCommonSCell-r10,
    uplinkPowerControlCommonSCell-r10       UplinkPowerControlCommonSCell-r10,
    -- A special version of IE UplinkPowerControlCommon may be introduced
    -- 3: Physical configuration, control
    soundingRS-UL-ConfigCommon-r10      SoundingRS-UL-ConfigCommon,
    ul-CyclicPrefixLength-r10           UL-CyclicPrefixLength,
    -- 4: Physical configuration, physical channels
    prach-ConfigSCell-r10                       PRACH-ConfigSCell-r10          OPTIONAL,    -- Cond
TDD-OR-NoR11
    pusch-ConfigCommon-r10              PUSCH-ConfigCommon
  }                                                                            OPTIONAL,    -- Need OR
  ...,
  [[ ul-CarrierFreq-v1090                   ARFCN-ValueEUTRA-v9e0          OPTIONAL    -- Need
OP
  ]],
  [[ rach-ConfigCommonSCell-r11             RACH-ConfigCommonSCell-r11     OPTIONAL,    -- Cond
ULSCell
    prach-ConfigSCell-r11                     PRACH-Config                   OPTIONAL,    -- Cond
UL
    tdd-Config-v1130                          TDD-Config-v1130               OPTIONAL,    -- Cond TDD2
    uplinkGrantlessControlCommonSCell-v1130
                        UplinkGrantlessControlCommonSCell-v1130 OPTIONAL    -- Cond UL
    uplinkPowerControlCommonSCell-v1130
                        UplinkPowerControlCommonSCell-v1130 OPTIONAL    -- Cond UL
  ]],
  [[ pusch-ConfigCommon-v1270           PUSCH-ConfigCommon-v1270       OPTIONAL    -- Need
OR
  ]],
  [[ pucch-ConfigCommon-r13                 PUCCH-ConfigCommon         OPTIONAL,    -- Cond UL
    uplinkGrantlessControlCommonSCell-v13xx UplinkGrantlessControlCommonPSCell-r12 OPTIONAL
  -- Cond UL
    uplinkPowerControlCommonSCell-v13xx UplinkPowerControlCommonPSCell-r12 OPTIONAL    --
Cond UL
  ]]
}
BCCH-Config ::=                         SEQUENCE {
  modificationPeriodCoeff                   ENUMERATED {n2, n4, n8, n16}
}
PCCH-Config ::=                         SEQUENCE }
  defaultPagingCycle                        ENUMERATED {
```

-continued

```
                                    rf32, rf64, rf128, rf256},
  nB                              ENUMERATED {
                                    fourT, twoT, oneT, halfT, quarterT, oneEighthT,
                                    oneSixteenthT, oneThirtySecondT}
}
UL-CyclicPrefixLength ::=         ENUMERATED {len1, len2}
-- ASN1STOP
```

**[0080]** Turning now to dynamic access allocations, in view of the dynamic pattern of traffic associated with different devices and services, in accordance with some examples, the UL access allocations (e.g., allocations **600***a-d*) may also be dynamically managed by a given NR-node, such that system resources are managed and/or grant-less UL transmissions are controlled to ensure that various performance requirements are met for different devices and services. As used herein, a Dynamic Access Configuration Time Interval (DACTI) refers to a fixed or variable time interval for which a specific Access Allocation scheme, which can apply to DL and/or UL messages, is applied. The length of the DACTI may be signaled to UEs via common RRC signaling, dedicated RRC signaling, or via MAC CE signaling. The NR-node (e.g., a RAN Node or apparatus) may also signal the DACTI to the UE as a response to a request from the UE, or as a result of an autonomous NR-node decision. In an example, the NR-node may be configured to periodically signal the DACTI to the UEs under its coverage. The DACTI may also be signaled dynamically on the down link control channel via the Downlink Control Information (DCI). As used herein, an Access Configuration Signal may be shared with other control signals (e.g., pilots for synchronization or reference signals for radio link estimation or measurements). Alternatively, an Access Configuration Signal may be a dedicated control signal for the access configuration (allocation).

**[0081]** Referring to FIG. **8**, if the access configuration signal is shared with other control signals, in an example, a pattern of pilot locations along the frequency axis (e.g., subcarriers in an OFDM grid) may be used for indicating the current DACTI's Dynamic Access Allocation. As shown in FIG. **8**, a specific pattern of pilots **802***a* may be at the center of an access sub-band **802** with respect to frequency. Alternatively, or additionally, a pattern of pilots **802***b* may be at the edges of the sub-band **802**. The pilots **802***a* and **802***b* may indicate the access type and allocation of the corresponding sub-band **802**. The pilots **802***a* and **802***b* may be sent from an NR-node as a DL configuration signal, in an example of indicating the grant-less access allocation. The NR-node may configure this DL configuration signal (shared or dedicated) through system information broadcasting or RRC signaling message.

**[0082]** As used herein, an Access Configuration Channel, unless otherwise specified, may refer to a shared or dedicated control channel. If shared with other control channels, certain Information Elements (IEs) of the control channel message may be used for indicating the Dynamic Access Allocation. For example, the DCI of a Downlink Shared Control Channel may indicate the access type and location. A given NR node may configure this DL shared or dedicated control channel through system information broadcasting or RRC signaling message. In some cases, the NR node may configure more than one DL shared control channels for a UE. Once configured, the channel might be activated or deactivated for a dynamic indication of the grant-less access allocation. In some examples, the NR node may activate or deactivate the channel through MAC CE signaling or RRC signaling.

**[0083]** As shown in FIGS. **9** and **10**, the grant-less access allocation may be indicated at the first DL control signal or channel of a DACTI. These dynamic allocations may be signaled by a DL control channel, or a DL control channel may signal several allocations or allocation of several sub-bands. In some cases, a special, pre-defined Radio Network Temporary Identifier (RNTI) may be used on the DL control channel to indicate that this allocation is for DACTI.

**[0084]** Referring in particular to FIG. **9**, an example allocation **900** represents an example full band allocation. A first DL control signal or channel **902***a* within a first DACTI **904***a* indicates that the DACTI **904***a* is allocated for URLLC grant-less UL only. In an example, the DCI **902***a* associated with the Grant-less UL configuration is decoded, and then the Grant-less UL allocation within the current DACTI **904***a* is decoded. In accordance with the illustrated example, a second DL control signal or channel **902***b* within a second DACTI **904***b* indicates that the second DACTI **904***b* is allocated for eMBB granted DL and/or UL communications mixed with URLLC grant-less UL messages. In accordance with the illustrated example, a third DL control signal or channel **902***c* within a third DACTI **904***c* indicates that the third DACTI **904***c* is allocated for eMBB grant DL and/or UL communications only. In accordance with the illustrated example, a fourth DL control signal or channel **902***d* within a fourth DACTI **904***d* indicates that the fourth DACTI **904***d* is allocated for URLLC devices grant-less UL only.

**[0085]** Referring also to FIG. **10**, an example allocation **1000** represents an example partial band allocation. In accordance with the illustrated example, a first DL control signal or channel **1002***a* within a first DACTI **1004***a* indicates that the DACTI **1004***a* is split with respect to the frequency domain so as to include a URLLC device grant-less UL only sub-band **1006***a* and a eMBB DL and/or UL only sub-band **1006***b*. In some examples, the DCI of a Grant-less UL configuration is decoded, and then the Grant-less UL allocation within the current DACTI is decoded. In accordance with the illustrated example, a second DL control signal or channel **1002***b* within a second DACTI **1004***b* indicates that the DACTI **1004***b* is split with respect to the frequency domain so as to include a sub-band **1008***a* and/or **1010***a* for only mMTC device grant-less UL access, and a sub-band **1008***b* for eMBB grant DL and/or UL and URLLC device grant-less UL. In accordance with the illustrated example, a third DL control signal or channel **1002***c* within a third DACTI **1004***c* indicates that the DACTI **1004***c* is split with respect to the frequency domain so as to include a sub-band **1010***a* for only mMTC device grant-less UL access when no indicated by the second DL control signal or

channel **1002***b*, and a sub-band **1010***b* for only eMBB grant DL and/or UL. In accordance with the illustrated example, a fourth DL control signal or channel **1002***d* within a fourth DACTI **1004***d* indicates that the DACTI **1004***d* is split with respect to the frequency domain so as to include a sub-band **1012***a* for only URLLC device grant-less UL messages and a sub-band **1012***b* for only eMBB grant DL and/or UL communications.

**[0086]** Turning now to FIGS. **11**A and **11**B, further details of dynamic access allocation in the time and frequency domains are illustrated in accordance with example embodiments. In accordance with the illustrated example: (A) represents a granted DL time interval; (B) represents a granted UL time interval, (B') represents a grant-less UL time interval; (X) represents a gap between granted DL and UL time intervals; and X' represents a gap (with respect to the time domain) between DL control signals and grant-less UL messages.

**[0087]** In some examples, a DL control channel may contain DCIs for DL TX, UL ACK/NACK, UL grant, NR-node defined UL grant-less configurations (e.g., NR-node defined code seed or index of the code book for UL multi-user multiplexing in code domain), etc. In some examples, a UL control channel may contain UCIs for UL grant-less transmission configuration, such as DL Ack/Nack, UL HARQ scheme, UE selected UL grant-less configurations (e.g., UE selected code seed or index of the code book for UL multi-user multiplexing in code domain), etc. In some cases, as shown in FIGS. **11**A and **11**B, each Interval or Container, (A, B, X; B', X') may coincide within each DACTI, and multiple Intervals may also coincide within one DACTI, for example, if the DCI(s) on the downlink for Grant-less UL configure multiple self-contained containers. In some examples, multiple DACTIs may also coincide within a Container, for example, for fast dynamic grant-less UL management. In some cases, a given NR-node may dynamically manage the grant-less UL access allocation for a given UE based on, for example and without limitation: the UE's device type and/or capabilities; the UE's service requirements; a connection density associated with the UE; a UL data traffic pattern or schedule associated with the UE; the UE's feedback regarding its failed contentions or its success rate of contention; the UE's report of radio link measurements; UE's report of mobility status associated with the UE; an amount of grant-less UL transmissions that the NR-node has received; the number of grant-less UL packets that the NR-node has decoded successfully or the number of NACKs that the NR-node has sent in order to receive UL re-transmissions; traffic loading associated with the system; the radio link budget, resource utilization, scheduling, and slicing associated with the system; and/or the interference or power control and management.

**[0088]** Turning now to Priority Collision Avoidance Contention Access, as described above, URLLC devices are required to meet very tight latency requirements, and therefore URLLC devices might need to have higher priority than other devices for contention based access. An example CSMA/CA based 2-dimensional (time and frequency) priority collision avoidance contention access mechanism is shown in FIG. **12**, where Device **1**, Device **2** and Device **3** have higher priority than Device **4** for UL contention access. The following terms are defined to help describe the illustrated example embodiment. In accordance with the illustrated example, a Contention Time Interval (CTI) refers to a time interval that UEs contend for UL transmission. In some examples, a UE may acquire the CTI from the system info or RRC signaling for static or semi-static configured CTI. In some cases, a UE may decode the CTI from the DL DCIs and dynamic grant-less UL transmission configurations. In another example, a UE may receive the CTI in a grant-less setup response from the NR-node.

**[0089]** With continuing reference to FIG. **12**, in accordance with the example, a Dedicated Contention Area (DCA) **1201** may refer to an area (e.g., lean carrier) dedicated for UEs to detect UL resource availability of the current CTI. This area **1201** may be narrow in frequency, for example, such that it contains few subcarriers, for ease of detection and low overhead. The DCA **1201** may be located, for example, on either edge, or at the center, of a sub-band for contention detection. In FIG. **12**, the DCA **1201***a* is located at the lower edge of the contention access sub-band. There may be one or more DCAs **1201** for an allocated contention based accessing area, and a UE may contend at one or more DCAs **1201**, as directed by the NR-node for example. A UE may acquire the DCA **1201** from the system info or RRC signaling for static or semi-static configured DCA(s), may decode the DCA from the DL DCIs and dynamic grant-less UL transmission configurations for DCA (s), or may receive the DCA within a grant-less setup response from the NR-node.

**[0090]** A UE Access Pilot (UAP) **1203**, unless otherwise specified, refers to a UE pilot or reference signal, which may be inserted at a given DCA **1201** to indicate that the UE is transmitting its data using the resources belonging to the given DCA **1201**. The UAP **1203** may also be interleaved with the Grant-less UL Control Information (GLUCI) (e.g., mixed with the data on UL transmission) to help the NR-node decode the received GLUCI and demodulate the UL data. When interleaved with GLUCI, in some cases, the location of the UAPs may be different for each UE. A given UE may acquire the location for the UAPs from the system info or RRC signaling for static or semi-static configured UAP information. Alternatively, a given UE may decode UAP information from the DL DCIs and dynamic grant-less UL transmission configurations, or the UE may receive UAP information within a grant-less setup response from the NR-node. The UAP may be orthogonal among different UEs, such that a receiver at a given NR-node may use it to detect the UEs transmitting the UL data, and to estimate the channel for demodulating the UL data. The UAP may be designed with the UE ID in a sequence with the following properties, for example and without limitation: cyclically shifted versions of itself are orthogonal to one another, and cross-correlation between two prime lengths of the sequences is constant or near constant. An example of the implementation of orthogonal UAP may be a set of Zadoff-Chu sequences combined with UE IDs. The UAP at each DCA may also be used by other UEs to detect if the resources under the DCA are available or not for grant-less UL transmissions.

**[0091]** Unless otherwise specified, Grant-less UL Control Info (GLUCI) refers to information elements (IEs) containing various control information for UL grant-less transmissions, such as, for example and without limitation, coding rate, modulation, transmitting power level, UL transmission redundancy, code seed or index for UE defined multi-user multiplexing in code domain, etc.

**[0092]** Referring again to FIG. **12**, in accordance with the illustrated example, at a first CTI **1202***a* for time interval $t_0$, across the frequency range, Device **1**, Device **2**, and Device **3** sense (listen to) the Dedicated DCA Areas (DCAs) indicated as C**01** and C**02**, and determine that contention areas C**01** and C**02** are available for accessing by sensing that the C**01** and C**02** are below a predefined detection threshold, as an example. In the example, Device **4** senses at DCA C**02** only, and also determines that C**02** is available for accessing. In accordance with the illustrated example, Device **1** randomly selects UL resources belonging to DCA C**01** by inserting its UAP at C**01**. Further, Device **1** transmits the first redundant version of its UL transmission at A**02**, and the second redundant version of its UL transmission at A**03**, for example, if its UL Transmission Redundancy value is two or more. In some cases, a UL transmission Redundancy value may be assigned by an NR-node dynamically via the DL control channel DCIs or an UL grant-less setup procedure, or defined by the UE and indicated to the NR-node via a GLUCI on the UL control channel. In the example, Device **2** and Device **3** both randomly select UL resources that belong to DCA C**02**, by inserting their UAPs at C**02**. Continuing with the example, Device **2** randomly selects B**01** for its first redundant version of an UL transmission, B**03** for its second redundant version, and B**04** for its third redundant version, for example, if its UL Transmission Redundancy value is three or more. Device **3** randomly selects B**03** for its first redundant version of UL transmission, and B**02** for its second redundant version, for example, its UL Transmission Redundancy value is two or more.

**[0093]** Thus, as described above, in some cases, more than one Device may select the same frequency and time resource for transmitting a redundant version of their respective UL transmissions. In the illustrated example, Device **2** and Device **3** both select B**03** for transmitting one of their redundant versions. In accordance with the illustrated example, in some cases, if enough orthogonality is built between the redundant version **2** transmission of Device **2** and the redundant version **1** of Device **3**, the NR-node may be able to detect and differentiate the overlapped UL transmissions. Different non-orthogonal multiple access schemes have different mechanisms for building the multi-user orthogonality. For example, if the multi-user orthogonality is created in a code domain, then the NR-node and UEs for grant-less UL transmission may have an orthogonal code book. If the code book is not large enough to cover vast numbers of UEs such as mMTC devices, then the NR-node may assign the code to UEs based on their UL transmission schedule. For example, the NR-node may use a temporary code for the time duration that the UE is scheduled to set UL data; assign the code seed or index of the code book with the DL control channel Dices; assign the temporary code to UEs on demand; and/or assign a ground code seed or index to a group with each the UEs within the group may randomly generate code at different times if they have different schedules for grant-less UL transmission. The seed or index of the temporary code or group code of the code book may be assigned by NR-node dynamically via the DL control channel DCIs or an UL grant-less setup procedure, or defined by the UE and indicated to NR-node via a GLUCI on the UL control channel.

**[0094]** In other cases, for example, in which no orthogonality exists between two overlapped transmissions, the NR-node may still be able to decode the stronger UL data. The UL data may be stronger, for example, if is received with a higher signal to noise and interference ratio, as compared to other data, such that it can decoded by a receiver of the NR-node. If the NR-node is not able to decode the data, the NR-node may treat the overlapped transmissions as a collision and discard the received data. In such an example, with continuing reference to FIG. **12**, the NR-node may still be able to successfully decode other non-overlapped transmissions from Device **2** and Devices **3**. Further, the NR-node may combine UL transmission redundant versions **1** and **3** from Device **2**. Therefore, devices that require ultra-high reliability may insert multiple redundant versions for their grant-less UL transmissions to avoid failures of UL data receptions due to, for example, poor channels or contention collisions. In accordance with the illustrated example, Device **4** waits for a back-off time, which may be randomly seeded by Device **4** or an NR-Node, before sensing that C**02** has been taken by Device **2** and Device **3**. Device **4** may sense that by determining that C**02** is above a predefined detection threshold, for example. Accordingly, Device **4** may stop contention for C**02** for the remaining time in the first CTI **1202***a*.

**[0095]** With continuing reference to the example illustrated in FIG. **12**, at a second CTI **102***b* during time interval $d_1$, Device **1** continues its transmission over A**1** and A**3** by extending its UAP into DCA C**1**. Device **4** senses that DAC C**12** is available and senses again that C**12** is still available after a random back-off time. Device **4** inserts its UAP at C**12** and randomly selects B**1** for its UL transmission. At a third CTI **102***c* during time interval $\mathbf{2}_T$, Device **4** continues its transmission over B**2** by extending its UAP into DCA C**2**. In some cases, frequency hopping may be also applied in the 2D Priority Collision Avoidance Contention Access scheme described above. The hopping parameters may be statically or semi-statically configured, or may be assigned by an NR-node dynamically via the DL control channel DCIs or a UL grant-less setup.

**[0096]** Turning now to Multi-user Orthogonality and Contention Management examples, with reference to FIGS. **13**A-C, in accordance with grant-less UL transmissions, no UE is specifically granted UL transmission resources, or scheduled to use an UL transmission resource. Thus, in examples, grant-less UL transmissions are contention based, which may cause multiple UEs to contend for the same UL resources at the same time, thereby causing collisions as depicted in FIGS. **13**A-C for different example scenarios.

**[0097]** If full or partial orthogonal multi-user multiplexing is applied, for example, it is recognized herein that advanced receivers at an NR-node of the access network may still be able to demodulate the collided messages from multiple UEs. But it is also recognized herein that collisions increase the inter-user interferences, which may degrade the system performance and also limit the system capacity. For example, the achievable SIR may be limited to a certain value, which may be dependent on the number of multiplexed UEs. In an example embodiment, to support ultra-reliable performance requirements for URLLC devices and massive connection requirements for mMTC devices, multi-user orthogonality with proper contention allocation is implemented in a NR network.

**[0098]** Non-Orthogonal Multiple Access (NOMA) schemes are generally code, sequence, or inter-leaver based. The multi-user orthogonality is realized by the orthogonal code book design, orthogonal or quasi-orthogonal sequence

generation, or partial orthogonal inter-leaver pattern design. Therefore, multi-user orthogonality among large number of UEs is a challenge to build with limited orthogonal codes, sequences, or inter-leaver patterns. Building multi-user orthogonality with reduced collision possibility for contention based grant-less UL transmissions, in accordance with various embodiments, is now discussed.

**[0099]** In an example embodiment, multi-user orthogonality and contention management is implemented by reusing the code, sequence, or inter-leaver patterns in time, frequency, and space; and controlling the number of UEs that contend for the same resources at the same time for both collision based and collision avoidance multiple accessing schemes.

**[0100]** As used herein, unless otherwise specified, a Contention Subcarrier Group (COG) refers to a group of subcarriers allocated for contending for UL access. The COG may vary for different devices or services. For example, various contention subcarrier groups may have different system numerologies, as shown in FIG. **14**A. As used herein, unless otherwise specified, the Contention Time Interval (CTI) refers to a time interval allocated for contending for UL access. This time interval may vary for different devices or services, and may have different system numerologies, as shown in FIG. **14**B. As used herein, unless otherwise specified, a Contention Block (CB) refers to a block of resources defined by a specific Contention Timed Interval (CTI) and a specific Contention Subcarrier Group (COG). The size of the block may vary with respect to time and number of subcarriers for different devices or services, or for different system numerologies, as shown in FIG. **14**C. As used herein, unless otherwise specified, a Contention Space (CS) refers to a set of Contention Blocks that UEs contend with the same spatial beams. A set of orthogonal or quasi-orthogonal codes, sequences, or inter-leaver patterns may be reused for different Contention Spaces.

**[0101]** With respect to a Multi-Dimension Contention Resource (MACRO): in a MIMO OFDM system, a UL resource may be defined in the dimensions of time, frequency and space. For example, micro (time(i), frequency (j), space(k)) may represent a resource of a Contention Block, which may be further described as: marc (CTI(i), COG(j), spatial-beam(k)), which is the unit that a UE contends for a UL transmission. A UE may contend for one or more contention blocks (CBs) in a Contention Space. For example, an mMTC device may contend for two CBs (e.g., CB(Cit$_i$, Cog) and CB(CTI$_{i+1}$, CSG$_j$)), for two contention time intervals CTI$_i$ and CTI$_{i+1}$ on the subcarrier group CSG$_j$, for an UL transmission in a Contention Space along the time axis with 1 spatial beam b$_k$, {mdrc[CB(CTI$_i$, CSG$_j$),b$_k$], mdrc[CB(CTI$_{i+1}$, CSG$_j$),b$_k$]}, using a set of codes, sequences, or inter-leaver patterns assigned by the NR-node. Continuing with the example, a URLLC device may contend for three CBs (e.g., CB(CTI$_i$, CSG$_j$), CB(CTI$_i$, CSG$_{j+1}$) and CB(CTI$_i$, CSG$_{j+2}$)) for three subcarrier groups CSG$_j$, CSG$_{j+1}$, and CSG$_{j+2}$ in the contention time interval CTI$_i$ in a Contention Space along the frequency axis for each of two spatial beams b$_k$ and b$_{k+1}$ for spatial redundance transmission, {mdrc[CB(CTI$_i$, CSG$_j$), b$_k$], mdrc[CB(CTI$_i$, CSG$_{j+1}$), b$_k$], mdrc[CB(CTI$_i$, CSG$_{j+2}$), b$_k$]; mdrc[CB(CTI$_i$, CSG$_j$), b$_{k+1}$], mdrc[CB(CTI$_i$, CSG$_{j+1}$), b$_{k+1}$], mdrc[CB(CTI$_i$, CSG$_{j+2}$), b$_{k+1}$]}, using a set of codes, sequences, or inter-leaver patterns assigned by the NR-node.

**[0102]** In some cases, to build multi-user orthogonality with a reduced collision possibility, the NR-node of a radio access network may define a Contention Space with a predetermined number of Contention Blocks dedicated to the Contention Space. Continuing with the example, the NR-node may further define a set of orthogonal or quasi-orthogonal codes, sequences, or inter-leaver patterns to be used by the group of UEs contending for this Contention Space. In some cases, the set of orthogonal or quasi-orthogonal codes, sequences, or inter-leaver patterns may be reused by different groups of UEs contending for different Contention Spaces. In this example, the collisions may occur only among the UEs contending in the same CS, and such collisions may be mitigated by multi-user orthogonality among the UEs contending in the same CS. In some examples, the Contention Spaces may be controlled and managed by a NR-node based on the following, presented by way of example and without limitation: access network available resources and accessibility; access network traffic characteristics and schedules; access network radio link measurements (e.g., link quality); the number of UEs in the relevant serving area; the total system through put, contention accessing delay, and contention failure rate; the device type and capabilities in the serving area; and/or other parameters associated with the UE, such as traffic type, data rate, data size, latency requirements, error rate, contention failure rate tolerance, and other service QoS requirements.

**[0103]** Turning now to static or semi-static multi-user orthogonality and contention configuration, as described above, URLLC devices may require short latency and high reliability for delivering small or medium size data, and mMTC devices may require low signaling overhead and reasonable reliability for delivering small data. To meet these requirements, among others, various UL contention allocations may be used, in accordance with various example embodiments, such as the example contention allocations depicted in FIGS. **13**A-C. In some examples, a multi-user orthogonality and contention configuration may contain various parameters, such as, for example and without limitation: parameters that indicate a grant-less UL access allocation configuration and parameters that indicate a contention space allocation configuration. With respect to contention space allocation configurations, parameters may indicate, for example and without limitation, the available Contention Blocks (time, frequency); a set of orthogonal code indices, orthogonal sequence indices, or orthogonal interleaver pattern indices; types of devices and/or services to which the allocation applies, types of RAN slice to the which the allocation applies, a contention accessing type (e.g., collision based, contention avoidance, etc.); accessing priority and related random generation seed, code index, and/or other accessing parameters used for priority based contention accessing schemes; schedule or time duration allocated to this CS; numerologies supported; maximum CBs allowed in time and/or frequency per UE; and coding rate, modulation, etc. that is supported by the allocation.

**[0104]** With respect to a Static Configuration, the example allocations described herein may be preconfigured via a GUI (such as the GUI **3600**) on the devices. In some cases, allocations may be configured by device manufacturers or service providers. Alternatively, an allocation may statically be provisioned on the device using Open Mobile Alliance Device Management (OMA DM) protocol or any other Over-The-Air (OTA) device provisioning protocol. This

contention allocation, (e.g., contention space with the associated CBs and set of codes, sequences, or inter-leaver patterns) may be known to the devices prior to any communication session is established.

**[0105]** With respect to semi-static configuration, the example allocations described herein may also be broadcast to a UE through System Information, or signaled to a UE through common RRC signaling, dedicated RRC signaling, or MAC Control Element (MAC CE) signaling. For example, using common RRC signaling, an example allocation may be: periodically broadcasted or multi-casted by an NR-node as part of System Info in the RadioResourceConfigCommonSIB as shown in Example A below; or aperiodically unicasted by an NR-node in an RRC message in the rrcConnectionReconfiguration message or MAC CE message as System Info on-demand.

**[0106]** In some examples, a UE may acquire the contention allocation information by searching the system information on a DL broadcasting or multicasting channel that is transmitted from an NR-node. In some examples, a given UE may send a request to the NR-node for the contention allocation information, as on-demand system information. The NR-node (e.g., NextGen RAN Node) may signal the contention configuration (allocation) to a UE in a response to a request from the UE, or as result of an autonomous NR-node decision.

Example A

**[0107]**

```
-- ASN1START
RadioResourceConfigCommonSIB ::=   SEQUENCE {
   rach-ConfigCommon                    RACH-ConfigCommon,
   bcch-Config                          BCCH-Config,
   pcch-Config                          PCCH-Config,
   prach-Config                         PRACH-ConfigSIB,
   pdsch-ConfigCommon                   PDSCH-ConfigCommon,
   pusch-ConfigCommon                   PUSCH-ConfigCommon,
   pucch-ConfigCommon                   PUCCH-ConfigCommon,
   soundingRS-UL-ConfigCommon           SoundingRS-UL-ConfigCommon,
   uplinkGrantlessControlCommon         uplinkGrantlessControlCommon
   uplinkGrantlessContentionCommon      uplinkGrantlessContentionCommon
   uplinkPowerControlCommon             UplinkPowerControlCommon,
   ul-CyclicPrefixLength                UL-CyclicPrefixLength,
   ...,
   [[ uplinkGrantlessControlCommon-v1070   uplinkGrantlessControlCommon -v1070 OPTIONAL -- Need
OR
   ]],
   [[ uplinkGrantlessContentionCommon-v1090   uplinkGrantlessContentionCommon -v1090 OPTIONAL
-- Need
OR
   ]],
   [[ uplinkPowerControlCommon-v1020   UplinkPowerControlCommon-v1020   OPTIONAL   -- Need
OR
   ]],
   [[ rach-ConfigCommon-v1250          RACH-ConfigCommon-v1250     OPTIONAL   -- Need OR
   ]],
   [[ pusch-ConfigCommon-v1270         PUSCH-ConfigCommon-v1270      OPTIONAL   -- Need
OR
   ]]
}
RadioResourceConfigCommon ::=      SEQUENCE {
   rach-ConfigCommon                   RACH-ConfigCommon                OPTIONAL,   -- Need
ON
   prach-Config PRACH-Config,
   pdsch-ConfigCommon                  PDSCH-ConfigCommon               OPTIONAL,   -- Need
ON
   pusch-ConfigCommon                  PUSCH-ConfigCommon,
   phich-Config                        PHICH-Config                     OPTIONAL,   -- Need
ON
   pucch-ConfigCommon                  PUCCH-ConfigCommon               OPTIONAL,   -- Need
ON
   soundingRS-UL-ConfigCommon          SoundingRS-UL-ConfigCommon       OPTIONAL,   -- Need
ON
   uplinkGrantlessControlCommon        UplinkGrantlessControlCommon     OPTIONAL,   -- Need
ON
   uplinkGrantlessContentionCommon     UplinkGrantlessContentionCommon  OPTIONAL,   -- Need
ON
   uplinkPowerControlCommon            UplinkPowerControlCommon         OPTIONAL,   -- Need
ON
   antennaInfoCommon                   AntennaInfoCommon              OPTIONAL,   -- Need ON
   p-Max                               P-Max                            OPTIONAL,   -- Need
OP
   tdd-Config                          TDD-Config                       OPTIONAL,   -- Cond
TDD
   ul-CyclicPrefixLength               UL-CyclicPrefixLength,
   ...,
   [[ uplinkGrantlessControlCommon-v1070   UplinkGrantlessControlCommon-v1070     OPTIONAL   -
```

-continued

```
- Need
ON
   ]],
   [[ uplinkGrantlessContentionCommon-v1090    UplinkGrantlessContentionCommon-v1090
   OPTIONAL       -- Need
ON
   ]],
   [[ uplinkPowerControlCommon-v1020    UplinkPowerControlCommon-v1020    OPTIONAL    -- Need
ON
   ]],
   [[ tdd-Config-v1130                  TDD-Config-v1130                  OPTIONAL    -- Cond TDD3
   ]],
   [[ pusch-ConfigCommon-v1270          PUSCH-ConfigCommon-v1270          OPTIONAL    -- Need
OR
   ]],
   [[ uplinkPowerControlCommon-v13xy    UplinkPowerControlCommon-v13xy    OPTIONAL    -- Need
ON
   ]]
}
RadioResourceConfigCommonPSCell-r12 ::= SEQUENCE {
   basicFields-r12                      RadioResourceConfigCommonSCell-r10,
   pucch-ConfigCommon-r12               PUCCH-ConfigCommon,
   rach-ConfigCommon-r12                RACH-ConfigCommon,
   uplinkGrantlessControlCommonPSCell-r17    UplinkGrantlessControlCommonPSCell-r17,
   uplinkGrantlessContentionCommonPSCell-r19    UplinkGrantlessContentionCommonPSCell-r19,
   uplinkPowerControlCommonPSCell-r12   UplinkPowerControlCommonPSCell-r12,
   ...,
   [[ uplinkPowerControlCommon-v13xy    UplinkPowerControlCommon-v13xy    OPTIONAL    -- Need
ON
   ]]
}
RadioResourceConfigCommonSCell-r10 ::= SEQUENCE {
   -- DL configuration as well as configuration applicable for DL and UL
   nonUL-Configuration-r10              SEQUENCE {
      -- 1: Cell characteristics
      dl-Bandwidth-r10                     ENUMERATED {n6, n15, n25, n50, n75, n100},
      -- 2: Physical configuration, general
      antennaInfoCommon-r10                AntennaInfoCommon,
      mbsfn-SubframeConfigList-r10         MBSFN-SubframeConfigList      OPTIONAL,   -- Need
OR
      -- 3: Physical configuration, control
      phich-Config-r10                     PHICH-Config,
      -- 4: Physical configuration, physical channels
      pdsch-ConfigCommon-r10               PDSCH-ConfigCommon,
      tdd-Config-r10                       TDD-Config                    OPTIONAL    -- Cond
TDDSCell
   },
   -- UL configuration
   ul-Configuration-r10                    SEQUENCE {
      ul-FreqInfo-r10                      SEQUENCE {
         ul-CarrierFreq-r10                ARFCN-ValueEUTRA              OPTIONAL,   -- Need
OP
         ul-Bandwidth-r10                  ENUMERATED {n6, n15,
                                              n25, n50, n75, n100}       OPTIONAL,   -- Need
OP
         additionalSpectrumEmissionSCell-r10    AdditionalSpectrumEmission
      },
      p-Max-r10                            P-Max                         OPTIONAL,   -- Need OP
      uplinkGrantlessControlCommonSCell-r17   UplinkGrantlessControlCommonSCell-r17,
      uplinkGrantlessContentionCommonSCell-r19  UplinkGrantlessContentionCommonSCell-r19,
      uplinkPowerControlCommonSCell-r10    UplinkPowerControlCommonSCell-r10,
      -- A special version of IE UplinkPowerControlCommon may be introduced
      -- 3: Physical configuration, control
      soundingRS-UL-ConfigCommon-r10       SoundingRS-UL-ConfigCommon,
      ul-CyclicPrefixLength-r10            UL-CyclicPrefixLength,
      -- 4: Physical configuration, physical channels
      prach-ConfigSCell-r10                PRACH-ConfigSCell-r10         OPTIONAL,   -- Cond
TDD-OR-NoR11
      pusch-ConfigCommon-r10               PUSCH-ConfigCommon
   }                                                                     OPTIONAL,   -- Need OR
   ...,
   [[ ul-CarrierFreq-v1090                 ARFCN-ValueEUTRA-v9e0         OPTIONAL    -- Need
OP
   ]],
   [[ rach-ConfigCommonSCell-r11           RACH-ConfigCommonSCell-r11    OPTIONAL,   -- Cond
ULSCell
```

-continued

```
    prach-ConfigSCell-r11                    PRACH-Config                    OPTIONAL,   -- Cond
UL
    tdd-Config-v1130                         TDD-Config-v1130                OPTIONAL,   -- Cond TDD2
    uplinkGrantlessControlCommonSCell-v1170
                        UplinkGrantlessControlCommonSCell-v1170 OPTIONAL   -- Cond UL
    uplinkGrantlessContentionCommonSCell-v1170
                        UplinkGrantlessContentionCommonSCell-v1170   OPTIONAL   -- Cond
UL
    uplinkPowerControlCommonSCell-v1130
                        UplinkPowerControlCommonSCell-v1130 OPTIONAL   -- Cond UL
  ]],
  [[ pusch-ConfigCommon-v1270          PUSCH-ConfigCommon-v1270      OPTIONAL   -- Need
OR
  ]],
  [[ pucch-ConfigCommon-r13                  PUCCH-ConfigCommon        OPTIONAL,   -- Cond UL
    uplinkGrantlessControlCommonSCell-v17xx UplinkGrantlessControlCommonPSCell-r17 OPTIONAL
  -- Cond UL
    uplinkGrantlessContentionCommonSCell-v19xx UplinkGrantlessContentionCommonPSCell-r19
  OPTIONAL   -- Cond UL
    uplinkPowerControlCommonSCell-v13xx UplinkPowerControlCommonPSCell-r12 OPTIONAL   --
Cond UL
  ]]
}
BCCH-Config ::=                     SEQUENCE {
  modificationPeriodCoeff             ENUMERATED {n2, n4, n8, n16}
}
PCCH-Config ::=                     SEQUENCE {
  defaultPagingCycle                  ENUMERATED {
                                        rf32, rf64, rf128, rf256},
  nB                                  ENUMERATED {
                                        fourT, twoT, oneT, halfT, quarterT, oneEighthT,
                                        oneSixteenthT, oneThirtySecondT}
}
UL-CyclicPrefixLength ::=           ENUMERATED {len1, len2}
-- ASN1STOP
BCCH-Config ::=                     SEQUENCE {
  modificationPeriodCoeff             ENUMERATED {n2, n4, n8, n16}
}
PCCH-Config ::=                     SEQUENCE {
  defaultPagingCycle                  ENUMERATED {
                                        rf32, rf64, rf128, rf256},
  nB                                  ENUMERATED {
                                        fourT, twoT, oneT, halfT, quarterT, oneEighthT,
                                        oneSixteenthT, oneThirtySecondT}
}
UL-CyclicPrefixLength ::=           ENUMERATED {len1, len2}
-- ASN1STOP
```

**[0108]** Turning now to Dynamic Multi-user Orthogonality and Contention Management, in addition to the static and semi-static configurations discussed above, the contention configuration (allocation) may also be conducted (e.g., activated and/or deactivated) dynamically via the DCIs on the DL control channel, in accordance with an example embodiment. It is recognized herein that various devices and services may have dynamic traffic patterns, availabilities, and the like, which may require that, in some cases, Multi-user Orthogonality and Contention is dynamically managed by an NR-node. Such dynamic management (e.g., activation, deactivation, re-configuration, etc.) may ensure that system resources are appropriately used to meet various grant-less UL performance requirements.

**[0109]** As used herein, unless otherwise specified, a Dynamic Access Configuration Time Interval (DACTI) refers to a fixed or variable time interval in which a specific Access Allocation scheme, either DL and/or UL, is applied. The length of a given DACTI may be signaled to UEs via common RRC signaling (e.g., in broadcasted or multi-casted system information), via dedicated RRC Connection Reconfiguration signaling, or via MAC CE signaling. A NR-node may also signal the DACTI to the UE as a response to a request from the UE, or as a result of an autonomous NR-node decision. By way of example of an autonomous NR-node decision, a NR-node may be configured to periodically signal a DACTI to the UEs under its coverage. The DACTI may also be signaled dynamically on the down link control channel via Downlink Control Information (DCI). As used herein, unless otherwise specified, an Access Configuration Signal refers to a signal that may be shared with other control signals or to a control signal that is dedicated to grant-less access configurations. As used herein, an Access Configuration Channel may be shared (e.g., shared between grant and grant-less) or dedicated (e.g., dedicated to grant or grant-less only) control channel. In some cases, Control Information Elements (IEs) of a DL control channel message may be used for indicating, for example and without limitation, a Dynamic Access Allocation configuration, a Contention Allocation configuration with the associated Contention Blocks, and orthogonal or quasi-orthogonal codes, sequences, or inter-leaver patterns. The NR-node may configure this DL shared or dedicated control channel through RRC signaling message. The NR-node may con-

figure more than one DL shared or dedicated control channel for a UE. Once configured, the channel might be activated or deactivated. The NR node may activate or deactivate the channel through MAC CE signaling or RRC signaling.

**[0110]** Referring now to FIGS. **15**A and **15**B, details of an example dynamic access allocation and contention allocation in the time and frequency domains are shown. As shown, the example Dynamic Access Configuration Time Intervals **1502***a-c* include the following variables: A, B, B', C, X, and X'. In accordance with the illustrated examples, A represents a grant DL time interval, B represents a grant UL time interval, B' represents a grant-less UL time interval, X represents a gap with respect to time between grant DL and UL intervals, and X' represents a gap with respect to time between grant DL control signal(s) (channels) and a grant-less UL interval.

**[0111]** The DL control channels may contain DCI for DL control and/or data configurations, UL control and/or data configuration (e.g., the grant-less access allocation, Contention Spaces with associated Contention Blocks, and orthogonal or quasi-orthogonal codes, UE sequences, or inter-lever patterns, etc.). The UL control channel may contain UCI for UL Tx configurations, DL Ack/Nack, etc.

**[0112]** In some cases, as shown in FIG. **15**A, each Interval (A, B, X; B', X') may correspond within a respective DACTI **1502***a* and **1502***b*. In other examples, multiple containers, for instance intervals **1504***a* and **1504***b*, may be within one DACTI **1502***c*, for example, if the DCI for a given Grant-less UL are configured for multiple self-contained Intervals.

**[0113]** Another example of dynamic access allocation and contention allocation in the time and frequency domains is illustrated in FIGS. **16**A and **16**B, where the self-contained Intervals **1602***a-d* may include the following variables: A', B**1**', X**1**', B**2**', and X**2**'. In accordance with the illustrated examples, A' represents a grant-less DL time interval, B**1**' represents the grant-less first UL time interval, B**2**" represents the grant-less second UL time interval, X**1**' represents a gap with respect to time between the grant-less DL and the first UL, and X**2**' represents a gap with respect to time between a grant-less first UL and second UL.

**[0114]** Referring now to FIG. **17**, example grant-less physical control signals and channels **1702** and **1704** are shown. In accordance with the example, DL Synchronization Pilots **1702***a* may be included in the DL control channel **1702**. The DL Synchronization Pilot may be used for fast synchronization in frequency (e.g., subcarrier spacing) and time (e.g., for TA estimation as described above) prior to a grant-less UL transmission, while switching from a Grant-less Inactive state to a Grant-less Active State. DL reference signals **1702***b* may include in the DL control channel **1702**. The DL Reference Signal **1702***b* may be used for radio channel estimation and radio link measurements, e.g. received power of the reference signals may be used for UL path loss estimation as proposed above). It is recognized herein that the reference signal sequence needs to be designed with good orthogonality or quasi-orthogonality to avoid intra-call interference among different TRPs and limit the inter-call interference at the cell edge. M sequence may be an example for its implementation. DL Control Information (DCI) **1702***c* may be included in the DL control channel **1702**. DCI may contain the grant-less UL transmission configurations, which may include various parameters, for example and without limitation: grant-less access allocation parameters; grant-less Contention Space allocation parameters, Grant-less Contention Blocks; a set of codes, sequences, or inter-leaver patterns for UL NOMA; a DL reference signal's transmit power level; a coding rate and modulation for UL; parameters related to accessing priority and related random generation seed, code index, and/or other accessing parameters used for priority based contention accessing schemes; a schedule or time duration allocated to this CS (e.g., number of Intervals in time); an indication of numerologies supported; or a maximum number of CBs allowed in time and/or frequency per UE.

**[0115]** Still referring to FIG. **17**, UL UE pilots **1704***a* may be included in the UL control channel/signal **1704**. The UL UE pilot **1704***a* may be used to indicate the UE to the NR-node receiver (e.g., differentiated from other UEs sending grant-less UL transmissions). In an example, the pilot **1704***a* includes an ID of the UE. In another example, the pilot **1704***a* is scrambled with the UE ID assigned during attachment or a grant-less setup with the NR-node. To reduce the possible collision among UEs pilots, a UE, in some examples, may randomly select the start location for its pilot. For example, the UE may randomly select position **1** or **2** at the start point for its pilot as shown in FIG. **17**. The selection of the position of the pilot may also be based, at least in part, on the UE ID. UL Control Information (UCI) **1704***b*, which may be included in the UL control signal/channel **1704** may contain the grant-less UL transmission configurations, which may include the following indications, presented by way of example and without limitation: an index of codes, sequences, or inter-leaver patterns for UL NOMA; the UL reference signal's transmit power level; Next transmission or schedule update Coding rate and modulation for UL; a number of CBs used for the UL transmission; a redundancy indication and index; latency indication for successful UL contention; a failure rate for UL contention; radio link measurements; and a device capability or service type that corresponds to the UCI.

**[0116]** Turning now to Grant-less UL Transmissions in a Subframe, with initial reference to FIG. **18**, in an example subframe **1802** of a reference numerology, different kinds of grant-less slots may be allocated differently. Example wide band Grant-less Slots **1-5** are illustrated in FIG. **18**. Different partial sub-band Grant-less Slots **1-3** are shown in Slot **1** of the reference numerology within the Subframe **1802**, which may be statically configured (e.g., in SI), semi-statically signaled (e.g., RRC or MAC CE), or dynamically indicated (e.g., DCIs in the DL control channel in Slot **1**), and different full sub-band Grant-less Slots **4** and **5** are shown in Slot **2** of the reference numerology within the Subframe **1802**, which may be statically configured (e.g., in SI), semi-statically signaled (e.g., RRC or MAC CE), or dynamically indicated (e.g., DCIs in the DL control channel in Slot **1** or the Secondary DL control channel in Slot **2**).

**[0117]** Example narrow band Grant-less Interval/Slots **1-5**, which may cross the slot boundary of the reference numerology, such as shown by Grant-less Interval **1** and Grant-less Interval **2**, are illustrated in FIG. **19**. Different Grant-less Intervals or Slots are shown in an example subframe **1902** of the reference numerology. The Grant-less Interval/Slots **1-5** may be pre-defined or pre-configured by the system administration; statically or semi-statically configured via a higher layer, such as viaRRC signaling or MAC CEs; or dynamically signaled by the Grant-less DCIs carried on a DL Control Channel and/or a Secondary DL Control channel, if applicable.

**[0118]** Examples of Grant-less Slot (e.g., Grant-less mini-slot) configurations, which may be statically configured (e.g., in SI), semi-statically signaled (e.g., RRC or MAC CE), or dynamically indicated (DCIs in the DL control channel in Slot **1** or Slot **2**), containing Grant-less DL Signals and/or Control Info (e.g., DCI), Grant-less UL Pilots/Preambles, Control Info (e.g., UCI), and Data are illustrated in FIG. **20** and FIG. **21**. A Grant-less Slot configuration, such as the example configurations shown in FIGS. **18**-**21**, may contain the following parameters, presented by way of example and without limitation: Gap **1**, which may refer to a gap in time from the DL Control of the reference numerology, which may dynamically indicate the Grant-less slot configuration with the reference numerology (e.g, Slot **1**), or from the secondary DL control that may dynamically indicate the Grant-less slot configuration with the reference numerology sot (e.g., Slot **2**), if applicable; Gap **2**, which may be optional, and which may refer to a in time between Grant-less Slots; Length of a Grant-less DL, which may refer to a number of symbols carrying Grant-less; DL Sync, for time and frequency synchronization; DL Reference Signals for DL path loss, DL propagation delay, DL radio link measurements, and for decoding the DL Control Info; DL Control Info carrying the configurations for the Grant-less UL transmission, such as a contention resource pool (e.g., Contention Space) allocation (partial sub-band of full sub-band in frequency) in the unit of Contention Blocks, or a grant-less signature pool (e.g., UE pilots) to differentiate multiple UEs that are multiplexed; an NR-node DL time stamp; a DL Reference Signal power level; hybrid automatic repeat request (HARQ) or re-transmission scheme; Length of the Grant-less UL, which may indicate a number of symbols carrying the Grant-less; UL UE pilots/preambles used; UL Control Info (UCI) for supporting the NR-node to decode the UL Data (e.g., UE ID, Contention Blocks used, UL HARQ scheme, Index of the UL Signature, re-transmission scheme and/or redundancy index, UL Reference Signal power level, Radio link measurement, Latency for successful UL contention or failure rate for UL contention, Device capability or service type, location, mobility, schedule (e.g. next UL transmission), etc.); UL Data, which may be carried on the same symbol carrying the UL UCIs for small size data if wide band Grant-less is configured; and Gap **3**, which may refer to gap in time between the Grant-less DL and UL (if applicable).

**[0119]** The above mentioned example configuration parameters or control info may be pre-defined or pre-configured by the system administration, or statically or semi-statically configured by a higher layer, such as via RRC signaling or MAC CEs, or dynamically indicated by the DCIs in one or more DL control channels, such that a UE may determine from the parameters where a Grant-less slot is allocated. The UE, based on the received parameters, may also identify the parameters and/or control info associated with the slot structure and DL and UL configurations. An example Grant-less Slot structure and contents **2200** are depicted in FIG. **22**.

**[0120]** Referring now to FIGS. **23**A and **23**B, retransmissions in wide band grant-less mini-slots are illustrated in accordance with an example embodiment. FIGS. **24**A and **24**B depict example retransmissions in narrow band grant-less mini-slots in accordance with another example embodiment. As shown, for example, a Grant-less DL control channel **2302** may contain DCI for configuring the Grant-less UL transmission(s), and the Grant-less UL control channel **2304** may contain UCI for a hybrid automatic repeat request (HARQ) scheme for the grant-less UL transmission **2306**. For example, the HARQ, such as a ACK/NACK delivery with the next Grant-less mini-slot **2308** for example. The ACK/NACK may be sent in the same reference numerology slot on the Grant-less DL control as transmission **2306** (e.g., Slot **1** as shown in FIG. **23**A) or the next slot reference numerology slot (e.g., Slot **2** as shown in FIG. **23**B) on a shared DL control **2301***b* or a Grant-less DL control **2302***b*. The ACK/NACK carried on the Grant-less DL control channel **2308** in the next Grant-less mini-slot determines whether the grantless UL data is re-transmitted at **2310**/**2320***b* or not. For example, if a NACK is received, in some cases, the UL portion **2306** of the Grant-less mini-slot **2306** is retransmitted. In some examples, a Time Adjustment (TA), a Transmit Power Control (TPC), a Modulation and Coding Scheme (MCS), etc. are carried on the Grant-less DL control channel in the next Grant-less mini-slot, such that the retransmission parameters are indicated. As shown, for example in FIG. **24**B, the retransmission may be conducted at a different frequency from the original transmission.

**[0121]** Referring now to FIGS. **25**A to **26**B, an example system **2500** is shown which includes an mMTC UE **2502**, an NR-node **2504**, and a core network (CN) **2506**. The NR-node **2504** comprises a RAN slice management function or apparatus (node) **2508** and an mMTC slice **2510**. The CN **2506** includes a CN Slice Management function or apparatus (node) **2512** and an mMTC slice **2514**. The mMTC **2514** may include a mobility management node or apparatus **2516**, gateways **2518** (e.g., SWG, PGW) and a subscription management function or apparatus (node) **2520** (e.g., HSS). It will be appreciated that the example system **2500** is simplified to facilitate description of the disclosed subject matter and is not intended to limit the scope of this disclosure. Other devices, systems, and configurations may be used to implement the embodiments disclosed herein in addition to, or instead of, a system such as the system illustrated in FIGS. **25**A to **26**B, and all such embodiments are contemplated as within the scope of the present disclosure.

**[0122]** Referring in particular to FIG. **25**A, at **1**, in accordance with the illustrated example, the UE **2502** after power up. After powering, the UE **2502** may conduct cell search and synchronization, and then the UE may acquire system information, for example, from MIB and SIBs. At **2**, the UE **2502** sends a Radio Connection Request to the NR-node **2504**. In particular, the UE may send Radio Connection Request message to the RAN slicing management apparatus **2508** (at **2**A) or the mMTC slice **2510** (at **2**B). The request may be a request for access to a UE selected RAN slice **2510** at the NR-node **2504**. The request may include various context information associated with the UE **2502**. The context information may include, for example and without limitation, a device type (e.g., mMTC, URLLC) of the UE **2502**, a service associated with the UE **2502** (e.g., forest fire monitoring or traffic monitoring), a latency requirement (e.g, 100 ms or ultra-low latency of 0.5 ms, data traffic context (e.g., data packet size or data rate), a traffic type (e.g., non-IP or IP based); mobility context associated with the UE **2502** (e.g., static, pedestrian, vehicular), a planned schedule of data transmissions from the UE **2502**, type of access that can be performed by the UE **2502** (e.g., grant access, grant-less

access, or access that switches between grant and grant-less). In some cases, operations **3**, **4**, and **5** are not performed when the UE selects the slice **2510**.

**[0123]** In some cases, for example when the UE **2502** does not select a slice, the RAN Slicing Management **2508**, at **3**A, selects the slice **2510** as the UE's radio accessing slice, for example, based on the UE context in the request at **2**A. The selection may further be based on RAN traffic loading and resource allocations. At **4**A, in accordance with the illustrated example, the RAN Slicing Management **2508** sends a RAN Slice Connection Request to the mMTC Slice **2510** that was selected. The request may also forward all or some of the UE's context from **2**A, so that a radio connection can be established between the UE **2502** and the mMTC slice **2510**. At **5**A, the mMTC Slice **510** may send a RAN Slice Connection Response to the RAN Slicing Management **2508**. The response may indicate whether the slice connection request has been accepted. If the request is rejected, the one or more reasons for the rejection may be included in the response message.

**[0124]** At **6**, in accordance with the illustrated example, the RAN Slicing Management **2508** (at **6**A) or the mMTRC Slice **2510** (at **6**B) sends a RAN Slice Connection Response to the UE **2502**. In this message, the RAN Slice Management **2508** or the RAN mMTC Slice **2510** may confirm whether the radio connection request has been accepted. If the request is rejected, one or more reasons for the rejection may also be included in the response message. In the illustrated example, the UE **2502** receives a confirmation that a successful radio connection with the mMTC Slice **2510** has been established. At **7**, the UE may send a registration request to the RAN Slicing Management **2508** (at **7**A) or the RAN mMTC Slice **2510** (at **7**B). The registration request may be sent to establish a secured service connection with the Core Network (CN) **2506**.

**[0125]** Referring now to FIG. **25**B, at **8**, the registration request is sent to CN Slicing Management apparatus **2512** (**8**C and **8**C') or the CN mMTC slice **2514** (**8**D and **8**D'). The request may be sent by the RAN Slicing Management **2508** (**8**C and **8**D) or the mMTC Sliced **2510** (**8**C' and **8**D'). The request may include the context information associated with the UE, information associated with the mMTC slice **2510**, such as the slice ID for example. In some cases, operations **9** and **10**, which are now described, are skipped when the NR-node **2504** selects the CN slice **2514**. At **9**C, in accordance with the illustrated example, the CN Slicing Management apparatus **2512** selects the mMTC IP traffic slice **2514**, for example, based on the UE context, the RAN mMTC Slice **2510**, traffic loading of the CN **2506**, available mMTC slices, or the like. At **10**C, in accordance with the illustrated example, the CN Slicing Management node **2512** sends a registration request to the Mobility Management node **2516**. The Registration Request may include the UE's context information and information associated with the RAN mMTC Slice **2510**.

**[0126]** Referring now to FIG. **26**A, continuing with the illustrated example, at **11**, the Mobility Management node **2516** exchanges messages with the Subscription Management node **2520**, so as to authenticate the UE **2502** for access to services. After the authentication, at **12**, the Mobility Management node **2516** exchanges messages with the UE **2502**, such that the UE **2502** and the Mobility Management node **2516** mutual authenticate each other, and then establish a Secured Mode between them. At **13**, in accordance with the illustrated example, the Mobility Management node **2516** may exchange messages with the Subscription Management node **2520**, so that a location of the UE **2502** is updated. Location Update: Mobility Management exchanges messages with the Subscription Management for Location Update. At **14**, an IP session may be established between the RAN mMTC slice **2510** and the CN mMTC slice **2514**. The IP session may also be established within the CN mMTC slice **2514**.

**[0127]** With continuing reference to FIG. **26**A, in accordance with the illustrated example, at **15**, grant-less operations are setup. The NR-node **2504**, in particular the -RAN mMTC Slice **2510**, may exchange messages with the UE **2502** to configure the Grant-less operation parameters described herein, for example. Example parameters include, without limitation: contention access allocation parameters; grant-less configuration parameters (e.g., DACTI, CTI, DCA, UAP, GLUCI, etc.); seed or index of the orthogonal code for code-domain multiple accessing; seed or value of the random back-off for priority collision avoidance contention access; redundancy parameters for reliable transmissions; timers at the Inactive state (e.g., for listening to a broadcasting channel for pages or for system information changes, for conducting measurements for the radio link management, for updating statuses related to reachability and mobility, etc.); grant-less power control values (e.g., minimum and maximum UL transmission power levels and incremental adjustments, which may be calculated by the NR-node **2504** based, at least in part, the path loss and required received signal quality during the message exchanges described above between the UE **2502** and the NR-node **2504**); parameters related to a schedule for grant-less UL transmissions; a coding rate; modulation scheme, etc.

**[0128]** At **16**A, in accordance with the illustrated example, the UE **2502** confirms the grant-less configuration (allocation) with a higher layer of the UE **2502** as compared to the physical layer. Alternatively, or additionally, the UE **2502** may confirm the Grant-less setup with the NR-node **2504**, in particular the RAN Slicing Management node **2508** (at **16**B) or the mMTC slice **2510** (at **16**C). Accordingly, the UE **2502** may receive an entering "Grant-less" operation mode command from the higher layer or from the NR-node **2504**. At **17**, the UE **2502** enters into an inactive state (e.g., lower power state with no data to transmit) of the Grant-less operation mode. The inactive state may be preconfigured. In some cases, the inactive state may be triggered by the higher layer or the NR-node's command to operate in Grant-less mode after registration. In some cases, the UE **2502** may automatically enter the inactive state in Grant-less operation mode if configured to do so. At **18**, in accordance with the illustrated example, the UE **2502** receives data from the higher layer that it needs to transmit in an UL transmission. Example data includes, without limitation, "keep alive" small data, measurement data, data associated with a reachability and mobility status of the UE **2502**, or the like. At **19**, the UE **2502** may need to check system information on a broadcast channel. By way of further examples, at **19**, the UE **2502** may need to conduct a radio link measurement, or select a new cell based on system information or results of the radio link measurement. At **20**, in accordance with the illustrated example, the UE **2502** synchronizes with reference signals or an available synchronization pilot, for

instance the first available synchronization pilot, at the symbol timing boundary for allocating a contention access area.

**[0129]** At **21**, in accordance with the illustrated example, the UE **2502** sends a grantless UL transmission to the NR-node **2504**, in particular the RAN mMTC slice **2510**. In some cases, the UE **2502** may conduct contention access for the grant-less UL transmission (without redundant versions) at the initial UL transmitting power, which may defined at the Grant-less setup stage (at **15**) or signaled by the NR-node **2504** via System Information broadcasting or RRC signaling. In some cases, the UE **2502** may indicate if an acknowledgement (ACK) is required for this transmission at the transmitting power level. The UE **2502** may also include radio link measurements, a reachability or mobility status, or other information with the UL data transmission at **21**. At **22**, the UE **2502** may wait for an ACK response, to its UL transmission, from the mMTC slice **2510**. The UE **2502** may wait until an ACK timer expires if, for example, an ACK is required. At **23**, in accordance with an example, the UE **2502** conducts a re-transmission of the UL message. The UE **2502** may conduct contention access again, for example, if reliable transmission is required for its grant-less UL data. At **24**, in accordance with the illustrated example, the NR-node **2504**, in particular the mMTC slice **2510**, sends an ACK message to the UE **2502** that indicates that the UL transmission from the UE **2502** was successfully received. The message at **24** may also include a power adjustment value for the UE's next grant-less UL transmission, thereby providing quasi-closed-loop Power Control. At **25**, the UE **2502** may enter an inactive state of grantless operation mode. The inactive state generally refers to a state in which the UE is not transmitting. The inactive state may be preconfigured or triggered by the higher layer's command after a grant-less UL transmission. The inactive state may also be triggered when the UE **2502** or receives an ACK from the NR-node **2502**, for example, when an ACK is required for the transmission. In some cases, the UE **2502** may automatically enter the inactive state after a grant-less UL transmission, if, for example, the UE **2502** is configured to do so.

**[0130]** Referring also to FIGS. **27**A to **28**B, an example of grant-less UL transmission for URLLC devices is illustrated. An example system **2700** is shown which includes an URLLC UE **2702**, an NR-node **2704**, and a core network (CN) **2706**. The NR-node **2704** comprises a RAN slice management function or apparatus (node) **2708** and a RAN URLLC slice **2710**. The CN **2706** includes a CN Slice Management function or apparatus (node) **2712** and an URLLC slice **2714**. The URLLC slice **2714** may include a mobility management node or apparatus **2716**, one or more gateways **2718** (e.g., SWG, PGW) and a subscription management function or apparatus (node) **2720** (e.g., HSS). It will be appreciated that the example system **2700** is simplified to facilitate description of the disclosed subject matter and is not intended to limit the scope of this disclosure. Other devices, systems, and configurations may be used to implement the embodiments disclosed herein in addition to, or instead of, a system such as the system illustrated in FIGS. **27**A to **28**B, and all such embodiments are contemplated as within the scope of the present disclosure.

**[0131]** The example embodiment for URLLC devices illustrated in FIGS. **27**A to **28**B may be similar to the example embodiment for mMTC devices described above, and therefore similar operations are described with reference to FIGS. **25**A to **26**B. With respect to URLLC devices, however, that the context information associated with the UE **2702** may include a value that indicates that the UE **2702** can switch between grant and grant-less operations. Further, an eMBB/URLLC slice may be selected at the NR-node **2704** in order to optimize the overall system resource utilization. In an example, the URLLC slice **2714** is selected to meet short latency requirements across the system (network) **2700**. In some examples, the UE **2702** conducts its grant-less UL transmission with redundancies. In one example, at **24**, the UE **2702** switches from a grant-less operation mode to a grant operation mode after receiving a command from the higher layer. By way of example, the UE **2702** may include a traffic monitor that switches from a grant-less mode to a grant operation mode to upload the images of a traffic accident to the network.

**[0132]** Referring now to FIGS. **29**A to **30**B, the example system **2500** is shown. In the illustrated example, grant-less UL operations are performed for the mMTC device **2502**. In accordance with the illustrated example, the RAN Slicing Management node **2508** and the CN Slicing Management node **2512** may be logical entities that perform common control functions in the RAN and the CN **2506**, respectively. For example, the RAN Slicing Management node **2508** and the CN Slicing Management node **2512** may exchange service subscription and policy information, which may be used to validate a request for access to a slice. Such information may also be used to establish security settings, power charging parameters, or the like. The RAN Slicing Management node **2508** and the CN Slicing Management node **2512** may also exchange context information associated with the UE **2502**. Such context information may include, for example, mobility information, location information, transmission schedule information, data traffic information, etc. The context information may allow the appropriate, for instance optimal, slice to be selected in the RAN and the CN **2506**.

**[0133]** The Mobility Management node **2516** and the Subscription Management node **2520** may represent common functions for the CN slices (slice common) associated with a service provider. In some cases, the Mobility Management node **2516** and the Subscription Management node may be part of the CN Slicing Management **2506**, or may represent specific functions inside the CN slice **2514** provided by a specific service provider (slice specific), as shown.

**[0134]** Referring in particular to FIGS. **29**A and **29**B, at **1**, in accordance with the illustrated example, the UE **2502** powers up. After power up, the UE **2502** may conduct cell/TRP/slice search and synchronization. The UE **2502** may further acquire system information from MIB and SIBs. At this time, in some cases, the UE **2502** may be in similar states as EMM-deregistered, ECM-Idle, and RRC-Idle, as defined in the current LTE system. At **2**, the UE **2502** may send a Radio Connection Request to the RAN Slicing Management node **2508** (at **2**A) or the mMTC Slice **2510** (at **2**B). The request may include various context information associated with the UE **2502**, such as, for example and without limitation: a device type (e.g., mMTC or URLLC), a service (e.g., service for forest fire monitoring or traffic monitoring); a latency requirement (e.g., 100 ms or ultra-low latency 0.5 ms); context related to data traffic (e.g., data packet size and/or data rate and/or duty cycle); CN traffic type (e.g., non-IP or IP based); mobility context (e.g., static,

pedestrian, or vehicular, or low speed in a confined area, etc.); location context (e.g., UE tracking area at RAN); schedule context (e.g., schedule of data transmissions); access context (e.g., grant or grant-less accessing, whether switchable between grant and grant-less, accessing priority, etc.). In some cases, operations **4** and **5** are not performed, for example, when the UE **2502** selects the RAN slice **2510**.

**[0135]** At **3**A, the RAN Slicing Management node **2508** may select the RAN slice **2510**. The selection may be based, at least in part, on the context information associated with the UE **2502**, traffic loading and resource allocations at various RAN slices, a relevant service profile or subscription, a charging policy, or the like. Information may be stored at the NR-node **2504**, or received from the CN **2506** via the CN slicing Management node **2512** and/or the Subscription Management entity **2520** on the CN **2506**. At **3**A, the RAN Slicing Management **2508** selects the mMTC slice **2510** as the radio accessing slice for the UE **2510**. At **3**B, the RAN slice **3510** may determine to accept the UE's connection request for the RAN-selected or UE-selected RAN slice **3510**. At **4**A, the RAN Slicing Management **2508** may send a RAN slice connection request to the mMTC Slice **2510**. The connection request may include the context information associated with the UE **2502**, so that a radio connection can be established between the UE **2502** and the slice **2510**. At **5**A, in accordance with the illustrated example, the mMTC Slice **2510** sends a RAN Slice Connection Response to the RAN Slicing Management **2508**. The response may indicate whether the slice connection request has been accepted. If the request is rejected, the reasons for rejection may be included in the response message. If the request is accepted if accepted, radio configuration parameters (e.g., SRB1-like and/or DBR-like dedicated radio resource configuration for the UE **2502**) for the selected RAN slice **2510** may be included in the response.

**[0136]** Still referring to FIGS. **29**A and **29**B, at **6**, in accordance with the illustrated examples, the RAN Slicing Management **2508** (at **6**A) or the mMTC Slice **2510** (at **6**B) sends a Radio Connection Response to the UE **2502**. The response may indicate that radio connection is confirmed by the RAN Slice Management **2508** or the RAN mMTC Slice **2510**. If the request for the selected RAN slice **2510** is rejected, the reasons for rejection may also be included in the response message. If the request is accepted, the radio configuration parameters (e.g., SRB1-like and/or DRB-like dedicated resource configuration for the UE **2502**) for the selected RAN slice **2510** may be included in the response. In some cases, the RAN Slicing Management **2508** or the selected RAN slice **2510** may send (e.g, within the response message) an SBR1 and/or DRB resource (e.g., SRB and/or DRB configuration) that is dedicated to the UE **2502**. Thus, the UE **2502** may be confirmed as having a successful radio connection with the mMTC Slice **2510**, which may be a NAS connection with the selected RAN slice **2510**. At **7**, in accordance with the illustrated examples, the UE **2502** may send a registration request to the RAN Slicing Management **2508** (at **7**A) or the RAN mMTC Slice **2510** (at **7**B). The registration request may sent at the NAS layer, and may be encapsulated in the Radio Connect Complete message, which may also include the radio configuration as instructed by the selected RAN slice **251**. The RAN Slicing Management **2508** may send the registration request to the CN Slicing Management **2512** (at **8**A) or the Mobility Management **2516** (at **8**D). Alternatively, the RAN mMTC Slice **2510** may send the registration request to the Mobility Management **2516** (at **8**D'). The registration request may be sent to the Mobility Management **2516** when the slice **2512** is selected by the NR-node **2510**. In some examples, the registration request may be sent to the CN Slicing Management **2512** when the RAN slice **2510** is selected by the UE **2502** (at **8**B). The registration request may include context information associated with the UE, and slice information (e.g., an ID) associated with the mMTC slice **2510**.

**[0137]** In some examples, the NR-node **2504** or the CN **2506** may select the CN slice **2514** based on various context information associated with the UE **2502**. For example, CN slice selection may be based, at least in part, on an ID of the UE assigned by the RAN-Slicing Management **2508** or the RAN slice **2510** in the NR-node **2508**, the type of the UE **2502** (e.g., mMTC or URLLC), a service performed by the UE **2502** (e.g., forest fire monitoring or traffic monitoring), a latency requirement (e.g., long latency 100 ms or ultra-low latency 0.5 ms for the session or flow end-to-end delay); data traffic (e.g., data bit rate and/or traffic load for the session or flow); a route type (e.g., non-IP or IP based), mobility (e.g., static, pedestrian, or vehicular, or low speed in a confined area); a location (e.g., UE's tracking and/or routing area in the network, such as TAI and ECGI in LTE system); schedule (e.g, schedule of UL data transmissions); charge (e.g., on-line or off-line charging), etc.

**[0138]** In some cases, for example, when the NR-node **2504** selects the CN slide **2514**, operations **9** and **10** are not performed. In other cases, at **9**C, the CN Slice Management **2512** selects an mMTC IP traffic slice (slice **2514**) based on at least a portion of the context information associated with the UE, the RAN mMTC Slice **2510**, CN traffic loading, or available mMTC slices, etc. At **10**C, the CN Slicing Management **2506** may send a registration request to the Mobility Management node **2616**. The registration request may include context information associated with the UE **2502** and information related to the RAN mMTC slice **2510**. At **10**C, in some cases, the connection between the NAS layers of the UE **2502** and the Mobility Management **2516** or the CN slice **2514** is established. Then, the UE may transit to various states, like EMM-Registered, ECM-Connected and RRC-Connected state in LTE system.

**[0139]** Referring now to FIG. **30**A, at **11**, in accordance with the illustrated example, the Mobility Management **2516** exchanges messages with the Subscription Management **2520** for authenticating the UE **2502** with the requested services. The exchanged messages may include, for example and without limitation, UE IDs (such as IMSI and Serving Network ID) and context, RAN slice and CN slice info (such as RAN slice ID and CN slice ID), service network ID, UE service profile or subscription and charging policy, an assigned UE default IP address, etc. The Security keys may be generated for establishing a secured connection in the CN **2506** and RAN. At **12**, the Mobility Management node **2516** and the UE **2502**, after the authentication with the Subscription Management **2520**, may exchanges messages to mutual authenticate each other, and then to establish a Secured Mode for NAS signaling between them. At **23**, in accordance with the illustrated example, the Mobility Management **2516** and the Subscription Management **2520** exchange messages to update a location associated with the UE **2502**. At **14**, in accordance with the illustrated example, an IP or non-IP session is established within the CN mMTC

slice **2514** on the radio bearer between the UE **2502** and the Mobility Management **2516** in the CN **2506**, over the interface between the RAN mMTC slice **2510** and the CN mMTC Slice **2514** and the network connection bearer in the core network **2506**.

**[0140]** At **15**, grant-less operations are setup. The NR-node **2504**, in particular the -RAN mMTC Slice **2510**, may exchange messages with the UE **2502** to configure the Grant-less operation parameters described herein, for example. Example parameters include, without limitation: contention access allocation parameters; accessing priority and/or contention priority; grant-less configuration parameters (e.g., DACTI, CTI, DCA, UAP, GLUCI, etc.); seed or index of the orthogonal code for code-domain multiple accessing; seed or value of the random back-off for priority collision avoidance contention access; redundancy parameters for reliable transmissions; timers at the Inactive state (e.g., for listening to a broadcasting channel for pages or for system information changes, for conducting measurements for the radio link management, for updating statuses related to reachability and mobility, etc.); grant-less power control values (e.g., minimum and maximum UL transmission power levels and incremental adjustments, which may be calculated by the NR-node **2504** based, at least in part, the path loss and required received signal quality during the message exchanges described above between the UE **2502** and the NR-node **2504**); parameters related to a schedule for grant-less UL transmissions; a coding rate; modulation scheme, etc. At **16**A, in accordance with the illustrated example, the UE **2502** confirms the grant-less configuration (allocation) with a higher layer of the UE **2502** as compared to the physical layer. Alternatively, or additionally, the UE **2502** may confirm the Grant-less setup with the NR-node **2504**, in particular the RAN Slicing Management node **2508** (at **16**B) or the mMTC slice **2510** (at **16**C). Accordingly, the UE **2502** may receive an entering "Grant-less" operation mode command from the higher layer or from the NR-node **2504**.

**[0141]** Referring now to FIG. **20**B, at **17**, the UE **2502** enters into an inactive state of the Grant-less operation mode. The inactive state may be preconfigured. In some cases, the inactive state may be triggered by the higher layer or the NR-node's command to operate in Grant-less mode after registration. In some cases, the UE **2502** may automatically enter the inactive state in Grant-less operation mode if configured to do so. At **18**, in accordance with the illustrated example, the UE **2502** receives data from the higher layer that it needs to transmit in an UL transmission. Example data includes, without limitation, "keep alive" small data, measurement data, data associated with a reachability and mobility status of the UE **2502**, or the like. At **19**, the UE **2502** may need to check system information on a broadcast channel. By way of further examples, at **19**, the UE **2502** may need to conduct a radio link measurement, or select a new cell based on system information or results of the radio link measurement. At **20**, in accordance with the illustrated example, the UE **2502** synchronizes with reference signals or an available synchronization pilot, for instance the first available synchronization pilot, at the symbol timing boundary for allocating a contention access area. The UE **2502** may also estimate the Time Advance (TA) for grant-less UL synchronization, at **20**. Further, the UE **2502** may estimate the Transmit Power (TP) level, using the received DL reference signal, for the UL transmission.

**[0142]** At **21**, in accordance with the illustrated example, the UE **2502** sends a grantless UL transmission to the NR-node **2504**, in particular the RAN mMTC slice **2510**. In some cases, the UE **2502** may conduct contention access for the grant-less UL transmission (without redundant versions) at the initial UL transmitting power, which may defined at the Grant-less setup stage (at **15**) or signaled by the NR-node **2504** via System Information broadcasting or RRC signaling. In some cases, the UE **2502** may indicate if an acknowledgement (ACK) is required for this transmission at the transmitting power level. The UE **2502** may also include radio link measurements, a reachability or mobility status, or other information with the UL data transmission at **21**. At **22**, the UE **2502** may wait for an ACK response, to its UL transmission, from the mMTC slice **2510**. The UE **2502** may wait until an ACK timer expires if, for example, an ACK is required. At **23**, in accordance with an example, the UE **2502** conducts a re-transmission of the UL message with an adjusted (e.g., increased) TP level if reliable transmission is required. The UE **2502** may conduct contention access again, for example, if reliable transmission is required for its grant-less UL data. At **24**, in accordance with the illustrated example, the NR-node **2504**, in particular the mMTC slice **2510**, sends an ACK message to the UE **2502** that indicates that the UL transmission from the UE **2502** was successfully received. The message at **24** may also include

a power adjustment value for the UE's next grant-less UL transmission, thereby providing quasi-closed-loop Power Control. At **25**, the UE **2502** may enter an inactive state of grantless operation mode. The inactive state generally refers to a state in which the UE is not transmitting. The inactive state may be preconfigured or triggered by the higher layer's command after a grant-less UL transmission. The inactive state may also be triggered when the UE **2502** or receives an ACK from the NR-node **2502**, for example, when an ACK is required for the transmission. In some cases, the UE **2502** may automatically enter the inactive state after a grant-less UL transmission, if, for example, the UE **2502** is configured to do so.

**[0143]** Referring also to FIGS. **31**A to **32**B, an example embodiment for URLLC devices is illustrated in which may be similar to the example embodiment for mMTC devices described above, and therefore similar operations are described with reference to FIGS. **29**A to **30**B. With respect to URLLC devices, however, the context information associated with the UE **2702** may include a value that indicates that the UE **2702** can switch between grant and grant-less operations. Further, at **3**A or **2**B, an eMBB/URLLC slice **2710** may be selected at the NR-node **2704** in order to optimize the overall system resource utilization. In an example, at **9**C or **8**D, the URLLC slice **2714** is selected to meet short latency requirements across the system (network) **2700**. In some examples, the UE **2702** conducts its grant-less UL transmission with redundancies, for example, by using multiple contention blocks for sending the same data. In one example, at **24**, the UE **2702** switches from a grant-less operation mode to a grant operation mode after receiving a command from the higher layer. By way of example, the UE **2702** may include a traffic monitor that switches from a grant-less mode to a grant operation mode to upload the images of a traffic accident to the network.

**[0144]** Turning now to example Grant-less and Grant UL Transmissions, as shown in FIGS. **33**A and **33**B, a UE may be preconfigured with a registration to a subscription man-

agement node in the core network. Alternatively, the UE may be registered via "attach" procedures, where the UE may be assigned with a radio network temp ID for grant-less access. The UE may set up grant-less related parameters, which may be referred to generally as its grant-less configuration, after the registration (if applicable). In some cases, a that is UE pre-configured for registration may also be pre-configured with grant-less parameters. FIGS. **34**A and **34**B depict an example of grant-less and grant operations for URLLC devices, wherein the UE (URLLC device) transitions between the grant-less and grant states in accordance with direction by the NR-node. In FIG. **35**A, at **4**, the UE radio network temp ID is indicated to the UE. At **9**, **10**, and **11**, a switch to the grant state is indicated by the NR-node/TRP/Slice, for example, based on performance (e.g., error rate). FIGS. **35**A and **35**B depict an example of grant-less and grant operation for mMTC devices, wherein the UE (mMTC device) transitions between the grant-less and grant states as commanded by a higher layer (as compared to the physical layer).

**[0145]** Referring now to FIG. **36**, an example graphical user interface (GUI) **3600** for configuring a UE's grantless operations is depicted. In particular, using the GUI **3600**, a user may configure a UE to only transmit UL data using grant-less operations. Alternatively, using the GUI **3600**, a user may enable a UE to switch between grant and grantless operations, such that the UE can operate in duel states. It will be understood that the GUI can be adapted to display or configure additional, or alternative, parameters as desired. Further, the GUI can display parameters in various visual depictions as desired.

**[0146]** Thus, as described above, an apparatus may configure plurality of devices to operate in a grant-less mode in accordance with a respective grant-less access allocation, such that, when the plurality of devices transmit messages uplink in the network, the messages are transmitted using frequency resources defined by the respective grant-less access allocation, and the plurality of devices transmit the messages without being granted access to transmit the messages, so as to operate in the grant-less mode. In an example, the plurality of devices include a first set of devices and a second set of devices that have different operating requirements as compared to the first set of devices. For example, the first set of devices may be Ultra-high Reliability and Low Latency Communications (URLLC) devices, and the second set of devices may be massive Machine Type Communication (mMTC) devices. The apparatus may configure the first set of devices, such that, when the first set of devices transmit messages uplink in the network, the messages are transmitted within a first sub-band of the frequency resources. The apparatus may configure the second set of devices, such that, when the second set of devices transmit messages uplink in the network, the messages are transmitted within a second subband of the frequency resources that is separate from the first subband. In an example, the first sub-band defines a first slice of the network for a first type of device or service, and the second sub-band defines a second slice of the network for a second type of device or service that is different than the first type of device or service. In another example, the apparatus may configure the second set of devices, such that, when the second set of devices transmit messages uplink in the network, the messages are transmitted within the first sub-band of the frequency resources, and the messages are transmitted so as to have a higher priority than the messages transmitted by the first set of devices. In another example, as described above, the first-subband may be shared by granted enhanced mobile broad band (mMBB) devices that are overriden by the URLLC devices whether there is a conflict between their respective message transmissions.

**[0147]** In yet another example, the apparatus may configure the first set of devices, such that, when the first set of devices transmit messages uplink in the network, the messages are transmitted within a first sub-band of the frequency resources, and within a second sub-band of the frequency resources, wherein the first set of devices share the first sub-band and the second sub-band with a third set of devices. The apparatus may further configure the second set of devices, such that, when the second set of devices transmit messages uplink in the network, the messages are transmitted within a guard band that is between the first sub-band and the second sub-band. As also described above, the apparatus may obtain context information associated with each of the plurality of devices, and based, at least in part, on the context information, the apparatus may determine the respective grant-less allocation for which each device of the plurality of devices is configured. The context information may include at least one of a device type associated with each device, a service associated with each device, a latency requirement of each device, mobility associated with each device, a traffic type associated with each device, or a planned schedule of data transmissions from each device.

**[0148]** As also described above, an apparatus may send a first access allocation signal to at least one device, wherein the first access allocation signal comprises a first access allocation scheme and an indication of a first dynamic access configuration time interval. The apparatus may receive, from the at least one device, a first grant-less uplink transmission during the first dynamic access configuration time interval. The first grant-less uplink transmission may be sent in accordance with the first access allocation scheme. Further, based on traffic associated with the at least one device, the apparatus may send a second access allocation signal to the at least one device, wherein the second access allocation signal comprises a second access allocation scheme and an indication of a second dynamic access configuration interval that is different than the first dynamic access configuration time interval. In response, the apparatus may receive a second grant-less uplink transmission during the second dynamic access configuration time interval. In an example, the second grant-less uplink transmission is sent in accordance with the second allocation scheme that is different than the first allocation scheme. In another example described above, the apparatus may receive a request from the at least one device for the first dynamic access configuration time interval, and the apparatus may send the first allocation access signal to the at least one device in response to the request. The first access allocation signal may be periodically transmitted to a plurality of devices within a coverage area of the apparatus. Alternatively, the first access allocation signal may be sent over a first channel dedicated to access allocation signals or a second channel that is shared with other control signals.

**[0149]** In yet another example described above, an apparatus obtains a first dedicated contention area and a contention time interval, and, without being granted specific resources for transmission, the apparatus transmits a mes-

sage uplink in the network during the contention time interval and within the dedicated contention area. The apparatus may receive a negative acknowledgement. In response to the negative acknowledgement, the apparatus may re-transmit the message uplink in the network during the contention time interval and within a second dedicated contention area. In an alternative example, the apparatus waits for a predetermined time, and when the predetermined time elapses without receiving a positive acknowledgement, the apparatus re-transmits the message uplink in the network during the contention time interval and within a second dedicated contention area.

**[0150]** The various techniques described herein may be implemented in connection with hardware, firmware, software or, where appropriate, combinations thereof. Such hardware, firmware, and software may reside in apparatuses located at various nodes of a communication network. The apparatuses may operate singly or in combination with each other to affect the methods described herein. As used herein, the terms "apparatus," "network apparatus," "node," "entity", "function," "device," and "network node" may be used interchangeably, without limitation unless otherwise specified.

**[0151]** The 3rd Generation Partnership Project (3GPP) develops technical standards for cellular telecommunications network technologies, including radio access, the core transport network, and service capabilities—including work on codecs, security, and quality of service. Recent radio access technology (RAT) standards include WCDMA (commonly referred as 3G), LTE (commonly referred as 4G), and LTE-Advanced standards. 3GPP has begun working on the standardization of next generation cellular technology, called New Radio (NR), which is also referred to as "5G". 3GPP NR standards development is expected to include the definition of next generation radio access technology (new RAT), which is expected to include the provision of new flexible radio access below 6 GHz, and the provision of new ultra-mobile broadband radio access above 6 GHz. The flexible radio access is expected to consist of a new, non-backwards compatible radio access in new spectrum below 6 GHz, and it is expected to include different operating modes that can be multiplexed together in the same spectrum to address a broad set of 3GPP NR use cases with diverging requirements. The ultra-mobile broadband is expected to include cmWave and mmWave spectrum that will provide the opportunity for ultra-mobile broadband access for, e.g., indoor applications and hotspots. In particular, the ultra-mobile broadband is expected to share a common design framework with the flexible radio access below 6 GHz, with cmWave and mmWave specific design optimizations.

**[0152]** It will be understood that for different RAN architectures, the grant-less UL control and management described above may be conducted at an NR-node, Transmission and Reception Point (TRP), Remote Radio Head (RRH), or the like, as well as the central controller in RAN or the control function in a RAN slice. Embodiments described herein proposed may also applicable to TRP, RRH, central controller, and control function in different RAN architectures.

**[0153]** 3GPP has identified a variety of use cases that NR is expected to support, resulting in a wide variety of user experience requirements for data rate, latency, and mobility. The use cases include the following general categories: enhanced mobile broadband (e.g., broadband access in dense areas, indoor ultra-high broadband access, broadband access in a crowd, 50+ Mbps everywhere, ultra-low cost broadband access, mobile broadband in vehicles), critical communications, massive machine type communications, network operation (e.g., network slicing, routing, migration and interworking, energy savings), and enhanced vehicle-to-everything (eV2X) communications. Specific service and applications in these categories include, e.g., monitoring and sensor networks, device remote controlling, bi-directional remote controlling, personal cloud computing, video streaming, wireless cloud-based office, first responder connectivity, automotive ecall, disaster alerts, real-time gaming, multi-person video calls, autonomous driving, augmented reality, tactile internet, and virtual reality to name a few. All of these use cases and others are contemplated herein.

**[0154]** FIG. **37**A illustrates one embodiment of an example communications system **100** in which the methods and apparatuses described and claimed herein may be embodied. As shown, the example communications system **100** may include wireless transmit/receive units (WTRUs) **102***a*, **102***b*, **102***c*, and/or **102***d* (which generally or collectively may be referred to as WTRU **102**), a radio access network (RAN) **103/104/105/103***b*/**104***b*/**105***b*, a core network **106/107/109**, a public switched telephone network (PSTN) **108**, the Internet **110**, and other networks **112**, though it will be appreciated that the disclosed embodiments contemplate any number of WTRUs, base stations, networks, and/or network elements. Each of the WTRUs **102***a*, **102***b*, **102***c*, **102***d*, **102***e* may be any type of apparatus or device configured to operate and/or communicate in a wireless environment. Although each WTRU **102***a*, **102***b*, **102***c*, **102***d*, **102***e* is depicted in FIGS. **37**A-**37**E as a hand-held wireless communications apparatus, it is understood that with the wide variety of use cases contemplated for 5G wireless communications, each WTRU may comprise or be embodied in any type of apparatus or device configured to transmit and/or receive wireless signals, including, by way of example only, user equipment (UE), a mobile station, a fixed or mobile subscriber unit, a pager, a cellular telephone, a personal digital assistant (PDA), a smartphone, a laptop, a tablet, a netbook, a notebook computer, a personal computer, a wireless sensor, consumer electronics, a wearable device such as a smart watch or smart clothing, a medical or eHealth device, a robot, industrial equipment, a drone, a vehicle such as a car, truck, train, or airplane, and the like.

**[0155]** The communications system **100** may also include a base station **114***a* and a base station **114***b*. Base stations **114***a* may be any type of device configured to wirelessly interface with at least one of the WTRUs **102***a*, **102***b*, **102***c* to facilitate access to one or more communication networks, such as the core network **106/107/109**, the Internet **110**, and/or the other networks **112**. Base stations **114***b* may be any type of device configured to wiredly and/or wirelessly interface with at least one of the RRHs (Remote Radio Heads) **118***a*, **118***b* and/or TRPs (Transmission and Reception Points) **119***a*, **119***b* to facilitate access to one or more communication networks, such as the core network **106/107/109**, the Internet **110**, and/or the other networks **112**. RRHs **118***a*, **118***b* may be any type of device configured to wirelessly interface with at least one of the WTRU **102***c*, to facilitate access to one or more communication networks, such as the core network **106/107/109**, the Internet **110**, and/or the other networks **112**. TRPs **119***a*, **119***b* may be any

type of device configured to wirelessly interface with at least one of the WTRU **102***d*, to facilitate access to one or more communication networks, such as the core network **106/107/109**, the Internet **110**, and/or the other networks **112**. By way of example, the base stations **114***a*, **114***b* may be a base transceiver station (BTS), a Node-B, an eNode B, a Home Node B, a Home eNode B, a site controller, an access point (AP), a wireless router, and the like. While the base stations **114***a*, **114***b* are each depicted as a single element, it will be appreciated that the base stations **114***a*, **114***b* may include any number of interconnected base stations and/or network elements.

**[0156]** The base station **114***a* may be part of the RAN **103/104/105**, which may also include other base stations and/or network elements (not shown), such as a base station controller (BSC), a radio network controller (RNC), relay nodes, etc. The base station **114***b* may be part of the RAN **103***b*/**104***b*/**105***b*, which may also include other base stations and/or network elements (not shown), such as a base station controller (BSC), a radio network controller (RNC), relay nodes, etc. The base station **114***a* may be configured to transmit and/or receive wireless signals within a particular geographic region, which may be referred to as a cell (not shown). The base station **114***b* may be configured to transmit and/or receive wired and/or wireless signals within a particular geographic region, which may be referred to as a cell (not shown). The cell may further be divided into cell sectors. For example, the cell associated with the base station **114***a* may be divided into three sectors. Thus, in an embodiment, the base station **114***a* may include three transceivers, e.g., one for each sector of the cell. In an embodiment, the base station **114***a* may employ multiple-input multiple output (MIMO) technology and, therefore, may utilize multiple transceivers for each sector of the cell.

**[0157]** The base stations **114***a* may communicate with one or more of the WTRUs **102***a*, **102***b*, **102***c* over an air interface **115/116/117**, which may be any suitable wireless communication link (e.g., radio frequency (RF), microwave, infrared (IR), ultraviolet (UV), visible light, cmWave, mmWave, etc.). The air interface **115/116/117** may be established using any suitable radio access technology (RAT).

**[0158]** The base stations **114***b* may communicate with one or more of the RRHs **118***a*, **118***b* and/or TRPs **119***a*, **119***b* over a wired or air interface **115***b*/**116***b*/**117***b*, which may be any suitable wired (e.g., cable, optical fiber, etc.) or wireless communication link (e.g., radio frequency (RF), microwave, infrared (IR), ultraviolet (UV), visible light, cmWave, mmWave, etc.). The air interface **115***b*/**116***b*/**117***b* may be established using any suitable radio access technology (RAT).

**[0159]** The RRHs **118***a*, **118***b* and/or TRPs **119***a*, **119***b* may communicate with one or more of the WTRUs **102***c*, **102***d* over an air interface **115***c*/**116***c*/**117***c*, which may be any suitable wireless communication link (e.g., radio frequency (RF), microwave, infrared (IR), ultraviolet (UV), visible light, cmWave, mmWave, etc.). The air interface **115***c*/**116***c*/**117***c* may be established using any suitable radio access technology (RAT).

**[0160]** More specifically, as noted above, the communications system **100** may be a multiple access system and may employ one or more channel access schemes, such as CDMA, TDMA, FDMA, OFDMA, SC-FDMA, and the like. For example, the base station **114***a* in the RAN **103/104/105** and the WTRUs **102***a*, **102***b*, **102***c*, or RRHs **118***a*, **118***b* and TRPs **119***a*, **119***b* in the RAN **103***b*/**104***b*/**105***b* and the WTRUs **102***c*, **102***d*, may implement a radio technology such as Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access (UTRA), which may establish the air interface **115/116/117** or **115***c*/**116***c*/**117***c* respectively using wideband CDMA (WCDMA). WCDMA may include communication protocols such as High-Speed Packet Access (HSPA) and/or Evolved HSPA (HSPA+). HSPA may include High-Speed Downlink Packet Access (HSDPA) and/or High-Speed Uplink Packet Access (HSUPA).

**[0161]** In an embodiment, the base station **114***a* in the RAN **103/104/105** and the WTRUs **102***a*, **102***b*, **102***c*, or RRHs **118***a*, **118***b* and TRPs **119***a*, **119***b* in the RAN **103***b*/**104***b*/**105***b* and the WTRUs **102***c*, **102***d*, may implement a radio technology such as Evolved UMTS Terrestrial Radio Access (E-UTRA), which may establish the air interface **115/116/117** using Long Term Evolution (LTE) and/or LTE-Advanced (LTE-A). In the future, the air interface **115/116/117** may implement 3GPP NR technology.

**[0162]** In an embodiment, the base station **114***a* and the WTRUs **102***a*, **102***b*, **102***c* may implement radio technologies such as IEEE 802.16 (e.g., Worldwide Interoperability for Microwave Access (WiMAX)), CDMA2000, CDMA2000 1×, CDMA2000 EV-DO, Interim Standard 2000 (IS-2000), Interim Standard 95 (IS-95), Interim Standard 856 (IS-856), Global System for Mobile communications (GSM), Enhanced Data rates for GSM Evolution (EDGE), GSM EDGE (GERAN), and the like.

**[0163]** The base station **114***c* in FIG. **37**A may be a wireless router, Home Node B, Home eNode B, or access point, for example, and may utilize any suitable RAT for facilitating wireless connectivity in a localized area, such as a place of business, a home, a vehicle, a campus, and the like. In an embodiment, the base station **114***c* and the WTRUs **102***e* may implement a radio technology such as IEEE 802.11 to establish a wireless local area network (WLAN). In an embodiment, the base station **114***c* and the WTRUs **102***e* may implement a radio technology such as IEEE 802.15 to establish a wireless personal area network (WPAN). In yet an embodiment, the base station **114***b* and the WTRUs **102***c*, **102***d* may utilize a cellular-based RAT (e.g., WCDMA, CDMA2000, GSM, LTE, LTE-A, etc.) to establish a picocell or femtocell. As shown in FIG. **37**A, the base station **114***b* may have a direct connection to the Internet **110**. Thus, the base station **114***c* may not be required to access the Internet **110** via the core network **106/107/109**.

**[0164]** The RAN **103/104/105** and/or RAN **103***b*/**104***b*/**105***b* may be in communication with the core network **106/107/109**, which may be any type of network configured to provide voice, data, applications, and/or voice over internet protocol (VoIP) services to one or more of the WTRUs **102***a*, **102***b*, **102***c*, **102***d*. For example, the core network **106/107/109** may provide call control, billing services, mobile location-based services, pre-paid calling, Internet connectivity, video distribution, etc., and/or perform high-level security functions, such as user authentication.

**[0165]** Although not shown in FIG. **37**A, it will be appreciated that the RAN **103/104/105** and/or RAN **103***b*/**104***b*/**105***b* and/or the core network **106/107/109** may be in direct or indirect communication with other RANs that employ the same RAT as the RAN **103/104/105** and/or RAN **103***b*/**104***b*/**105***b* or a different RAT. For example, in addition to being connected to the RAN **103/104/105** and/or RAN **103***b*/**104***b*/

**105***b*, which may be utilizing an E-UTRA radio technology, the core network **106/107/109** may also be in communication with another RAN (not shown) employing a GSM radio technology.

**[0166]** The core network **106/107/109** may also serve as a gateway for the WTRUs **102***a*, **102***b*, **102***c*, **102***d*, **102***e* to access the PSTN **108**, the Internet **110**, and/or other networks **112**. The PSTN **108** may include circuit-switched telephone networks that provide plain old telephone service (POTS). The Internet **110** may include a global system of interconnected computer networks and devices that use common communication protocols, such as the transmission control protocol (TCP), user datagram protocol (UDP) and the internet protocol (IP) in the TCP/IP internet protocol suite. The networks **112** may include wired or wireless communications networks owned and/or operated by other service providers. For example, the networks **112** may include another core network connected to one or more RANs, which may employ the same RAT as the RAN **103/104/105** and/or RAN **103***b*/**104***b*/**105***b* or a different RAT.

**[0167]** Some or all of the WTRUs **102***a*, **102***b*, **102***c*, **102***d* in the communications system **100** may include multi-mode capabilities, e.g., the WTRUs **102***a*, **102***b*, **102***c*, **102***d*, and **102***e* may include multiple transceivers for communicating with different wireless networks over different wireless links. For example, the WTRU **102***e* shown in FIG. **37**A may be configured to communicate with the base station **114***a*, which may employ a cellular-based radio technology, and with the base station **114***c*, which may employ an IEEE 802 radio technology.

**[0168]** FIG. **37**B is a block diagram of an example apparatus or device configured for wireless communications in accordance with the embodiments illustrated herein, such as for example, a WTRU **102**. As shown in FIG. **37**B, the example WTRU **102** may include a processor **118**, a transceiver **120**, a transmit/receive element **122**, a speaker/microphone **124**, a keypad **126**, a display/touchpad/indicators **128**, non-removable memory **130**, removable memory **132**, a power source **134**, a global positioning system (GPS) chipset **136**, and other peripherals **138**. It will be appreciated that the WTRU **102** may include any sub-combination of the foregoing elements while remaining consistent with an embodiment. Also, embodiments contemplate that the base stations **114***a* and **114***b*, and/or the nodes that base stations **114***a* and **114***b* may represent, such as but not limited to transceiver station (BTS), a Node-B, a site controller, an access point (AP), a home node-B, an evolved home node-B (eNodeB), a home evolved node-B (HeNB), a home evolved node-B gateway, and proxy nodes, among others, may include some or all of the elements depicted in FIG. **37**B and described herein.

**[0169]** The processor **118** may be a general purpose processor, a special purpose processor, a conventional processor, a digital signal processor (DSP), a plurality of microprocessors, one or more microprocessors in association with a DSP core, a controller, a microcontroller, Application Specific Integrated Circuits (ASICs), Field Programmable Gate Array (FPGAs) circuits, any other type of integrated circuit (IC), a state machine, and the like. The processor **118** may perform signal coding, data processing, power control, input/output processing, and/or any other functionality that enables the WTRU **102** to operate in a wireless environment. The processor **118** may be coupled to the transceiver **120**, which may be coupled to the transmit/receive element **122**. While FIG. **37**B depicts the processor **118** and the transceiver **120** as separate components, it will be appreciated that the processor **118** and the transceiver **120** may be integrated together in an electronic package or chip.

**[0170]** The transmit/receive element **122** may be configured to transmit signals to, or receive signals from, a base station (e.g., the base station **114***a*) over the air interface **115/116/117**. For example, in an embodiment, the transmit/receive element **122** may be an antenna configured to transmit and/or receive RF signals. In an embodiment, the transmit/receive Although not shown in FIG. **37**A, it will be appreciated that the RAN **103/104/105** and/or the core network **106/107/109** may be in direct or indirect communication with other RANs that employ the same RAT as the RAN **103/104/105** or a different RAT. For example, in addition to being connected to the RAN **103/104/105**, which may be utilizing an E-UTRA radio technology, the core network **106/107/109** may also be in communication with another RAN (not shown) employing a GSM radio technology.

**[0171]** The core network **106/107/109** may also serve as a gateway for the WTRUs **102***a*, **102***b*, **102***c*, **102***d* to access the PSTN **108**, the Internet **110**, and/or other networks **112**. The PSTN **108** may include circuit-switched telephone networks that provide plain old telephone service (POTS). The Internet **110** may include a global system of interconnected computer networks and devices that use common communication protocols, such as the transmission control protocol (TCP), user datagram protocol (UDP) and the internet protocol (IP) in the TCP/IP internet protocol suite. The networks **112** may include wired or wireless communications networks owned and/or operated by other service providers. For example, the networks **112** may include another core network connected to one or more RANs, which may employ the same RAT as the RAN **103/104/105** or a different RAT.

**[0172]** Some or all of the WTRUs **102***a*, **102***b*, **102***c*, **102***d* in the communications system **100** may include multi-mode capabilities, e.g., the WTRUs **102***a*, **102***b*, **102***c*, and **102***d* may include multiple transceivers for communicating with different wireless networks over different wireless links. For example, the WTRU **102***c* shown in FIG. **37**A may be configured to communicate with the base station **114***a*, which may employ a cellular-based radio technology, and with the base station **114***b*, which may employ an IEEE 802 radio technology.

**[0173]** FIG. **37**B is a block diagram of an example apparatus or device configured for wireless communications in accordance with the embodiments illustrated herein, such as for example, a WTRU **102**. As shown in FIG. **37**B, the example WTRU **102** may include a processor **118**, a transceiver **120**, a transmit/receive element **122**, a speaker/microphone **124**, a keypad **126**, a display/touchpad/indicators **128**, non-removable memory **130**, removable memory **132**, a power source **134**, a global positioning system (GPS) chipset **136**, and other peripherals **138**. It will be appreciated that the WTRU **102** may include any sub-combination of the foregoing elements while remaining consistent with an embodiment. Also, embodiments contemplate that the base stations **114***a* and **114***b*, and/or the nodes that base stations **114***a* and **114***b* may represent, such as but not limited to transceiver station (BTS), a Node-B, a site controller, an access point (AP), a home node-B, an evolved home node-B

(eNodeB), a home evolved node-B (HeNB), a home evolved node-B gateway, and proxy nodes, among others, may include some or all of the elements depicted in FIG. **37**B and described herein.

**[0174]** The processor **118** may be a general purpose processor, a special purpose processor, a conventional processor, a digital signal processor (DSP), a plurality of microprocessors, one or more microprocessors in association with a DSP core, a controller, a microcontroller, Application Specific Integrated Circuits (ASICs), Field Programmable Gate Array (FPGAs) circuits, any other type of integrated circuit (IC), a state machine, and the like. The processor **118** may perform signal coding, data processing, power control, input/output processing, and/or any other functionality that enables the WTRU **102** to operate in a wireless environment. The processor **118** may be coupled to the transceiver **120**, which may be coupled to the transmit/receive element **122**. While FIG. **37**B depicts the processor **118** and the transceiver **120** as separate components, it will be appreciated that the processor **118** and the transceiver **120** may be integrated together in an electronic package or chip.

**[0175]** The transmit/receive element **122** may be configured to transmit signals to, or receive signals from, a base station (e.g., the base station **114***a*) over the air interface **115/116/117**. For example, in an embodiment, the transmit/receive element **122** may be an antenna configured to transmit and/or receive RF signals. In an embodiment, the transmit/receive element **122** may be an emitter/detector configured to transmit and/or receive IR, UV, or visible light signals, for example. In yet an embodiment, the transmit/receive element **122** may be configured to transmit and receive both RF and light signals. It will be appreciated that the transmit/receive element **122** may be configured to transmit and/or receive any combination of wireless signals.

**[0176]** In addition, although the transmit/receive element **122** is depicted in FIG. **37**B as a single element, the WTRU **102** may include any number of transmit/receive elements **122**. More specifically, the WTRU **102** may employ MIMO technology. Thus, in an embodiment, the WTRU **102** may include two or more transmit/receive elements **122** (e.g., multiple antennas) for transmitting and receiving wireless signals over the air interface **115/116/117**.

**[0177]** The transceiver **120** may be configured to modulate the signals that are to be transmitted by the transmit/receive element **122** and to demodulate the signals that are received by the transmit/receive element **122**. As noted above, the WTRU **102** may have multi-mode capabilities. Thus, the transceiver **120** may include multiple transceivers for enabling the WTRU **102** to communicate via multiple RATs, such as UTRA and IEEE 802.11, for example.

**[0178]** The processor **118** of the WTRU **102** may be coupled to, and may receive user input data from, the speaker/microphone **124**, the keypad **126**, and/or the display/touchpad/indicators **128** (e.g., a liquid crystal display (LCD) display unit or organic light-emitting diode (OLED) display unit). The processor **118** may also output user data to the speaker/microphone **124**, the keypad **126**, and/or the display/touchpad/indicators **128**. In addition, the processor **118** may access information from, and store data in, any type of suitable memory, such as the non-removable memory **130** and/or the removable memory **132**. The non-removable memory **130** may include random-access memory (RAM), read-only memory (ROM), a hard disk, or any other type of memory storage device. The removable memory **132** may include a subscriber identity module (SIM) card, a memory stick, a secure digital (SD) memory card, and the like. In an embodiment, the processor **118** may access information from, and store data in, memory that is not physically located on the WTRU **102**, such as on a server or a home computer (not shown).

**[0179]** The processor **118** may receive power from the power source **134**, and may be configured to distribute and/or control the power to the other components in the WTRU **102**. The power source **134** may be any suitable device for powering the WTRU **102**. For example, the power source **134** may include one or more dry cell batteries, solar cells, fuel cells, and the like.

**[0180]** The processor **118** may also be coupled to the GPS chipset **136**, which may be configured to provide location information (e.g., longitude and latitude) regarding the current location of the WTRU **102**. In addition to, or in lieu of, the information from the GPS chipset **136**, the WTRU **102** may receive location information over the air interface **115/116/117** from a base station (e.g., base stations **114***a*, **114***b*) and/or determine its location based on the timing of the signals being received from two or more nearby base stations. It will be appreciated that the WTRU **102** may acquire location information by way of any suitable location-determination method while remaining consistent with an embodiment.

**[0181]** The processor **118** may further be coupled to other peripherals **138**, which may include one or more software and/or hardware modules that provide additional features, functionality and/or wired or wireless connectivity. For example, the peripherals **138** may include various sensors such as an accelerometer, biometrics (e.g., finger print) sensors, an e-compass, a satellite transceiver, a digital camera (for photographs or video), a universal serial bus (USB) port or other interconnect interfaces, a vibration device, a television transceiver, a hands free headset, a Bluetooth® module, a frequency modulated (FM) radio unit, a digital music player, a media player, a video game player module, an Internet browser, and the like.

**[0182]** The WTRU **102** may be embodied in other apparatuses or devices, such as a sensor, consumer electronics, a wearable device such as a smart watch or smart clothing, a medical or eHealth device, a robot, industrial equipment, a drone, a vehicle such as a car, truck, train, or airplane. The WTRU **102** may connect to other components, modules, or systems of such apparatuses or devices via one or more interconnect interfaces, such as an interconnect interface that may comprise one of the peripherals **138**.

**[0183]** FIG. **37**C is a system diagram of the RAN **103** and the core network **106** according to an embodiment. As noted above, the RAN **103** may employ a UTRA radio technology to communicate with the WTRUs **102***a*, **102***b*, and **102***c* over the air interface **115**. The RAN **103** may also be in communication with the core network **106**. As shown in FIG. **37**C, the RAN **103** may include Node-Bs **140***a*, **140***b*, **140***c*, which may each include one or more transceivers for communicating with the WTRUs **102***a*, **102***b*, **102***c* over the air interface **115**. The Node-Bs **140***a*, **140***b*, **140***c* may each be associated with a particular cell (not shown) within the RAN **103**. The RAN **103** may also include RNCs **142***a*, **142***b*. It will be appreciated that the RAN **103** may include any number of Node-Bs and RNCs while remaining consistent with an embodiment.

**[0184]** As shown in FIG. **37**C, the Node-Bs **140***a*, **140***b* may be in communication with the RNC **142***a*. Additionally, the Node-B **140***c* may be in communication with the RNC **142***b*. The Node-Bs **140***a*, **140***b*, **140***c* may communicate with the respective RNCs **142***a*, **142***b* via an lub interface. The RNCs **142***a*, **142***b* may be in communication with one another via an lur interface. Each of the RNCs **142***a*, **142***b* may be configured to control the respective Node-Bs **140***a*, **140***b*, **140***c* to which it is connected. In addition, each of the RNCs **142***a*, **142***b* may be configured to carry out or support other functionality, such as outer loop power control, load control, admission control, packet scheduling, handover control, macro-diversity, security functions, data encryption, and the like.

**[0185]** The core network **106** shown in FIG. **37**C may include a media gateway (MGW) **144**, a mobile switching center (MSC) **146**, a serving GPRS support node (SGSN) **148**, and/or a gateway GPRS support node (GGSN) **150**. While each of the foregoing elements are depicted as part of the core network **106**, it will be appreciated that any one of these elements may be owned and/or operated by an entity other than the core network operator.

**[0186]** The RNC **142***a* in the RAN **103** may be connected to the MSC **146** in the core network **106** via an IuCS interface. The MSC **146** may be connected to the MGW **144**. The MSC **146** and the MGW **144** may provide the WTRUs **102***a*, **102***b*, **102***c* with access to circuit-switched networks, such as the PSTN **108**, to facilitate communications between the WTRUs **102***a*, **102***b*, **102***c* and traditional land-line communications devices.

**[0187]** The RNC **142***a* in the RAN **103** may also be connected to the SGSN **148** in the core network **106** via an IuPS interface. The SGSN **148** may be connected to the GGSN **150**. The SGSN **148** and the GGSN **150** may provide the WTRUs **102***a*, **102***b*, **102***c* with access to packet-switched networks, such as the Internet **110**, to facilitate communications between and the WTRUs **102***a*, **102***b*, **102***c* and IP-enabled devices.

**[0188]** As noted above, the core network **106** may also be connected to the networks **112**, which may include other wired or wireless networks that are owned and/or operated by other service providers.

**[0189]** FIG. **37**D is a system diagram of the RAN **104** and the core network **107** according to an embodiment. As noted above, the RAN **104** may employ an E-UTRA radio technology to communicate with the WTRUs **102***a*, **102***b*, and **102***c* over the air interface **116**. The RAN **104** may also be in communication with the core network **107**.

**[0190]** The RAN **104** may include eNode-Bs **160***a*, **160***b*, **160***c*, though it will be appreciated that the RAN **104** may include any number of eNode-Bs while remaining consistent with an embodiment. The eNode-Bs **160***a*, **160***b*, **160***c* may each include one or more transceivers for communicating with the WTRUs **102***a*, **102***b*, **102***c* over the air interface **116**. In an embodiment, the eNode-Bs **160***a*, **160***b*, **160***c* may implement MIMO technology. Thus, the eNode-B **160***a*, for example, may use multiple antennas to transmit wireless signals to, and receive wireless signals from, the WTRU **102***a*.

**[0191]** Each of the eNode-Bs **160***a*, **160***b*, and **160***c* may be associated with a particular cell (not shown) and may be configured to handle radio resource management decisions, handover decisions, scheduling of users in the uplink and/or downlink, and the like. As shown in FIG. **37**D, the eNode-Bs **160***a*, **160***b*, **160***c* may communicate with one another over an X2 interface.

**[0192]** The core network **107** shown in FIG. **37**D may include a mobility management gateway (MME) **162**, a serving gateway **164**, and a packet data network (PDN) gateway **166**. While each of the foregoing elements are depicted as part of the core network **107**, it will be appreciated that any one of these elements may be owned and/or operated by an entity other than the core network operator.

**[0193]** The MME **162** may be connected to each of the eNode-Bs **160***a*, **160***b*, and **160***c* in the RAN **104** via an S1 interface and may serve as a control node. For example, the MME **162** may be responsible for authenticating users of the WTRUs **102***a*, **102***b*, **102***c*, bearer activation/deactivation, selecting a particular serving gateway during an initial attach of the WTRUs **102***a*, **102***b*, **102***c*, and the like. The MME **162** may also provide a control plane function for switching between the RAN **104** and other RANs (not shown) that employ other radio technologies, such as GSM or WCDMA.

**[0194]** The serving gateway **164** may be connected to each of the eNode-Bs **160***a*, **160***b*, and **160***c* in the RAN **104** via the S1 interface. The serving gateway **164** may generally route and forward user data packets to/from the WTRUs **102***a*, **102***b*, **102***c*. The serving gateway **164** may also perform other functions, such as anchoring user planes during inter-eNode B handovers, triggering paging when downlink data is available for the WTRUs **102***a*, **102***b*, **102***c*, managing and storing contexts of the WTRUs **102***a*, **102***b*, **102***c*, and the like.

**[0195]** The serving gateway **164** may also be connected to the PDN gateway **166**, which may provide the WTRUs **102***a*, **102***b*, **102***c* with access to packet-switched networks, such as the Internet **110**, to facilitate communications between the WTRUs **102***a*, **102***b*, **102***c* and IP-enabled devices.

**[0196]** The core network **107** may facilitate communications with other networks. For example, the core network **107** may provide the WTRUs **102***a*, **102***b*, **102***c* with access to circuit-switched networks, such as the PSTN **108**, to facilitate communications between the WTRUs **102***a*, **102***b*, **102***c* and traditional land-line communications devices. For example, the core network **107** may include, or may communicate with, an IP gateway (e.g., an IP multimedia subsystem (IMS) server) that serves as an interface between the core network **107** and the PSTN **108**. In addition, the core network **107** may provide the WTRUs **102***a*, **102***b*, **102***c* with access to the networks **112**, which may include other wired or wireless networks that are owned and/or operated by other service providers.

**[0197]** FIG. **37**E is a system diagram of the RAN **105** and the core network **109** according to an embodiment. The RAN **105** may be an access service network (ASN) that employs IEEE 802.16 radio technology to communicate with the WTRUs **102***a*, **102***b*, and **102***c* over the air interface **117**. As will be further discussed below, the communication links between the different functional entities of the WTRUs **102***a*, **102***b*, **102***c*, the RAN **105**, and the core network **109** may be defined as reference points.

**[0198]** As shown in FIG. **37**E, the RAN **105** may include base stations **180***a*, **180***b*, **180***c*, and an ASN gateway **182**, though it will be appreciated that the RAN **105** may include any number of base stations and ASN gateways while remaining consistent with an embodiment. The base stations

**180***a*, **180***b*, **180***c* may each be associated with a particular cell in the RAN **105** and may include one or more transceivers for communicating with the WTRUs **102***a*, **102***b*, **102***c* over the air interface **117**. In an embodiment, the base stations **180***a*, **180***b*, **180***c* may implement MIMO technology. Thus, the base station **180***a*, for example, may use multiple antennas to transmit wireless signals to, and receive wireless signals from, the WTRU **102***a*. The base stations **180***a*, **180***b*, **180***c* may also provide mobility management functions, such as handoff triggering, tunnel establishment, radio resource management, traffic classification, quality of service (QoS) policy enforcement, and the like. The ASN gateway **182** may serve as a traffic aggregation point and may be responsible for paging, caching of subscriber profiles, routing to the core network **109**, and the like.

**[0199]** The air interface **117** between the WTRUs **102***a*, **102***b*, **102***c* and the RAN **105** may be defined as an R1 reference point that implements the IEEE 802.16 specification. In addition, each of the WTRUs **102***a*, **102***b*, and **102***c* may establish a logical interface (not shown) with the core network **109**. The logical interface between the WTRUs **102***a*, **102***b*, **102***c* and the core network **109** may be defined as an R2 reference point, which may be used for authentication, authorization, IP host configuration management, and/or mobility management.

**[0200]** The communication link between each of the base stations **180***a*, **180***b*, and **180***c* may be defined as an R8 reference point that includes protocols for facilitating WTRU handovers and the transfer of data between base stations. The communication link between the base stations **180***a*, **180***b*, **180***c* and the ASN gateway **182** may be defined as an R6 reference point. The R6 reference point may include protocols for facilitating mobility management based on mobility events associated with each of the WTRUs **102***a*, **102***b*, **102***c*.

**[0201]** As shown in FIG. **37**E, the RAN **105** may be connected to the core network **109**. The communication link between the RAN **105** and the core network **109** may defined as an R3 reference point that includes protocols for facilitating data transfer and mobility management capabilities, for example. The core network **109** may include a mobile IP home agent (MIP-HA) **184**, an authentication, authorization, accounting (AAA) server **186**, and a gateway **188**. While each of the foregoing elements are depicted as part of the core network **109**, it will be appreciated that any one of these elements may be owned and/or operated by an entity other than the core network operator.

**[0202]** The MIP-HA may be responsible for IP address management, and may enable the WTRUs **102***a*, **102***b*, and **102***c* to roam between different ASNs and/or different core networks. The MIP-HA **184** may provide the WTRUs **102***a*, **102***b*, **102***c* with access to packet-switched networks, such as the Internet **110**, to facilitate communications between the WTRUs **102***a*, **102***b*, **102***c* and IP-enabled devices. The AAA server **186** may be responsible for user authentication and for supporting user services. The gateway **188** may facilitate interworking with other networks. For example, the gateway **188** may provide the WTRUs **102***a*, **102***b*, **102***c* with access to circuit-switched networks, such as the PSTN **108**, to facilitate communications between the WTRUs **102***a*, **102***b*, **102***c* and traditional land-line communications devices. In addition, the gateway **188** may provide the WTRUs **102***a*, **102***b*, **102***c* with access to the networks **112**, which may include other wired or wireless networks that are owned and/or operated by other service providers.

**[0203]** Although not shown in FIG. **37**E, it will be appreciated that the RAN **105** may be connected to other ASNs and the core network **109** may be connected to other core networks. The communication link between the RAN **105** the other ASNs may be defined as an R4 reference point, which may include protocols for coordinating the mobility of the WTRUs **102***a*, **102***b*, **102***c* between the RAN **105** and the other ASNs. The communication link between the core network **109** and the other core networks may be defined as an R5 reference, which may include protocols for facilitating interworking between home core networks and visited core networks.

**[0204]** The core network entities described herein and illustrated in FIGS. **37**A, **37**C, **37**D, and **37**E are identified by the names given to those entities in certain existing 3GPP specifications, but it is understood that in the future those entities and functionalities may be identified by other names and certain entities or functions may be combined in future specifications published by 3GPP, including future 3GPP NR specifications. Thus, the particular network entities and functionalities described and illustrated in FIGS. **37**A, **37**B, **37**C, **37**D, and **37**E are provided by way of example only, and it is understood that the subject matter disclosed and claimed herein may be embodied or implemented in any similar communication system, whether presently defined or defined in the future.

**[0205]** FIG. **37**F is a block diagram of an exemplary computing system **90** in which one or more apparatuses of the communications networks illustrated in FIGS. **37**A, **37**C, **37**D and **37**E may be embodied, such as certain nodes or functional entities in the RAN **103/104/105**, Core Network **106/107/109**, PSTN **108**, Internet **110**, or Other Networks **112**. Computing system **90** may comprise a computer or server and may be controlled primarily by computer readable instructions, which may be in the form of software, wherever, or by whatever means such software is stored or accessed. Such computer readable instructions may be executed within a processor **91**, to cause computing system **90** to do work. The processor **91** may be a general purpose processor, a special purpose processor, a conventional processor, a digital signal processor (DSP), a plurality of microprocessors, one or more microprocessors in association with a DSP core, a controller, a microcontroller, Application Specific Integrated Circuits (ASICs), Field Programmable Gate Array (FPGAs) circuits, any other type of integrated circuit (IC), a state machine, and the like. The processor **91** may perform signal coding, data processing, power control, input/output processing, and/or any other functionality that enables the computing system **90** to operate in a communications network. Coprocessor **81** is an optional processor, distinct from main processor **91**, that may perform additional functions or assist processor **91**. Processor **91** and/or coprocessor **81** may receive, generate, and process data related to the methods and apparatuses disclosed herein.

**[0206]** In operation, processor **91** fetches, decodes, and executes instructions, and transfers information to and from other resources via the computing system's main data-transfer path, system bus **80**. Such a system bus connects the components in computing system **90** and defines the medium for data exchange. System bus **80** typically includes data lines for sending data, address lines for sending

addresses, and control lines for sending interrupts and for operating the system bus. An example of such a system bus **80** is the PCI (Peripheral Component Interconnect) bus.

**[0207]** Memories coupled to system bus **80** include random access memory (RAM) **82** and read only memory (ROM) **93**. Such memories include circuitry that allows information to be stored and retrieved. ROMs **93** generally contain stored data that cannot easily be modified. Data stored in RAM **82** can be read or changed by processor **91** or other hardware devices. Access to RAM **82** and/or ROM **93** may be controlled by memory controller **92**. Memory controller **92** may provide an address translation function that translates virtual addresses into physical addresses as instructions are executed. Memory controller **92** may also provide a memory protection function that isolates processes within the system and isolates system processes from user processes. Thus, a program running in a first mode can access only memory mapped by its own process virtual address space; it cannot access memory within another process's virtual address space unless memory sharing between the processes has been set up.

**[0208]** In addition, computing system **90** may contain peripherals controller **83** responsible for communicating instructions from processor **91** to peripherals, such as printer **94**, keyboard **84**, mouse **95**, and disk drive **85**.

**[0209]** Display **86**, which is controlled by display controller **96**, is used to display visual output generated by computing system **90**. Such visual output may include text, graphics, animated graphics, and video. The visual output may be provided in the form of a graphical user interface (GUI). Display **86** may be implemented with a CRT-based video display, an LCD-based flat-panel display, gas plasma-based flat-panel display, or a touch-panel. Display controller **96** includes electronic components required to generate a video signal that is sent to display **86**.

**[0210]** Further, computing system **90** may contain communication circuitry, such as for example a network adapter **97**, that may be used to connect computing system **90** to an external communications network, such as the RAN **103/104/105**, Core Network **106/107/109**, PSTN **108**, Internet **110**, or Other Networks **112** of FIGS. **37**A, **37**B, **37**C, **37**D, and **37**E, to enable the computing system **90** to communicate with other nodes or functional entities of those networks. The communication circuitry, alone or in combination with the processor **91**, may be used to perform the transmitting and receiving steps of certain apparatuses, nodes, or functional entities described herein.

**[0211]** It is understood that any or all of the apparatuses, systems, methods and processes described herein may be embodied in the form of computer executable instructions (e.g., program code) stored on a computer-readable storage medium which instructions, when executed by a processor, such as processors **118** or **91**, cause the processor to perform and/or implement the systems, methods and processes described herein. Specifically, any of the steps, operations or functions described herein may be implemented in the form of such computer executable instructions, executing on the processor of an apparatus or computing system configured for wireless and/or wired network communications. Computer readable storage media include volatile and nonvolatile, removable and non-removable media implemented in any non-transitory (e.g., tangible or physical) method or technology for storage of information, but such computer readable storage media do not includes signals. Computer readable storage media include, but are not limited to, RAM, ROM, EEPROM, flash memory or other memory technology, CD-ROM, digital versatile disks (DVD) or other optical disk storage, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices, or any other tangible or physical medium which can be used to store the desired information and which can be accessed by a computing system.

**[0212]** The following is a list of acronyms relating to access technologies that may appear in the above description. Unless otherwise specified, the acronyms used herein refer to the corresponding term listed below.

ACK Acknowledgement

AID Association Identifier (802.11)

AP Access Point (802.11)

APN Access Point Name

AS Access Stratum

BS Base Station

CA Collision Avoidance

CD Collision Detection

CFI Control Format Indicator

CN Core Network

CMAS Commercial Mobile Alert System

C-RNTI Cell Radio-Network Temporary Identifier

CSMA Carrier Sensing Multiple Access

**[0213]** CSMA/CD CSMA with Collision Detection

CSMA/CA CSMA with Collision Avoidance

DCA Dedicated Collision Area

DCI Downlink Control Information

DACTI Dynamic Access Configuration Time Interval

DL Downlink

DRX Discontinuous Reception

ECGI E-UTRAN Cell Global Identifier

ECM EPS Connection Management

**[0214]** eMBB enhanced Mobile Broadband

EMM EPS Mobility Management

eNB Evolved Node B

ETWS Earthquake and Tsunami Warning System

E-UTRA Evolved Universal Terrestrial Radio Access

E-UTRAN Evolved Universal Terrestrial Radio Access Network

FDM Frequency Division Multiplex

FFS For Further Study

GERAN GSM EDGE Radio Access Network

**[0215]** GSM Global System for Mobile communications

GUTI Globally Unique Temporary UE Identity

HE High Efficiency

HSS Home Subscriber Server

IE Information Element

IMSI International Mobile Subscriber Identity

IMT International Mobile Telecommunications

KPI Key Performance Indicators

LTE Long Term Evolution

MAC Medium Access Control

MBMS Multimedia Broadcast Multicast Service

MCL Maximum Coupling Loss

MIB Master Information Block

MME Mobile Management Entity

MTC Machine-Type Communications

**[0216]** mMTC Massive Machine Type Communication

NACK Negative Acknowledgement

NAS Non-access Stratum

NR New Radio

OBO OFDM Back-off (802.11)

OFDM Orthogonal Frequency Division Multiplex

PDCCH Physical Downlink Control Channel

PDSCH Physical Downlink Shared Channel

PHY Physical Layer

PCFICH Physical Control Format Indicator Channel

PDCP Packet Data Convergence Protocol

PHICH Physical Hybrid ARQ Indicator Channel

PPDU PLCP Protocol Data Unit (802.11)

PRACH Physical Random Access Channel

PRB Physical Resource Block

PUCCH Physical Uplink Control Channel

PUSCH Physical Uplink Shared Channel

QoS Quality of Service

RA Random Access

RACH Random Access Channel

RAN Radio Access Network (3GPP)

RMSU Reachability and Mobility Status Update

RB Resource Block

RLC Radio Link Control

RNTI Radio Network Temporary Identifier

RRC Radio Resource Control

RU Resource Unit (802.11)

SI System Information

SIB System Information Block

SR Scheduling Request

STA Station (802.11)

TAI Tracking Area Indicator

TAU Tracking Area Update

TBD To Be Defined

TDM Time Division Multiplex

TEID Tunnel Endpoint ID

TRP Transmission and Reception Point

TTI Transmission Time Interval

UCI Uplink Control Information

UE User Equipment

UL Uplink

UR/LL Ultra Reliable-Low Latency

URLLC Ultra-Reliable and Low Latency Communications

**[0217]** This written description uses examples to disclose the invention, including the best mode, and also to enable

any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims.

What is claimed:

**1**. An apparatus comprising a processor, a memory, and communication circuitry, the apparatus being connected to a network via its communication circuitry, the apparatus further comprising computer-executable instructions stored in the memory of the apparatus which, when executed by the processor of the apparatus, cause the apparatus to perform operations comprising:

configuring a plurality of devices to operate in a grant-less mode in accordance with a respective grant-less access allocation, such that, when the plurality of devices transmit messages uplink in the network, the messages are transmitted using frequency resources defined by the respective grant-less access allocation, and the plurality of devices transmit the messages without being granted access to transmit the messages, so as to operate in the grant-less mode.

**2**. The apparatus as recited in claim **1**, wherein the plurality of devices comprise a first set of devices and a second set of devices that have different operating requirements as compared to the first set of devices.

**3**. The apparatus as recited in claim **2**, wherein configuring the plurality of devices further comprises:

configuring the first set of devices, such that, when the first set of devices transmit messages uplink in the network, the messages are transmitted within a first sub-band of the frequency resources; and

configuring the second set of devices, such that, when the second set of devices transmit messages uplink in the network, the messages are transmitted within a second subband of the frequency resources that is separate from the first subband.

**4**. The apparatus as recited in claim **3**, wherein the first sub-band defines first slice of the network for a first type of device or service, and the second sub-band defines a second slice of the network for a second type of device or service that is different than the first type of device or service.

**5**. The apparatus as recited in claim **2**, wherein configuring the plurality of devices further comprises:

configuring the first set of devices, such that, when the first set of devices transmit messages uplink in the network, the messages are transmitted within a first sub-band of the frequency resources; and

configuring the second set of devices, such that, when the second set of devices transmit messages uplink in the network, the messages are transmitted within the first sub-band of the frequency resources, and the messages are transmitted so as to have a higher priority than the messages transmitted by the first set of devices.

**6**. The apparatus as recited in claim **5**, wherein the first set of devices are Ultra-high Reliability and Low Latency Communications (URLLC) devices, and the second set of devices are massive Machine Type Communication (mMTC) devices.

**7**. The apparatus as recited in claim **6**, wherein the first subband is shared by granted enhanced mobile broad band (mMBB) devices that are overriden by the URLLC devices whether there is a conflict between their respective message transmissions.

**8**. The apparatus as recited in claim **2**, wherein configuring the plurality of devices further comprises:

configuring the first set of devices, such that, when the first set of devices transmit messages uplink in the network, the messages are transmitted within a first sub-band of the frequency resources, and within a second sub-band of the frequency resources, wherein the first set of devices share the first sub-band and the second sub-band with a third set of devices; and

configuring the second set of devices, such that, when the second set of devices transmit messages uplink in the network, the messages are transmitted within a guard band that is between the first sub-band and the second sub-band.

**9**. The apparatus as recited in claim **1**, wherein the apparatus further comprises computer-executable instructions stored in the memory of the apparatus which, when executed by the processor of the apparatus, cause the apparatus to perform further operations comprising:

obtaining context information associated with each of the plurality of devices; and

based, at least in part, on the context information, determining the respective grant-less allocation for which each device of the plurality of devices is configured.

**10**. The apparatus as recited in claim **9**, wherein the context information comprises at least one of a device type associated with each device, a service associated with each device, a latency requirement of each device, mobility associated with each device, a traffic type associated with each device, or a planned schedule of data transmissions from each device.

**11**. An apparatus comprising a processor, a memory, and communication circuitry, the apparatus being connected to a network via its communication circuitry, the apparatus further comprising computer-executable instructions stored in the memory of the apparatus which, when executed by the processor of the apparatus, cause the apparatus to perform operations comprising:

sending a first access allocation signal to at least one device, wherein the first access allocation signal comprises a first access allocation scheme and an indication of a first dynamic access configuration time interval; and

receiving, from the at least one device, a first grant-less uplink transmission during the first dynamic access configuration time interval, the first grant-less uplink transmission sent in accordance with the first access allocation scheme.

**12**. The apparatus as recited in claim **11**, the apparatus further comprising computer-executable instructions stored in the memory of the apparatus which, when executed by the processor of the apparatus, cause the apparatus to perform further operations comprising:

based on traffic associated with the at least one device, sending a second access allocation signal to the at least one device, wherein the second access allocation signal comprises a second access allocation scheme and an indication of a second dynamic access configuration

interval that is different than the first dynamic access configuration time interval; and

receiving, from the at least one device, a second grant-less uplink transmission during the second dynamic access configuration time interval, the second grant-less uplink transmission sent in accordance with the second allocation scheme that is different than the first allocation scheme.

**13**. The apparatus as recited in claim **11**, wherein the apparatus further comprising computer-executable instructions stored in the memory of the apparatus which, when executed by the processor of the apparatus, cause the apparatus to perform further operations comprising:

receiving a request from the at least one device for the first dynamic access configuration time interval; and

sending the first allocation access signal to the at least one device in response to the request.

**14**. The apparatus as recited in claim **11**, wherein the first access allocation signal is periodically transmitted to a plurality of devices within a coverage area of the apparatus.

**15**. The apparatus as recited in claim **11**, wherein the first access allocation signal is sent over a first channel dedicated to access allocation signals or a second channel that is shared with other control signals.

**16**. An apparatus comprising a processor, a memory, and communication circuitry, the apparatus being connected to a network via its communication circuitry, the apparatus further comprising computer-executable instructions stored in the memory of the apparatus which, when executed by the processor of the apparatus, cause the apparatus to perform operations comprising:

obtaining a first dedicated contention area and a contention time interval;

without being granted specific resources for transmission, transmitting a message uplink in the network during the contention time interval and within the dedicated contention area.

**17**. The apparatus as recited in claim **16**, the operations further comprising:

receiving a negative acknowledgement; and

in response to the negative acknowledgement, re-transmitting the message uplink in the network during the contention time interval and within a second dedicated contention area.

**18**. The apparatus as recited in claim **16**, the operations further comprising:

waiting for a predetermined time; and

when the predetermined time elapses without receiving a positive acknowledgement, re-transmitting the message uplink in the network during the contention time interval and within a second dedicated contention area.

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